Planning Design and Maintenance of Pedestrian Facilities

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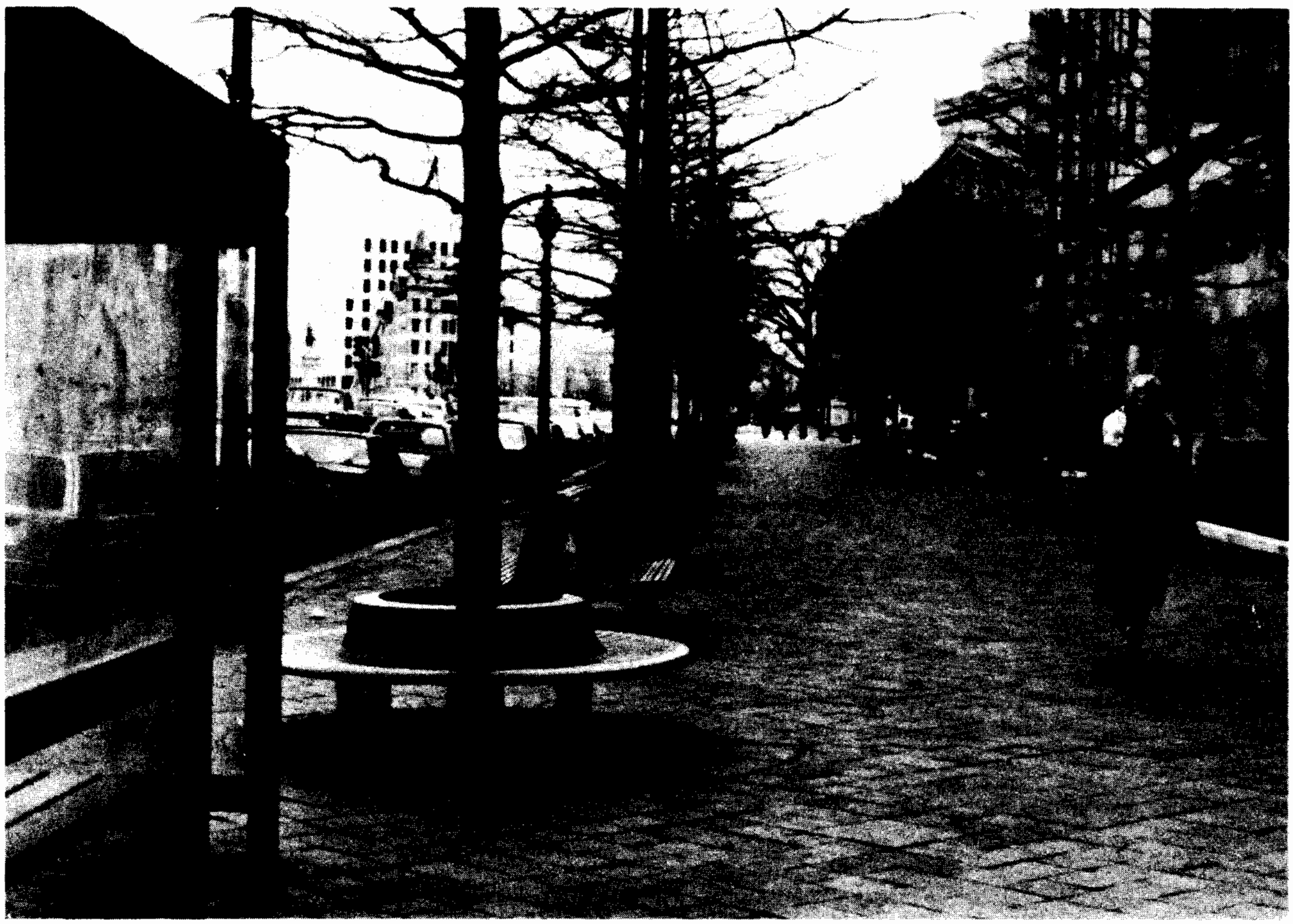

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
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FOREWORD

This new pedestrian handbook consolidates the current state-of-the-art pertaining to pedestrian facilities. It provides up-to-date information on pedestrian facilities in a single document to serve the needs of both planners and traffic engineers. In those instances where additional in-depth information is required, the handbook identifies relevant publications to locate information.

Chapters in the handbook address: pedestrian characteristics, pedestrian traffic studies, pedestrian safety studies, sidewalks and walkways, crosswalks, curb ramps, and refugee islands, vertical reparation, horizontal separation, pedestrian traffic control devices, pedestrian accommodations in work zones, and pedestrian facility maintenance.

Limited copies of the handbook are available from the Federal Highway Administration RD&T Report Center (HRD-11), Turner-Fairbank Highway Research Center, 6300 Georgetown Pike, McLean, Virginia 22101-2296, Telephone (703) 285-2144.

The handbook may be purchased from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22164, Telephone (703) 487-4600. The report PB No. is 89194849/AS.

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Director, Office of Implementation

NOTICE

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16. Abstract

Pedestrian safety and accessibility has long been a concern to Federal, State, and local agencies. The result has been a wide diversity of published reports, recommended practices and changes in accessibility standards for the planning, design and maintenance of pedestrian facilities. Much of this information is out of date, too technical or detailed and occasionally too confusing to provide the necessary assistance for traffic engineering professionals and planners to provide adequate pedestrian facilities. This handbook consolidates the current state-of-the-art pertaining to pedestrian facilities. It is designed to provide up-to-date information on pedestrian facilities in one document to serve the needs of planners and engineers in the majority of cases. In those instances where additional in-depth information is required, the handbook serves to identify the relevant publications from which the information can be obtained.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

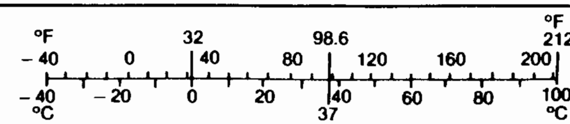
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

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

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

These factors conform to the requirement of FHWA Order 5190.1A.

(Revised April 1989)

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CHAPTER 1 - INTRODUCTION

Pedestrian accidents annually account for approximately 16 percent of total traffic fatalities in the United States with 6,771 pedestrian fatalities occurring during 1986.[1] The pedestrian safety problem is largely an urban one. Each year approximately 85 percent of all pedestrian accidents and 60 percent of all pedestrian fatalities occur in urban areas. In some large urban areas 40 to 50 percent of those killed in traffic accidents are pedestrians.[2]

In many cases pedestrians essentially travel at their own risk. This situation is not created intentionally but rather as a consequence of designing first for the vehicle, and only as an afterthought, for the pedestrian. Traditionally, worry about pedestrian safety by home and shop owners was due to their potential liability resulting from pedestrians slipping on sidewalks. Until recently intentionally building pedestrian safety and accessibility into street and sidewalk design was a seldom practiced art. This is evidenced by the following hazards frequently encountered by pedestrians on the roadway network.

- Suburban residential streets that strive to maintain the rural environment by not providing sidewalks. The result is the exposure of pedestrians and playing children to the hazards of moving traffic.
- Intersection signal timing that provides inadequate time for pedestrians to cross. These intersections are specially dangerous for the elderly and handicapped.
- Uncontrolled crossings on busy roadways adjacent to schools.
- Narrow sidewalks on urban streets often cluttered with poles, low hanging branches, trash containers and other obstacles which impede pedestrian flow.
- Pedestrian facilities which are inaccessible and hazardous for use by the handicapped and elderly.
- Construction areas with improper or insufficient safeguards for pedestrian movement.

Providing facilities that afford accessible and safe movement of pedestrians accomplishes more than increasing pedestrian safety. Urban redevelopment projects are rediscovering the importance of the pedestrian in the economy of urban centers. Pedestrian traffic is being recognized as the most efficient form of downtown transportation. The safe access to activity centers and downtown shopping malls should be as much, if not more, concerned with pedestrian needs than with the needs of motorists.

Complicating the implementation of adequate pedestrian facilties is the diverse characteristics of pedestrians. Wide variations in walking speed, the needs of the handicapped and the willingness of pedestrians to assume safety risks in order to save time and distance combine to complicate the planning, design and implementation of pedestrian facilities. Because effective and safe design relies heavily on local conditions, the ultimate responsibility for pedestrian safety and mobility resides with local jurisdictions. Federal and State-level interest and support can help, but for the most part, it is only the locality that can effectively identify, plan and implement facilities that meet the simultaneous needs of its pedestrians and the economic needs of the community.

Many local areas; especially those experiencing rapid development and essentially changing from a rural to a high density area, are often understaffed. Providing sufficient roadway capacity on a roadway network primarily designed to serve rural farming needs frequently requires all of the roadway agency's resources and time. As a result, recognizing the location of pedestrian trip generators and attractors is often never accomplished. The need for pedestrian facilities is recognized only after pedestrian accidents and fatalities accentuates areas in need of improvement.

The Federal Highway Administration, and other Federal agencies, have long recognized the need for pedestrian safety and mobility. This need has been addressed by increased funding for physical improvements, safety education grants, establishment of uniform accessibility standards and funded research. The last activity, plus other related activities by other sources, has resulted in a wide diversity of published reports. These reports have been directed at researchers, engineering professionals, planners, maintenance workers and traffic engineers at all levels of expertise and knowledge. Much of this information is out of date, too technical or detailed, and sometimes too confusing to provide the required assistance for the planning, design and maintenance of pedestrian facilities.

In recognition of this problem, the Federal Highway Administration funded a project to consolidate the current state-of-the-art pertaining to pedestrian facilities. This handbook is a result of that project. It is designed to provide up-to-date information on pedestrian facilities in 1 document that will serve the needs of planners and designers in the majority of cases. In those instances where additional in-depth information is required, the handbook serves to identify the relevant publications from which the information can be obtained.

PURPOSE AND ORGANIZATION OF THE HANDBOOK

The purpose of this handbook is to provide a primary source document on the planning, design, and maintenance of pedestrian facilities. Due to the diversity of pedestrian facility types, physical site locational characteristics and of the pedestrians themselves it was not possible to include every aspect of each facility type. Those topics which are encountered more frequently by traffic engineering professionals are discussed in greater depth than less frequently encountered topics. Pedestrian traffic studies (chapter 3) for example are discussed in greater depth than pedestrian malls (chapter 8). References are cited throughout the text and, where appropriate, suggestions for further reading are included to enable the user to obtain required additional information. The "Walk Alert - 1988 Program Guide" should be obtained for detailed information on educational enforcement and public information campaigns designed to increase pedestrian safety.[3]

CHAPTER 2 - PEDESTRIAN CHARACTERISTICS

The pedestrian characteristics of interest to traffic engineers and planners include walking speeds, typical walking distances, trip purpose, trip generation rates, and pedestrian traffic flow relationships. Walking speeds are of primary interest in determining signal timing and the potential need for supplemental aids such as safety islands. Walking distances determine the effective service area of public transportation systems, and are a factor in evaluating the feasibility of street malls and the economic viability of retail developments which are dependent upon pedestrian accessibility and convenience. Trip generation rates assist in determining the expected pedestrian activity associated with different types of land use. Trip generation studies and pedestrian traffic impact analyses are required by some municipalities as part of the environmental review and approval process for new buildings in high density areas.

Pedestrian traffic flow relationships are of value in determining the adequacy and convenience of sidewalks, corners, and crosswalks for different levels of pedestrian activity. Flow relationships can also be applied to other facilities such as the design of corridors, ramps, and stairs in transportation terminals and other buildings, and for emergency egress design and planning. Generally, most sidewalks, corners, and crosswalks can accomodate significant volumes of pedestrians conveniently and safely, with problems due to inadequacy occurring only in the larger cities. However, even small cities can have spot locations near heavy traffic generators, such as a theater or stadium, which may require analysis and special treatment. Pedestrian traffic analyses may also be required for crowd management and public safety at special events.

WALKING SPEEDS

The walking speeds of people unimpeded by crowding has been found to vary over a wide range depending on the age, sex, and physical condition of the individual, and other factors including the purpose of the walking trip, time of day, weather, and environmental setting. Pedestrians not limited by disabilities can vary their speeds from a casual "stroll" at 2 to 3 feet per second (fps) (0.6 to 0.9 mps), to a purposeful fast pace of 5 to 6 fps (1.5 to 1.8 mps). The average free-flow walking speed of the general population found in most studies is 4.5 fps (1.4 mps).[4] This has been the traditional value used by many traffic engineers to evaluate the adequacy of the green interval for crossing pedestrians. Using the average walking speed for this purpose would not apply at busy intersections where crowding would reduce crossing speeds, or where the adequacy of the crossing interval to accomodate elderly or physically impaired persons is of concern.

Older Pedestrians - A controlled laboratory study of healthy men ranging in age from 20 to 87 determined that the average walking speed for the 20 to 25 age group was 4.5 fps (1.4 mps). The average walking speed for the 61 to 87 age group 3.6 fps (1.1 mps) with the majority of walking speed decrease occurring after the age of 65. In the laboratory environment, all of the men involved in the study were able to increase their normal speeds by appoximately 40 percent, with the elderly group able to attain speeds of 4.9 fps (1.5 mps) for short periods of time. Women were determined to walk approximately 5 percent slower than men. These results indicate that, for non-physically imparied persons, 4.5 fps (1.4 mps) is a speed attainable by most individuals while crossing a street.

Younger Pedestrians - The normal walking speed of children is functionally slower than adults due to their shorter legs and smaller pace distance. However, children are naturally more energetic than adults and can be observed to mix running with walking thereby increasing their overall walking rate. A study of children crossing streets determined an average speed of 5.3 fps (1.6 mps), compared to the typical average adult speed of 4.5 fps (1.4 mps).[4]

Distribution of Walking Speeds - Figure 1 displays a frequency distribution of free-flow walking speeds for 967 persons oberved in 2 transportation terminals in New York City. Studies of street crossing speeds display slightly different results due to oncoming vehicles and impending signal change prompting non-disabled pedestrians to move faster. The frequency distribution indicates that although 4.5 fps (1.4 mps) was the observed average, 78 percent of the pedestrians normally walked slower than this. The median speed, considered to be more representative than the average, was 4.0 fps (1.2 mps). Figure 1 indicates that the normal average walking speed of 3.6 fps (1.1 mps) observed in the laboratory study of healthy older men was in the 25th percentile of the distribution. An average crosswalk walking speed of 3.3 fps (1.0 mps), observed in a time-lapse photography study of pedestrians in dense platoons crossing New York City streets, is also noted in figure 1.[4]

The walking speed distribution curve indicates that when an average walking speed of 4.5 fps (1.4 mps) is used to determine the pedestrian clearance interval, 78 percent of pedestrians will have to walk faster than their normal walking speed to cross safely within the allotted green time. While it is possible for pedestrians without disabilities to accomplish this, it presents a hardship for people with disabilities.

The Crossing Dilemma - Pedestrians crossing unsignalized intersections are faced with the dilemma of judging the speed and closing distance of oncoming vehicles, relative to their own walking speed, to select a gap

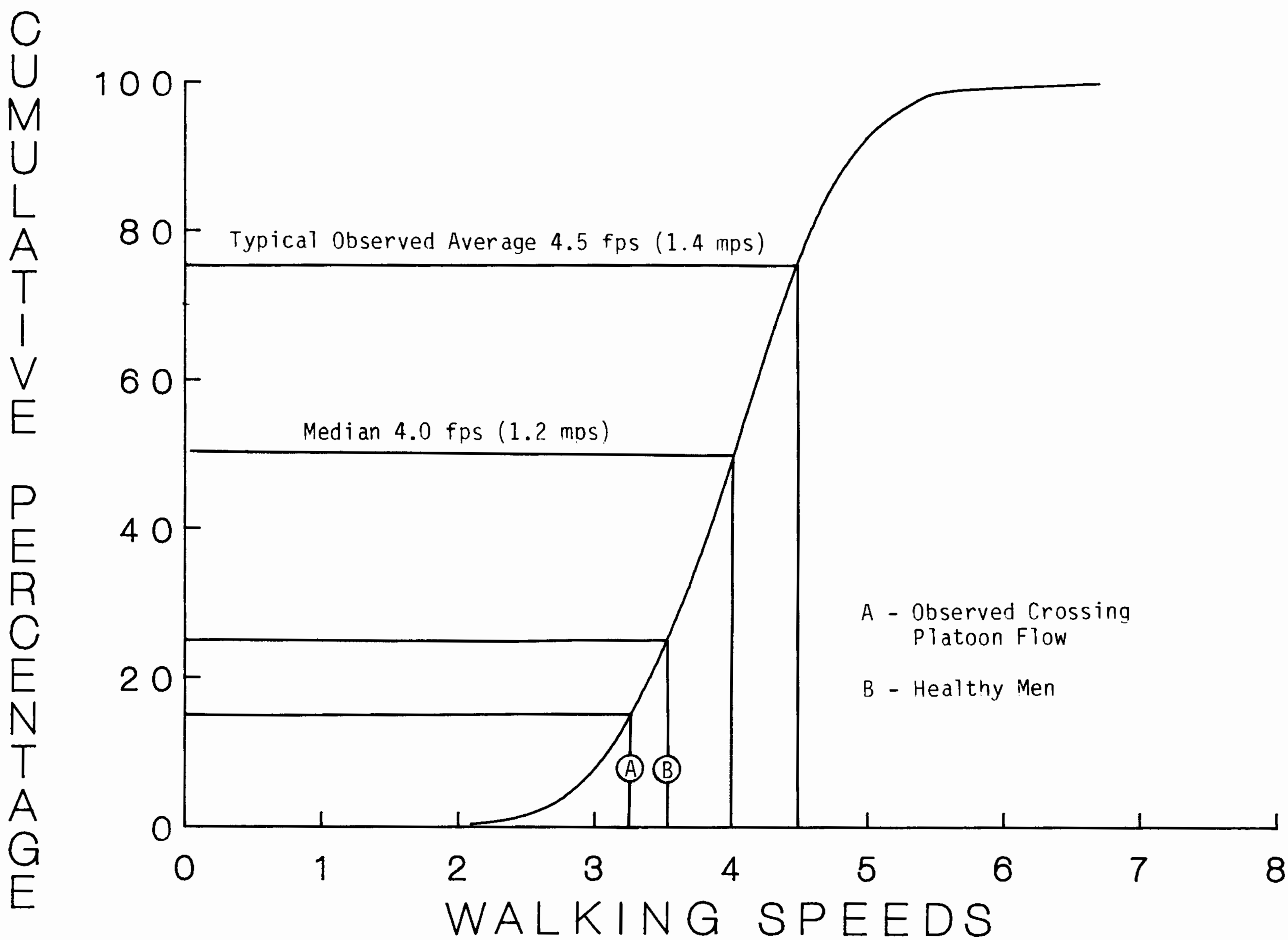


Figure 1. Distribution of walking speeds.
(Source: [4])

in traffic that will allow them to cross safely. Judging the speed of an oncoming vehicle has been found to be difficult for younger pedestrians who lack the experience to estimate approaching vehicle speeds, closing distances, and their own crossing times. It is even more difficult for those with visual impairments. The time required to cross a 4-lane, 48-feet (14.6 m) wide roadway is 10.7 seconds at the typical average walking speed of 4.5 fps (1.4 mps), and 13.3 seconds at a walking speed of 3.6 fps (1.1 mps). An approaching vehicle moving at 30 mi/h (48 km/h) travels 470 feet (143.3 m) in 10.7 seconds and 585 feet (178.3 m) in 13.3 seconds. Increasing the street width to 6 lanes at 72-feet (21.9 m), and the vehicle speed to 50 mi/h (80 km/h), increases the vehicle distance travelled during the crossing time to 1,195 and 1,467 feet (364.2 and 447.1 m), respectively.

The relatively large pedestrian crossing time and associated vehicle travel distances emphasizes the difficulties experienced by many pedestrians in safely crossing an unsignalized intersection. These problems become worse where the lines of sight of pedestrians and drivers are limited by curves, hills, vehicles, or other obstructions, and where the pedestrian's vision or ability to walk quickly is impaired.

WALKING DISTANCES

Pedestrians prefer to limit walking distance and will often take unusual short cuts to save even a few steps and seconds of time. This characteristic requires careful consideration in the planning of overpasses and underpasses. Experience has shown that overpasses and underpasses will not be fully used if a more direct, but potentially less safe route exists. Motorists make every effort to park as close as possible, usually 500 feet (152.4 m) or less, to their initial destination at a shopping mall. However, after entering a large indoor shopping mall, the total distance involved in shopping itself can exceed a mile.

Acceptable walking distances are dependent on trip purpose, total travel time related to this purpose, physical condition of the pedestrian, walking environment, perceived safety and security of the walking route, and in some instances economic factors. Pedestrians will generally not travel further than 600 feet to use a pedestrian overpass if an alternative, but less safe, at-grade crossing is available. The usual parking distance limit of 500 feet (152.4 m) becomes significantly expanded, particularly for daily commuter work trips, if there is an economic incentive, such as a lower parking fee. Captive walking distances at Chicago's O'Hare airport can approach 2,000 feet (609.6 m) between the entry curb and the most remote aircraft gate, and can be as much as 8,000 feet (2,438.4 m) where an interline transfer is required. Walking distances in the larger museums in New York City can exceed 3 miles if the total collection is viewed.

Figure 2 illustrates walking distance patterns compiled from a number of studies.[6] The longer walking distances shown for the bus mode in figure 2 are based on an origin and destination survey of passengers in a large inter-city bus terminal located in a major city. The survey was conducted during fair weather with walking balanced against paying an additional transit fare and unpredictable transit travel times of buses in dense city traffic. Figure 2 indicates that the practical limit for most walking trips is about 3,000 feet (914.4 m), approximately a 10 to 12 minute walk for the average non-disabled pedestrian.[6]

PEDESTRIAN TRIP GENERATION

Pedestrian trip activity varies according to the type of land use, the size of the traffic generator, and the characteristics of the supporting pedestrian circulation system. Trip generation data are available for estimating peak activity based on comparable land uses, but surveys may be necessary to more accurately establish local traffic patterns and trends.[7]

Office Building Activity - Office traffic depends upon the resident worker population and visitor ratios. The typical office building occupancy factor averages between 200 to 250 square feet (18.6 to 23.2 m^2) per employee. Visitor ratios depend on the type of occupancy, with mixed-use offices attracting more visitors than a single tenant company headquarters. Peak pedestrian activity periods correspond closely with work start, quit, and lunch times. External lunch period trips would be less where there are in-house eating facilities. Buildings using "flex-time" or staggered work hour programs would have less pronounced peaking. A diversified use commercial building can have a 5-minute starting, quitting, and lunch time peak of 10 to 12 percent of total building occupancy, and a single purpose building with common work times as high as 15 to 20 percent of occupancy. A composite study of 8 office buildings indicated hourly activities ranging between 1 to 3 in and out trips per 1,000 square feet (92.9 m^2) of building space, an 8 to 9 AM and lunch period peak 1.6 times this average, and a 5 to 6 PM peak of 1.2 times the average.

Retail Activity - Traffic patterns for retail land use depend upon the type of store, surrounding land use, parking availability, and pedestrian accessibility. A study of 8 general merchandise department stores

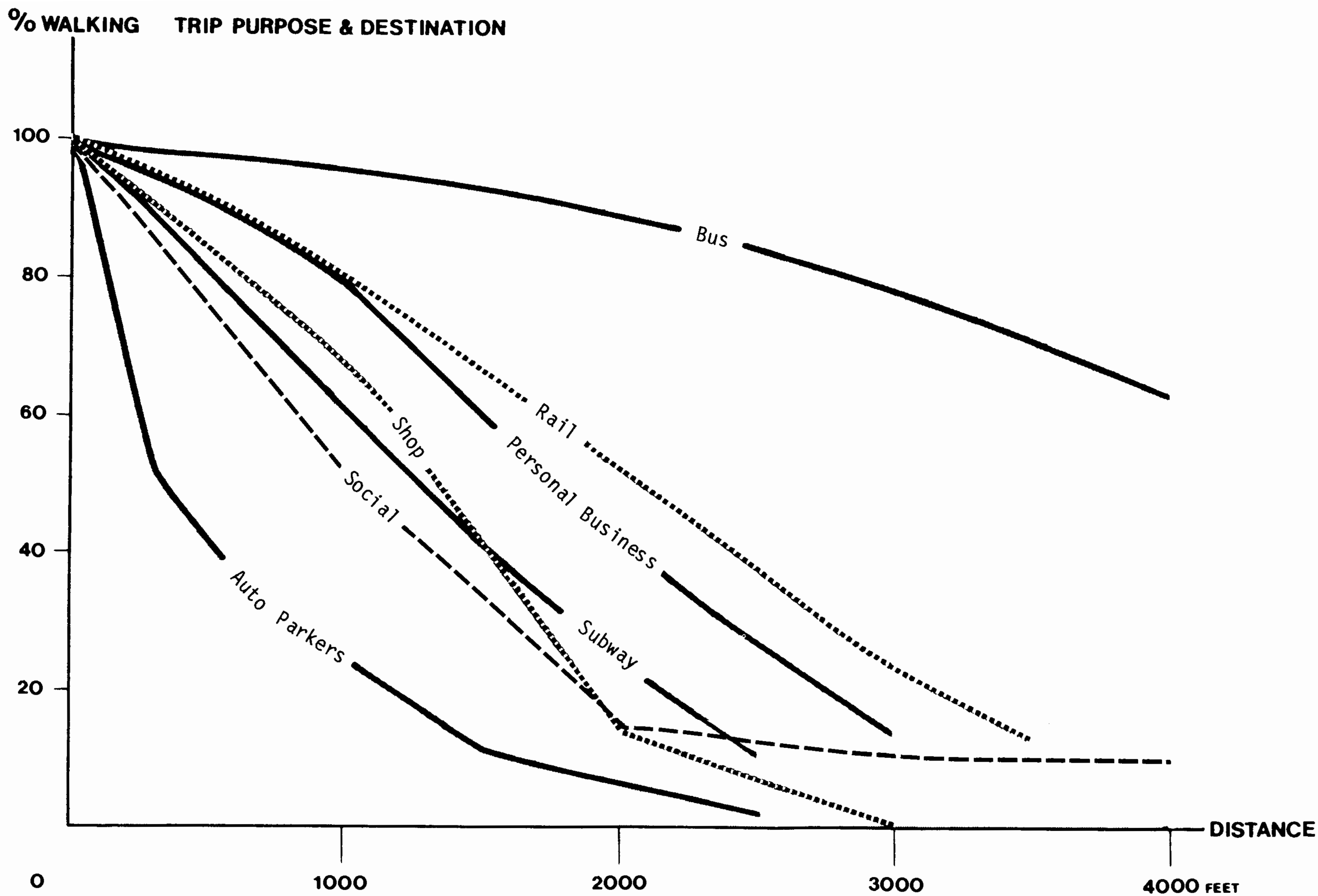


Figure 2. Walking distances. (Source: [6])

indicated average hourly pedestrian activity of 3 to 6 in and out trips per 1,000 square feet (92.9 m^2) of building space, with a peak hour 3 times the average. Specialty retail outlets can range from a low of 3 average hourly trips per 1,000 square feet (92.9 m^2) to 55 hourly trips for a small bookstore.

Hotel Activity - The number of rooms, size of conference facilities and the presence of restaurants determine pedestrian activity for hotels. A study of 2 large hotels in Boston indicated a peak hour pedestrian rate of 90 trips per 100 rooms with 25 trips per 100 rooms in the peak 15 minutes. Average daily trip activity in another study was 12 to 14 trips per hour per 1,000 square feet (92.9 m^2) of hotel floor space. Hotels with large ballrooms or meeting spaces experience heavy short-term peaks at the end of social events and meetings.

Residential Activity - Trip activity for residential uses are related to numbers of rooms and floor space, household size and demographics. Residential traffic is typically more balanced during the day than that of other land uses, with peaking associated with morning and evening work trips. Hourly rates observed for apartment house occupancies are about 7 to 8 trips per 1,000 square feet (92.9 m^2) of floor space.

Public Assembly Spaces - Trip activity for theaters, stadiums, and other places of public assembly is directly related to the number of seats. Consecutive theater performances can cause overlapping traffic patterns. Occupancies greater than the seating capacity, and potentially dangerous crowding, can occur with general admission events like rock concerts where patrons are allowed to stand on playing fields to increase paid attendance. Entry crowding for this type of event can also become a problem as illustrated by the 1979 Cincinnati "Who" concert crowd disaster in which 11 people were killed.

Peak activity in places of public assembly is unique in that all patrons wish to depart immediately at the end of a performance or sporting event. This causes crowding and delay even at the most well-designed pedestrian facilities. A large stadium or sports arena can take up to 30 minutes to empty for some events. Arrivals at these facilities are much more gradual and less peaked, but large crowds can be accumulated if facilities are not opened sufficently prior to the event.

Sidewalk Activity - Sidewalk pedestrian traffic is a composite of the surrounding area land uses, with heavier concentrations nearer the largest traffic generators and attractors such as transit stops, department stores, and restaurants. The selection of specific sidewalk routes by pedestrians is dependent primarily on directness to their destination, with the added influence of perceptions of security along the route, relative impedances (street crossings, signal delays, crowding), route attractiveness and interest and weather conditions. Sidewalk movement is interrupted by traffic signals at intersections which concentrate pedestrians at corners and releases them in a "platoon" at crosswalks. Platooning causes alternative surges and gaps in sidewalk flow which should be considered in analyzing this traffic.[8]

Transportation Terminal Activity - Pedestrian activity at transportation terminals depends on whether the terminal is a line or end-of-line facility, surrounding land uses, and time of day. During the AM journey-to-work period pedestrian activity at end line terminals is directly related to transit vehicle arrivals and occupancy. At New York's Pennsylvania Railroad Station it is possible for 2 long trains to arrive almost simultaneously at a single platform, and for as many as 3,000 passengers to be discharged on the platform within 75 seconds. Under these circumstances it can take more than 8 minutes for the platform to clear. In the evening PM journey-from-work period arrivals at transportation terminals are less peaked, but accumulations of passengers occur waiting for departing transit vehicles.

Peaks and Demand Management - It is important to understand the characteristics of pedestrian traffic patterns and peaking for analysis, design, and possible management. Generally the 15 minute traffic peak is selected for evaluation purposes, but shorter peaks may be analyzed for specific facilities where there is a low tolerance to delay. During a 15 minute peak, traffic surges of up to 2 times the average rate for the peak can occur, which can cause short-term crowding problems.

Pedestrian demands have been managed and peaking reduced by the institution of staggered hours and flex-time programs. With staggered hours, different employers, or groups of employees of the same employer, agree to start and end work at different times to reduce peaking effects on elevators, sidewalks, and transit services. Flex-time programs allow individual employees to schedule their own working hours, such as a 4-day work week, or to vary workday hours within the required weekly work hours total.

Metering, or the control of pedestrian flow by physical design and/or security personnel, is another demand management strategy that has been used at transit and public assembly places where severe crowding could be potentially dangerous (i.e., at the head of stairs). Metering has been used to limit the number of people entering a transit station to control platform crowding. The pedestrian bridge connecting the Oakland Stadium with the BART transit system in San Francisco has been designed as a meter, with the pedestrian traffic capacity of the bridge set at the passenger capacity of the trains serving the station. Metering by physical design must be carefully evaluated because it causes back-up crowding at the metering point. Well-designed meters shift crowd accumulations to points where they can be more safely controlled. A form of time control metering has also been accomplished for special exhibits at museums by the issuing of "time of arrival" tickets, acceptable only during specific half hour intervals. Observed average hourly and peak 15 minute pedestrian activity rates for different types of land use are presented in tables 1 and 2.

PEDESTRIAN TRAFFIC FLOW RELATIONSHIPS

The fundamental relationships of speed, volume, and density of pedestrian traffic are similar to those used to analyze vehicular flow. As the volume and density of pedestrian traffic increases, speed and ease of movement decreases from the free-flow norms eventually reaching a critical density. At the critical density the level of crowding is such that "shuffling" occurs with speeds and volumes becoming erratic and unpredictable. Pedestrian flow on sidewalks is affected by reductions in effective width caused by various types of "street furniture", such as parking meters, light poles, mail boxes and trees, and the platoon affects previously discussed. The level-of-service (LOS) concept, first used to define relative degrees of convenience on highways, has also been applied to pedestrian facilities. With this concept, pedestrian volume and density are related to individual pedestrian convenience factors such as the ability to:

- Select desired walking speed.
- Bypass slower pedestrians.
- Walk in a reverse counter flow direction.
- Cross a major traffic stream.
- Maneuver without conflicts and changes in direction, walking speed, and gait.

Fundamentally, all of these pedestrian traffic flow convenience factors are related to the average density or area available to the individual person within the traffic stream.

Table 1. Hourly pedestrian trip generation rates. (Source: [7])

Comparative Pedestrian Activity and Land Use Hourly in and out trips per 1,000 sq. ft.					
Building Type	Hourly Trips	Building Type	Hourly Trips	Building Type	Hourly Trips
Department Store	3-6	Shopping Center		Office Building	
Specialty Retail		Neighborhood	12	Average (8) Large	1-3
		Community	7	Municipal Bldg.	3-4
Mens Clothing	3	Regional	5	Branch Banks	25-30
Womens Clothing	33	Supermarkets	24-31	Stock Brokers	4
Shoe Stores	25-35			Medical Office	15
Book Stores	40-55			Post Office	15
Boutiques	25	Restaurants		Residential	
Gift Stores	14	Fast Food, Carryout	128	Motels/Hotels	12-14
Office Supplies	15-28	Fast Food, Service	48	Apartments	7-8
		Full Service Rest.	12		

Table 2. Peak 15 pedestrian trip generation rates. (Source: [7])

<u>Building Uses and Peak Pedestrian Activity</u>

In and out trips per 1,000 sq. ft.

Use	Daily	Peak 15 Min.	15 Min. Peak as Percent Day	Time of Peak
Cafeteria	492	22	4.5	Noon
Department Store	252	16	6.3	12:45 PM
Supermarket	285	12	4.2	5:00 PM
Restaurant	173	10	5.8	1:15 PM
Office - Headquarters	14	1	7.1	8:45 AM 5:00 PM
Office - Mixed Use	17	1	5.9	4:45 PM
Residential	8	0.25	3.1	5:45 PM

Flow-Density Relationship - The basic relationship between density, speed, and volume for pedestrians is the same as that used for vehicles:

Volume = Speed x Density
$V = S \times D$

Volume is expressed in units of pedestrians per foot per minute (pfm) of the effective width of a walkway or stair, speed in feet per minute (fpm), and density in pedestrians per square foot (psf).[9] However, the reciprocal of density, square feet area per person (sfp), is more useful and easier to visualize. Changing the equation slightly results in:

Volume = Speed/Area
$V = S/M$

In this instance, M is the pedestrian "module", or average area per person in square feet. In order for the flow equation to apply, it is necessary that pedestrian movement be continuous and relatively uniform to conform with the basic hydraulic flow model. In pedestrian environments where this does not apply, other analysis techniques, such as the "time-space" method, may be necessary.

The observed relationships between pedestrian volume (V) and average area per pedestrian (M), obtained from different photographic studies of pedestrian flow, are illustrated in figure 3. Inspecting figure 3 indicates that the maximum volume or capacity of a walkway (about 25 persons per foot of effective width) is obtained when the average area per pedestrian is relatively small (about 5 square feet per person (sfp)). Below 5 sfp the volume is unpredictable since the walkway becomes too crowded for continuous forward movement.

It is obvious that as a walkway becomes more crowded walking speeds are reduced because of the smaller pacing area available and the inability to bypass slower walkers. At capacity levels walking is reduced to a "shuffling" gait, and intermittent stops are possible. Figure 4 illustrates the observed relationships between the average area per person and walking speed based on photographic studies. The walking speed relationship of figure 4 also suggests points of demarcation that can be used in determining the various degrees of convenience which are the basis of LOS descriptions. The outer range of observations indicates that at 15 sfp (1.4 smp) even the slowest pedestrians are not able to achieve their normal free-flow walking speed and that 40 sfp (3.7 smp) or more is required for the faster pedestrians to attain their normal speeds.

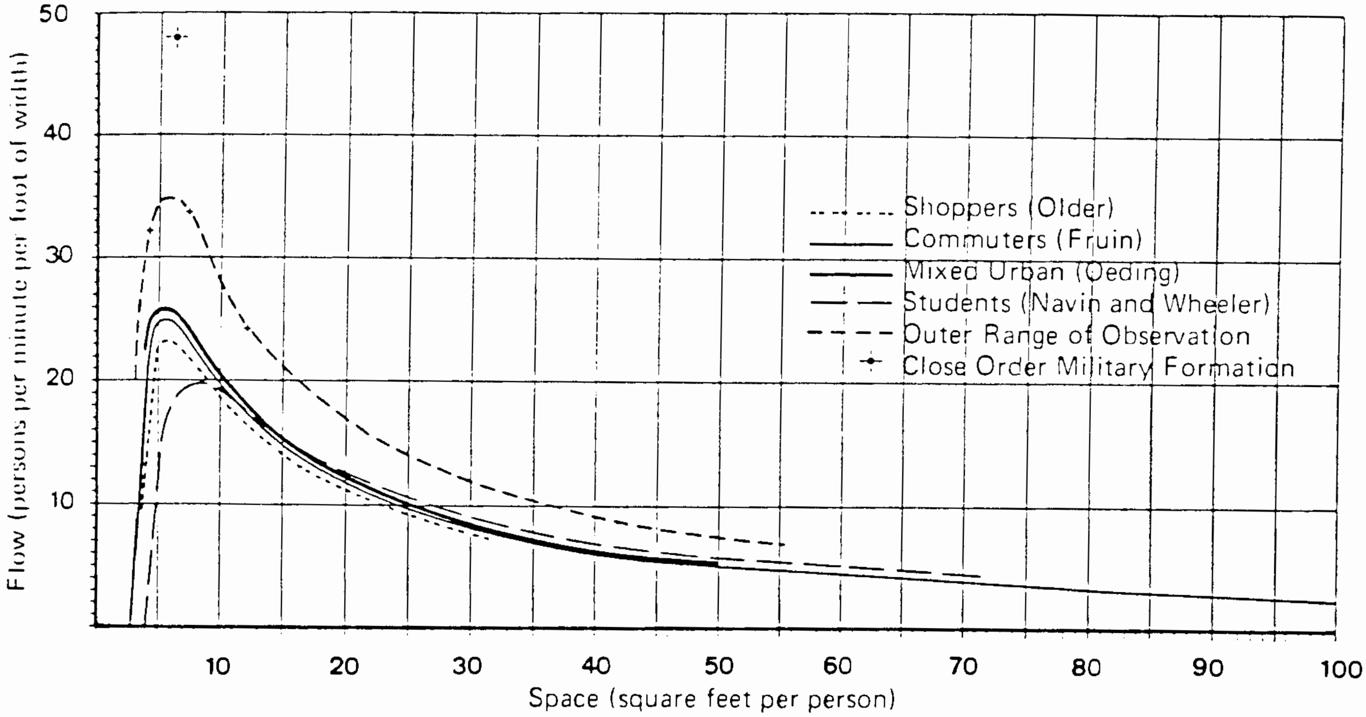


Figure 3. Relationships between pedestrian volume and average area per pedestrian obtained from various photographic studies.
(Source: [9] p. 13-4)

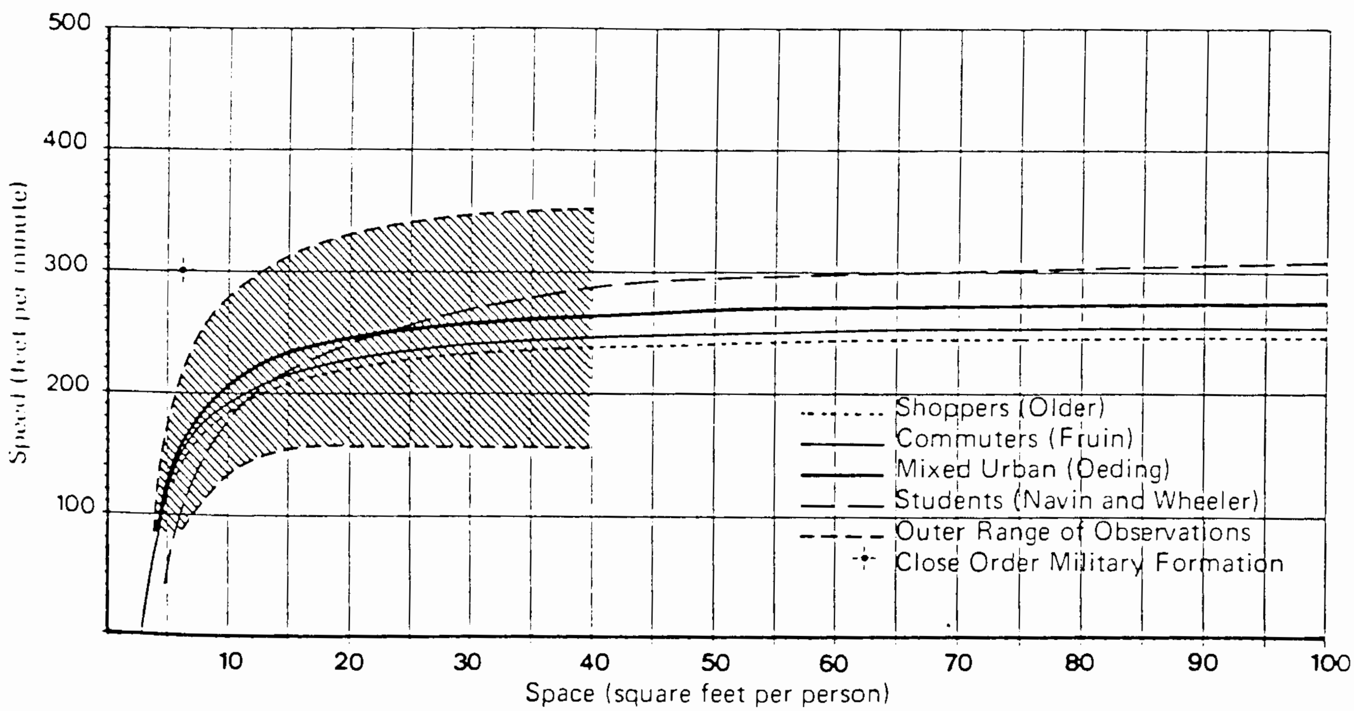


Figure 4. Relationships between average area per person and walking speed obtained from various photographic studies.
(Source: [9] p. 13-5)

Effective Walkway Width - The concept of pedestrian "lane" is sometimes used in a manner analogous to a highway lane to analyze pedestrian flow. Photographic studies, however, have shown that pedestrians do not walk in organized lanes. The lane concept is only meaningful where it is used to determine how many persons can conveniently walk abreast and pass each other, or for setting up walking and waiting areas on sidewalks for a curb stop bus operation. To avoid interference with each other while passing, or while waiting in lines, pedestrians should have at least a 2.5 feet (0.8 m) wide lane each.

The effective walkway width is the portion of the walkway available to, and typically used, by pedestrians for movement. Moving pedestrians will shy away from the curb, building walls, window shoppers, and street furniture. This "buffer-effect" must be taken into consideration when determining the useable, or net effective width of the walkway. Table 3 lists typical sidewalk obstacles and approximate widths that should be deducted from total sidewalk width to determine the effective width used for analysis. An additional 1 foot should be deducted from the total walkway width for buffer effects adjacent to building walls and other obstructions.

Effect of Platoons - Platooning, or the formation of groups within the traffic stream that are more dense than the stream average, can be observed on all sidewalks. Platoons are caused by the accumulation of pedestrians at corners during the red cycle, and their subsequent release as a group during the green. Platoons can also occur near transit facilities due to the rapid unloading of transit vehicles. It is important for analysts to determine if platooning or other unusual traffic patterns alter the underlying assumptions of uniform flow inherent in the LOS descriptions. The Highway Capacity Manual (HCM) indicates that the platooning effect for sidewalks can be estimated by the addition of 4 pedestrians per foot width of walkway per minute (pfm) to the average pedestrian volume, for flows greater than 0.5 pfm (0.05 pmm) of effective sidewalk width.

Walkway Levels of Service - Walkway LOS, based on the average area per person in the traffic stream, are graphically illustrated and described in figure 5. Table 4 summarizes area, speed, volume, and the volume to capacity ratio for the various LOS. The practical working capacity of the walkway used for the walkway V/C ratio is 25 pfm. All of the LOS represent crowded conditions likely to occur in larger cities, or near heavy traffic generators in smaller cities. LOS C represents a crowded but relatively fast moving traffic stream, such as might be experienced in a busy transportation terminal or crosswalk.

Table 3. Dimensions - sidewalks - obstacles. (Source: [8])

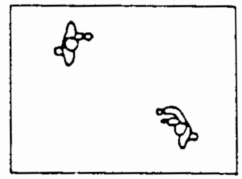
Urban Streets Fixed Obstacle Width Adjustment Factors for Walkways*	
Obstacle	Approx. Width Preempted (ft.)[a]
Street Furniture	
Light Poles	2.5 - 3.5
Traffic Signal Poles and Boxes	3.0 - 4.0
Fire Alarm Boxes	2.5 - 3.5
Fire Hydrants	2.5 - 3.0
Traffic Signs	2.0 - 2.5
Parking Meters	2.0
Mail Boxes (1.7 ft. by 1.7 ft.)	3.2 - 3.7
Telephone Booths (2.7 ft. by 2.7 ft.)	4.0
Waste Baskets	3.0
Benches	5.0
Public Underground Access	
Subway Stairs	5.5 - 7.0
Subway Ventilation Gratings (raised)	6.0+
Transformer Vault Ventilation Gratings (raised)	5.0+
Landscaping	
Trees	2.0 - 4.0
Planting Boxes	5.0
Commercial Uses	
Newsstands	4.0 - 13.0
Vending Stands	variable
Advertising Displays	variable
Store Displays	variable
Sidewalk Cafes (two rows of tables)	variable, try 7.0
Bulding Protrusions	
Columns	2.5 - 3.0
Stoops	2.0 - 6.0
Cellar Doors	5.0 - 7.0
Standpipe Connections	1.0
Awning Poles	2.5
Truck Docks (trucks protruding)	variable
Garage Entrance/Exit	variable
Driveways	variable

* To account for the avoidance distance normally occurring between pedestrians and obstacles, an additional 1.0 to 1.5 ft. must be added to the preemption width for individual obstacles.

[a] Curb to edge of object, or bulding face to edge of object.

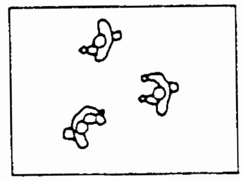
Walkway Level of Service A

Average Flow Volume: 4 PFM* or less
Average Speed: 260 ft./min.
Average Pedestrian Area Occupancy: $\geq$ 65 sq.ft./person or greater
Description: Virtually unrestricted choice of speed; minimum maneuvering to pass; crossing and reverse movements are unrestricted; flow is approximately 25 percent of maximum capacity.



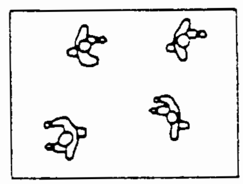
Walkway Level of Service B

Average Flow Volume: $\leq$ 7 PFM
Average Speed: 25-260 ft./min.
Average Pedestrian Area Occupancy: $\geq$ 40 sq.ft./person
Description: Normal walking speeds only occasionally restricted; some occasional interference in passing; crossing and reverse movements are possible with occasional conflict; flow is approximately 35 percent of maximum capacity.



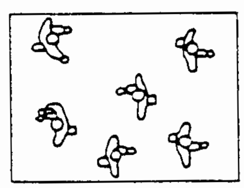
Walkway Level of Service C

Average Flow Volume: $\leq$ 10 PFM
Average Speed: 230-250 ft./min
Average Pedestrian Area Occupancy: $\geq$ 24 sq.ft./person
Description: Walking speeds are partially restricted; passing is restricted but possible with maneuvering; crossing and reverse movements are restricted and require significant maneuvering to avoid conflict; flow is reasonably fluid and is about 40-65 percent of maximum capacity.



Walkway Level of Service D

Average Flow Volume: $\leq$ 10 PFM
Average Speed: 200-230 ft./min.
Average Pedestrian Area Occupancy: $\geq$ 15 sq.ft./person
Description: Walking speeds are restricted and reduced, passing is rarely possible without conflict; crossing and reverse movements are severely restricted with multiple conflicts; some probability of momentary flow stoppages when critical densities might be intermittenly reached; flow is approximately 65-80 percent of maximum capacity.

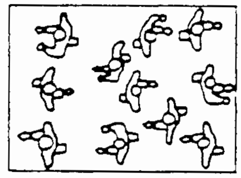


*PFM = Pedestrians per foot width of walkway, per minute.

Figure 5. Graphic illustrations of walkway level of service description. (Source: [7])

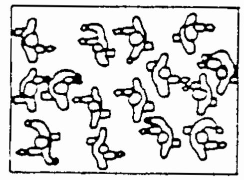
Walkway Level of Service E

Average Flow Volume: $\leq$ 25 PFM*
Average Speed: 110-200 ft./min
Average Pedestrian Area Occupancy: $\geq$ 6 sq.ft./person
Description: Walking speeds are restricted and frequently reduced to shuffling; frequent adjustment of gait is required and passing is impossible without conflict; crossing and reverse movements are severly restricted with unavoidable conflicts; flow attains maximum capacity under pressure, but with frequent stoppages and interruptions of flow.



Walkway Level of Service F

Average Flow Volume: 25 PFM or more
Average Speed: 0-110 ft./min.
Average Pedestrian Area Occupancy: $<$ 6 sq.ft./person
Description: Walking speed is reduced to shuffling; passing is impossible; crossing and reverse movements are impossible; physical contact is frequent and unavoidable; flow is sporadic and on the verge of complete breakdown and stoppage.



*PFM = Pedestrians per foot width of walkway, per minute.

Figure 5. Graphic illustrations of walkway level of service description (continued). (Source: [7])

Table 4. Pedestrian level of service on walkways*.
[Source: [9], p. 13-18 (modified)]

Level of Service	Space (SQ FT/PED)	Expected Flows and Speeds		
		Av. speed S (FT/MIN)	Flow Rate, v (PED/MIN/FT)	VOL/CAP Ratio, V/C
A	≥ 65	≥ 260	≤ 4	≤ 0.08
B	≥ 40	≥ 250	≤ 7	≤ 0.28
C	≥ 24	≥ 240	≤ 10	≤ 0.40
D	≥ 15	≥ 225	≤ 15	≤ 0.60
E	≥ 6	≥ 150	≤ 25	≤ 1.00
F	≥ 6	≥ 150	Variable	

* Average conditions for 15 minutes.

LOS A, the threshold of free-flow conditions, is 65 sfp (6.0 smp), which differs from the Highway Capacity Manual standard of 130 sfp (12.0 smp). The 65 sfp (6.0 smp) standard is partially derived from the observation that eye contact between pedestrians approaching each other occurs at a distance of about 25 feet (7.6 m), and 2 2.5 feet (0.8 m) wide lanes would have to be available for them to conveniently avoid each other. Based on the closing speed of 4.5 fps (1.4 mps) each, about 3 seconds is available to both pedestrians to recognize a potential conflict and to take evasive action. The 3 seconds is within observed perception and reaction times for most persons. Beyond 65 spf (6.0 smp), free-flow conditions, which are more non-uniform and less applicable to analysis by the hydraulic flow analogy, would occur.

Levels of Service - Queuing - Waiting areas such as transit platforms, and the red signal queues occurring on street corners, have also been defined in level of service terms. Most waiting areas require sufficient space for standing, and depending on the type of use, additional area for limited movement. Involuntary bodily contact occurs below 3 square feet per person, and potentially dangerous crowding effects can result at occupancies lower than 2 sfp. Standing pedestrians prefer to occupy more area than this even in competitive situations, with 5 sfp observed in queues at stairs and escalators, and 7 sfp on a crowded corner waiting for the signal to change. Queuing LOS descriptions based on average standing areas and relative convenience of movement within the waiting space are graphically illustrated in figure 6.

Stairway Level of Service - Stairways are less efficient than walkways, and frequently pedestrian delay and queuing will occur where the 2 interface. Safety is the primary concern in stairway design. The National Bureau of Standards has estimated that there are almost 4,000 fatal accidents on stairs each year in the United States. Primary design-related causes of stair accidents are non-uniform riser or tread dimensions, risers that are too high or treads that are too narrow for safe use, absence of handrails or handrails that are not graspable, and short flight stairs of 1 or 2 risers in unexpected locations. Recommended stair riser dimensions are 6 to 7 inches (15.2 to 17.8 cm), treads 11 to 12 inches (27.9 to 30.5 cm), and handrails with a gripping perimeter of 4 to 5 inches (10.2 to 12.7 cm), equivalent to a 1.5 inch (3.8 cm) diameter circular handrail. Graphic illustrations and descriptions of stairway LOS for different flow volumes are shown on figure 7.

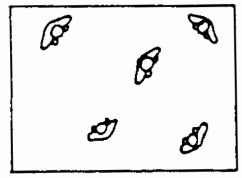
LEVEL OF SERVICE DESIGN AND ANALYSIS

Application of LOS criteria for design and analysis purposes where pedestrian volumes are known is a simple procedure. For example, in design where the effective width of a walkway is required to accommodate a volume of pedestrians at a desired level of convenience, the appropriate LOS is selected, and the average flow per foot width of walkway for that LOS is divided into that volume to determine the effective walkway width. The resulting walkway width is then adjusted by additions for buffer affects, sidewalk furniture, and obstructions. Where it is desired to determine walkway LOS for known traffic volumes and walkway widths, the effective walkway width, determined by subtractions for buffer effects and obstructions, is divided into the pedestrian volume to determine the average area per pedestrian in the traffic stream, and the LOS from table 4 or figure 5.

The LOS criteria of table 4 and illustrated in figure 5, are based on photographic studies of pedestrian movement and the assumptions of uniform rates of flow, and the continuous, somewhat competitive movement of pedestrians toward an objective. This is the underlying assumption of the fundamental hydraulic flow analogy, which is the theoretical basis for both vehicular and pedestrian flow equations. However, unlike vehicular flow

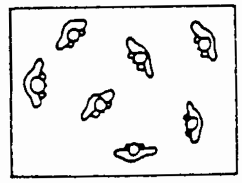
Queuing Level of Service A

Average Pedestrian Area Occupancy: 13 sq.ft./person or more
Average Inter-Person Spacing: 4 ft. or more
Description: Standing and free circulation through the queuing area is possible without disturbing others within the queue.



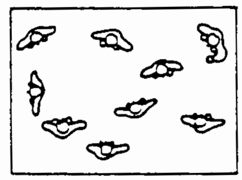
Queuing Level of Service B

Average Pedestrian Area Occupancy: 10-13 sq.ft./person
Average Inter-Person Spacing: 3.5-4.0 ft.
Description: Standing and partial circulation to avoid disturbing others within the queue is possible.



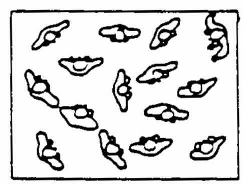
Queuing Level of Service C

Average Pedestrian Area Occupancy: 7-10 sq.ft./person
Average Inter-Person Spacing: 3.0-3.5 ft.
Description: Standing and restricted circulation through the queuing area by disturbing others within the queue is possible; this density is within the range of personal comfort.



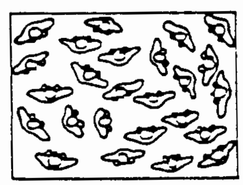
Queuing Level of Service D

Average Pedestrian Area Occupancy: 3-7 sq.ft./person
Average Inter-Person Spacing: 2-3 ft.
Description: Standing without touching is possible; circulation is severely restricted within the queue and forward movement is only possible as a group; long-term waiting at this density is discomforting.



Queuing Level of Service E

Average Pedestrian Area Occupancy: 2-3 sq.ft./person
Average Inter-Person Spacing: 2 ft. or less
Description: Standing in physical contact with others is unavoidable; circulation within the queue is not possible; queuing at this density can only be sustained for a short period without serious discomfort.



Queuing Level of Service F

Average Pedestrian Area Occupancy: 2 sq.ft./person or less
Average Inter-Person Spacing: Close contact with persons
Description: Virtually all persons within the queue are standing in direct physical contact with those surrounding them; this density is extremely discomforting; no movement is possible within the queue; the potential for panic exists in large crowds at this density.

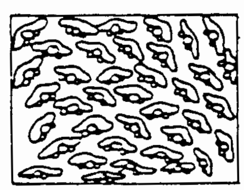
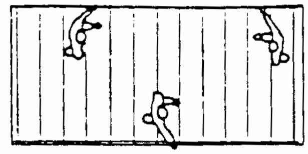


Figure 6. Graphic queuing level of service description.(Source: [7])

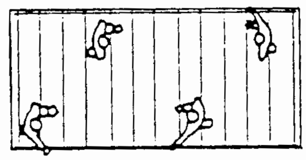
Stairway Level of Service A

Average Flow Volume: 5 PFM* or less
Average Speed: 125 ft./min. or more
Average Pedestrian Area Occupancy: 20 sq.ft./person
Description: Unrestricted choice of speed; relatively free to pass; no serious difficulties with reverse traffic movements; flow is approximately 30 percent of maximum capacity.



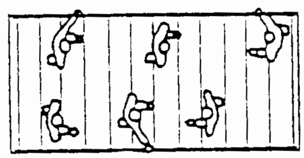
Stairway Level of Service B

Average Flow Volume: 5-7 PFM
Average Speed: 120-125 ft./min.
Average Pedestrian Area Occupancy: 15-20 sq.ft./person
Description: Restricted choice of speed; passing encounters interference; reverse flows create occasional conflicts; flow is approximately 34 percent of maximum capacity.



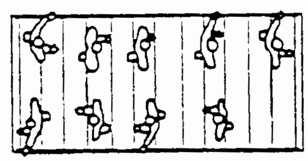
Stairway Level of Service C

Average Flow Volume: 7-10 PFM
Average Speed: 115-120 ft./min.
Average Pedestrian Area Occupancy: 10-15 sq.ft./person
Description: Speeds are partially restricted; passing is restricted; reverse flows are partially restricted; flow is approximately 50 percent of maximum capacity.



Stairway Level of Service D

Average Flow Volume: 10-13 PFM
Average Speed: 105-115 ft./min.
Average Pedestrian Area Occupancy: 7-10 sq.ft./person
Description: Speeds are restricted; passing is virtually impossible; reverse flows are severely restricted; flows are approximately 50-65 percent of maximum capacity.

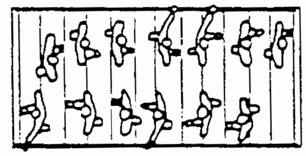


*PFM = Pedestrians per foot width of stairway, per minute.

Figure 7. Graphic stairway level of service description. (Source: [7])

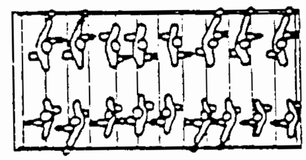
Stairway Level of Service E

Average Flow Volume: 13-17 PFM*
Average Speed: 85-115 ft./min.
Average Pedestrian Area Occupancy: 4-7 sq.ft./person
Description: Speeds are severely restricted; passing is impossible; reverse traffic flows are severely restricted; intermittent stoppages of flow are likely to occur; flows are approximately 65-85 percent of maximum capacity.



Stairway Level of Service F

Average Flow Volume: 17 PFM or greater
Average Speed: 0-85 ft./min.
Average Pedestrian Area Occupancy: 4 sq.ft./person or less
Description: Speed is severely restricted; flow is subject to complete breakdown with many stoppages; passing as well as reverse flows are impossible.



*PFM = Pedestrians per foot width of stairway, per minute.

Figure 7. Graphic stairway level of service description (continued). (Source: [7])

which is organized into traffic lanes and moving uniformly and continuously ahead at an optimum speed for a given density, there are pedestrian environments which involve both standing and movement, or places where movement is not as competitive, ("strolling"), or where there are crossing movements, back-tracking, or otherwise nonuniform and continuous flow. Examples of this type of pedestrian environment include street corners where there is a combination of people walking through the corner while others are waiting to cross, transit platforms where both standing and movement occur simultaneously, and shopping centers where walking speeds are slow and "browsing" may occur. These spaces can be analyzed by the "Time-Space" (TS) method, which uses the personal area and convenience relationships established in the LOS standards, and the estimated average occupancy time of the space.[10]

The TS analysis method assumes that the supply of time-space available is the product of the area in square feet of the section being analyzed, and the length of the analysis period in minutes or seconds. The time-space demand is the product of the number of persons passing through the space during the analysis period, and their estimated occupancy time. Dividing TS demand into TS supply yields the average area per pedestrian, where the dimensions of the space are known. Where the width of the section must be determined, a LOS and personal area is selected to establish the TS demand. Examples of both methods of determining LOS for a known walkway width for a uniform flow situation, and for a non-uniform flow situation by using an estimated space occupancy time is shown below.

LOS - Uniform Flow - Hydraulic Analogy
Sidewalk volume = 100 pedestrians per minute
Walkway width = 20 ft. (less parking meters and buffer)
Effective width = 20-2-2 = 16 ft.
Flow rate per ft. = 100/16 = 6.25 pfm
Add platooning affect: 6.25 pfm + 4 pfm = 10.25 pfm
From table 4 LOS = C, average area per ped $\geq$ 24 sfp

LOS - Non-Uniform Flow - Time Space-Method
Sidewalk volume = 100 pedestrians per minute
Length of sidewalk section = 200 ft.
Net effective width (above) = 16 ft.
Analysis period = 1 minute
Estimated pedestrian occupancy time in section for walking and window shopping = 3 minutes

TS supply = 200 ft. x 16 ft. x 1 minute
= 3,200 sq. ft. minutes
TS demand = 100 peds. x 3 min. occupancy
= 300 ped minutes
Average ped. area = supply/demand
= 3,200 sfm/300 pm
= 10.7 sq. ft. person
LOS from table 4 = E (crowded)

The TS method indicates that for the expected volume of pedestrians and expected occupancy time, the section analyzed will be much more crowded than indicated by the flow analogy method, potentially requiring control measures.

A sample worksheet for estimating sidewalk LOS adapted from the Highway Capacity Manual (HCM), using the hydraulic flow assumption is presented in Appendix A. The HCM uses the TS method for analyzing corners and crosswalks. An advantage of the method is that the effect of turning vehicles moving through the crosswalk during the pedestrian crossing cycle can be estimated. This can be used to determine how many vehicles can conveniently turn at different pedestrian crossing volumes, or if turning restrictions are necessary at heavy volume crosswalks.

<u>Analyzing Street Corners</u> - The Highway Capacity Manual uses the time-space method to determine corner LOS. The available TS at the corner is the product of the area of the corner and the total signal cycle length. The TS demand is divided into 2 parts, the average "holding" TS occupied by standing pedestrians waiting to cross during red intervals, and the circulation TS used by all pedestrians moving through the corner during the cycle. The holding TS is the product of the number of pedestrians held back during the red percentage of the cycle, and an assumed standing area. The holding TS is subtracted from the available TS supply available during the cycle, leaving the TS available for circulation. The TS circulation demand is determined by the product of the total volume of pedestrians moving through the corner and their estimated occupancy time, which the HCM assumes as 4 seconds for most corners. Dividing the circulation demand in pedestrian minutes into the circulation TS supply in square feet minutes yields an average area per pedestrian which can be used to determine corner LOS.

<u>Analyzing Crosswalks</u> - The HCM method for analyzing crosswalks assumes that the TS supply is the product of the green time allotted during the cycle for the pedestrian crossing, and the area of the crosswalk

in square feet. The TS demand is the product of the total number of pedestrians crossing during the cycle and their crossing time based on the average walking speed of 4.5 fps. The HCM also estimates the LOS for the surge that occurs immediately after the start of the green interval, when pedestrians held during the red are released as a platoon.

The effect of turning vehicles on pedestrian LOS is determined by subtracting the TS used by vheicles moving through the crosswalk from the TS supply. The HCM assumes a "tracking width" of 8 feet, and a vehicle turning or crosswalk occupancy time of 5 seconds to determine vehicle turning TS. The TS supply, adjusted for turning movements, is then divided by the pedestrian TS demand to determine LOS. Turning restrictions may be indicated where the resulting average LOS is "C" or worse.

Modifications of the HCM Method - Time lapse photography studies conducted in New York City to validate the HCM corner and crosswalk analysis procedure and assumptions, confirmed that the TS method provided a good estimate of pedestrian densities and LOS observed in photos, but recommended several changes in HCM assumptions to improve the accuracy of the method.[11] These changes are as follows:

- Standing area - in corners for those waiting to cross from the HCM value of 5 square feet per person to 7 square feet;

- Occupancy time - for those moving through the corner from a constant of 4 seconds per person regardless of corner dimensions to an equation:

- Occupancy time (To) secs. = 0.12 (Wa + Wb) + 1.4, where Wa and Wb are the intersecting sidewalk widths in feet;

- Start up time - the delay of 3 seconds before crossing assumed in the HCM is eliminated because of its minimal affect and to simplify calculations;

- Walking speed - reduced in crosswalk analysis from the free-flow average of 4.5 fps (1.4 mps) in the HCM, to 3.3 fps (1.0 mps), to an average more representative of observed crosswalk platoon flow.

Blank worksheets and completed sample problems; adapted from the Highway Capacity Manual, that reflect the changes in the analysis procedures for walkways, corners and crosswalks are presented in appendix A pages 199 through 204.

CHAPTER 3 - PEDESTRIAN TRAFFIC STUDIES

The measurement of pedestrian volume and activity characteristics is necessary to determine the maximum flow rates, flow variations within peak hours and capacity limitations and needs. Such pedestrian information is required in the analysis of traffic signal need, the sufficiency of current facilities, design of new facilities and the impact of new pedestrian trip generators. Obtaining information on pedestrian volumes and trip characteristics is, however, more difficult than obtaining comparable information on vehicles. Pedestrians are not constrained to marked traffic lanes, have a wider variation in travel speeds and are more unpredictable in their movements than vehicles. Midblock traffic counts are the simplest to obtain, but pedestrian traffic on streets is concentrated at intersections, making corner and crosswalk counts necessary to properly determine pedestrian system adequacy. Typically, mid-block surveys will show two connecting sidewalks operating at favorable LOS, whereas their corner intersection is at capacity.

The primary method used for obtaining pedestrian data is manual observation. In addition to manual counting methods, pedestrian traffic studies have been conducted using aerial still photography, time-lapse photography, video-taping and pedestrian trip origin and destination (O & D) surveys. Various analytical techniques using O & D surveys or other sources of trip generation data are sometimes combined with manual counts to develop a pedestrian trip assignment matrix. Automatic counting devices such as turnstiles, electric eyes, ultra-sonic detectors, and pneumatic mats such as those used for opening doors, have been employed on a very limited basis to obtain pedestrian volume data.[12] Turnstile counts at transit stations have been used in studies of pedestrian movement in CBD's to develop assignment of pedestrian trips.

Prior to initiating any data collection efforts it is necessary to determine what data is needed to operationally define the events to be measured and determine what data collection method is required. For example, suppose a crosswalk at a signalized intersection has been experiencing a large number of pedestrians still on the crosswalk when the opposing traffic flow has the right-of-way. It has been decided to conduct a pedestrian operation study to determine if the signal timing and pedestrian phase should be adjusted. Prior to conducting the study it will be necessary to completely define the possible behaviors so that they are completely understood by all observers. In this instance an operational definition of "aborted crossing" might be defined as "pedestrian returns to curb after stepping with both feet into the roadway". This observation could be obtained by either manual or photographic methods. An operational definition of running that is not subjective (such as speed $\geq$ 6.6 ft/sec (2 m/s)), on the otherhand, requires that photographic data collection efforts be used to obtain the required accuracy.

The purpose of the pedestrian study defines the required accuracy and time period of pedestrian volume information. For example, a study to determine whether or not pedestrian volumes meet traffic signal warrants requires a relatively high level of accuracy for applying the hourly signal warrants. Estimates of 24-hour pedestrian volumes to obtain an accident rate measure, however, does not require as high an accuracy level as that required for the signal warrant study. Every traffic survey, therefore, requires careful advance planning to assure that all necessary data is accurately obtained. Field personnel should be given clear instructions on their assignments, and on the necessity of recording data that can be clearly and fully understood by others who will later compile and analyze it Preferrably, supervisors should visit the study site prior to the survey, make preliminary spot counts, establish counting locations, set up data sheets, and identify potential problems. Experience has shown that inadequate preparation and training can result in failures to accurately record counting locations, traffic directions, starting and ending times, street dimensions, signal cycle splits, and other simple, but often vital data. This can require costly repetition of surveys, or data gaps where repitition is not possible.

MANUAL DATA COLLECTION METHODS

Manual data collection is performed by using 1 or more observers in the field and recording behaviors of interest. The data can be recorded using paper and pencil or by tape recording observations for later transferral to data forms. The latter procedure permits a limited review of the data that is not available when the data is recorded by pencil in the field. Many of the pedestrian traffic studies require the development of data forms that are specific to the location being studied. For example, the pedestrian collection form, presented in appendix A, page 206, could be modified to record pass-by pedestrians in addition to in and out volumes of a transit station.

Pedestrian Flow Study

The pedestrian flow study obtains pedestrian volumes by direction. The study can be modified to provide data by pedestrian age groups, queue length and the influence of unusual events contributing to delay. Pedestrian flow counts are often conducted at intersections to determine the need for traffic signals and the adequacy of the existing signal phasing. Pedestrian flow information is necessary to characterize the "level of service" of the site and the direction of movement to determine required countermeasures.

Field counts should be made on "typical" days, free from distortions of weather, or other seasonal effects. Unusually hot, cold, windy, or rainy weather keeps people off streets and cause atypical diversions. Special events, holidays, and parades should be avoided. Unusual happenings, such as accidents or fires may affect the validity of counts and require postponement of surveys. Field personnel should be instructed to record the locations of street or sidewalk repairs, new construction, or any incidents that could influence pedestrian trip volume and direction. The number of personnel required for manual count surveys is dependent on the expected volume of traffic, and the experience of field personnel. Untrained personnel can have difficulty counting heavy volume traffic, but under ideal conditions, an exprienced technician can count up to 10,000 persons per hour on walkways, in a 1-direction flow situation, and 2,000 persons per hour in each direction for 2-way flow.[13,7] An ideal counting location is a clearly delineated or channelized walkway with an unobstructed view. Chalk marks on the pavement or temporary channelization can be set up on heavy traffic locations to divide the walkway into separate counting lanes.

Pedestrian counts are made using tally marks on paper, by tape recorder or by the use of manual or electronic counting boards. Data is recorded for an established time interval of 5 to 15 minues or in the case of some intersection studies, for each signal cycle. At heavy volume locations counts can be made in "5s", or 1 tally on the counter equal to a "set" of 5 persons, which is expanded in the data summary. Where set counting is employed, it must be noted on the data sheet, (i.e., 1 count = 5 peds).

Intersection counts are naturally more complicated than mid-block counts. At a low volume signalized intersection without significant parking, a trained technician should be capable of counting all 4 legs of the intersection for a total intersection volume of up to 500 persons per hour. Two technicians, alternately counting each adjacent crosswalk at a signalized intersection are required for up to 4,000 persons per hour total intersection volume. Four or more technicans are required for extreme high volume intersections, particularly near heavy traffic generators with severe peaking.

Short-Count Methods

Pedestrian volumes vary greatly by hour of the day. An estimate of peak hourly pedestrian volumes requires that pedestrian counts be made during each hour that is likely to have heavy pedestrian travel. Estimates of pedestrian volumes for each of these time periods could be based on short sample counts taken at the middle of each of these periods. For example, hourly estimates of pedestrian volumes, at an intersection in a downtown office area, could be obtained by obtaining short sample counts of 5, 10, 15 or 30 minutes each during the morning, afternoon and evening peak periods. Average daily pedestrian volume estimates, however, would be more accurately determined by dividing the day into 1-, 2- or 4-hour time periods and making estimates of pedestrian volumes, for each of these time periods, based on sample counts. The time period 6:30 A.M. to 6:30 P.M., for example, could be divided into 2-hour increments and sample pedestrian counts taken in the middle of each 2-hour time period.[14]

The rotation of field personnel, for the purpose of counting pedestrian volumes at more than 1 location during a survey period, can be employed to reduce the number of people required for large, areawide surveys. Short counts can also be used in preliminary planning to identify heavy volume locations. An example of a short counting procedure would be counting 12 minutes on one side of the street, then 12 minutes on the other, with a 3 minute break to allow for movement between counting locations and set up. Short counts are expanded to equivalent peak 15 minute or peak hour pedestrian volume by indexing them to a "control station" where a 100 percent count has been made for the full period during which the rotation of personnel has taken place. The control station must be carefully selected. It should be a high volume location where pedestrian traffic patterns are representative of the study area and free from distortion by nearby traffic generators. In a CBD where there is a predominance of work trips, transit station entrance and exit volumes could be used as the control point for a peak period count.

A pedestrian traffic data summary sheet showing information that should be collected and summarized for a typical street intersection is presented in appendix A, page 205. This includes street names and widths, the total net effective widths of sidewalks, (total less light poles, parking meters, etc.), corner radii, midblock volume counts by direction, crosswalk volumes by direction, non-crossing pedestrian volumes moving diagonally between 2 intersecting sidewalks and signal cycle splits. Also included are pedestrian LOS for sidewalks, corners, and crosswalks determined by the Highway Capacity Manual procedure. Spaces for date, day of week, weather, names of counting and analysis personnel, and notes are also required.

A typical intersection pedestrian volume tally sheet showing a small key plan, spaces for time intervals, pedestrian counts by direction and count location, street names, date, counter's name, weather, and notes is presented in appendix A, page 206. Where pedestrian volumes are counted by signal cycle, survey start and end times, and the numerical sequence of cycles should be noted. If set counting is used, it must be noted on the data sheet.

Building Entrance Count Study

Entrance and exit counts of buildings are frequently made and correlated with land use and O & D survey data to develop pedestrian trip generation and assignment models. Studies have also been made of internal movement within buildings by tracking individuals through the use of "time stamping" at check points.[15] The procedures are the same as for other types of pedestrian counts, with the exception that building management should be informed in advance about the purpose of the survey and survey procedures. Building managers are usually cooperative because of their interest in survey results for elevator service and real estate planning purposes. This will aid in obtaining data such as building gross and net rentable area, percent space occupancy, and building population, which are required for modelling purposes.

Pedestrian Traffic Signal Observance Study

The pedestrian traffic signal observance study records the signal indication during which an individual steps from the curb onto the pavement of the intersection. The signal indications for the crossing being studied are noted as "green", "yellow" and "red". If pedestrian signal indications are present then the appropriate indications of the pedestrian signal (such as WALK, flashing DONT WALK and steady DONT WALK) are used. The data form provided in appendix A, page 207, is designed to check 1 crosswalk with provisions for recording diagonal crossings.[16] The compliance of bicycle riders can also be recorded on this form by using the letter "B" for bicycle and the tally mark for pedestrians.

Analysis of the data requires summing the tally marks to provide subtotal and total values. The subtotals consist of each direction of movement compliance category and direction of movement. The combination of subtotals permits the observance characteristics to be summarized as totals for each compliance category. The total number of observations that did and did not comply are also summed. The resultant totals and subtotals are divided by the sample size to provide proportions or percentages. This permits direct comparison to other observance studies with different sample sizes.

Pedestrian Conflict Study

Pedestrian conflict studies investigate the behavior and interaction of pedestrians and vehicles to obtain an insight into problem areas and the potential for accident occurrence. The collection of conflict data permits the identification of appropriate countermeasures prior to the actual occurrence of accidents. Pedestrian conflicts can also be used as variables in pedestrian/vehicle prediction models to help identify potential accident sites.[17] The specific type of conflicts obtained is dependent upon the purpose of the study. Two conflict studies, and their associated data forms, will be presented in this section. The first conflict study, pertaining to analyzing right-turn-on-red (RTOR), will be discussed in depth to provide an insight into the type of data obtained. The purpose of the second study is to provide a general pedestrian conflict data form that contains those conflict types that are appropriate for the majority of conflict studies.

Warrant 4 of the MUTCD (Section 2B-37) states that RTOR may be prohibited when an engineering study determines that significant pedestrian conflicts are resulting from RTOR manuevers.[18] The basic types of RTOR conflicts which may be collected are as follows:[19]

1. RTOR Pedestrian Conflict - A RTOR vehicle interacts with a pedestrian such that either the pedestrian or RTOR vehicle must stop, speed up, or change direction to avoid a collision. A RTOR pedestrian conflict may occur in either the near or far crosswalk, as illustrated in figure 8. Note that a RTOR pedestrian conflict in the far crosswalk may result when a pedestrian crosses against the light (i.e., during the DON'T WALK interval). Specific types of RTOR pedestrian conflicts are discussed below:

    - Vehicle Hesitation (VH) - Vehicle slows or stops to avoid hitting a pedestrian while executing a RTOR maneuver as presented in figure 9.

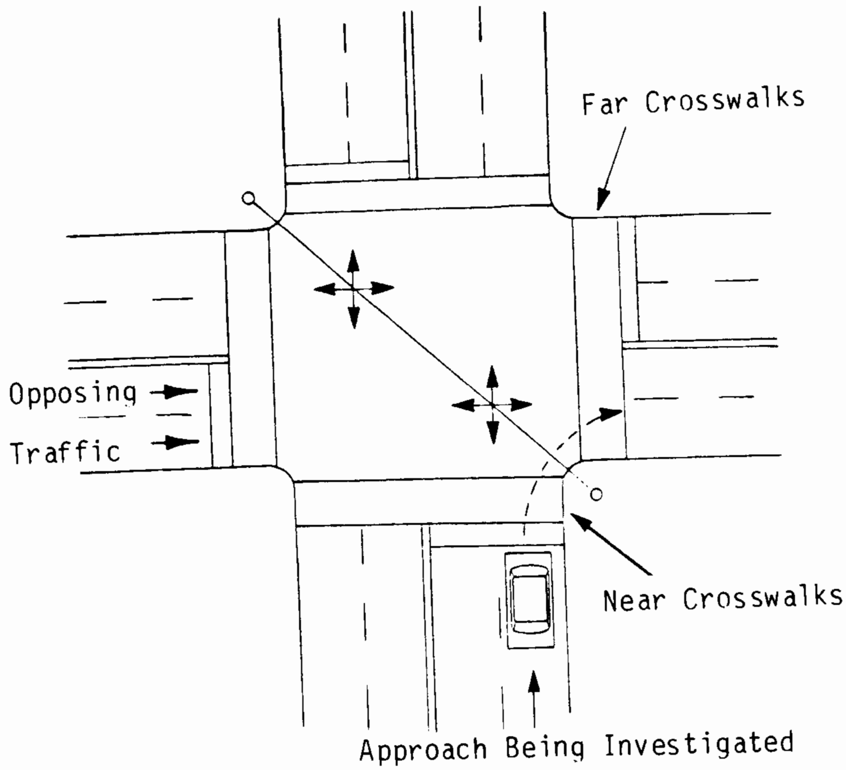


Figure 8. Illustration of the near and far crosswalks.

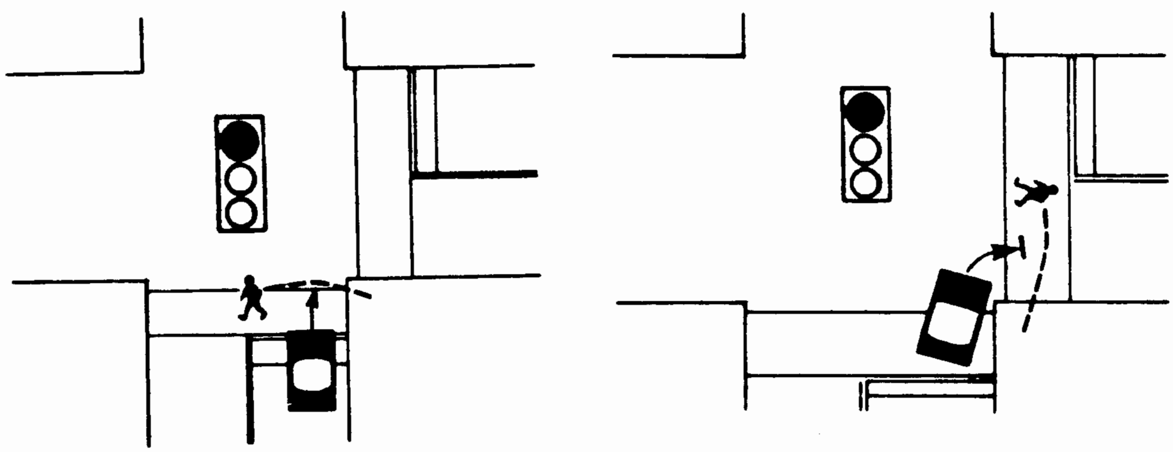


Figure 9. Vehicle slows or stops to avoid hitting a pedestrian.

- Vehicle Swerve (VS) - Vehicle swerves to avoid hitting a pedestrian as presented in figure 10.

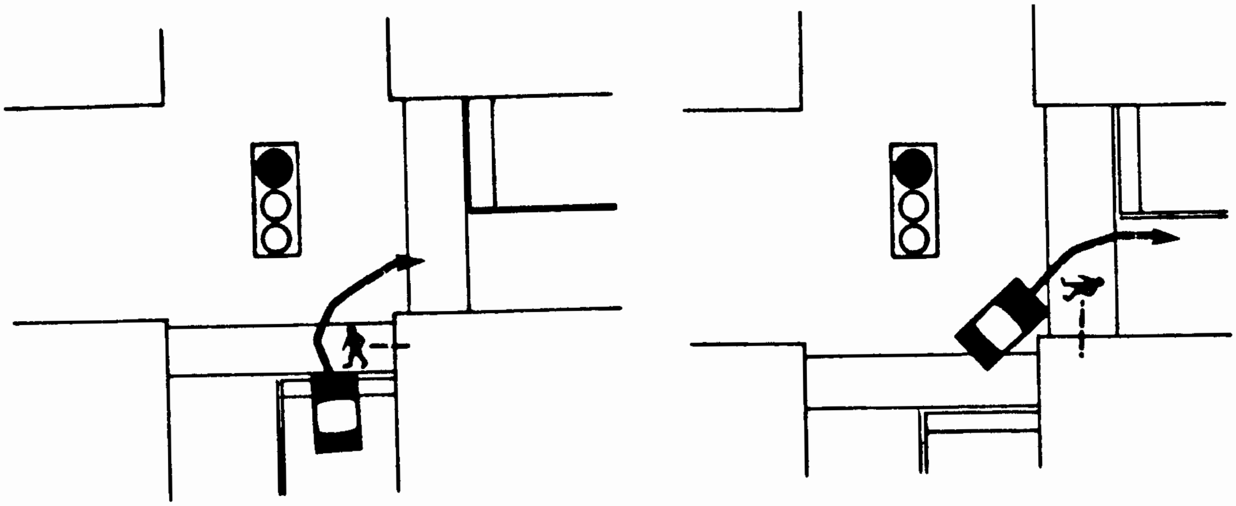


Figure 10. Vehicle swerves to avoid hitting a pedestrian.

- Pedestrian Hesitation (PH) - Pedestrian slows, stops, or reverses direction of travel to avoid a collision as presented in figure 11.

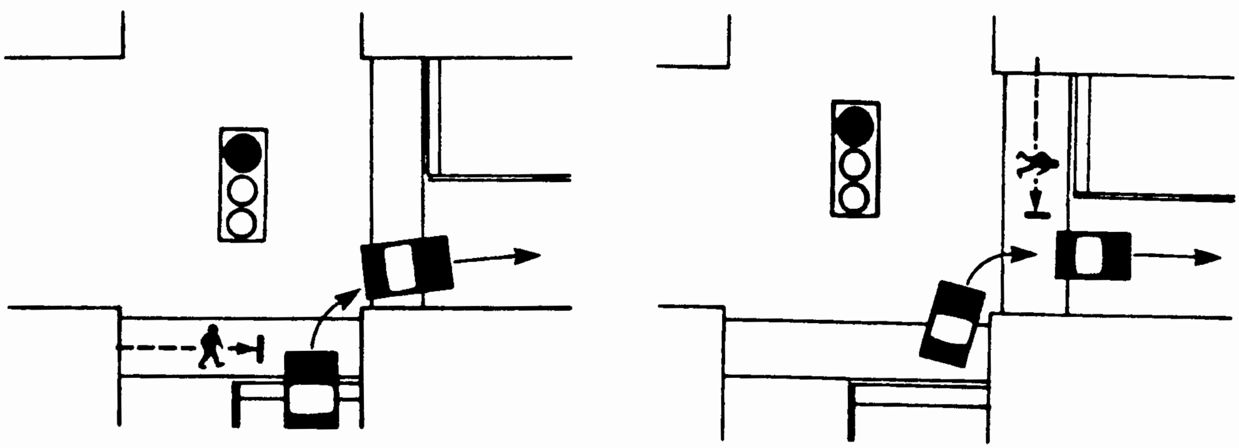


Figure 11. Pedestrian slows, stops, or reverses direction of travel to avoid a collision.

- Pedestrian Run (PR) - Pedestrian increases walking speed or runs to avoid a collision as presented in figure 12.

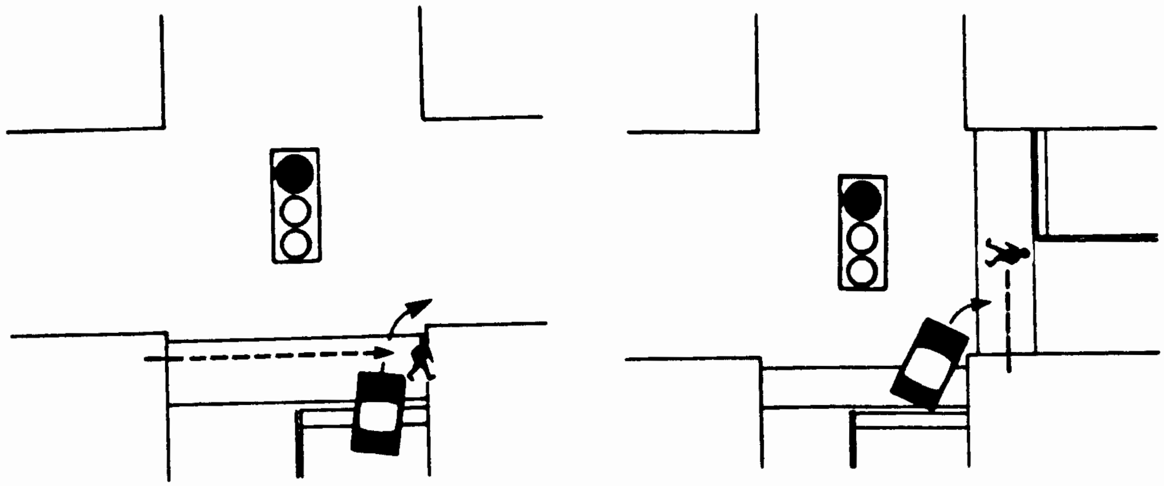


Figure 12. Pedestrian increases walking speed or runs to avoid a collision.

2. Interaction (1) - Neither the vehicle nor the pedestrian reacts, but the pedestrian is in a moving lane and is within 20 feet (6 m) of the RTOR vehicle as presented in figure 13.

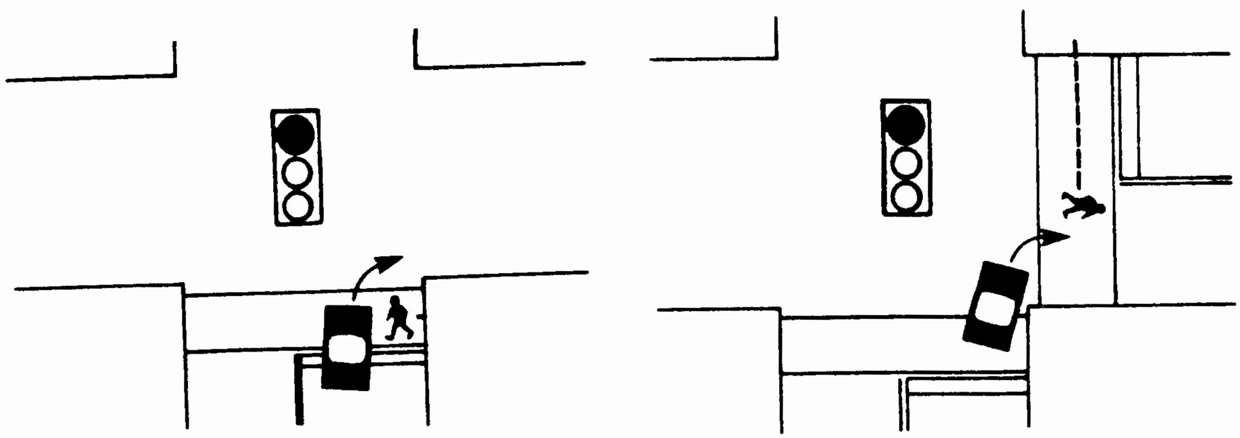


Figure 13. Interaction where neither the vehicle nor pedestrian reacts, pedestrian is in a moving lane within 20 feet (6 m).

3. Secondary Conflicts (SC) may also be collected, if desired. These occur when a vehicle is forced to brake or weave as a result of a previous RTOR conflict as presented in figure 14. Secondary conflicts are usually rare, and may be of minor importance compared to the primary conflict types.

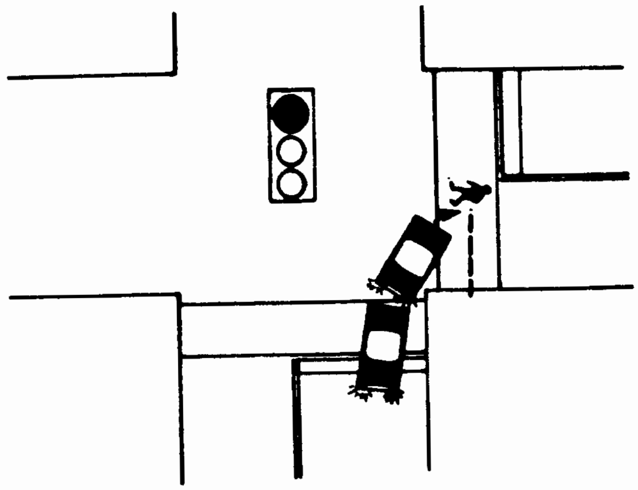


Figure 14. Secondary conflict occurs when a vehicle is forced to brake or weave as a result of a previous RTOR conflict.

As evident from the RTOR conflict types, the type of vehicle-pedestrian interaction which is observed is dependent upon the purpose of the study. If, for example, an outlying suburban area is under going rapid development, then the need for sidewalks on a high-volume arterial can partially be determined by observing the number of vehicles that brake or weave for pedestrians walking on the shoulder. A data collection form for different types of pedestrian conflicts is presented in appendix A, pages 208 and 209.

Conflict data are commonly collected in 10-minute intervals and should include such information as:

- Start time and end time of the data collection period (military time).
- Approach (northbound, eastbound, etc.).
- The pedestrian volume on the approach or facility being analyzed.
- The number of vehicles that could interact with pedestrians.
- The number of conflict opportunities (i.e., simultaneous presence of pedestrians and vehicles).

Whenever a pedestrian-related conflict occurs, the observer should place a symbol which identifies the type of conflict which occurred in the corresponding box. For the RTOR conflicts the symbols (VH, VS, PH, PR, or I which are defined on the form of page 208) should be used. The conflict data is totaled for each conflict type to determine the number of conflicts per hour. A decision that must be made is the number of conflicts which may be considered to be "significant" (i.e., corresponds to an unsafe level). There is no specific number that should be considered as an absolute cutoff value for all situations. Collecting conflict data at locations with similar volumes but no problems can often serve as a base for decision making. For RTOR analysis, the results of a study on 111 approaches with RTOR allowed and 95 approaches with RTOR prohibited can be used as a starting point.[19] This study collected conflict data for 4 to 8 hours per approach, which included both peak and off-peak periods.

Summaries obtained during the RTOR study, of the peak hour conflict levels at RTOR-allowed sites, are given in table 5, separately for RTOR pedestrian conflicts and total RTOR conflicts (i.e., pedestrian plus cross traffic conflicts). These levels are expressed in terms of percentiles, from 0 to 100. For example, the RTOR pedestrian conflicts per intersection approach ranged from 0 to 20 per peak hour. Ninety percent of the locations had peak hour conflicts of 6 or less, 50 percent of the locations had 2 or less conflicts, etc. Thus, a user may wish to select a percentile level to use as a basis, and then use the corresponding conflict level as a critical value. For example, if a user considers the top 5 percent of sites (i.e., 95 percentile level) as candidates for RTOR prohibition, then a value of 7 RTOR pedestrian conflicts per hour may be selected as a critical level.

The same kind of analysis may be used to analyze total RTOR conflicts (i.e., includes pedestrians plus cross-street conflicts). Critical values may be selected in the same way based on selected percentile levels. A 95 percentile level of total RTOR conflicts would be 11 per peak hour. The determination of what percentile level to select is strictly a decision of the user, and should be based on the user's perception of the effectiveness of NTOR signs on local intersections. A value of 80 to 95 percent would be a reasonable range, which would correspond to 4 to 7 RTOR pedestrian conflicts per hour, or 6 to 11 total RTOR conflicts per hour.

Note that the actual numbers of RTOR conflicts with cross-street traffic and pedestrians will vary widely, depending on such factors as:

Table 5. Summary of conflict distributions at RTOR allowed sites. (Source: [19], page 22)

Level	Number of Conflicts per Peak Hour*	
	RTOR-Pedestrian Conflicts	Total RTOR Conflicts (Pedestrian & Cross Traffic)
0 Percentile (Minimum Value)	0	0
10 Percentile	0	0
20 Percentile	0	1
30 Percentile	1	2
40 Percentile	1	2
50 Percentile	2	3
60 Percentile	2	3
70 Percentile	3	5
80 Percentile	4	6
90 Percentile	6	10
95 Percentile	7	11
100 Percentile (Maximum Value)	20	32

* Values exlude interactions and secondary conflicts.

- The volumes of cross-street traffic and pedestrians at the site.
- The number of RTOR vehicles per hour.
- The number of RTOR motorists that make a full stop before making a RTOR.
- Signal timing, roadway geometrics, and other site conditions.

The use of table 5 assumes that the locations of interest represent a similar range of conditions as the sites used in the research study, which consisted of sites in urban and urban fringe areas in the cities (and surrounding areas) of Detroit, Michigan; Washington, D.C.; and Austin and Dallas, Texas. Most of the intersections were selected in areas with heavy to moderate pedestrian activity.

The RTOR conflict distributions are intended to be a starting point for initial use. Users should first test the conflict levels based on their own local conditions for numerous sites. If the conflict levels at the agency's sites differ substantially from table 5, then the agency should develop their own critical conflict levels for use based on local conditions and conflict patterns.

Pedestrian Gap Studies

Pedestrian crossing safety is dependent upon an appraisal of street width, vehicular speeds and volumes, pedestrian volumes, and gaps in the traffic stream. The minimum length of gap that will permit a group of pedestrians to cross a street of width (w) depends on group size, perception-reaction time and walking time. The minimum length of gap must equal the time needed by the group to safely cross the roadway. The minimum gap time (G) is computed from the following equation:[20]

$$G = \frac{W}{V} + P + K(N - 1)$$

Where:

W = width of the pavement to be crossed, ft or m

V = juvenile pedestrian walking speed (usually taken at 3.5 ft/s or 1 m/s)

P = pedestrian perception and reaction time, which is the number of seconds required for a juvenile to look both ways, make a decision, and start to walk across the street (usually taken at 3.0 s)

N = number of rows of pedestrians

K(N -1)= total added time required for the entire group to enter the roadway, seconds; K is the time between the rows (usually taken as 2.0 s)

The roadway crossing width is measured manually as the curb-to-curb (shoulder-to-shoulder) width. If a median exists and is wide enough to service the waiting pedestrian demand, the median-to-curb width may be used to represent the required roadway crossing width. The width information study time and locational criteria are recorded on the data collection form. The cumulative group sizes from the data collection forms are inspected to determine the 85th percentile of all group sizes observed in the field, as in the example of figure 15. The size of each row (i.e., the number of pedestrians walking abreast), can also be determined but is often found to be 5.[21] The number of rows is determined by dividing the row size into the 85th percentile of the observed group size and rounding up to the next higher interger. The pedestrian observation studies should be performed on a normal activity day during the heaviest hour of crossing activity. A pedestrian group size form is provided in appendix A, page 210.

STUDY DATE 3/2/74 TIME: From 8 a.m. To 9 a.m. LOCATION 4th and L

CROSSWALK ACROSS 4th Street CURB-TO-CURB DISTANCE 40'

DIVIDED ROADWAY Yes No WIDTH OF ISLAND NA

Group size	Number of groups		Cumulative	Computations
	Tally	Total		
5 or fewer	/	1	1	60 x .85 = 51
6-10	𝍸	5	6	
11-15	𝍸 𝍸 //	12	18	
16-20	𝍸 𝍸 𝍸 ///	18	36	
21-25	𝍸 𝍸 ///	13	49	85% = 26-30 pedestrians
26-30	𝍸 //	7	56	
31-33	///	3	59	
36-40	/	1	60	
41-45				
46-50				
	TOTAL NUMBER OF GROUPS	60		

Figure 15. Sample pedestrian-group size study field sheet. (Source: [20], p. 17)

The field study also requires measurements of the gaps between passing vehicles. The vehicle gap study should be performed simultaneously with the pedestrian demand study and can be recorded on the pedestrian delay study form provided in appendix A, page 211. The vehicle gaps that are equal to or greater than the acceptable gap time for the established 85th percentile group size are the periods when the pedestrians can safely cross the roadway. The time intervals between the acceptable gaps is the amount of time that the pedestrians are delayed. The total available crossing time is the sum of all time during which each vehicle gap was equal to or greater than the acceptable gap. This total (t) is subtracted from the total survey time (T) and applied in the following equation to determine the percentage of potential pedestrian delay, D:

$$D(\%) = \frac{T - t}{T} \times 100$$

Similar methods can be used to determine pedestrian delay at signalized intersections. In this instance it is necessary to substitute cycle length C for T and measure only the gaps between vehicles turning both right and left across the crosswalk being studied.

PHOTOGRAPHIC STUDY TECHNIQUES

Photographic and videotaping techniques have a number of advantages, but have the disadvantage that they can consume significant amounts of time for data take-off and analysis, up to 10 times the real time recorded. Time-lapse photography and videotaping have the advantage of providing a permanent record that can be repeatedly used to obtain different types of data, additional and often unexpected insights into traffic characteristics, and used as a presentation media for other interest groups. Time-lapse photography of intersections can supply a variety of data such as pedestrian and vehicle volumes by direction, pedestrian accumulations in corners and crowding in crosswalks, vehicle delays due to crossing pedestrians, jay walking and pedestrian risk taking, pedestrian crossing speeds, and effects of weather and other transient conditions.

Time-lapse photography requires a movie camera equipped with an intervalometer, a timing device that regulates the frame interval, and an "analyst" projector with single frame still projection capability and a frame counting mechanism.[22] The frame counter is needed to catalog film sequences and correlate them to real time. Field procedures for time-lapse photography are dependent on the availability of a vantage point high enough to view the study area through the camera lens. It is advisable to shoot trial footage at the study site to check camera angles and site coverage.[23] More than 1 camera may be required for a comprehensive study of a large intersection. Definitive reference points, within the camera field of view, must be established where density and speed measurements will be taken off the film, to allow corrections for parallax. Frame intervals for time-lapse photography depend on the type of study and length of the survey period. Where detailed measurements of pedestrian flow will be made, 2 frames per second may be necessary, whereas in more generalized traffic studies over longer periods of time, 6 to 10 frames per minute may be adequate.

The time required for data take off from time-lapse films is dependent on the degree of detail required. It can be very difficult and time consuming to count individual pedestrians in heavy density traffic in corners and crosswalks. As of this writing, there is no proven application of a light pen - touch screen CRT computerized data take off procedure, but this method is considered to be well within the capability of available technology.

Sky Counts

Aerial photography has been used with some success in wide area studies of traffic conditions at airports and large interchanges, and has been used for generalized pedestrian density studies in CBDs. Aerial photography can give a single "freeze frame" look at CBD pedestrian traffic, and help pinpoint critical intersections.[24] Pedestrian density counts have been obtained from aerial photos by means of microscopes, and the resulting data used to develop a predictive model of sidewalk activity based on nearby land use. However, this technique is not recommended because of its high cost and doubtful accuracy.

Automatic Counting Devices

For many years there has been the hope that an automatic pedestrian counter would be developed comparable to the simple vehicle counters that are in wide use. The City of Seattle developed a rubber mat counter based on a modified pneumatic mat door opener, and has used it for pedestrian volume studies with reported accuracy of up to 90 percent.[25] The mat must be taped to the sidewalk to minimize tripping hazards. Turnstiles, electric eyes, ultra-sonic detectors, infra-red and induction sensors have been used to obtain pedestrian count data under controlled conditions where pedestrians are channelized through a doorway or limited space, but these methods can not be used effectively for counting wider walkways. "Pattern recognition" using video camera and computer micro-processing is a technology which may lead to the development of a more adaptable pedestrian counting system. With this technology the computer is programmed to recognize the shape of a moving pedestrian on the video camera, to track it and record it in real time. Data output would be the direction and number of pedestrians recorded by time intervals.

PEDESTRIAN TRAFFIC IMPACT STUDIES

Pedestrian traffic impact studies have been required as part of the environmental impact study (EIS) process in New York City for many years. The City requires developers to provide an analysis of pedestrian traffic impacts on sidewalks, corners, crosswalks, and transit station pedestrian facilities, as part of the approval process for new projects. In some cases, developers have had to widen sidewalks, make transit station improvements, or provide other pedestrian amenities, to obtain project approvals. The City requires developers to assess 3 stages of pedestrian activity, (1) existing traffic conditions; (2) the "no-build" alternative with all other programmed development added to existing traffic without the proposed project; and (3) the build alternative, full development with inclusion of the proposed project.

The impact process involves surveys and analysis of existing pedestrian traffic on sidewalks, corners, crosswalks, and transit stations in the vicinity of the proposed project site, development of pedestrian trip generation estimates for the no-build and build alternatives based on programmed land use and expected patterns of pedestrian activity, and analysis of impacts for 3 stages based on Highway Capacity Manual LOS estimating procedures.

The inclusion of pedestrian traffic analysis in the environmental impact process should become the national standard for large developments, rather than the exception. There are many examples throughout the United States of major shopping malls that have been designed almost exclusively for automobile access, without any consideration of the pedestrian and bicycle transportation modes. This has resulted in dangerous exposures of pedestrians and cyclists who need to access the shopping center, but may be too young or too old to drive an auto, or too poor to own one.

QUESTIONNAIRE AND INTERVIEW SURVEYS

Various levels of questionnaire surveys, ranging from short interviews of individual pedestrians to large scale trip origin and destination surveys, have been employed to develop models of pedestrian trip characteristics, and estimates of pedestrian volumes and route choices. Short interviews at strategic locations can be used to develop route choice percentages and other basic data. Portable computers have been used for direct input of short interview field data as an innovative means of obtaining quick results without the need for further compilation by office personnel. Tape recorders have also been used to collect field data to eliminate the distractions of notetaking, but this requires later data reduction off of the tapes. A sample of a pedestrian questionnaire survey to determine trip patterns and walking route choices for a large CBD office complex is shown in appendix F, page 248.

Depending on methodology and scope, larger scale origin and destination surveys can determine socio-economic characteristics of the trip maker, trip purpose and frequency, route choice, and trip generation rates for various types of land use. Origin and destination surveys have been conducted by home interview (either in person or by telephone), by mailed questionnaires, by field distribution and collection (either at cordon points or as a mailback), or by distribution to controlled populations, such as selected groups of employees.

The postcard mailback survey is the most popular form of O & D survey, because of its convenience and lower cost, and reasonably high return rate when it is properly publicized and return incentives offered. Incentives that have proved to be effective include the award of theater tickets or dinner for 2, based on a random drawing of questionnaire returns.

Strict statistical control of questionnaire distribution, related to the population sampled, is important since results will be expanded and considered representative of the whole population. The design of questionnaires will determine the amount and credibility of returns.[26] Attractive graphic design, with cheerful, concise, and simple explanations of survey purpose and method are necessary. Questions should be kept short, simple and direct, without ambiguity. The number of questions should be limited, and the temptation to request other useful but secondary information, avoided. Where more information is desirable, several versions of the questionnaire, can be developed with the same primary questions, but with variations in secondary questions to obtain the additional information. Since the large O & D survey may represent a significant investment in time and money, smaller trial surveys can be attempted to test interpretation of questions and survey logisitics.

CHAPTER 4 - PEDESTRIAN SAFETY STUDIES

Conducting pedestrian safety studies can best be accomplished by a State or local agency by following a 6-step process, referred to as a "Model Pedestrian Safety Program" as follows:[27]

- Step 1 - Determine the Extent of the Pedestrian Safety Problem. This involves determining the types and locations of pedestrian accidents, as well as collecting data on pedestrian volumes, drivers and pedestrian behavior, and traffic and roadway conditions.

- Step 2 - Identify Alternative Solutions. Based on past agency experiences with various countermeasures, candidate safety improvements should be suggested for specific locational problems.

- Step 3 - Select the Best Alternative. This step should involve tailor fitting specific treatments which are judged to be optimal at each individual site. Advantages and disadvantages of the alternative should be carefully weighed.

- Step 4 - Implement Selected Alternatives. The selected safety improvements are designed, scheduled and implemented in this step. Financial considerations must be worked out.

- Step 5 - Evaluate the Effectiveness of the Implemented Alternative. This involves determining the effectiveness of the completed improvement in enhancing pedestrian safety.

- Step 6 - Maintain the Pedestrian Safety Program. This step relates to the activities to maintain and modify pedestrian safety efforts within the agency's jurisdiction.

The success of an agency's pedestrian safety program depends on using a comprehensive process involving engineering improvements to the roadway, education programs for pedestrians and motorists, and police enforcement of local laws and ordinances. Detailed discussions of these 3 E's are found in numerous other publications.[27,28,29,30,31] This chapter, however, will focus primarily on engineering improvements and related procedures.

DETERMINE THE EXTENT OF THE PEDESTRIAN SAFETY PROBLEM

A highway agency can best accomplish a pedestrian safety analysis by identifying locations with abnormally high pedestrian accidents and sites with a high potential for accidents (e.g., based on dangerous pedestrian or vehicle activity). Common sources of information for locating such problems include:[27]

- Citizen complaints.
- Analysis of pedestrian accidents.
- Collection and analysis of behavioral data (including pedestrian/vehicle conflicts).

Citizen complaints can be useful in helping to identify problems which may otherwise be overlooked by transportation officials. Private citizens, local police officials, school officials, or others may all be aware of situations where pedestrians face special hazards. Agencies have often been found to be negligent in lawsuits resulting from accidents when citizen complaints have been ignored. Accident studies and field investigations of pedestrian and motorist behavior are necessary at such sites to determine whether in fact a problem does exist.[27]

Analysis of pedestrian accidents is another important step in quantifying a potential pedestrian safety problem. A formal procedure has been developed for classifying pedestrian accidents by type based on the sequence of behavior by both the pedestrian and motorist and on other contributing factors. Two approaches developed by the National Highway Transportation Safety Administration (NHTSA) for classifying accident types are termed Computer Accident Typing (CAT) and Manual Accident Typing (MAT). Details of these procedures are available from NHTSA publications.[32,33]

The most common types of pedestrian accidents in urban, rural, and freeway situations are summarized and explained in tables 6 through 8, respectively. For example, the most frequently occurring accident types in urban areas are the result of pedestrians, not at an intersection, darting into traffic and being struck before the pedestrian has crossed less than halfway (dartout - first half = 23 percent).[34,35] The most common pedestrian accident types in rural areas include dart-outs (21 percent for both types combined) and walking along roadway (12 percent).[35,36] On freeways, the most prevalent types include disabled vehicle-related (20 percent) and pedestrians struck as a result of a vehicle crash (10 percent).[35,37] Illustrations of the most common pedestrian accident types are provided in figure 16.[38]

The unsafe behavior of pedestrians and/or vehicles is another source of information which is valuable in detecting pedestrian safety problems. Since pedestrian accidents are the result of a certain pattern of behavior

Table 6. Urban pedestrian accident types and critical behavior descriptors. (Source: [27], p. 8]

Accident Type	Percent of Accidents Studied	Location and/or Critical Behavioral Descriptors
Dart Out (First Half)	23	Midblock (not at intersection). Pedestrian sudden appearance and short time exposure. Driver has no time to react to avoid collision. Pedestrian crossed less than halfway.
Dart Out (Second Half)	9	Same as above except pedestrian gets more than halfway across before being struck.
Midblock Dash	7	Midblock (not at intersection). Pedestrian running but not sudden appearance or short time exposure as above.
Intersection Dash	12	Intersection. Short time exposure or running. Same as "Dash Out" except occurs at intersection.
Vehicle Turn Merge with Attention Conflict	4	Intersection or vehicle merge location. Vehicle turning or merging into traffic. Driver attending to auto traffic in one direction collides with pedestrian located in different direction than that of driver's attention.
Turning Vehicle	5	Intersection or vehicle merge location. Vehicle turning or merging into traffic. Driver attention not documented. Pedestrian not running.
Multiple Threat	3	One or more vehicles stop in traffic lane (e.g., Lane 1) for pedestrian. Pedestrian hit stepping into parallel same direction traffic lane (e.g., Lane 2) by vehicle moving in same direction as stopped vehicle. Collision vehicle driver's vision of pedestrian obstructed by stopped vehicle.
Bus stop Related	2	At bus stop. Pedestrian steps out from in front of bus at bus stop and is struck by vehicle moving in same direction as bus while passing bus Same as "Multiple Threat" except stopped vehicle is bus at bus stop.

Table 6. Urban pedestrian accident types and critical behavior descriptors (continued).

(Source: [27], p. 8)

Accident Type	Percent of Accidents Studied	Location and/or Critical Behavioral Descriptors
Vendor, Ice Cream Truck	2	Pedestrian struck while going to or from vendor in vehicle on street.
Disabled Vehicle Related	1	Pedestrian struck while working on or next to disabled vehicle.
Result of Vehicle-Vehicle Crash	3	Pedestrian hit by vehicle(s) as result of vehicle-vehicle collision.
Trapped	1	Signalized intersection. Pedestrian hit when traffic light turned red (for pedestrian) and cross traffic vehicles started moving.

Table 7. Rural pedestrian accident types and critical behavior descriptors. (Source: [27], p. 9)

Accident Type	Percent of Accidents Studied	Location and/or Critical Behavioral Descriptors
Dart Out (First Half)	11	Pedestrian sudden appearance, short time exposure. Driver does not have time to react to avoid collision. Pedestrian crossed less than halfway.
Dart Out (Second Half)	10	Same as above except pedestrian more than halfway across before being struck.
Midblock Dash	10	Midblock (not at intersection). Pedestrian running but not sudden appearance or short time exposure as above.
Intersection Dash	10	Intersection. Short time exposure or running. Same as "Dart Out" except occurs at intersection.
Vehicle Turn Merge with Attention Conflict	1	Intersection or vehicle merge location. Vehicle is turning or merging into traffic. Driver attending to auto traffic in one direction collides with pedestrian located in different direction than that of driver's attention.
Turning Vehicle	2	Intersection or vehicle merge location. Vehicle turning or merging into traffic. Driver attention not documented. Pedestrian not running.
Multiple Threat	2	One or more vehicles stop in traffic lane (e.g., Lane 1) for pedestrian. Pedestrian hit stepping into next parallel same direction traffic lane (e.g., Lane 2) by vehicle going in same direction as stopped vehicle. Collision vehicle driver's vision of pedestrian obstructed by stopped vehicle.
School Bus Related	3	Pedestrian hit while going to or from school bus or school bus stop.
Vendor Ice Cream Truck	1	Pedestrian struck while going to or from vendor in vehicle on street.

Table 7. Rural pedestrian accident types and critical behavior descriptors (continued).

(Source: [27], p. 9)

Accident Type	Percent of Accidents Studied	Location and/or Critical Behavioral Descriptors
Disabled Vehicle Related	6	Pedestrian struck while working on or next to disabled vehicle.
Result of Vehicle-Vehicle Crash	1	Pedestrian hit by vehicle(s) as result of vehicle-vehicle collision.
Backing Up	2	Pedestrian hit by vehicle backing up.
Walking Along Roadway	12	Pedestrian struck while walking along edge of highway or on shoulder. Can be walking facing or in same direction as traffic.
Hitchhiking	2	Pedestrian hit while attempting to thumb ride.
Weird	8	Unusual circumstances. Not countermeasure corrective.

Table 8. Freeway pedestrian accident types and critical behavior descriptors. (Source: [27], p. 10)

Accident Type	Percent of Accidents Studied	Location and/or Critical Behavioral Descriptors
Disabled Vehicle Related	20	Pedestrian struck while working on or next to disabled vehicle.
Result of Vehicle-Vehicle Crash	10	Pedestrian hit by vehicle(s) as result of vehicle-vehicle collision.
Weird	10	Unusual circumstances. Not countermeasure corrective.
Hitchhiking	9	Pedestrian hit while attempting to thumb ride.
Walking to/from Disabled Vehicle	8	Pedestrian struck while walking along edge or shoulder of highway. Reason for walking because of disabled vehicle. Can be walking facing or in same direction as traffic.
Dart Out	5	Not at interchange. Pedestrian sudden appearance and short time exposure. Driver does not have time to react to avoid collision.
Walking Along Roadway	5	Pedestrian struck while walking along edge of highway or on shoulder. Can be walking facing or in same direction as traffic.
Working on Roadway	3	Pedestrian (flagperson or other construction worker) struck while working on roadway or shoulder.
Midblock Dash	*	Not at interchange. Pedestrian running but not sudden appearance or short time exposure.

* Less than 1 percent.

Table 8. Freeway pedestrian accident types and critical behavior descriptors (continued).

(Source: [27], p. 10)

Accident Type	Percent of Accidents Studied	Location and/or Critical Behavioral Descriptors
Vehicle Turn-Merge with Attention Conflict	*	Vehicle merge location. Vehicle merging into traffic. Driver attending to auto traffic in one direction collides with pedestrian located in different direction than that of driver's attention.
Turning Vehicle	*	Vehicle merge location. Vehicle merging into traffic. Driver attention not documented. Pedestrian not running.

* Less than 1 percent.

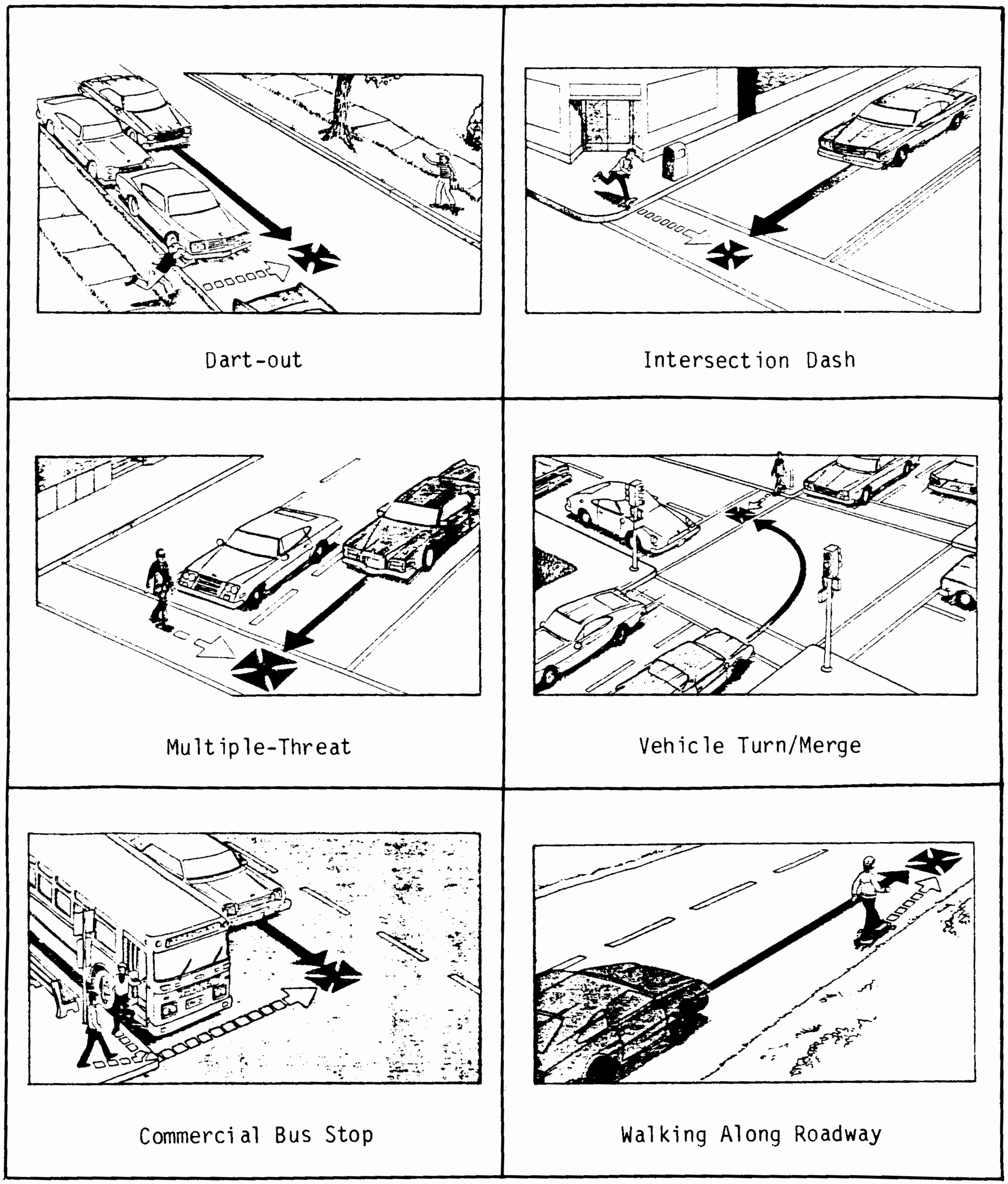


Figure 16. Illustration of common types of pedestrian accidents. (Source: [38], pp. 12-30)

(e.g., pedestrian violates DON'T WALK signal at busy intersection or runs into the street between parked cars in front on an oncoming vehicle), it is often useful to collect data on the frequency of such behavior which can lead to accidents. Numerous examples of such behavior by pedestrians or motorists are listed in table 9.[28] In addition to these, specific types of pedestrian-vehicle conflicts have been defined for use in safety and operational studies, where a pedestrian conflict involves a vehicle which brakes or swerves to avoid hitting a pedestrian. The specific conflict types include:[39]

- Pedestrian, far-side conflict - a through vehicle brakes or swerves to avoid hitting a pedestrian on the far side of the intersection.
- Pedestrian near-side conflict - same as above, only the pedestrian is crossing the street on the near side of the intersection.
- Right-turn, vehicle-pedestrian conflict - a right-turn vehicle at an intersection brakes or swerves to avoid an accident with a pedestrian in the crosswalk.
- Left-turn, vehicle-pedestrian conflict - same as above, only the vehicle turns left.
- Right-turn-on-red, vehicle-pedestrian conflict - right-turn-on-red vehicle brakes suddenly or swerves around a pedestrian after beginning a RTOR maneuver.

Sketches of these 5 conflict types are illustrated in figure 17. Details of traffic conflict techniques are described in greater detail on page 33. For further information the user should see "Traffic Conflict Techniques for Safety and Operations".[39]

IDENTIFY ALTERNATIVE SOLUTIONS

Identifying the nature and extent of the problem enables the idenfication of candidate improvements which are likely to be effective in reducing the problem. Numerous engineering solutions are available, which may be matched with the specific accident type discussed earlier, as presented in tables 10 through 12. Table 10 lists 20 types of pedestrian accidents and corresponding candidate countermeasures which may be appropriate in urban situations.[34,35] For example, if a roadway location has a high incidence of intersection dash pedestrian accidents, some of the solutions that may be appropriate include:

Table 9. Examples of pedestrian and vehicle behavior measures. (Source: [28], p. 11)

Pedestrian Behavior	Definition
Aborted Crossing:	Return to curb after having both feet in roadway.
Pedestrian Conflict:	Pedestrian walks in front of a turning vehicle, causing the vehicle to brake or swerve.
Pedestrian Hesitation (turning vehicle):	Pedestrian hesitates because of turning vehicles.
Crossing Against Light:	Entry and exit from roadway while traffic has green signal or pedestrian signal shows flashing or steady don't walk.
Pedestrian Hesitation (through vehicle):	Pedestrian stops in roadway to allow one or more vehicles to pass.
Leaving Crosswalk:	Exiting from crosswalk area into traffic lane.
Walking Outside of Crosswalk:	Crossing all traffic lanes outside crosswalk area.
Trapped on Median:	Waiting for passage of one or more vehicles while on median.
Bus Stop Related:	Crossing (against the light) in front of bus stopped at bus stop.
Vehicle Overtaking:	Pedestrian steps into roadway and moves in front of standing vehicle into next lane of traffic (multiple threat behavior).
Running Into Roadway:	Entry into roadway while running.
Running in Roadway:	Start of running after entry into roadway.
Sudden Appearance:	Running into roadway from between parked vehicles (dart-out behavior).
Backup Movement:	Momentary reversal in pedestrian direction of travel.
Approach Search Behavior:	Looking for oncoming traffic before stepping off curb.
Crossing Search Behavior:	Looking for oncoming traffic while crossing the roadway.

Table 9. Examples of pedestrian and vehicle behavior measures (continued). (Source: [28], p. 11)

Pedestrian Behavior	Definition
Gap Size Accepted:	Distance of closest vehicle in lane as pedestrian enters lane.
Delay:	Length of time spent waiting for acceptable gap.

Vehicle Behavior	Definition
Delay:	Length of time spent waiting for pedestrian to clear roadway.
Approach Speed:	Travel velocity.
Turning Conflict (Vehicle):	Number of turning vehicles having pedestrian cross in front of them.

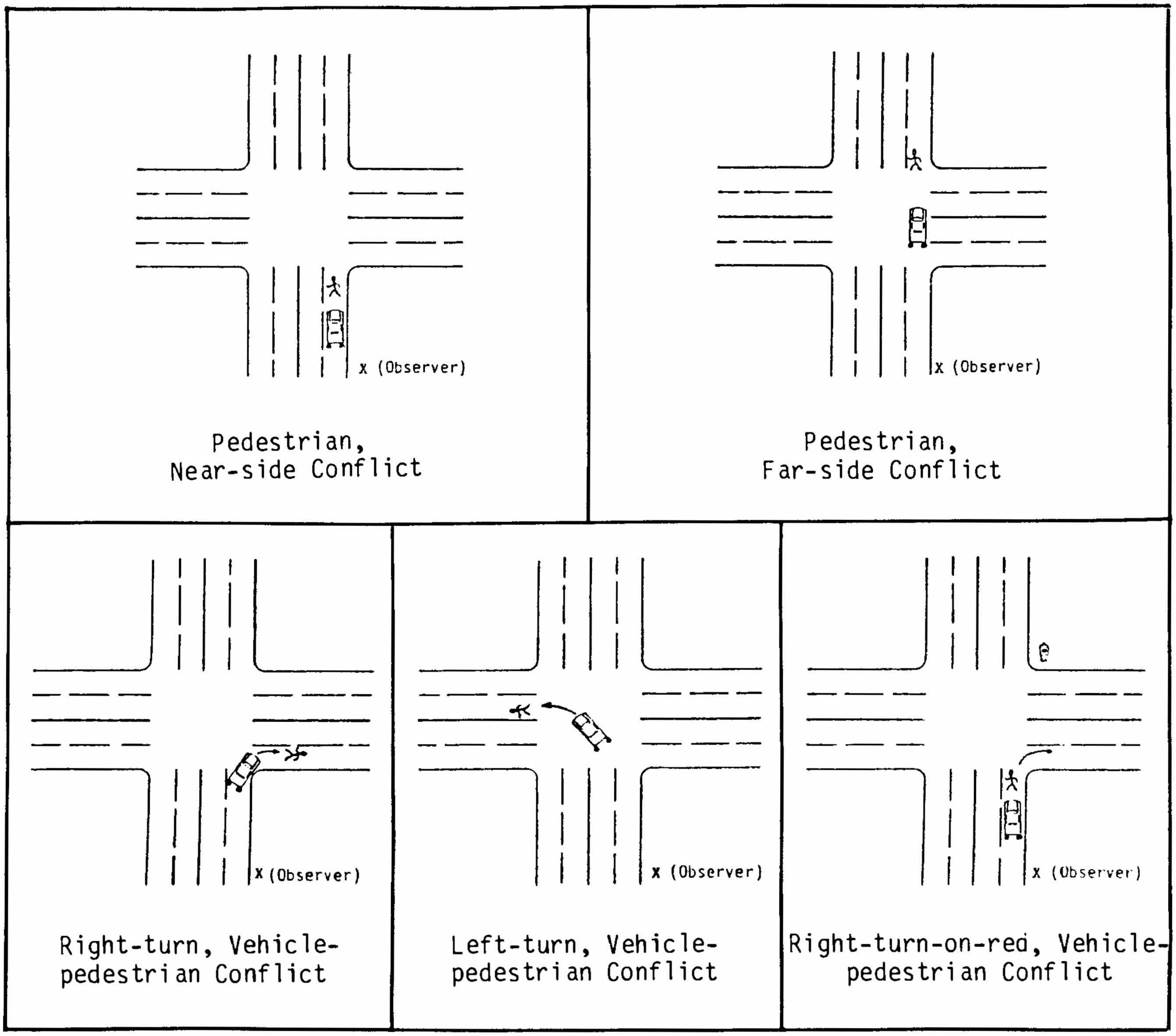


Figure 17. Pedestrian-vehicle conflict types.
(Source: [39])

Table 10. Urban setting relationship between frequently occurring accident types and potential countermeasures. (Source: [27], p. 32)

Countermeasures / Behavioral and Locational Accident Type	Engineering and Physical																					Child			Educ.		
	Barrier: Median	Barrier: Roadside/Sidewalk	Barrier: Street Closure	Bus Stop Relocation	Crosswalk: Intersection	Crosswalk: Midblock	Diagonal Parking-1 Way Street	Grade Separation	Facilities for Handicapped	Lighting: Crosswalk	Lighting: Street	One-Way Streets	Retroreflective Materials	Safety Islands	Sidewalk/Pathway	Signal: Ped. (Shared)	Signal: Ped. (Delayed)	Signal: Ped. (Separated)	Signal: Traffic	Signs and Markings	Urban Ped Environment	Crossing Guards	Play Streets	Safe Route to School	Education: Pedestrian	Education: Driver	Enforcement
Dart-out (First Half)	●	●				●	●														●		●		●	●	●
Dart-out (Second Half)	●	●				●	●							●							●		●		●	●	●
Midblock Dash	●	●				●								●							●		●		●	●	●
Intersection Dash					●			●						●											●	●	
Turn-Merge Conflict								●									●	●				●			●	●	
Turning Vehicle								●									●	●				●			●	●	
Multiple Threat								●		●	●					●	●	●	●		●		●		●	●	
Bus Stop Related				●																	●				●	●	
School Bus Stop Related				●																					●	●	
Ice Cream Vendor																				●					●	●	
Trapped								●						●		●	●	●							●	●	
Backup																									●	●	
Walking on Roadway		●									●		●		●					●					●	●	
Result Vehicle-Vehicle Crash																				●					●	●	
Hitchhiking											●		●												●	●	
Working in Roadway																				●						●	
Disabled Vehicle Related																				●							
Nighttime Situation										●	●		●												●	●	
Handicapped Pedestrians									●																	●	
In General																									●	●	●

Table 11. Rural setting relationship between frequently occurring accident types and potential countermeasures.

(Source: [27], p. 33)

Countermeasures / Behavioral and Locational Accident Type	Engineering and Physical																					Child			Educ.		
	Barrier: Median	Barrier: Roadside/Sidewalk	Barrier: Street Closure	Bus Stop Relocation	Crosswalk: Intersection	Crosswalk: Midblock	Diagonal Parking-1 Way Street	Grade Separation	Facilities for Handicapped	Lighting: Crosswalk	Lighting: Street	One-Way Streets	Retroreflective Materials	Safety Islands	Sidewalk/Pathway	Signal: Ped. (Shared)	Signal: Ped. (Delayed)	Signal: Ped. (Separated)	Signal: Traffic	Signs and Markings	Urban Ped Environment	Crossing Guards	Play Streets	Safe Route to School	Education: Pedestrian	Education: Driver	Enforcement
Dart-out (First Half)	●	●				●																			●	●	●
Dart-out (Second Half)	●	●				●						●		●											●	●	●
Midblock Dash	●	●				●								●											●	●	●
Intersection Dash					●					●	●			●			●	●		●					●	●	●
Turn-Merge Conflict																	●	●							●	●	
Turning Vehicle																	●	●							●	●	
Multiple Threat										●	●					●	●	●	●						●	●	
Bus Stop Related				●																					●	●	
School Bus Stop Related				●																					●	●	
Ice Cream Vendor																				●					●	●	
Trapped					●									●			●								●	●	
Backup																									●	●	
Walking on Roadway		●									●		●		●					●					●	●	
Resu'' Vehicle-Vehicle Crash																				●					●	●	
Hitchhiking											●		●												●	●	
Working in Roadway																				●						●	
Disabled Vehicle Related																				●							
Nighttime Situation										●	●		●												●	●	
Handicapped Pedestrians									●																	●	
In General																									●	●	●

Table 12. Freeway setting relationship between frequently occurring accident types and potential countermeasures.
(Source: [27], p. 34)

Countermeasures / Behavioral and Locational Accident Type	Engineering and Physical																					Child			Educ.		
	Barrier: Median	Barrier: Roadside/Sidewalk	Barrier: Street Closure	Bus Stop Relocation	Crosswalk: Intersection	Crosswalk: Midblock	Diagonal Parking-1 Way Street	Grade Separation	Facilities for Handicapped	Lighting: Crosswalk	Lighting: Street	One-Way Streets	Retroreflective Materials	Safety Islands	Sidewalk/Pathway	Signal: Ped. (Shared)	Signal: Ped. (Delayed)	Signal: Ped. (Separated)	Signal: Traffic	Signs and Markings	Urban Ped Environment	Crossing Guards	Play Streets	Safe Route to School	Education: Pedestrian	Education: Driver	Enforcement
Dart-out (First Half)	●	●						●																	●	●	●
Dart-out (Second Half)	●	●						●																	●	●	●
Midblock Dash	●	●						●																	●	●	●
Interchange Dash	●	●													●										●	●	●
Turn-Merge Conflict		●						●																	●	●	
Turning Vehicle		●																							●	●	
Multiple Threat								●			●														●	●	
Bus Stop Related																											
School Bus Stop Related																											
Ice Cream Vendor																											
Trapped																											
Backup																									●	●	
Walking on Roadway		●									●		●							●					●	●	●
Result Vehicle-Vehicle Crash		●																		●					●	●	
Hitchhiking		●									●		●							●					●	●	●
Working in Roadway											●		●							●					●	●	
Disabled Vehicle Related																				●					●	●	
Nighttime Situation											●		●												●	●	
Handicapped Pedestrians																											
In General																									●	●	●

- Intersection crosswalk,
- Grade separation (e.g., overpass or underpass),
- Safety island, or
- Education programs directed at pedestrians or motorists.

It should be mentioned that tables 10 through 12 are intended to provide only a list of potential countermeasures for a location with a specific type of pedestrian accident. However, these are not all-inclusive lists and should only be used to assist in the initial selection of improvements. Based on the specific site conditions, other roadway improvements may also be appropriate for consideration. Tables 11 through 12 provide similar lists of candidate countermeasures for rural locations and freeway locations, respectively. Notice that a different set of candidate countermeasures are given for rural or freeway locations than in urban areas for a similar accident type. For example, for an intersection dash accident on rural areas, possible countermeasures (from table 11) include:

- Intersection crosswalk,
- Lighting (street and crosswalk),
- Safety islands,
- Delayed or separated pedestrian signal, or
- Signs and markings.

If 2 or more pedestrian accident types are prevalent at a location candidate countermeasures should be considered from the tables which correspond to both accident types.

While these tables are related to pedestrian accident types, there are many locations which may have a high incidence of specific pedestrian-vehicle conflicts. Rapidly developing fringe areas, for example, can have numerous pedestrian-vehicle conflicts (and/or near-accidents) without a high incidence of pedestrian-vehicle accidents. In such situations the types of pedestrian-vehicle conflicts may be indiciative of a high potential for certain pedestrian accident types.

Of the types of pedestrian-vehicle conflict types discussed earlier, general countermeasures have been developed for unsignalized intersections (figure 18) and signalized intersections (figure 19). For example, assume

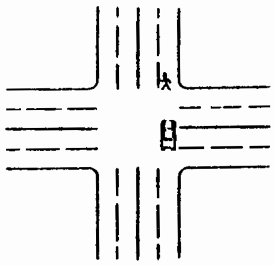
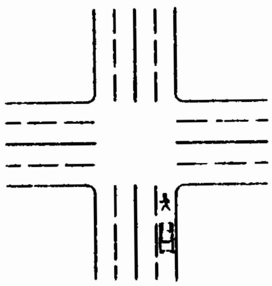
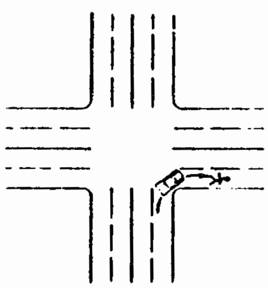
Conflict Type	Possible Cause	General Countermeasure
	1. Excessive delay to pedestrians prior to getting adequate gaps in traffic.	1. Install traffic signals with pedestrian WALK/DON'T WALK signals (see MUTCD signal warrants). 2. Install stop signs. 3. Provide pedestrian overapass or underpass (if justified based on high pedestrian volumes with high traffic speeds or volume). 4. Install pedestrian refuge islands (wide streets with two-way traffic.
	2. Children crossing in school zones.	1. Provide adult crossing guards. 2. Install pedestrian overpass or underpass. 3. Install school regulatory flashers (e.g., SPEED LIMIT 25 MPH FLASHING). 4. Use school zone signs and pavement markings. 5. Remove on-street parking near the intersection (e.g., within 100 feet).
Pedestrian	3. High vehicle speeds.	1. Provide police enforcement of speed limit. 2. Install pedestrian overpass or underpass. 3. Install traffic signals with WALK/DON'T WALK signals if warranted (see MUTCD signal warrants).
	1. Large volume of pedestrians and right-turn vehicles.	1. Install traffic signals with pedestrian WALK/DON'T WALK signals (all MUTCD signal warrants). 2. Install stop signs. 3. Move crosswalks further from intersection. 4. Add warning signs for pedestrians (e.g., PEDESTRIANS WATCH FOR TURNING VEHICLES. 5. Add regulatory signs for motorists (e.g., YIELD TO PEDESTRIANS WHEN TURNING) at the intersection.
	2. Substantial number of school children crossing and large right-turn vehicle movement.	1. Provide adult crossing guards during school crossing periods. 2. Provide police enforcement at the intersection. 3. Educate children about safe crossing behavior (e.g., using such films as "Willie Whistle" and "Keep On Looking"). 4. Provide pedestrian overpass or underpass.
Right-Turn, Vehicle-Pedestrian	3. Inadequate sight distance and/or intersection geometrics.	1. Remove sight obstructions and/or roadside obstacles (e.g., mailboxes, poles, newsstands, trash cans). 2. Move crosswalk further away from intersection. 3. Install pedestrian warning signs and/or motorist regulatory signs.

Figure 18. General countermeasures by type of traffic conflict for unsignalized intersections.
(Source: [39])

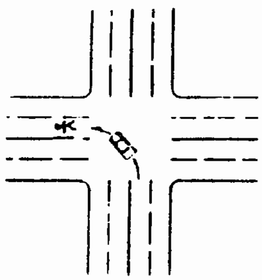
Conflict Type	Possible Cause	General Countermeasure
	1. Large volume of pedestrians and left-turn vehicles.	1. Prohibit left turns. 2. Provide traffic signals with WALK/DON'T WALK signals if warranted (see MUTCD signal warrants). 3. Convert to one-way street network (if justified by surrounding area-wide pedestrian and traffic volume study). 4. Install warning signs for pedestrians (e.g., PEDESTRIANS WATCH FOR TURNING VEHICLES.
 Left-Turn Vehicle-Pedestrian	2. Substantial number of school children crossing and large left-turn vehicle movement.	1. Provide adult crossing guards during school crossing periods. 2. Provide police enforcement at the intersection. 3. Educate children about safe crossing behavior (e.g., using such films as "Willie Whistle" and "Keep On Looking"). 4. Provide pedestrian overpass or underpass. 5. Install pedestrian refuge islands for wide two-way streets.
	3. Inadequate sight distance and/or intersection geometrics.	1. Remove sight obstructions and/or roadside obstacles (e.g., mailboxes, poles, newsstands, trash cans). 2. Prohibit left turns. 3. Install pedestrian warning signs and/or motorist regulatory signs.

Figure 18. General countermeasures by type of traffic conflict for unsignalized intersections (continued).
(Source: [39])

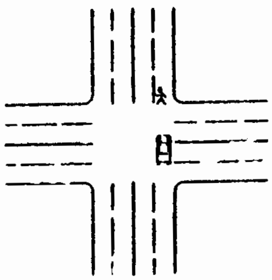
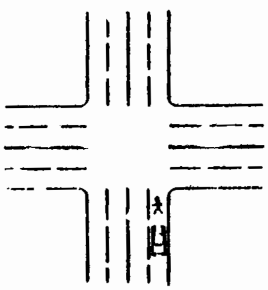
Conflict Type	Possible Cause	General Countermeasure
	1. Pedestrians cannot see signal.	1. Install a pedestrian WALK/DON'T WALK signal.
	2. Children crossing in school zones.	1. Provide adult crossing guards. 2. Install pedestrian overpass or underpass. 3. Use pedestrian signals. 4. Install school regulatory flashers (e.g., SPEED LIMIT 25 MPH WHEN FLASHING). 5. Provide school zone signs and pavement markings.
	3. Excessive delay to pedestrians prior to getting the WALK interval.	1. Retime signal to be more responsive to pedestrian needs (e.g., shorter cycle lengths). 2. Provide pedestrian push-buttons. 3. Install pedestrian overpass or underpass (if justified based on high pedestrian volumes with high traffic speeds or volumes). 4. Provide pedestrian refuge islands (wide, two-way streets with modified signal timing).
Pedestrian	4. Lack of pedestrian compliance due to other causes.	1. Use police enforcement. 2. Install pedestrian warning signs. 3. Provide pedestrian refuge islands (wide, two-way streets) in conjunction with modified signal timing. 4. Remove on-street parking near intersection (e.g., within 100 feet).

Figure 19. General countermeasures by type of traffic conflict for signalized intersections.

(Source: [39])

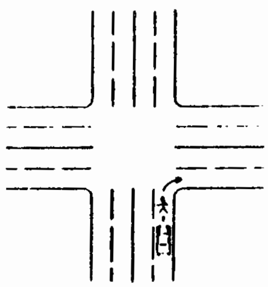
Conflict Type	Possible Cause	General Countermeasure
	1. Large volume of pedestrians and/or right-turn vehicles.	1. Add special pedestrian signal phasing (e.g., exclusive protected signal interval). 2. Add warning signs for pedestrians (e.g., PEDESTRIANS WATCH FOR TURNING VEHICLES). 3. Add regulatory signs for motorists (e.g., YIELD TO PEDESTRIANS WHEN TURNING) on the intersection approach. 4. Install NO TURN ON RED signs (see MUTCD). 5. Convert to one-way street network (if justified by surrounding area-wide pedestrian and traffic volumes study.
	2. Substantial number of school children crossing and large right-turn vehicle movement.	1. Provide adult crossing guards during school crossing periods. 2. Provide police enforcement at the intersection. 3. Educate children about safe crossing behavior (e.g., using such films as "Willie Whistle" and (Keep On Looking"). 4. Provide pedestrian overpass and underpass.
Right-Turn Vehicle-Pedestrian	3. Inadequate sight distance and/or intersection geometrics.	1. Remove sight obstructions and/or roadside obstacles (e.g., mailboxes, poles, newsstands, trash cans). 2. Move crosswalk further away from intersection. 3. Provide special pedestrian signal phasing (e.g., exclusive protected pedestrian signal interval). 4. Install NO TURN ON RED signs (see MUTCD). 5. Install pedestrian warning signs and/or motorist regulatory signs (see MUTCD).

Figure 19. General countermeasures by type of traffic conflict for signalized intersections (continued).
(Source: [39])

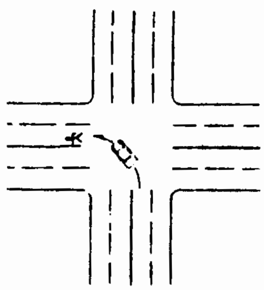
Conflict Type	Possible Cause	General Countermeasure
 Left-Turn Vehicle-Pedestrian	1. Large volume of pedestrians and/or left-turn vehicles.	1. Prohibit left turns. 2. Provide separate left-turn phase and WALK/DON'T WALK signals. 3. Add special pedestrian signal phasing (e.g., exclusive protected pedestrian signal interval). 4. Convert one-way street network (if justified by surrounding area-wide pedestrian and traffic volume study). 5. Install warning signs for pedestrians (e.g., PEDESTRIANS WATCH FOR TURNING VEHICLES).
	2. Substantial number of school children crossing and large left-turn vehicle movement.	1. Provide adult crossing guards during school crossing periods. 2. Provide police enforcement at the intersection. 3. Educate children about safe crossing behavior (e.g., using such films as "Willie Whistle" and "Keep On Looking"). 4. Provide pedestrian overpass and underpass. 5. Install pedestrian refuge islands for wide two-way streets.
	3. Inadequate sight distance and/or intersection geometrics.	1. Remove sight obstructions and/or roadside obstacles (e.g., mailboxes, poles, newsstands, trash cans). 2. Provide special pedestrian signal phasing (e.g., exclusive protected pedestrian signal interval). 3. Install pedestrian warning signs and/or motorist regulatory signs (see MUTCD).

Figure 19. General countermeasures by type of traffic conflict for signalized intersections (continued).

(Source: [39])

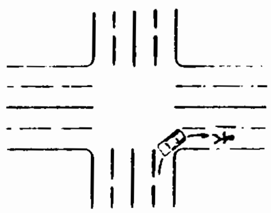
Conflict Type	Possible Cause	General Countermeasure
	1. Unusual or confusing signal timing.	1. Install NO TURN ON RED sign if warranted. 2. Retime traffic signal. 3. Install part-time RTOR prohibition sign or variable message NO TURN ON RED display. 4. Install RIGHT TURN ON RED AFTER STOP sign to encourage full stops.
 Right-Turn-On-Red Pedestrian	2. Inadequate sight distance or geometrics.	1. Prohibit RTOR if warranted. 2. Install offset or angled stop bars. 3. Relocate crosswalk further from intersection. 4. Install RIGHT TURN ON RED AFTER STOP sign to encourage full stops. 5. Remove roadside clutter. 6. Widen intersection approach.
	3. Large volumes of pedestrians and right-turn volume.	1. Install NO TURN ON RED sign if warranted. 2. Install pedestrian overpass and underpass (particularly if child pedestrian volumes are high). 3. Install NO TURN ON RED WHEN PEDESTRIANS ARE PRESENT signing. 4. Provide exclusive pedestrian phase. 5. Install regulatory YIELD TO PEDESTRIAN sign. 6. Install PEDESTRIANS WATCH FOR TURNING VEHICLES warning sign. 7. Provide offset or angled stop bars.

Figure 19. General countermeasures by type of traffic conflict for signalized intersections (continued).

(Source: [39])

that a high incidence of right-turn vehicle-pedestrian conflicts occur at an unsignalized intersection. According to figure 18, there are 3 possible causes:[39]

- Large volume of pedestrians and right-turn vehicles.
- Substantial number of school children crossing and large right-turn vehicle movement.
- Inadequate sight distance and/or intersection geometrics.

If inadequate sight distance is the reason for the conflict problem at the site, three general countermeasures are listed:[38]

- Remove sight obstructions and/or roadside obstacles.
- Move crosswalk further away from the intersection.
- Install pedestrian warning signs and/or motorist regulatory signs.

For the left-turn and through vehicle-pedestrian conflicts at unsignalized intersections, other possible causes and general countermeasures are given. Likewise, figure 19 provides possible causes and countermeasures for conflict types at signalized intersections.[39] Notice that many of these countermeasures relate to signals and signal timing. Again, these tables are not intended to present all possible countermeasures, since the specific site conditions may lead the engineer to additional countermeasures as well.

A 1987 NCHRP report ("Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas") provides information on possible solutions for numerous pedestrian problems including unique problems that often exist in rural and suburban areas.[40] Information is also provided in appendix B, page 212, on the limitations of applications and the potential effectiveness of candidate countermeasures.

SELECT THE BEST ALTERNATIVE

The next step is to choose which of the candidate countermeasures are best suited to the location. Some of the considerations in project selection include:[27]

- Facility costs (design costs, construction costs, and maintenance and operating costs).

- Potential accident reduction (if this can be estimated).

- Vehicle and pedestrian delay.

- Area economic effects.

- Ecological effects (air and noise pollution and aesthetic impact, if any).

Pedestrian-related improvements should be "tailor-fit" to individual locations in order to be most effective. The results of a 1988 study lists such factors as traffic conditions (e.g., volumes, speeds, turning movements), pedestrian volumes and mix (e.g., young children, college students, older adults, handicapped), street width, existing traffic controls, area type, sight distance, accident patterns, presence of enforcement, and others.[29] The information of appendix B summarizes details of conditions when various countermeasures are most effective and least effective (or harmful).

To select the improvements which best fit the locational conditions, one or more of the following engineering studies may be necessary to resolve the following:

- Traffic and pedestrian volume counts

  - Is a traffic signal warranted?

  - Should pedestrian WALK/DON'T WALK signals be added at signalized locations?

  - Is pedestrian traffic so intermittent throughout the day that pedestrian push-button signals are justified?

  - Are 1-way streets practical based on vehicular flows and the existing street network?

  - Are pedestrian volumes high enough to justify prohibition of right-turn-on-red?

  - Is left-turn volume high enough to justify separate left-turn phasing? If so, how will that affect pedestrian safety?

- Vehicle speed studies

  - Are excessive speeds on the section creating a hazard to crossing pedestrians? If so, should the speed limit be lowered? Should selective police enforcement be used?

  - If the excessive speeds are in school zones, should crossing guards and/or regulatory school speed limit signs and flashers be used?

- If high speeds are found for vehicles traveling off expressway ramps, what type of control will minimize the problem to pedestrians where the ramp intersects with a local street?

- Locational and geometrics inventory

  - What are the widths of the lanes and roadway? Is the street too wide for pedestrians to safely cross? Are refuge islands justified? Should the signal timing be modified to provide adequate crossing time?

  - Are all signs and pavement markings uniform, appropriate and well-maintained? Are crosswalks needed at the site, and if not, should they be removed?

  - Are traffic signals legible to pedestrians on each corner? If not, pedestrian signals are needed.

  - If a refuge island is on the street, are pedestrian signals needed so pedestrians know whether to cross halfway or the full street width during each phase?

  - Is the motorists' view of pedestrians in the right lane blocked, and if so, would offset stop bars help?

  - Are lanes and crosswalks clearly marked?

  - Are sidewalks needed, do they exist, and if so, are they wide enough and clear of obstacles?

  - Are curb cuts needed at the sites for older adults and handicapped pedestrians?

  - Would a pedestrian mall be feasible?

- Lighting study

  - Is nighttime lighting sufficient for motorists to see pedestrians adequately?

  - Is there a need for lighting the crosswalk?

- School zone study

  - Is on-street parking causing hazards to children crossing near the school?

  - Are crossing guards used to assist young children in street crossings and if not, is this justified? If so, are they properly trained?

  - Are traffic control devices appropriate but not overused in the school zone?

- Pedestrian/motorist behavior studies
  - Are pedestrians crossing the street unsafely, such as running into the street, crossing against the signal?
  - Are motorists running the red signal or failing to yield to pedestrians when turning?
  - Are certain types of pedestrian/vehicle conflicts found to be abnormally high?
- Sight distance study
  - Are stopped buses blocking the line of sight between pedestrians and motorists, and if so, are far-side bus stops practical?
  - Is sight distance limited to pose a serious threat for pedestrians on the street? If so, what types of improvements could be used to increase sight distance or prevent pedestrians from crossing at that site (e.g., barriers)?

Detailed discussions on these and other safety engineering studies are given in other publications.[41,42,43]

THE REMAINING STEPS

After the improvement alternatives are selected, they should be implemented according to the recommended program goals and objectives. Financial support for project construction and continuing maintenance is an important part of implementation. Projects should be scheduled carefully to best allocate manpower and resources. The user can find details of implementation activities in other reports.[27,43]

To determine the effectiveness of completed projects in reducing pedestrian accidents or reducing unsafe pedestrian or motorist behavior, project evaluations should be conducted. Accident-based evaluations may only be practical for improvements covering a large area (e.g., conversion to 1-way streets, adding barriers over several blocks) or by grouping numerous similar projects together for evaluation purposes (e.g., installing pedestrian signals at 20-30 intersections). Proper accident based before/after evaluations require the selection and use of suitable control sites to control for "regression to the mean" and other potential threats to validity. Pedestrian projects may appropriately be evaluated using conflicts, pedestrian violations, or other operational measures of effectiveness. Details of project evaluations are discussed in further detail elsewhere.[39,44]

Maintaining an effective pedestrian safety program is a never-ending process. Monitoring locations and areawide pedestrian problems requires early detection and quick action before the problem becomes worse. The reader is urged to refer to the "Model Pedestrian Safety Program Users Guide" for further details.[27,28]

CHAPTER 5 - SIDEWALKS AND WALKWAYS

Sidewalks and walkways are prepared exterior routes designed to provide pedestrian accessibility. Walkways are general pedestrian routes, including plazas and courts, and sidewalks are walkways that parallel a vehicular roadway. Properly planned sidewalks and walkways are effective in increasing pedestrian mobility, safety and accessibility particularly for disabled persons. Residential areas and 2-lane roadways are less hazardous to pedestrians if sidewalks are present.[45]

Relatively high pedestrian volumes and the need to access adjacent activity centers have resulted in sidewalks being the norm in urban centers. In spite of the recognized benefits of sidewalks, they are generally not provided in rural or low density residential areas due to the relatively high cost and expected low use. Builders prefer not to provide sidewalks due to high cost and will occasionally receive support from residents who believe that sidewalks ruin the "rural aesthetics" of their planned development. A recent NCHRP report summarized some of the impediments to the installation of and problems associated with, sidewalks.[40]

- The low density residential development in suburban settings has resulted in distances that make utilitarian walking impractical. The results are residential developments that are practically totally dependent upon the automobile. A study by the U.S. Department of Transportation indicated that developing a more compact land use format would have a substantial impact on increasing pedestrian travel.[46]

- The needs of pedestrians are often not foreseen in the initial development stages. Suburban growth tends to move outward progressively further from the urban center. The growth takes place in stages with subdivisions being built on farmland that is served by narrow winding roads. Since there are no destinations within a comfortable walking distance, pedestrian accommodations are not originally considered in the process of building the residences. As shopping, school and recreational facilities follow to support the residents, the planning of pedestrian facilities becomes complicated. By this time potential pedestrian pathways are often under private ownership or decisions on their construction delayed until roadway improvements are made. Although steps can be taken to retrofit the situation, a more expedient and cost-effective procedure is to plan for the pedestrian from the beginning.

- Zoning ordinances, subdivision regulations and other local codes are often so restrictive that they inhibit design variations that would favor pedestrian movement. While regulations are necessary for the long range benefit to planning and design, they should be sufficiently flexible to permit creative solutions.

SIDEWALK PLANNING CONCEPTS

Many of the problems related to proper sidewalk installation can be alleviated by planning pedestrian facilities within the framework of the overall planning process. The following is a summary of elements to be included in local and State planning processes to adequately accommodate pedestrian facilities.[46]

- Policy statements should be included in the master plan that relate to pedestrian needs and objectives. While these statements do not necessarily guarantee the provision of pedestrian facilities they at least indicate a recognition of the need. This increases the likelihood that further steps will be taken toward the planning and implementation of pedestrian facilities.

- The community master plan should include specific recommendations on pedestrian facilities. A master plan of walkways or master trails plan can be a combination of recreational and utilitarian paths, including conventional sidewalks, that comprise the pedestrian network. These facilities should be formally indicated on a map with consideration to topography and the probable location of roadways.

- Pedestrian considerations are often not given the requisite priority since they must compete with many other factors involved with the design and financial aspects of the development process. Pedestrian facilities, however, not only improve pedestrian circulation but can enhance the marketability of a development. This is especially true if the pedestrian network is part of a landscaping plan. In suburban downtown areas or main street areas of small towns, the addition of pedestrian improvements and amenities can help counter the flight of retail activity to outlying malls.

- State and local ordinances, standards, warrants and specifications should clearly state the guidelines for sidewalk installation, including funding responsibility. These documents typically govern the design of transportation facilities and, thereby, govern the extent to which pedestrian considerations are implemented. Subdivision regulations have the greatest impact on the location and design of sidewalks and walkways. These regulations often aid the design consultant to sell pedestrian related design amenities to the developer.

- A checklist should be developed to assist both the developer and reviewer in identifying items that should be considered in the planning of pedestrian facilities. The checklist should remind a developer of the need to include basic pedestrian facilities and the design principles that should be employed. An example checklist is presented in figure 20. This checklist should be modified to include items that are of regional concern. For example, if bicycle facilities are of concern, then checklist items pertaining to bicycle facility design principles should be included.

Site Review Checklist for Pedestrian Facilities
<u>Overall Pedestrian System:</u> • Are both utilitarian and recreational walking considered in the plan? • Are utilitarian paths direct? Do they provide for connections to existing pedestrian magnets nearby? • Do recreational pathways take advantage of unique site features? Are they generally visible from homes or other buildings? • Does the pedestrian system consider the type and probable location of future development on adjacent or nearby parcels of land? Is there flexibility to provide direct connections to adjacent parcels, should that be desired later on? • Are pedestrian entrances clearly evident through either design features, topography, signing or marking? • Are walkways along the street separated and buffered from traffic as much as possible?
<u>Safety and Security:</u> • Are crossings of wide expanses of parking lot held to a minimum? • Are pathways generally visible from nearby buidlings and free from dark, narrow passageways? • Is adequate lighting provided for nighttime security? • Are sight distances adequate for vehicles to see pedestrians at crossings? • Do pathways lead to the safest crossing points? • Are pedestrian/vehicle conflict points kept to a minimum? • Are pedestrians clearly visible to traffic where they cross the street?
<u>Walking Surfaces and Amenities:</u> • Are the walking areas scaled to the pedestrian? • Are the walking surfaces skid-resistant and sloped for drainage, but less than 12:1? • Are provisions made for curb ramps and are they properly designed? • Are major changes in grade properly treated with stairways and handrails?

Figure 20. Checklist of site plan review items for pedestrian facilities. (Source: [40], p. 23)

GENERAL PRINCIPLES FOR SIDEWALK INSTALLATION

Many local and State agencies do not have guidelines that help them determine where and what type of pedestrian facilities should be installed. This is of particular concern in developing rural and fringe suburban areas that are experiencing changing pedestrian needs. General principles of sidewalk installation that require consideration include:[40,45]

- All roadways should have some type of walking facility out of the travelled way. A separate walkway is preferable but a roadway shoulder can also provide a safer pedestrian accommodation than walking on the road. A study of rural and suburban pedestrian accidents revealed that approximately 15 percent of pedestrian accidents occurred while the pedestrian was walking along the road. The majority of these accidents occurred while the pedestrian was walking in the same direction as traffic movement. While the presence of sidewalks or shoulders will not eliminate all of these accidents, their presence will clearly reduce the potential for pedestrian accidents.

- Provisions should be made to provide direct connections between residences and activity areas. It is usually not difficult to ascertain where connections between residential areas and activity centers will be required during the early stages of development. This will prevent the later construction of circuitous routes. Typical routes in a suburban area require the pedestrian to walk out of the subdivision to a main road and then parallel with the major road network to arrive at activity centers. This can result in a walking distance to "as the crow flies" ratio of 5:1. Easements permitting pedestrian access through the middle of residential blocks can provide a direct connection for pedestrians with school and commercial needs at a later date. The actual construction of sidewalks can be provided when development progresses to generate pedestrian demand.

- Many of the benefits of sidewalks are not quantifiable with the actual magnitude of the safety benefit unknown. This is partially because individuals tend to walk where there are sidewalks and sidewalks tend to be built where people walk. Sidewalk installation warrants based on pedestrian volume are, therefore, not practical. In addition, pedestrian volumes are not regularly collected by most agencies and cannot be easily forecast. Development density can be used as a surrogate for pedestrian usage in determining the need for sidewalks.

- The need for sidewalks should be related to the functional classification of streets. For example, collector streets are more likely to have greater pedestrian volumes than residential streets. Collector streets are normally used by pedestrians to access bus stops and commercial developments on the arterial to which they feed. Sidewalks should also be provided along developed frontages of arterial streets in zones of commercial activity.

- Sidewalks and walkways can be constructed of materials other than the traditional concrete surface. The use of asphalt can contribute to a park-like atmosphere and alleviate the concerns occasionally expressed by some developers and communities that the sidewalks are aesthetically unpleasing. Sidewalks for recreational purposes need not be elaborate or expensive. For recreational or developing rural areas, a surface of wood chips or a narrow 3-foot (0.9 m) asphalt patch is often sufficient. A more ample surface can await future development and expansion of the roadway. Since the path may eventually be replaced, grading can be kept to a minimum, following the natural contour of the ground and curved to avoid trees.

- The cost of sidewalk installation in some existing residential areas may be prohibitive in comparison to the benefits that could be realized. For example, some older residential areas in hilly terrain have retaining walls that extend to the street line. The need for sidewalks in older single dwelling residential neighborhoods should be determined by residents along the street.

- Collector and arterial streets in the vicinity of schools should be provided with sidewalks to increase school trip safety.

GUIDELINES FOR SIDEWALK INSTALLATION

Variations in development density, spacial distribution of activity centers, the lack of and problems with forecasting pedestrian volumes and the absence of quantified safety benefits combine to make establishing a strict set of sidewalk installation warrants difficult. The result is that decisions on proper pedestrian facilities are often dependent upon the knowledge, imagination and experience of the planners and engineers involved. A set of guidelines should be adopted, however, in each community to assist in identifying the location and design of sidewalks and walkways. A study conducted by Knoblauch for the Federal Highway Administration contacted practitioners in different parts of the United States to establish guidelines for sidewalk installation.[45] The guidelines from this study are presented as figure 21.

SIDEWALK DESIGN

The appropriate design of sidewalks, similar to roadway design, is dependent upon the location, purpose and anticipated volume or demand on the facility. Sidewalk design elements that require consideration are

Proposed Minimum Sidewalk Widths

Central Business Districts - Conduct level of service analysis according to method in 1985 Highway Capacity Manual.

Commercial/industrial areas outside a central business district - Minimum 5 feet (1.5 m) wide with 2-foot (0.6 m) planting strip or 6 feet (1.8 m) wide with no planting strip.

Residential areas outside a central business district:

Arterial and collector streets - Minimum 5 feet (1.5 m) with minimum 2-foot (0.6 m) planting strip.

Local Streets:

- Multi-family dwellings and single-family dwellings with densities greater than four dwelling units per acre - Minimum 5 feet (1.5 m) with minimum 2-foot (0.6 m) planting strip.
- Densities up to four dwelling units per acre - Minimum 4 feet (1.2 m) with minimum 2-foot (0.6 m) planting strip.

Land-Use/Roadway Functional Classification/Dwelling Unit	New Urban and Suburban Streets	Existing Urban and Suburban Streets
Commercial & Industrial/ All Streets	Both sides.	Both sides. Every effort should be made to add sidewalks where they do not exist and complete missing links.
Residential/Major Arterials	Both sides.	
Residential/Collectors	Both sides.	Multi-family - both sides. Single-family dwellings - prefer both sides required at least one side.
Residential/Local Streets More than 4 Units Per Acre	Both sides.	Prefer both sides, required at least one side.
1 to 4 Units Per Acre	Prefer both sides; required at least one side.	One side preferred, at least 4-foot (1.2 m) shoulder on both sides required.
Less than 1 Unit Per Acre	One side preferred, shoulder both sides required.	At least 4-foot (1.2 m) shoulder on both sides required.

Figure 21. Guidelines for sidewalk installation and minimum width. (Source: Reference [45], p. 142-143)

NOTES:

(1) Any local street within two blocks of a school site that would be on a walking route to school - sidewalk on at least 1 side.

(2) Sidewalks may be omitted on 1 side of new streets where that side clearly cannot be developed and where there are no existing or anticipated uses that would generate pedestrian trips on that side.

(3) Where there are service roads, the sidewalk adjacent to the main road may be eliminated and replaced by a sidewalk adjacent to the service road on the side away from the main road.

(4) For rural roads not likely to serve development, provide a shoulder at least 4 feet (1.2 m) in width, preferably 8 feet (2.4 m) on primary highways. Surface material should provide a stable, mud-free walking surface.

Figure 21. Guidelines for sidewalk installation and minimum width (continued). (Source: [45], p. 142-143)

sidewalk width, pavement materials, whether vertical or rolled curbing will be used and the setback distance of the sidewalk from the street. Minimum sidewalk width for permanent installations is 4 feet (1.2 m) with widths of 8 feet (2.4 m) or greater required in commercial areas. The actual width required in high density commercial or urban environments is dependent upon pedestrian volumes and can be determined using the procedures of chapter 2. When determining the appropriate sidewalk width it is important to consider that the effective sidewalk width for pedestrian movement in most urban environments is reduced by parking meters, planters, mail boxes, light poles, signs and many other obstructions.

Concrete paving is preferable to asphalt or block paving because it maintains its walking service integrity longer, requires less maintenance and is generally less slippery when wet. Rolled curbs are more economical than vertical set curbing but a vertical set curb provides a more positive wheel stop and better drainage.

The setback distance of the sidewalk from the roadway is an important safety and design factor. Sidewalks too close to high-speed traffic discourage pedestrian travel due to the high noise level and perception of hazard. Wider setbacks, therefore, add to the convenience and perceived safety of pedestrian travel and should be used whenever possible.[48] However, installing a sidewalk on the very edge of a road is preferable to not having any sidewalk at all. Increasing the setback distance has the added advantage of providing room for plantings and utilities. If the sidewalk is placed next to plantings that will become large trees then eventually the tree roots can lift sidewalk sections causing tripping hazards accompanied by overgrowth of foilage obstructing walking. The setback should, therefore, be made as wide as practical and generally be from 4 to 8 feet (1.2 to 2.4 m) plus the sidewalk width. In rural areas larger setbacks are usually applicable. A typical cross-section for residential street design showing typical roadway, setback and sidewalk dimensions, is presented as figure 22. Wheelchair ramps at corners are required in new sidewalk construction in most States and is a requirement for federally financed roadway improvements. Specifications on the design of wheelchair ramps are provided in chapter 6. A summary of the advantages and disadvantages of sidewalks and pedestrian paths is presented in appendix C, pages 217 and 218.

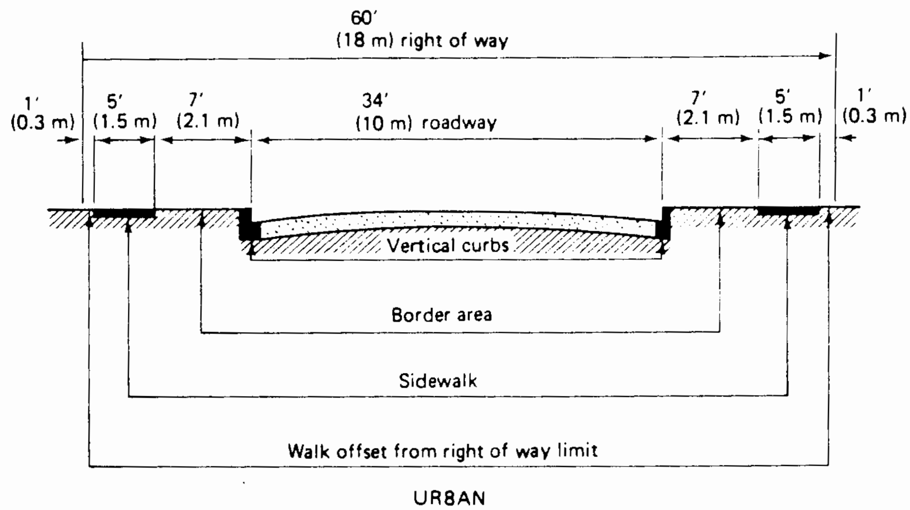


Figure 22. Typical cross-section of a residential roadway. (Source: [49], p. 2)

CHAPTER 6 - CROSSWALKS, CURB RAMPS AND REFUGE ISLANDS

Crosswalks are areas on the surface street system used by pedestrians to cross roadways. The purpose of crosswalks is to concentrate pedestrian movements to selected areas, thereby, reducing the potential number of conflict points between pedestrians and motor vehicles. There are 2 general types of crosswalks: marked and unmarked. The marked crosswalk consists of transverse markings, usually painted lines, that serve to channelize pedestrians and warn motorists of possible pedestrian presence. Unmarked crosswalks are pedestrian crossing areas designated by prolongation of the lateral lines of sidewalks or pedestrian pathways on opposite sides on the street.

This chapter concentrates on marked crosswalks emphasizing where marked crosswalks should be present, safety concerns, types of treatments, special crosswalks and median/safety islands. It should be realized that marked crosswalks do not totally separate pedestrians from vehicles. Their effectiveness in increasing pedestrian safety is, similar to all traffic control devices, dependent upon the respect they command from both motorists and pedestrians. Retaining this respect requires that marked crosswalks only be installed where required.

LOCATION OF MARKED CROSSWALKS

For a long period of time, crosswalks were considered as a public safety item under the assumption that "something was better than nothing." Citizens and traffic engineers assumed that painted lines provided a measure of driver notification to the possibility of pedestrian conflicts. This rationale resulted in the absence of installation criteria and the placement of painted crosswalks where ever requested or thought beneficial. A study conducted by Herms in the City of San Diego, however, resulted in substantial controversy over the actual effectiveness of crosswalk markings.[50] This study compared the 5-year accident rates between painted and unpainted crosswalks at 400 unsignalized intersections. The results indicated that the pedestrian accident rate at marked crosswalks was twice as high as the rate at unmarked crosswalks. These results have lead to increasing concern that crosswalk markings are more of a detriment than a benefit to pedestrian safety.

Prior to condeming marked crosswalks based on the Herms' study, however, it is necessary to closely consider the experimental design used. Herms compared the accident rate of crosswalks at intersections that had 1 marked and 1 unmarked crosswalk, both crossing the same roadway. The study reported that the very young and very old had the highest accident representation in both the marked and unmarked crosswalks. What Herms did not do was to determine why a crosswalk was marked or to obtain pedestrian usage data by age. Failure to obtain these data results in the inability to answer design validity questions. For example, 1 leg of an intersection may have been marked, because, more high risk pedestrians (the very young or elderly) used that crosswalk. Similarily, since 1 crosswalk was marked the high risk pedestrians may have gone out of their way to use the marked crosswalk. Since the high risk pedestrian was over represented in the accident occurrence at marked crosswalks the usage rate of high risk pedestrians should have been obtained to permit comparisons between marked and unmarked crosswalks. If differences did exist, then the comparison of marked and unmarked crosswalk pairs may not have been an appropriate experimental design.

Knoblauch, in a more recent study on pedestrian safety, obtained results that were opposite those obtained by Herms.[45] Knoblauch's study used data obtained from large scale field studies conducted in 5 standard metropolitan statistical areas. Vehicular volumes and pedestrian volumes, demographic characteristics, activity and behavior were observed and recorded. In addition, the sites at which the observations were conducted were described, measured and photographed. This information, in conjunction with accident data, was used to develop hazard scores for site characteristics, pedestrian volume and pedestrian-vehicle exposure levels. Knoblauch determined that marked crosswalks were safe and unmarked crosswalks were hazardous for the majority of roadway characteristics. The results of his study did not disclose any analysis category where unmarked crosswalks were safer than marked crosswalks.

For marked crosswalks to provide their maximum pedestrian safety potential, it is important that they be installed only where needed. The motorist may lose respect for all pedestrian regulations and traffic controls if marked crosswalks occur at a large number of intersections where the motorist rarely encounters pedestrians. Due to the associated safety consequences, the cost of installation and the continued cost of maintenance crosswalks should only be installed when the following conditions exist.[51,52]

- In urban or rural areas whenever there is a need for increased visibility and designation of the crossing area.
- When multiple pedestrian crossing locations exist and a marked crossing would serve to channelize pedestrian crossing at a single location.

- Where there is substantial conflict between motorist and pedestrian movements.

- When the best location for pedestrians to cross may be unclear due to geometric or traffic operational conditions.

- When pedestrian volumes are sufficiently high that a familiar driver would anticipate pedestrians desiring to cross in the crosswalk.

- At arterial crossings in central business districts.

- At signalized intersections equipped with pedestrian signals.

- At approved school crossings that have been established by the school or local agency authority.

- At crossings on recommended safe school routes.

Many larger agencies have established guidelines to assist in determining where marked crossings should be provided. These guidelines consider combinations of roadway vehicular volume, pedestrian crossing volume, speed limit along the approach and traffic controls at the crossing. The City of Phoenix, for example, considers the installation of a marked crosswalk whenever the number of crossing pedestrians exceeds 30 per hour during any hour of a 24-hour period.[52] Smaller communities will never attain the magnitude of volume levels that have been established by larger communities for marked crosswalk implementation. This requires smaller communities to use objective engineering judgement to establish installation criteria in accord with their peak volumes.

Knoblauch developed crosswalk marking guidelines on current research information and comments and suggestions of practicing traffic engineers. The guidelines, developed by Knoblauch for installing crosswalk markings, are the following:[45]

Crosswalk markings should be installed at the following locations:

- All signalized intesections with pedestrian signal heads.

- All locations where a school crossing guard is normally stationed to assist children in crossing the street.

- All intersections and midblock crossings satisfying the minimum vehicular and pedestrian volume criteria in figure 23. As long as the basic criteria governing sight distance, speed limit, etc., are met, a crosswalk is deemed appropriate if the pedestrian and

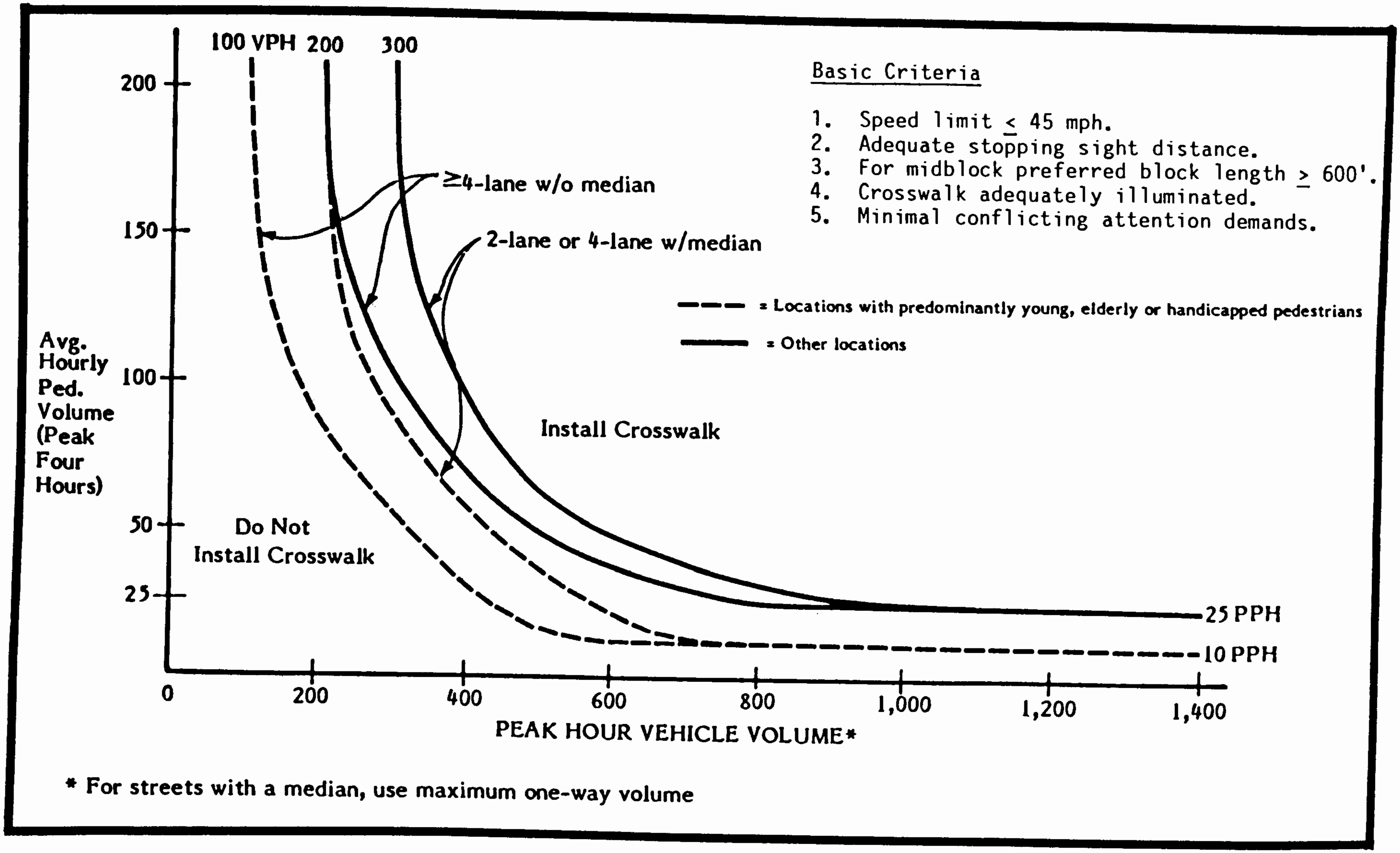


Figure 23. Guidelines for crosswalk installation at uncontrolled intersection legs, midblock crossings, and signalized intersections without pedestrian heads. (Source: [45], p. 56)

vehicular volumes place it above the appropriate curve in figure 23. Each crosswalk is analyzed by approach leg, indicating that a crosswalk might be warranted on one side of an intersection and not the other. Thus, the guidelines might suggest that only one crosswalk need be marked at a given intersection. If each approach warranted a crosswalk, then all would be marked.

- All other locations where there is a need to clarify the preferred crossing location when the proper location for crossing would otherwise be confusing.

Knoblauch acknowledges that it will generally be difficult to reach the pedestrian volume thresholds in suburban areas. This can be considered as an advantage since it will essentially result in more selective use of crosswalk markings; possibly resulting in improved compliance with markings in general. For locations where a significant proportion of the pedestrian population are the young, elderly or handicapped, the volume thresholds are reduced. The amount of this reduction is left to the judgement of the engineer, but a value of 50 percent or more is suggested.

Crosswalks are usually marked in the immediate vicinity of intersections. Locating crosswalks at midblock locations is a practice that varies from locality to locality. Some agencies strictly prohibit marked crossings at midblock based on the premise that drivers do not expect to encounter pedestrian crossings that are removed from the intersection. Other agencies believe that properly designed midblock crossings can be safer than intersection crossings since there is no side street turning traffic. Proper design of midblock crossings requires that special consideration be provided for prohibiting parking, ensuring adequate sight distance for both pedestrians and motorists and advance warning for motorists of midblock crossing presence. Midblock crossings are not normally installed if an intersection is within 400 feet of the proposed midblock location.

It is interesting to note that Section 11-503 of the Uniform Vehicle Code does not prohibit pedestrians from crossing between adjacent intersections that are not controlled by traffic signals.[53] It may be undesirable, therefore, but not illegal for pedestrians to cross without a marked pedestrian crossing between unsignalized intersections (i.e., jaywalk). Since enforcement cannot be used to increase pedestrian safety in this instance, marked midblock crosswalks or measures to encourage use of adjacent intersection crosswalks such as sidewalk barriers may be necessary. The potential application advantages and disadvantages of pedestrian barriers are presented in chapter 9, page 171, and in appendix C, page 233, of this handbook.

A summary of the advantages, disadvantages and implementation considerations for unmarked, marked and midblock crossings is presented in table 13.

SAFETY CONSIDERATIONS IN CROSSWALK PLANNING

Safe crosswalk design requires that consideration be given to the needs and problems that can be encountered by all potential users. This requires that special considerations be given to the safety requirements of the visually impaired, wheelchair users, elderly and individuals of small stature.

Crosswalk Angle With the Curb

Crosswalks should, whenever possible, be installed so that they form 90° angles with the curb. Crosswalks that form angles other than 90° pose problems for visually impaired pedestrians to stay within the crosswalk limits. Visually impaired pedestrians are conditioned to depart the curb at 90° and to proceed straight to the opposite curb. If the crosswalk is not at 90°, they may become disorientated and unintentionally stray out of the crosswalk. In addition, pedestrians tend to take the shortest path between 2 points. If the crossing is placed at an oblique angle and does not represent the shortest path, then pedestrians will walk outside of the crosswalk.

Crosswalks intersecting the curbs at other than 90°, as presented in figure 24, should be avoided whenever possible. If it is not possible to avoid an angled crosswalk, then at least 1 of the marking lines should be retained at 90° to the curb.[54] When it is necessary to use angled crosswalks, then the pavement marking that indicates the edge of the crosswalk should be comprised of material that is detectable to the visually impaired using long cane techniques.

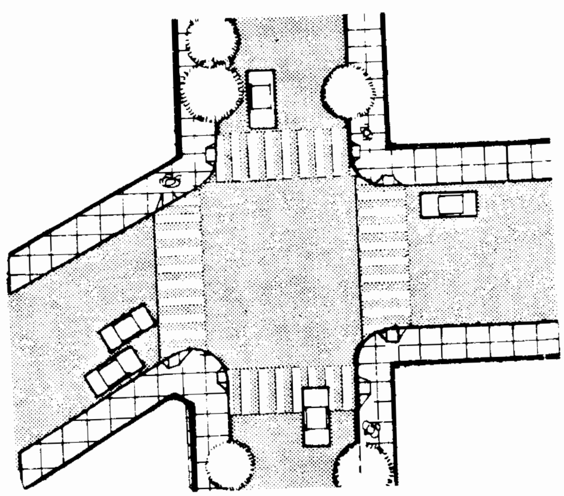


Figure 24. Crossings that do not make 90° angles with the curb should be avoided whenever possible.

Table 13. Summary of advantages, disadvantages and implementation considerations of basic pedestrian crosswalk types. (Source: [27], pg. 52 and 53)

	Advantages	Disadvantages	People	Locations	Implementation Considerations
Unmarked	No expense. Fewer accidents than marked crosswalks.	Does not clearly indicate the preferred pedestrian path		Locations that don't meet the criteria for marked crosswalks.	Traffic engineering studies or warrants may show the need to change some marked crosswalks to unmarked crosswalks.
Marked	High pedestrian compliance. Can reduce vehicle violations of pedestrians right of way. Acts as a warning device and reminder to motorists of the potential presence of pedestrians. Relatively inexpensive. May help enforce pedestrian regulations. Channelizes pedestrians across complicated or dangerous intersections. Can position pedestrians where they can best be seen. May show pedestrians the shortest route.	Creates an illusion of safety; pedestrians may feel overly secure. Does not totally separate pedestrians and vehicles. Has more accidetns (per usage than unmarked crosswalks. Motorists don't see crosswalks as well as pedestrians may think. Overuse may cause disrespect for all pedestrian and traffic control devices. Pedestrians won't use them if they feel they are necessary or if they are inconvenient. Require pedestrian education. Need continual maintenance (snow removal, repainting).	All pedestrians. Motorists	Intersections in downtown or commercial areas and along school routes. Areas of high pedestrian concentration. Locations with low or moderate vehicle flow. Complex or confusing intersections requiring pedestrian channelization. Signalized intersections. Midblock locations where many pedestrians cross. Not at locations at the top of a hill or where other sight restrictions.	Uniformity of crosswalk design and location is necessary for good compliance. A careful engineering study should be made before marking crosswalks at locations without signals or stop signs. Warrants should be developed and used in determining the need for marked crosswalks. Warrants should reflect:[6-1] - Pedestrain channelization needs - Vehicle speeds and gaps - Pedestrian volume - General conditions(illumination, geometry, accident history, pedestrian visibility) Factors to consider in desigining a crosswalk include: - The needs of the handicapped - Advance warning signs - Vehicle stop lines - Overhead lighting - Reflectorization - Adequate sight-distance through the elimination of visual clutter.

Table 13. Summary of advantages, disadvantages and implementation considerations of basic pedestrian crosswalk types. (continued) (Source: [27]. pg. 52 and 53)

	Advantages	Disadvantages	People	Locations	Implementation Considerations
Midblock	If they are available, pedestrians will use and obey them. Prevent pedestrians from crossing from behind parked vehicles. Prevent running in the road, pedestrian hesitation and crossing out of the crosswalk. May reduce vehicle speeds in the area around the crosswalk.	Pedestrians may develop a false sense of security. Reduces the number of parking spaces. May reduce traffic flow capacity. Programmed signal systems may have to be retimed.	All pedestrians, particularly those who run or walk into the street at midblock.	Locations with heavy midblock pedestrian flow.	Warning signs should be posted to alert drivers to potential pedestrians. Adequate sight distance must be provided. This can be done by prohibiting parking near the crosswalk.

Available Sight Distance

Crosswalks should be located where they are in clear view of approaching motorists. Crosswalks should not, therefore, be located immediately past the crest of vertical curves or on horizontal curves where the motorist will have insufficient stopping sight distance available after noticing the presence of the crosswalk. If the planned crosswalk location is not signalized and the stopping sight distance, specified by AASHTO, is not available, then the planned crosswalk location should be moved.[55] If the physical conditions of the site do not allow a safe relocation of the crosswalk, or the relocation requires a displacement of 500 feet or more, then additional countermeasures should be considered. These measures include providing a traffic signal with appropriate motorist advance warning, or a grade separated pedestrian structure.

It is necessary to not only provide the requisite sight distance for motorists to recognize the presence of the crosswalk but also to provide an unobstructed visual field between motorists and pedestrians. Street furniture, such as utility poles, mailboxes, telephone booths, trees, decorative planters, etc., as presented in figure 25, should not hide the pedestrian from view.

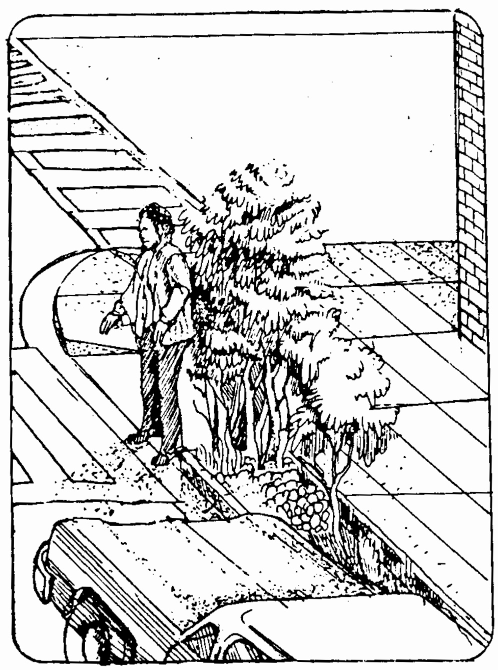


Figure 25. Example of undesirable visual obstruction resulting from improper placement of plantings.

Parked vehicles can also pose visual obstructions, especially for children, wheelchair occupants or individuals of small stature, as illustrated by figure 26. Parking should be prohibited within 20 feet (6 m) of the nearest crosswalk. At signalized intersections, parking should not be permitted within 30 feet (9 m) of the closest intersection crosswalk.

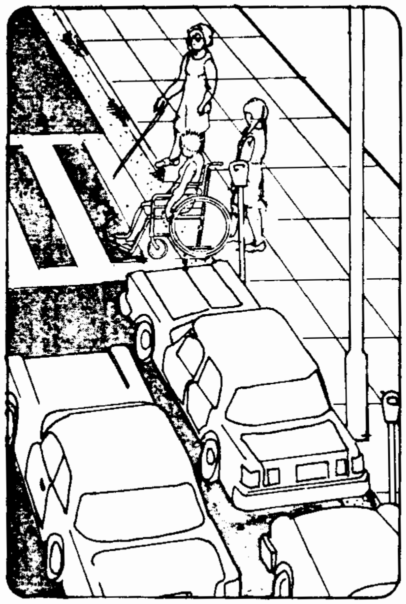
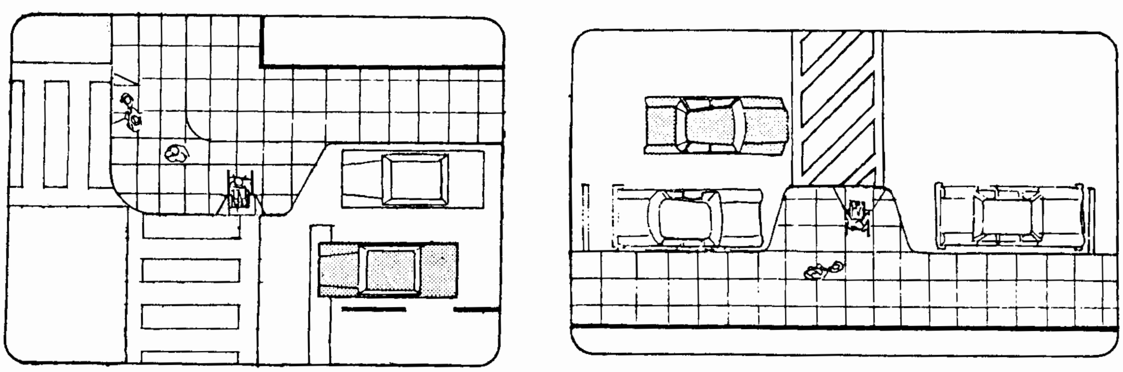


Figure 26. Example of undesirable visual obstruction resulting from parked vehicles.

At those locations where there is strong pressure from the business community to retain legal on-street parking, the sidewalk can be extended. The extension requires projecting that part of the sidewalk which adjoins the crosswalk out to the edge of the parking lane. This extension improves pedestrian visibility and can be performed at intersections and at midblock locations, as illustrated in figure 27.

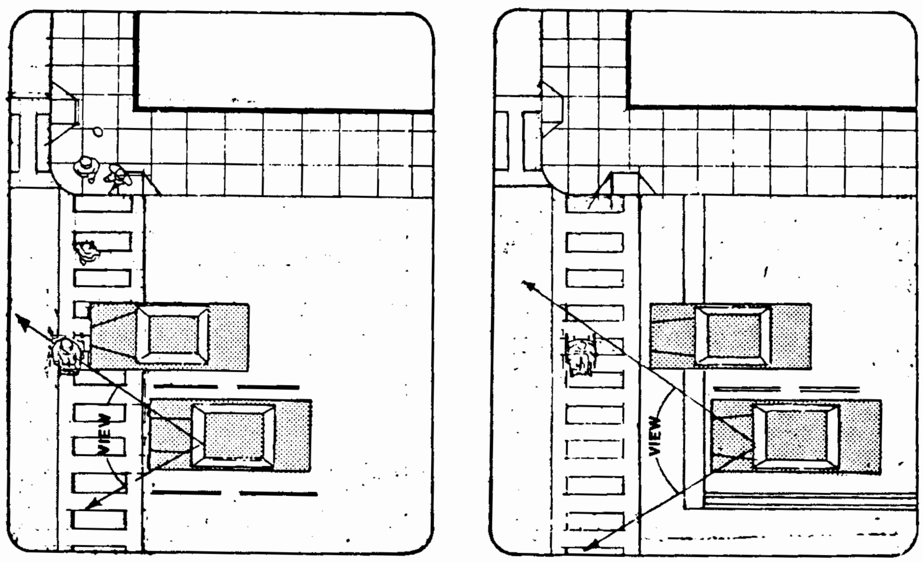


(a) (b)

Figure 27. Examples of sidewalk extensions to improve pedestrian visibility at intersections (a) and midblock locations (b).

Stop Line Provision

The installation of stop lines at crosswalk locations controlled by traffic signals or stop signs is effective in reducing vehicle encroachments on the crosswalk. Vehicle encroachment on the crosswalk poses a physical barrier to pedestrian movement often requiring them to pass out of the crosswalk around the encroaching vehicle. As illustrated by figure 28(a), an encroaching vehicle can also pose sight restrictions between adjacent vehicles stopped on the approach and pedestrians already in the crosswalk. This sight restriction is especially true for persons in wheelchairs or pedestrians of small stature. Providing stop lines prior to the crosswalk can reduce vehicle encroachment. Even when vehicles stop over the stop line, which often occurs, the crosswalk itself is not overrun and visibility is improved as demonstrated by figure 28(b). The stop lines should be placed 4 feet (1.2 m) in advance of and parallel to the crosswalk.



(a) (b)

Figure 28. Typical vehicle encroachment and resultant sight restriction occurring without stop lines (a) and benefits of stop line installation (b).

Crosswalk Width

Crosswalks that are too narrow result in congestion and interference with pedestrians passing in opposite directions. Longer than desirable pedestrian dwell times are the ultimate result with the possibility of pedestrians being caught in the crossing with the traffic signal. In addition, narrow crosswalks increase the possibility of pedestrians of small stature being obscured by stopped vehicles; especially if no stop line is provided. Crosswalks should never be less than 6 feet (1.8 m) in width. [18] A 10 foot (3.0 m) crosswalk width is preferable.[54]

The procedure of crosswalk capacity analysis provided in chapter 2 can be used to determine the crosswalk width required to provide an acceptable level of pedestrian service. This procedure is especially applicable when planning new pedestrian facilities required to service future land use developments. Crosswalk width for existing facilities are usually taken as 10 feet (3.0 m) or the width of the servicing sidewalk or walkway; whichever is greater.

Crosswalk Length

The acceptable length of the crosswalk depends on the distance to be travelled and the amount of time allotted by the traffic signal. Timing of the traffic signal results in conflicts between the needs of the major roadway traffic flow and those needs of crossing pedestrians. This is especially true when the major roadway is wide and intersects with a low volume arterial. In this instance, efficient traffic management requires that a relatively small portion of the total signal cycle be allotted to the green phase of the low volume arterial while simultaneously ensuring that adequate time be provided for pedestrians to cross the wide major roadway leg. The result is that the minor roadway green phase is often determined by the pedestrian timing requirements. Those pedestrians, therefore, that have a slower walking speed than the walking speed used to determine the minor street green phase can get caught in the crosswalk if their walking speed is slow or if they become tired during the crossing.

A refuge or pedestrian island should be considered for installation whenever the roadway width, curb-to-curb, exceeds 75 feet (22.9 m).[54] This consideration becomes especially prevalent when there are a substantial number of elderly and handicapped pedestrians. An example of a pedestrian refuge island is presented in figure 29. (See page 124 for design details of pedestrian refuge islands.)

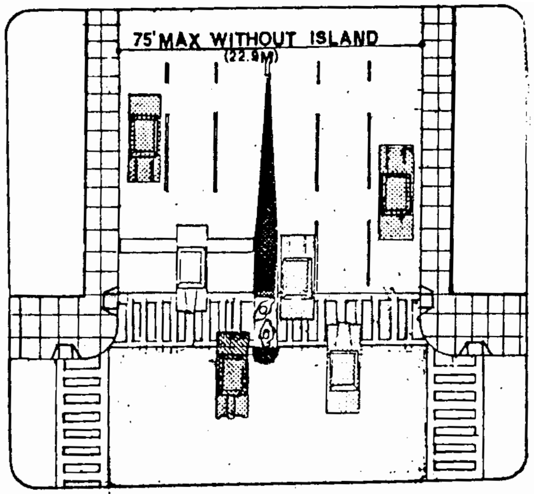


Figure 29. Pedestrian refuge island.

Bus Stop Concerns

Pedestrian crossing safety is impacted differently depending upon the presence of a near or far side bus stop. Each type of operation has its advantages and disadvantages. Far side bus stop operation has, however, been determined as resulting in fewer bus stop related accidents.[34] The primary disadvantage of the near side bus stop is that the stopped bus poses a visual screen for all pedestrians crossing in the bus vicinity. The result is an increased potential for pedestrians who cross in front of the bus of being struck by a vehicle, as presented in figure 30. In addition, the use of far side stops results in buses not obscuring traffic control devices or pedestrian movements at the intersection and reduces conflicts between buses and right turning vehicles.[56,57]

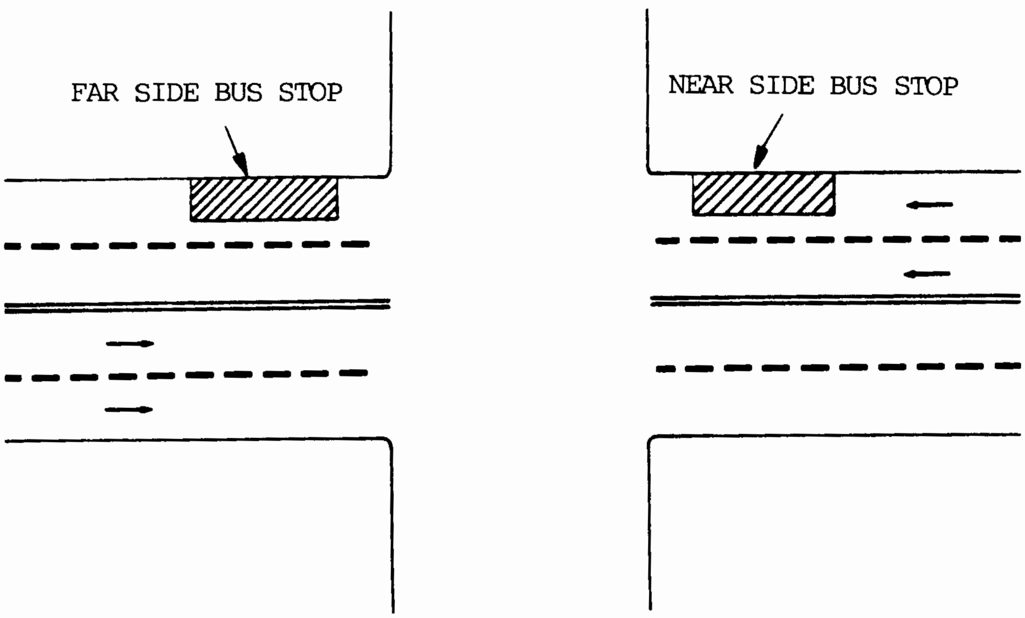


Figure 30. Examples of near and far side bus stops.

When possible, transit stops should be located on the far side of the intersection to minimize pedestrian and other bus stop related accidents. A disadvantage of the far side design is that when the bus stop is too short for occasional heavy demand or when a vehicle illegally parks in the bus stop, then buses may overhang through the pedestrian crosswalk. The far side bus stop must, therefore, be properly designed and parking prohibitions strictly enforced to realize the potential benefits of far side bus stops. A summary of the advantages and disadvantages of far side bus stops is provided in appendix C, page 219.

Turning Vehicle Concerns

Turning vehicles can cause potential safety problems with pedestrians crossing at the intersection in two primary ways. The first way is to pose a physical obstruction in the crosswalk. This occurs often times when right-turn-on-red is permitted and physical obstructions on the left block the driver's view of approaching traffic. The driver will often advance into the crosswalk, as presented in figure 31, in order to see past the obstruction. Pedestrians are forced to either wait until the turning vehicle has passed or to travel outside the crosswalk into the moving lane of vehicles.

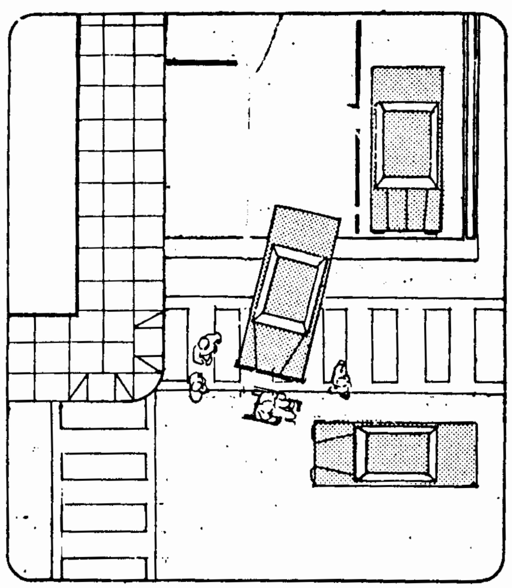


Figure 31. Vehicle encroaching on crosswalk to make a right-turn-on-red.

The second way in which turning vehicles can pose safety problems for pedestrians in crosswalks is by attention diversion. The driver waiting to make the turn is searching for a gap in the oncoming traffic flow. Identifying an appropriate gap demands all of the driver's attention resulting in the pedestrian in the crosswalk not being identified until the turning vehicle has initiated its turning maneuver. Typical examples in which this situation can occur, at stop and signal controlled intersections, are presented in figure 32. Prohibiting right-turn-on-red and providing left turn phasing, when warranted, can help reduce pedestrian conflicts with turning vehicles. Details on conducting pedestrian conflict studies are contained in chapters 3 and 4.

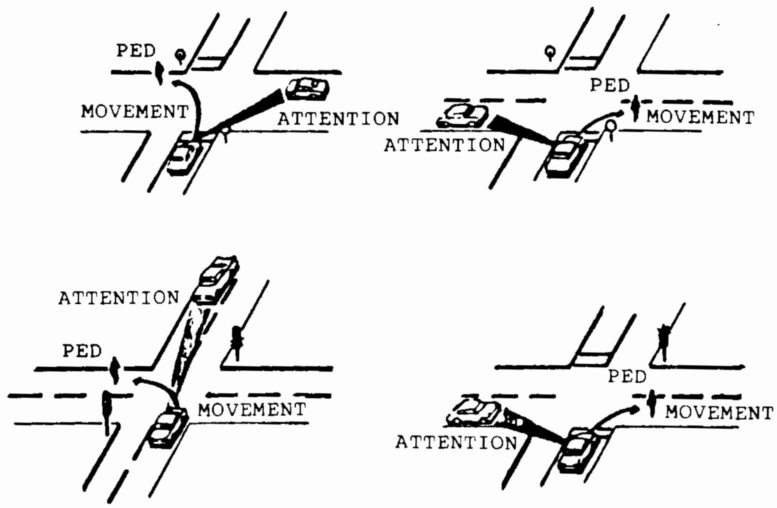


Figure 32. Examples of attention diversion resulting from turning maneuvers.

Right turning vehicles and pedestrians also interact to reduce respective capacities. High volumes of right turning vehicles, and simultaneous high volumes of pedestrians crossing their intended path during the green phase, can result in low levels of service for pedestrians, right turning vehicles or both. The capacity procedures described in chapter 2 can be used to estimate the effect of turning vehicles moving through the crosswalk during the pedestrian crossing cycle. This can be used to determine how many vehicles can conveniently turn at various pedestrian crossing volumes. If excessive delays or unacceptable levels of service are experienced by either turning vehicles or pedestrians, then corrective measures should be taken. These measures can include vehicle turning restrictions, changes to traffic signal timing and/or phasing or crosswalk closure. The closure of crosswalks or an intersection leg requires the vertical separation of pedestrian facilities or the rerouting of pedestrians around the remaining intersection legs. The effective closure of crosswalks requires that physical barriers be installed at each end and proper signing be used to increase pedestrian compliance.

One-Way Street Concerns

The pedestrian safety effect resulting from 1-way street operation can be positive and negative. The positive effect is that pedestrians familiar with the roadway only need to place their primary attention in 1 direction. In addition, at intersections, 1 of the crosswalks will be on the far side of vehicle stopping maneuvers. This provides additional perception and reaction time to both the motorists stopped on the approach and to pedestrians crossing in the far side crosswalk. The 1-way operation also reduces the number of potential turning movements and the consequent pedestrian conflicts which can occur.

The negative pedestrian safety aspects are related to vehicle speed and the attention of unfamiliar pedestrians. One-way streets, because of the decrease in opposing traffic flow, have a tendancy to operate at higher vehicle speeds than the same roadway would if configured as a 2-way operation. The higher speeds result in greater required stopping distances and possible pedestrian errors in judging the available time gap between vehicles. Unfamiliar pedestrians can get into trouble if they check to their left, and seeing that no traffic is present, proceed into the crosswalk when all traffic is actually approaching from the right. A summary of 1-way street concerns is presented in appendix C, page 220.

Midblock Crossing Concerns

Midblock crossings place pedestrians on a portion of the roadway network where they are not normally expected to be encountered by motorists. Midblock crossings have, therefore, the potential of experiencing a higher pedestrian-vehicle accident rate than intersection crosswalks. If midblock crosswalks are used, it is important to take steps that provide the motorists with advance warning that pedestrian activity can be expected. Midblock crosswalks should be accompanied with properly installed advance warning signs (W11A-2) and parking prohibitions to allow motorist identification of pedestrians on the sidwalk waiting to cross and pedestrian identification of approaching vehicles. The use of diagonal or horizontal markings on midblock crossings can also be used to help alert the motorist to the possible pedestrian presence.

Proper placement of the advance warning signs can be difficult in CBD areas that have high pedestrian volumes and permitted on-street parking. The driving task, visual clutter and high sidewalk activity can result in the motorist not recognizing the presence of the advance warning sign. Some agencies erect overhead pedestrian crossing signs on span wires or mast arms to provide additional motorist warning of midblock crossings.

TYPES OF CROSSWALK TREATMENTS

Crosswalks must be clearly discernible to pedestrians to guide them in their proper path, and to motorists to warn them of the pedestrian crossing point. Crosswalk lines are solid lines at least 6 inches in width (15.2 cm) and not less than 6 feet (1.8 m) apart that mark the boundaries of the path pedestrians should use to cross the roadway. Under special circumstances such as where a stop line is not provided or vehicle speeds exceed 35 mph (56 kph), the width of the crosswalk line can be extended up to 24 inches (61.0 cm) in width. Crosswalk lines on both sides of the crosswalk should extend the full width of the intersection leg to discourage diagonal walking between the crosswalks.

The primary types of crosswalk markings are presented in figure 33. The white diagonal lines, at a 45-degree angle, or the white longitudinal lines, at 90°, are used to provide added emphasis to the motorist. The diagonal and longitudinal lines should be 12 to 24 inches (30.5 to 61.0 cm) in width and spaced 12 to 24 inches (30.5 to 61.0 cm) apart. When they are used at a crossing, it is permissible to omit the transverse crosswalk lines. The diagonal and longitudinal lines are intended for use at locations that have a substantial number of pedestrians crossing without any other traffic control device present at locations where added visibility of the crosswalk is desired or at places where a pedestrian crosswalk is unexpected. Midblock and other non-intersection crossings are often treated with diagonal or longitudinal lines. Care should be exercised not to overuse diagonal and longitudinal markings in crosswalks. If used everywhere they tend to lose their emphasis value to motorists. When diagonal or longitudinal lines are used for increased emphasis it is important to use slip-resistant marking material. Similarly, manhole covers, gratings and other access covers should not be located within crosswalks. If it is not possible to avoid their location within crosswalks then they must be readily visible and made slip-resistant.

Crosswalk Illumination

Crosswalk illumination is an important consideration in increasing pedestrian safety during darkness. Vehicle headlamps often do not provide

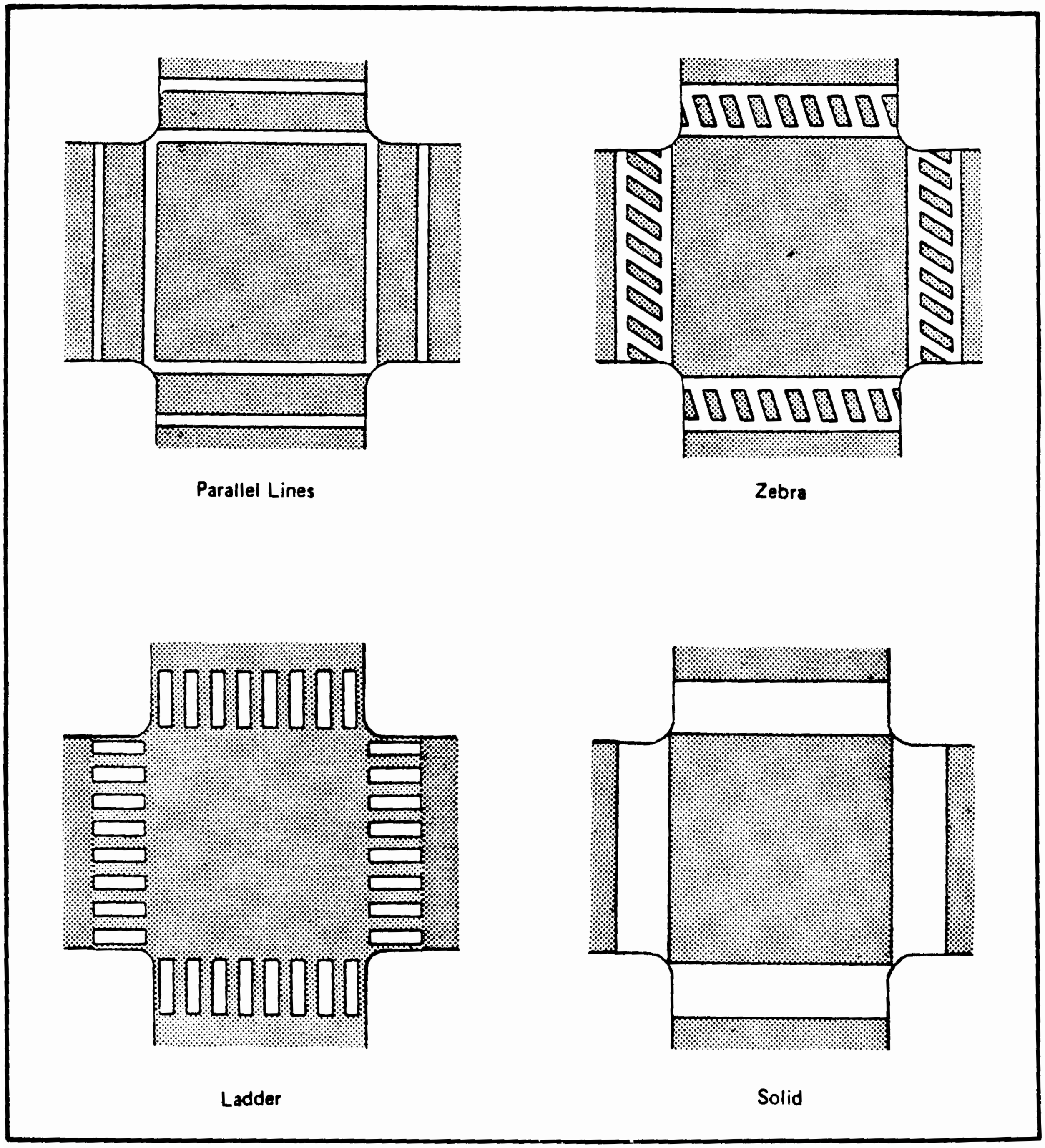


Figure 33. Typical crosswalk markings. (Source: [58], p. 6)

sufficient illumination to permit the motorist to identify pedestrian presence. A study by Smeed determined that darkness doubled pedestrian casualities and that rainfall increased the risk to pedestrians by a factor of 9 at night.[59] The benefits derived from pedestrian crosswalk illumination include factors of security and pedestrian comfort in addition to safety benefits. These additional benefits are considered by many agencies when determining if crosswalk illumination should be provided. In general, illumination should be considered as warranted when the night visibility requires lighting in order to provide the mutual sight distance capabilities described as necessary in AASHTO.[55] Specific locational characteristics that should be considered for crosswalk illumination include:[60,61]

- Roadways that have a speed limit in excess of 40 mph that do not provide adequate pedestrian conflict elimination.

- Intersections, access and decision points and areas adjacent to changes in roadway alignment and cross section.

- Bus stops and crossings servicing other mass transit transfer locations.

- Areas adjacent to pedestrian generating centers and parking lots.

- Refuge islands, including their approach-end treatment should be sufficiently illuminated to show the general layout of the island and immediate vehicular travel paths. The greatest concentration of illumination should occur at points of possible danger to pedestrians or vehicles, as at barrier curbs or other structures.

- Any location where the improvement of nighttime visibility will reduce the potential of vehicle-pedestrian conflicts.

A comprehensive set of quantitative warrants were developed by Freedman, et al., as a result of a study performed for the Federal Highway Administration.[60] These warrants are based on the study of a distinctive color of illumination that served as a visual clue to motorists and pedestrians that a hazardous area was ahead.[62] A summary of these warrants follows:

- Volume Warrant - The volume warrant is based on a combination of vehicles and pedestrians for different roadway types. Data for the warrant study should be obtained during the nighttime period of 10 hour duration; from the beginning of darkness until dawn. It is recommended that data be collected for 3 representative nights of normal traffic patterns. The data is averaged to obtain a measure of the vehicles and pedestrians present during an average 10 hour period. The pedestrian volume is defined as the total number of pedestrians crossing the subject crosswalk for all area classifications except residential. For residential areas, the volume of pedestrians includes the total number of pedestrians using all crosswalks which traverse the roadway in the direction of the subject crosswalk. Vehicle volume is the total number of vehicles which pass across the subject crosswalk. Crosswalk illumination is warranted if the volumes of table 14 are exceeded for the roadway type being studied. If, however, the heavy pedestrian volume exists for a single period of short duration each night, or is seasonal, then crosswalk illumination is not required.

Table 14. Warranting conditions according to volume.(Source: [60], p. 108)

Area	Roadway Classification		
	Major Arterial	Collector Distributor	Local
CBD (Commercial)	Because of the generally high volume of pedestrian and vehicular traffic at these types of locations, it is recommended that other warrants be examined for justification of special lighting.	500 veh/night 100 ped/night	200 veh/night 50 ped/night
Fringe (Intermediate)	1000 veh/night 100 ped/night	500 veh/night 100 ped/night	200 veh/night 50 ped/night
CBD (Intermed-Comm)	1000 veh/night 100 ped/night	500 veh/night 100 ped/night	200 veh/night 50 ped/night
Residential	1000 veh/night 50 ped/night	500 veh/night 50 ped/night	200 veh/night 50 ped/night

- Accident Warrant - Crosswalk illumination is warranted by an occurrence of 3 pedestrian accidents, during a 4-year period, which can be attributed to poor visibility of the pedestrian that can be remedied by illumination.

- Adverse Geometry and Environmental Warrant - Crosswalk illumination is warranted when roadway geometry, local structures and/or environmental conditions (such as prevalence of fog) cause reduced visibility to the extent that pedestrians cannot be seen until within the normal safe stopping distance to the crosswalk.

- Pedestrian Behavior Warrant - Crosswalk illumination is warranted when it is determined that a minimum proportion of 5 percent of the observed pedestrians, using the subject crosswalk, demonstrated unsafe or inappropriate cross behavior and the volume warrant is satisfied to 2/3 of the prescribed level.

- Combined Warrant - Crosswalk illumination may be warranted if any 2 of the previous warrants are met to 2/3 of their prescribed level.

Levels of Recommended Crosswalk Illumination

Where warranted, the lighting levels in pedestrian areas should be at least as high as those recommended by the Illuminating Engineering Society (IES) that are summarized in table 15. When providing the structures to support the lighting fixtures, it is important to ensure that they will not be placed so as to result in sight restrictions to either pedestrians or motorists. A summary of the advantages and disadvantages to roadway lighting is presented in appendix C, page 221.

Table 15. Recommended pedestrian crosswalk illumination. (Source: [63])

Pedestrian Walkways	Commercial		Intermediate		Residential	
	Footcandle	Lux	Footcandle	Lux	Footcandle	Lux
Sidewalks	0.9	10	0.6	6	0.2	2
Pedestrian walks*	2.0	22	1.0	11	0.5	5
Building Sites			Values are given in minimum average maintained horizontal footcandles and lux.			
Entrances	5.0	55				
Grounds	1.0	11				
Parking Areas						
Self Parking	1.0	11				
Attendant Parking	2.0	22				

* Crosswalks traversing roadways in the middle of land blocks at street intersections should be provided with additional illumination producing from 1.5 to 2 times the normal roadway lighting level.

Special Crosswalks

The elderly, handicapped and children require special considerations in crosswalk design to help provide accessibility and safety. Many cities have begun to respond to the needs of these groups by modifying and adding elements at the crossing environment.

Considerations for Elderly and Handicapped

Providing accessibility and safety to all types of potential crosswalk users often requires a tradeoff between their individual type needs in addition to maintenance needs. For example, an ideal situation for wheelchair users would be a long, gentle sloped curb ramp with no bumps or small steps. Ramps that are too long, however, pose problems for some elderly pedestrians in maintaining their footing. Similarly, ramps with no perceptible change in grade and no textured surface poses difficulties for visually handicapped pedestrians to recognize when they are on the ramp and subsequently near the traffic stream. Texturized surfaces that are beneficial to the visually handicapped can pose problems to wheelchair users, drain poorly and cause snow removal problems if textured too roughly. The discussion of this section presents concerns that should be considered and the design detail compromises that best serves the needs of all potential users and maintenance requirements.

Curb Ramps

One of the prevalent impediments to the movement of elderly and handicapped pedestrians is the presence of curbs. Curbs serve not only as a physical separator between vehicular and pedestrian traffic but also as an integral part of the roadway drainage system. The relatively recent emphasis on barrier free design has resulted in the installation of curb ramps on many high pedestrian volume, residential neighborhood and high handicapped usage routes. The installation of a curb ramp requires the removal or termination of a portion of a continuous roadway curb to permit the sloped connection between the lower surface roadway and higher surface pedestrian walkway. If the curb ramp is not properly installed, it can result in an increase in certain accident types, difficulty in usage by the segments of the pedestrian population it was intended to help, improper drainage and maintenance difficulty.

Acceptable Curb Ramp Slopes

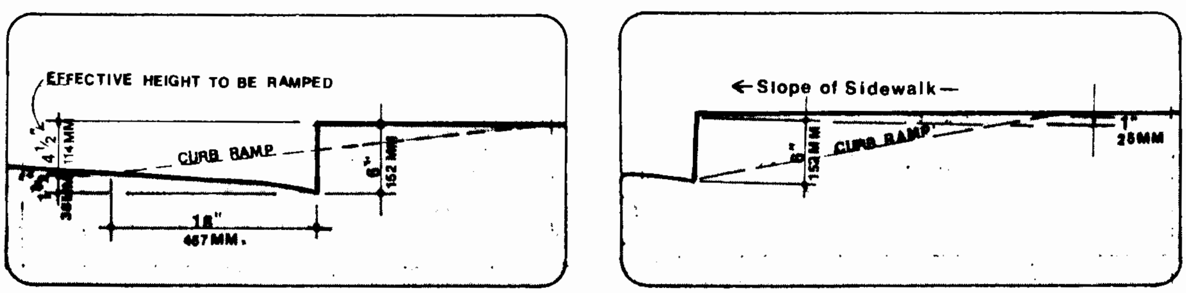
Curb ramp slopes that are too steep require many wheelchair users to take a "run" at the ramp. Curb ramps that are too steep, too long and too steep and long cannot be transversed by some users. The maximum slope for new construction shall be 1:12. Curb ramps constructed on existing sites may have the slopes and rises as presented in table 16.

Table 16. Allowable ramp dimensions for construction in existing sites, buildings and facilities. (Source: [64], p. 60)

Slope*	Maximum Rise in.	Maximum Rise mm	Maximum Run ft.	Maximum Run m
Steeper than 1:10 but no steeper than 1:8	3	75	2	0.6
Steeper than 1:12 but no steeper than 1:10	6	150	5	1.5

*A slope steeper than 1:8 not allowed

Determining the effective slope requires that the gradient of the existing sidewalk and camber of the roadway be considered when calculating the slope and length of the new curb ramp. For example, if the curb ramp will protrude into the roadway as in figure 34(a), then the upward slope of the roadway towards the crown will effectively reduce the total change in elevation. If, as in figure 34(b), the sidewalk slopes up away from the curb, the total height difference will increase as the ramp protrudes into the sidewalk.



(a) (b)

Figure 34. Examples of changes in effective height due to different curb ramp designs.

Curb Ramp Transitions

The transition of the ramp to the sidewalk and the roadway should be flush. A change in the level as small as 1/2 inch (12.7 mm) can pose a difficult obstacle to some wheelchair users. Not only can there be possible difficulty in going over the step, but the step in combination with the "run" required by some users to make the ramp can throw the wheelchair off balance or result in the wheelchair being overturned. Vertical changes in level between the curb ramp and street or sidewalk up to 1/4 inch (6.4 mm) may be used without edge treatment, as presented in figure 35(a). Changes in level between 1/4 inch and 1/2 inch (6.4 mm and 12.7 mm) shall be leveled with a slope no greater than 1:2, as presented in figure 35(b).

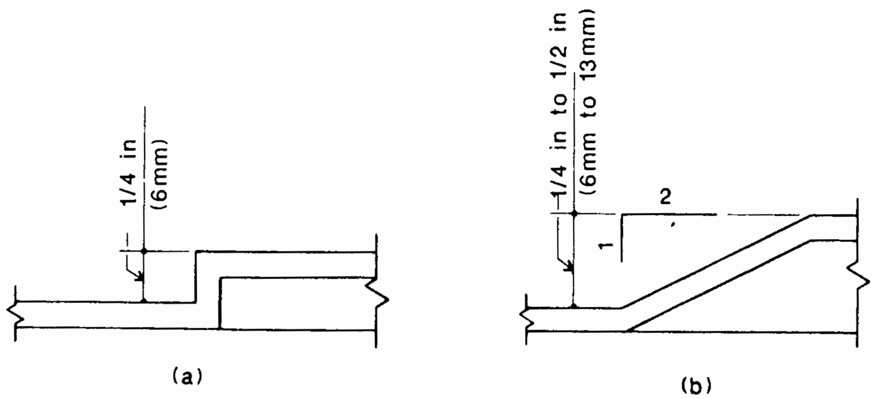


Figure 35. Sharp transitions not acceptable.

If the transition points between the curb ramp and the street or sidewalk are not gradual there is the added possibility that the wheelchair footrests will snag at the transition point. The slope of the adjacent sidewalk and roadway shall never exceed 1:20, as presented in figure 36.

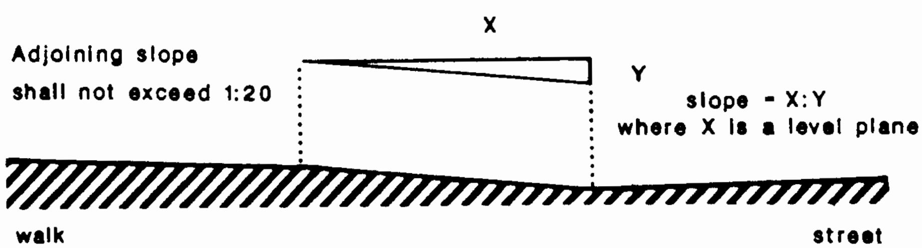


Figure 36. Acceptable range of roadway and sidewalk transitions.

Curb Ramp Width

The proper curb ramp width is dependent upon the volume of pedestrian traffic and the requirements of snow removal equipment. When narrow ramps are installed at heavy pedestrian traffic areas the handicapped individuals may be forced to remain in the roadway until the ramp clears. If the ramps are too wide, then there is no level area remaining for individuals who do not wish to use the ramp. The width of curb ramps should, therefore, be sized to suit the volume of expected pedestrian traffic. They should be no wider than necessary, but no narrower than 36 inches (91.4 cm). In areas where snow removal is a concern, the ramp should be no less than 48 inches (121.9 cm) in width to be negotiable by snow clearance equipment. A diagram of the recommended ramp widths is presented as figure 37.

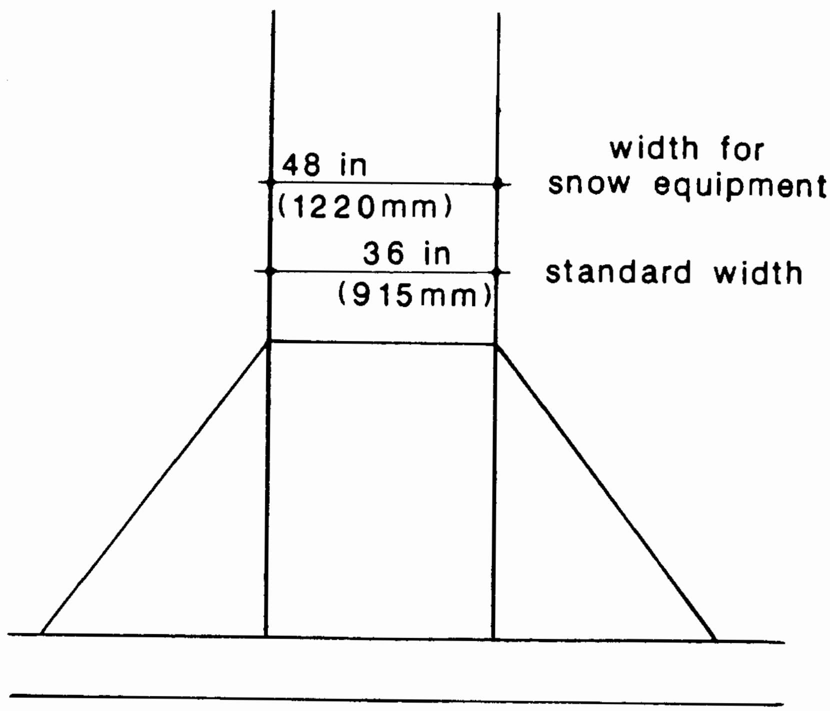
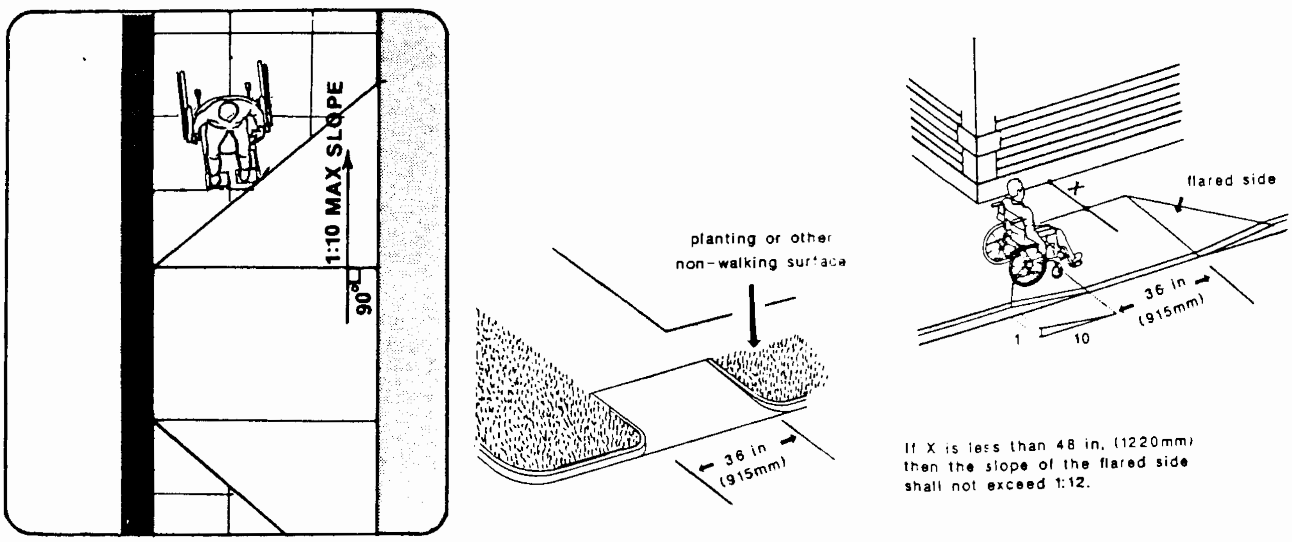


Figure 37. Minimum recommended curb ramp widths.

Curb Ramp Flares

The flares at the sides of curb ramps are often used by all pedestrians to gain access to the ramp itself. If the flares are too steep, they can be hazardous; especially for wheelchair users. If the ramp is placed such that the flares are within the path that pedestrians must use (figure 38(a)), or where it is not complemented by handrails, then the flares should not be steeper than 1:10. If the ramp does not lie in the pedestrian path then returned curbs may be used (figure 38(b)). If the ramp flares are intended to be normally used by wheelchairs to enter or exit the curb ramp such as when the sidewalk end of the ramp is closer than 48 inches (121.9 cm) from a physical obstruction, then the flares should not be steeper than 1:12 (figure 38(c)). The slope of the flares is measured in the direction of right angles to the curb ramp.



(a) (b) (c)

Figure 38. Recommended maximum gradient of curb ramp flares.

Textured Surface for Visually Impaired

The absence of a curbed separation between the sidewalk and roadway can result in visually impaired pedestrians unintentionally walking into the road. If there is no separation point that can easily be detected by visually impaired pedestrians, then one should be constructed that is easily detectable. This can be accomplished by providing a texturized strip (figure 39) that can be detected by visually impaired pedestrians using a cane. Barriers such as planters are used by some agencies in non-crosswalk areas to help channelize the visually impaired to the proper crossing points. The use of planters or other physical obstacles on the pedestrian path, however, has the disadvantage of impeding pedestrian flow.

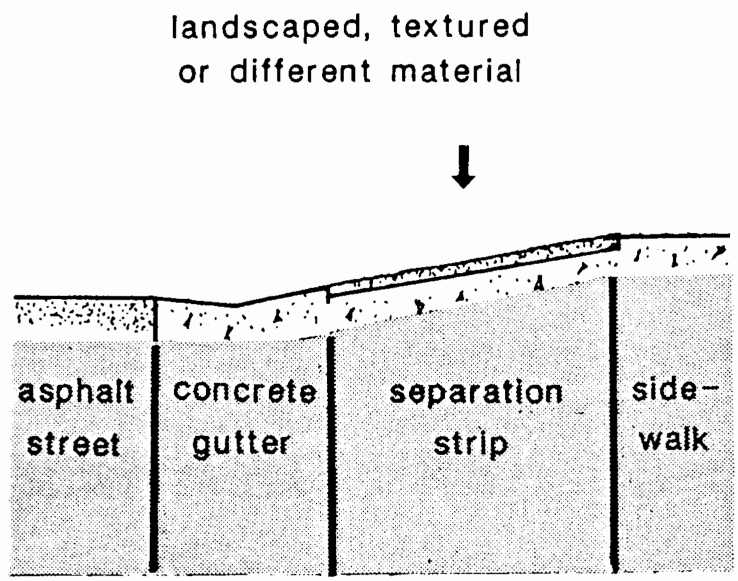


Figure 39. Textured surface as an aid to the visually impaired.

<u>Curb Radii</u>

Intersections constructed with large curb radii do not provide satisfactory directional information about the crosswalk to visually impaired pedestrians. When possible, it is best to limit curb radii to 25 feet (7.6 m) or less in heavy pedestrian traffic areas. When large radius curbs are unavoidable, due to the turning movement pattern of trucks and buses, then paired curb ramps should be provided. Single curb ramps, such as that presented in figure 40, directs the user out of the marked crosswalk and requires the user to make abrupt turns. Curb ramps that do not line up and point in the same direction as the crosswalk can result in directional confusion for the visually impaired and should be avoided. Curb ramps should be positioned within, line up with, and run generally in the same direction as the marked crosswalk.

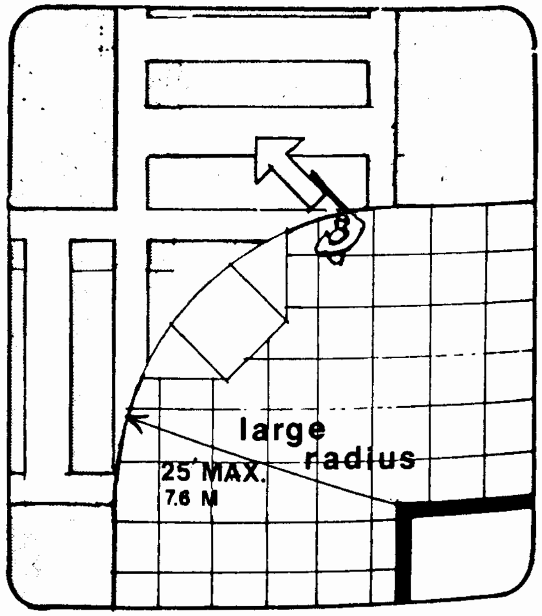


Figure 40. Example of the directional confusion that can result from using single-corner curb ramp at large radius curbs.

Curb Ramp Overrun Distances

The size of the wheelchair plus the need of many wheelchair users to take a "run" at the ramp requires that space be provided at the top and bottom of ramps to slow down, stop or change direction. A minimum of 48 inches (121.9 cm) is needed at the top and bottom of the ramp for wheelchairs to safely negotiate curb ramps as shown in figure 41. If it is not possible to provide at least 48 inches (121.9 cm) at the top of the curb ramp then the slope of the flared sides should not exceed 1:12.

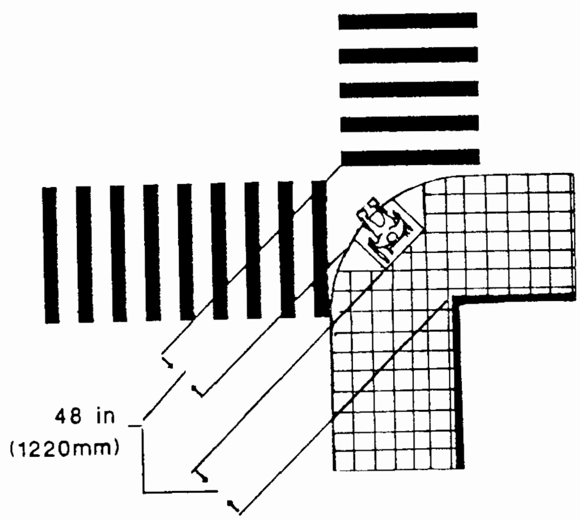


Figure 41. Recommended minimum overrun distances at top and bottom of curb ramps for safe wheelchair use.

The required overrun distance at the bottom of the ramp may need to be obtained by installing the ramp so that they direct the user onto the crosswalk. Corner recessed curb ramps, presented in figure 42, are not recommended since they force the pedestrians to travel in the moving traffic lane. If corner recessed curb ramps already exist, the potential danger can be reduced by placing the crosswalk markings on the extension of the curb line. Notice that this is where the crosswalk markings are placed in figure 41.

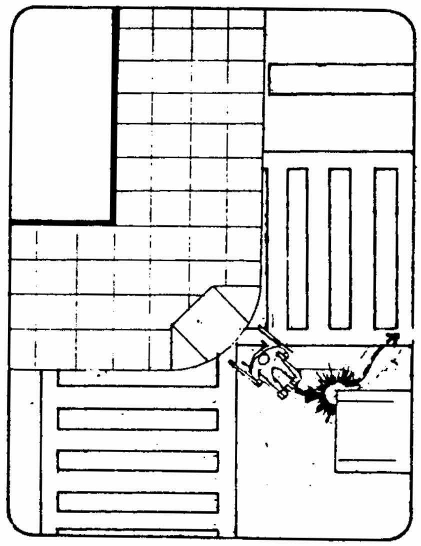
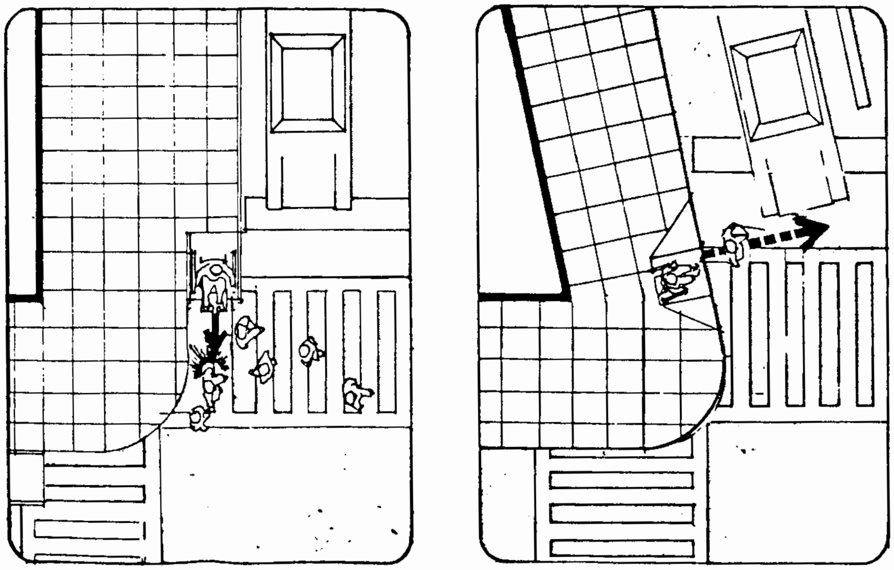


Figure 42. Potential safety hazard resulting from absence of proper overrun distance at the bottom of curb ramps.

Knowledge of the overrun distances and the maneuverability requirements of wheelchairs should preclude curb ramp designs as presented in figure 43(a) and 43(b). Figure 43(a) represents a curb ramp that is undesirable from both the aspect of the ramp user and other pedestrians. This design requires the ramp user to make abrupt turns in order to continue in the desired direction. Pedestrians not using the ramp are exposed to being hit by wheelchairs coming off the ramp and walking around wheelchair users trying to go up the ramp. Figure 43(b) results in the wheelchair user being directed out of the crosswalk.



(a) (b)

Figure 43. Examples of safety deficiencies resulting from improper ramp design.

Curb Ramp Placement

Curb ramps should not be placed so that pedestrians must cross storm water gratings, manhole covers and other access lids as presented in figure 44. Storm water gratings pose potential hazards to wheelchair wheels, crutches, canes and certain types of shoes. Manhole covers and other access lids tend to be slippery when wet and may ice quicker than the road surface. The position of storm water gratings is also designed as a low spot on the roadway surface. The water flow, debris and ice formation are, therefore, likely to be at a maximum at these points. New construction, whenever possible, should avoid locating storm water inlets close to potential crosswalk locations.

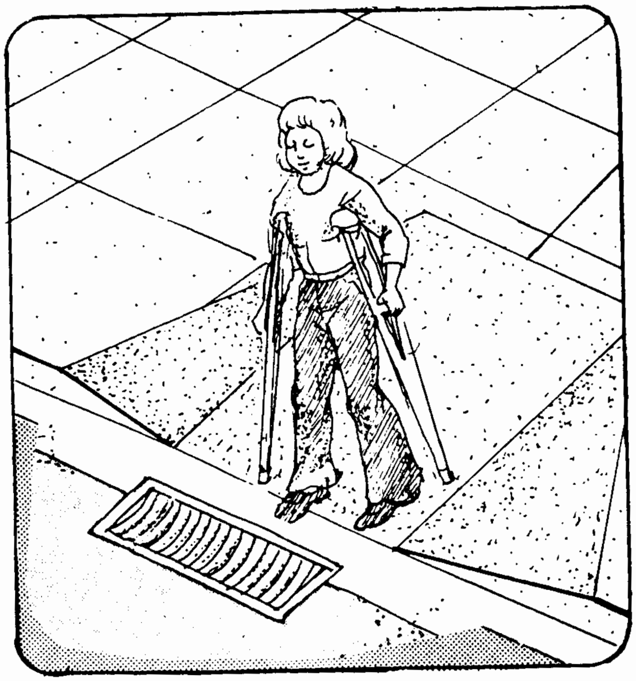


Figure 44. Example of undesirable placement of storm sewer inlet.

If gratings are located within walking surfaces, then they shall have spaces no greater than 1/2 inch (12.7 mm) wide in 1 direction. If the gratings have elongated openings, then they shall be placed so that the long dimension is perpendicular to the predominant direction of travel, as presented in figure 45.

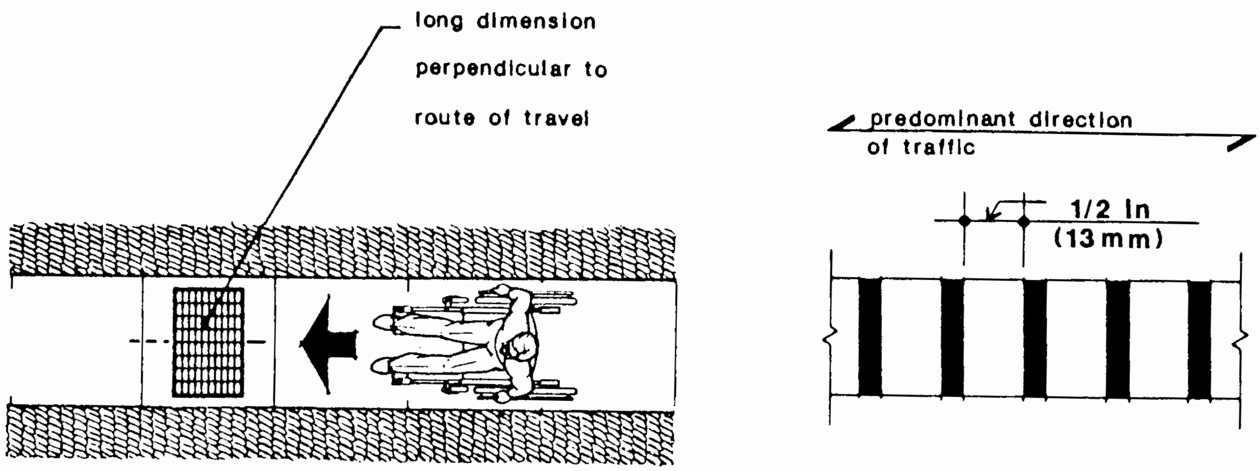


Figure 45. Required grating orientation and design when located within walking surfaces.

Adjoining curb ramps at an intersection corner should be separated as much as possible so that pedestrians are not presented with an area of undulating ground as presented in figure 46. This presents an uncomfortable sensation for pedestrians and can result in them losing their footing and falling. Curb ramps that service adjoining crosswalks should, therefore, be separated as much as possible.

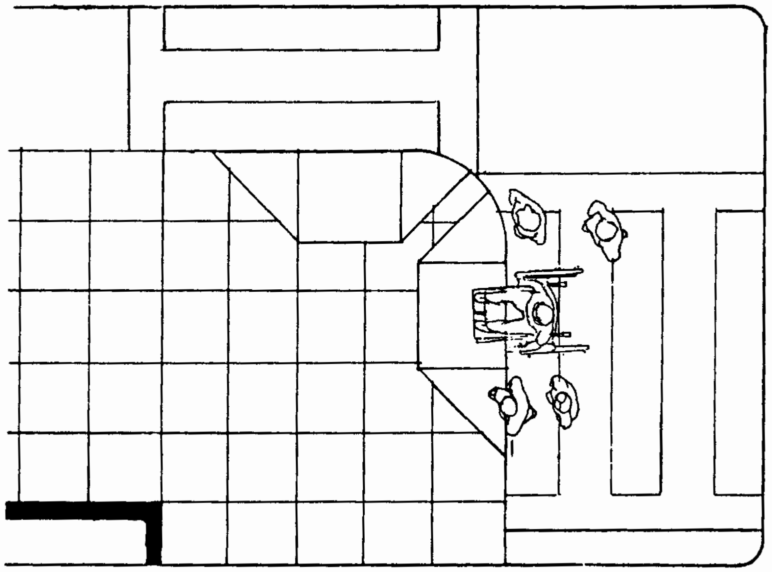


Figure 46. Example of undesirable placement of adjacent curb ramps too close together.

Visually impaired pedestrians find it easier to locate the edge of a roadway by identifying the presence of a curb. When possible, therefore, curb ramps should be constructed away from the direct line of travel, as presented in figure 47, to retain curb presence for use by the visually impaired. In all cases the curb ramp must be within the crosswalk lines.

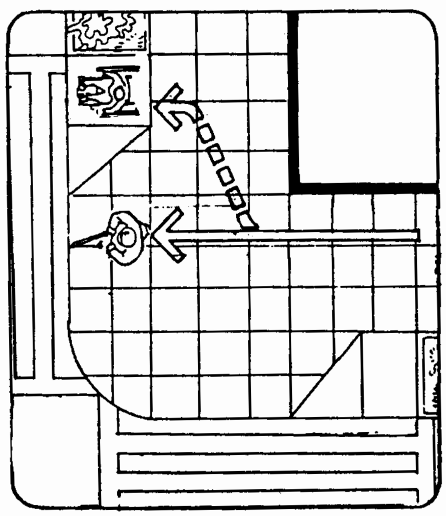


Figure 47. Recommenued installation of curb ramp out of the direct line of pedestrian travel.

Curb Ramp Surfaces

The surfaces of curb ramps are occasionally finished differently than the sidewalk and roadway surfaces. This difference is used to increase the conspicuity of the ramp and to provide a slip-resistant surface. These 2 objectives, increasing conspicuity and slip-resistance, can work against each other. For example, efforts to increase the conspicuity by painting the ramp with yellow paint often results in a smooth surface texture making the ramp slippery. A slippery surface can also occur when the ramp surface consists of rough texturized gravel. The gravel can loosen making the ramp surface unstable and hazardous as well as the rough surface being difficult to sweep clean.

Curb ramps should be constructed with a slip-resistant finish that enables visually impaired pedestrians to detect the difference between the ramp, the roadway and the sidewalk. The use of grooves and patterns that will prevent proper drainage should be avoided. Rough textured surfaces should maintain their integrity and not permit the materials of the finish to break loose from the base.

Curb Ramp Types

The type of crosswalk that is appropriate for a particular location is dependent upon the physical characteristics of the proposed location. Curb ramps must never be planned, however, for 1 side of the roadway without a matching ramp existing on the opposite side of the road and on existing refuge islands. If planned for 1 corner of an intersection due to reconstruction, they must be simultaneously installed on the opposite intersection corners. If the ramp construction is phased, instead of being installed simultaneously, the ramp users will be caught in the roadway with no exit except their point of entry.

The advantages, disadvantages and possible locations for various curb ramp types are summarized in table 17. The contents of this table are intended to provide information on the different types of curb ramp configurations that are available. Close inspection should be given to the listed advantages and disadvantages for each type of curb ramp prior to ramp selection and construction.

A checklist that can be used to help ensure proper ramp design is presented in figure 48. This checklist is intended to remind the planner of the basic elements required to obtain a fully functional curb ramp. The list is designed so that "yes" entries indicate that no further action is required with a "no" indicating a design deficiency. Items should be added to the checklist if local practice encompasses design items not included on the checklist.

Table 17. Applicable locations advantages and disadvantages of various curb ramp types. (Source: [54], pps. 113-123)

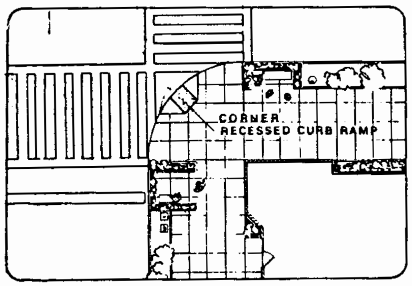
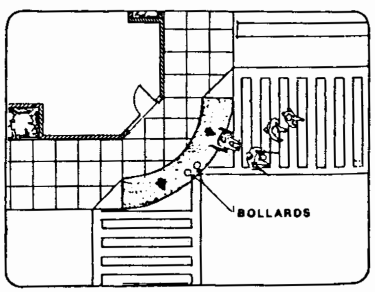
Type	Feasible Where	Should Not Be Used Where	Advantages	Disadvantages
Corner Recessed Curb Ramp 	Sidewalk is wide enough to include ramp and overrun. Wheelchair overrun in the street can be made without leaving the crosswalk.	Sidewalk is not wide enough to include ramp and overrun. Wheelchair overrun cannot be made without leaving crosswalk. It occurs within the direct path of travel for the visually impaired.	Less costly than most alternatives. Less likely to be in the way of visually impaired pedestrians than most alternatives. Permits pedestrians to choose to use a curb or ramp.	Ramp not oriented in direction of travel - confusing for the visually impaired. Wheelchair users must change direction when entering and leaving ramp. The location of the curb/ramp makes wheelchair users more vulnerable to accidents involving turning vehicular traffic. Pedestrian's intentions less clear to vehicle drivers.
Wraparound Recessed Curb Ramp 	Sidewalk is wide enough to include ramp and overrun.	Corner drainage catch basin occurs. Sidewalk is not wide enough to include ramp and overrun.	Permits wheelchairs to enter and leave the crosswalk without changing direction. Permits overrun space for wheelchairs. Permits pedestrians to turn the corner without traveling over the ramp.	Some additional danger that turning vehicles will ride over ramp. Increases the danger that those with limited vision may unintentionally walk into the street. Unless other landmarks are present, may be more difficult for the visually impaired to select a location to wait, before crossing. Provides no alternatives to those who prefer to use curbs rather than ramps.

Table 17. Applicable locations advantages and disadvantages of various curb ramp types. (continued) (Source: [54], pps. 113-123)

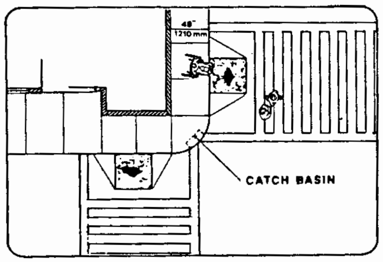
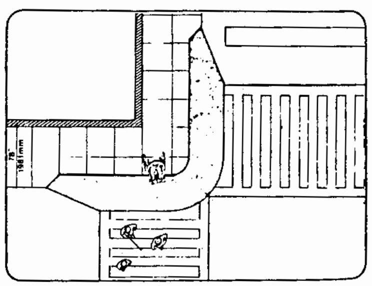
Type	Feasible Where	Should Not Be Used Where	Advantages	Disadvantages
Paired Projecting Curb Ramp 	Sidewalks are narrow. Sidewalks are on a hill or have a substantial gradient. Drainage catch basis is at the corner. Parking is permitted on both streets.	Ramps will not be located within the crosswalk. Ramps will be close together. This is not a usual design for the city.	Relatively inexpensive, requires no demolition. Can usually be short where it takes advantage of slope of street pavement. Directs users into the crosswalk. Can be located out of direct path of visually impaired pedestrians. Does not create an uneven area within the sidewalk.	Some additional danger that turning vehicles may drive over the ramps. Makes the use of snow plows difficult. Occupies the straight portion of curbs that the visually impaired may prefer to use. Will require special provision for storm water flow. Driver's view of pedestrians more likely to be obscured by parked cars.
Wraparound Partial Projecting Curb Ramp 	Sidewalks are narrow. Sidewalks are on a hill or have a substantial gradient. There is no drainage catch basin.	Corner drainage catch basin occurs. This design is an unusual curb ramp for the city.	Can usually be short where it takes advantage of the slope of the street pavement. Relatively inexpensive, requires little demolition before construction Does not create an uneven area within the sidewalk.	Some danger that turning vehicles will ride over the ramp. Increased danger that those with limited vision may unintentionally walk into the street. Unless other 'landmarks' are present, may be more difficult for the visually impaired to select a location to wait at before crossing. Gives no alternative to those who do not wish to use curb ramps. May be some obstacle to snow plows.

Table 17. Applicable locations advantages and disadvantages of various curb ramp types. (continued) (Source: [54], pps. 113-123)

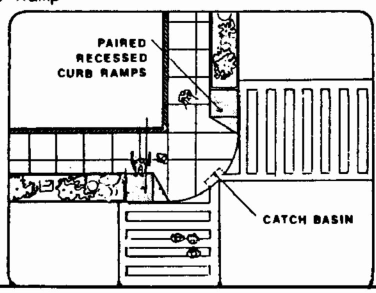
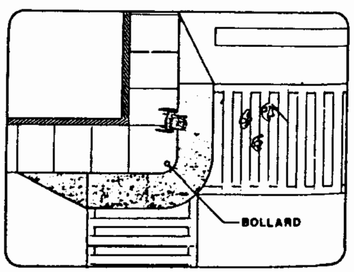
Type	Feasible Where	Should Not Be Used Where	Advantages	Disadvantages
Paired Recessed Curb Ramp 	Both sidewalks are wide enough to include ramps and overrun.	Ramps must be set close together. Either sidewalk is too narrow for ramp and overrun. Ramps will not be located within crosswalk.	Avoids the cost involved in moving the drainage provisions where the catch basin is located on the corner. Directs users straight into a crosswalk. Can be located out of direct path of visually impaired pedestrians.	More expensive than corner recessed curb ramp. Occupies more of the sidewalk than corner recessed curb ramp. Pedestrian users may be obscured by parked cars, etc.
Wraparound Projecting Curb Ramp 	Both sidewalks are too narrow for ramps to be constructed within the sidewalk. Sidewalks are on hill or with substantial cross slopes.	Drainage catch pits are present. This is an unusual pattern for the city.	Relatively inexpensive, does not require demolition before construction. Can usually be short because it takes advantage of the slope of the street pavement.	Some danger that turning vehicles may ride over the ramp. Increased danger that those with limited vision may unintentionally walk into the street. Unless some useable landmarks are present, may be more difficult for the visually impaired to select a location to wait, before crossing. Gives no alternative to those who do not wish to use ramp. Some obstacle to snow plow. May require special provisions for drainage.

Table 17. Applicable locations advantages and disadvantages of various curb ramp types. (continued) (Source: [54], pps. 113-123)

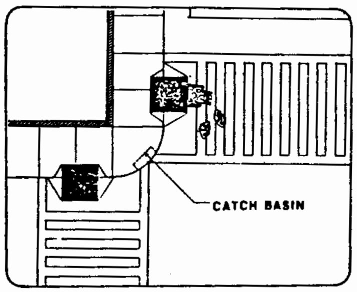
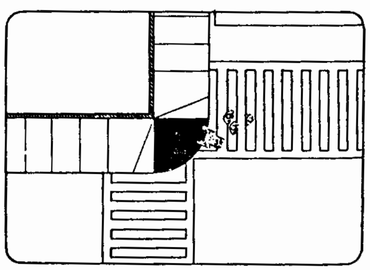
Type	Feasible Where	Should Not Be Used Where	Advantages	Disadvantages
Paired Partial Projecting Curb Ramps 	Sidewalks are narrow. Sidewalks are on a hill or have a substantial gradient. Drainage catch basin is at the corner.	Ramps will not be located within the crosswalk. Ramps will be close together. This design is unusual for the city.	Relatively inexpensive, requires little demolition. Can usually be short where it takes advantage of the slope of the street pavement. Directs users into the crosswalk. Can be located out of the direct path of visually impaired pedestrians. Will not create an uneven area within the sidewalk.	Some additional danger that turning vehicles will ride over the ramp. Makes the use of snow plows more difficult. May occupy the straight portion of the curb that the visually impaired may prefer to use. May interfere with storm water flow. Drivers' view of pedestrians may be obscured by parked vehicles.
Swept Corner 	Sidewalks are narrow.	Corner drainage catch basin occurs.	Permits wheelchairs to enter and leave the crosswalk without changing direction. Provides unlimited overrun space for wheelchairs.	All people using wheelchairs (and other pedestrians) must cross the flares of the ramps, and the ramps. Some additional danger that turning vehicles will ride over the ramp. All pedestrians must travel over it even if they only wish to turn the corner. Increases the danger that those with limited vision may unitentionally walk into the street. Unless other landmarks are present, may be more difficult for the visually impaired to select a location to wait, before crossing.

Table 17. Applicable locations advantages and disadvantages of various curb ramp types. (continued) (Source: [54], pps. 113-123)

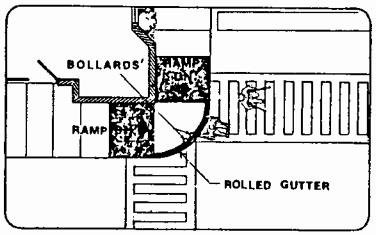
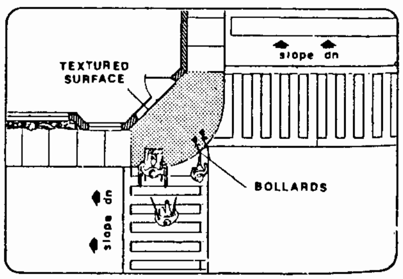
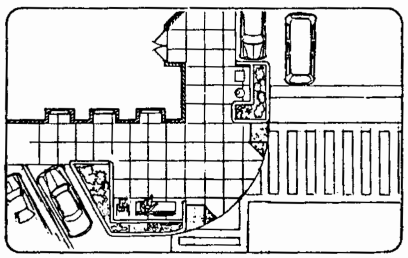
Type	Feasible Where	Should Not Be Used Where	Advantages	Disadvantages
Ramped Sidewalk 	Sidewalks are very narrow. Curbs are high and there is insufficient run for for other ramp types.		Wheelchair users do not have to make their greatest efforts out in the traffic. Provides wheelchair users with adequate 'overrun' space. Permits wheelchair to enter and leave the crosswalk without changing direction.	Some additional danger that turning vehicles will ride over the ramp. All pedestrians must travel over the ramp, even if they wish to turn the corner. Increases the danger that those with limited vision may unintentionally walk into the street. Unless other landmarks are present, may be difficult for the visually impaired to select a location to wait, before crossing the street. May require alternative entrance to the building on the corner. Will require a rolled gutter in order to clear storm water from the sidwalk.
Raised Intersections 	Sidewalks are too narrow for other solutions.	There is high speed vehicular traffic that will be adversely affected.	Requires little or no physical effort to traverse. Obviates the risk of slipping on ramps or tripping, etc., at curbs. The raised intersection may be an effective means of reduing traffic speed at crosswalks.	Expensive. Will probably require the whole intersection and the storm water system to be modified. Some additional danger that turning vehicles will ride over the sidewalk corner. Increases the danger that those with limited vision may unintentionally walk into the street.

Table 17. Applicable locations advantages and disadvantages of various curb ramp types. (continued) (Source: [54], pps. 113-123)

Type	Feasible Where	Should Not Be Used Where	Advantages	Disadvantages
				Unless other landmarks are provided, may be difficult for the visually impaired to select a location at which to wait before crossing the street. May require special precaution to keep the sidewalk free from storm water.
Extended Sidewalks 	Sidewalks are too narrow for alternative solutions. Parking is permitted. Pedestrian traffic is heavy.	Parking is not permitted.	Provides drivers with excellent view of pedestrians. Provides curb ramp space outside the confines of the main sidewalk. Provides additional space for 'platoons' of pedestrians to form. Provides additional space for seating. Reduces the total distance to be crossed (and therefore, effort and danger).	Moderately expensive.

CURB RAMP DESIGN CHECKLIST[1]	Yes	No
1. Is the slope of the curb ramp acceptable in accord with the maximum values presented on page 106?	____	____
2. Has the slope of the existing sidewalk and street been considered? (page 106)	____	____
3. Is the slope of the ramp flares in accord with the maximum slope recommendations of the ramp design? (page 109)	____	____
4. Does the design permit a bottom overrun distance of at least 48 inches (121.9 cm) within the crosswalk?	____	____
5. Does the design permit a top overrun distance of 48 inches (121.9 cm) on the sidewalk?	____	____
6. Is the ramp located within the crosswalk?	____	____
7. Is the ramp located outside of the direct route of the visually impaired?	____	____
8. Does the design permit the visually impaired to locate the ramp, the separation between the roadway and sidewalk and the direction of the crosswalk?	____	____
9. Does the design permit wheelchair users to enter and leave the crosswalk without changing direction?	____	____
10. Is the ramp located so that its use is an alternative such that people who do not wish to use the ramp need not?	____	____
11. Is the use of the ramp not impeded by street furniture?	____	____
12. Do drivers have an unimpeded view of pedestrians?	____	____
13. Does the ramp design not interfere with snow plow use?	____	____
14. Are there usable curb ramps on the other side of the roadway and refuge islands?	____	____
15. Are construction details ensuring that lips or steps higher than 1/4 inch (16 mm) do not exist?	____	____

[1] Checklist modified from p. 124 of Source [54].

Figure 48. Curb ramp design checklist.

Refuge Islands

Refuge islands are areas between vehicular traffic lanes that are intended to provide refuge for pedestrians who are unable to cross the entire roadway width at one time due to changing traffic signals or oncoming traffic. The necessity for refuge islands should be established based on careful study since they occupy space normally available for vehicular traffic. Typical urban locations that should be investigated for the need of refuge islands include:

- At crosswalks with considerable pedestrian traffic and where it would be difficult or dangerous to cross the entire roadway at 1 time in safety. Refuge islands should be considered, for example, if the total crosswalk length is greater than 75 feet (22.9 m) and a relatively large number of elderly and handicapped pedestrians are present. Similarily, at signalized intersections a refuge 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.

- At complex or irregularily shaped intersections refuge islands should be considered to provide elderly and handicapped pedestrians the opportunity to rest and become orientated to the flow of oncoming traffic.

Refuge Island Design Concerns

The refuge islands should preferably be at least 6 feet (1.8 m), and in no case less than 4 feet (1.2 m) wide to reduce the danger of island users, particularly those in wheelchairs propelled by attendants, from projecting into the traffic lanes. Refuge islands smaller than 6 feet (1.8 m) wide often create a feeling of isolation and unease in pedestrians due to the moving vehicles passing too close. The length of the refuge island should not be less than 12 feet (3.7 m), or the width of the crosswalk, whichever is greater. The approach nose of the refuge island must be appropriately treated to provide sufficient motorist warning of island presence. The approach nose of an island separating opposing traffic movements should be offset to the left; as faced by approaching traffic. The right side of the island should form a diverging taper to direct traffic to the right. If the island separates traffic moving in the same direction then appropriate tapers should be used to direct traffic in the proper directions. A diagram depicting the size and shape of refuge islands is presented in figure 49. Detailed criteria for the design of islands are contained in A Policy on Geometric Design of Highways and Streets, 1984.[55]

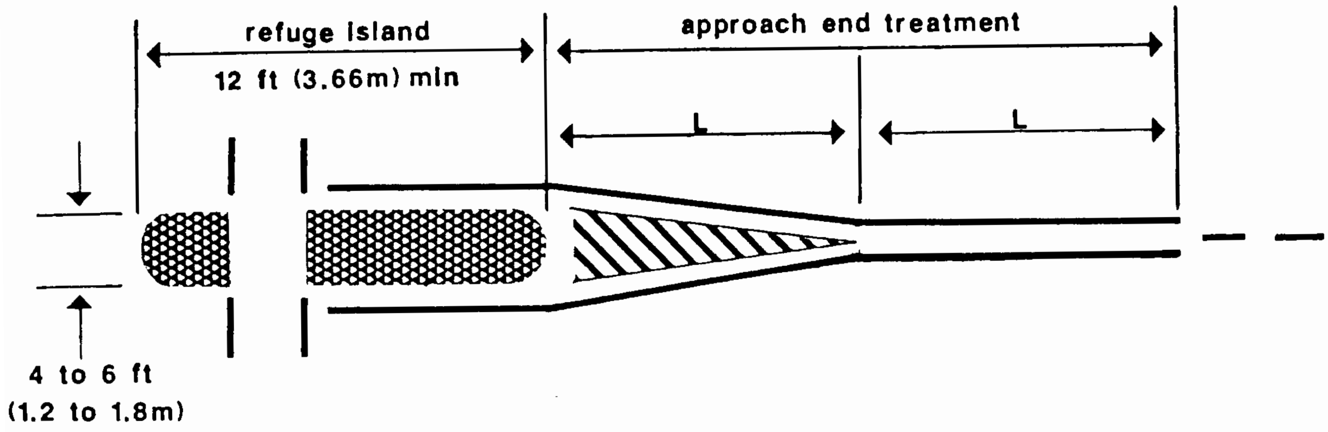


Figure 49. Minimum size and shape requirements of refuge islands.

The presence of refuge islands must be easily recognized by motorists to permit efficient and safe operation. Inherent in the efficient and safe operation are requirements of proper geometric design, traffic signing and pavement markings. The exact criteria for these requirements will depend upon the island function, location within the roadway and whether it is located in an urban or rural environment. Since many standard traffic control signs and markings are applicable it is recommended to refer to the appropriate manual on uniform traffic control devices for guidance on signing and marking selection and placement.

In general, islands should be designed to minimize the potential hazard to both motorists and pedestrians. In areas of high traffic volumes refuge islands are more visible to the motorist and safer for the pedestrian if they are raised and outlined with barrier curbs. Object markers should be used on the island approach noses to indicate the presence of the raised curb. The design of the refuge island, however, must not include features such as foliage, barriers, signs and electrical or signal boxes that will pose visibility restrictions for motorists, pedestrians of small stature and people in wheelchairs.

Raised islands shall be cut through level with the street or have curb ramps at both sides leading to a level area at least 48 inches (121.9 cm) long in the part of the island intersected by the crossing.

A level surface less than 48 inches (121.9 cm) increases the possibility of wheelchair users needing to restrain themselves on the ramp slope or inadvertently rolling onto the roadway. Individuals on crutches, cane users and the elderly also have trouble maintaining their balance on a sloped surface. Where the refuge island is too narrow to provide the required slope and a 48 inch (121.9 cm) level area, then the crosswalk must continue through the island at roadway level without curb ramps. If the walkway surface of the refuge island is maintained at the same level as the crosswalk, then special provisions for the visually impaired should be provided to assist them in identifying the location of the refuge island. This can be accomplished by providing appropriate tactical clues that can be detected by long cane techniques.

Refuge islands located on wide roadways should provide sufficient area for pedestrians to stop and rest away from the normal pedestrian path. Adequate space for a wheelchair and when possible, a bench should be provided, as presented in figure 50, to permit the opportunity for resting before proceeding to cross the remaining roadway. A summary of the advantages and disadvantages of refuge islands is presented in appendix C, page 222.

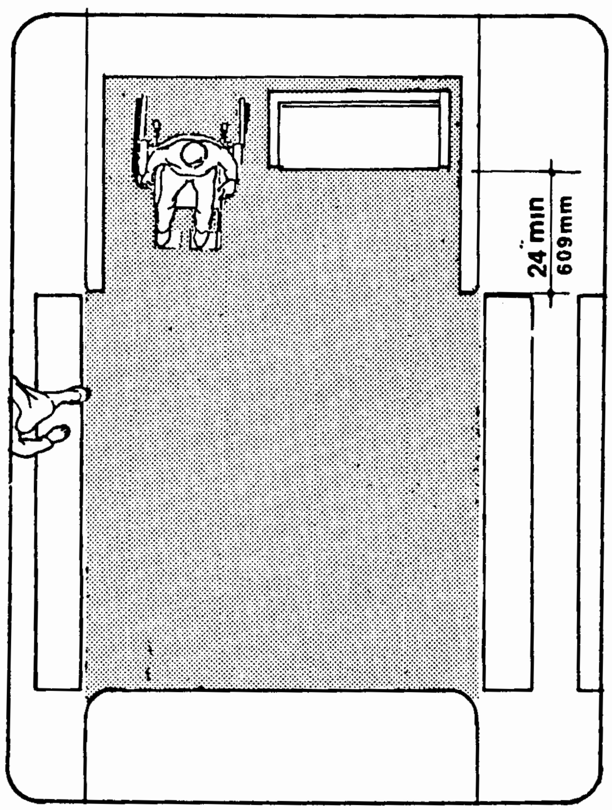


Figure 50. Rest area provisions for refuge islands.

CHAPTER 7 - VERTICAL SEPARATION - OVERPASSES AND UNDERPASSES

Separation of pedestrians and vehicles by means of grade separation structures is the most effective means of pedestrian protection. In addition to increasing pedestrian safety, pedestrian grade separation structures are effective in reducing vehicle delay, vehicle accidents and in increasing highway capacity. Pedestrian grade crossing structures are, however, expensive to construct and maintain and unless properly located and designed, will not be used to their full potential. The majority of grade separation structures require extra effort and travel distance by pedestrians. If pedestrians do not perceive increased safety benefits by the use of the crossing structure they will attempt to directly cross the traffic stream.

PLANNING CONSIDERATIONS

Candidate locations for grade separation include areas where there are "attractors" such as large schools, shopping centers, recreational areas, parking garages or other types of activity centers that are separated by arterials from residential "generators". Grade separations needs are more prevalent in suburban and rural areas where the arterial is wide and traffic volumes and operating speeds are high. Central business districts that are undergoing urban renewal afford an opportunity to provide grade separated pedestrian systems as part of the downtown renewal plans. Locations where there are natural or man-made barriers which would encourage use of the separation structure and topography that would reduce right-of-way and approach structure requirements, are more advantageous than level open sites.[65,66,67]

The location of grade separation structures in relation to other crossing alternatives has a major impact on its degree of use. Experience has shown that the separation will not be used simply because it improves safety. Pedestrians will mentally weigh the perceived safety benefits derived from structural use with the extra effort required. Figure 51 illustrates the results of 1 study of the sensitivity of pedestrians to delay connected with the use of over and underpasses.[68] The study determined that use drops sharply when an alternative, but less safe, crossing is shorter and takes less time. Ideally, the separation structure should be on the normal path of pedestrian movement, increase convenience due to elimination of crossing delays and conflicts and not require the pedestrian to divert long distances.[69] Railings, fencing, and median barriers may be necessary to discourage alternative grade level crossings at alternative locations which pedestrians may believe to be more direct.

Barrier design must be continuous to be effective, without gaps which would allow short-cutting the separation structure.[70] Escalators have been used for underpass access in Europe to encourage greater use but this is an expensive feature which can be justified at only the most intensively used urban locations.

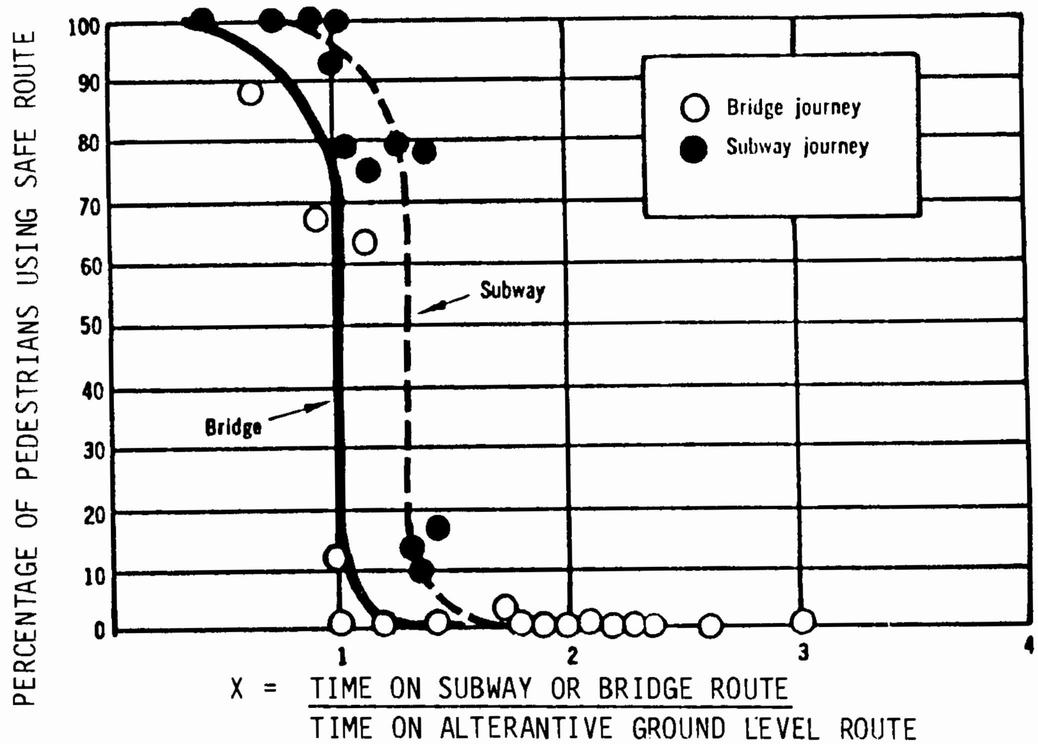


Figure 51. Use of pedestrian overpasses and underpasses. (Source: [68], p. 56)

OVERPASSES VS. UNDERPASSES

Overpasses are more commonly used than underpasses with each having inherent advantages and disadvantages. Overpasses require a greater vertical separation than that required for underpasses due to the need to provide adequate clearance for large trucks. The greater vertical height of overpasses generally requires greater right-of-way to provide acceptable ramp slopes and access stair placement. In addition, overpasses, unless enclosed, are open to the atmospheric environment, exposed to traffic noise and pollution and must be equipped with countermeasures to prevent dropping of debris on vehicles passing underneath. The basic types of overpass structures are presented in figure 52.

The underpass clearance height (usually 7 to 8 feet) (2.1 to 2.4 m) can be less than half that of overpass resulting in shorter stair flights and ramps and reduced right-of-way (ROW) requirements. The disadvantages to underpass structures include the possible expensive relocation of

OVERPASS TYPES

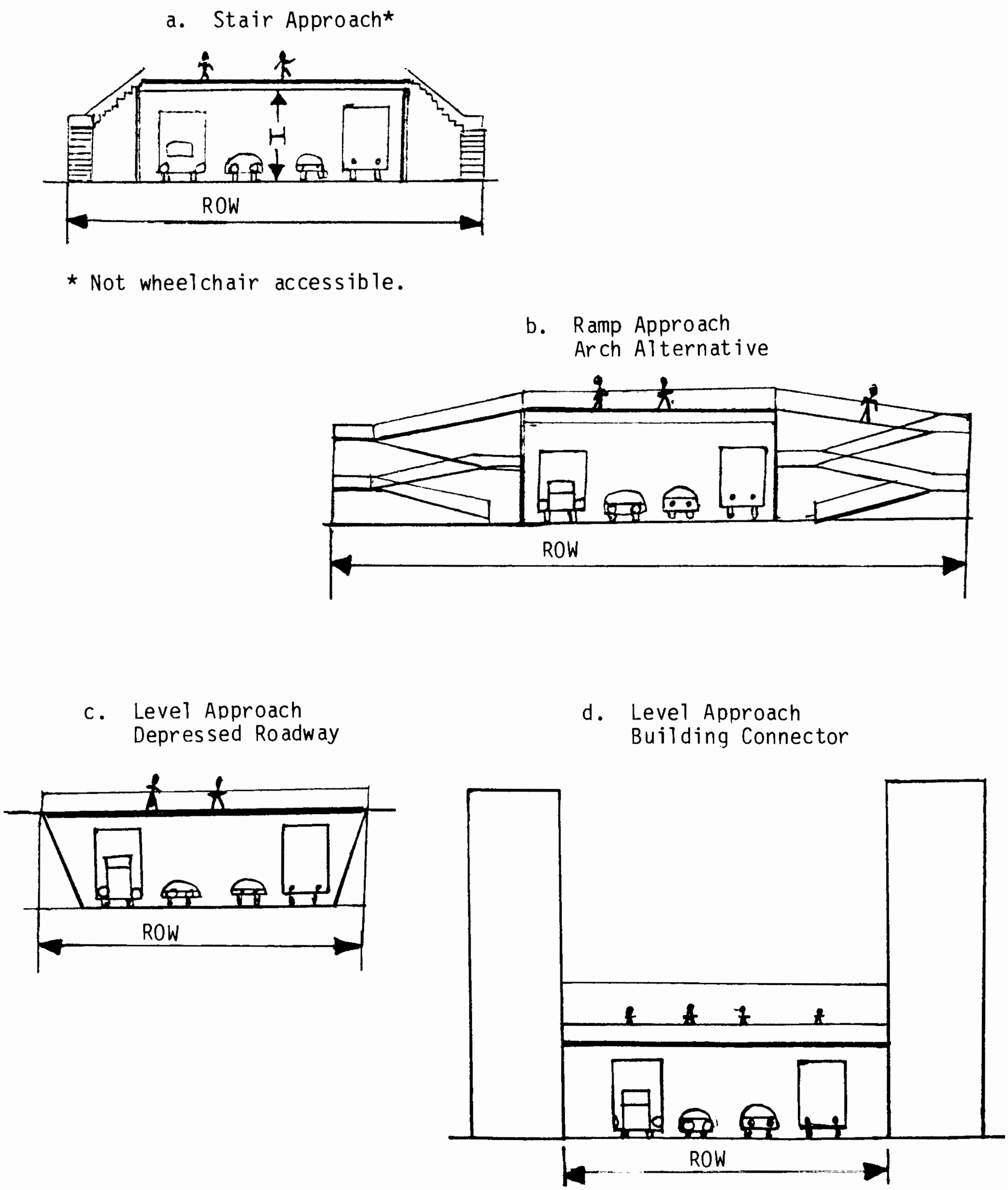


Figure 52. Pedestrian overpass grade separation concepts.

utilities, drainage problems and perceptions of insecurity leading to pedestrian avoidance.[71] Figure 53 presents some common underpass structure concepts.

The relative elevations of the highway and pedestrian crossing have a significant affect on grade separation cost and potential use. Crossing structure costs and ROW requirements are substantially less where the highway is depressed or elevated relative to the pedestrian crossing. Use of the separation will also be greater because of the "barrier" effect of the highway itself and the reduction in length or elimination of access stairs and ramps. The feasibility of underpasses can be improved where it is possible to slope the roadway up over the underpass. The New Town development of Stevenage, England has a complete grade separated pedestrian network of 120 underpasses based on sloping the vehicle roadway up at 2 times the downgrade of the underpass approach slope. This reduces the "tunnel" affect of the underpass, making it more open and improving its perceived security. Underpass security can be further increased by providing wall and roof openings for "daylighting", by high artificial lighting levels (approximately 10 footcandles), by avoiding changes in path direction that may produce hidden areas and by consistent maintenance and cleaning.[71]

DESIGN CONSIDERATIONS

Basic design considerations for grade separation structures include the choice of materials and finishes, their durability and maintainability, resistance to vandalism, lighting for security, accessibility for the physically impaired, protective guardrails and screening and channelization barriers that may be required to encourage use of the separation. Underpass construction has been accomplished with precast concrete sections similar to culvert design practices, or cast in place concrete. Overpass structures are typically constructed of steel which may be in an arch, truss, box or through girder type of configuration. The arch has the advantage of reducing pedestrian ramp approach and right-of-way requirements. Through girder or through truss type configurations minimize the depth of the overpass deck, which also reduces approach length and right-of-way. Protective screening and enclosures are necessary on overpasses to prevent the dropping of objects on vehicles below and to prevent climbing on the outside of the structure and possible falls.

Accessibility

Table 18 summarizes the design features which should be considered to assist elderly and handicapped pedestrians, the reason for the design

UNDERPASS TYPES

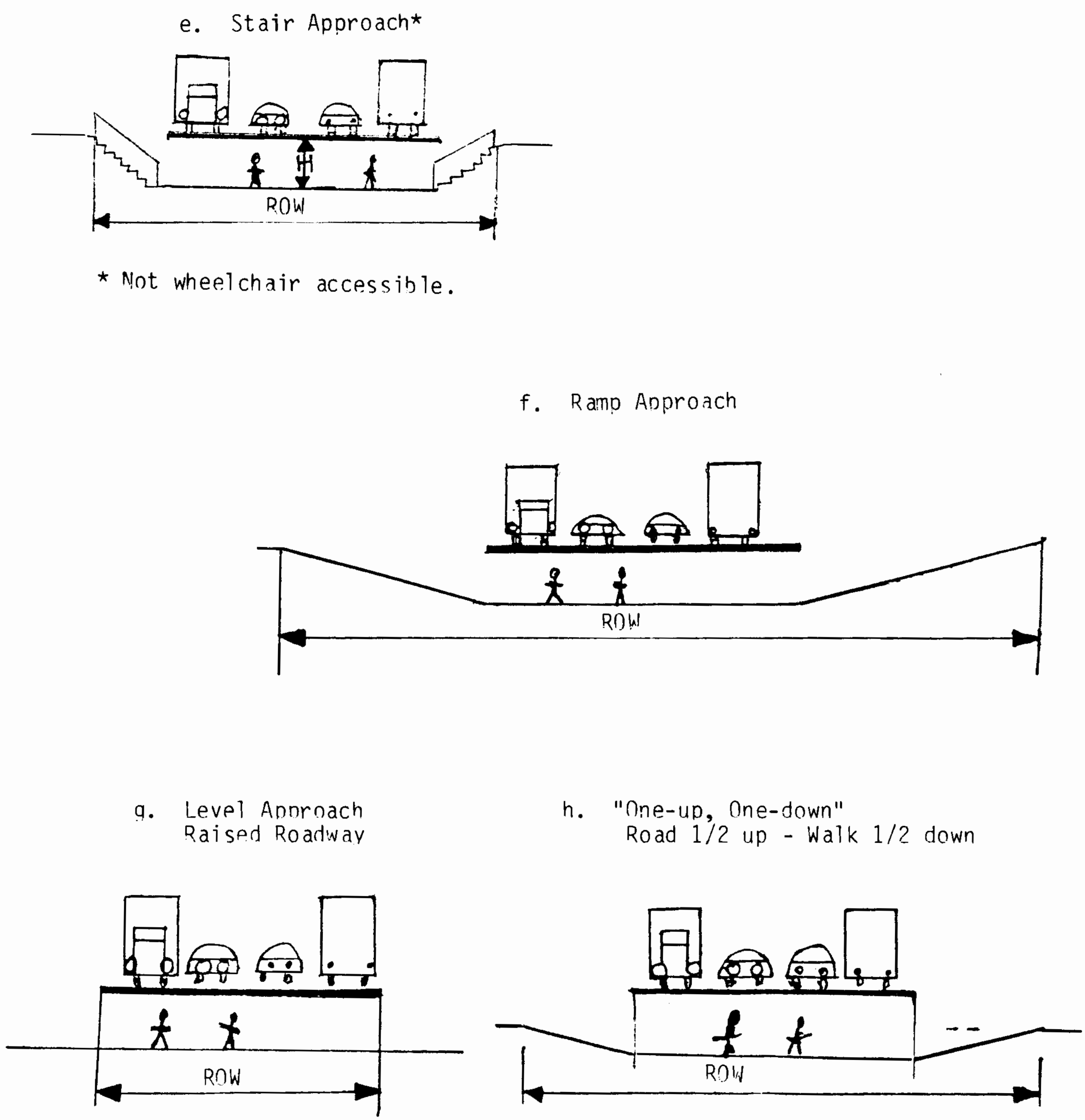


Figure 53. Pedestrian underpass grade separation concepts.

Table 18. Recommended features for accessible design of grade separated structures. (Source: [72], p. 3)

Design Features	Reason for Providing	Criteria References
1. Stopping or resting places (landings)	Elderly and handicapped pedestrians lack stamina and strength.	GSA-AS Sec. 5.1* ATBCB-MGRAD** Section 1190.70
2. Benches	Periodic resting places with benches provide seating for pedestrians and allow them to regain strength.	
3. Special signal timing for pedestrians	The slower movement and reaction time of elderly and handicapped pedestrians requires more crossing time at signalized intersections.	
4. Detectable warning cues	Blind persons need to be alerted to potential hazards such as stairs, intersections, driveways, etc.	ATBCB-MGRAD** Section 1190.190 (reserved)
5. Detectable guidance	Where the natural cues are not available, supplementing guidance cues are useful.	
6. Protection from low projections	Overhead projections avoided by sighted persons are hazardous to visually impaired pedestrians.	GSA-AS Sec. 5.13* ATBCB - MGRAD ** Section 1190.50 ANSI ***
7. Tactile signs	Route layout signs for visually impaired pedestrians are needed for guidance.	GSA-AS Sec. 5.1* ATBCB-MGRAD** Section 1190.200 (reserved) ANSI***
8. Large legend signs	Handicapped persons with limited vision can often read signs if the letters are large.	GSA* ATBCB** ANSI***
9. Ramps with moderate grades	Handicapped persons in wheelchairs can utilize over- or undercrossings if ramp access is provided.	GSA-AS Sec. 5.1* ATBCB-MGRAD** Section 1190.70
10. Non-heat conducting handrails	Some elderly and handicapped persons are dependent on handrails and may be injured because of a high sensitivity to heat or cold.	ATBCB-MGRAD** Section 1190.90 ANSI***
11. Dual access facilities (steps and ramps)	Handicapped persons on crutches or using canes often find stairs easier to negotiate than ramps.	

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feature and the applicable reference and standard. This table can also be used as a checklist to ensure that the reviewed portions of the proposed design meet the needs of the potential users.

The walking widths should be designed to accommodate the projected pedestrian traffic using the procedures provided in chapter 2 of this handbook. If the projected pedestrian density is relatively small then the walkway width on the structure approaches and on the structure itself should be a minimum of 8 feet (2.44 m) to allow sufficient space for wheelchair passing and turning, as presented in figure 54. Minimum clear widths of off structure walks should be 4 feet (1.22 m) (figure 55) to permit pedestrians to pass. When the minimum off structure widths are used then wheelchair turning and passing areas, as presented in figure 56, should occur every 200 feet (61.0 m)

The approach ramp length is dependent upon the vertical height to be gained and the allowable gradient. The maximum allowable ramp gradients for various ranges of vertical height are presented in table 19. The overall vertical rise and length of approach ramp also determine how many landing areas are required.

Table 19. Maximum allowable ramp lengths and gradients. (Source: [72], p. 14)

Vertical Rise	Maximum Slope	Landing Number 1	2	3	4	5	6
0 to 9 ft. (2.7m)	1:10	45 ft. (13.5m)					
9 ft. (2.7m) to 14 ft. (4.3m)	1:11	69 ft. (20.7m)	124 ft. (37.2m)				
14 ft. (4.3m) to 16 ft. (4.9m)	1:13	83 ft. (24.9m)	148 ft. (44.4m)	192 ft. (57.6m)			
16 ft. (4.9m) to 20 ft. (6.0m)	1:15	96 ft. (28.8m)	170 ft. (51.0m)	215 ft. (64.5m)	245 ft. (73.5m)	275 ft. (82.5m)	305 ft. (91.5m)

WARRANTS FOR PEDESTRIAN OVER AND UNDERPASSES

The high cost of pedestrian separation structures makes it difficult to develop a strict series of warrants which would uniformly justify their construction. Opportunities for over and underpass installations are best when their need is recognized early in the planning of new developments which will generate pedestrian crossing activity. At this stage they can

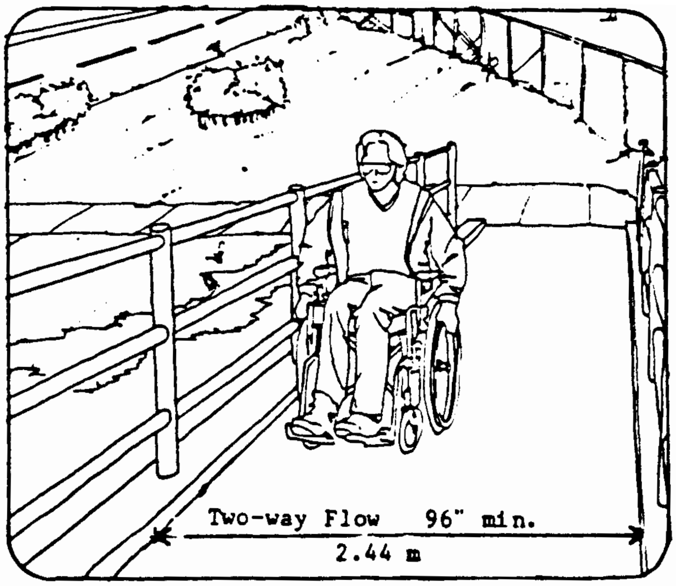


Figure 54. Recommended minimum width for walkways on approaches and structures.

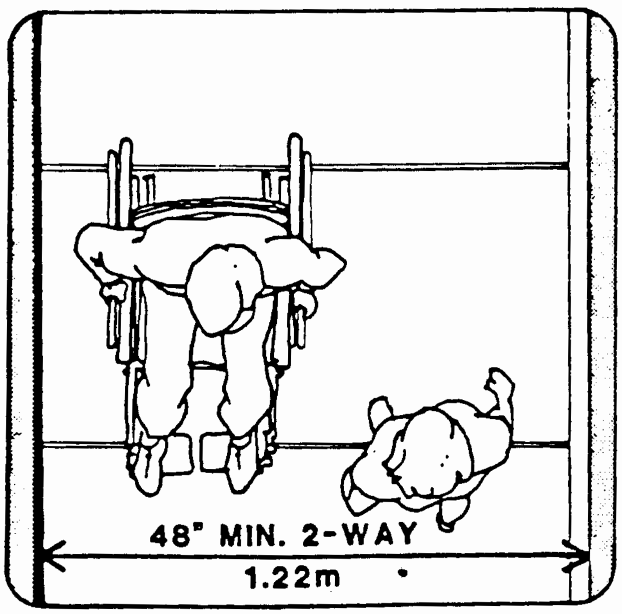


Figure 55. Recommended minimum width for off-structure walks.

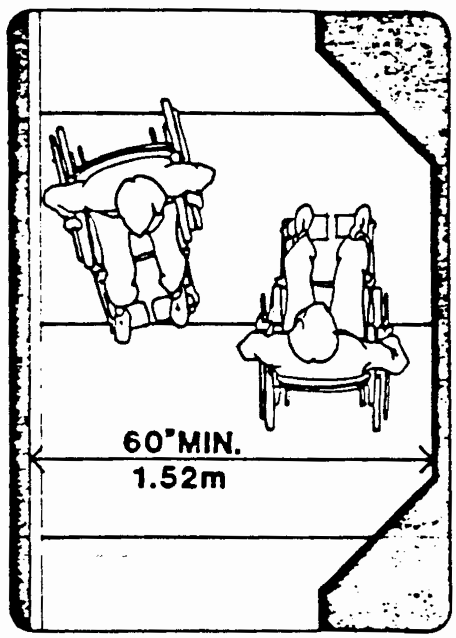


Figure 56. Passing area provided every 200 feet when minimum walkway width is used.

be incorporated more easily into the development plan, with potential contributions by the developer, as a prerequisite to obtaining local approvals. Pedestrian separation warrants are summarized below:[73]

1. Pedestrian volume should be a total of over 300 in the 4 highest continuous hour period if vehicle speed is over 45 mph and the proposed sites are in urban areas and not over or under a freeway. Otherwise, pedestrian volume should be a total of over 100 pedestrians in the 4 highest continuous hour period.

2. Vehicle volume should be over 10,000 in the same 4-hour period used for the pedestrian volume warrant or ADT over 35,000 if both vehicle speed is over 45 mph and the proposed sites are in urban areas. If the 2 conditions are not met, vehicle volume should be over 7,500 in 4 hours or ADT over 25,000.

3. A proposed site should be at least 600 feet from the nearest alternative "safe" crossing. A "safe" crossing is where a traffic control device stops vehicles to create adequate gaps for pedestrians to cross. Another "safe" crossing is an existing over or underpass near the proposed one.

4. A physical barrier to prohibit at-grade crossing of the roadway is desirable as part of overpass or underpass design plan.

5. Artificial lighting should be provided to reduce potential crime against users of underpasses and overpasses. It may be required to light underpasses 24 hours a day and overpasses all night.

6. Topography of the proposed site should be such that elevation changes are minimal to users of overpasses and underpasses and construction costs are not excessive. Elevation change is a factor effecting the convenience of the users.

7. A specific need should exist or be projected for a GSPC based on existing or proposed land use(s) adjoining the proposed site which generate pedestrian trips. These land use(s) should have direct access to the GSPC.

8. Funding for construction of the pedestrian overpass or underpass must be available prior to construction commitment.

COSTS AND BENEFITS OF OVER AND UNDERPASSES

Cost benefit analysis procedures have been developed for evaluating the economic feasibility of separation facilities, and to develop priority ratings for the allocation of resources. The high cost of pedestrian grade separation can be offset by developers, either as a pre-requisite for project approval by reviewing agencies, or to enhance pedestrian access to their developments. Minneapolis, Minnesota has a large grade separated pedestrian network formed by bridges connecting many of its major downtown buildings, financed almost entirely by private interests, but developed under the guidance and control of the municipality. Similar grade separated underground pedestrian networks, funded by abutting developers, exist in Montreal, Canada; Houston, Texas; and New York City. There have also been examples of special local tax districts set up specifically to assess benefitting property owners for pedestrian facility improvements where the community has requested and supported their development. A summary of the advantages of pedestrian over and underpasses is presented in appendix C, pages 223 to 225.

A formalized procedure has been developed for evaluating the costs and benefits of proposed over and underpasses.[74,75] This procedure assigns values to the benefits derived from the separation and weighs these benefits based on relative importance to local community interests. The method recognizes that communities differ in their perception of grade crossing problems and the importance of pedestrian improvements. Lists of the benefit variables and cost elements considered in the procedure are shown in tables 20 and 21, respectively. Users requiring further information on quantifying the costs and benefits of pedestrian structures should obtain "Quantifying the Benefits of Separating Pedestrians and Vehicles", NCHRP No. 189, 1978, and "A Manual to Determine Benefits of Separating Pedestrians and Vehicles," NCHRP No. 240, 1981.[74,75]

Table 20. Pedestrian facility evaluation variables.

Pedestrian Transportation	1. Travel Time 2. Ease of Walking 3. Convenience 4. Special Provision for Various Groups.
Other Transportation	5. Motor Vehicle Travel Costs 6. Use of Automobiles 7. Impact on Existing Transportation Systems 8. Adapatability to Future Transportation Development Plans
Safety	9. Societal Cost of Accidents 10. Accident Threat Concern 11. Crime 12. Emergency Access/Medical & Fire Protection
Environment/ Health	13. Pedestrian Oriented Environment 14. Effects of Air Pollution 15. Noise Impacts 16. Health Effects of Walking
Residential/ Community	17. Residential Dislocation 18. Community Pride and Cohesion 19. Community Activities 20. Aesthetic Impact, Compatibility with Neighborhood
Commercial/ Industrial Districts	21. Gross Retail Sales 22. Displacement, Replacement, or Renovation Required or Encouraged by Facility 23. Ease of Deliveries & Employee Commuting 24. Attractiveness of Area to Business
Urban Planning	25. Adaptability to Future Urban Development Plans 26. Net Change on Tax Receipts and Other Revenue 27. Public Participation in the Planning Process

Table 21. Major cost components of pedestrian facilities.

1. Design and architect costs
2. Financing costs and legal fees
3. Site preparation
   - Real estate acquisition
   - Demolition
   - Drainage
   - Grading
   - Utilities relocation
   - Foundations
   - Required permits
4. Construction
   - Height, width and length of facility
   - Length of span (if any)
   - Method of support
   - Enclosures (if any)
   - Materials
   - Walkway paving, curbs
5. Finishing touches
   - Lighting
   - Street furniture
   - Amenities
   - Landscaping
6. Operation and maintenance
   - Cleaning
   - Gardening
   - Maintenance and repairs
   - Lighting
   - Security
   - Taxes
   - Insurance

CHAPTER 8 - HORIZONTAL SEPARATION - PEDESTRIAN PRIORITY ZONES

Horizontal separation of pedestrians and vehicles improves pedestrian safety by reducing conflicts between people and vehicles and by selectively reducing traffic volumes and speeds. Separation techniques include pedestrian malls, auto restricted zones (ARZs) in central business districts or residential areas, and temporary street closings for play streets, school access, or for special events. Pedestrian malls have been primarily promoted in small and medium sized cities to stabilize downtown business activity and property values, and in some cities, as a means of locally competing with regional shopping malls. Auto restricted zones (ARZs) in larger cities, which can incorporate pedestrian malls, may be part of a comprehensive transportation systems management plan to reduce vehicle miles travelled within a central business district, reduce air and noise pollution, promote public transportation and improve the urban environment.

The objectives of auto restricted zones in residential areas are to discourage nonessential traffic by controlling vehicular movement, volume and speed, and thereby improve neighborhood identity, social interaction, safety and security. Temporary street closings, where alternative traffic routing is possible, are a means of providing vehicle free areas during periods of increased or specialized pedestrian activity.

PEDESTRIAN MALL TYPES

Pedestrian malls are classified by the amount and type of vehicular activity allowed within the pedestrian priority area.[76] In the continuous or exclusive mall, only emergency services and small cleaning vehicles may be allowed on the pedestrian street, with truck deliveries and pick-ups relegated to off-hour periods, or rear alleyways where available. Interrupted malls allow vehicles on cross streets, but not within the mall itself. Transitways allow operation of transit buses or light rail vehicles, and emergency service vehicles on a narrow right-of-way within the mall space. Interrupted and transitway configurations, often in combination, are the most commonly applied form of pedestrian mall in the United States because of the minimum disruption of local vehicle circulation, public transit operations, emergency and commercial services.[77]

There have been a number of unsuccessful street malls, traceable mostly to a lack of complete commitment by all interests affected by the mall development, poor transportation and retail planning, and inadequate financing.[78] If the pedestrian mall is being implemented as a means to reverse downtown decay, as is the case in many United States examples, the timing of the project is essential to its success. If the project is implemented too late, when the major shopping facilities have already left, then the remaining facilities may be unable to reverse the trend. This occurred in Riverside, California where by the time the plans for a pedestrian area were announced, all but 1 department store had left the area and the vacancy rate had reached 16 percent. In Kalamazoo, Michigan, however, it was the vision and sense of timing of the local merchants that ensured a prompt recovery of the downtown area.

For urban street malls to be successful they must provide a viable and attractive alternative to regional shopping malls. This can be difficult when it is considered that street malls must necessarily be planned and designed around existing roadway configurations, traffic patterns, parking, retail mix, and other constraints. Street widths can be too wide, walking distances too long, and retail development poorly located to encourage the patterns and volume of pedestrian activity needed to support a successful urban mall.[79,80] The regional shopping mall, on the other hand, offers a climate controlled and attractively designed environment, plentiful nearby parking, concentrated retail exposure within short walking distances, freedom from exposure to vehicular conflicts and pollution, off-street truck facilities, and other advantages over the street mall. In order to succeed, the street mall must, therefore, capitalize on its primary advantage as an outdoor activity space by promoting parades, street fairs, bicycle and track races, antique car rallies, marching band competitions, concerts, and other similar public events to encourage pedestrian activity and establish an area identity.

Planning Considerations for Street Malls

The success or failure of an urban pedestrian mall is dependent upon many factors some of which are directly controlled during the planning process. Providing a rigid planning framework is not possible due to the physical layout and socio-economic composition of the proposed development site. Planning considerations are, therefore, presented as a series of concerns with references, where appropriate, to concepts that have both failed and succeeded.[81] The primary objectives of the pedestrian mall should be to reestablish or fortify an urban area's economic viability while simultaneously creating a social setting capable of responding to a variety of needs. The following considerations identify elements of planning essential to the effective realization of pedestrian malls.

Relationship of Mall to Central Area Development

Pedestrian malls succeed or fail according to their degree of accessibility either by public transit or by private automobile. The successful downtown Nicollet Mall in Minneapolis, Minnesota is open to buses that connect it to the metropolitan area and is also served by a number of multilevel parking structures connected to the mall through a network of "skyways". Local downtown merchants in Lake Charles, Louisiana, on the other hand, having already paid for an elaborate pedestrian mall, eliminated a provision that would have created improved parking facilities. The Lake Charles project ultimately suffered from a loss of patronage.

The success of a pedestrian zone is directly related to its ability to create a range of activities to suit a variety of users. Albany's government mall in New York State has suffered a loss of vitality because it is only able to attract patrons during lunch break hours and is practically deserted otherwise. A more balanced use of the area's resources over extended periods of time, a high level of urban vitality and an increased feeling of safety can be achieved by attracting a full spectrum of users through mixed use zoning.

Cooperation and Support

Progress in implementing the planned improvements can be much more rapid when commercial and public interests can be demonstrated to coincide. Many proposals meet opposition from shop owners who believe that their trade will suffer if vehicular access is restricted along their premises. Shop keepers are often resistive to the mall concept until they are made aware of the potential benefits. It is important to obtain the cooperation of commercial interests at the initial planning stages in order to ensure viability of the proposals.

Community involvement can often be generated by launching instant beautification campaigns in order to project a new image for the main downtown area to be redeveloped. Vacancies can also be temporarily eliminated by providing store front space at nominal rents to service oriented, public interest organizations or businesses likely to increase the level of urban viability in the area. Similarly, clean-up campaigns, the elimination of signs of vandalism and neglect, wall paintings and the introduction of landscaping elements can prove helpful in generating hope and enthusiasm for the downtown challenge. Eliciting public support during the course of the pedestrian mall development is important in guaranteeing the success of the mall. The creation of a pedestrian mall affects a wide range of user groups whose participation is vital. The interest groups should be consulted and involved during the early planning stages to project implementation. The proposed Madison Mall in New York City was rejected by the urban community which perceived the mall as an example of authoritarian planning imposed against their wishes and paid for with their own tax money.

Existing Vehicle Traffic Patterns

Some cities have radically altered circulation patterns in order to decrease traffic congestion and redistribute traffic flow in the area of the pedestrian mall. This can be accomplished by introducing left hand turns, limiting access to certain categories of vehicles, redesigning intersections and retiming traffic signals.

Public Transit Services

Most cities with successful pedestrian malls have introduced policies that encourage the use of public transport. The success of these policies has varied depending on the extent of traffic congestion and the efficiency of the public transportation system. As always, the public transit should be inexpensive, fast, comfortable, safe and enjoyable to ride. The successful public transit system in Seattle, Washington offers what is termed "magic carpet" service that is open to everyone both day and night. Other tactics that can be successful are reserved lanes for public vehicles, low fares, provisions of special vehicles and better security. Those pedestrian malls that are built as transit ways can provide mobility to pedestrians by dropping them at major department stores or activity centers within the mall itself.

Parking Supply

Effective parking policies have a significant impact on both the regulation of parking density and the attractiveness of parking spaces to mall users. Some cities use different strategies to meet the demands of employees seeking day-long parking and visitors looking for short term parking. Some cities, such as Chicago, offer park and ride systems to allow downtown employees to park their cars at the periphery of the city limit and ride to work via rapid transit or special buses. On street parking meters and multi-storied parking facilities at the edge of the pedestrian mall areas can charge time incremental rates to promote a quick turnover.

Mobility of Goods

Oppositions of many merchants to the ideal of pedestrian mall results from the problem of delivering merchandise to stores and making it possible for customers on foot to handle the purchases easily. One of the most common strategies has been to allow structural changes in the street pattern to make possible store deliveries from courtyards and alleys as well as using time restrictions on the use of pedestrian mall space by commercial trucks. Some downtown merchants have introduced free pushcarts in order to meet customer demand for assistance in delivering their goods to either the central transportation terminal or to where their car is parked. Other establishments that sell bulk goods, such as grocery stores, should be relocated to the periphery of the mall where ready access to parked vehicles is available.

Essential Services

Essential services such as emergency fire, police, medical, refuse removal, taxis, vehicle pick-up and drop-off, truck delivery and pick-up, and mall cleaning must also be considered. Provisions must be provided to allow emergency service vehicles to quickly access areas within the pedestrian mall. Problems are often encountered in that the effective width of the street is made smaller to encourage pedestrian movement and the placement of amenities, such as planters, within the street right-of-way. Additional amenities within the pedestrian mall such as canopies and covered ways will need to be sufficiently high in order to enable emergency vehicles to pass underneath. It is important, therefore, to consult with the appropriate emergency services at an early stage in the planning of the pedestrian mall. In addition to the fact that emergency vehicles will have to have access to the pedestrian mall at all times of the day, there are also certain types of businesses that also require vehicle access at all times. For example, a hotel located in the street to be made into a pedestrian mall will need to have continuous access for its viability. Similarly, security vehicles will need to reach banks and businesses located within the pedestrian mall.

Financial Considerations

Quality of design and durability of construction materials have proven to be essential elements in the success of pedestrian malls. A pedestrian mall in Trenton, New Jersey was constructed too cheaply and has suffered from early obsolesence and increased vandalism. Cheap, minimal attempts at beautification frequently result in an effect worse than if no treatment was imposed. Beautification treatments if not properly maintained, usually at a maintenance cost significantly higher than simple sidewalk cleaning and maintenance, can be unsightly and even hazardous. Poor housekeeping techniques can result in planters being used as depositories for trash resulting in an appearance of neglect.

The paving system for pedestrian malls must be constructed at a higher standard than used for ordinary sidewalks. This is required because the absence of the street delineation will result in emergency vehicles, service trucks and other heavy equipment using all portions of the paved surface. Simple sidewalk paving systems, which are intended to beautify the pedestrian mall, can become broken either through poor design or poor maintenance and thus become serious public liabilities.

Accessibility Needs

The walkway width and design requirements discussed in chapter 6 to provide access for wheelchair users and handicapped are applicable in design of pedestrian malls as well. Care must be taken that the paving system used does not provide impediments to the safe and easy movement of wheelchairs. Planters, benches and other amenities should be placed in a straight line to satisfy the expectancy of the visually impaired.

Design Considerations

The ideal pedestrian mall design occurs where there is a relatively narrow street right-of-way, preferrably less than 60 feet (18.3 m), with concentrated shopping and commercial land uses within the normally accepted walking distance limit of 1/4 mile (0.4 km) (5 minute walk), and larger traffic generators ("anchors") at opposite ends of the mall to encourage walking along the mall. Many successful European shopping streets have benefitted by the narrowness of the street right-of-way, a heritage of their medieval city design, and a concentration of retail activities.[82] Excessively wide streets dilute pedestrian activity, making a mall appear dull and uninteresting, and also reduces exposure to retail edges due to the increased sight distances.[83]

Longer malls in the United States, beyond 1/4 mile (0.4 km) in length, have typically used mini-buses or other means to reduce walking distances. Transport to and from parking and the street mall is an advantage, but transportation within the mall itself can have the disadvantage of discouraging walking and concomitant retail exposure. Similarly transitway configurations can reduce pedestrian activity if the location of transit stops is not carefully considered in relation to other land uses and their pedestrian trip generation potential. Transit routing in a loop construction with stops at the ends of a mall may prove to be a better strategy to encourage pedestrian activity within the mall, than a transitway with frequent stops along the mall.[84]

Amenities such as benches arranged in groups in small rest areas, local street maps and points of interest displays, programs of future events, transit stop enclosures and transit system information displays will improve the convenience and attractiveness of the mall. The Portland, Oregon transitway provides well-designed bus shelters along the mall incorporating comprehensive transit system maps, video displays of bus schedules, and the "Teleride" computer generated voice telephone information system to provide passengers with route, schedule, and other transit service information.[85]

Some successful street malls are located in areas such as historical sites where there is an established pattern of tourist and visitor activity.[86] When this pattern exists, it can be enhanced by design treatment of storefronts and street furniture in keeping with the "theme" of the site. Where this pattern does not exist, it is necessary to develop design and marketing strategies which will encourage downtown activities and use of the mall. The primary advantage of a street mall is the ability to conduct large-scale outdoor events. Event spaces for setting up concerts, grandstands, outdoor skating rinks, and etc., should be considered in the mall design. Larger scale events such as parades and bicycle races may not be feasible within the mall itself, but might occur on parallel streets with reviewing stand facilities in the mall.

Street furniture, paving treatments, and lighting are important design considerations.[87] In order to reduce clutter, street furniture elements should be of modular design incorporating several components in a single unit. Pavers are a popular surface treatment in malls, but the pavers must be placed on a substantial sub-base to avoid settlement or "frost-heaving" and dislodgement, which can result in tripping hazards. Since emergency vehicles require access to all parts of the pedestrian mall the paved areas need to be designed to take the weight of fire engines and allow them to move around easily. Level pavement surfaces are also necessary for wheelchair accessibility. Pedestrian oriented lighting, with control of overhead illumination so as not to overpower shop window lighting, is preferred to restore a more intimate and natural scale to the converted street. Landscaping should be carefully chosen, not only for appearance, but for maintenance and growing characteristics. Plants or trees that interrupt sight lines and potentially provide concealment can reduce perceived security and discourage pedestrian activity at night.

AUTO RESTRICTED ZONES (ARZ)

ARZs employ various traffic engineering and regulatory techniques to discourage nonessential vehicular activity within selected downtown areas or local neighborhoods. The techniques used to accomplish the diversion of traffic for the 2 areas may be similar, but the development objectives are somewhat different. The objectives of downtown ARZs, generally as part of a larger comprehensive transportation systems management (TSM) plan, are to reduce total VMT and resultant air and noise pollution, encourage the use of public transportation and high occupancy vehicles, enhance the esthetic design of street spaces, and promote walking trips by improving pedestrian safety and convenience. The neighborhood ARZ is a community sponsored program to improve area image, safety, and security, by reducing vehicle operating speeds and nonessential through traffic volumes by converting selected street spaces to other community uses.

The types of traffic controls that have been used to restrict vehicular activity are listed below, and partially illustrated in figure 57. Not all of these techniques presented in figure 57 are recommended or considered as good traffic engineering strategies. The use of any of these techniques must, therefore, be considered within the total context of the traffic control application.

Auto Diversion Traffic Controls

Traffic controls used in ARZ's can be classified into 4 categories: (1) geometric design features to control vehicle speed, (2) changes in traffic circulation patterns or roadway use to discourage through traffic, (3) traffic control devices, and (4) regulatory and enforcement practices. Permanent changes in roadway alignments, construction of medians to block through movements, concrete diverters, signalization, or other substantial installations should be carefully evaluated before implementation.[88] Changes in traffic circulation by means of 1-way street designations, temporary barriers, signs, or other purely operational strategies, can be instituted more quickly and altered at less expense based on experience with their effectiveness and public acceptance.

A listing of potential strategies within the 4 general control categories are as follows:

A. Geometric Design

- Serpentine roadway alignment.
- Sidewalk widening.

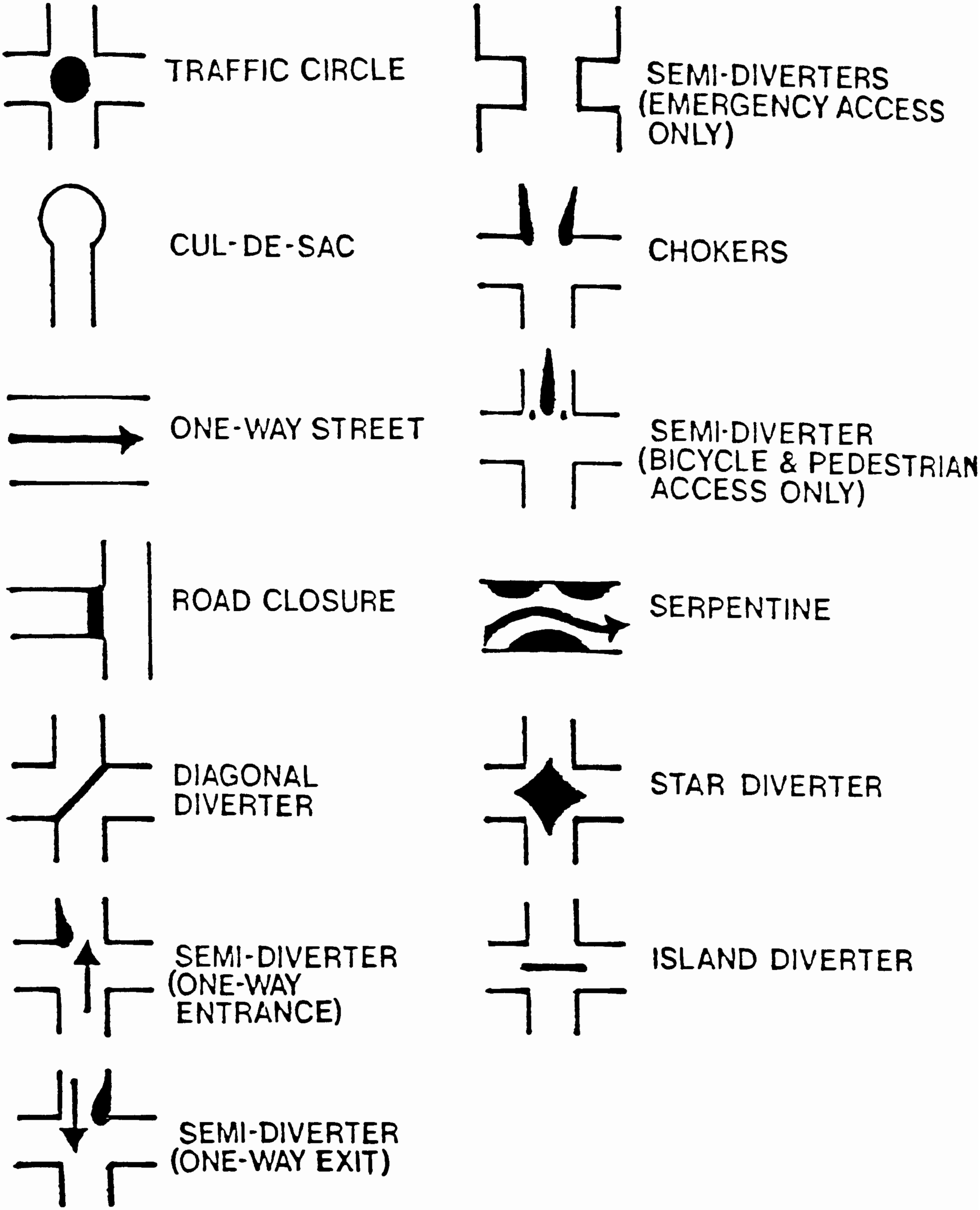


Figure 57. Conceptual auto diversion techniques.

- Islands, median barrier across intersection.
- Street narrowing ("chokers"), necked intersections.
- Rumble strips, speed humps.
- Traffic circles.
- Channelization.

B. Circulation and Roadway Use

- 1-way streets, 1-way entrances or exits to 2-way streets, 1-way streets back-to-back.
- Parking configurations, on-street to reduce lanes, speed.
- Cul-de-sacs, street closings, play streets.
- Temporary traffic diverters.
- Turn restrictions.

C. Traffic Control Devices

- Traffic signals.
- Stop signs.
- Speed limit and warning signs.

D. Regulatory and Enforcement

- Low speed limits.
- Strict enforcement, radar check points, security patrols.
- Truck size and weight restrictions.
- Turn restrictions.
- Regulate parking to reduce auto trips, promote transit.

Planning and design considerations for downtown ARZs are very similar to that of pedestrian malls, but on a larger scale, requiring a more comprehensive impact analysis. A large downtown ARZ could incorporate 1 or more pedestrian zones within the ARZ. Post application studies of downtown ARZs show that they attain most of their objectives such as reducing air and noise pollution, promoting walking trips and the use of public transportation but business interests have shown concern about reduced vehicular accessibility.

Strict residential traffic controls have been applied widely in Europe, particularly in the Netherlands, but have received a mixed reception in the United States. The European "Woonerf" (residential precinct), is designed for very slow operating speeds of 10-12 mi/h (15-20 kp/h) by using serpentine roadway alignments, plantings, restricted parking and play spaces in converted roadway sections to create a neighborhood enclave.[89] Experience in San Francisco where permanent neighborhood traffic diverters were installed, and subsequently had to be removed after residents protested, indicated that residents support the concept of reducing through traffic, but resented traffic controls that reduced their own neighborhood accessibility and convenience.[90] Part of the problem was that residents did not understand the use of traffic diverters and other techniques and their effects on an areawide traffic network. The San Francisco experience showed the need for a careful program of local support, educating residents on traffic control measure design and effects, trial installations, and final approval in the form of a local referendum requiring majority approval.

Different types of problems can occur where traffic controls are instituted on the boundaries between 2 political jurisdictions, such as occurred with the City of Cleveland, and the suburban community of Shaker Heights, Ohio. Traffic diverters in place for more than 10 years became a source of conflict with charges of racism and segregation being leveled at Shaker Heights, despite its record as an integrated community, because through traffic from Cleveland did not have direct access to it. Press accounts indicated that Cleveland intended to retaliate by installing diverters to purposely inconvenience Shaker Heights residents, but without any traffic engineering rationale. State courts and the U.S. Supreme Court have upheld the legality of residential traffic controls to limit nonessential through traffic where there is a well-supported traffic engineering basis.

In addition to the planning and design considerations listed for pedestrian malls, neighborhood traffic control programs require:

- Understanding of the effects that local traffic controls may have on other nearby neighborhoods and jurisdictions, in terms of traffic circulation, social and political considerations such as neighborhood blight, segregation.

- Documentation of impacts of control techniques on vehicle volumes and speeds, advantages and disadvantages of controls, in a form that is suitable for use by public officials and easily understood by affected community interests.

- Understanding of the representativeness of neighborhood associations, their role in neighborhood planning, reciprocal relationships with abutting associations.

- A step-by-step approval process, possibly involving trial installations, local referenda, and other techniques to assure complete understanding and acceptance of the control program.

TEMPORARY STREET CLOSINGS

Street closings for play streets, school access, or public events involve all the planning considerations noted for other types of ARZs, but on a much smaller scale, and because of their temporary nature, with fewer impacts and potential problems. The play street can be quickly implemented by installing temporary wooden barricades and traffic control signing for certain times of the day and periods of the year, such as summer vacation.[91] The advantages of play streets are that they are inexpensive compared to parks and other types of permanent recreational facilities, and will reduce the number of accidents due to dart-outs and similar play related accident risks. However, children's use of play streets and other recreational areas, and resulting reductions in play related vehicle accidents have been found to be localized within approximately a quarter mile radius of the play area. Disadvantages of play streets are disruption of vehicle circulation and parking, and the need of responsible adult supervision, preferrably on a well-organized volunteer basis.

Temporary street closings for school access can provide space for safer loading and unloading of school buses, street crossings, and other school related activities. Where bypass street routing is feasible, it can provide an alternative to low speed limit zones on school access streets, which typically show a poor level of driver compliance.

Street closings for public events such as street fairs or other similar large scale outdoor activities can provide safer environments for pedestrians who may be distracted by the activity and not attentive to vehicles. It also can facilitate vehicular movement which could be excessively delayed by heavy pedestrian volumes, which would exceed crosswalk capacity and signal timing, effectively blocking the intersection and restricting turning movements. The guidelines for planning the temporary street closings would require establishing patterns and estimated volumes of pedestrian and vehicular movement for the event, the location and amount of available parking, and the development of replacement street routings. Temporary street closings on a trial basis have been an effective means of evaluating the feasibility of installing a permanent street mall. A summary of the advantages and disadvantages of pedestrian malls and street closures is presented in appendix C, page 226.

CHAPTER 9 – PEDESTRIAN TRAFFIC CONTROL DEVICES AND PROCEDURES

Pedestrian safety and movement is affected by the actions of motorists in addition to those of the pedestrians themselves. Some traffic control devices, such as traffic signs and pavement markings, are directed toward motorists to inform them of possible pedestrian presence. Traffic control signs intended for pedestrian information and for increasing pedestrian safety fall into the same basic categories of regulatory warning and guide signs used for vehicle traffic. The Manual on Uniform Traffic and Control Devices (MUTCD) contains the design and placement criteria for traffic signs contained within the public right-of-way.[18] Information contained within the MUTCD is supplemented by the Traffic Control Devices Handbook.[51] The majority of States have adopted the information from these publications; supplementing with sign types and procedures that reflect area needs and accepted practice. Signs, pavement markings and locational criteria may vary between the individual State manuals and the MUTCD.

REGULATORY SIGNS

Regulatory signs are intended to inform highway users of traffic laws or regulations and indicate the applicability of legal requirements that would not otherwise be apparent. They are rectangular in shape, consisting of a black legend on a white background and should be reflectorized or illuminated (with a few exceptions). Regulatory signs, which are directed at pedestrians, include the following:[18]

- PEDESTRIANS PROHIBITED (R5-10c) signs are sometimes placed on interchange ramps to expressways or other locations where safe pedestrian facilities are not provided. The symbolic alternative (R9-3a) or the PEDESTRIANS AND BICYCLES PROHIBITED signs (R5-10b) may also be used.
- WALK ON LEFT FACING TRAFFIC (R9-1) can be used to encourage safer walking habits along rural highways which have no sidewalks or pedestrian pathways.
- NO HITCHHIKING (R9-4) or the symbolic alternative (R9-4a) may be used to prohibit people from standing near a roadway to solicit a ride.
- PEDESTRIAN CROSSING (R9-2) signs are used usually in urban areas to limit pedestrian crossings to safe locations. The CROSS ONLY AT CROSSWALKS (R9-2) sign may be used to discourage jaywalking along routes with clearly-defined crosswalks. The NO PEDESTRIAN CROSSING word sign (R9-3) or symbolic (R9-3a) sign may be used at hazardous crossing locations, such as in front of schools or

public buildings. As a supplement to either of the no crossing signs, the USE CROSSWALK (R9-3b) signs (with an arrow) may be used.

- Traffic signal signs directed at pedestrians include the CROSS ON GREEN LIGHT ONLY (R10-1), CROSS ON WALK SIGNAL ONLY (R10-2), PUSH BUTTON FOR GREEN LIGHT (R10-3), and PUSH BUTTON FOR WALK SIGNAL (R10-4).

In addition to the signs for pedestrians, as described above, many of the motorist regulatory signs can also have a direct or indirect impact on pedestrians. For example, stop signs, yield signs, left-turn prohibition signs, speed limit signs, and many others affect vehicle speed or movement and, thus, can influence the interaction of motorists and pedestrians. However, of all the motorist regulatory signs, the NO TURN ON RED sign is one of the few in which specific pedestrian-related warrants are given in the MUTCD. The right-turn-on-red issue is discussed in detail later in this chapter.

WARNING SIGNS

Warning signs are used to warn traffic of conditions that are hazardous or potentially hazardous. While such signs may be of considerable value at certain problem sites, their use should be kept to a minimum, since overuse breeds a general disrespect of traffic control signs.[51] All warning signs related to pedestrian needs are diamond-shaped with black letters and border on a yellow background. For signs that are relevant to periods of darkness, the background should be reflectorized, or illumination should be used. Signs should be placed to provide adequate time for drivers to react in time to perform any necessary maneuver. Placement guidelines based on vehicle speed and type of manuever required are given in section 2C-3 of the MUTCD. Warning signs directed at motorists for possible pedestrian conflicts include the following:[18]

- Pedestrian crossing sign (W11A-2), which is a symbolic sign of a pedestrian with crossing lines. It is used to advise motorists as to the specific point where pedestrians are likely to be crossing the street. Advance crossing signs (without the crossing lines) may be placed prior to the crossing locations to warn motorists of a crossing point ahead.

- Playground sign (W15-1) can only be used along a roadway in advance of an area where a potentially high concentration of young children may be playing. This sign is not intended to regulate vehicle speeds, but serves to warn motorists of locations where they may need to slow down when hazardous conditions exist (e.g., young children playing near the street).

- School warning signs (S sign series) include school crossing signs, school advance warning signs, bus stop ahead signs, and others. School-related traffic control measures are discussed in more detail in a later section.

GUIDE SIGNS

Guide signs are intended to direct vehicle operators to frequent destinations, such as cities, towns, rivers, parks, historical sites, and to provide travel information. Guide signs may also be used to direct pedestrians to bus stops, sidewalks, walkways, hiking trails, overpasses and other facilities. In most cases, guide signs on conventional (i.e., non-freeways) roads and streets have a white message on a green background. [18]

Criteria for Sign Placement

Little information exists in the literature on the effectiveness of specific signs on accidents and pedestrian movement under various conditions. This is probably due to the relatively small influence of a single sign on pedestrian and motorist behavior compared with all of the other roadway and environmental factors (e.g., road width, sight distance, other traffic control devices, weather conditions, mix of drivers and vehicles, and others). Also, some studies have shown that many signs are not seen or understood, and many are ignored, particularly when overused or unnecessary.

The decision on where to install specific signs must be largely a matter of judgement based on a careful review of site conditions. Follow-up observations of motorist and pedestrian behavior (and/or related accidents) can provide insights as to the effect of certain signs and conditions when they are most effective or least effective. A 1988 study conducted for the Transportation Research Board summarized experiences of 48 State and local highway agencies on conditions where regulatory and warning signs were most and least effective.[29] This summary is provided in appendix C, pages 227 and 228 along with advantages and disadvantages of using such signs.[27]

One of the major benefits of sign uniformity in shape and color is that motorists recognize and interpret the sign message with minimal effort. Traffic signs which do not conform with the size, shape and color of similar purpose signs create confusion and do not effectively convey their intended message. Similarily signs with nonuniform messages, such as CAUTION - CHILDREN AT PLAY or SLOW - CHILDREN, should not be permitted on any roadway at any time. These signs convey the unintended message that it is permissible for children to play on the roadway. This impression is contrary to efforts intended to point out that children should not play on or near the road, street or alley, no matter how remote or safe the facility may appear. Sign removal should carry a high priority when the signs are nonstandard or obsolete.

SIGNALIZATION

Various types of signals can have an effect on pedestrian safety and movement, including the following:[29]

- Traffic signals (with various timing options, turn phasing, etc.).
- Pedestrian signals (i.e., WALK/DONT WALK or symbolic signals) with various timing options.
- Push-button actuation of traffic and/or pedestrian signals.

Traffic Signals

The purpose of traffic signals is to assign the right-of-way to vehicular and pedestrian traffic. When properly used, traffic signals can have many benefits, including the interruption of heavy volumes of motor vehicles to permit pedestrians and other traffic to cross. When unwarranted or improperly used, however, traffic signals can result in excessive delay (for motorists and/or pedestrians), signal disobedience and an increase in certain accident types. New traffic signal installations have been found to often result in increased numbers of rear-end and total accidents with an accompanying reduction in more severe right-angle accidents. The effect of traffic signal installations on pedestrian safety is somewhat unclear. A study of new traffic signals at 152 intersections in Cincinnati, Ohio, determined that pedestrian accidents decreased at 32 sites, increased at 30 sites, and had no significant change at 90 sites. [92] The different locational characteristics of the sites may have been an important factor in the effects of the signals.

Although many traffic signals include only the green, yellow and red signal faces, a variety of lenses in signal faces may be used, depending on needed signal phasing. Studies have suggested, however, that highly-complex, multi-phase signals often result in confusion and hazardous situations for pedestrians.

The MUTCD (Part 4C) provides 11 separate warrants for the installation of traffic signals. These include the following:[18]

- Warrant 1 - Minimum vehicular volume.
- Warrant 2 - Interruption of continuous traffic.
- Warrant 3 - Minimum pedestrian volume.
- Warrant 4 - School crossings.
- Warrant 5 - Progressive movement.
- Warrant 6 - Accident experience.
- Warrant 7 - Systems.
- Warrant 8 - Combination of warrants.
- Warrant 9 - Four-hour volumes.
- Warrant 10 - Peak-hour delay.
- Warrant 11 - Peak-hour volume.

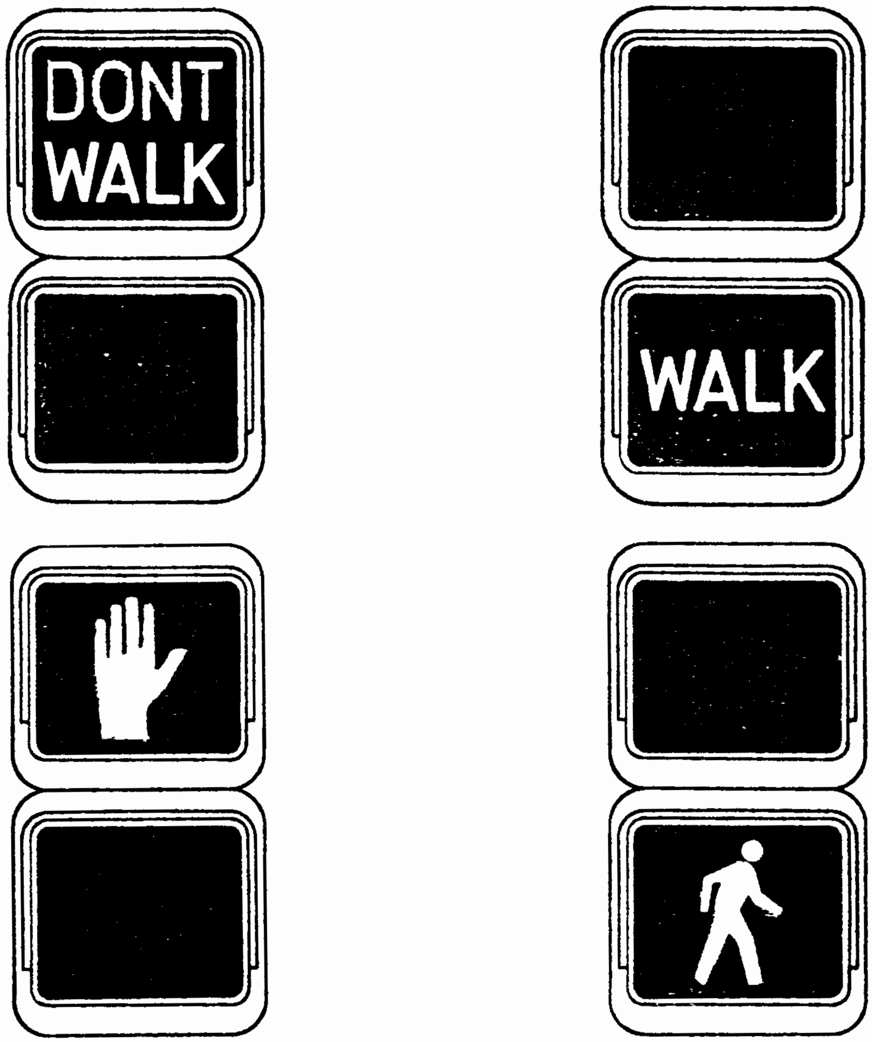
Warrant numbers 3 and 4 directly relate to pedestrians, although warrant number 6 also makes some reference to pedestrian considerations. Studies have shown that only a small percentage of new traffic signals have been installed based primarily on pedestrian considerations. However, recent revisions in the minimum pedestrian warrant are expected to result in easier justification of traffic signals based on pedestrian considerations.

Revisions to the minimum pedestrian volume warrant state that a traffic signal may be warranted when the pedestrian volume crossing the major street at an intersection or mid-block location during an average day is: 1) 100 or more for each of any 4 hours; or 2) 190 or more during any 1 hour. These volume requirements can be reduced as much as 50 percent when the predominant crossing speed is below 3.5 feet per second (1.1 mps). In conjunction with these volumes there shall be less than 60 gaps per hour, in the traffic stream, of adequate length for pedestrians to cross during the same period. The revised warrant 3 should be investigated in its entirety to ensure its proper application to the location being analyzed. [18]

Pedestrian Signals

Indications. Pedestrian signals include WALK/DONT WALK or symbolic (i.e., man/hand) indications which are installed at some locations in conjunction with traffic signals to convey the crossing interval to pedestrians (figure 58). Steady DONT WALK (or steady display of the open hand) indicates the interval when pedestrians should not be in the roadway in the direction of the signal indication. The flashing DONT WALK (or flash-

Single Section with Cut-out Letters



Two Section Type

Figure 58. Pedestrian signal face designs. (Source: [18], p. 4D-3)

ing hand message) means that pedestrians should not start crossing the street in the direction of that message but should finish crossing if they are already in the street. A WALK signal message means that pedestrians may cross in the direction of the indication.[18]

In some cities, a flashing WALK is used at selected sites to warn pedestrians to watch for turning vehicles, while a steady walk is used at sites where no turning vehicles are allowed (e.g., crosswalks on the intersection approach legs of 1-way streets). However, most cities use WALK indications only in the steady mode during crossing intervals. Previous studies have shown a general lack of pedestrian understanding of the flashing WALK [93,94], and the flashing WALK will be discontinued on December 31, 1990 in the United States. The symbolic pedestrian signals have been determined to be an acceptable substitute for the verbal WALK/DONT WALK signal indications.[95] Some State agencies are replacing the verbal pedestrian traffic signals with 12 inch (30.5 cm) symbolic signals during their upgrading projects.

Applications. The MUTCD specifi s that pedestrian signal indications shall be installed at traffic signal locations under the following conditions:[18]

- When a traffic signal is installed under the Pedestrian Volume or School Crossing warrant.
- When an exclusive interval or phase is provided or made available for pedestrian movement in 1 or more directions, with all conflicting vehicular movements being stopped.
- Where vehicular indications are not visible to pedestrians such as on 1-way streets, at "T" intersections; or when the vehicular indications are in a position which would not adequately serve pedestrians.
- At established school crossings at intersections signalized under any warrant.

The MUTCD further states that pedestrian signals may be installed under any of the following conditions:[18]

- When any volume of pedestrian activity requires use of a pedestrian clearance interval to minimize vehicle-pedestrian conflicts or when it is necessary to assist pedestrians in making a safe crossing.
- When multi-phasing indications (as with split-phase timing) would tend to confuse pedestrians guided only by vehicle signal indications.

- When pedestrians cross part of the street, to or from an island, during a particular interval (where they should not be permitted to cross another part of that street during any part of the same interval).

The first criterion of the discretionary conditions (i.e., where pedestrian-vehicle conflicts need to be minimized) is sufficiently vague that it could be used to justify pedestrian signals at almost any signalized intersection where 1 or more pedestrians cross; or at practically no locations, depending on its interpretation. Due to the liberal interpretation of the pedestrian conflict criteria, some cities have adopted a policy of installing pedestrian signals at nearly every signalized location. Since they are expensive to install and maintain the installation of pedestrian signals should be supported by appropriate traffic engineering studies. Information on conducting pedestrian conflict studies is contained in chapters 3 and 4 of this handbook.

Design Requirements. The WALK/DONT WALK pedestrian signal indications should be rectangular in shape and legible to pedestrians at distances from 10 feet (3.0 m) to the full width of the crossing area. The WALK (or symbolic man) indication should be white and the DONT WALK (or hand) message should be Portland Orange. For crossings of 60 feet (18.3 m) or less, from the near curb to the pedestrian indication, letters of at least 3 inches (7.6 cm) or symbols of at least 6 inches (15.2 cm) should be used. For distances of more than 60 feet (18.3 m), 4 1/2 inch (11.4 cm) letters or 9 inch (22.9 cm) symbols are needed. Other design requirements for pedestrian signals are given in Section 4D-4 of the MUTCD.[18]

Signal Timing. Pedestrian signals are timed according to one of the following options:[18,29,94,95]

- Standard (or concurrent) Timing: Pedestrians are given a WALK indication to cross parallel (concurrently) with moving traffic. During the green signal phase, and after yielding to pedestrians, motorists are allowed to turn right (or left at many intersections) across the path of pedestrians. The great majority of pedestrian signals are timed in this manner.

- Early Release Timing: This option releases pedestrians earlier than parallel traffic movements to allow pedestrians to establishing their presence in the crosswalk before parallel and turning vehicles are released. The intent is that turning vehicles will notice pedestrians in the crosswalk and wait for a gap in pedestrian flow before turning.

- Late Release Timing: Pedestrians are held for the first part of the interval and then given the WALK interval late after vehicles have had a chance to make their turns. As with early release, the late release interval is intended to also reduce the interaction between crossing pedestrians and turning vehicles.

- Exclusive Timing: This timing option involves providing an exclusive interval for pedestrians to cross while all motorists are faced with red signals. Scramble or Barnes Dance timing is a form of exclusive timing where pedestrians are permitted to cross an intersection diagonally as well as in other directions.

A 1985 study evaluated the effect of pedestrian signals and various timing options on pedestrian accidents. The study performed an analysis of pedestrian accidents in conjunction with traffic and pedestrian volumes, geometrics, and signal data collected at 1,297 signalized intersections in 15 United States cities. Overall, no significant effect on pedestrian accidents was found due to the presence of standard-timed pedestrian signals when compared to intersections with no pedestrian signals. However, exclusive timing intervals (including scramble timing) were associated with significantly lower pedestrian accidents when compared to sites with standard timing and sites with no pedestrian signals. An insufficient sample of early or late release sites were available for analysis.[94]

There are certain intersections where pedestrian signals are needed to provide basic pedestrian protection. Standard timing can be harmful, however, if pedestrians incorrectly believe the WALK signal provides a protected walk interval. While scramble timing appears to offer improved pedestrian safety compared to standard timing, scramble timing increases both motorist and pedestrian delay. Thus, scramble timing may be most practical operationally at intersections in downtown areas with relatively low traffic volumes and high pedestrian volumes. Denver, Colorado, is 1 of the few large cities which still maintains a substantial number of scramble timed intersections. A study on the delay and pedestrian compliance at intersections concluded that:[96]

- Standard timing nearly always results in the minimum total intersection delay.

- Early release of pedestrians increases overall delay at an intersection.

- Late release of pedestrians should only be used at locations where there is a need to reduce a capacity problem in the right-turn lane (or left-turn lane on a 1-way street).

- Scramble timing can be effective in improving pedestrian safety if pedestrian compliance is good. Pedestrian delay is greatly increased using scramble timing compared to standard timing.

Pedestrian Push Button: At locations where pedestrian signals are not warranted on a full-time basis, use of pedestrian-actuated signals (i.e., push-buttons) may be desirable. Pedestrian push-buttons are appropriate where occasional pedestrian movements occur and adequate opportunity for pedestrians to cross does not exist.[18] Where no pedestrian signals are present, actuation of the push-buttons may be used to extend the green phase to allow pedestrians ample crossing time. Push-buttons may also be used with pedestrian signals, where activation of the buttons may result in a quicker WALK interval with sufficient WALK time for safe pedestrian crossing.

Pedestrian push-buttons should be mounted 3 1/2 to 4 feet (1.1 to 1.2 m) above the sidewalk and placed in a conspicuous, convenient location.[18] Signs such as PUSH BUTTON FOR WALK SIGNAL are needed in conjunction with the actuation devices to explain their meaning and use. When 2 actuation devices are placed close together for crossings oriented in different directions, it is important to indicate which crosswalk signal is controlled by each pushbutton (e.g., PUSH BUTTON TO CROSS SECOND AVENUE). Push-button actuation devices may also be needed on medians and refuge islands where pedestrians may be stranded.[18]

Pedestrian safety can be enhanced by the installation of push-buttons only if they are correctly installed and maintained. Many agencies resist installing pedestrian push-buttons because their experience indicates that they are either not used or used improperly by pranksters wishing to disrupt traffic flow. Problems that have been identified contributing to pedestrian push-button nonuse are:[94]

- Many push-button devices are hidden from pedestrian view or out of reach (such as on telephone poles 10 to 20 feet (3.0 to 6.1 m) from the crosswalk).

- Signing is often confusing and doesn't indicate which push-button corresponds to each crosswalk.

- At many locations, timing requires that pedestrians wait 1 minute or more after the buttons are pushed before the WALK interval is given. Often, pedestrians would push the button and cross the street before the WALK interval. Then, traffic would be stopped late in the cycle when no pedestrians were present.

- Many push-buttons were inoperative or operated only during off-peak hours (and pedestrians were not instructed that the push-buttons only worked during certain periods of the day).

The effectiveness of pedestrian push-buttons can be improved by adhering to the following recommendations:[94]

- Repair and maintain the push-buttons where necessary and make them more responsive to pedestrians (i.e., time them to provide a WALK interval to pedestrians within 30 seconds after the buttons are pushed).

- Provide signs with push-buttons to explain specific streets to be crossed when activated.

- Provide illuminated push-buttons similar to those used with elevators to indicate when the actuation device is operational. This reassures the pedestrian that their signal call is received by the controller.

- Provide a sign specifying operational times at those pedestrian actuation devices designed to only operate for specific times of the day.

Details are given in appendix C, pages 229 and 230, on the effectiveness of various signalization options and their inherent advantages and disadvantages.[29,27]

PAVEMENT MARKINGS

Pavement markings are used primarily to supplement regulations or warnings of traffic signs, signals, or other traffic controls. For motor vehicles, some common pavement markings are centerlines, lane lines, no passing zone markings, and pavement edgelines. Examples of pavement markings which relate to pedestrians as well as motorists include:

- Painted crosswalks (which are discussed in detail in chapter 6).

- Stop lines

- Pavement word and symbol markings (e.g., STOP AHEAD).

Stop Lines

Stop lines (or stop bars) are solid white lines which indicate the point at which motorists are required to stop. Stop lines are usually 12 to 24 inches (30.5 to 61.0 cm) in width and should extend across all approach lanes. When used in conjunction with painted crosswalks they should be parallel to and 4 feet (1.2 m) in advance of the crosswalks. Where no marked crosswalk exists, stop lines should be located between 4 and 30 feet (1.2 and 9.1 m) from the edge of the intersecting street.[18]

The placement of, and motorist compliance to, stop lines is important in keeping the crosswalks clear of vehicles and in permitting unobstructed view between motorists and pedestrians. The placement of stop lines is varied by some agencies in an attempt to minimize certain types of pedestrian accidents. For example, the State of North Carolina often places stop lines 20 to 30 feet (6.1 to 9.1 m) from the crosswalk to provide an unobstructed view between pedestrians in the crosswalk and vehicles in all approaching lines.[97] Setting the stop bar back tends to reduce the probability of pedestrians being struck by a vehicle whose view was obscured by a stopped vehicle in an adjacent lane as illustrated in figure 59. The disdavantage to this stop bar placement is that it increases the visibility trianqle possiblv resulting in sight restrictions to cross street traffic. It is often necessary, therefore, to prohibit right turns on red if the stop bars are set back a distance of 20 to 30 feet (6.1 to 9.1 m)

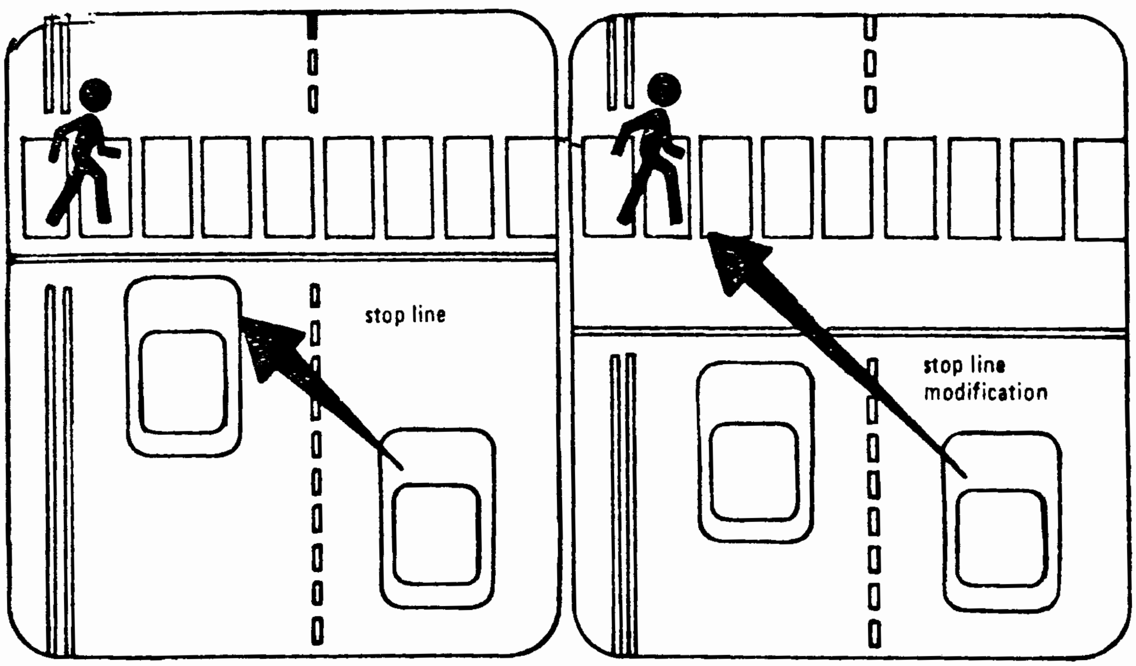


Figure 59. Example of stop line modification to improve motorist view of pedestrian.

Offset (or angled) stop lines can also be used to provide an unobstructed view between crosswalk pedestrians and motorists stopped at multi-lane approaches. In such cases, the stop line in the right lane is located 4 to 6 feet (1.2 to 1.8 m) in front of the stop line in the adjacent lanes. Thus, a vehicle stopped at a red light in the right-hand lane has a clear view of pedestrians and vehicles to the driver's left. This scheme provides for safer right-turn-on-red (RTOR) maneuvers than the setback scheme.

Pavement Word Markings

Word and symbolic messages may also be placed on the roadway lanes to convey a message to motorists. Such markings should be white in color and be limited to no more than 3 lines of information. Examples of motor- ist pavement messages that may directly impact pedestrians include: PED X-ING, SCHOOL X-ING, and SCHOOL. Other such pavement messages such as STOP, 25 MPH, STOP AHEAD, SIGNAL AHEAD and others can also affect pedestrians, since they can reinforce the need for motorists to obey speed and stopping requirements where pedestrians may be crossing. Some agencies also use pavement markings directed at the pedestrian. These markings are usually placed in the crosswalk or on the sidewalk, approximately 2 to 3 feet (0.6 to 0.9 m) from the curb, facing the direction of pedestrian travel (i.e., parallel to vehicle travel). These markings can convey the messages CAUTION, LOOK BOTH WAYS, or other appropriate verbal or symbolic messages.

VEHICULAR CONTROL MEASURES THAT CAUSE PROBLEMS FOR PEDESTRIANS

Roadway geometric and traffic control strategies installed to increase vehicle flow and safety can have an adverse impact on pedestrian movement and safety. Frequently roadway and operational improvements will be implemented without proper consideration to pedestrian provisions. When this occurs it is often necessary to go back to the improvement site and institute remedial countermeasures. This often results in a system that is not as efficient or safe as could be realized if the conflicting needs of the vehicular and pedestrian traffic were considered during the initial planning stages. Vehicular traffic control measures which frequently produce effects to pedestrians include:[29]

- Permitting right-turn-on-red.
- The addition of protected left-turn traffic signal phasing, especially at locations with high volumes of pedestrians and left-turning motorists or pedestrians which have trouble seeing the signals.
- The absence of adequate traffic control in construction areas.
- Complex or inadequate traffic signal phasing (such as 8-phase signals) without the use of pedestrian signals.
- Roadways having 2-way, center left-turn lanes.

- Large intersection turning radii (which allows vehicles to make right turns at a fairly high rate of speed and thus, endanger pedestrians attempting to cross the street).

- Stop signs and yield signs (which can give pedestrians a false sense of security).

- Channelization at intersections which allows for free-flow of right-turn vehicles.

- Wide (i.e., multi-lane) highways that create greatly increased crossing time for pedestrians, particularly with narrow or no safety islands.

- Traffic signals with insuffient walking time for pedestrians (particularly on high-speed suburban streets).

An easy list of solutions that will correct potential pedestrian problems resulting from vehicular control measures does not exist. All feasible roadway treatments should be considered at each site (including the do-nothing option). Information is given throughout this handbook on many of those potential solutions. For some types of pedestrian problems, however, no engineering treatments are appropriate requiring rather educational and/or police enforcement programs.

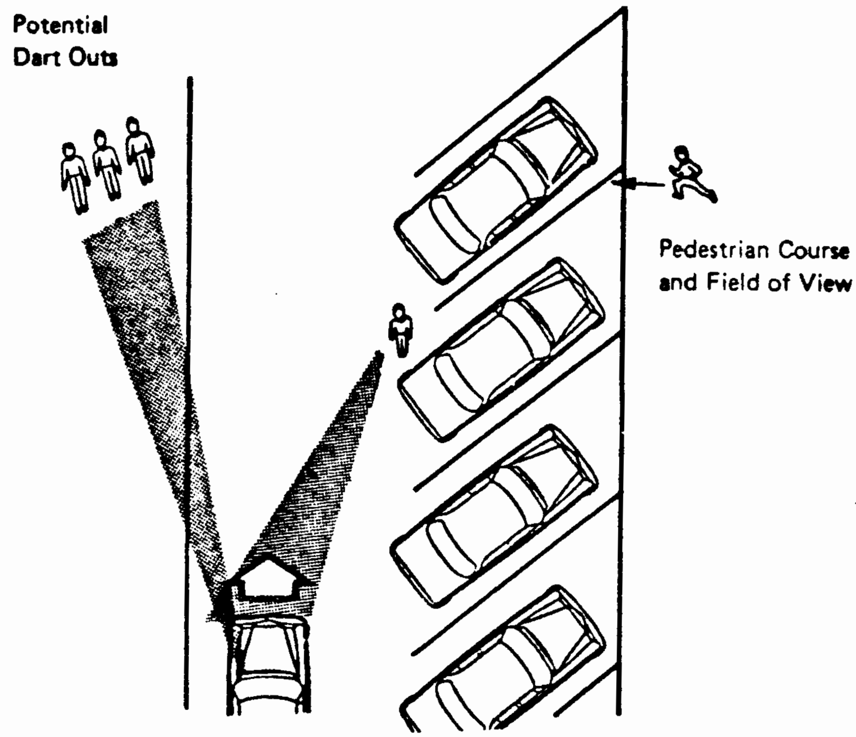
CURB PARKING REGULATIONS

Approximately 39 percent of urban pedestrian accidents involve pedestrians who run into the street at midblock locations.[35] One of the factors which contributes to such accidents is the presence of visual obstructions between motorists and pedestrians, such as on-street parking. This type of pedestrian accident may be reduced at many locations through curb parking prohibition.

Parking should preferrably be prohibited at least 100 feet (30.5 m) in advance of a crosswalk or intersection for roads with vehicle speeds of 35 mi/h (56 km/h) or greater to increase vehicle stopping sight distances. [98] Nearby business owners are, however, strongly opposed to curb parking restrictions. It is interesting to note, especially in areas without metered parking, that a large number of curb parking spaces are usually occupied by the merchant's employees not customers. Also, in cases where curb parking is prohibited, vehicle speeds sometimes increase, which can be harmful to pedestrian safety.[29]

Parking Configuration

Angle parking (sometimes called diagonal parking) can reduce the number of pedestrians darting into the street from between parked cars (see figure 60).[27] Angle parking improves pedestrian and motorist fields of vision, causes pedestrians to act more cautiously, and results in reduced vehicle speeds.[99] The disadvantages associated with angle parking is that it takes up space from travel lanes and increases the potential of accidents from vehicles backing out of the parking spaces. Angle parking is more commonly used in conjunction with 1-way streets than with 2-way streets.[27] Appendix C, page 231, summarizes the advantages and disadvantages of curb parking regulations and lists conditions when they are beneficial and of least value.



One Way Street with Diagonal Parking

Figure 60. Illustration of angle parking.

SCHOOL ZONE TREATMENTS

Young pedestrians, under 15 years of age, experience an accident involvement rate which is twice that of any other age group. The youngest students of 5 to 8 years old are particularly over-involved in school walking trip accidents.[100] Some of the characteristics of young children which are related to this high incidence of pedestrian accidents include: [51,100]

- Inattentive and careless behavior in crossing streets (children from 6 to 16 years old).

- Periperhal vision is not as well developed in children as with adults.

- Small physical size of children under 9 years old (average height of 3.6 feet (1.1 m)), which presents problems in seeing oncoming vehicles from beyond parked cars and makes them more difficult for drivers to see.

Some of the behavior patterns of young pedestrians with respect to various traffic controls include the following:[51,98]

- Crosswalk use: At uncontrolled intersections, about 66 percent of children will use marked crosswalks, while 83.7 percent use them at signalized intersections. Virtually all children will use marked crosswalks at locations when crossing guards are present.

- Traffic signals: Where crossing guards are present activating the traffic signal, nearly all children will cross signalized intersections on the green phase. Only about 65.5 percent cross on the green without crossing guards. More than half of children will cross during gaps in traffic without activating pedestrian pushbuttons at sites where no crossing guards are present.

- Grade separated crossings: Children of ages 5 to 16 will commonly use overpasses or underpasses when crossing guards are nearby or when fences are present to channel pedestrians to the crossing locations.

The majority of motorists do not reduce vehicle speed in school zones unless they perceive a potential danger such as activated flashing beacons, presence of police or crossing guards or clearly visible children.

It is not uncommon for local traffic engineers to receive demands for additional signs, signals and other traffic controls at school zones by parents, teachers, and other citizens. The selection of appropriate school zone traffic control is dependent upon traffic characteristics, school location and age of the pupils. In general, the most effective method of school zone traffic controls are well-trained, adult, crossing guards. Inappropriate use of traffic control devices can increase pedestrian accidents.[51] The following is a discussion of signs, signals, markings, crossing guards, and other measures which may affect pedestrian safety in school zones.

School Zone Signing

Several types of signs are given in the MUTCD for use at selected school zone locations, including the following:[18]

- School advance sign (S1-1) should be installed between 150 and 700 feet in advance of a school ground or a school crossing.
- School crossing sign (S2-1) is used at established school crossings (including signalized intersections but not stop sign locations).
- School bus stop ahead sign (S3-1) for use in advance of locations where a school bus, when stopped to pick up or let off passengers, is not visible by motorists for a distance of 500 feet.
- School speed limit signs (S4-1, S4-2, S4-3, S4-4) are used to indicate a reduced speed limit for a school area (e.g., SCHOOL SPEED LIMIT 20 WHEN FLASHING).
- Parking and stopping signs (R-7 series) include signs which limit vehicles stopping near school areas, such as NO PARKING 8:00 A.M. TO 5:00 P.M. SCHOOL DAYS ONLY, 5 MINUTE LOADING 8:00 A.M. TO 5:00 P.M. SCHOOL DAYS ONLY, and others.

The presence of school signs alone, even with activated flashers and illuminated 25 mi/h (40 km/h) speed limits, have been found to be ineffective in reducing speed to 25 mi/h (40 km/h).[101] The greatest amount of speed compliance occurs at sites with adult crossing guards and police enforcement. It is recommended to strive for school zone speeds of 35 mi/h (56 km/h), in lieu of 25 mi/h (40 km/h) at locations with high posted speed limits (i.e., 55 mi/h (88 km/h)). The higher school zone speed will reduce the potential for rearend accidents due to decreased speed uniformity and may result in higher motorist compliance.[101] A recent study of motorist and pedestrian behavior at school zones revealed the following: [100]

- The effectiveness of school crossing signs are improved when used in conjunction with the regulatory speed limit flashing signs.
- Regulatory signs and flashers are generally more effective in obtaining speed compliance in urban and suburban areas than in rural areas.
- School zone speeds are higher when school buildings are set back a greater distance from the road.
- The presence of adult crossing guards results in greater speed reductions.
- The regulatory sign with flasher alone does not create gaps in traffic suitable for children to cross safely.
- School zone speed limits most commonly used in various jurisdictions are 15 mi/h (25 km/h), 20 mi/h (30 km/h), or 25 mi/h (40 km/h).

School Zone Signals

At school zone crossings, standard traffic control signals are sometimes needed to create adequate gaps in vehicular traffic to allow children to cross safely. Signal installations at school crossing locations have several advantages over police supervision or crossing guards, in that they can be coordinated with adjacent signals to minimize traffic disruption and have relatively low operating costs. The disadvantages of signals are their high initial costs and periodic maintenance need. Signals also require supplemental use of adult crossing guards to provide adequate safety for children.[18]

Traffic signals are warranted at established school crossing locations when the number of adequate gaps in the traffic stream during school crossing periods is less than the number of minutes in that same period. For example, for a crossing period of 25 minutes (e.g., 8:00 to 8:25 A.M.), there must be less than 25 adequate gaps in traffic for pedestrians to cross to warrant a traffic signal. Information on determining the sufficiency of traffic gaps for pedestrian crossing needs is presented in chapter 3 of this handbook. Where new signals are installed at mid-block school crossings, police supervision and/or enforcement should also be used initially. At school crossing locations where traffic signals meet the minimum traffic gap warrant only, the MUTCD specifies that:[18]

- Pedestrian signals shall be provided at each school crossing.
- School advance sign and a school crossing sign may be used.
- The signal should be traffic actuated when used at an intersection.
- At non-intersection crossings, the traffic signal should have pedestrian push-button actuation, parking should be prohibited for 100 feet or more in advance of a crosswalk (and 20 feet beyond it), and standard school zone signing and pavement markings should be used.

Factors such as sight distance, accident history, vehicle speeds, age of children and other locational characteristics should be considered to determine the specific type of traffic control appropriate at each school crossing location.[51] Traffic signals, crossing guards, and police officers are all possible countermeasures. "Assistance" measures such as student patrols, signs, pavement markings, and sidewalks or roadway shoulders are also appropriate.[102]

School Zone Markings

Pavement markings in school zones include the following:[18]

- Crosswalk lines, which should be marked at all intersections on established routes to school where conflicts exist between vehicles and kindergarten or elementary children. They should also be used between intersections where children are allowed to cross and also to show the proper place to cross.

- Stop lines, are solid white lines (12 to 24 inches wide) (30.5 to 61.0 cm) which extend across all approach lanes and show the point where vehicles should stop. They may be used in conjunction with stop signs, traffic signals, or other legal requirements.

- Curb markings of white or yellow may be used to show locations where parking is restricted. They are commonly used in conjunction with NO PARKING signs.

- Word and symbol markings such as the SCHOOL message may be installed on the pavement to convey guidance, warning, or a regulation. Markings should be white in color and may be supplemented by signs.

School Zone Crossing Guards

School crossing supervision may include the use of adult guards (to supervise pedestrians and vehicles) or student patrols (to supervise pedestrians only). Adult guards are appropriate at locations where special problems make it necessary to help children safely cross the street. Section 7C-6 of the Traffic Control Devices Handbook provides examples of criteria which may be of value in determining where crossing guards are warranted.[51]

Other School Zone Traffic Control Measures

In addition to the traffic control measures discussed above, other measures which may be effective in improving pedestrian safety in school zones include:

- Educational programs to teach children safe habits for crossing streets and walking near roadways. Educational programs for the driving public may also be helpful.

- Police enforcement related to speed limits, parking regulations, drunk driving laws, sign and traffic signal violations, and other laws and ordinances.

- Construction of grade separated crossings at school crossings on high hazard streets.

- Construction of sidewalks and other pedestrian paths to connect residential neighborhoods with schools.

- Closer supervision of children near school areas.

- Use of retroreflective clothing and/or patches on children's clothing.

- Safe route to school plans, such as those used by the American Automobile Association.[102]

Many cities and towns around the United States strongly emphasize school zone safety. Examples of such cities include Erie, Pennslyvania; Cuyahoga Falls, Ohio; Seattle, Washington; Dallas, Texas; and San Diego, California. A description of the school and child safety programs in each of these towns is provided in appendix D, pages 237 to 243.[31]

BARRIERS

Approximately 40 percent of pedestrian deaths and injuries occur as a result of pedestrians crossing the street between intersections. Barriers represent a type of device which is intended to reduce mid-block accidents. Pedestrian barriers include fences, chains or other devices which are used to separate pedestrians from vehicular traffic. Some barriers are used to channel pedestrians to safe crossing locations (e.g., to overpasses or signalized crossings), while others are intended to prevent pedestrians from crossing the street. There are several types of pedestrian barriers, including:[27]

- Median Barriers, which usually are chain link fences separating opposing lanes of traffic to prevent pedestrians from crossing at midblock locations. This type of barrier may be added solely for pedestrian purposes, or may be incorporated with vehicle barriers (e.g., guardrail or concrete barriers). These are sometimes used on urban freeways.

- Sidewalk Barriers, which are located between the sidewalk and the street to prevent them from crossing at dangerous locations. They are also used to channel pedestrians to crosswalk locations. Sidewalk barriers are typically constructed of chain link fencing, pipe and chain, concrete planters, or hedges. Parking meter post barriers are chain sections about 3 feet high supported by parking meters.

- Roadside Barriers, generally refer to high chain link fencing which is installed along a freeway or other road to prevent pedestrians from crossing the highway.

Various types of barriers are also used at some locations to benefit pedestrians by rerouting or limiting vehicular traffic movements. For example, street closure barriers are sometimes used on a temporary or permanent basis to restrict motor vehicles in neighborhoods of high pedestrian activity (particularly young children). Traffic diversion barriers are sometimes installed within selected intersections to prevent certain through or turning movements.[27,29] These and other types of neighborhood traffic management strategies are discussed in more detail in chapter 8 of this handbook. A summary of the advantages of roadside pedestrian barriers and conditions which result in barriers being beneficial are presented in appendix C, pages 233 and 234.

While barriers may provide a beneficial effect for pedestrians at certain locations, there are also some potential problems from barriers. For example, when high barriers are placed along a roadway, stranded motorists may be forced to walk a considerable distance along high-speed or hazardous roads. A problem with rigid roadside barriers is that they provide a roadside obstacle to motor vehicles. There is also evidence that barriers near high schools or college campuses are of limited effectiveness, since students commonly maneuver over or under them.[29] Examples of barrier use for pedestrian safety include:[31]

- In Ada, Oklahoma, fences are used around school playgrounds to channel school children to underground passageways instead of crossing at street level.

- In Concord, California, partial barriers have been installed at midblock crosswalk locations in some residential areas to block children from running or riding bicycles or skateboards into the street. In addition, parking is prohibited for 20 to 30 feet on either side of the crosswalk at such locations to increase sight distance.

- Janesville, Wisconsin, blocks off 1 street during winter months to allow safe sledding on the hill.

- San Diego, California, has used pedestrian barriers extensively to channel pedestrians away from hazardous crossing legs of intersections to intersection legs with lower traffic and/or better sight distance. Where midblock crossing problems exist, median chain link fencing has also been used, often in conjunction with grade-separated crossings.

- In Seattle, Washington, pipe fences have been used to direct pedestrians to marked crosswalks and away from where a legal crosswalk is being permanently closed. Signs reading DO NOT CROSS HERE are used in conjunction with such fencing. In a few residential areas, raised medians (i.e., traffic diverters) have been constructed to connect diagonal corners of selected intersections, which forces vehicles to turn at these locations. The result of these vehicle diverters is reduced vehicle speeds and reduced volumes of through traffic in those neighborhoods. However, their use is limited due to objections by local residents.

RIGHT-TURN-ON-RED

Motorists in the United States currently have the option to make a right-turn-on-red (RTOR) maneuver at signalized intersections after they stop and yield the right-of-way to pedestrians and other traffic. Unless otherwise signed (i.e., NO TURN ON RED), RTOR is allowed nationwide, except for New York City, where RTOR is prohibited unless specifically allowed by sign (i.e, RIGHT TURN ALLOWED AFTER STOP). Some states also allow motorists to make a left-turn-on-red (LTOR) from a 1-way street onto another 1-way street, unless signed with a prohibition.[19,103]

The subject of RTOR has been controversial for many years. Supporters of RTOR claim that it has been successfully used in many western states for decades with significant savings in motorist time and fuel and with a minimal safety impact. Opponents of RTOR claim that it presents considerable danger to pedestrians, particularly to children, elderly, and handicapped people. There are also claims that the permissive RTOR rule (or Western rule) has bred motorist disregard for traffic signals, stop signs, and other traffic controls.[103]

Although there may never be total agreement on this subject, there is evidence to suggest that RTOR presents a problem to pedestrians at some locations. The typical RTOR pedestrian accidents involve motorists who stop at a red light, look to the left for approaching vehicles, and fail to see the pedestrian crossing at the driver's right. A recent study determined that 67 percent of pedestrians struck in RTOR accidents were crossing from the right compared to only 4 percent from the left as evidenced by figure 61.[104] A description of countermeasures which have the potential for reducing right-turn-on-red pedestrian accidents is provided in appendix E, pages 244 to 247.[103]

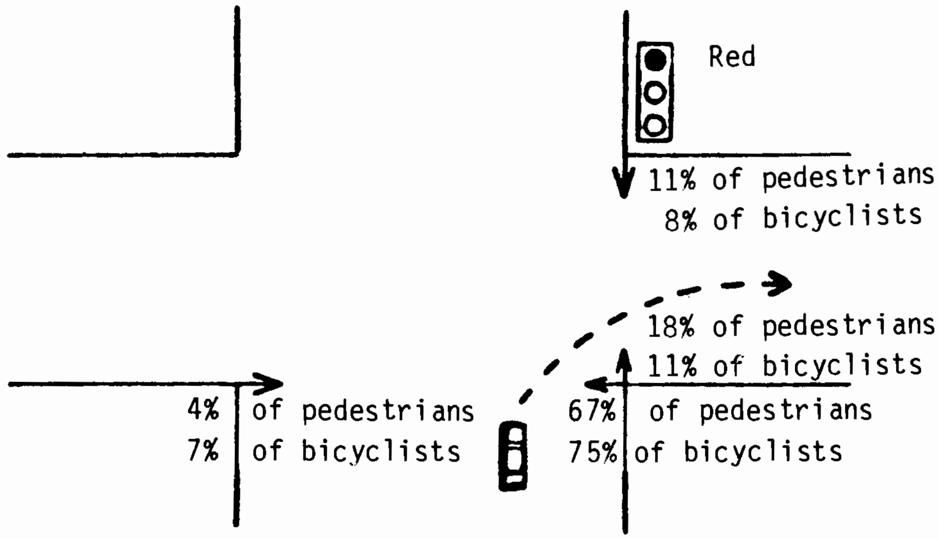


Figure 61. Directional movements of pedestrians and bicyclists involved in RTOR accidents.

TRAFFIC CONTROLS FOR THE HANDICAPPED

Handicapped people who experience greater than normal levels of risk to traffic accidents include:[54,104]

- Individuals with developmental restrictions based on their maturity and size.
- Wheelchair users.
- Individuals with leg and feet impairments who walk with special aids (i.e., crutches).
- Individuals with severe sign impairments (i.e., blind or partially blind).

Some older adults have one or more of these types of handicaps, so the traffic controls discussed herein also relate to areas with a substantial population of older adult pedestrians. Special facilities for handicapped pedestrians which have been used in the roadway environment include:[27, 29]

- Signal-related treatments, such as audible pedestrian signals in which horns, buzzers, bells, bird calls or other sounds are emitted to indicate the crossing interval to visually impaired individuals. Such signals have been used in San Diego, Washington, D.C., and other cities in the United States and abroad at selected locations. Special push-button devices are in use in some jurisdictions which, when activated, extend the WALK interval for pedestrians with slower walking speeds.

- Sign-related measures include Braille maps and certain types of warning signs (e.g, "CAUTION BLIND CHILDREN") aimed at motorists. It should be mentioned, however, that the Traffic Control Devices Handbook warns against using non-uniform traffic controls.[51]

- Crosswalk-related measures include guidestrips parallel to crosswalks. These are raised markings made of gravel and epoxy which can be detected with a cane by blind people and therefore used to assist in crossing the street (see figure 62).

- Sidewalk-related measures include:

  - sidewalk widening.

  - curb ramps to assist wheelchair users, people on crutches, and many older adults in general.

  - guidestrips, which are tactile strips of glass beads or sand set in thermoplastic strips and located on a sidewalk or walkway to guide blind people.

  - handrails, which can assist people with equilibrium problems.

  - careful placement of street furniture (e.g., litter barrels, newspaper stands, poles, signposts, benches, and planters) which can provide more space to walk and operate wheelchairs.

- Other types of facilities include the use of pedestrian refuge islands, prohibition of right-turn-on-red, widened crosswalks, mid-block crossings, overpasses and underpasses, elimination of some vehicle turns, and others.

Details of these and other facilities for handicapped are given in numerous publications and reports.[27,29,31,54,105,106]

Figure 62. Illustration of guidestrips for the blind.

CHAPTER 10 - PEDESTRIAN FACILITIES IN WORK ZONES

Traffic control problems are magnified whenever roadway and roadside construction, maintenance activities and utility work sites exist. Considerable effort is usually expended on safety, reducing inherent delay and other negative impacts to the motorist. In addition to motorists, however, pedestrians and construction site workers are susceptible to danger at the work site area. Pedestrians are exposed to vehicular conflicts due to the traffic as well as being endangered by construction equipment, construction operations and debris. Therefore, whenever the work area encroaches upon a sidewalk, crosswalk or other pedestrian use areas, special consideration must be given to pedestrian safety. Failure to properly consider pedestrian needs at work sites can result in pedestrian injuries, economic losses to abutting commercial establishments and possible tort liability claims.

PLANNING CONSIDERATIONS

Effective planning requires knowledge of pedestrian characteristics, type and duration of construction activities and the level of hazard posed to pedestrians. For example, some work activities, such as minor sidewalk repair, may require minimal pedestrian accommodations even with high pedestrian volume. Other activities such as building construction may require pedestrian detour or covered walkways.

Pedestrian Characteristics

Prior to the initiation of any work activities the work site should be visited to determine the number of pedestrians using the existing facilities, origins and destinations and pedestrian traffic generators. The visit to the site should be conducted during the highest pedestrian volume hours, such as the noon lunch hours for central business district areas. The visit should also be conducted during the evening hours to determine the need for nighttime accommodations.

The origins, destinations and walking paths should be noted to determine where pedestrian access is required and where it can be blocked without providing an alternate path. Pedestrians typically choose the shortest route. If it is necessary to block the shortest route then barriers, barricades, etc., are needed to make it impossible or extremely difficult for pedestrians to enter where they are not supposed to be. The alternate routes must be realistic and safe providing access to commercial establishments in the vicinity of, and on, either side of the work zone.

Pedestrians should feel secure and not be subjected to undue risk or forced to travel a long distance out of their normal pathway. Pedestrians will generally accept inconveniences when they feel that their needs have been adequately met. In addition, adequate accommodations should be provided to meet the needs of all types of pedestrians including the elderly, handicapped and school children who can reasonably be expected to use the facility. The need for special provisions can be ascertained by identifying the location of pedestrian use facilities in the vicinity of the work site.

The type of area in which the work will take place is often a direct indication of the type and volume of pedestrians that will be affected and, hence, the intensity of pedestrian accommodations that will be required. The need for pedestrian accommodations can be determined by answering the following guideline questions.[107]

1. Does the existing pedestrian usage, pathways and walk trip generators indicate that there is a need for pedestrians to travel through the work zone?

2. Will the work zone require that the existing pathway be closed, blocked, restricted in width or made more hazardous as a result of the work zone?

A positive response to either of the above guideline questions indicates that pedestrians should be considered as part of the traffic control plan. The underlying assumption is that if pedestrian usage existed prior to the work activity then this usage should be allowed to continue regardless of the volume level. The rights of pedestrians to legally transverse an area should be considered as important as providing motorist access. The pedestrian should be accommodated and adequately protected from hazard.

Work Zone Characteristics

The types of pedestrian accommodations required to facilitate pedestrian movement and increase safety is dependent upon the characteristics of the work zone. The following classifications by the type of construction have been developed.[108]

- Highway Work Zones - These work zones include all roadway construction and maintenance that have an impact upon pedestrian movement or safety.

- Utility Work Zones - Included in this classification is any work on utilities (gas, water, telephone, electric, cable, etc.) that has an impact upon pedestrian movement or safety.

- Building Work Zones - The building work zone includes building construction or maintenance activities that has an impact upon pedestrian flow or safety.

- Other Work Zones - This category includes all maintenance, construction or reconstruction that does not fall under any of the above categories.

The level of protection afforded by the pedestrian accommodations is the principal consideration used in selecting the appropriate pedestrian accommodations. Consideration must also be given to the time duration of each work zone to determine the cost/safety tradeoffs associated with the different levels of pedestrian accommodations. The duration of work zones can generally be classified into 1 of the following classifications of time duration.[108]

- Short Term - These work zones require pedestrian control, but are not performed during hours of darkness and require less than 1 period of daylight to complete. Utility and maintenance work zones are often short term work zones.

- Medium Term - These work zones extend in time from 1 day to 1 month. Sidewalk reconstruction, driveway installation and minor roadway improvements are examples of medium term work zones.

- Long Term - Long term zones require pedestrian accommodations that extend beyond 1 month. Examples include major roadway reconstruction and building construction.

Pedestrian Pathway Characteristics

Different pedestrian pathways can be provided at work sites. The pathway which is most appropriate is dependent upon the type and duration of the work zone, roadway geometrics and the constraints of the construction activity. Pedestrian pathways through a work zone can be provided in the following ways.

- Existing Pathway - The existing pathway is available for use either at its full width or in a restricted width. Full width pathways with overhead protection can often be used, for example, in building work zones. Restricted width pathways can be appropriate where construction and maintenance activities or material storage encroach upon the existing pedestrian pathway. Determining if the available pedestrian right-of-way is sufficient requires consideration of pedestrian volumes, facility use by the elderly and handicapped and project duration.

- Bypass Pathway - A bypass pathway is the use of an area adjacent to the work zone and within the right-of-way limits (i.e., curb lane, grass separation strip, etc.) for the pedestrian path. This pathway is appropriate when the existing pedestrian pathway requires complete closure due to construction activities or material storage.

- Detour Pathway - Detour pathways are required when complete closure of the existing facility is required and no accompanying area for a bypass pathway is available. Detour pathways can often be accomplished by directing pedestrians to facilities on the opposite side of the roadway.

PEDESTRIAN PATHWAY DESIGN FOR WORK ZONES

The proper design of pedestrian pathways for work zones necessitates consideration to minimum pathway width requirements, acceptable pathway surface materials and pathway delineation protection needs.

Minimum Pathway Width Requirements

The minimum pathway width is normally a function of the existing pedestrian volume. Wider pathways are required to accommodate higher pedestrian volumes. High pedestrian volumes on narrow pathways will result in congestion and encourage pedestrians to walk in unsafe areas. A minimum width of 4 feet (1.2 m) is suggested for most work areas. This minimum width will permit 2 persons to walk abreast or to pass each other. In rural or suburban areas with very low pedestrian volumes, a minimum width of 2 feet (61 cm) is acceptable. If wheelchair users need to transverse the work zone then a minimum of 60 inches (1525 mm) are required to permit two wheelchairs to pass.[109]

Pedestrian Pathway Surface Materials

Pathway surface materials should be reasonably stabilized, free of hazards such as holes and cracks, slip resistant and level. The most common types of temporary pathway surfaces include stabilized earth and gravel, asphalt, concrete, wood and steel plates. The type of surface material that is appropriate is dependent upon the pedestrian volume, project duration and stability of subbase. In general, high pedestrian volume and long project duration require more stable and durable pathway surfaces. Which materials may be appropriate with regard to pedestrian volume and project duration is presented in table 22. This table is presented as only a guide. Additional considerations such as environmental conditions, use of existing pathway by handicapped and elderly and cost constraints should be additional considerations in surface material selection. For example, stabilized earth and gravel should not be used where handicapped pedestrians are observed using the existing facility.

Table 22. Suggested pedestrian pathway surface type. (Source: [108], p. 793)

Project Duration (1)	Pedestrian Volume Level		
	Low (2)	Medium (3)	High (4)
Short (<1 Day)	Stabilized surface (e.g., gravel, soil, etc.)	Stabilized surface (e.g., gravel, soil, etc.)	Stabilized gravel
Medium (1 Day - 1 Month)	Stabilized gravel Wood planks or steel plates for no base conditions	Stabilized gravel Wood planks or steel plates of no base conditions	Stabilized gravel Wood Planks or steel plates for bridging purposes Asphalt
Long Term (>1 Month)	Stabilized gravel Wood planks or steel plates for bridging purposes	Stabilized gravel Wood planks or steel plates for bridging purposes Asphalt	Asphalt Concrete Wood planks or steel plates for bridging purposes

Note: Wood plank surface to be used where no base is available for supporting gravel or asphalt surface. Wooden surface should be treated with roofing felt material to provide a non-skid or non-slip surface.

Appropriate Separation and Protection Devices

The selection of devices to separate pedestrians from vehicular traffic and construction activities is dependent upon the pedestrian level of hazard, project duration and type of construction. Assessing protection device need by type of construction requires determining from which direction pedestrian hazards could possibly arrive. For example, a pedestrian walkway adjacent to the construction of a high rise building should be a canopy type to provide overhead pedestrian protection from falling debris.

The level of protection should increase with the level of hazard. Penetratable devices, such as cones and barricades, may be appropriate for low hazard, short duration situations. Solid, nonpenetratable devices, such as concrete barriers, are appropriate for high hazard, long term situations. A planning guide that can be used to help select barriers based on the level of hazard and project duration is presented in table 23.

PEDESTRIAN INFORMATION

The appropriate type of pedestrian information is dependent upon the type of pathway being provided and need to be determined for each situation. This determination requires assessing the changes to the existing pedestrian information and control devices that will be required by the work site. Table 24 is provided as a general guide to the type of information needed at different locations through the work zone for the primary types of pedestrian pathways.

Advance Information

Advance information is only required for pedestrians when the work zone has resulted in a restricted or blocked pathway. In most cases, this results in advance warning only being required for detours and pathways that are too narrow to accommodate wheelchairs. When advance information is required it should be placed sufficiently in advance of the work site to permit the choice of alternate paths. For a sidewalk closure this may require the placement of advance information a block prior to the work site. If a crosswalk is blocked on the far side of an intersection, then the pedestrians should be redirected at the near side to prevent attempted crosswalk use.

For pathway blockage and detour the pedestrians should be informed of the blockage and provided alternate path directions. Even in cases where it appears obvious that a closure exists, advance information should be provided. This often requires that signs be tailored to the specific circumstances of the site. The sign messages which are frequently required include; 1) SIDEWALK CLOSED AHEAD, 2) SIDEWALK CLOSED, USE OTHER SIDE, and 3) PEDESTRIAN DETOUR, FOLLOW ARROW.

Table 23. Suggested devices for pedestrian protection. (Source: [108], p. 794)

Project Duration (1)	Separator[a] (2)	Hazard Level[c]: Low (non-incapacitating injury) (3)	Hazard Level[c]: Medium (incapacitating injury) (4)	Hazard Level[c]: High (fatal) (5)
Short	P-C	Cones Tubes	Cones with flagging tape Tubes with flagging tape	Portable fence, barricades with flagging tape
	P-V	Cones Tubes	Barricades	Barrels Drums (with hand rail)
Medium	P-C	Cones Tubes	Cones Tubes (with continuous tape or hand rail)	Solid plywood wall
	P-V	Barricades Type I and II	Barricades Type I and II	Barricade Type III Barriers (portable concrete safety barriers)
Long-Term	P-C	Barricades Type I and II	Handrail Screening	Solid plywood wall
	P-V	Barricades Type I and II	Portable concrete safety barriers Solid fencing	Portable concrete safety barriers

[a] P-C: Pedestrian-Construction separator; P-V: Pedestrian-Vehicle separator.
[b] Low hazard level, intermittent-type separator required. Medium hazard level, continuous-type separator required. High hazard level, continuous solid and rigid barrier required.
[c] Flashers to be installed for nighttime use of separators.

Table 24. Pedestrian information needs for guidance through work zones.
(Source: [108], p. 795)

Location Relative To Work Zone (1)	Type of Pedestrian Pathway: Existing Pathway: Full Width (2)	Type of Pedestrian Pathway: Existing Pathway: Restricted Width (3)	Type of Pedestrian Pathway: Bypass (4)	Type of Pedestrian Pathway: Detour (5)
Advance of work zone	none	none	none	closure ahead alternate path
Transition	none	delineation of pathway	bypass location and entry point	closure prohibition
Work Zone Area	delination of pathway	delineation of pathway	delineation of pathway	none
Exit	none	none	end of work, return to original pathway	direction to original pathway

Existing pedestrian signs and signals should be closely inspected to ensure that they do not provide contradictory guidance. This may require that existing devices be covered or removed for the duration of construction. Another option for crosswalks, equipped with pedestrian signals, that are to be closed is to provide a confirmatory message by keeping the DON'T WALK message lit at all times or covering the signal head with a R9-3a, NO PEDESTRIANS sign.

Transition Information

The transition information is intended to inform pedestrians of any restrictions and aid them in identifying the location of the pathway and its boundaries. Transition information is generally not needed where the existing pathway is maintained at its full width. When the existing pathway is used at a restricted width, then the pedestrian should be channelized into the restricted pathway. Similarly, a bypass pathway requires that positive information on the new path be provided in addition to channelization to the new path. For detour situations the pedestrian should be informed of the closure and the alternative route information, similar to the advance information, should be provided.

In some situations, especially when extensive additional walking is required due to the work zone pathway, it may be necessary to install physical barriers to prevent pedestrians from unsafe movements. If the pathway is used at night, sufficient illumination and area lighting should be provided. Typical devices which can be used to channelize pedestrians include temporary marking tape, cones, type I or II barricades, continuous rope guide rail, wood railings, fencing material and concrete barriers. Longer term projects typically require more durable treatments such as fencing material and concrete barriers.

Work Area Information

The primary purpose of the work area information is to make pedestrians aware of the boundaries of the pathway as they proceed through the work zone. This informational need is required for all pathways with the exception of detours. In general, the same devices selected for channelizing pedestrians in the transition area are appropriate for the work zone area. The added consideration for the work zone area, however, is that protection for pedestrians from construction hazards must also be provided. Pedestrians should also be cautioned against any possible interruptions in their path resulting from construction equipment and unexpected hazards such as abrupt changes in elevation.

Exit Information

In the majority of instances no additional information, other than informing pedestrians of the end of construction, is necessary. This is due to the transition information on each end of the pathway being able to also serve as the exiting information. Detour pathways require sufficient information to guide the pedestrian back to the original path. Since detour pathways result in greater pedestrian volumes, than originally on the detour pathway, close inspection should be given to traffic signal timing and pedestrian/motorist information.

Maintenance and Inspection Needs

The planned pedestrian accommodations should be made part of the traffic control plan and, for projects let for bid, be part of the contractor's bid. Whether the construction work is being performed by contract, force account or utility company it is important to inspect the implemented pedestrian accommodations to ensure that they follow the control plan. For projects of long duration periodic inspections of signs and signals are required to ensure continued safe operation. Also, for long duration projects, especially in high pedestrian volume work sites, continued inspection of the pathway surface for wear and damage is required. Similar inspection of the channelization devices is also required and defective elements repaired or replaced.

Construction activities in work zones frequently change in type of activity and location. Frequently these changes necessitate a corresponding change in the pedestrian accommodations. When these changes are anticipated due to the construction plan then a staged change in the pedestrian accommodations should also be planned. Frequent inspections can help ensure that the pedestrian accommodations are the proper response to changing construction activities. The inspections should also check for any material in the pedestrian pathway such as debris, spilled concrete, construction materials and equipment.

Construction Zone Worker Concerns

The safety of construction workers is dependent upon the work zone traffic control plan and worker visibility to motorists. Workers and flaggers exposed to vehicular or construction hazards should be readily discernable by the use of orange vests or jackets, headgear and have their position delineated by cones, flashers, barricades, or high-level warning devices. For nighttime conditions the outside garments of workers must also be reflectorized.[110]

Worker protection is required under 2 primary types of roadway construction operations: mobile and fixed. Mobile protection is required in those instances where the work zone is moving along the roadway, such as roadway patching or painting activities. Fixed protection is required at stationary work sites.

Mobile protection should be designed to provide advance warning to motorists that slow moving vehicles or equipment are ahead, thereby, allowing sufficient time for safe lane change, deceleration and stops as required. The use of a shadow vehicle is usually justified especially where restricted sight distance, high vehicle speeds or other conditions result in the workers and equipment being exceptionally vulnerable to harm. The shadow vehicle usually consists of a loaded dump truck equipped with a lighted directional arrow along with slow moving vehicle emblems. The shadow vehicle may also be equipped with an energy absorption device which lessens the impact severity of vehicles striking the rear of the shadow vehicle. The shadow vehicle should follow at a sufficient distance from the work crew to provide crew safety in case of a vehicle impacting the rear of the shadow vehicle.

Delineation for fixed work zones consists of the use of lighted arrows, signs, lights and barricades to mark the location of and direct traffic from the work zone. One of the most dangerous activities associated with fixed work zones is the initial set up of the delineation devices. All work zone personnel should receive training on how to set up and take down the devices as safely and rapidly as possible.

Shadow vehicles and precast concrete barriers may also be used at fixed work sites. Precast concrete barriers not only provide positive worker protection but also serve to guide motorists around or through the work zone. An added advantage to the concrete barriers are that they serve to help redirect vehicles with minimal damage thus decreasing the possibility of personal injury.

Pedestrian Accommodation Guidelines

The primary considerations required for planning, implementing and maintaining pedestrian accommodations at work zones is summarized in figure 63. Figure 63 can be copied and, with appropriate notes, included in each project file as an aid in safely accommodating pedestrians at work sites.[111]

A. Planning Considerations

1. Consider the origins, destinations, and walking paths in determining where pedestrian access is required and where it can be blocked without providing an alternate path.

2. The typical pedestrian will take the shortest route. Therefore, the following planning considerations are important.

   - Make it impossible or difficult to walk where pedestrians are not supposed to be. Use barricades, barriers, signals, etc.

   - Provide a usable, safe route with necessary signs, signals, etc.

   The key is that the pedestrians must feel that their needs through a work zone environment have been adequately met or they will choose their own "safe" route. Pedestrians should feel secure and not be subjected to undue risk. Further, adequate accommodations should be provided to meet the needs of all types of pedestrians, including school children, blind, elderly, or handicapped persons who may be expected to use the pathway.

3. Check for pedestrian generating land-use facilities - schools, senior citizen centers, facilities used by handicapped persons, shopping centers, recreation, and restaurants, etc.

4. Determine the minimum pedestrian-activity level. For sites with low pedestrian volumes, provide warning signs as a minimum if it is not feasible or practical to provide a seperate walkway.

5. Consider needs for nighttime accommodation.

6. To avoid the hazard of construction material, equipment, and debris stacked in the pedestrian pathway, establish a designated location for these items as a part of the contract, especially for long-term projects.

7. Consider stage construction techniques when there is no acceptable alternate routing for pedestrians and access should be maintained.

B. Information Needs

1. Advance Information

   - Advance information required only for detours and bypasses.

   - Pedestrians need advance information to forewarn them of any sidewalk/path blockages. Information should advise of blockage and give alternate path.

Figure 63. Guidelines for planning pedestrian accommodations at work zones. (Source: [111], pp. 16-19)

- In general, no advance information is needed for the following situations:
  - Where pedestrian walkway is provided through the work zones and there is no need for sidewalk blockage or closure and no pedestrian diversion involved.
  - Where the continuity of the pedestrian pathway is maintained and the pathway itself is obvious to the pedestrians.
- Tailor sign messages to specific needs. Typical messages include: SIDEWALK CLOSED AHEAD, SIDEWALK CLOSED - USE OTHER SIDE, and PEDESTRIAN DETOUR - FOLLOW ARROW.

2. Transition Information

- Provide proper transition and channelization into work zone path - bypass or detour.
- Select channelization devices based on project duration.
- Devices suitable for channelization purposes include: cones or tubes, temporary marking tape, barricade - Type I or II, ropes or chains, wood railings, portable concrete barriers, etc.

3. Guidance Through Work Zones

- Deadline boundaries of the pathway through the work zone - all pathway situations except detour.
- Select guidance and pathway delineation devices consistent with the duration of the project and the level of hazard.
- Devices suitable for pathway delineation and protection include: cones, tubes, wooden railings, barricades, and barriers - portable concrete type.
- Pathway should be illuminated for use at night.

4. Exit Information

- No information required where existing pathway is used or pedestrian can clearly see the exit path.
- In case of a bypass and detour, pedestrians need positive direction to return to the original path. Use of appropriate signing and devices will accomplish this.

Figure 63. Guidelines for planning pedestrian accommodations at work zones (continued). (Source: [111], pp. 16-19)

C. Pedestrian Pathway Considerations

1. Provide walkway widths consistent with original sidewalk width or to satisfy current pedestrian volumes.

2. Boundaries of pathway should be clearly defined preferably by markings, cones, barriers, and other devices, such as roping and flagging.

3. Walkway surface should be even and free of holes, wide cracks, fixed obstructions, and steep grades. Pedestrian walkway surface should be of stabilized material.

4. Provide nonslip surface for temporary, wood pathway.

5. Transition into and out of redefined or relocated walkway should be clearly defined by markings, signs, or barricades to provide positive direction.

6. Physical barrier may be necessary to keep pedestrians from wandering into traffic lane or construction area.

7. Provide ramping where grade differential along pathway is more than 6 inches between existing and temporary designated sidewalk. All ramping should be rigid and firmly secured for safety of wheelchair, etc.

8. Do not allow changes in construction to block pedestrian pathway. A periodic inspection and maintenance of work zone area is desirable.

9. Physical separators between pedestrian and traffic should be selected based on duration of project and space availability. In all cases, separator should be used to confine pedestrians into a safe walkway space.

10. Interior of overhead protected - canopy type - pedestrian walkways should be properly illuminated for nighttime visibility.

D. Intersection Crossings

1. If the original crosswalk is altered or removed, provide clearly defined new crosswalk path using temporary marking tape.

2. Keep crosswalk clear of debris, mud, construction materials, construction equipment, and other devices.

3. Warn motorists if pedestrian crossing is unexpected. Possible need for pedestrian crossing sign, orange color. Special warning signing may be needed if problem is severe.

Figure 63. Guidelines for planning pedestrian accommodations at work zones (continued).(Source: [111], pp. 16-19)

4. Provide signing and/or marking to define entrance to crosswalk. Channelize pedestrians into new crosswalk area.

5. Modify traffic signal timing/phasing and location if changed pedestrian needs warrant it.

6. Consider deactivating pedestrian signals or covering signal heads and push-button signs, when crossing is not to be used.

7. Provide cover, or bridge with metal plates over any cuts or ditches in crosswalk area for the entire width of original or modified crosswalk.

8. Consider lighting the area for nighttime visibility if cut in pavement is deep or hazardous. This applies to sidewalk cuts as well.

E. Sidewalk Closure and Blockage

1. If existing sidewalk through a work zone is to be closed two alternatives are possible:

   - Detour pedestrian traffic onto other side where sidewalk or a pedestrian path is available. Provide adequate signs for diverting pedestrian traffic using designated crosswalks. Signs should be placed logically and conspicuously for proper visibility from all approaches. Possible sign messages are: SIDEWALK CLOSED AHEAD and SIDEWALK CLOSED PEDESTRIANS USE OTHER SIDE, with arrow.

2. Divert pedestrians onto the planting strip, if there is one, or into the curb lane. When using the curb lane, pedestrians must be protected from moving traffic by adequate physical separation. Possible sign messages are: SIDEWALK CLOSED and PEDESTRIANS USE TEMPORARY WALKWAY.

3. Sidewalk closure should be accomplished with a substantial barrier, Type III barricade. Use signs indicating sidewalk closure and pedestrian diversion.

4. If pedestrians have to cross highway because of sidewalk closure, make sure that adequate crossing is provided using signing, crosswalk markings, traffic signal modification, and pedestrian signs, if warranted.

5. For short-term utility operations, use less permanent devices, such as Type I or II barricade, or even cones. Use signs and cones for delineation and channelization for safe walking around work zone.

F. Pedestrian Protection

1. Separators provided on both traffic and construction sides should be compatible to the level of hazard.

Figure 63. Guidelines for planning pedestrian accommodations at work zones (continued). (Source: [111], pp. 16-19)

2. The type of separator used should not create a hazard itself.

3. Physical separator may be needed if sidewalk on the construction side is to be closed and pedestrian traffic is to be diverted close to moving traffic.

4. Where there is construction overhead and the possibility of falling debris or wet concrete, overhead protection should be provided for walkways below.

G. Inspection and Maintenance

1. Check for compliance with traffic control plan for pedestrian accommodations.

2. Periodically check for missing signs or other traffic control devices installed for pedestrian accommodations in work zones.

3. Check for changes in construction activity that would require change in pedestrian accommodations.

4. Check for any material in pedestrian pathways, such as spilled concrete, debris, construction materials, and equipment.

5. Maintain signal equipment in operational condition. Check bulbs periodically.

Figure 63. Guidelines for planning pedestrian accommodations at work zones (continued). (Source: [111], pp. 16-19)

CHAPTER 11 - PEDESTRIAN FACILITY MAINTENANCE

The primary concerns in the maintenance of pedestrian facilities is to keep the original design concepts intact, periodic refurbishing and debris removal. The intensity and term of periodic inspection is dependent upon the facility type and the locational weather patterns. Areas in northern climates, for example, require snow and ice removal from crosswalks but usually require pavement marking refurbishing only once a year. Other areas, such as the southwest U.S., need not be concerned with snow and ice removal but require pavement marking reapplication more than once a year due to the debilitating effect of the sun.

The degree of maintenance performed on pedestrian facilities has a direct impact on the facility effectiveness, service life, degree of use, liability and community image. Activities such as painting exposed steel structural members or refurbishing pavement markings are maintenance activities whose need and benefits are readily evident. Not so evident are the benefits and maintenance frequency required to maximize use, reduce liability and enhance the community image. Vandalism, such as stolen or defaced signs, graffiti and broken lighting fixtures provide poor impressions to users if not quickly corrected. Accompanying the poor impression is a feeling of lack of security and fear for personal safety. The result is often a decrease in facility usage with a possible increase in pedestrian accidents due to the use of alternative, less safe routes.

A periodic inspection and maintenance schedule should be established to help ensure the timely notice of deficient elements. Often times the engineering department can obtain assistance from other agency departments in this task. Small notification pads [usually 3 x 5 inches (7.6 x 12.7 cm)] can be distributed to selected employees to complete and forward to the engineering department upon the identification of a deficiency during the employees normal work activities. One example of this process is requesting the water department to have their meter readers identify cracked and pop-up sidewalk segments.

The criteria used to identify when maintenance is required should be predicated on the needs of the most discriminating user. Sidewalk sections in high pedestrian volume areas, therefore, that have vertical differences greater than 1/4 inch (0.6 cm) should be repaired to meet the needs of the wheelchair users and prevent tripping.[108] Residential areas on the otherhand usually do not need such stringent criteria with some cities allowing up to 1/2 inch (1.3 cm) or even 3/4 inch (1.9 cm) vertical difference between adjacent sidewalk slabs prior to repair.

The maintenance requirements for pedestrian facilities is presented in table 25 as a list of concerns and maintenance activities. The frequency with which the facilities should be inspected and maintenance activities conducted is dependent upon the needs of the locational area. The recommendations of table 25 are intended only as a guide to assist in the development of a systematic inspection and maintenance program. They must be adjusted to meet the needs of the local agency.

Table 25. Pedestrian facility maintenance requirements.

Pedestrian Facility	Concern	Maintenance Activity
Sidewalks and Walkways	1. Tree roots cracking and heaving the sidewalk.	1. Remove failed sidewalks, cut roots and install new sidewalk. A local arborist should be contacted prior to removing large roots.
	2. Section pop-up of vertical height greater than 1/2 inch (12 mm).	2. Replace defective section or provide temporary asphalt shim.
	3. Cracked or spalling surface and poorly placed temporary patches.	3. Replace defective sections.
	4. Snow and ice buildup.	4. Enact and enforce local regulations requiring abutting land users to perform timely clearance activity. • Hire private contractor to clear sidewalk and assess cost to abutting land users.
	5. Separation of expansion and construction joints so that space between adjoining sections are greater than 1/2 inch.	5. Fill joint with hardening expansion compound.
	6. Trash, loose sand, oil and grease on walkways.	6. Serve notice to abutting land owners to clean and maintain sidewalks.
	7. Material, signs, vending machines, etc. restricting effective sidewalk width.	7. Require responsible parties to remove obstructions.
	8. Low hanging tree limbs, bushes, weeds and other foilage growing into sidewalk and/or posing obstructions and sight restrictions.	8. Enact and enforce local regulations requiring abutting land users to perform timely clearance activity. • Hire private contractor to clear sidewalk and assess cost to abutting land users.

Table 25. Pedestrian facility maintenance requirements.(continued)

Pedestrian Facility	Concern	Maintenance Activity
Crosswalks and Curb Ramps	1. Curb ramp surface is worn into a glazed and slippery surface.	1. Replace curb ramp. ● Texturize surface with shallow, transverse grooves.
	2. Poor drainage causing water retention in gutter area.	2. Clean gutter and catch basin area.
	3. Street rutting causing water ponding in cross-walk.	3. Resurface street or crosswalk area.
	4. Street repaving resulting in step or transition problem at bottom of curb ramp.	4. Repaving contract specifications should specify a maximum of 1/4 inch (6 mm) vertical edge between new pavement and gutter or curb ramp.
	5. Slippery manhole covers in crosswalk.	5. When manholes must be located in crosswalk they should have slip resistant cover design and be flush with the surface and visible.
	6. Snow and ice buildup.	6. A maintenance program should be developed to ensure snow and ice removal.
	7. Stop bar and crosswalk pavement markings.	7. Identify high volume locations that require additional refurbishing activities.
	8. Separation of expansion and construction joints so that space between adjoining sections are greater than 1/2 inch.	8. Fill joint with hardening expansion compound.

Table 25. Pedestrian facility maintenance requirements.(continued)

Pedestrian Facility	Concern	Maintenance Activity
Crosswalks and Curb Ramps (con't)	9. Pedestrians do not have time to clear roadway prior to signal change.	9. Review pedestrian clearance/timing plan assuming a maximum speed of 3.5 ft per second (1.07 m/sec) plus a tolerance of 2 seconds for reaction time. ● Add refuge island in middle of street. ● Extend sidewalk to edge of parking lane.
Overpasses and Underpasses	1. Falling objects from overpass.	1. Enclose overpass with chain-link fencing.
	2. Sparce pedestrian use of underpasses.	2. Underpass should be well lighted to provide a feeling of personal security. ● Underpass should be free of water, dirt and debris. ● Increase security patrols.
	3. Worn step or ramp surfaces.	3. Overlay, replace or texturize to slip free and unbroken surface.
	4. Snow and ice buildup.	4. A maintenance program should be developed to ensure snow and ice removal.
	5. Section pop-up of vertical height greater than 1/2 in (12 mm).	5. Replace defective section or provide temporary asphalt shim.
Work Zones	1. Temporary pathways at work zones are typically constructed of relatively inexpensive, short life materials.	1. The pathway surface should be frequently inspected. ● Pathway surface materials constructed of wood should be treated with no slip strips or surface treatment.

Table 25. Pedestrian facility maintenance requirements.(continued)

Pedestrian Facility	Concern	Maintenance Activity
Work Zones (con't)		• Surface materials with holes, cracks or abrupt changes in elevation should be replaced.
	2. Detour pedestrian paths place greater volumes on detour roadway.	2. The detour pathway should be checked periodically for: • Adequacy of pedestrian and vehicular signal timing. • Proper pedestrian detour signing. • Pedestrian traffic hazards. • Proper motorist information.
	3. Construction materials debris in pathway.	3. Require the contractor to maintain a clear pathway.
	4. Changing pedestrian accommodation needs due to dynamic construction activities.	4. Perform periodic inspection to ensure pedestrian information needs keep pace with construction activities.
	5. Damaged traffic barriers.	5. Damaged traffic barriers should be replaced and their adequacy reevaluated to ensure pedestrian safety.
Traffic Control Devices	1. Signs must be readily visible to pedestrians.	1. Inspect the signs from the vantage point of the pedestrian who is expected to read it. The signs should not be obscured by other signs or foilage.
	2. Pedestrian signs must be at a mounting height that can be read by all pedestrians.	2. If the sign extends into an accessible route they must be mounted in accord with the MUTCD to permit safe passage under the sign.

Table 25. Pedestrian facility maintenance requirements.(continued)

Pedestrian Facility	Concern	Maintenance Activity
Traffic Control Devices (con't)		• Signs mounted on a wall should be mounted at a height between 54 in and 66 in (1,370 mm and 1,675 mm).
	3. Pedestrian signals must be maintained.	3. Pedestrian signals should be periodically: • Inspected for damage due to turning vehicles. If damaged, consider back bracketing the pedestrian assembly. • Refurbished including lens cleaning and bulb replacement.

WALKWAY ANALYSIS WORKSHEET

Location: ______________________

City, State: ______________________

COUNTS

Date: ______________

Time: ______________

PEAK 15-MIN FROM

________ to ________

Curb Line/Sidewalk Edge

W_T = ____

W_{B1} (curb) = ft

W_{B2} (street furn.) = ft

W_E (effective width) = ft

W_{B3} (window shop) = ft

W_{B4} (bldg protrusions) = ft

W_{B5} (inside clearance = ft

Wall Line/Sidewalk Edge

← V_1 = ________

→ V_2 = ________

(ped/15 min)

Pedestrian Volume

V_1 = ________ ped/15 min

V_2 = ________ ped/15 min

$V_p = V_1 + V_2$ = ________ ped/15 min

Walkway Width

W_T = ________ ft

$W_B = W_{B1} + W_{B2} + W_{B3} + W_{B4} + W_{B5}$ = ________ ft

$W_E = W_T - W_B$ = ________ ft

Average Walkway LOS

$v = V_p/15W_E$ = ________ ped/min/ft

Average LOS = ________ (Table 4)

Platoon Walkway LOS

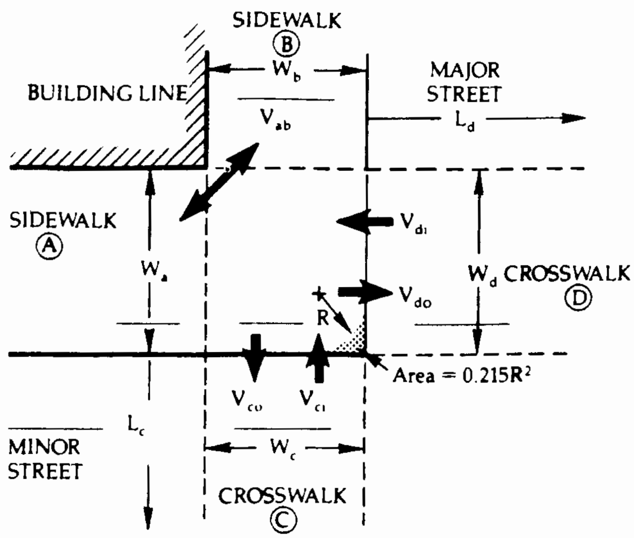
$v_p = v + 4$ = ________ ped/min/ft

Platoon LOS = ________ (Table 4)

STREET CORNER ANALYSIS WORKSHEET

Location: ______________________

City, State: ______________________



SIGNAL TIMING (sec)

C = ______

G_{mj} = ______ R_{mj} = ______

G_{mi} = ______ R_{mi} = ______

PEDESTRIAN VOLUMES

Flow	Ped/Min	Ped/Cyc
v_{ci}		
v_{co}		
v_{di}		
v_{do}		
$v_{a,b}$		
v_{tot}		

NET CORNER AREA $A = W_aW_b - 0.215R^2 =$ ______ sq ft

AVAILABLE TIME-SPACE $TS = A \times C/60 =$ ______ sq ft-min

HOLD AREA WAITING TIMES
(use ped/cycle)

$Q_{tco} = [(v_{co})(R_{mj}/C)(R_{mj}/2)]/60 =$ ______ ped-min

$Q_{tdo} = [(v_{do})(R_{mi}/C)(R_{mi}/2)]/60 =$ ______ ped-min

HOLD AREA TIME-SPACE

$TS_h = 7(Q_{tco} + Q_{tdo}) =$ ______ sq ft-min

CIRCULATION TIME-SPACE

$TS_c = TS - TS_h =$ ______ sq ft-min

TOTAL CIRCULATION VOLUME

$v_c = v_{ci} + v_{co} + v_{do} + v_{di} + v_{a,b} =$ ______ ped

TOTAL CIRCULATION TIME

$t_o = 0.12(W_a + W_b) + 1.4$ (sec) $t_c = v_c \times t_o/60 =$ ______ ped-min

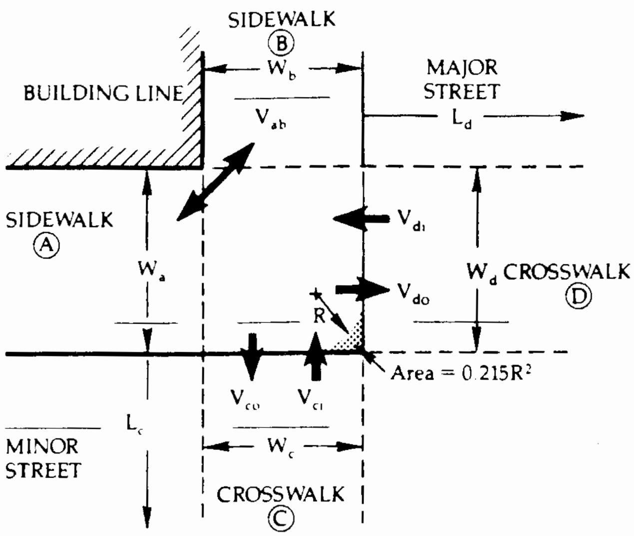
PEDESTRIAN SPACE AND LOS

$M = TS_c/t_c =$ ______ sq ft/ped; LOS = ______
(Table 4)

CROSSWALK ANALYSIS WORKSHEET

Location: ______________________________

City, State: ______________________________



SIGNAL TIMING (sec)

C = ________

G_{mj} = ________ R_{mj} = ________

G_{mi} = ________ R_{mi} = ________

PEDESTRIAN VOLUMES

Flow	Ped/Min	Ped/Cyc
v_{ci}		
v_{co}		
v_{di}		
v_{do}		
$v_{a,b}$		
v_{tot}		

CROSSWALK AREAS

$A_c = L_c W_c =$ ________ sq ft

$A_d = L_d W_d =$ ________ sq ft

CROSSWALK TIME-SPACE

$TS_c = A_c (G_{mj})/60 =$ ________ sq ft-min

$TS_d = A_d (G_{mi})/60 =$ ________ sq ft-min

CROSSING TIMES

$t_{wc} = L_c/3.3 =$ ________ sec

$t_{wd} = L_d/3.3 =$ ________ sec

CROSSWALK OCCUPANCY TIME
(use ped/cycle)

$T_{wc} = (v_{ci} + v_{co})(t_{wc}/60) =$ ________ ped-min

$T_{wd} = (v_{di} + v_{do})(t_{wd}/60) =$ ________ ped-min

AVERAGE PEDESTRIAN SPACE AND LOS

$M_c = TS_c/T_{wc} =$ ________ sq ft/ped; LOS = ________ (Table 4)

$M_d = TS_d/T_{wd} =$ ________ sq ft/ped; LOS = ________ (Table 4)

MAXIMUM SURGE
(use ped/min)

$V_{mc} = (v_{ci} + v_{co})(R_{mj} + t_{wc})/60 =$ ________ ped

$V_{md} = (v_{di} + v_{do})(R_{mi} + t_{wd})/60 =$ ________ ped

SURGE PEDESTRIAN SPACE AND SURGE LOS

$M_c\,(Max) = A_c/V_{mc} =$ ________ sq ft/ped; LOS = ________ (Table 4)

$M_d\,(Max) = A_d/V_{md} =$ ________ sq ft/ped; LOS = ________ (Table 4)

WALKWAY ANALYSIS WORKSHEET

Location: ELIZABETH & RICE STREETS

City, State: ROUNDSVILLE

COUNTS

Date: 10/19/88

Time: PM

PEAK 15-MIN FROM 4:15 to 4:30

Curb Line/Sidewalk Edge

W_{B1} (curb) =	1.5	ft
W_{B2} (street furn.) =	0	ft
W_T = 14′ — W_E (effective width) =	9.5	ft
W_{B3} (window shop) =	3.0	ft
W_{B4} (bldg protrusions) =	0	ft
W_{B5} (inside clearance =	0	ft

Wall Line/Sidewalk Edge

← V_1 = 625

→ V_2 = 625

(ped/15 min)

Pedestrian Volume

V_1 = 625 ped/15 min

V_2 = 625 ped/15 min

$V_p = V_1 + V_2$ = 1250 ped/15 min

Walkway Width

W_T = 14.0 ft

$W_B = W_{B1} + W_{B2} + W_{B3} + W_{B4} + W_{B5}$ = 4.5 ft

$W_E = W_T - W_B$ = 9.5 ft

Average Walkway LOS

$v = V_p/15W_E$ = 8.8 ped/min/ft

Average LOS = C (Table 4)

Platoon Walkway LOS

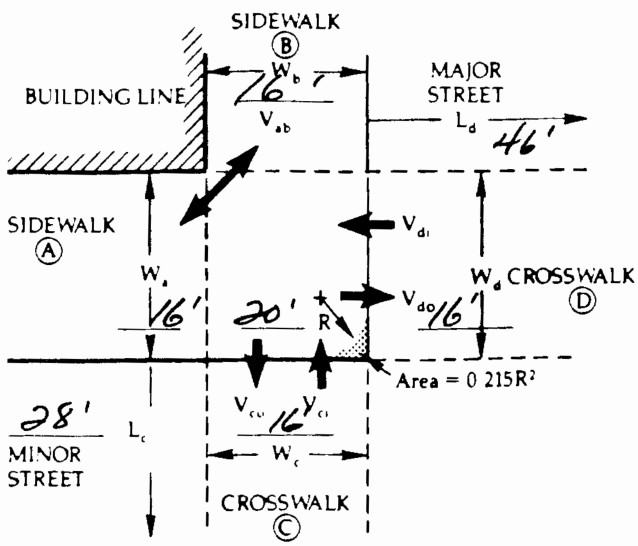
$v_p = v + 4$ = 12.8 ped/min/ft

Platoon LOS = D (Table 4)

STREET CORNER ANALYSIS WORKSHEET

Location: ELIZABETH & RICE STREETS

City, State: ROUNDSVILLE



SIGNAL TIMING (sec)

C = 80

G_{mj} = 48 R_{mj} = 32

G_{mi} = 32 R_{mi} = 48

PEDESTRIAN VOLUMES

Flow	Ped/Min	Ped/Cyc
v_{ci}	36	48
v_{co}	20	27
v_{di}	30	40
v_{do}	16	21
$v_{a,b}$	15	20
v_{tot}	117	158

NET CORNER AREA $A = W_aW_b - 0.215R^2 =$ 170 sq ft

AVAILABLE TIME-SPACE $TS = A \times C/60 =$ 227 sq ft-min

HOLD AREA WAITING TIMES
(use ped/cycle)

$Q_{tco} = [(v_{co})(R_{mj}/C)(R_{mj}/2)]/60 =$ 2.9 ped-min

$Q_{tdo} = [(v_{do})(R_{mi}/C)(R_{mi}/2)]/60 =$ 5.0 ped-min

HOLD AREA TIME-SPACE

$TS_h = 7(Q_{tco} + Q_{tdo}) =$ 55.3 sq ft-min

CIRCULATION TIME-SPACE

$TS_c = TS - TS_h =$ 171.7 sq ft-min

TOTAL CIRCULATION VOLUME

$v_c = v_{ci} + v_{co} + v_{do} + v_{di} + v_{a,b} =$ 156 ped

TOTAL CIRCULATION TIME

$t_o = 0.12(16+16)+1.4 = 5.2$ SEC

$t_o = 0.12(W_a + W_b) + 1.4$ (sec)

$t_c = v_c \times t_o/60 =$ 13.5 ped-min

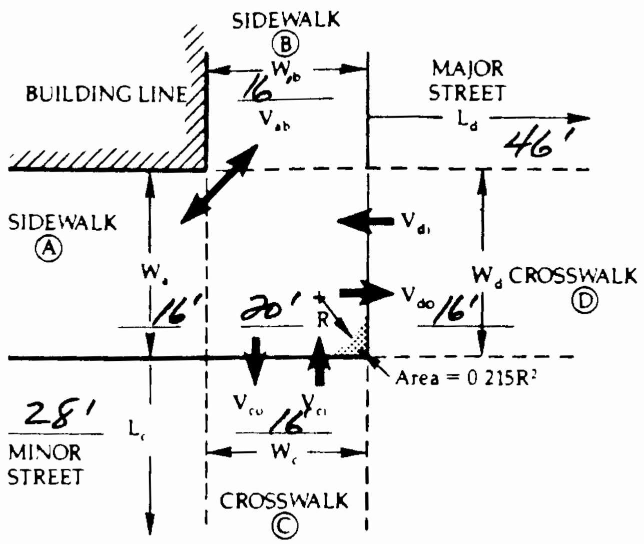
PEDESTRIAN SPACE AND LOS

$M = TS_c/t_c =$ 12.7 sq ft/ped; LOS = E
(Table 4)

CROSSWALK ANALYSIS WORKSHEET

Location: Elizabeth & Rice Streets

City, State: Roundsville



SIGNAL TIMING (sec)

C = 80
G_{mj} = 48
G_{mi} = 32
R_{mj} = 32
R_{mi} = 48

PEDESTRIAN VOLUMES

Flow	Ped/Min	Ped/Cyc
v_{ci}	36	48
v_{co}	20	27
v_{di}	30	40
v_{do}	16	21
$v_{a,b}$	15	20
v_{tot}	117	156

CROSSWALK AREAS

$A_c = L_c W_c =$ 448 sq ft

$A_d = L_d W_d =$ 736 sq ft

CROSSWALK TIME-SPACE

$TS_c = A_c (G_{mj})/60 =$ 358 sq ft-min

$TS_d = A_d (G_{mi})/60 =$ 392 sq ft-min

CROSSING TIMES

$t_{wc} = L_c/3.3 =$ 8.5 sec

$t_{wd} = L_d/3.3 =$ 13.9 sec

CROSSWALK OCCUPANCY TIME
(use ped/cycle)

$T_{wc} = (v_{ci} + v_{co})(t_{wc}/60) =$ 10.6 ped-min

$T_{wd} = (v_{di} + v_{do})(t_{wd}/60) =$ 14.1 ped-min

AVERAGE PEDESTRIAN SPACE AND LOS

$M_c = TS_c/T_{wc} =$ 33.7 sq ft/ped; LOS = C (Table 4)

$M_d = TS_d/T_{wd} =$ 27.8 sq ft/ped; LOS = C (Table 4)

MAXIMUM SURGE
(use ped/min)

$V_{mc} = (v_{ci} + v_{co})(R_{mj} + t_{wc})/60 =$ 37.8 ped

$V_{md} = (v_{di} + v_{do})(R_{mi} + t_{wd})/60 =$ 47.6 ped

SURGE PEDESTRIAN SPACE AND SURGE LOS

$M_c\,(Max) = A_c/V_{mc} =$ 11.9 sq ft/ped; LOS = E (Table 4)

$M_d\,(Max) = A_d/V_{md} =$ 15.4 sq ft/ped; LOS = D (Table 4)

SAMPLE DATA SUMMARIES SHEET ___ OF ___

FILE NO.______

DATA SUMMARY - PEDESTRIAN TRAFFIC SURVEY

RE: Highway Capacity Manual

Location:
(Intersection) ____________________

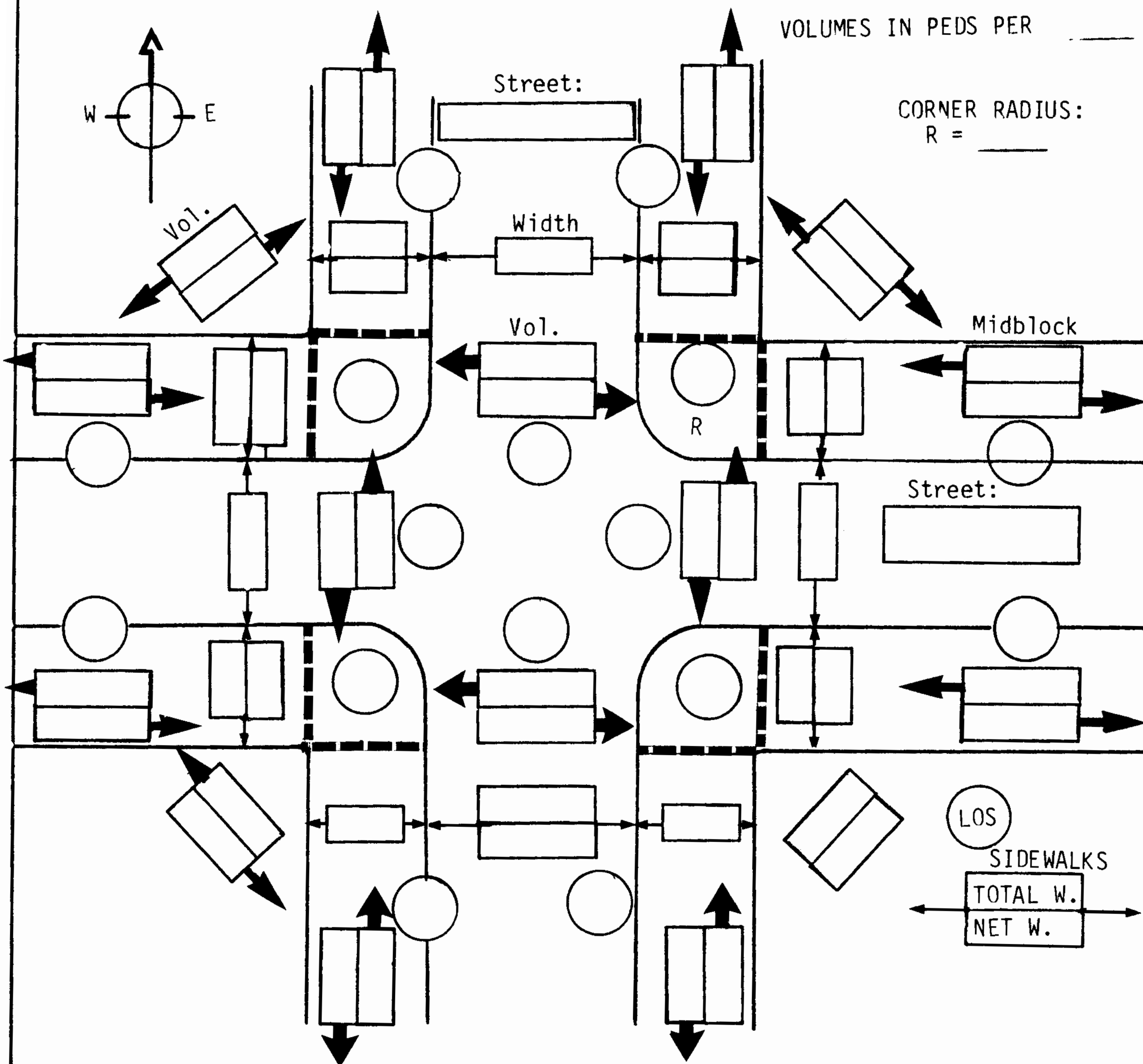
Date & Day: ____________________
Weather: ____________________
Counted by: ____________________
Summary by: ____________________

Time: Begin __________
End __________

Signal Timing
C = ________ secs.
NS Green ______ Red ______
EW Green ______ Red ______

VOLUMES IN PEDS PER _____

CORNER RADIUS:
R = ______



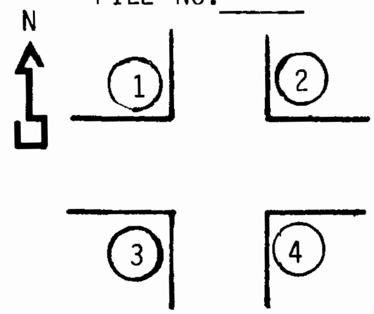
NOTES: ____

VOLUME SUMMARY

SHEET ___ OF ___

FILE NO.____

PEDESTRIAN VOLUME



Location: ______________________

____

Date & Day: ______________________

Weather: ______________________

Counted By: ______________________

Time Begin: ________ Time End ________

Signal cycle ____ secs.

Time	North X Walk			South X Walk			East X Walk			West X Walk			Inter. Total
	1→2	2→1	Total	3→4	4-3	Total	2→4	4→2	Total	1→3	3→1	Total	

NOTES: ______________________

Compiled by: ______________ Date: ______________

PEDESTRIAN OBSERVANCE OF TRAFFIC SIGNALS
FIELD SHEET

Location ______________________________

Time ____________ to ____________ Weather ____________

Pedestrians crossing ____________ St. on the (N.S.E.W.)________ side ________

of ____________ St. in ____________ direction ____________

STEPPED FROM CURB ON	CROSSED STRAIGHT (crosswalk)	TOTAL
RED / WALK		
YELLOW / FLASHING DON'T WALK		
GREEN / STEADY DON'T WALK		
	CROSSED DIAGONALLY	
RED / WALK		
GREEN OR YELLOW / DON'T WALK		
TOTAL		

Date ____________ Recorder ____________

RTOR Conflicts and Volume Data Form

City: ____________________ Observer: ____________________

Intersection: ____________________ Approach: ____________________

Weather: ____________________ Date: ____________________

Ped. Conflict Types

- VH = Vehicle Hesitation
- VS = Vehicle Swerve
- PH = Pedestrian Hesitation
- PR = Pedestrian Run
- I = Interaction

Period	Time		Right-Turn Volume		Right-Turn-on-Red				Pedestrian Volume	
						Conflict with Traffic	Ped. Conflict			
	From	To	RTOR	RTOG	No Conflict		Near Crosswalk	Far Crosswalk	Near Crosswalk	Far Crosswalk
1										
2										
3										
4										
5										
6										
Total										

Data Collection Form for Pedestrian Conflicts and Events

Location ____________ Observer ____________ Date ____________ Weather ____________

Time		Slow or Stop For Ped.	Slow or Stop for Ped. Previous	Weave For Ped. Cross.	Break or Weave - Ped. Standing	Break or Weave - Ped. Walking on Shoulder	Vehicle Ignore Crossing Guard	Turn Conflict	Ped. Run. Across Street	Ped. Stop In Street	Ped. Traf. Signal Viola-tion	False Start Across Street	Jay Walk-ing	Total Ped. Volume
Start	End													

PEDESTRIAN GROUP SIZE STUDY

Study date________ Time: From_________ to________ Location______________

Crosswalk across________________________ Curb-to-curb distance__________

Divided roadway? Yes No Width of Island_________

Group Size	Number of Rows (N)	Number of Groups		Cumulative	Computations
		Tally	Total		
46 - 50	10				
41 - 45	9				
36 - 40	8				
31 - 33	7				
26 - 30	6				
21 - 25	5				
16 - 20	4				
11 - 15	3				
6 - 10	2				
5 or less	1				
		Total Number of Groups		X 0.15 =	N =

PEDESTRIAN DELAY TIME STUDY

Study date_______ Location_________________ Crosswalk across _________

End of Survey (to nearest minute) _______	Number of Rows - "N"_______
Start to Survey (to nearest minute)_______	Roadway Width - "W" _______ ft.
Total Survey Time (minutes) _______	Adequate Gap Time - "G"_____ secs.

Gap Size (Seconds)	Number of Gaps: Tally	Number of Gaps: Total	Multiply by Gap Size	Computations
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				T = Total survey time x 60
28				
29				
30				T = x 60
31				
32				T = secs.
33				
34				
35				
36				
37				$D = \left(\frac{T - t}{T}\right) 100$
38				
39				
40				
41				
42				
43				
"t" (total time of all gaps equal or greater than "G")			______secs.	D = _____%

Summary of pedestrian facility problems and possible solutions. (Source: [40])

Description of Problem	Magnitude of Problem	Possible Solutions	Current Level of use or Acceptance	Limitations in Applicability	Potential Effectiveness	Barriers to Implementation	Cost	Impact on Other Groups	Comment
Lack of coordination and continuity in pedestrian facilities	Major	1. Make master planning for pedestrian facilities mandatory in state law.	Moderate	None	High	Moderate	Low	Positive	Only way to ensure ped planning takes place is to require it by law.
		2. Increase public investment in completing sidewalks and pathways.	Moderate	None	High	Moderate to High	High	Positive	Consider specifying minimum funding levels by law.
Lack of communication in development process	Major	1. Develop more rigorous administrative procedures to force communication.	Moderate	None	Moderate	High	Low	Positive	Cannot make administration so elaborate that it slows down the development process.
		2. Designate person in public agency as the pedestrian advocate.	Low to Moderate	None	High	Moderate	Low	Positive	One of the most effective low-cost actions.
Lack of vocal, organized advocacy group addressing pedestrian needs	Major	1. Establish citizen task force on pedestrian needs.	Low	None	High	Moderate	Low	Positive	Relies on citizens taking an interest.
	Major	2. Establish pedestrian facility "hot line".	Low	None	Moderate	Moderate	Low	Positive	Provides recognized avenue for input.
Inflexibility in zoning and subdivision regulations	Major	1. Build in flexibility to regulations (e.g., performance zoning).	Moderate	Usually depends on local perspective on development.	High	High	Low	Depends on situation	Offers greater potential benefit but also greater risk.
		2. Provide special zones of development for pedestrian orientation.	Low to Moderate	Subject to local and state law.	High	Moderate	Low	Positive	Special ped-oriented design guidelines would be provided.
Suburban land use patterns discourage pedestrian travel	Major	1. Provide incentives for mixed-use and development clustering.	Low to Moderate	Some areas not physically or politically suited to ped-oriented development.	Moderate	Low	Low	Possibly negative	Higher density development needed for ped-orientation sometimes opposed by community.
		2. Employ "urban village" concept.	Moderate	Must be planned under right physical conditions.	High	Moderate	Low	Positive	Applicable to original development or redevelopment.
		3. Provide for minimum F.A.R.'s as well as maximum.	Low	Only in areas planned for higher density development.	Low	High	Low	Possibly negative	Developers usually incentive toward higher F.A.R.'s anyway.

Summary of pedestrian facility problems and possible solutions (continued). (Source: [40])

Description of Problem	Magnitude of Problem	Possible Solutions	Current Level of use or Acceptance	Limitations in Applicability	Potential Effectiveness	Barriers to Implementation	Cost	Impact on Other Groups	Comment
Lack of improper application of crosswalk markings	Moderate	1. Develop and implement reasonable crosswalk application guidelines.	Moderate	None, but acceptable guidelines need to be developed.	High	Moderate	Low	Positive	
		2. Develop symbol to identify preferred crossing location without marking crosswalk.	Low (Some in Europe)	Needs to be more fully tested before widespead application.	Moderate	Moderate to High	Low	Uncertain	Primary purpose is to reduce false sense of security.
Open parking areas, not enforcing disciplined traffic flow and making pedestrian crossings hazardous	Moderate to High	1. For new parking lots, enact local parking lot landscaping standards, emphasizing landscaped islands.	Moderate	None	High	Moderate	Moderate	Positive	
		2. For existing parking lots, islands sufficient to discipline traffic flow.	Low	Parking lot must have ample spaces to accommodate users.	High	Moderate	Moderate	Positive	Owners often more concerned about having adequate space than having landscaping.
Overpass or underpass underutilized because at-grade route more convenient	High	1. Install barrier in median.	Low	Must have median available and no nearby intersections.	High	Moderate	Moderate	Minimal impact	Limits accessibility but increases safety.
		2. Design over/underpass to minimize travel path (e.g., provide stairs in addition to ramps and grade approaches).	Low	Topography must be conducive.	High	Low	Moderate to High	Minimal impact	Handicapped requirements sometimes counterproductive in accessibility for others
Inadequate street lighting at pedestrian crosing points	Moderate to Major	1. Provide traditional street lighting.	Moderate	None	Moderate	Moderate	High	Positive	Should be more intense at intersections and key crossing points.
		2. Provide special pedestrian-oriented lighting.	Low	Provide only at primary crossing points with heavier ped volumes.	High	Moderate	Moderate		Contrast to normal lighting provides greater conspicuity at key points.
Institutional and Legal Problems									
General lack of respect of pedestrians by drivers	Major	1. Selective enforcement (preceded by publicity) of ped right-of-way.	Low	Should focus on situations where driver yielding is a problem.	High	High	High	Perceived negative	Affect on accident rates is uncertain.
		2. Increase fines for violations of ped right-of-way.	Low	None	Moderate	Moderate	Low	Perceived negative	Needs to be backed by increased enforcement.

Summary of pedestrian facility problems and possible solutions (continued). (Source: [40])

Description of Problem	Magnitude of Problem	Possible Solutions	Current Level of use or Acceptance	Limitations in Applicability	Potential Effectiveness	Barriers to Implementation	Cost	Impact on Other Groups	Comment
Obstructions in sidewalk	Moderate	1. Provide local guidelines limiting location of obstacles.	Low	None	Moderate	Moderate	Low to Moderate	Minimal impact	Can easily be provided in local ordinances. Alternate locations not always possible.
		2. Obtain easements, where necessary, to locate objects out of ped path.	Low	Most common objects are controller cabinets, mail boxes and trash containers.	High	High	Moderate to High	Minimal impact	Easement process time consuming and sometimes costly.
Security problem on certain isolated pedestrian pathways	Major	1. Refrain from constructing pathways in secluded areas. Provide paths primarily along street footages.	Moderate	Residents must be willing to accept pathways in front of homes.	High	Moderate	Low	Minimal impact	Rear yard walkways known to have security problems in some areas.
		2. Provide clearview of pathways from residences and/or street.	Moderate	Difficult to maintain visibility on many recreational pathways.	High	Moderate	Low to Moderate	Slightly negative	Residents can perceive visibility as invasion of privacy.
		3. Provide more lighting, telephones, patrols or alarm systems.	Low	Primarily needed where visibility is a problem.	Moderate	Moderate	Moderate to High	Minimal impact	Security problem will still be perceived.
Signalization									
No accommodation for peds at some suburban signals, but ped volumes are low	Moderate to Major	1. Provide ped actuated signal regardless of ped volume.	Moderate	Only needed where min. crossing time not provided each cycle.	High	Moderate	Moderate to High	Slightly to very negative	Represents the classic dilemma in facilitating ped vs. vehicular flow.
		2. Inform ped that full crossing time may not be available in one phase.	Low	None	Moderate to High	Low	Low	Minimal impact	If adequate full crossing time not provided, ped should be informed of this.
Minimum ped clearance time inadequate to accommodate slow walking peds	Moderate to Major	1. Lengthen ped clearance times where proportion of slower peds is higher than normal. Take time from WALK phase if WALK longer than minimum.	Low	Needed primarily near elderly housing, schools, etc.	High	Moderate	Low	Varies by circumstance	Impact depends on nature of traffic congestion.
Peds frequently do not obey signal indications	Moderate (see comment)	1. Upgrade ped enforcement efforts.	Low	If done, should be selective enforcement.	Low	High	High	Slightly positive	Although lack of compliance is rainpant, impacts are not necessarily negative.

Summary of pedestrian facility problems and possible solutions (continued). (Source: [40])

Description of Problem	Magnitude of Problem	Possible Solutions	Current Level of use or Acceptance	Limitations in Applicability	Potential Effectiveness	Barriers to Implementation	Cost	Impact on Other Groups	Comment
Excessive traffic speeds in residential or commercial areas	Moderate to Major	1. Design curvature and circuity into road system. Keep streets narrow.	Moderate	Limited mostly to local and collector streets. Not appropriate on major highways.	High	Moderate	Moderate	Slightly negative	Can create some waste or inefficiency in lot layout.
		2. Increased enforcement.	Moderate	Cost is primary limitation.	Moderate	Moderate to High	High	Negative	Better to control speed thru goemetric design.
		3. Provide speed control devices (e.g., speed humps, traffic circles, intersection flares, etc.).	Low	Primarily used in residential areas. Not appropriate for major highways.	High	High	Low to Moderate	Negative	Devices have been controversial and not yet widely accepted.
Safety/convenience of walking in commercial area with many poorly channelized driveways	Moderate to Major	1. Consolidate driveway entrances - requires local regulation.	Low	Feasible in some newly developing strips. Generally infeasible in existing strips.	High	High	Moderate in new strips	Both pos. and neg. impacts	
		2. Provide service road in newly developing areas.	Low	Must have ample right-of-way.	Low to Moderate	High	High	Both pos. and neg. impacts	Greatly amplifies problems at intersections.
		3. Improve driveway channelization. Would require local mandate.	Moderate	Particularly needed where parking areas open directly to street.	Moderate to High	High	Moderate	Positive	Public participation would usually be needed.
Difficult and hazardous pedestrian movement thru interchange area	Major	1. Provide sidewalk and markings on all new interchanges accessible to peds.	Moderate	Applies only to facilities not excluding ped traffic.	High	Moderate	Moderate	Positive	Should become routine practice, required in state/local guidelines.
		2. Provide barrier between traffic lanes and ped walkway.	Low	Not necessary for low speed facilities.	Moderate	High	Moderate	Minimal impact	Provides additional measure of safety for pedestrians.
		3. For existing interchanges without sidewalk or shoulders, consider routing peds onto median.	Low	Primarily applicable to full or partial cloverleaf interchanges.	Moderate	Moderate	Low	Low	Removes peds from hazardous ramp crossings.
Missing sidewalk links	Major	1. Perform sidewalk inventory, priority improvement program, and master plan of walkways.	Moderate	None	High	Low	Low	Minimal impact	Must be followed with funding and construction.
		2. Provide public funds for sidewalk construction with provision for recovering costs from landowner when development occurs.	Low	Legal mechanism must be provided to recover costs.	High	Moderate	Low	Minimal impact	Allows sidewalk to be completed even if area is only partially developed.
		3. Obtain easements or take part of roadway lane to fill in missing links where barriers exist (e.g., retaining walls).	Low	Will be unusual to be able to take part of roadway lane.	Moderate	High	Moderate	Slightly negative	Practical only for limited set of conditions.

Summary of pedestrian facility problems and possible solutions (continued). (Source: [40])

Description of Problem	Magnitude of Problem	Possible Solutions	Current Level of use or Acceptance	Limitations in Applicability	Potential Effectiveness	Barriers to Implementation	Cost	Impact on Other Groups	Comment
Cross-section Design									
Difficulty of crossing wide arterial streets, especially undivided arterials.	Major	1. Install medians on all new suburban highways of 4 or more lanes.	Moderate	Virtually no limitations for new highways. However some limitations are currently perceived.	High	Moderate	Moderate	Positive	Potentially the most effective solution to street crossing problems.
		2. Install European style refuge islands in strategic locations on existing undivided highways.	Low	Must usually narrow lanes on existing highways to accommodate refuge islands. Must be well lighted.	High	Moderate	Low to Moderate	Minimal Impact	This solution is greatly under-utilized in U.S.
		3. Design for reduced street width between signalized inter-sections (since capacity con-straints are at signals).	Low	Could only be done where spacing between inter-sections is high.	Moderate	High	Low	Negative	Probably not feas-ible as a general practice.
		4. Introduce additional traffic signals to facilitate pedes-trian crossings.	Low	Sould only be done in a few selected locations.	Moderate	High	Moderate	Highly Negative	More feasible were pedestrian crossings are concentrated at a point.
		5. Provide midblock actuated flashing pedestrian signal.	Low	Could only be installed in key locations.	Moderate	Moderate	Low	Slightly Negative	Design to inform driver of presence of ped. Does not necessarily make crossing easier.
		6. Provide pedestrian overpass.	Low	Only effective where at-grade crossing is blocked or is inconvenient.	Moderate - depends on no. peds.	Moderate	High	Positive	Lack of use of facility continues to be a problem.
Difficulty of crossing high-ways with two-way left-turn lanes.	Moderate to Major	1. Reduce use of this technique and provide medians to control access.	Low	Would need to design in frequent U-turn capability.	High	High	Moderate to High	Negative	Merchants and drivers will object heavily.
		2. Install refuge islands in spots where no turning is necessary.	Low	Must have at least some "dead spots" where turning would not generally occur.	High	Moderate	Low	Minimal Impact	Islands must be well lighted and marked.
No facilities provided for pedestrian to walk along side of road.	Major	1. Require sidewalk/pathway with all new highway construction. Paved or stabilized shoulder adequate in outlying areas.	Moderate	Only allowed exclusion should be low volume residential streets.	High	Moderate	Moderate	Minimal Impact	Could be required by FHWA for Federal projects.
		2. Provide easier methods for ob-taining easements, to address existing highways constrained by right-of-way.	Low	Probably would be viewed as giving excess authority to public agencies.	High	High	Low	Negative	Would put property owners at a disadvantage.
Narrow bridges with no pedestrian accommodations.	Moderate	1. Design all new bridges with shoulder or raised walkway.	Moderate	None	Moderate to High	Moderate	Moderate to High	Positive	
		2. Design low-cost walkway system for attaching to outside of bridge.	Low	Feasibility and design dependent on structural nature of existing bridge.	Moderate to High	Moderate	Moderate	Positive	

APPENDIX C - DETAILS OF VARIOUS PEDESTRIAN MEASURES

SIDEWALKS AND PEDESTRIAN PATHS

Conditions Where Sidewalks Are Most Beneficial

- Suburban streets particularly with moderate to high pedestrian travel and/or streets with high volumes or speeds and where a high percent of truck traffic exists.
- Streets where there is no other place for pedestrians to walk except in or near travel lane.
- Narrow streets with pedestrian traffic.
- High pedestrian accident areas.
- On roads near schools, parks, or areas with young children at play.

Conditions Where Sidewalks Are Least Beneficial or Most Harmful

- When constructed too close to high-speed roadways.
- When used by bicyclists and/or too narrow.
- When sidewalks are cluttered with poles, trash cans, fire hydrants, benches and/or other obstacles.

Conditions Where Separate Pedestrian Paths in Rural and Suburban Areas Are Most Beneficial

- An area near schools or other areas heavily travelled by pedestrians.
- Areas with high traffic speeds or volumes and heavy volumes of pedestrians.
- Areas with considerable pedestrian activity with well-defined origins and destinations (e.g., connecting residential area with shopping center).
- On narrow streets with narrow shoulder or areas where pedestrians would otherwise have to walk in the road, particularly where nighttime pedestrian activity exists.
- Recreational areas with joggers, etc.

Conditions Where Separate Pedestrian Paths in Rural and Suburban Areas Are Least Beneficial or Most Harmful

- In high crime areas.
- When pedestrian activity is low.

SIDEWALKS AND PEDESTRIAN PATHS (CONTINUED)

Advantages of Pedestrian Paths and Sidewalks

- Can reduce the number of pedestrian accidents in residential and business areas.
- Provide separation between pedestrians and motor vehicles.
- Can provide a more direct pathway than the road (such as on college campuses).
- Can provide safer and more easily traveled areas for all pedestrians (particularly the elderly and the handicapped).
- Provides paved places for children to play as an alternative to playing in the street.
- Sidwalks are often funded by property owners.
- Sidewalk widening:
  - Increases space for pedestrians.
  - Reduces pedestrian congestion.
  - May provide an additional buffer zone between pedestrians and vehicles in some cases.
  - Reduces visual obstruction caused by parked motor vehicles.
  - Provides more space for necessary sidewalk furniture.

Disadvantages of Pedestrian Path and Sidewalks

- Can create snow removal problems.
- Cracking of sidewalks caused by severe weather requires expenditures for maintenance.
- Sidewalk widening:
  - May reduce the width for vehicle travel lanes and/or parking space.
  - More expensive than temporary walkways.
  - In areas with substantial bicycle travel, conflicts or accidents may occur between bicyclists and pedestrians on pedestrian paths and sidewalks.

FAR-SIDE BUS STOPS

Conditions Where Far-Side Bus Stops Are Most Beneficial

- In areas of high bus traffic and high bus ridership (and/or with exclusive bus lanes).
- Along streets with a moderate or heavy volume of right-turn traffic on the bus street.
- In CBD areas and/or other areas with heavy pedestrian volumes and high traffic volumes.
- At either signalized or nonsignalized intersections with 1 or more of the conditions mentioned above.

Conditions When Least Beneficial or Most Harmful

- When large volumes of pedestrians must cross a busy street to reach the far-side bus stop.
- With a large number of transfers, pedestrian movements at an intersection may be substantially increased.
- When most of the pedestrian demand is near-side.

Advantages of Far-Side Bus Stops

- Can reduce the number of bus-stop-related accidents when used appropriately.
- Buses at far-side bus stops are less likely to obscure traffic signals and signs or pedestrian movements at intersections than at near-side bus stops.
- Can reduce conflicts between stopped buses and right-turning vehicles.
- Can reduce the number of people that enter the street in front of a bus.

Disadvantages of Far-Side Bus Stops

- May increase the time of bus stop operation, since delays at signals will no longer be used for passenger pickup/dropoff.
- Cars illegally parked in far-side bus stops may cause buses to overhang into the cross street.

ONE-WAY STREETS

Conditions Where 1-Way Streets Are Most Beneficial

- Downtown grid street networks, particularly on narrow streets with high traffic volumes.
- Streets with inadequate gaps for vehicle turns.
- Streets with heavy pedestrian activity and a high frequency of conflicts between turning vehicles and pedestrians.
- Where there is a substantial number of left-turn accidents, right-turn accidents, and/or midblock pedestrian accidents.

Conditions Where Least Beneficial or Most Harmful

- When vehicle speeds would be substantially increased as a result (e.g., some very wide streets).
- Where numerous complex intersections exist along the route for which wrong-way driving is likely.
- Where traffic circulation and overall travel time in the area would be hampered.
- Streets with relatively low traffic volume.

Advantages to 1-Way Streets

- Drivers do not have to be concerned with opposing traffic and can thus give more attention to pedestrians.
- Greater gaps in traffic often result.
- Street capacity often is higher.
- Can reduce pedestrian and vehicle delay.

Disadvantages to 1-Way Streets

- At some signalized intersections, pedestrians may not be able to see the traffic signals because there is only 1 direction of traffic flow, while there are 2 directions of pedestrian flow. Thus, pedestrian signals may be needed.
- One-way streets may result in increased vehicle speed and vehicle volume.
- Possible problems with neighborhood acceptance may occur.
- Possible negative effects for transit emergency vehicles.
- Some vehicles will have to increase their travel distance.

ROADWAY LIGHTING

Conditions Where Roadway Lighting is Most Beneficial

- Arterial streets and other roadways with high traffic volumes, particularly near intersections.
- Streets if areas with high nighttime pedestrian activity, particularly where other high-pedestrian areas in the city or area are also lighted.
- High-crime areas.
- Streets or intersections with a high incidence of nighttime accidents.
- Dark residential streets with high volumes of child and/or older adult pedestrians.

Conditions Where Least Beneficial or Most Harmful

- Where placed improperly overhead lighting can make traffic signals less visible.
- Where light intensity is insufficient.
- Where the poles interfere with pedestrians (e.g., lack of adequate right-of-way).

Advantages of Roadway Lighting

- Helps pedestrians to use streets more safely at night.
- Increases clothing brightness from drivers' perspective.
- Causes some pedestrians to be more alert at street crossing locations.
- May provide adequate stopping sight distance for motorists at night if sufficient illumination is used.

Disadvantages of Roadway Lighting

- Pedestrians may develop a false sense of security on well-lighted streets.
- Some overhead street lighting configurations primarily illuminate the crosswalk and the top of the pedestrian's head. This may not make the pedestrian more visible to the driver.
- Under certain situations, may reduce sight distance.

PEDESTRIAN REFUGE ISLANDS

Conditions Where Refuge Islands Are Most Beneficial

- Wide 2-way streets with high vehicle volumes, high speeds of travel, and large pedestrian volume.
- Wide streets where elderly, handicapped, and/or child pedestrians cross regularly.
- Streets where signal timing is not sufficient for pedestrians to cross safely.
- Wide, 2-way intersections with heavy traffic volumes and crossing pedestrians.

Conditions Where Refuge Islands Are Least Beneficial or Most Harmful

- On narrow streets and/or when narrow safety islands are used.
- Where a high turning volume of large trucks exists.
- Where roadway alignment obscures the island so it is not easily seen and vehicles are likely to drive into them.
- In areas where the presence of a safety island hampers snow plowing.

Advantages of Pedestrian Refuge Islands

- Can reduce pedestrian exposure to traffic, and allow pedestrians to cross in stages.
- Permit pedestrians to look for traffic in only 1 direction at a time.
- Give pedestrians a resting place when crossing wide roads or intersections.

Disadvantages of Pedestrian Refuge Islands

- May present an "illusion of safety".
- May cause street sweeping or plowing problems.
- May cause damage to vehicles if drivers hit them.

GRADE-SEPARATED CROSSINGS

Conditions Where Grade-Separated Crossings Are Most Beneficial

- Where pedestrian demand is moderate to high to cross freeways or expressways.
- Large volume of young children (i.e., near schools) who regularly must cross a high-speed and/or high-volume road.
- Streets with high vehicle volumes and high pedestrian crossing volumes and where extreme hazard exists for pedestrians (e.g., high-speed traffic, wide street, poor sight distance).
- One or more of the conditions stated above in conjunction with well-defined pedestrian origin and destination (e.g., residential neighborhood to school, parking structure to university, apartment complex to shopping mall).

Conditions Where Least Beneficial or Most Harmful

- In high-crime areas (where underpasses in particular are often under-utilized).
- When the facility is poorly designed and inconvenient for use by handicapped or other pedestrians.
- When no physical barriers are built to control at-grade crossing activity.
- In areas where the majority of pedestrians are unlikely to use the facility (e.g., near high schools).

Advantages of Grade-Separated Crossings

- Provide separated facilities for pedestrians and vehicles.
- Often improves vehicle circulation.
- Can reduce pedestrian and vehicle delay.
- Overpasses/bridges:
    - Provides convenient and safe crossings for pedestrians.
    - Usually easier to maintain and less expensive to construct than underpasses.
- Underpasses/tunnels:
    - Do not create as much visual clutter as overpasses.
    - Protect pedestrians from bad weather conditions.

GRADE-SEPARATED CROSSINGS (CONTINUED)

- Underpasses are usually shorter in length than overpasses, (i.e., they only have to be deep enough for a pedestrian to go under the road, whereas overpasses must be high enough to allow trucks to pass under them). However, underpasses must be strong enough to support the weight of motor vehicles, while overpasses must only support the weight of pedestrians.

- Below-grade networks:
  - Provide protection for pedestrians from sun and harsh weather.
  - Don't disturb the urban street system.
  - Don't have to follow grid pattern of streets.
- Elevated walksways:
  - Can provide direct, convenient paths free of motor vehicles.
  - Is often a compact and efficient arrangement of retail space.
  - Provide a cover for at-grade pedestrian level below.
  - Can be enclosed to protect pedestrians from bad weather.

Disadvantages of Grade-Separated Crossings

- Some pedestrians won't use grade-separated facilities.
- Can increase pedestrian travel time by forcing pedestrians to take a longer route.
- Poorly planned or designed grade-separated facilities often are not used by most pedestrians, and therefore may not be effective in reducing accidents at sites where they are installed.
- Overpass/bridge:
  - Expensive, especially for adding provisions for handicapped pedestrians.
  - High clearance for trucks are required.
  - Can be visually displeasing.
  - Additional right-of-way area may need to be purchased.
- Underpass/tunnel:
  - Typically high construction costs.
  - Potential maintenance problems from drainage, litter, vandalism, and lighting.

GRADE-SEPARATED CROSSINGS (CONTINUED)

  - Require adequate design and lighting to discourage crime and encourage use.

- Below-grade network:

  - Can create emergency service problems.

  - Some pedestrians consider them to be unsafe and monotonous, unless properly planned and lighted.

- Elevated walkways:

  - Potential danger of falling objects if not properly enclosed.

  - There is a possible decline in retail activity at-grade.

  - Additional visual clutter may result.

  - Emergency service problems may exist.

  - May be difficult to coordinate at-grade and below-grade systems.

PEDESTRIAN MALLS AND STREET CLOSURES

Conditions Where Pedestrian Malls are Most Beneficial

- CBD and high-pedestrian volume areas.
- Where sidewalks are overcrowded and vehicle volumes are low.
- High-density downtown shopping areas with heavy pedestrian activity.
- Where vehicular traffic circulation would not be adversely affected.

Conditions Where Least Beneficial or Most Harmful

- Where truck delievery shares mall space.
- High-crime areas.
- In high-speed areas with relatively low pedestrian activity.

Advantages of Pedestrian Malls and Street Closures

- May reduce pedestrian delays and/or relieve pedestrian congestion.
- May enhance the aesthetic and social environment of the downtown area.
- Can provide greater accessibility to retail merchants.
- Can increase the use of public transportation.
- May decrease noise and air pollution on affected street.
- Can increase revenues, sales, and land values.
- Can be implemented in stages.

Disadvantages of Pedestrian Malls and Street Closures

- Malls generally have high cost of installation, maintenance, and operation.
- Vehicle traffic must be re-routed to other streets.
- On nearby streets, may reduce retail activity and increase noise and air pollution.
- May disrupt utility and emergency services.
- Can disrupt bus routes and delivery of goods.
- Placement problems may exist with street furniture for visually handicapped pedestrians.
- Parking problems must be corrected.
- Security and policing problems may be a concern.

SIGNING

Conditions Where Highway Signing is Most Beneficial

- Regulatory and/or warning signs aimed at <u>Motorists</u> are most useful in areas such as:

  - Where motorists do not expect pedestrians.

  - Visibility obstructions exist (e.g., crosswalks on hill crest or sharp horizontal curves).

  - School crossing locations.

  - Rural and high-speed locations.

  - Midblock crossing locations.

  - Intersections with heavy turning movements.

- Regulatory and/or warning signs aimed at <u>Pedestrians</u> are most useful in areas such as:

  - At complex intersection geometrics (5 or more legs, offset approach legs, etc.).

  - Complex signal phasing.

  - At prohibited pedestrian crossings.

  - Where pedestrians must cross high-speed or other unsafe roadways.

  - Where there are unexpected conflicts to pedestrians and/or heavy turning volumes exist.

Conditions Where Highway Signing is Least Beneficial or Most Harmful

- Regulatory and/or warning signs aimed at <u>Motorists</u> are least beneficial in areas such as where:

  - Used excessively or needlessly (unwarranted).

  - Time restrictions are used.

  - Vague, confusing, lengthy, or unreasonable messages are used.

  - Pedestrians are given a false sense of security by the signs.

  - Signs are hidden or difficult to read.

  - Motorist laws are not enforced by police.

- Regulatory and/or warning signs aimed at <u>Pedestrians</u> are least beneficial in areas such as:

- Those with low vehicle traffic volumes and speeds.

- Where used as a "quick-fix" to attempt to correct a serious pedestrian safety problem.

- Where the sign is vague, unreasonable, unnecessary, and/or confusing.

- Where overused.

- Where pedestrian laws are not enforced.

Advantages of Signing

- Relatively inexpensive.

- Signs can tell people of regulations which are specific to locations or times.

- Give advance warning of schools or other locations where extra caution in needed.

Disadvantages of Signing

- Some people have difficulty understanding signs.

- Installation of new or novel signs may require a publicity program.

- In urban areas, signs may be ineffective if they have to compete with other visual objects.

- Signs may be easily destroyed.

- Signed regulations considered unnecessary or unwarranted will often be violated.

- Excessive use of warning signs may cause most motorists to ignore them.

- Pedestrians often do not believe warning signs.

PEDESTRIAN SIGNALS

Conditions Where Pedestrian Signals Are Most Beneficial

- Where one or more of the following conditions exists (as specified in the MUTCD), pedestrian signals shall be installed:
  - When a traffic signal meets the minimum pedestrian volume or school crossing warrant.
  - When an exclusive pedestrian phase is provided.
  - When vehicular signal indications are not visible to the pedestrian.
  - At established school crossings.
- At intersections with multi-phase (e.g., left-turn phasing) signals.
- At intersections with complex designs (e.g., 5 or more intersection legs, wide streets, refuge islands for pedestrians to cross only part of the street during a single signal phase).
- Pedestrian signals are most effective in cities where pedestrian compliance is high.
- At intersections or midblock locations where pedestrian push-buttons are used. (In some cities, the push-button actuation alters the cycle split to allow for more time for pedestrians to cross the street.)
- In areas with considerable volumes of young children and/or older adults.

Conditions Where Pedestrian Signals are Least Beneficial or Most Harmful

- Very low pedestrian volumes with high-speed traffic.
- Where there is a long delay in signal cycle between WALK intervals.
- Where pedestrians rely on the pedestrian signals to protect them.
- Where not timed to provide adequate WALK and clearance time.

Advantages of Signals and Signal Timing

- Traffic signals:
  - Can create artificial gaps in traffic flow, so pedestrians may cross the street while traffic is stopped.
  - Pedestrians often understand and obey traffic signals more frequently than pedestrian signals.

- Can improve the traffic capacity of intersection.

- Pedestrian signals:
  - Warn pedestrians (and motorists) of an impending signal change sooner than the vehicle amber signal.
  - Can give pedestrians more time to cross the street.

- Exclusive phase signals will result in completely separate intervals for pedestrians and vehicles as long as pedestrians and motorists all obey their signals (e.g., pedestrians crossing during the DONT WALK interval and motorists running the red light present the risk of a pedestrian accident).

Disadvantages of Signals and Signal Timing

- Traffic signals:
  - Traffic signals are more expensive than many other facilities (except grade separation and horizontally separated pedestrian environments).
  - May increase pedestrian congestion on sidewalks and pedestrian delay at corners.
  - In rural and residential areas, many children don't wait for the WALK or green phase signal before crossing.
  - Suspension overhead traffic signals often cannot be seen by pedestrians standing on the corner. In such cases, pedestrian signals (i.e., WALK/DONT WALK) are needed.
  - Drivers and pedestrians often disobey signals.

- Pedestrian signals:
  - There is a lack of pedestrians' understanding of the meanings of the flashing DONT WALK (i.e., only about half of pedestrians understand the difference between the flashing and steady DONT WALK).
  - Younger pedestrians often disregard the pedestrian signal or overdepend on it.
  - Pedestrians may feel overly safe (from turning vehicles and other traffic) when they see a WALK indication.
  - Many pedestrians will not use the push-button.

- Separated signal phasing (i.e., scramnble timing) can cause serious vehicle and pedestrian delay.

CURB PARKING REGULATIONS

Conditions Where Curb Parking Restrictions Are Most Beneficial

- Where pedestrian dart-out accidents are common.
- Where no sidewalk exists or sight distance at the intersection is poor.
- Where vehicles park too close to the crosswalk.
- At mid-block crossing locations.

Conditions Where Least Beneficial or Most Harmful

- Strip business areas where convenient alternative parking is unavailable (i.e., when businesses are adversely affected).
- Wide streets with high vehicle speeds.

Advantages to Front-In Angle Parking

- Can improve driver and pedestrian sight lines and also pedestrian scanning behavior.
- Can reduce vehicle speeds. Some drivers may use more caution when they observe vehicles backing out of angle parking space.

Disadvantage to Front-In Angle Parking

- Reduces the space from travel lanes.
- Increases the risk of a parked vehicle being hit while pulling out of parking space.

Advantages to Restricting Curb Parking

- Can improve the stopping sight distance between motorists and pedestrians.
- Roadway or intersection capacity may increase, particularly during peak periods on major arterials.

Disadvantages to Restricting Curb Parking

- Eliminates parking spaces for motorists.
- Is usually opposed by nearby business owners.
- Vehicle speeds may increase after on-street parking is removed (which is undesirable for pedestrians).

CHILD PEDESTRIAN MEASURES

Conditions Where Adult School Crossing Guards Are Most Beneficial

On Roadways near schools, particularly:

- When there are not adequate gaps in the traffic stream for pedestrian crossings.
- Where there are dense pedestrian movements on high-speed and/or high-volume roads, particularly where no traffic signals exist.
- As part of a coordinated safety program involving the school board and local traffic officials.
- When warrants are met (see publication entitled "A Program for School Crossing Protection" by the Institute of Transportation Engineers).
- Large numbers of young pedestrians (i.e., elementary school).
- Roadways with poor sight distance.

Conditions Where Adult School Crossing Guards Are Least Beneficial or Most Harmful

- Poorly instructed crossing guards (who may stop traffic needlessly causing motorist violations).
- Low volumes of pedestrians with low traffic speeds and volumes.
- Where older children (e.g., high school) cross.

Advantages of Child Protection Measures

- Often necessary at locations where there are insufficient gaps in traffic, confusing traffic situations, and/or high vehicle speeds or volumes.
- Can help motorists to be more aware of children so they can take proper precautions.

Disadvantages of Child Protection Measures

- May give some children a false sense of security so they are not as cautious.
- Some children may place too much reliance on them and fail to look out for themselves (although some children are just too young to be able to look out for themselves. Parental supervision is often critical).

PEDESTRIAN BARRIERS

Conditions When Roadside Barriers Are Most Beneficial

- In conjunction with pedestrian overpasses.
- High vehicle speeds on uncontrolled access roads and young pedestrians.
- Where little or no separation exists between roadway and sidewalk on high-speed roadways, particularly where no curbs exist and curves exist.
- Near schools, arenas, or other high pedestrian generators where pedestrians spread out in numerous directions.
- Downtown areas with high pedestrian flows on high-volum high-density roadways, where jaywalking is common.
- On bridges with both pedestrian and vehicle traffic.
- When pedestrian flows cannot otherwise be controlled.

Conditions Where Least Beneficial or Most Harmful

- Where needed pedestrian crossing points are not provided.
- Where stranded motorists need access to sidewalk.
- On roads and streets with curb parking.
- Where city blocks are too long.
- In situtations where pedestrians are likely to climb over or under barriers and/or walk in the street inside of the barriers.
- In cases where barriers cause sight restrictions.

Advantages of Barriers

- May be helpful in channelizing pedestrians to safe crossing facilities (e.g., overpasses, underpasses, signalized intersections).
- Can prevent some pedestrians from crossing at hazardous locations.
- Can reduce the frequency of pedestrians running into the roadway.
- Can protect pedestrians from hazards that are not always obvious (e.g., where sight distance is restricted.
- Can protect pedestrians from errant vehicles.

PEDESTRIAN BARRIERS (CONTINUED)

Disadvantages of Barriers

- Can cause maintenance problems with snow, leaf, and trash removal.
- Some people try to climb barriers or cut holes in them.
- Physical barriers are more expensive than some types of treatments (e.g., signs and markings).
- Can interfere with on-street parking, vehicle loading and unloading, and emergency vehicles (e.g., fire trucks, ambulances).
- May put stranded motorists in danger by forcing them to walk along high-speed or hazardous roads (e.g., freeways).
- Rigid roadside barriers present a roadside obstacle to motorists.

MARKED CROSSWALKS

Conditions Where Marked Crosswalks Are Most Beneficial

- Signalized intersections with heavy pedestrian volumes, particularly with complex intersection geometrics (e.g., 5 or more legs, skewed intersecting roadways, wide streets).
- Midblock crossing locations that are controlled by traffic signals and pedestrian signals.
- School crossing locations that are controlled by adult (or police) crossing guards during school crossing periods.

Conditions Where Least Beneficial or Most Harmful

- Unsignalized midblock crossings.
- Unsignalized intersections.
- When markings are overused in a city or area and/or when 2 or more crosswalks are closely spaced.
- When poorly located (e.g., not well seen by approaching motorists due to poor sight distance).
- When crosswalks are painted in an attempt to relocate pedestrian movements.

Advantages of Marked Crosswalks

- Can channelize pedestrians across complex or dangerous intersections.
- Can help position pedestrians where they can be best seen by drivers.
- Midblock crosswalks tend to be used by pedestrians when they are available and may reduce crossings from behind parked vehicles and running in the road.

Disadvantages of Marked Crosswalks

- Pedestrians may feel overly secure near marked crosswalks.
- Motorists don't notice marked crosswalks as well as pedestrians may think.
- Overuse of such markings may cause disrespect for other pedestrian and traffic control devices.
- Pedestrians won't use them if they feel they are inconvenient.
- Midblock crosswalks may reduce increase vehicular traffic delay.

CURB RAMPS

Conditions Where Curb Ramps Are Most Beneficial to Handicapped Pedestrians

- Where persons in wheelchairs must cross the street unassisted.
- In areas near hospitals or retirement homes.
- Downtown areas and/or dense pedestrian movements.

Conditions Where Curb Ramps Are Least Beneficial to Handicapped Pedestrians

- When ice and snow are not removed.
- On sidewalks not used by persons in wheelchairs.
- Poor designs that point directly into moving traffic.
- Poor construction that can cause tripping and stumbling.
- On narrow sidewalks with short curb radii.

APPENDIX D – EXAMPLES OF SCHOOL ZONE TREATMENTS

ERIE, PENNSYLVANIA

SCHOOL AND CHILD SAFETY PROGRAM

Crossing Guards Program

The Police Department has hired 58 adult crossing guards who work 2 or 3 times a day. AAA guidelines are followed in choosing the guards and student patrol members. In August every year the adults go through a one day classroom training program. They are continually checked during a probationary period and periodically thereafter. The student patrols are trained by the schools with the assistance of the police. Adult guards supervise the student patrols at the crossings. Police officers substitute for absent crossing guards when necessary.

Since the 1940's Erie schools have been involved in the Erie Times Green Pennant Program, a local effort rewarding schools which have no pedestrian traffic accidents. Schools with 1 accident-free year are given a green pennant to put on their flagpole. For each subsequent accident-free year, a gold star is added to the pennant. An assembly is held at the school to present the pennant, and the awards are highly publicized in the media. At the end of the year a picnic is held for the Safety Patrols of schools with green pennants. The school and the patrol members receive certificates.

Schools that have a child pedestrian accident may not fly their pennant for a month, and must take off a gold star. This applies to any pedestrian accident involving a child that attends that school. When an accident occurs, a "suspension" letter is sent to the school and to the local newspaper. Because its stars are highly valued by the schools and children, this program almost forces them to be aware of traffic safety.

School Crosswalks

All school-related intersections have marked crosswalks. There are some problems with parents who park on the crosswalks while picking up their children. Snow and large snowbanks also cause difficulties by hiding children from a motorist's view. Children are forced to climb over the snow to get to the street.

Education

Safety education programs have largely been left up to the schools. Some schools have their own safety programs, assemblies, or plays. The police are ready to give talks to assemblies when requested and to help in the safety program in any other way. At these assemblies the police try to develop a good rapport with the children, talking about all aspects of their work and often demonstrating the use of police dogs and motorcycles. If a school area has a particularly poor accident record, or a large number of safety-related complaints from parents or the PTA, the police will initiate a visit to see if a crossing guard or other countermeasure is required.

Some teachers have individually initiated a Safe Route to School program for their students. The police will assist in setting this up if requested.

MILWAUKEE, WISCONSIN

SCHOOL AND CHILD SAFETY PROGRAM

The Milwaukee Safety Commission, in cooperation with the police and parochial school systems is responsible for developing and teaching all school safety education programs.

Crossing Guard Program

Milwaukee has some 9,000 trained Safety Cadets, taken from the 3rd through 8th grades. The responsibility of the Safety Cadets at school crossings is to keep the children on the curb until there is a sufficient gap in the traffic for them to cross. The Cadets don't go into the streets themselves, except to look around parked vehicles. Local McDonald's Restaurants have been involved in the awards and incentive program by giving away T-shirts and other awards to Cadets. Other prizes include trips to baseball games, the Wisconsin Dells (a large state park near Madison), parks, etc. for the best Safety Cadet at the end of the school year.

Four employees of the MSC go to the 220 elementary schools and hold training programs for new Cadets during the spring. By the time they start working in September, the new members have had some experience.

The 260 adult crossing guards are uniformed, paid paraprofessional police personnel posted only at major arterial highway crossings. They do enter the road to stop traffic when necessary. Adult guards and Safety Cadets are used only at elementary school crossings.

School Crossings/Safe Route Program

All signed school crosswalks also have pavement markings. This serves to keep the children within fairly well-defined limits, and also brings drivers' attention to the possibility of children in the vicinity.

The Safe Route to School program designed by the Institute of Traffic Engineers is used. School district maps, marked with arrows indicating preferred streets for children to follow to and from school are handed out in the classroom.

Education

The MSC gives over 900 "Officer Friendly" type presentations each year to both public and private schools. Preschool programs are made available in the public libraries. The Public Health Department encloses pedestrian safety literature in the package sent to new parents with their baby's birth certificate.

Because of the large number of school-age children to be reached, the Safety Commission uses School Cadets as supplemental instructors. The School Cadets are taught by the MSC. Cadets then go into individual classrooms and explain the pedestrian signal system, using an instructional aid, "Minisignal."

SAN DIEGO, CALIFORNIA

SCHOOL AND CHILD SAFETY PROGRAMS

In San Diego, the School Traffic Safety Program is composed of 4 elements: safety planning, safety education, safety operation and special arbitration.

Safety Planning

This is a joint function of the School District, and Planning, Transportation and Police Departments. The purpose is to forestall future pedestrian problems by determining the best locations for new schools, school boundaries and school routes such that there will be a minimal conflict between school children and traffic.

Safety Education

The main thrust of pedestrian safety education occurs at the elementary school level and is handled primarily by the Police Department. A special School Safety Unit consisting of 14 policemen has been established on a full-time basis by the Police Department. This unit works directly with each school principal in both the public and private schools. The officers conduct safety classes for the students, give talks and show films. Of particular interest are some of their special programs and live demonstrations including: "Kids and Skids," "Officer Friendly". "Bicycle Rodeos" and "Safe Route to School Programs."

Having the Police Department handle this program has been extremely effective in terms of safety, and has given children an opportunity to become personally acquainted with police officers under friendly and favorable circumstances, thereby forming positive attitudes on safety and law enforcement.

Safety Operations

The core of the safety operations is the School Safety Patrols which guard selected crossing locations and control the movement of school children and vehicular traffic at these locations. This function is also under the responsibility of the Police Department School Safety Unit. Fifth and 6th grade boys and girls are selected on the basis of leadership, scholarship and citizenship to participate in this program. They wear special easily seen uniforms consisting of white trousers, red blazers and yellow caps. They recieve individual training under police supervision and meet weekly with their assigned police officer supervisor to discuss problems and procedures. Special incentive awards and activities are provided including scholarships, summer camp, Christmas barbeque picnics, and special outings to pro-baseball/pro-football games, the zoo, etc. The effectiveness of this program can be measured by the fact that in 42 years, since its inception, there have been no fatalities and only 2 child injuries in a school crossing.

ATLANTA, GEORGIA

SCHOOL AND CHILD SAFETY PROGRAM

Crossing Guard Program

Atlanta hires over 100 adult crossing guards, working 1 per school. They are trained individually on-the-job for several days to introduce them to the unique characteristics of their posts. One police officer works full-time coordinating this program and conducting periodic checks of the guards. The crossing guards are responsible to the Police Department and a police officer will fill in for any guard who is ill.

Student Patrols work under the crossing guards and school supervision: they are not involved with the police. Most schools have student patrols, using the post as a reward for attendance.

School Crossing/Safe Route Program

The Traffic Engineering Department works with the schools by developing and installing appropriate traffic control measures. Safe routes to school are identified based on pedestrian flows. These are designated using signing, flashing speed limit signs, and crosswalk markings.

Requests for special traffic signals where children enter main streets from isolated subdivisions are studied as they arise. There have been very few school trip accidents in Atlanta; however, this may be a side-effect of the bussing program now in operation.

Education

The Police Department, with the help of the Georgia Traffic Safety Council, has administered several educational programs for school children. As part of the "Officer Friendly" program, a police officer will go on request to an elementary school and give a talk to an assembly, usually at the beginning of the year. Materials used are provided by the Council.

Traffic safety programs have also been conducted in shopping centers. Unfortunately, lack of funds has led to their dissolution.

APPENDIX E - RIGHT-TURN-ON-RED ACCIDENT COUNTERMEASURES

Alternative countermeasures for right-turn-on-red accidents. (Source: [103])

Category	Device	Description	Comments
Signing	Full prohibition of RTOR	Install NTOR sign at locations with high traffic or pedestrian volumes, poor sight distances, at school crossings, or where other such factors influence the safe RTOR maneuver.	There are some locations where RTOR maneuvers are unduly hazardous; although the MUTCD has guidelines on the application of NTOR signs, they are general and prone to a wide variety of interpretations; this leads to a nonuniform application of RTOR prohibitions; because conditions may change based on time of day, day of week, and season, a full-time prohibition may not always be warranted at a site.
	Partial prohibition of RTOR for certain lanes or during specific times of the day.	Install special signs that prohibit RTOR for certain times (7:00 a.m. to 7:00 p.m.), days (school days), conditions (when children are present), seasons (September to June), lanes (NTOR, except curb lane), or other factors.	Because conditions may change at a site (by time of day or day of week), the prohibition should ideally only cover those times and conditions where warranted; however, some of the legends may require special knowledge by the motorists (school days), require motorists to drive "with one eye on the clock", or may be difficult to read.
	Illuminate NTOR sign	Illuminate the NTOR sign for increased visibility; this could be accomplished by using an illuminated case sign (internal source) or external lighting.	Designed for areas where there is a nighttime RTOR-related problem or where no intersection lighting exists or both.
	Larger NTOR sign	Use an NTOR larger than the current MUTCD standard 24 x 30 in. or 24 x 24 in.	NTOR sign should ideally be placed near the signal; it is applicable for near signal placement when the signal is located on the far side of a wide street or is otherwise difficult to read; it may be particularly helpful in cities or locations where overhead sign placement is not possible.
	Near-signal placement of NTOR sign	Install NTOR sign on span arm, span wire, or signal pole near the signal head where motorists tends to look.	MUTCD guidelines for NTOR sign placement state that signs should be located adjacent to the signal face to which they apply; many communities do not follow these guidelines and have the sign post mounted at the corner of the intersection.
	Redundant NTOR signs	Install two or more NTOR signs on both posts (near or far side) and overhead to increase visibility of sign.	Although this countermeasure is applicable for some locations with high violation rates, high conflict rates, or poor sign visibility, redundant sign placement should be miniminzed.

Alternative countermeasures for right-turn-on-red accidents (continued). (Source: [103])

Category	Device	Description	Comments
Signing (Con't)	Electrical or mechanical variable message NTOR sign	Install signs that can display different messages for different signal intervals, times of day, or days of week.	This device has two applications; (a) prohibit RTOR during portions of the day that have high pedestrian volumes or cross-street volumes, or (b) prohibit RTOR during portions of a cycle where a protected movement may conflict with the RTOR (such as an opposing protected left-turn maneuver); a blank-out display would avoid confusion when the message is not needed or other safety messages could be displayed; the cost for this device is expected to be high.
Signals	Retime traffic signal	Retime signal to reduce the conflicts and minimize delay; options include improved timing to accommodate flows, special pedestrian phasing, or use of multiphase operation.	This is applicable to locatins with high volumes of vehicle and pedestrian traffic, where turning movements are high, and where congestion is a problem; exclusive pedestrian crossing intervals, which have been noted to be related to lower pedestrian accidents, also increase delay and congestion to pedestrians and motorists.
	Traffic-actuated signal	Use presence detectors to determine the right-turn demand and actuated signals to accommodate the demand and reduce the number of RTORs.	May be applicable to some intersections with heavy right-turn demand.
	Remove unwarranted traffic signals	Remove unwarranted signals and replace with other types of traffic control.	Motorists lose respect for unwarranted signals, thereby, increasing violations; many communities have begun programs to remove unwarranted signals whre they no longer meet the warrants; although this may have the benefit of improving flow, reducing operating costs, and saving energy, pedestrians must cross the street without signal assistance.
Pavement Markings	Relocate crosswalk farther from intersection	Move the crosswalk farther from the intersection to increase visibility of pedestrians.	Moving the stop bar and crosswalk farther from the intersection may discourage RTOR and increase the visibility of pedestrians; however, motorists failing to stop at the stop bar will block the crosswalk; this device may result in less sight distance of cross-street traffic and may encourage jaywalking.
	Offset or angled stop bars	Angle or offset the stop bar so that drivers in the middle lanes are stopped farther back from the intersection than right-turn vehicles in the curb lane.	For sites where RTOR is allowed; applicable to multilane approaches where there is a high incidence of truck and bus traffic that obstructs the driver's view; allows the RTOR vehicle to see cross-street traffic and pedestrians for a safer turn; the effectiveness may be reduced if vehicles in the middle lanes do not observe the offset stop bar.

Alternative countermeasures for right-turn-on-red accidents (continued). (Source: [103])

Category	Device	Description	Comments
Pavement Markings (Con't)	Pedestrian barriers	Install barriers to channelize pedestrians to the crosswalk, thereby, minimizing the conflict area.	The pedestrian barrier is also expected to reduce other types of pedestrian accidents, particularly dart-out and jaywalking-related accidents; however, barriers may cause difficulty in accessing parked vehicles along the curb, may be unsightly, and may create another roadside obstacle.
	Pedestrian overpass or underpass	Grade separation of pedestrians and motorists to eliminate conflicts.	Applicable to wide, high-speed intersections with safety problems; very expensive countermeasure, and the cost cannot be justified based on RTOR accidents alone; there may also be difficulties in accommodating elderly and handicapped pedestrians and bicyclists.
	Far side bus stop	Allow buses to stop to drop-off and pick-up passengers only after crossing the intersection.	Applicable where RTOR is allowed; eliminates congestion at the approach but may create a sight obstruction; far side bus stops are being used by many transit agencies to reduce intersection delays.
	Eliminate parking near the intersection	Remove on-street parking near the intersection on either side or both sides of the street.	On-street parking poses a site obstruction when near the crosswalk; this countermeasure may reduce other types of accidents at the intersection and may also increase capacity; however, it reduces parking availability; parking restrictions must be enforced to be effective.
	Separate right-turn lane	Provide a separate lane for right turns and thus increase the opportunities for vehicle to make an RTOR.	Applicable to sites with high volumes of right-turn traffic; increases the use of RTOR where RTOR is allowed; reduces intersection delay and increases capacity.
Other	Intersection lighting	Illuminate the intersection to provide better visibility of pedestrians at night.	Applicable to locations with high nighttime pedestrian volumes and where nighttime safety problems exist; may reduce other types of nighttime accidents at the intersection and may be useful in reducing crime at night.
	Education campaign	Educate the public by using various forms of media to increase awareness and to teach proper understanding of RTOR.	Educational campaigns can be directed at both the motorists and pedestrians related to RTOR safety and other safety issues; educational programs may not reach all individuals and may not have lasting impact; difficult to evaluate, especially relative to RTOR.

Alternative countermeasures for right-turn-on-red accidents (continued). (Source: [103])

Category	Device	Description	Comments
Other (Con't)	Clear roadside clutter	Remove roadside items to increase motorist visibility of pedestrians and traffic control devices.	Removing all but essential roadside items should improve the motorist's ability to perceive pedestrians and traffic control devices and reduce distractions; may reduce other types of intersection accidents and improve aesthetics.
	Selective traffic enforcement	Enforce violations of the NTOR sign and the requirement to complete a full stop before turning right on red where permitted; other pedestrian and motorist laws can also be enforced simultaneously.	Enforcement or police presence near the intersection may reduce other violations; effectiveness may diminish once the police leave, because manpower is limited in most agencies; police time may be better spent in other areas of traffic enforcement or crime protection.

APPENDIX F - SAMPLE PEDESTRIAN O & D SURVEYS

______________ DOWNTOWN SURVEY

This survey is being conducted to improve ____________ shopping district. Your participation in this survey will help to make ____________ a better place to shop. All responses are confidential. Thank you for your co-operation!

OFFICE USE ONLY:

(1) Site: ____________
(2) Day: 1 M-F
2 S/S
(3) TIME: 1 (10-11:59)
2 (noon-2 pm)
3 (2:01-4 pm)
4 (4:01-6 pm)

(4) Q-1A How did you arrive here today? (circle 1 number)

1 Walk
2 Auto
3 Bus (local)
4 Bus (inter-city)
5 Bike
6 Taxi
7 PATH
8 NJ Transit
9 Other (specify): ______________

(5) Q-1B If you came by car, where did you park? (circle 1 number)

1 Washington Street (metered space)
2 Washington Street (double parked)
3 Sidestreet (specify): ______________
4 Parking garage/lot (specify): ______________

(6) Q-2 How long did it take you to get here? (circle 1 number)

1 Five minutes or less
2 6-10 minutes
3 11-15 minutes
4 16-30 minutes

(7) Q-3A Where are you coming from? (circle 1 number)

1 Home
2 Work
3 School
4 Other (specify): ______________

(8) Q-3B If you are coming from work, what is the zip code of your employer? ____________

(9) Q-4 Are you here today ...... (circle 1 number)

1 Alone
2 With 1 other person
3 With 2 other people
4 With 3 other people
5 With 4 or more other people

Q-5 What are all the things you are doing in ________ shopping district today? (circle all applicable numbers)

(10) 1 Working
(11) 2 Major shopping
(12) 3 Errands
(13) 4 Eating in a restaurant
(14) 5 Purchasing take out food
(15) 6 Strolling or window shopping
(16) 7 Meeting friends and socializing
(17) 8 Passing through
(18) 9 Visiting a professional office (Doctor or lawyer)
(19) 10 Banking
(20) 11 Other (specify):______________________

(21-22) Q-6 What is your main reason for being downtown today, using the above list? (please enter a number only) #___________

(23) Q-7 How long do you expect to be in this area today (not including your work time) (please circle 1 number)

1 15 minutes or less
2 16 to 30 minutes
3 31 to 60 minutes
4 over an hour

(24) Q-8 How important is patronizing downtown business to you?

1 Very important
2 Somewhat important
3 Important
4 Not very important
5 No opinion

(25) Q-9 How frequently do you come to ________ shopping district? (circle 1 number)

1 1 or more times a day
2 2 or more times a week
3 Once a week
4 2 or more times each month
5 Once a month
6 Less than once a month

(26-27) Q-10 What one product do you tend to purchase most frequently in ___________ shopping district?

____

(28) Q-11 For how many years have you been continuously patronizing the shops in downtown ________ on a regular basis? (circle 1 number)

1 Less than 1 year
2 1 to 3 years
3 4 to 6 years
4 7 to 10 years
5 over 10 years

(29) Q-12 Within the past 5 years, how frequently have you been shopping in downtown __________? (circle 1 number)

1 More
2 Less
3 About the same
4 Don't know (have been in the area less than 5 years)

Q-13 Where would you be most likely to do or purchase the following? (circle the number)

		Seacacus	Paramus Park Mall	Bergen Mall	Garden State Plaza	NYC	Van Dyke Plaza
(30)	Groceries	1	2	3	4	5	6
(31)	Clothing	1	2	3	4	5	6
(32)	Shoes	1	2	3	4	5	6
(33)	Furniture	1	2	3	4	5	6
(34)	Toiletries and Medicine	1	2	3	4	5	6
(35)	Gifts	1	2	3	4	5	6
(36)	Appliances	1	2	3	4	5	6
(37)	Jewelry	1	2	3	4	5	6
(38)	Dine in a restaurant	1	2	3	4	5	6
(39)	Get hair styled/cut	1	2	3	4	5	6

Q-14 How would you rate the ________ shopping district for the following? (circle the number)

		Excellent	Good	Fair	Poor	Don't Know
(40)	Attractiveness of store facades	1	2	3	4	5
(41)	Attractiveness of window displays	1	2	3	4	5
(42)	Quality of eating places	1	2	3	4	5
(43)	Cleanliness	1	2	3	4	5
(44)	Number of convenient parking spaces	1	2	3	4	5
(45)	Smoothness of traffic flow	1	2	3	4	5
(46)	Safety (day)	1	2	3	4	5
(47)	Safety (night)	1	2	3	4	5
(48)	Convenience of shopping hours	1	2	3	4	5
(49)	Quality of goods sold and services offered	1	2	3	4	5
(50)	Variety of goods sold and services offered	1	2	3	4	5

(51) Q-15 Approximately how much did you spend today, including food, in __________ shopping district?

1 Less than $5.00
2 $5.00 - $10.00
3 $11.00 - $25.00
4 $26.00 - $50.00
5 $51.00 - $100.00
6 Over $100.00

(52-53) Q-16 Aside from ________, what other shopping districts have you regularly patronized during the past 3 months? (please do not list more than 3)

____
____
____

(54-55) Q-17 What types of shops would you like to see in __________ shopping district that are not already here? __________

____
____
____

Q-18 What types of places do you regularly patronize in ________ ____'s shopping district? (circle all applicable)

(56) 1 Supermarket
(57) 2 Grocery store
(58) 3 Home furnishings/appliances
(59) 4 Drug store
(60) 5 Restaurants
(61) 6 Banks
(62) 7 Doctor or lawyer's office
(63) 8 Variety store
(64) 9 Business offices
(65) 10 Social club
(66) 11 Antique shop
(67) 12 Gifts/Craft shop
(68) 13 Other (specify):__________

Past research has shown that people of different age, sex and income levels view downtown differently. We want to see if this is true in __________. This information is, of course, completely confidential.

(69) Q-19 Circle your sex:

1 Male
2 Female

(70) Q-20 Circle your age:

1 Under 18
2 18-25
3 26-30
4 31-35
5 36-40
6 41-45
7 46-50
8 51-55
9 56-60
10 61-65
11 Over 65

(71-72) Q-21 Which 1 of the following categories best describes your occupation?

1 Homemaker
2 Performing/visual artist
3 Professional/technical
4 Manager/administrator
5 Sales
6 Clerical/secretary
7 Craftsworker
8 Machine operator/laborer
9 Service worker
10 Student
11 Retired
12 Unemployed
13 Other (specify):________________

(73) Q-22 If you work, are you a ....

1 Full-time employee
2 Part-time employee

(74-75) Q-23 What is your total yearly income of your household? (circle 1 number)

1 Under $10,000
2 $10,001 - $15,000
3 $15,001 - $20,000
4 $20,001 - $25,000
5 $25,001 - $30,000
6 $30,001 - $35,000
7 $35,001 - $40,000
8 $40,001 - $45,000
9 $45,001 - $50,000
10 Over $50,000

(76) Q-24A How many people, other than yourself, live in your household? (circle 1 number)

1 None
2 1
3 2
4 3
5 4
6 5
7 6
8 7
9 8 or more

(77) Q-24B Of these people, how many are wage earners? (circle 1 number)

1 None
2 1
3 2
4 3
5 4
6 5
7 6
8 More than 6

(78) Q-25 Are you the head of the household? (circle 1 number)

1 Yes
2 No

(79) Q-26 What do you like <u>most</u> about downtown __________?

____

(80) Q-27 What are your suggestions for improving __________'s shopping district?

____

____

____

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