Chapter 1

Introduction to Pedestrian Facilities

1. Pedestrian Activity in New Jersey

All trips involve walking, irrespective of their primary mode. Many trips, especially those under 1.6 kilometers (1 mile) in length, are made solely on foot. Nationally, at least 8.5% of all trips are walking trips.

Between 2.5% and 6% of all *work* trips in the US are made via walking. In New Jersey, this share averages 4.1% and ranges from a high of 10.9% in Hudson County to a low of 0.2% in Passaic County (See Table 1).

Table 1:
Pedestrian Work Trips in New Jersey

County	Percent of Workers Walking to Work
Hudson	10.86
Atlantic	6.09
Mercer	5.86
Cape May	5.31
Essex	4.95
Burlington	3.97
Union	3.88
Warren	3.74
Bergen	3.46
Cumberland	3.41
Camden	3.19
Middlesex	3.16
Monmouth	3.01
Salem	2.78
Gloucester	2.58
Ocean	2.32
Hunterdon	2.29
Morris	2.22
Somerset	1.98
Sussex	1.78
Passaic	0.16

Source: 1990 Census

The 1990 Census shows that 156,500 New Jerseyans (4.1%) walk to work. After driving alone (71.6%), carpooling (12.4%) and using buses (5.4%), walking is the most frequent mode of commuting in New Jersey. Almost as many New Jerseyans walk to work as take the bus.

Despite the importance of the pedestrian travel mode, the expenditure spent on pedestrian facilities across the State is a very small fraction of that spent on other travel modes. Money that is spent for pedestrians tends to be utilitarian and minimal for the most part, aimed at merely accommodating pedestrian movement, rather than fostering it.

Walking to school accounts for at least one third of all pedestrian miles in the US. Providing adequate and safe facilities for such trips is therefore a very important component of planning for pedestrians.

Walking for shopping and business is a function of the land use pattern and can range from 3% for the typical suburban shopping center to as much as 90% for convenience stores in dense Suburban Activity Centers. Shopping averages 9% of all daily pedestrian trips.

Recreational walking and jogging is increasingly popular as public awareness of health and fitness expands. Social and recreational walking trips account for 12% of all pedestrian trips. Almost 90% of suburban area residents walk for exercise and recreation. Up to one-third do so at least five days per week and more than one-third also run or jog. The self-evident benefits of both recreational and functional walking in terms of health and energy savings are complemented by more subtle benefits that include increased neighborliness and a heightened awareness of the manmade and natural environment.

Data on pedestrian accidents shows that most accidents (around 60%) occur between 2:00 PM and 10:00 PM, peaking with the rush hour. Most susceptible to accidents are children, teenagers and the elderly. About one-third of the victims of both urban and rural accidents are children under 10 years of age; teenagers account for another 19% (urban) to 29% (rural); and the elderly (65 years plus) represent another 6% (rural) and 19% (urban) of accidents. The most common types of urban and rural pedestrian accidents - dart-outs, mid-block and intersection-dash - can all likely be reduced through proper design for pedestrians.

These Planning & Design Guidelines address the needs of pedestrians in all of the above settings and for all of these trip purposes. The Guidelines are concerned with defining appropriate facilities and design criteria to accommodate and foster pedestrian movement as well as to make it safer.

Since these guidelines are a companion document to NJDOT's Bicycle Compatible Roadways and Bikeways, it is appropriate to discuss the relationship between pedestrian and bicycle domains in general terms. While both functions need to be carefully planned for, the movement characteristics and needs of pedestrians and bicycles differ in obvious ways. The greater speed and size of the bicycle and rider means that, in general, bicycles are best accommodated as part of the roadway and not on sidewalks. Additional outside lane dimensions or widened shoulders perform this function most typically. For recreational pathways and other unique circumstances (e.g., certain bridges), pedestrian and bicycle movement is sometimes combined if adequate width can be provided and usage is not intense.

2. Goals and Visions for Pedestrian Use

The Intermodal Surface Transportation Efficiency Act (ISTEA) set a new direction for surface transportation in America that is enunciated in its statement of policy:

> ***"to develop a National Intermodal Transportation System that is economically efficient, environmentally sound, provides the foundation for the Nation to compete in the global economy and will move people and goods in an energy efficient manner."***

Provisions for walking, with its potential for providing economically efficient transportation, became an important policy goal of ISTEA. The Secretary of Transportation was directed to conduct a national study that developed a plan for the increased use and enhanced safety of bicycling and walking. The National Bicycling and Walking Study - Transportation Choices for a Changing America presents a plan of action for activities at the Federal, State and local levels for meeting the following goals:

- To double the current percentage (from 7.9 percent to 15.8 percent) of total trips made by bicycling and walking; and
- To simultaneously reduce by 10 percent the number of bicyclists and pedestrians killed or injured in traffic crashes.

The potential for increasing the number of pedestrian trips is evident in the National Personal Transportation Survey, which shows that more than a quarter of all trips are 1.6 kilometers (one mile) or less, and 40 percent are 3.2 kilometers (two miles) or less. Almost half are 4.8 kilometers (three miles) or less and two-thirds are 8.0 kilometers (five miles) or less. Approximately 53 percent of all people live less than 3.2 kilometers (two miles) from the nearest public transportation route.

New Jersey residents have become aware of the energy, efficiency, health and economic benefits of walking for transportation and recreational purposes. In 1995, New Jersey Department of Transportation completed a statewide plan that established policies, goals and programmatic steps to promote safe and efficient walking for transportation and recreation in New Jersey. Through an extensive outreach effort, residents established a statewide vision for the future of bicycling and walking for all communities in New Jersey:

> ***"New Jersey is a place where people choose to bicycle and walk. Residents and visitors are able to conveniently walk and bicycle with confidence and a sense of security in every community. Both activities are a routine part of transportation and recreation systems."***

In order to achieve this vision for New Jersey, it is necessary to plan and provide appropriate facilities that will accommodate, encourage and promote walking. This document provides direction regarding how appropriate facilities for pedestrians should be provided.

3. Pedestrian Characteristics and Level of Service Standards

This section presents some basic definitions of concepts and characteristics of pedestrian movement, their relationship to various land use contexts and common pedestrian accident types. It is designed as a resource when planning for pedestrian movement.

Where pedestrian movement is very dense, such as on pedestrian bridges or tunnels, at intermodal connections, outside stadiums, or in the middle of downtown, then pedestrian capacity analysis may be needed. Research has developed a Level of Service concept for pedestrians that relates flow rate to spacing and walking speed. Table 2 presents some of these data. In most situations, however, this level of analysis is unnecessary and simpler standards can be applied.

Table 2

Pedestrian Flow Characteristics on Walkways and Stairs

	Level of Service					
	A	B	C	D	E	F
Flow rate (ped./min./ft.)						
Walkways	<2	2-6.25	5.26-10	10-15	15-25	Variable
Stairs up	<5	5-7	7-10	10-13	13-17	Variable
Stairs down	<6	6-8	8-11	11-14	14-19	Variable
Spacing (sq. ft./ped.)						
Walkways	>130	40-130	24-40	15-24	6-15	<6
Stairs	>20	15-20	10-15	7-10	4-7	<4
Walking speed (ft./min.)						
Walkways	>260	250-260	240-250	225-240	150-225	<150
Stairs up	100	100	100	90-100	70-90	<70
Stairs down	120	120	120	100-120	75-100	<75

Source: Highway Capacity Manual, 1994.

Note: See Metric Conversion Tables in Appendix.

An average walking speed of 1.2 meters per second (four feet per second) has been used for many years. There is a growing tendency to use 1.1 meters per second (3.5 feet per second) as a general value and 0.9 or 1.0 meters per second (3.0 or 3.25 feet per second) for specific applications such as facilities used by the elderly or handicapped. Table 3 presents walk/trip characteristics by trip purpose based on a national sample. In assessing the probability of pedestrian trip making, these averages can serve as a helpful rule of thumb. Similarly, Figure 1 shows pedestrian trip generation rates for different land uses. Where roads abut such uses, either existing or proposed, these numbers provide an indication of potential trip making activity. The Highway Capacity Manual provides procedures for the operational analysis of walkways, crosswalks and street corners.

Specific accident classification types have been developed for pedestrian collisions. Accidents often occur because of deficient roadway designs or traffic control measures and/or due to improper behavior on the part of motorists and pedestrians. Examples of some of the more common types of pedestrian accidents and their likelihood of occurrence are shown in Figures 2 and 3.

Table 3

Walk Trip Characteristics by Purpose

	Daily pedestrian miles traveled in millions No. (%)	Average walk trip length (in miles)	Average trip time (in minutes)
To or From Work	0.18 (5.0%)	0.3	8.6
Work Related	0.23 (6.4%)	0.6	15.0
Shopping	0.33 (9.2%)	0.2	10.1
Other Family or Personal Business	0.19 (5.3%)	0.2	7.7
School/Church	1.15 (32%)	0.4	10.6
Doctor/Dentist	0.20 (5.6%)	0.6	19.4
Vacation	0.02 (0.5%)	0.7	19.8
Visit Friends or Relatives	0.12 (3.4%)	0.1	7.2
Other Social or Recreational	0.61 (17%)	0.5	11.8
Other	0.54 (15%)	0.5	12.5
TOTAL	3.57 (100%)		

Source: National Personal Transportation Survey, 1992.

Note: See Metric Conversion Tables in Appendix.

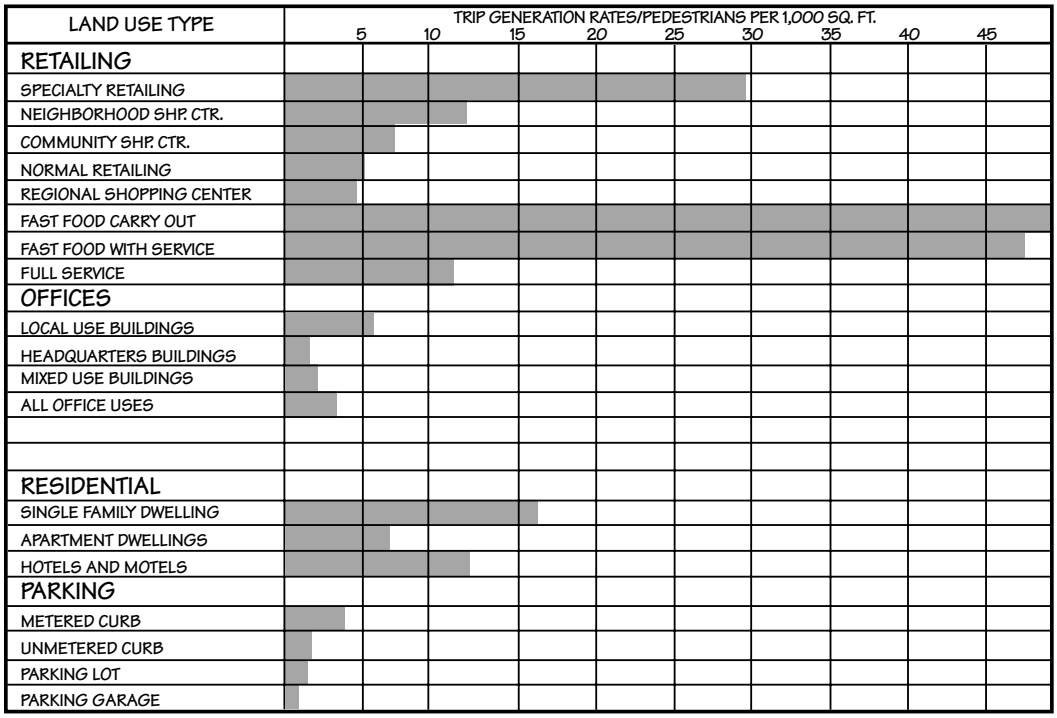


Figure 1

Pedestrian Trip Generation Rates by Land Use Type

Source: A Pedestrian Planning Procedures Manual, FHWA, 1979.

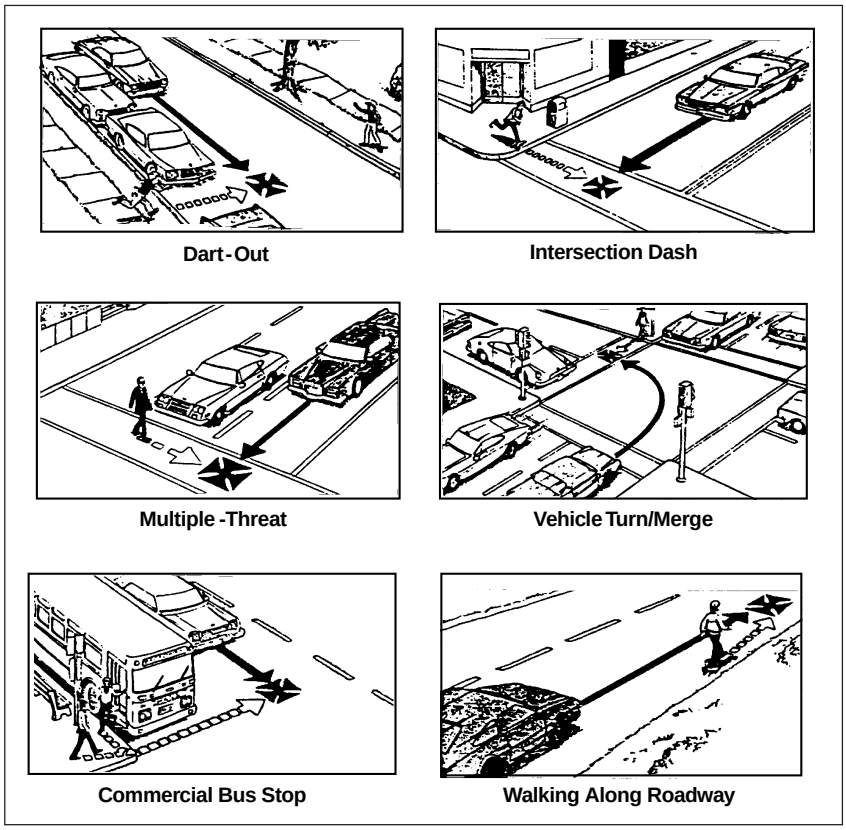


Figure 2

Common Types of Pedestrian Accidents

Source: Planning, Design and Maintenance of Pedestrian Facilities, FHWA, 1989

Figure 3

Pedestrian Accident Types (Urban Areas)

DART-OUT (FIRST HALF) (24%)
- Midblock (not at intersection)
- Pedestrian sudden appearance and short time exposure (driver does not have time to react)
- Pedestrian crossed less than halfway

DART-OUT (SECOND HALF) (10%)
- Same as above except pedestrian gets at least halfway across before being struck

MIDBLOCK DASH (8%)
- Midblock (not at intersection)
- Pedestrian running but *not* sudden appearance or short time exposure as above

INTERSECTION DASH (13%)
- Intersection
- Same as dart-out (short time exposure or running) except it occurs at an intersection

VEHICLE TURN-MERGE WITH ATTENTION CONFLICT (4%)
- Vehicle turning or merging into traffic
- Driver is attending to traffic in one direction and hits pedestrian from a different direction

TURNING VEHICLE (5%)
- Vehicle turning or merging into traffic
- Driver attention *not* documented
- Pedestrian *not* running

MULTIPLE THREAT (3%)
- Pedestrian is hit as he steps into the next traffic lane by a vehicle moving in the same direction as vehicle(s) that stopped for the pedestrian
- Collision vehicle driver's vision of pedestrian obstructed by the stopped vehicle

BUS STOP RELATED (2%)
- Pedestrian steps out from in front of bus at a bus stop and is struck by vehicle moving in same direction as bus while passing bus

VENDOR-ICE CREAM TRUCK (2%)
- Pedestrian struck while going to or from a vendor in a vehicle on the street

DISABLED VEHICLE RELATED (1%)
- Pedestrian struck while working on or next to a disabled vehicle

RESULT OF VEHICLE-VEHICLE CRASH (3%)
- Pedestrian hit by vehicle(s) as a result of a vehicle-vehicle collision

TRAPPED (1%)
- Pedestrian hit when traffic light turned red (for pedestrian) and vehicles started moving

WALKING ALONG ROADWAY (1%)
- Pedestrian struck while walking along the edge of the highway or on the shoulder

OTHER (23%)
- Unusual circumstances, not countermeasure corrective

Source: Florida Pedestrian Safety Plan, FDOT, 1992

4. Integrating Pedestrian Facilities into the Highway Planning Process

Guidelines on the design of a range of specific pedestrian facilities,including sidewalks, shoulders, medians, crosswalks, curb ramps, etc., are provided in Chapter Two. This section provides a policy context or criteria for the selection of appropriate facilities.

The selection of appropriate pedestrian facilities for different situations may be based on two factors:

- pedestrian facility problems or conditions that typically occur, and potential solutions related, for example, to cross section design, signalization, institutional or legal issues
- pedestrian safety factors and the potential enforcement/regulatory, engineering and physical countermeasures for these situations

Both site specific facility conditions and safety factors should be used and evaluated to select roadway improvements for pedestrians.

Table 4 presents a summary of pedestrian facility problems and potential solutions. Many of the concepts and design treatments presented in Chapter Two are addressed.

Figures 4 and 5 illustrate in matrix format the relationship between pedestrian accident types and their potential engineering and educational countermeasures.

Table 4
Summary of Pedestrian Facility Problems and Possible Solutions

Description of Problems	Magnitude of Problem	Possible Solutions	Current Level of Use Of Acceptance	Limitations in Applicability	Potential Effectiveness	Barriers to Implementation	Cost	Impact on Other Groups	Comment
Cross-section Design									
Difficulty of crossing wide arterial street, especially undivided arterials	Major	1. Install medians on all new suburban highways or 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 hwys.	Low	Must usually narrow lanes on existing hwys. to accommodate refuge islands. Must be well lighted.	High	Moderate	Low to moderate	Minimal impact	This solution is greatly under- utilized in US
		3. Design for reduced street width between signalized intersections (since capacity constraints are at signals).	Low	Could only be done where spacing between intersections is high.	Moderate	High	Low	Negative	Probably not feasible as a general practice.
		4. Introduce additional traffic signals to facilitate ped crossing.	Low	Could only be done in a few selected locations.	Moderate	High	Moderate	Highly negative	More feasible where ped crossings are concentrated at a point.
		5. Provide midblock actuated flashing ped signal.	Low	Should only be installed in key locations.	Moderate	Moderate	Low	Slightly negative	Designed to inform driver of presence of ped. Does not necessarily make crossing easier.
		6. Provide ped overpass.	Low	Only effective where at-grade crossing is blocked or is inconvenient.	Moderate - depends on no. of peds.	Moderate	High	Positive	Lack of use of facility continues to be a problem.
Difficulty of crossing highways 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.

Table 4
Continued

Description of Problems	Magnitude of Problem	Possible Solutions	Current Level of Use Of Acceptance	Limitations in Applicability	Potential Effectiveness	Barriers to Implementation	Cost	Impact on Other Groups	Comment
No facilities provided for ped to walk along side of road	Major	1. Require sidewalk/ pathway with all new hwy. 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 obtaining 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	
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 through geometric design.
		3. Provide speed control devices (e.g., speed bumps, 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.

Table 4
Continued

Description of Problems	Magnitude of Problem	Possible Solutions	Current Level of Use Of Acceptance	Limitations in Applicability	Potential Effectiveness	Barriers to Implementation	Cost	Impact on Other Groups	Comment
Safety/convenience of walking in commercial area with many poorly channelized driveways	Moderate to major	1. Consolidate drive-way entrances. Requires local regulation.	Low	Feasible in some newly developing strips. Generally infeasible in existing strips.	High	High	Moderate in new strips	Both positive and negative impacts	
		2. Provide service road in newly de-veloping areas.	Low	Must have ample right-of-way.	Low to moderate	High	High	Both positive and negative 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 in financing would usually be needed.
Difficult and hazardous pedestrian movement through interchange area	Major	1. Provide sidewalk and markings on all new inter-changes acces-sible 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 be-tween traffic lanes and ped walkways.	Low	Not necessary for low speed facilities.	Moderate	High	Moderate	Minimal impact	Provides additional measure of safety for pedestrians.
		3. For existing inter-changes w/o side-walk 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 pro-gram, 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 construc-tion with provision for recovering costs from land owner when development occurs.	Low	Legal mechanism must be provided to cover costs.	High	Medium	Low	Minimal impact	Allows sidewalk to be completed even if area is only partially developed.
		3. Obtain easements or take part of road-way 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.

Table 4
Continued

Description of Problems	Magnitude of Problem	Possible Solutions	Current Level of Use Of 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 frontages.	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 clear view 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, school, etc.	High	Moderate	Low	Varies by circumstance	Impact depends on nature of traffic congestion.

Table 4
Continued

Description of Problems	Magnitude of Problem	Possible Solutions	Current Level of Use Of Acceptance	Limitations in Applicability	Potential Effectiveness	Barriers to Implementation	Cost	Impact on Other Groups	Comment
Pedestrians frequently do not obey signal indications	Moderate	1. Upgrade ped enforcement effort.	Low	If done, should be selective enforcement.	Low	High	High	Slightly positive	Although lack of compliance is rampant, impacts are not necessarily negative.
Lack of or 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 widespread 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/under pass 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 crossing points	Moderate to high	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	Positive	Contrast to normal lighting provides greater conspicuity at key points.

Table 4
Continued

Description of Problems	Magnitude of Problem	Possible Solutions	Current Level of Use Of Acceptance	Limitations in Applicability	Potential Effectiveness	Barriers to Implementation	Cost	Impact on Other Groups	Comment
Institutional and Legal Problems									
General lack of respect for 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.
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 ped needs	Major	1. Establish citizen task force on pedestrian needs.	Low	None	High	Moderate	Low	Positive	Relies on citizens taking an interest.
		2. Establish pedestrian facility "hotline."	Low	None	Moderate	Moderate	Low	Positive	Provides recognized avenue for input.

Table 4
Continued

Description of Problems	Magnitude of Problem	Possible Solutions	Current Level of Use Of Acceptance	Limitations in Applicability	Potential Effectiveness	Barriers to Implementation	Cost	Impact on Other Groups	Comment
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.
		1. 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.

Source: Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas, **Transportation Research Board, 1987.**

Figure 4

Matrix - Pedestrian accident types and potential engineering countermeasures

Accident Type \ Countermeasures	Barrier: Median	Barrier: Roadway/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	Vehicular Traffic Division
	Engineering and Physical																					
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									•													

Source: Florida Pedestrian Safety Plan, FDOT, 1992

* Dots designate countermeasures believed to positively affect behavior/accident types.

Figure 5

Matrix - Pedestrian accident types and potential educational countermeasures

Accident Type \ Countermeasures	Parental Guidance	Traffic Safety Clubs	Television Programs	Walking in Traffic Safely	Watchful Willie	Officer Friendly	Demonstrations by Patrols	Education Within the Curriculum	Green Pennant Program	"Big Wheel" Spot	Willy Whistle Program	Child Intersection Dash Spot	"And Keep on Looking"	Assemblies	Drivers Education	Your Traffic Court	Talks to Groups	Community Action Program	Use of Mass Media	Multiple Threat Spot	Vehicle T/M Spot	Adult Intersection Dash Spot	Safety Courses	Talks to Groups	Community Contact Programs
	Pre-School					Elementary School								High School			General Public						Elderly		
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																									
Pedestrian Safety in General	•	•	•	•	•	•	•	•	•	•				•	•	•	•	•	•				•	•	•

Source: Florida Pedestrian Safety Plan, FDOT, 1992

* Dots designate countermeasures believed to positively affect behavior/accident types.

a. General Principles for Provision of Pedestrian Facilities

General principles for provision of pedestrian facilities that require consideration include the following:

- All roadways should have some type of walking facility out of the traveled way. A separate walkway is often preferable, but a roadway shoulder will also provide a safer pedestrian accommodation than walking on the road.
- Direct pedestrian connections should be provided 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.
- 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 can be related to the type, density and pattern of land uses in an area. Local residential streets, especially cul-de-sacs, can accommodate extensive pedestrian activity on the street because there is little vehicular activity. Minor collector streets, if they do not connect important origins, such as a residential cluster, with important destinations, such as a local shopping area, library or park, may have less pedestrian activity than the local street or cul-de-sac. However, if such collectors do perform an important linking function between land uses, then they may have more pedestrian usage than local roads and will require continuous sidewalks along both sides of the street. Collector streets are normally used by pedestrians to access bus stops and commercial developments on the arterial to which they feed. Sidewalks should be provided on all streets within a 0.4 kilometers (1/4 mile) of a transit station. Sidewalks should also be provided along developed frontages of arterial streets in zones of commercial activity.
- Collector and arterial streets in the vicinity of schools should be provided with sidewalks to increase school trip safety.

b. Factors in Identifying Need

Variations in development density, spatial 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.

Specific warrants based on pedestrian volumes are not established for sidewalks. Actual counts may not reflect the demand for pedestrian facilities because existing conditions may be so inadequate as to discourage pedestrian use and because weather conditions, school schedules, holidays and similar factors may cause significant fluctuations in daily pedestrian usage.

In general, sidewalks are considered warranted whenever the roadside and land development conditions are such that pedestrians regularly move or will move along the highway. Sidewalks should be constructed along any street or highway in developed areas having an AADT greater than 1200 and not provided with shoulders, even though pedestrian traffic may be light.

At a minimum, 1.5 meter (5 foot) sidewalks should be included on both sides of all roadways in Centers, as defined in the New Jersey State Planning Commission's State Development and Redevelopment Plan (SDRP), except limited access highways, unless unique land use patterns assure that no pedestrians will walk on one side. This dimension allows two adults to walk comfortably side-by-side or pass each other. Outside of Centers, 1.2 meter (4 foot) sidewalks provide an acceptable width for lightly used sidewalks and have traditionally been used as the minimum requirement in subdivision ordinances. Every effort should be made to add sidewalks to all existing streets in Cen-

ters where they do not exist, and to complete missing links. The priority for completing these links should go to areas serving schools, parks, transit stations and bus stops, libraries, military bases, recreation centers, tourist zones, and where high levels of elderly pedestrians can be anticipated.

Sidewalks should be included in all residential and commercial development plans submitted to public agencies in Centers, and in almost all development plans in Planning Areas 1 and 2.

c. Policies to Support Sidewalk Installation

The State Planning Commission's Report on Implementation Issues recommends that all long range and comprehensive plans include a pedestrian circulation element. Circulation should be planned to connect sidewalks and other pedestrian facilities with neighborhood shopping, recreational and public transit facilities. A plan to provide sidewalks on at least one side of all future neighborhood streets is required.

All MPO's should submit a ten year plan to provide sidewalks on both sides of all collector and arterial roads within the urbanized area.

To make up for the deficit of sidewalks on State system roadways, the following actions are highly encouraged for all designers or project managers:

- Extend project boundaries to include sidewalks for 1.6 to 3.2 kilometers (1 to 2 miles) on either end of a roadway improvement project to provide continuity to pedestrian travel. Sidewalks should continue to common destinations and reasonable terminal points.
- Work with community officials to add sidewalks to streets adjacent or parallel to arterial roads. This provides pedestrians with trip continuity and an alternative to busy arterials. This can help relieve congestion on the arterial.
- Whenever possible NJDOT should group a number of sidewalk improvements as a single independent sidewalk improvement project.

d. Policy Framework for the Provision of Sidewalks by the State

The 1992 SDRP seeks to change future development patterns by creating new compact, mixed-use settlement patterns in Centers of various kinds and encouraging the growth or redevelopment of existing Centers. This relates to and fulfills numerous other goals in the Plan, such as reducing sprawl and its associated consumption of rural land and character, maximizing the use of existing and contiguous infrastructure, increasing the potential for transit use, reducing excess infrastructure costs and revitalizing existing communities. This overall goal is captured in the Plan's title - "Communities of Place" - where the Centers become the pleasant and desirable focus of community activity and their core areas are the domain of the pedestrian:

> "In all cases the center core should be designed at a human scale. It should be a pedestrian-oriented area, with suitable amenities and infrastructure systems that encourage interaction within the community. The center core should group activities within walking distance, typically not more than one-half mile from origin to destination. Pedestrian routes should be safe, using sidewalks, walkways and paths that minimize conflict with vehicle and bicycle traffic. Architectural design guidelines, such as short to moderate building setbacks and the provision of street landscaping and furniture, are important for the physical elements that create a "sense of place." Coordination with school district master planning is also necessary, as schools can serve, and have often traditionally served, as focal points for educational, social, recreational, health care, and other activities within their communities."

The Plan calls for coordinating job growth areas with new housing areas so as to reduce lengthy solo auto trips and their associated pollution and to encourage a greater amount of walking trips. The Federal Clean Air Act Amendments identify New Jersey as a "non-attainment" state with 18 of its 21 counties identified as "severe" ozone areas; this further highlights the need for and importance of pedestrian planning. Concurrently, the Federal Intermodal Surface Transportation and Efficiency Act (ISTEA) legislation both points to and provides funding support for "enhancements" of the traditional, auto-oriented practices of transportation planning. These enhancements include pedestrian facilities for all trip purposes.

The SDRP requires coordination and consistency between the planning policies and actions of all State agencies. Since land use planning, transportation plans and pedestrian activ-

ity are all so interrelated, it is particularly important to relate the SDRP concepts to these Pedestrian Design Guidelines. Thus throughout the Guidelines, there are references to Centers and Planning Areas. (These terms are defined and discussed at length in the SDRP.)

In Table 5, SDRP's land use classification of Centers and Planning Areas is arrayed against different classes of State roads. The character of the roadways in these various settings and their potential for pedestrian use are related to State responsibilities for sidewalks. This table is designed as a guide only, since situations will occur that will elicit different responses than those indicated. Note that where sidewalks are not to be provided but where pedestrian movement may still occur on State roads, these Guidelines recommend provision of shoulders to accommodate this need.

Table 5:

Guide for Sidewalks in relation to the SDRP

	Composite Functional Classifications System for State Rural & Urban Roads				
	Interstate/Freeway [2]	Principal Arterial	Minor Arterial	Major Collector	Minor Collector/ Local Street
Centers [1]					
Urban Centers					
Core	❑	●	●	●	●
Dev. Area	❑	●	●	●	●
Town Centers					
Core	❑	●	●	●	●
Dev. Area	❑	❑	●	●	●
Regional Centers (new & existing)					
Core	❑	●	●	●	●
Dev. Area	❑	❑	●	●	●
Villages					
Core	❍ [3]	●	●	●	●
Dev. Area	❑	❑	❑	❍	❍
Hamlets	❍ [3]	❑	●	❑	❍
Planning Areas					
Metro (PA1)	❑	●	●	●	●
Subrbn (PA2)	❑	●	●	●	●
Fringe (PA3)	❍	❑	❑	❑	❑
Rural (PA4) [4]	❍	❍	❍	❍	❍
Env. (PA5)	❍	❍	❍	❍	❍

● Sidewalks required.
❑ Sidewalk optional.
❍ Sidewalk not required.

[1]Planning Areas consist of Centers and Environs. Criteria for designating the Centers is described in the SDRP, p93-100. Centers contain a Core, the densest "downtown" type area and a surrounding Development Area which is bounded by a Community Development Boundary. Outside this Boundary are the "environs" which are designated for less intensive development. Various Centers can occur in the different Planning Areas. Where this happens, the guide for sidewalk provisions in the Center takes precedence over the Planning Area guide.

[2]Sidewalk provisions for Interstate/Freeway classification column refer to cases where the pedestrian grid in urban areas is disrupted by the roadway, not necessarily areas along or parallel to the roadway itself.

[3]Many freeways bypass Villages and Hamlets and therefore their sidewalk provisions will be consistent with the Planning Area guidelines.

[4]On rural highways the use of curbs is not recommended and pedestrian walkways are provided along shoulders or in the roadside area. In Centers in Rural Planning Areas, however, curbs may be appropriate.

5. Integrating Pedestrian Facilities into the Municipal and County Planning Process

a. Overall Planning Process

Many of the problems pedestrians confront can be alleviated by planning pedestrian facilities within the framework of the overall planning process. Pedestrian considerations are often not given the priority they deserve 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. The following is a summary of actions which can be taken by local and State planning agencies to adequately provide for pedestrian facilities.

- Policy statements should be included in the State, regional, county and local master plans 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.

Systems of walkways and trails 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 as part of the circulation plan element of the master plan as described in the Municipal Land Use Law, N.J.S.A. 40:55D-28.b(4).

- 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 encourage the developer to provide pedestrian related design amenities.

- 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. A sample checklist is presented in Figure 6. 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.

b. Modifications to Local Plans and Ordinances that will Enhance Pedestrian Movement

This section illustrates how typical municipal land development ordinances may be modified to encourage pedestrian-friendly land development practices and to require provision of appropriate pedestrian amenities. Appropriate techniques are presented for each of the Planning Areas identified in the SDRP.

Metropolitan and Suburban Planning Areas (PA1 and PA2)

- Create options in the zoning ordinance for mixed use developments or Suburban Activity Centers with appropriate performance measures to cover the mix of land uses, transit relationships and pedestrian-oriented site planning.
- At a smaller scale, typically modules of 40-60 hectares (100-150 acres), provide the option in zoning ordinances for Traditional Neighborhood Design (TND) or neo-traditional site planning. The ordinance should require appropriate mixes of land uses and establish pedestrian-friendly streetscapes and road standards. Additional discussion of TND concepts is provided in Chapter Three.

- Allow small scale/retail/convenience services to locate within large employment concentrations to allow workers to walk for lunchtime, service and personal business trips.
- Modify typical highway commercial zones to allow transit friendly uses as permitted uses. Such uses include hotels, movie theaters, shopping centers, department and convenience stores, beauty and personal services, gyms, medium to high density residential development, 10 units per hectare (4 units per acre), cultural facilities, day care centers, middle/high schools and colleges, religious facilities, government agencies, correctional facilities, offices and financial institutions, medical facilities, employment parks and medium to high density manufacturing employment.
- Provide FAR incentives for appropriate types of pedestrian amenities (this can apply both in urban and suburban situations).
- Where reduced parking standards in commercial areas (for example, adjacent to transit systems) allow for additional retail square meters (square footage), require a pedestrian-friendly retrofit as a condition of granting additional square meters (square footage).
- Allow for PUDs; ensure that PUD ordinance language requires the construction of sidewalks on streets in addition to pathway systems through open space. Experience and research has shown that such pathways are frequently underused or perceived as unsafe unless they directly connect to attractive destinations. They cannot replace the need for sidewalks.
- In Centers, provide incentives for architectural design treatments which offer pedestrians protection from the elements, such as canopies or arcades.

Figure 6

Site Review Checklist for Pedestrian Facilities

Site Review Checklist for Pedestrian Facilities

Overall Pedestrian System:

- **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?**

Safety and Security:

- **Are crossings of wide expanses of parking lot held to a minimum?**
- **Are pathways generally visible from nearby buildings and free from dark, narrow passageways?**
- **Is adequate lighting provided for nighttime security?**
- **Are sight distances adequate for motorists to see pedestrians at intersections and other places where people are likely to enter the roadway?**
- **Do pathways lead to the safest crossing points?**
- **Are pedestrian/vehicle conflict points kept to a minimum?**
- **Are pedestrians clearly visible to traffic wherever they cross the street?**

Walking Surfaces and Amenities:

- **Are the walking areas scaled to the pedestrian?**
- **Are the walking surfaces skid-resistant and sloped for drainage?**
- **Are provisions made for curb ramps and are they properly designed?**
- **Are major changes in grade properly treated with stairways and handrails?**

Source: Planning, Design and Maintenance of Pedestrian Facilities, FHWA, 1989.

Suburban and Fringe Planning Areas*

- Consider modifications to road standards and subdivision regulations in the direction of current performance standards that are more tuned to functional classification.
- Sidewalk widths in suburban areas having a gross density greater than ten units per hectare (four units per acre) or where pedestrian volumes are high should be a minimum of 1.5 meters (5 feet) wide, rather than 1.2 meters (4 feet). Several studies support this dimension, which allows two people to walk comfortably side-by-side, rather than the more typical 1.2 meter (4 feet) standard which is too narrow. Where 1.2 meter (4 feet) sidewalks are allowed, ensure that 1.5 meter (5 feet) wide passing areas for wheelchairs are available every 60 meters (200 feet).
- Advocate separation of pedestrian sidewalks in suburban settings from the roadway by a grass strip of at least 0.9 meters (3 feet) wide.
- Dimensions for downtown area urban sidewalks should require a 1.2 meter (4 foot) zone for trees and street furniture and a 0.4 meter (1.5 foot) zone alongside the building facades, both of which are not part of the effective width of the sidewalk circulation area. Using a minimum effective sidewalk width of 2.2 meters (7.5 feet), this yields a total of 3.9 meters (13 feet) minimum. Where heavier use is anticipated, 5.4 meters (18 feet) is an appropriate minimum dimension. These urban settings generally apply in situations above 1500 pedestrians at the peak hour.
- Require construction of sidewalks or walkways along all arterial and collector roads located within 2.4 kilometers (1.5 miles) of a school.
- Require developers to extend sidewalks up to 120 meters (400 feet) beyond the boundary of the site to provide for sidewalk continuity.
- Municipal Master Plans should incorporate a pedestrian network or system as part of the circulation element of the master plan. Such an element should address both functional walking trips as well as recreational trips. Minimum components of the pedestrian element should be specified (e.g. inventory of current facilities, gaps in the system, any relationships or conflicts between bicycle and pedestrian use of facilities, areas of special focus such as mixed-use downtowns or transit centers, potential for enhancements, identification of high accident locations and incidents of pedestrian/vehicle conflict, etc.)
- Municipal Master Plan elements should include provisions that define and encourage linking of residential development and commercial areas by bicycle and pedestrian paths, even where roadway linkages are not present. These provisions may include "cut-throughs" between cul-de-sacs and retrofitting existing developments, as discussed further and illustrated in Chapter Three.
- State discretionary funds which are to be used through the SDRP or MPO as incentives to encourage local municipalities to develop appropriate plans, could specifically reference that NJDOT will allocate discretionary funds for sidewalks, landscaping, and other enhancements over and above the "minimum" only where municipalities have adopted community-wide pedestrian plans.

*** Note:** These techniques are applicable statewide, and need not be limited to the Suburban and Fringe Planning Areas.

Chapter 2

Guidelines for Accommodating Pedestrians on Roadways

1. Sidewalks

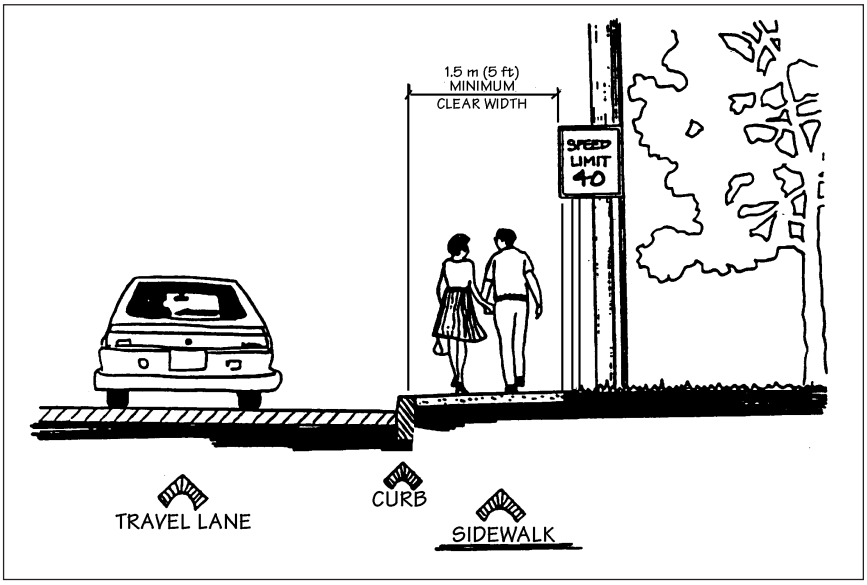
The minimum clear width of all sidewalks in Centers and where urban or suburban conditions apply (such as in PA1 and PA2), should be 1.5 meters (5 feet) exclusive of the curb (except on bridges where the sidewalk width will include the curb width). The 1.5 meter (5 feet) minimum clear width allows for safe and convenient pedestrian and handicapped travel through the following characteristics:

- Allows the sidewalk to adequately serve a collector function; accommodating pedestrian volumes and turning movements to and from adjacent properties.
- Allows persons with strollers, carriages or shopping carts or persons in wheelchairs or using walkers to easily pass each other.
- Provides queuing space for pedestrians at street corners and crosswalks.
- Allows two persons to travel abreast or pass.
- Provides space for children with tricycles, wagons or skates and provides space for other childhood games and activities while accommodating pedestrian use.

This clear width should be free of all trees, signs, utility poles, hydrants, parking meters, and other similar appurtenances. See Figures 7 and 8. The minimum vertical clearance to ceilings, sign panels and other overhead obstructions where pedestrians walk should be 2030 millimeters (80 inches).

The installation of sidewalks immediately adjacent to the curb is both uncomfortable and undesirable to pedestrians. They should only be placed there when severe right-of-way constraints exist.

Where sidewalks are adjacent to a parking lane, an additional 0.6 meters (2 feet) of width is required to compensate for the opening of car doors. See Figure 9. The minimum paved width, in this case, would then be 2.1 meters (7 feet) exclusive of the curb.



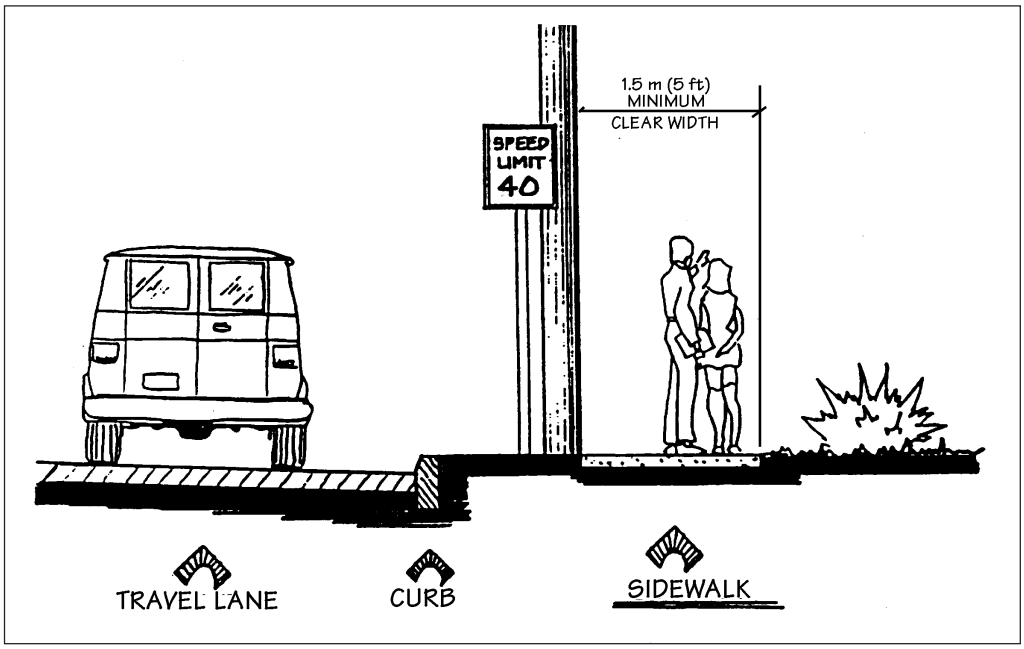
Source: Highway Design Manual, New York State Department of Transportation

Figure 7

Minimum Clear Width of Sidewalks

Figure 8

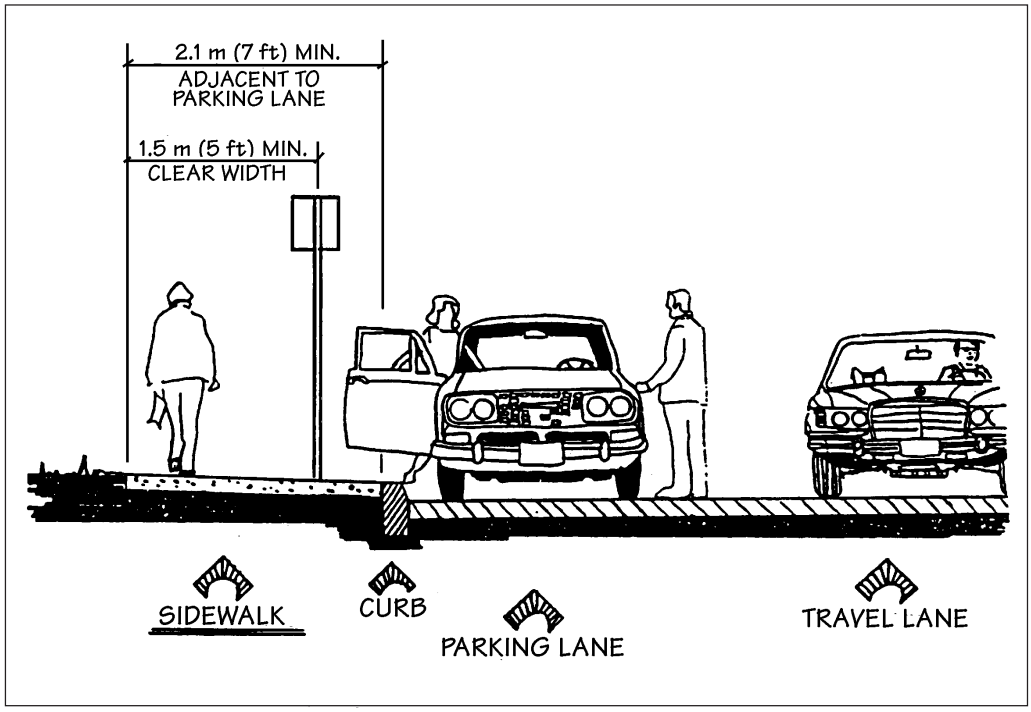
Minimum Clear Width of Sidewalks



Source: Highway Design Manual, New York State Department of Transportation

Figure 9

Sidewalks Adjacent to Parking Lane



Source: Highway Design Manual, New York State Department of Transportation

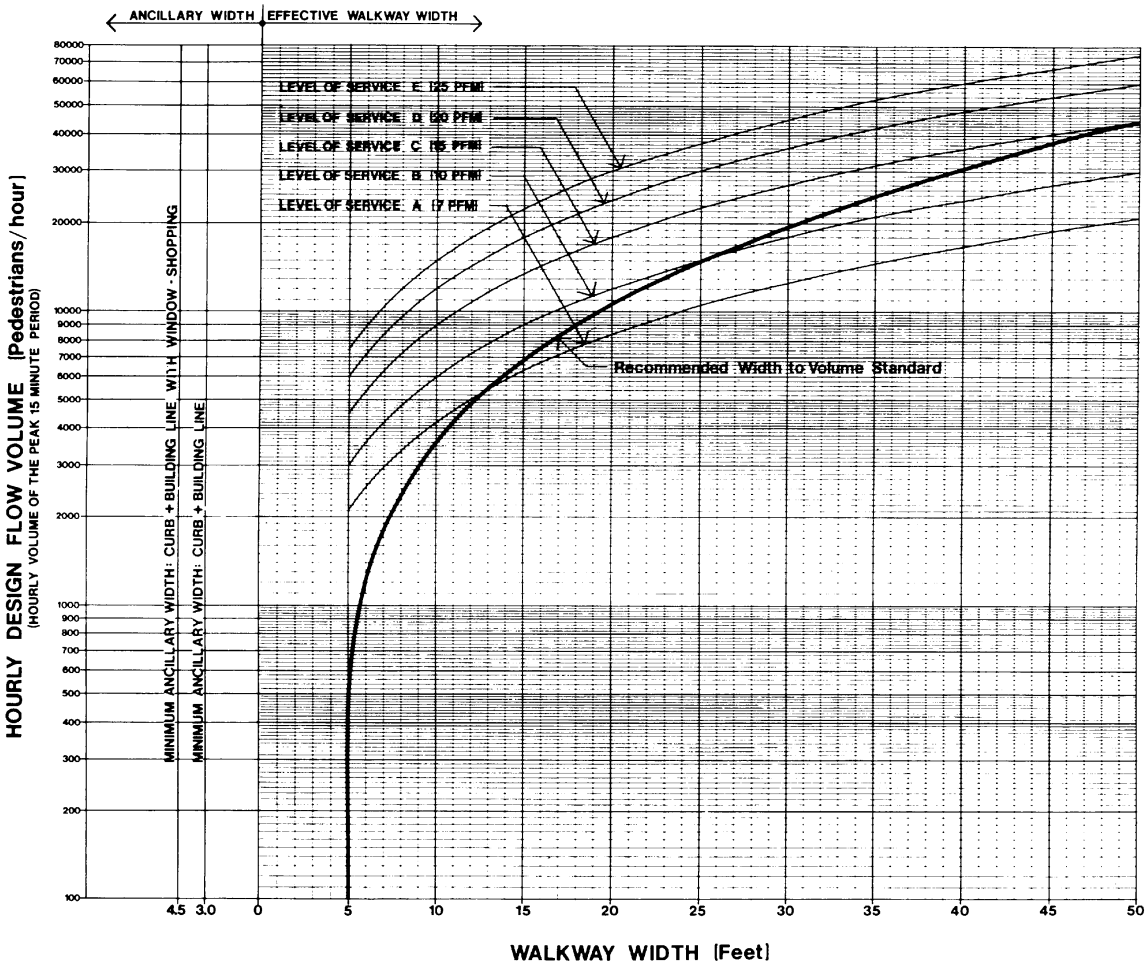
Every attempt should be made to design and construct a sidewalk free of obstructions. Every attempt should be made to place obstructions such as signs in the utility strip and not in the sidewalk. Often obstructions can be moved to adjacent property by obtaining easements or purchasing right of way. If they cannot be placed on the utility strip or removed, the sidewalk should be widened by the width of the obstruction.

The above comments apply in situations of light pedestrian traffic typical in suburban, fringe or rural planning areas. However, in Metropolitan Planning areas and in Centers, and especially in downtowns, sidewalks wider than 1.5 meters (5 feet) clear width must often be provided.

While pedestrian capacity analysis techniques described in the 1994 Highway Capacity Manual can be used to evaluate the widths of sidewalk required to accommodate higher levels of pedestrian flow, a more direct source is presented in Figure 10. Using this graph requires that pedestrian volumes be known. Data on existing or projected pedestrian volumes is usually not available, and generally volumes are not used as threshold criteria. However, where such data are available or can be generated, Figure 4 relates sidewalk dimensions to these volumes.

Figure 10

Hourly Design Flow Chart



Source: A Pedestrian Planning Procedures Manual, FHWA, 1979

Note: See Metric Conversion Tables in Appendix

Note that in addition to the effective walkway width, the ancillary walkway width (in which clearance requirements for buildings, curbs, window shoppers, trees, parking meters, hydrants, benches, etc. occur) must be added to yield the total sidewalk width. Figure 11 illustrates the derivation of these dimensions. In heavy pedestrian traffic areas, such as in the Central Business District (CBD), the utility strip should be replaced with additional sidewalk for maintenance purposes. This added sidewalk could be of a porous material, such as stone or brick, that can be easily removed and replaced. An exception should be allowed for landscaping areas.

The increased sidewalk needs apply most obviously to traditional "downtown" main streets; these standards, however, can also be used in larger suburban activity centers in either existing or planned regional cores where some increased pedestrian activity and continuity is a goal of the land use layout and the street system.

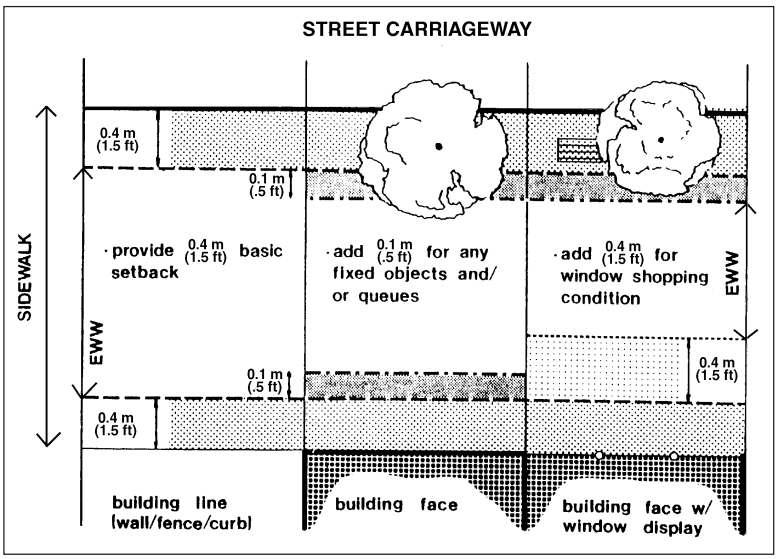
In areas with insufficient right-of-way to provide the standard 1.5 meter (5 foot) sidewalk, the following alternatives are offered.

- Use a reduced sidewalk width. However, a width of less than 0.9 meters (three feet) is too narrow for a wheelchair and also violates ADA regulations.
- Use a 0.6 meter (2 foot) utility strip with sign posts against the sidewalk or with signs behind the sidewalk.
- When traffic conditions permit, construct roads with narrower travel lanes to provide enough space for the sidewalk.
- Place sidewalk against curb. Some consideration should be given to installing a barrier curb between travel lanes and sidewalks for higher speed roads, particularly in school zones. AASHTO requires that sidewalks placed against curbs be a minimum of 1.8 meters (six feet) wide.
- Prohibit on-street parking, or single side parking, to make more of the existing right-of-way width available for a sidewalk.

In areas outside schools and other major pedestrian generators, the minimum width should be 2.4 meters (8 feet), to allow for gathering and movement needs. In Centers, sidewalk width and placement should be guided by Figure 11, using a minimum effective walkway width (EWW) of 1.5 meters (5 feet) and an overall minimum of 2.4 meters to 3.0 meters (8 feet to 10 feet) depending on edge conditions at the curb and building line. In downtown areas, an EWW of 2.2 meters (7.5 feet) and a total of about 3.9 meters (13 feet) is more appropriate.

Figure 11

Ancillary Walkway Width Requirements



Source: A Pedestrian Planning Procedures Manual, FHWA, 1979

2. Walkway Placement Within the R.O.W.

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. Increasing the setback distance has the added advantage of providing room for plantings and utilities and facilitates the design of curb ramps at intersections. However, installing a sidewalk on the very edge of a road is preferable to not having any sidewalk at all.

The desirable minimum space between edge of sidewalk and back of curb is 1.2 meters (four feet), although 2.4 meters (eight feet) or more is the preferred width on all but low traffic volume streets and roads. See Figures 12 and 13. This space accommodates snow storage and is generally grassed and planted with street trees. This space must be planned and designed to avoid clutter and visual screens which can contribute to safety problems. This width provides room for the majority of signs 915 millimeters (36 inches) or less without overhanging the street or sidewalk. Raising the signs to a 2.1 meter (seven foot) minimum clearance prevents most signs from being damaged by vehicles and impeding pedestrian travel. Furthermore, this space accommodates the following:

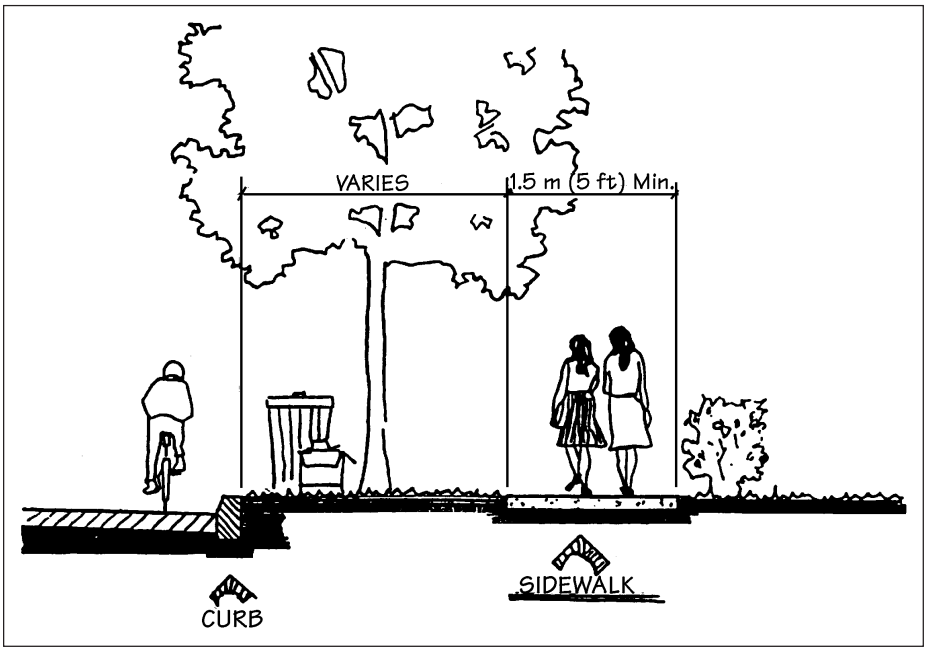
- Affords pedestrians walking or playing on the sidewalk greater protection.
- Allows storage space for trash and leaf collection and snow storage.
- Allows space to accommodate grade changes so that sidewalk grade variations at driveways are minimized.

The minimum width of a street tree planted strip should be 1.2 meters (four feet). Whenever widths less than 1.2 meters (four feet) are necessary, the strip should be at least 0.6 meters (two feet) wide to be seeded or sodded or it may be paved. Where widths less than 0.6 meters (two feet) are necessary, the strip should be paved.

When a minimum 1.2 meter (four foot) strip is not available, consideration can be given to providing tree planting behind the sidewalk, even if off the right-of-way. If off the R.O.W., property owner permission or easement is required before planting.

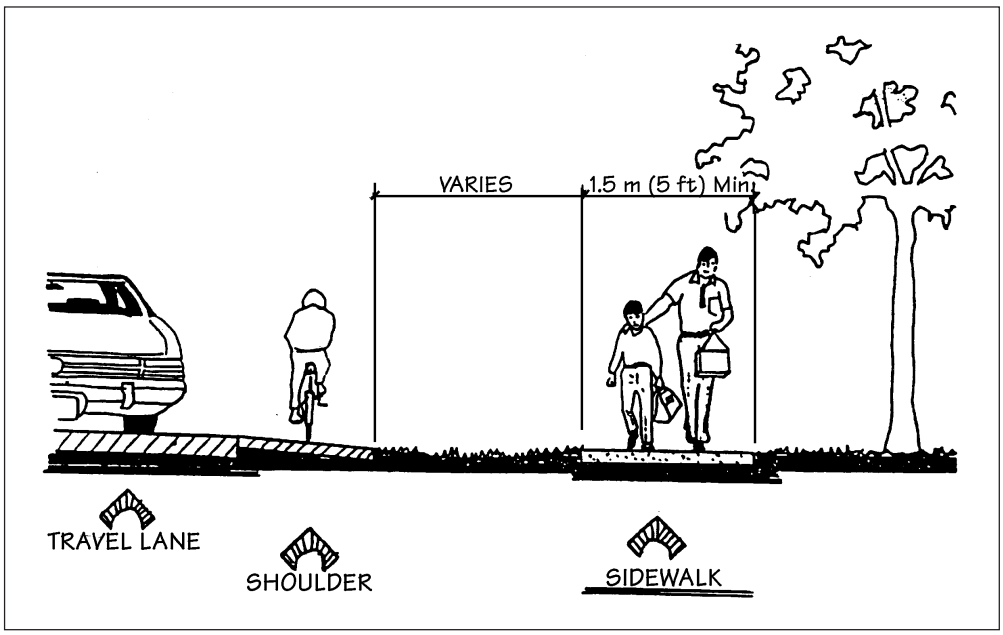
Figure 12

Sidewalk Distance from Travel Lane



Source: Highway Design Manual, New York State Department of Transportation

Figure 13
Sidewalk Distance from Travel Lane



Source: Highway Design Manual, New York State Department of Transportation

The installation of sidewalks on roadways without curb and gutter (rural section) creates several design, safety, and maintenance problems. The concern becomes how wide the clear zone or offset should be from the roadway. For installation of sidewalks on these roads, the design engineer should:

- Place sidewalks at the right-of-way line in sections of roadways without curbs and gutters.
- Consider potential sight restrictions due to vegetation and buildings.
- Consider the location of any drainage ditches. The pedestrian has little room for escape if the sidewalk is between the roadway and drainage ditch. If the sidewalk is behind the ditch, the ditch helps to redirect an out of control vehicle in a path parallel with the roadway. The pedestrian also has the opportunity of escaping onto private property.

3. Shoulders

Where sidewalks are not warranted, shoulders are generally considered adequate for pedestrian use when paved and at least 1.2 meters (four feet) wide.

Paved shoulder widths beyond 1.2 meters (four feet) are desirable and should be considered when one or more of the following conditions exist:

- Motor vehicle speeds exceed 65 km/h (40 mph)
- The percentage of trucks, buses and recreation vehicles exceeds 5%.
- Bicycle use of the shoulder is more than occasional.
- Pedestrian volumes are high, or groups of pedestrians typically travel together (e.g., routes to school).

Paved shoulder widths less than 1.2 meters (four feet) should be considered only on highways with AADT's of 2000 or less, with speeds less than 65 km/h (40 mph) and with only occasional pedestrian traffic. Project reports should support the decision to provide a shoulder less than 1.2 meters

(four feet) wide by including appropriate discussion concerning existing and expected pedestrian and motor vehicle traffic, relevant highway geometries, accident history and similar applicable data.

Lightly travelled rural roadways and suburban streets having an AADT less than 1200 seldom require a sidewalk or shoulder to accommodate pedestrians.

Figure 14 illustrates a high speed suburban arterial highway, provided with a 3.0 meter (10 foot) paved shoulder. Pedestrians are able to walk far enough away from the traffic lanes to achieve a reasonable level of safety. Even though the right-side shoulder was designed primarily for vehicular accommodations and safety, it also benefits pedestrians. It is recommended that paved shoulders at least 1.2 meters (four feet) in width be provided on all roadways within 8 kilometers (5 miles) of an urban area, specifically in response to bicycle and pedestrian needs. Figure 15 illustrates such a cross section on a two-lane road. Where sufficient shoulder width cannot be provided, separate paths are needed. Figure 16 illustrates a cross section with a narrow shoulder, but a separate pedestrian path. Because of the alternative path provided, the shoulder width is less of a concern.

Source: Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas, Transportation Research Board, 1987

Figure 14

High speed suburban arterial with 10-ft paved shoulder

Source: Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas, Transportation Research Board, 1987

Figure 15

Four-foot paved shoulders to accommodate pedestrian and bicycle traffic

Source: Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas, Transportation Research Board, 1987

Figure 16

Cross section with narrow shoulder but separate pedestrian path

4. Intersections

Generally the most concentrated area of pedestrian activity occurs at street intersections, especially in business districts. Not only do pedestrian flows intersect each other at these locations but these flows are interrupted by vehicular cross traffic and are exposed to vehicular turning movements. Since these areas have higher concentrations of pedestrians and cross traffic, they are the least desirable places for sidewalk impediments that constrict flow and may result in pedestrian overflow into vehicular spaces.

Pedestrian facilities should be designed to provide for pedestrian flows and the storage of pedestrians waiting to make their desired street crossing. It is desirable not to locate parking spaces, poles, mail boxes, bus stop shelters, planters, trees and similar items near crosswalks where they may obscure pedestrians and the handicapped from the motorists' view and decrease pedestrian storage and queuing areas.

Where there are heavy concentrations of pedestrians, the storage area and crosswalk areas should be calculated. Chapter 13 of the Highway Capacity Manual (TRB Special Report No. 209) contains the necessary equations, and explanations, for making these calculations.

Intersections, particularly signalized intersections, are the most complex part of the road network for pedestrians. There are 32 possible vehicle to pedestrian conflicts at the 4-way intersection of two roads. Many occur at high speeds.

It is preferable that intersection areas (conflict zone) be as small as possible to reduce the:

- unused pavement
- pedestrian to vehicle exposure
- pedestrian crossing distance

These practices make the vehicle paths clearer and reduce the relative speed between opposing movements. Channelization with medians, and right turn slip lanes with channelization islands can reduce the conflict zone and provide safe refuges for pedestrians, when wider intersection areas are required to accommodate wide curb radii or multiple turning lanes. Turning movements which are dangerous to pedestrians can be prohibited.

Right-turn-on-red (RTOR) has been demonstrated to increase pedestrian accidents. The person most at risk is the pedestrian crossing from the right to the left in front of a driver. Drivers focus their attention to the left and can start to turn before noticing the pedestrian on the right. Sixty-seven (67) percent of RTOR/pedestrian accidents involve this movement.

Roundabouts can be an effective treatment for reducing vehicle speeds in residential neighborhood streets. Lower vehicle speeds can facilitate pedestrian crossings and substantially reduce stopping distance.

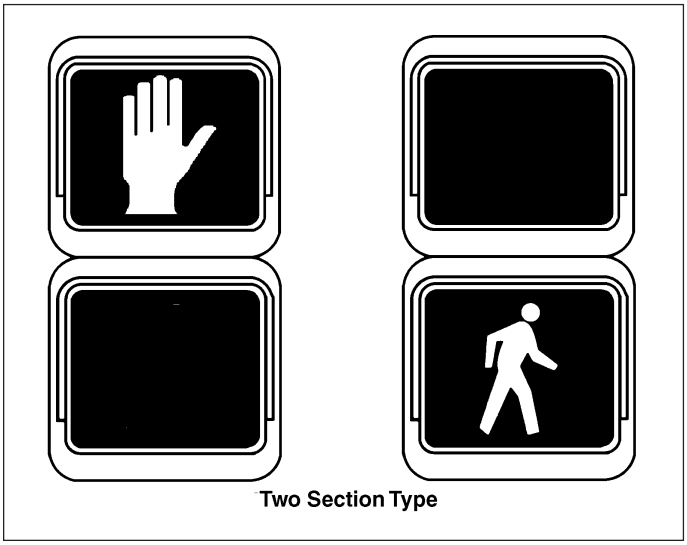
a. Policy Recommendations

1. Prohibit Right-Turn-On-Red at those intersections where pedestrian volumes are significant and field studies suggest this treatment.
2. Provide a median with a pedestrian refuge area whenever the crossing distance exceeds 18 meters (60 feet). Pushbuttons should be installed in the median and handicap ramps or a full cut should be provided through the median. Refuge islands should preferably be at least 1.8 meters (6 feet) in width and in no case less than 1.2 meters (4 feet) wide to reduce the danger to island users, particularly those in wheelchairs propelled by attendants, from projecting into the traffic lanes. Additional guidelines for refuge islands are provided in Sections 5 and 6.
3. Where warranted, install pedestrian buttons in accordance with DOT Standard Index #17784 in a standardized manner at all signalized crosswalks and in medians. Pushbuttons should be installed on separate poles according to illustration. This enables use by handicapped and sight impaired users and reduces the con-

fusion normally associated with these devices for the general population.

4. Pedestrian signal heads should be installed at urban signalized intersections, when field studies warrant. Install pedestrian signals on the poles that support the pushbuttons so they relate to the signal display. If the distance between the pedestrian signals across the road is greater than 18 meters (60 feet), another pedestrian signal should be installed in the median if possible. This will enable elderly and sight impaired pedestrians to see the signalheads. All signalheads should be brought up to current standards shown in MUTCD Figure 4-3, page 4D3. These standards specify the use of white and Portland orange colors only, since elderly pedestrians may have difficulty distinguishing color differences on the non-standard signalheads. Symbols should be used instead of words as the illustration in Figure 17 depicts.
5. Where possible, move existing drainage structures and install new structures out of the curb radius to prevent pedestrians from design-induced tripping. Drop inlets should be installed on the upstream side of corners to prevent large volumes of water flowing around the corner. Where an inlet is not provided, the gutter must be designed to carry water away from the pedestrian crossing even when the gutter is snow covered.
6. When diagonal spans supporting traffic signalheads would prevent pedestrians from seeing the current vehicle phases, convert existing spanwire installations and install new traffic signal installations using pole/mast arm mounted signals or box spans.
7. Parking should be prohibited within 18 meters (60 feet) of the approach to, and 9 meters (30 feet) on the departure from, a signalized intersection. Vehicles parked close to an intersection block a driver's view of pedestrians. Design of streetscape improvements should prohibit furniture, plantings, etc., which create visual screens.
8. On streets with parking, provide full corner and half corner sidewalk flares (bulbouts). See Figure 18. This rarely reduces vehicle capacity, yet allows more pedestrian queuing space, provides the pedestrian with a shorter crossing distance, and increases pedestrian visibility. The concept has been widely applied in older downtown areas in conjunction with revitalization and streetscape improvement efforts, but it is equally applicable to new roads, under the appropriate conditions.

   Sidewalk flares (bulbouts) tend to slow traffic at intersections or at mid-block locations by reducing the effective width of the street. The extent to which traffic is slowed depends on the design. Bulbouts should not infringe upon or restrict the roadway width required to accommodate bicycle traffic.

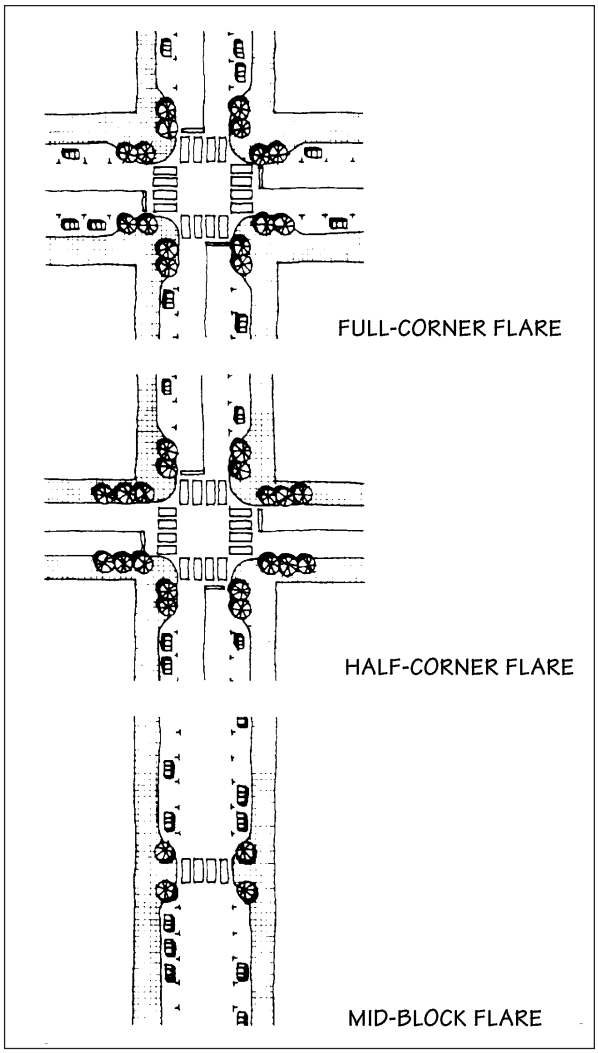


Source: Manual on Uniform Traffic Control Devices, 1988

Figure 17
Pedestrian Signal Face Designs

Figure 18

Alternative sidewalk flare designs



Source: Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas, Transportation Research Board, 1987

Turning movements by trucks and buses are often facilitated by the added roadway width provided by the parking lane. Therefore, when installing sidewalk flares, care should be used in providing adequate curb radii where it is important to maintain truck and school bus access. Required curb radii vary by the cross section of the intersecting streets.

On roads where parking occurs intermittently, adequate delineation of the flares is needed to keep vehicles from straying into the parking lane and crashing into the flare area.

Mid-block crossings are not normally installed if an intersection is within 120 meters (400 feet) of the proposed mid-block location, but should be considered where a need is apparent or where pedestrian behavior will dictate such crossings. Other speed control measures such as speed tables may be used in conjunction with this treatment to help reduce conflicts between pedestrians and vehicles.

9. Whenever possible, locate bus stops on the departure (far) side of the intersection so that the bus does not screen departing passengers from the traffic as they cross the street.
10. When the approaching drivers' view of pedestrians is restricted, clean-up the corner by using joint-use poles to support traffic signals, street names, light-

ing, and signs. Relocate or remove all other items or trim trees or shrubs.

11. When there is inadequate pedestrian walk and clearance time, re-time existing and new signals to ensure adequate crossing time for pedestrians. Signals frequently used by elderly or physically impaired persons should be re-timed to provide a crossing time commensurate with their ability.

b. Planning Considerations

Many signalized intersections are unfriendly to pedestrians because of the speed and complexity of vehicle movements and the number of lanes added for capacity. Future planning and project development should:

- Include the use of traditional neighborhood developments and grid systems to provide pedestrians with multiple crossing opportunities and to spread out vehicle turning movements.
- Use one-way pair streets, slip lanes and medians to reduce the number of lanes to be crossed.
- Prohibit left turns in downtown or commercial zones or where high concentrations of elderly pedestrians are present if analysis indicates that conflicts between pedestrians and turning vehicles is creating a safety or capacity problem. In some situations, protective phase left turns can mitigate these conflicts.
- Consider roundabouts on collector roads and minor arterials at intersections in residential neighborhoods since they effectively reduce vehicle speed and pedestrian/vehicle conflicts.

Factors affecting the danger to pedestrians by right turning vehicles include the number of turning lanes, turning volume, turn radius and distance from start of turn to crossing pedestrian. If there is little occasion for trucks to turn, current AASHTO guidelines permit 4.5 - 7.5 meters (15 - 25 foot) turning radii on minor streets. AASHTO further permits the use of a 12 meter (40 foot) turning radii on major streets if the occasional truck can turn with little encroachment. Radii of 12 meters (40 feet) or more are only recommended when large trucks or buses turn frequently. In these situations, right turn slip lanes should be considered, as they will provide a better operating environment for the large vehicle and the pedestrian.

Wherever turning volume and traffic types warrant, construct a right turn slip lane. Double right turn lanes are very dangerous for pedestrians because the vehicle in the inner lane blocks the vision of the driver in the second lane.

5. Medians

Medians should be provided as a standard feature of multi-lane suburban highways. Multi-lane highways with medians are substantially more convenient for pedestrians to cross than comparable highways without medians. This is particularly true at mid-block locations or unsignalized intersections, where medians can greatly simplify the pedestrian's task of crossing the street.

A pedestrian crossing an undivided street must wait until adequate gaps are available in both directions of travel. With a median, the pedestrian may treat each direction of travel as a separate crossing movement. The delay in crossing the road without a median can be as much as 10 times the delay incurred while crossing with a median. The heavier the traffic volume, the more important a median becomes in facilitating street crossings.

A median of at least 2.4 meters (8 feet) in width should be included on all new or reconstructed arterial and collector highways of four or more lanes to accommodate pedestrians in refuges. Wider medians are not necessarily needed for pedestrian crossings, but may be desirable for greater vehicular separation and accommodation of turning lanes, where jughandles are not provided.

If driveways are frequent and a service road cannot be provided, periodic median breaks still provide for adequate vehicular access while enhancing pedestrian convenience and safety. Figure 19 shows an example of a median with periodic openings for vehicular access. Some of the median segments are little more than pedestrian refuge islands, but they add greatly to the channelization of pedestrian and vehicular flows.

If access to all the driveways cannot be accomplished through direct median breaks and jughandles are infeasible, provisions can be made to permit U-turns. The most difficult situation in which to accommodate U-turns is a four-lane highway with a narrow median. Many vehicles cannot turn within the space provided, but provisions can be made to widen the far-side pavement to provide the required space, as illustrated in Figure 20. The median break for U-turns should be provided away from intersections and driveways (i.e., should be for the exclusive use of U-turns to minimize driver attention demands and to avoid driveway traffic conflicts), at least 60 meters (200 feet) upstream of an intersection.

Grass medians are preferred, but concrete medians are acceptable if there are overriding considerations of maintenance costs or other factors. For grass medians, paved walkways should be provided at all locations where pedestrian crossings are expected and especially where paths across the median are evident. These will primarily occur at intersections. Ideally, breaks in the median should be provided so that pedestrians can cross at street level (Figure 21). However, on medians sufficiently wide enough to accommodate a pair of curb ramps, a median-level walkway with properly designed curb ramps (Figure 22) may be preferred to more effectively accommodate mowing operations and to prevent ponding in the pedestrian walkway. This usually requires a median width greater than 4.8 meters (16 feet).

Figure 19

Application of short median segments to a wide arterial street

Figure 20

Example Application of Provision for U-Turns when Median is included

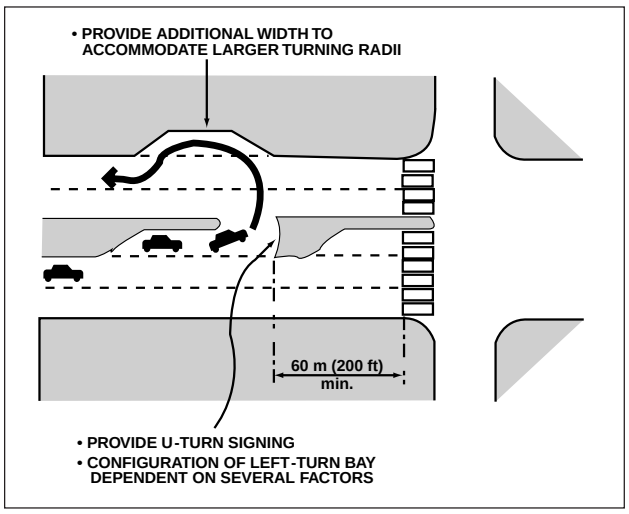


Figure 21

Median Opening to Accommodate Street-Level Pedestrian Crossings

Source: Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas, Transportation Research Board, 1987

In areas where a continuous median is, for some unusual reason, impractical to include in new roadway construction, efforts should be made to place pedestrian refuge islands at strategic points along the highway. Most refuge islands must be at least 1.2 meters (4 feet) wide, and 3.0 meters (10 feet) long, and should be well signed, marked, and lighted. These may be needed where intersection areas are large and crossing distances great. Guidelines for refuge islands are addressed in Section 6.

Source: Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas, Transportation Research Board, 1987

Figure 22

Well-Designed Elevated Median Crossing

On existing, undivided four-lane roadways, consideration should be given to re-striping the roadway to provide a lane for left turns, one through lane in each direction plus a shoulder. The center left turn lane will not provide the pedestrian with the same physical protection as a median. However, it does provide an area outside of the traffic stream, allowing the pedestrian to cross the roadway in two movements rather than one. This type of cross-section also reduces the crossing width for pedestrians and improves sight distances for both motorists and pedestrians.

6. Crosswalks, Curb Ramps and Refuge Islands

a. 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 be considered primarily for the following locations:

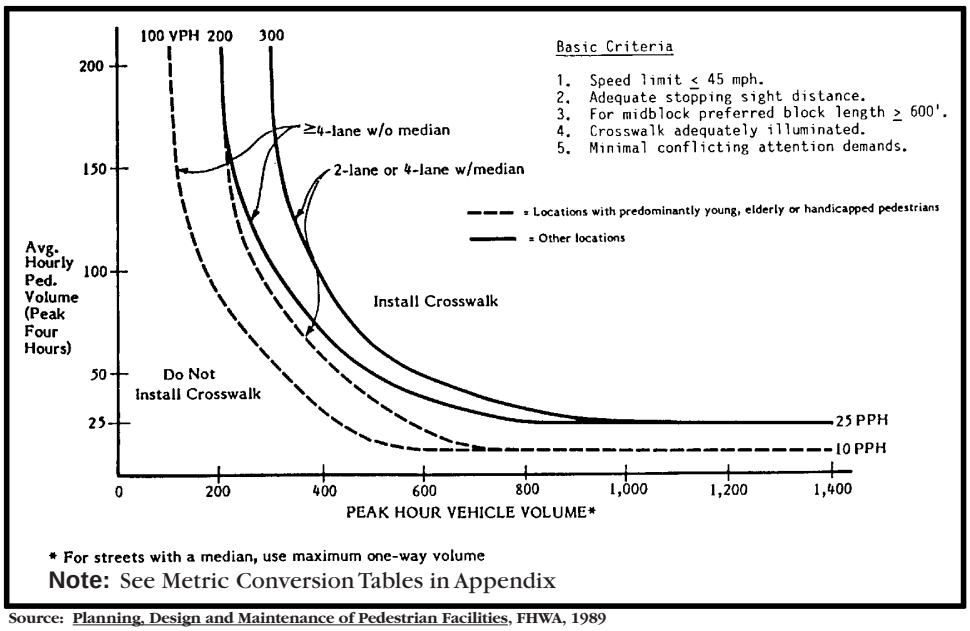
- All signalized intersections with pedestrian signal heads.
- All locations where a school crossing guard is normally stationed to assist children in crossing the street.
- All intersections and mid-block crossings satisfying the minimum criteria in MUTCD. As long as the basic criteria governing sight distance, speed limit, etc., are met, a crosswalk is deemed appropriate if the pedestrian and 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 warrants a crosswalk, then all should be marked.
- All locations within 0.4 kilometers (1/4 mile) of transit stations or schools.
- Situations where a dedicated pedestrian trail crosses a highway at a mid-block location and pedestrian traffic would not otherwise be anticipated.
- All other locations where there is a need to clarify the preferred crossing location when the proper location for a crossing would otherwise be confusing.

- Locations in both urban and non-urban areas where development on both sides of a highway results in concentrated pedestrian volumes crossing the highway and there is no highway intersection (e.g., where a large parking lot is on the opposite side of the road from a campus or manufacturing plant or where shopping or eating areas are across the road from workplace areas).

Suburban areas will generally not reach the pedestrian volumes which justify crosswalks in Figure 23. In suburban areas, professional judgement must be applied to the pattern of existing and future land use to assess if these patterns, rather than volumes, should warrant a crosswalk. For locations where a significant proportion of the pedestrian population are the young, elderly or handicapped, the volume thresholds should be reduced by a value of 50% or more.

Figure 23

Guidelines for Crosswalk Installation at Uncontrolled Intersection Legs, Midblock Crossing, and Signalized Intersections without Pedestrian Heads

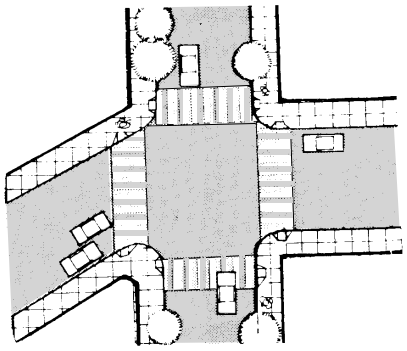


Source: Planning, Design and Maintenance of Pedestrian Facilities, FHWA, 1989

Crosswalks are usually marked in the immediate vicinity of intersections. Proper design of mid-block 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 mid-block crossing presence. Mid-block crossings are not normally installed if an intersection is within 120 meters (400 feet) of the proposed mid-block location.

If the warrants as set out in the MUTCD Section 4C-5 are met or if field studies warrant, then a signalized pedestrian crossing may be desirable. However, consideration should first be given to provision of a refuge island and an unsignalized crossing. A refuge may not be appropriate because the traffic volumes are very high, the road too narrow to construct a refuge, or special pedestrian needs may exist. If blind, very young, elderly or handicapped pedestrians are to be regular users of the crossing, their needs must be given special consideration. When crossings are to be installed, they must be installed on the pedestrian desire line.

Crosswalks should, whenever possible, be installed so that they form 90° angles with the curb. Perpendicular (90°) crosswalks minimize the walking distance and, therefore, the pedestrian exposure to vehicle conflicts. They also better accommodate the needs of blind pedestrians who are usually accustomed to perpendicular crossings. Crosswalks intersecting the curbs at other than 90°, as indicated in Figure 24, should be avoided whenever possible. If it is not possible to avoid an angled crosswalk, then at least one of the marking lines should be retained at 90° to the curb. When it is necessary to use angled crosswalks, 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.



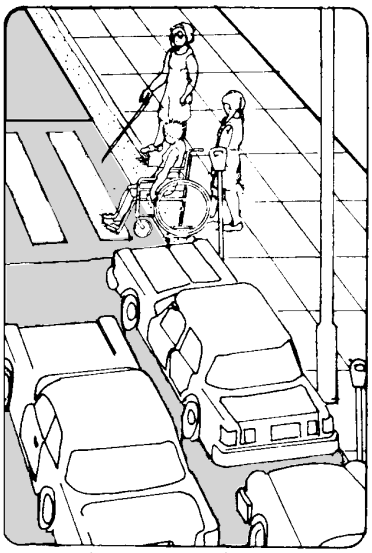
Crossings that do not make 90° angles with the curb should be avoided whenever possible.

Source: Planning, Design and Maintenance of Pedestrian Facilities, FHWA, 1989

Figure 24

Crosswalks Intersecting Curbs at other than 90 degrees

Parked vehicles can pose visual obstructions both for pedestrians and motorists. Children, wheelchair occupants or individuals of small stature present a special risk, as illustrated by Figure 25. Parking should be prohibited within 6 meters (20 feet) of the nearest crosswalk and within 6 meters (20 feet) of an intersection if a crosswalk is not provided.



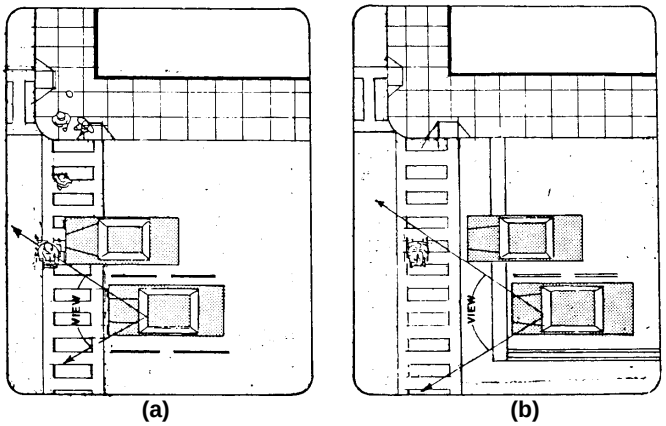
Source: Planning, Design and Maintenance of Pedestrian Facilities, FHWA, 1989

Figure 25

Examples of Undesirable Visual Obstruction Resulting from Parked Vehicles

Stop Lines

The installation of stop lines at crosswalk locations controlled by traffic signals or stop signs is effective in reducing vehicle encroachments on the crosswalk. The stop lines should be placed 1.2 meters (4 feet) in advance of and parallel to the crosswalk. See Figure 26.



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

Source: Planning, Design and Maintenance of Pedestrian Facilities, FHWA, 1989

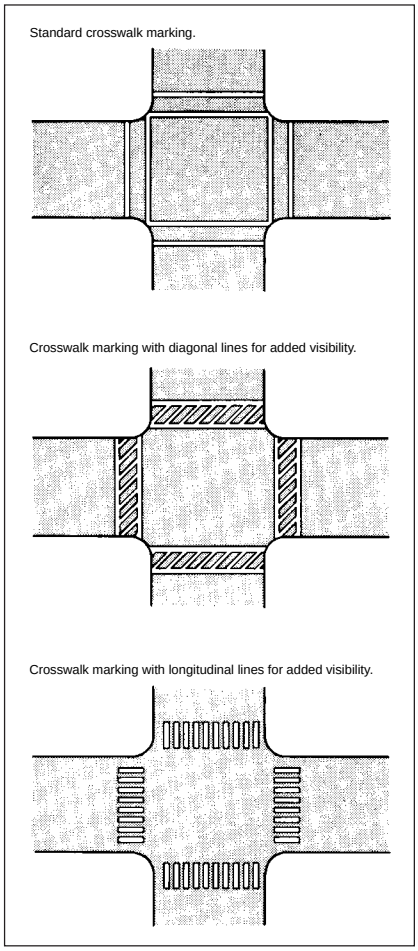
Figure 26

Installation of Stop Lines at Crosswalk Locations

Markings

Crosswalks should always be at least as wide as the sidewalk and should never be less than 1.8 meters (6 feet) in width. A 3.0 meter (10 foot) crosswalk width is preferable.

Figure 27
Typical Crosswalk Markings



Source: Handbook on Planning, Design and Maintenance of Pedestrian Facilities, FHWA, 1989

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 150mm (6") in width and not less than 150mm (6") apart that mark the boundaries of the path pedestrians should use to cross the roadway.

The primary types of crosswalk markings are presented in Figure 27. The white diagonal lines, at a 45° angle, or the white longitudinal lines, at 90°, are used to provide added emphasis to the motorist. The diagonal and longitudinal lines should be 305-610mm (12-24") in width and spaced 305-610mm (12-24") apart. When they are used at an intersection, 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. Mid-block and other non-intersection crossings are often treated with diagonal or longitudinal lines.

Obstructions

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.

Illumination

Crosswalk illumination can substantially enhance pedestrian safety during darkness. Vehicle headlamps often do not provide sufficient illumination to permit the motorist to identify the presence of a pedestrian in sufficient time to take the necessary evasive action. Special or additional street lighting may be required to assure that the pedestrian is adequately lit. Street lighting should be designed to ensure that the light is reflected off the pedestrian to driver's eyes. 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. Specific locational characteristics that should be considered for crosswalk and general intersection illumination include:

- Roadways that have a speed limit in excess of 65 km/h (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 rail stations or 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 problems associated with nighttime visibility has resulted in more frequent vehicle-pedestrian conflicts.

Where warranted, the lighting levels in pedestrian areas should meet those recommended by the Illuminating Engineering Society (IES). See Table 6.

Table 6

Recommended Pedestrian Crosswalk Illumination.

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.

b. Curb Ramps

Regulations of the Architectural and Transportation Barriers Compliance Board require that a ramp or curb ramp be provided anywhere there is an abrupt grade change greater than 13 millimeters (1/2 inch), or anywhere that the slope of an accessible pedestrian route is greater than 1:20, if no other means of accessible vertical access is provided.

Ramps and curb ramps were originally required to assure that buildings and facilities would be accessible to the disabled, and especially to persons in wheelchairs. However, the construction of these facilities quickly demonstrated that they could provide benefits to almost all pedestrians. Vertical changes in a pedestrian route pose a serious constraint and hazard for all pedestrians, not just persons using wheelchairs. Trips and falls associated with vertical changes are a common cause of injuries ranging from sprained ankles to broken bones and head injuries. Assuring that a change of grade is negotiated safely requires pedestrians to significantly slow down, reducing pedestrian capacity. Vertical steps require substantially more energy than normal walking, both in climbing and descending. Single steps, including steps off of curbs, are especially dangerous for pedestrians.

Curbs and other vertical obstructions along a pedestrian route can block the route for all wheeled vehicles, not just wheelchairs. Removal of these obstacles, through the

construction of ramps or curb ramps, will, therefore, also assist pedestrians pushing or pulling luggage carts, baby carriages or strollers and any other wheeled vehicles used by pedestrians. The provision of curb ramps and other pedestrian facilities that eliminate the need to negotiate steps and stairs has substantially expanded the number of walking opportunities available to the population as a whole, making walking a more viable means of transportation.

Numerous studies have demonstrated that where ramps or curb ramps have been provided along pedestrian routes, they are used by most pedestrians. Joggers, hurried commuters, children and the elderly will seek to use an available curb ramp in lieu of stepping over a curb, provided that the ramp is conveniently situated. Similarly, most pedestrians prefer to use ramps in lieu of steps, if the ramp is conveniently located and provides adequate capacity. Ramps and curb ramps especially benefit persons with arthritis or other disabilities which limit one's ability to negotiate vertical changes. As a result, these pedestrian facilities, originally provided to assist persons in wheelchairs, have been demonstrated to provide a major benefit to a broad cross section of the population.

Where provided, ramps and curb ramps should be designed to accommodate all pedestrians and should be located so that they are convenient. Minimum standards required to serve the needs of persons in wheelchairs seldom provide sufficient width to accommodate all pedestrians efficiently and may result in delays at intersection locations and hazards as a result of cross slopes along edges bounding the remainder of the sidewalk. As a result, ramps should be constructed with substantially wider widths than the minimums required by regulation.

Needs of Visually Impaired Persons

Curb ramps present special problems for visually impaired persons. Most severely affected are blind persons who are accustomed to using curb edges as a cue for the presence of a public street. Provision of a curb cut eliminates this traditional cue and can expose a blind person to the hazard of walking directly into a street with vehicles. As a result, curb ramps are now required to incorporate some form of detectable warning to alert blind persons that they are entering a street.

Blind persons also use the curb as a device to direct them into the adjacent crosswalk which they assume runs perpendicular to the curb face. Locating curb ramps along the curb corner can direct a blind person or a visually impaired person into the middle of a street intersection rather than into the crosswalk. As a result, where possible, curb ramps should be designed to protect against this hazard.

Locations Requiring Curb Ramps

A public sidewalk curb ramp with a level landing shall be provided wherever a public sidewalk or public pedestrian easement crosses a curb or other change in level. Examples of places which require the provision of a curb ramp include:

- intersections,
- painted crosswalks at mid-block locations,
- crosswalks at exit or entrance ramps,
- driveways,
- channelized islands or divisional islands, and
- median islands at mid-block locations.

The landing of a curb ramp consists of a level area at the top or bottom of a ramp run provided to allow a person in a wheelchair to change directions. Landings also provide a waiting area for pedestrians and wheelchair users. To accommodate the needs of a turning wheelchair, landings must consist of an area at least 1220 millimeters (48 inches) wide on all sides. Because landings are located at street intersections, it is often desirable to provide substantially wider landing areas to accommodate both moving and waiting pedestrians. The slope of a landing shall not exceed 1:50.

Types of Curb Ramps

There are four general methods of constructing curb ramps: perpendicular, parallel, diagonal or projected. Figure 28 illustrates the first three methods.

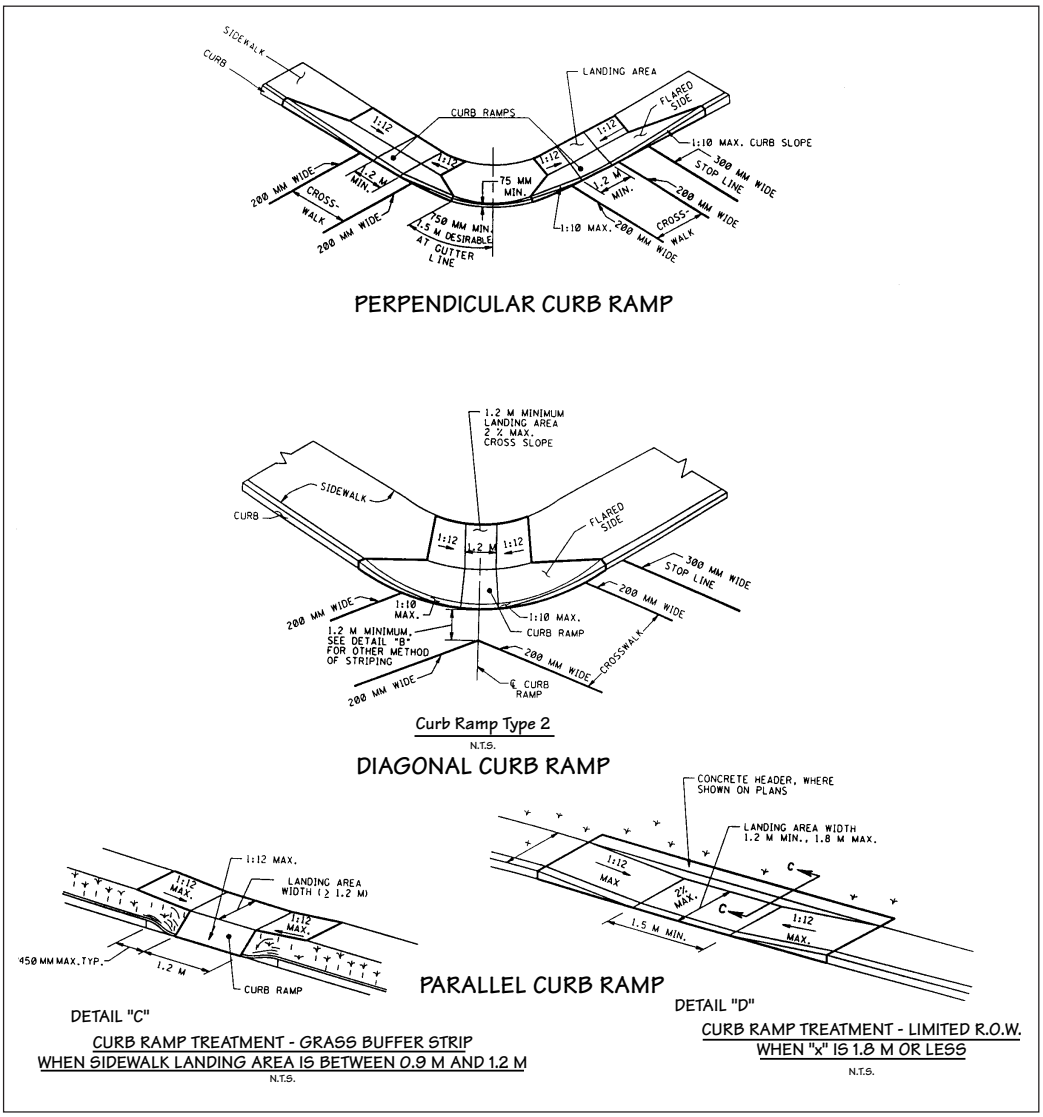
A perpendicular curb ramp runs perpendicular to and cuts through the curb. It connects to a street crossing at the bottom of its ramp run and to a landing at the top of the run. Perpendicular curb ramps are the generally preferred method of accommodating a grade change, provided that adequate right-of-way is available for its construction.

A parallel curb ramp runs parallel to the curb and consists of a ramped section of a sidewalk. It connects to a landing at the bottom of its run. The landing of a parallel curb ramp connects to the street crossing.

A diagonal curb ramp is located at the midpoint of a curb radius and runs perpendicular to and cuts through the curb. Because of its location on the midpoint of the curb radius, the axis of a diagonal curb ramp extends diagonally across the intersection of two intersecting streets. A diagonal curb ramp serves each of two intersecting street crossings at a corner. Because diagonal curb ramps direct pedestrians diagonally into the street intersection, they are generally discouraged in new construction except when they connect with a channelizing island located between a right turning roadway and the main portion of the intersection.

A projected (or built up) curb ramp consists of a perpendicular curb ramp constructed in part by extending the curb ramp into the gutter portion of the roadway (not illustrated in Figure 28). In existing locations where right-of-way is extremely limited, projected curb ramps may be the only method of accommodating the slope required for a curb ramp. A projected curb ramp can result in a reduced slope both because it allows for a longer curb ramp and because the total vertical change required is less. However, the projection of the curb ramp into the street can create drainage problems and may subject the ramp to damage from street cleaning equipment and from turning vehicles. Projected curb ramps may also encourage pedestrians to enter into the roadway prematurely. As a result, projected curb ramps are discouraged and should only be allowed when no other method of providing a curb ramp is available. When provided, a projected curb ramp should not extend into the moving traffic lane.

Figure 28
Types of Curb Ramps



Source: Standard Roadway Construction Details, NJDOT

Width of Curb Ramps

The minimum width of a curb ramp required by ADA regulations is 915 millimeters (36 inches), the width required to accommodate a wheelchair. On NJDOT projects, a minimum width of 1220 millimeters (48 inches) is required. However, because most pedestrians would prefer to make use of a curb ramp if it is available, it is generally preferable to provide a curb ramp which extends for the full length of the unobstructed pedestrian circulation path. The width of the curb ramp does not include the width of any flared sides required to raise the sides of the curb ramp back to the surrounding grade.

Slope of Curb Ramps

The minimum feasible running slope shall be provided for any public sidewalk curb ramp and shall be measured from a level plane. The maximum running slope of any curb ramp shall be 1:12, and the maximum cross slope shall be 1:50.

Edges

Where a side of a perpendicular curb ramp is contiguous with a sidewalk, it shall be flared with a maximum slope of 1:10. A perpendicular curb ramp may have a returned side or flare of any slope when not contiguous with a sidewalk or where the sidewalk is protected by a guardrail or other barrier. Because the introduction of the flared edge represents a safety hazard for pedestrians and persons in wheelchairs, it is preferable to avoid them through the use of curb ramp designs which do not place curb ramps next to sidewalks. This can be accomplished through the use of wide sidewalk set back areas or through the construction of extended street corners or bulb-outs.

Surfaces

The surface of a curb ramp should be stable, firm and slip resistant. Gratings and similar access covers should not be located on curb ramps or landings. The surface of a perpendicular curb ramp or the landing of a parallel curb ramp should contrast visually with adjoining sidewalk and roadway surfaces. To alert blind persons of the presence of the curb ramps, curb ramps should have a detectable warning material extending the full width and depth of the curb ramp.

Relationship to Crosswalks

When located at an intersection with marked crosswalks, the curb ramp should be wholly contained within the crosswalk markings. Crosswalk markings should be adjusted to accommodate the curb ramp as needed.

Transitions

Transitions between the curb ramp and the sidewalk and between the curb ramp and the street and gutter shall be free of abrupt changes. Counter slopes of adjoining gutters and road surfaces, connecting to the full width of a curb cut shall be a maximum of 1:20 for a distance of 610 millimeters (24 inches) as measured from the base of the curb ramp or landing edge at the street. Gratings or similar access covers shall not be located in the area at the base of the curb ramp or landing.

Obstructions

Curb ramps should be located or protected to prevent their obstruction in the street by parked vehicles or stopped buses. When necessary, bus stop locations should be moved away from the corner of an intersection a sufficient distance to assure that stopped buses will fully clear the curb ramp and crosswalk area.

The curb ramp and landing area should be kept clear of all obstructions such as light standards, traffic signals, meter boxes, controller boxes, junction boxes, utility poles, inlets, fire hydrants, guide rail, signs, planters, etc. Existing obstructions should be relocated as necessary so as to provide maximum visibility of pedestrians by motorists.

Drainage

Wherever possible, drainage inlets should be installed upstream of the bottom of the run of any curb ramp to remove as much drainage as possible from the gutter in the crossing area. Curb ramps should be located to avoid any drainage low points in the gutter grade. In new construction or major reconstruction of the street, gutter or intersection, the gutter should be pitched to draw water away from the pedestrian crossing.

Islands

Islands can assist pedestrians when crossing the street if they are designed to provide refuges and result in shorter roadway crossing distances. To be effective for this purpose, islands should be designed to facilitate pedestrian crossings. Where islands exist or are proposed at intersections with curb ramps, the following provisions shall apply:

(1) Where a small, raised channelizing island already exists at an intersection, it is not necessary to provide for a curb ramp or walkway opening for the island, but crosswalks should be adjusted to safely accommodate a person with disabilities without encroaching into the adjacent traveled way. Where a new island is proposed, it should be designed in accordance with paragraph 2 below.

(2) For larger channelizing islands, provide a 1.2 meter (four foot) wide walkway opening level with the street in the part of the island intersected by the crosswalk. In most cases, where larger channelizing islands are provided for right turns, the most effective crosswalk design will be to provide a diagonal curb ramp from the sidewalk to the island and then two perpendicular crosswalks from the island across each of the intersecting highway approaches. The refuge area within the island should be large enough to accommodate waiting pedestrians and to allow wheelchair users to adjust their direction of travel.

Except for very large islands, the slope required for a pair of curb ramps will prohibit introduction of a raised landing and refuge area as part of the island. However, where the walkway opening in the island would be long or would create drainage problems, it may be appropriate to place curb ramps at all sides of the island where it is intersected by crosswalks and have a level landing area of at least 1.5 meters (five feet) square between the curb ramps.

(3) At intersections where a left turn island or divisional island is encountered and the island cannot be moved back so that the nose is out of the crosswalk, provide a walkway opening level with the street in the part of the island intersected by the crosswalk. A minimum width of 1.2 meters (four feet) is required if the island is to serve as a refuge for pedestrians. Preferably a 1.8 meter (6 foot) width should be provided to protect a person pushing a stroller or wheelchair or to accommodate a person pushing a bicycle.

(4) At mid-block locations where a crosswalk intersects a median, an opening at least as wide as the crosswalk, but no narrower than 1.5 meters (5 feet), shall be provided in the median island. For medians wider than 3.6 meters (12 feet), a curb ramp may be provided at each side of the median island leading to a landing in the center of the median at least 1.5 meters (5 feet) in length. In wide median islands, this landing may be located at curb height; on narrower median islands, the landing may only be 25-50 millimeters (one or two inches) above the elevation of the roadway. In general, with wider median islands, maintenance of the pedestrian passage and of the island's landscaping will be facilitated through the provision of curb ramps and a raised landing area.

Sight Distance

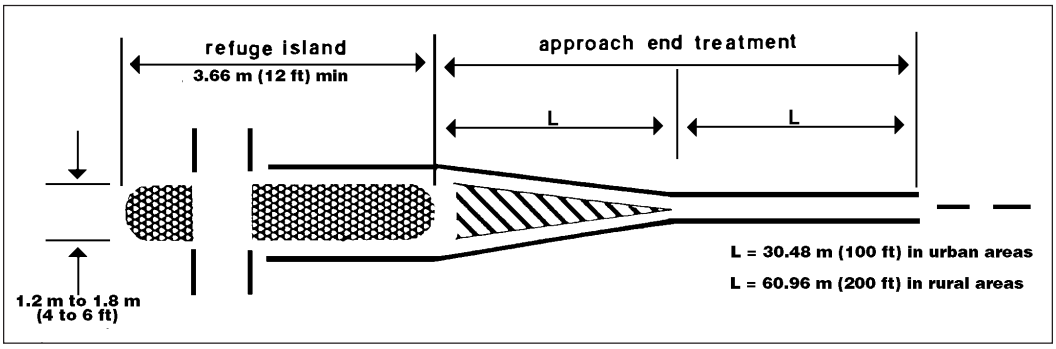
The sight distance at street crossings should be checked to ensure that curb ramps are not placed in such a location that a motorist will find it difficult to perceive the low profile of a wheelchair occupant crossing the roadway. Where necessary, parking controls should be enacted to prevent parked cars from blocking a motorists view of a person in a wheelchair.

c. Refuge Islands

Refuge islands were mentioned in the Section 5 on Medians. They are also an important element in Section 8, Upgrading and Retrofitting Existing Highways. This section provides specific design criteria for refuge islands.

Refuge islands should preferably be at least 1.8 meters (6 feet) wide, and in no case less than 1.2 meters (4 feet) wide, to reduce the possibility of island users, particularly those in wheelchairs propelled by attendants, from projecting into the traffic lanes. Refuge islands narrower than 1.8 meters (6 feet) often create a feeling of isolation and unease in pedestrians due to the proximity of moving vehicles. The length of the refuge island should not be less than 3.6 meters (12 feet), or the width of the crosswalk, whichever is greater. A diagram depicting the size and shape of refuge islands is presented in Figure 29.

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 their noses are raised and outlined with barrier curbs.



Source: Planning, Design and Maintenance of Pedestrian Facilities, FHWA, 1989

Figure 29
Minimum Size and Shape Requirements of Refuge Island

Object markers should be used on the island approach noses to indicate the presence of the raised curb.

Where the refuge island is too narrow to provide the required slope for a curb ramp plus a 1.2 meter (4 foot) level landing, then the crosswalk must continue through the island at roadway level. 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 tactile clues that can be detected by long cane techniques.

The refuge island should be sufficiently raised to assure that water will not pond in the refuge area. Ideally, drainage inlets should be provided along the median upstream of the pedestrian refuge, or else the roadway should be pitched away from the median.

7. Overpasses and Underpasses

In urban areas, pedestrian overpasses or underpasses may provide an appropriate method of facilitating pedestrian crossing of freeways or high volume arterial highways. They are not appropriate for widespread application in suburban, fringe or rural areas. While separation of pedestrians and vehicles by means of grade separation structures is theoretically the most effective means of pedestrian protection, grade crossing structures are expensive to construct and maintain, and unless properly located and designed, will not be used to their full potential.

Grade separation structures require extra effort and travel distance by pedestrians. As a result, pedestrians will frequently attempt to directly cross the traffic stream, despite the safety benefits offered by a grade separated crossing.

a. 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". Locations where there are natural or man-made barriers which would encourage right-of-way and approach structure requirements, are more advantageous than level open sites. Generally, there is more potential for cost-effective applications when overpasses and underpasses are integrated into other land development or highway construction schemes. Where urban cores are undergoing large-scale redevelopment, there exists potential to provide grade separated pedestrian systems as part of the downtown renewal plans.

The location of grade separation structures in relation to other crossing alternatives has a major impact on their 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 with the extra effort required. 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. 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.

b. 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 weather, exposed to traffic noise and pollution and must be equipped with countermeasures to prevent dropping of debris on vehicles passing underneath.

The underpass clearance height, usually 2.1 to 2.4 meters (7 to 8 feet), can be less than half that of an overpass resulting in shorter stair flights and ramps and reduced right-of-way requirements. The disadvantages to underpass structures include the expense of relocation of utilities, drainage problems and perceptions of insecurity leading to pedestrian avoidance.

The relative elevations of the highway and pedestrian crossing have a significant effect on grade separation cost and potential use. Crossing structure costs and ROW requirements are substantially less at locations where the highway is depressed or elevated relative to the pedestrian crossing. Use of the structure will also be greater at this type of location because fewer stairs and ramps will be needed. The feasibility of underpasses can be improved where it is possible to slope the roadway up over the underpass. Perceived underpass security can be increased by providing wall and roof openings for "daylighting", by high artificial lighting levels, approximately 108 lux (10 footcandles), by avoiding changes in path direction that may produce hidden areas, by consistent maintenance and cleaning and by providing greater horizontal or vertical clearances.

The walking widths should be designed to accommodate the projected pedestrian traffic. 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 2.4 meters (8 feet)

to allow sufficient space for wheelchair passing and turning. Minimum clear widths on approach walkways and ramps should be at least 1.5 meters (5 feet) to permit pedestrians to pass and to permit wheelchair passing.

c. Warrants for Pedestrian Over and Underpasses

Most pedestrians will seek to cross a highway at-grade unless a grade separated facility is perceived to be more convenient and direct than the nearest at-grade crossing. As a result, the construction of grade crossings should be limited to locations where traffic volumes provide insufficient gaps to permit safe crossing of the highway, or where the presence of roadway cuts or fill make construction of a pedestrian crossing both less expensive and more convenient for use.

The following warrants, based on an extensive national analysis of how pedestrians use grade crossing facilities, can guide designers on locations where pedestrian structures should be provided on existing highways. On new highways, greater opportunities are available for adjusting roadway grades to facilitate overpass or underpass construction. The warrants are, therefore, inappropriate for new construction or major reconstruction which includes substantial grade work.

Facility Type	Pedestrian Volume	Vehicular Volume	
	Total for 4 hours	Same 4 Hours	AADT
Freeway	100	7,500	25,000
Arterial	300	10,000	35,000

Pedestrian over or underpasses may also be warranted where either the vehicular or pedestrian volume is slightly less than the amount shown, but the other volume is substantially greater.

In addition, a grade separated pedestrian crossing is warranted any time that a safety evaluation of a pedestrian crossing has determined that erection of a fence to prohibit pedestrian crossings is required. Whenever designers feel that measures must be introduced to discourage at-grade pedestrian crossings, a companion project should be programmed to provide an alternative safe crossing on an expedited schedule.

In most situations, a pedestrian structure should not be constructed if a "safe" crossing location is available within 180 meters (600 feet). (A "safe" location could be a signal controlled intersection, a mid-block location either with or without signal control, or another grade separated crossing.)

Exception. A grade separated crossing may still be appropriate despite the availability of a nearby crossing. This is especially likely if the pedestrian demand is substantially greater than the minimum required for the warrant, or if grade differences make installation of an over or underpass especially convenient. Grade separated crossings would be especially appropriate on college or university campuses, at crossings linking recreation areas and schools, at major activity centers, adjacent to train or bus stops or at other unique sites having very high and concentrated pedestrian flows.

d. Conditions for Pedestrian Over and Underpasses

(1) Artificial lighting should be provided to increase the perception of safety on overpasses and in underpasses. Lighting in underpasses should be at least 108 lux (10 foot-candles).

(2) Approaches to pedestrian over or underpasses should be accessible by ramps constructed in conformance with ADA standards. Steps may supplement ramp access, but should not be the principal or most direct means of access.

(3) Pedestrian over and underpasses should be constructed at locations which have minimal elevation differences. Where substantial elevation differences exist, the design for the structure should seek to incorporate earthwork or other structural improvements which will provide pedestrians with the impression that little elevation change is required to cross the facility. Entry into adjoining buildings at basement or second floor level can help to create this impression.

(4) The pedestrian over or underpass should be located to provide pedestrians with the most direct pathway possible.

(5) Where vehicular traffic volumes substantially exceed the volume warrant listed previously, or where unique traffic conditions such as restricted sight distance limit pedestrian safety, consideration can be given to erecting a physical barrier to prohibit at-grade crossings of the roadway by pedestrians. However, in general the designer in these situations should avoid prohibiting at-grade crossings and instead seek to design the over or underpass to be as attractive to pedestrian use as possible.

e. Alternatives to Pedestrian Over and Underpasses

Before constructing an overpass or underpass to service only pedestrians, the following alternative solutions to a pedestrian crossing problem should be considered.

Mid-block crossing — If a median wider than 3.0 meters (10 feet) is available to create a safe pedestrian refuge, an at-grade, mid-block pedestrian crossing may offer an acceptable pedestrian crossing opportunity.

New street crossing — Pedestrians will frequently feel more secure crossing on an overpass or underpass which incorporates a street. The wider width, flatter grades and the presence of drivers can add to the sense of security of such a crossing. Where high pedestrian crossing volumes are present there could also be a latent demand for vehicular crossings. When integrated into the surrounding street network, such a crossing would also provide the pedestrian with better linkages to surrounding land uses.

Widened structure — Frequently stream crossings or railroad crossings can be modified to incorporate a pedestrian facility. Stream crossings are especially appropriate for this purpose since they can often be linked into a greenway plan for the surrounding community. Railroad structures over or under streets can provide a similar opportunity to create a pedestrian crossing. At stations, it may be possible to use an extended platform as the pedestrian crossing.

8. Upgrading and Retrofitting Existing Highways

Many problems of pedestrian convenience and safety are built into the existing highway system. Therefore, significant strides in improving pedestrian safety and convenience must include the upgrading and retrofitting of existing highways.

a. Medians

A median should be incorporated into any project involving the widening of a highway to four or more lanes. There should be exceptions to this rule only if signalized intersections are very frequent, at least every 240 meters (800 feet). If a trade-off must be made between narrow lanes with a median and 3.6 meter (12 foot) standard width lanes without a median, the median option is preferable. All multi-lane undivided highways in developed suburban areas should be considered candidates for median placement.

Figure 30

Retrofitted Striped Median

Source: Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas, Transportation Research Board, 1987

Highway widening should never be allowed to eliminate a sidewalk, even if only on one side. Similarly, every effort should be made not to eliminate shoulders if no sidewalks are available. A three lane roadway with shoulders is preferable to a four lane undivided roadway without shoulders.

Although a 0.6 meter (2 foot) median is a minimum under constricted cross section constraints, at least 1.2 meters (4 feet) is preferred. If existing lane widths on undivided roads are at least 3.6 meters (12 feet), lane widths should be reduced to 3.3 meters (11 feet) to accommodate the median width. If access to commercial establishments is a major factor, provide for frequent median breaks and/or U-turn capability.

A simpler, but less effective, approach to providing medians on existing highways is to provide a 1.2 meter (4 foot) striped median rather than a raised median. An example of this is shown in Figure 30.

b. Refuge Islands

There are many opportunities for using pedestrian refuge islands as a result of their relatively low cost and limited impact on vehicular delay and safety. They should be installed where continuous medians cannot be provided, speeds are generally less than 70 km/h (45 mph), and pedestrian crossing volumes are in excess of 100 persons per day or where pedestrian accidents, particularly those related to roadway width and crossing time, have occurred.

Figure 31

Street-Level Median with Special Refuge Island Delineation

Source: Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas, Transportation Research Board, 1987

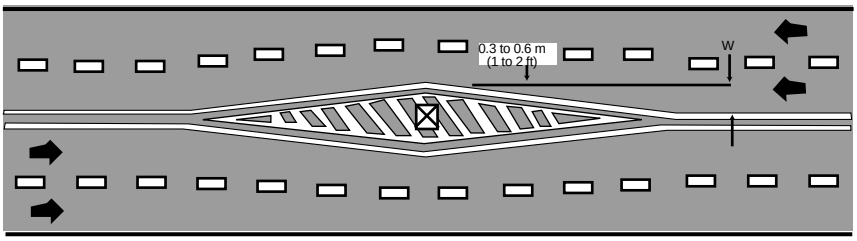
Use of refuge islands for mid-block pedestrian crossings across high volume highways where speeds are 70 km/h (45 mph) or more should be carefully evaluated. Such situations may be better served by traffic signals or pedestrian overpasses.

An example of a low-cost refuge area is shown in Figure 31. Although the refuge island is not raised, the stanchions provide a high-visibility holding area for pedestrians. Other types of flexible, high-visibility barriers could be developed to provide a similar function perhaps more attractively.

In some situations, isolated pedestrian refuge islands may be warranted on undivided multi-lane streets. Figure 32 illustrates a recommended striping and signing configuration for a fixed object on an undivided highway. Although not intended for pedestrian refuge islands, this same configuration can apply. Installation of this type of refuge may require reductions in lane width or increases in curb-to-curb cross section near the refuge island.

Figure 32

Sample Striping Pattern for Fixed-Object Delineation



Source: Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas, Transportation Research Board, 1987

c. Two-Way Left-Turn Lanes

Two-way left-turn lanes (TWLTLs) have been widely applied to facilitate left turns on roads with many access points. Their operational and safety effectiveness has been well-documented for vehicles, but their impact on pedestrian crossings has received little attention.

Although these roadways may be easier to cross compared to undivided multi-lane highways, they are still uncomfortable and potentially dangerous for pedestrians. The pedestrian must carefully observe not only two directions of through traffic, but two directions of left turning traffic simultaneously. Pedestrian crossing demand may be substantial along these roadways, since two-way left-turn lanes are often installed in locations with strip commercial development and near residential areas. There are many 5-lane roadway sections with two-way left-turn lanes, and even some seven-lane sections. Observation of pedestrian activity at two-way left-turn sections indicates that pedestrians often use the middle lane as a refuge. This leaves them vulnerable to both directions of turning traffic.

Solutions to the two-way left-turn lane problem are not easy. The ideal solution is to have a median with frequent openings, but this is not always possible. One alternative is to have a series of carefully placed, well-delineated pedestrian refuge islands. Because of the unique combinations of the number and locations of driveways, each situation must be treated as a special case. In principle, however, islands should be located every 100 to 150 meters (330 to 500 feet). The best way to locate the refuge islands is to plot all turning radii into and out of the driveways from both sides of the road. Nonconflict areas are candidate locations for refuge islands. Refuge islands should be as long as possible without interfering with vehicular turning movements or limiting possible future driveway locations.

Chapter 3

Guidelines for Encouraging Pedestrian Travel

1. Traffic Calming

a. What is "traffic calming"?

Traffic calming is a relatively new and very different approach to managing the roadway environment. Traffic calming seeks to reduce the dominance and speed of motor vehicles. It employs a variety of techniques to reduce vehicle speeds. Measures can include physical alterations to the horizontal and vertical alignment of the road and changes in priority. In some cases it may be possible to introduce a 30 km/h (20 mph) zone as part of a package of measures.

First developed and applied in several European countries, the principles and techniques of traffic calming are arousing considerable interest in the US today. Traffic calming has been used in the US to retrofit existing residential neighborhoods suffering from excessive through-traffic and in the design of new planned developments. Some techniques employed to calm traffic are familiar to US traffic engineers, others less so. What is different about traffic calming is its use as an overall integrating concept in designing for pedestrians and bicyclists over large areas. Traffic calming is rapidly being seized upon by many local communities and interest groups as an integrated alternative to conventional road planning and design. Its implementation is bound to be controversial because traffic calming reverses and challenges many currently accepted approaches to roadway design.

Aside from accident and casualty reduction, the benefits claimed for traffic calming are manifold. Slower vehicle speeds can create better driver discipline. Less acceleration and braking reduces fuel consumption, vehicle emissions and noise intrusion. Furthermore, the smoother flow of vehicles may actually improve travel times. Traffic calming also provides an opportunity for environmental improvements. Aside from a reduction in noise and air pollution from motor vehicles, aesthetic improvements such as plantings can easily be incorporated into a program of physical alterations to the road space.

In residential areas, traffic calming is frequently applied to foster the concept that roads are "living areas" and should therefore be made safe and attractive. Here particularly, changes to the street scene are applicable, and, where possible, traffic calming should provide community areas, including play spaces and places where people can sit and chat.

Traffic calming need not, however, be confined only to minor roads. In urban and suburban areas, arterial streets and highways carrying fast, heavy traffic generally pose the greatest danger to vulnerable user groups. Measures that reduce the speed and dominance of motor vehicles and facilitate safe passage for bicyclists and pedestrians are thus even more necessary on such main roads. However, the techniques seen as applicable to main urban thoroughfares generally differ from those employed to calm traffic on minor residential roads. A greater variety of features have been developed for minor roads where stricter speed control is unlikely to adversely affect roadway capacity or levels of service.

Normally, traffic calming should be applied as an area-wide technique. To apply it only to a particular street can easily shift accidents, pollution and traffic into neighboring areas.

In order that traffic calming may realize its full potential in terms of creating a safer and more attractive urban environment, it must be part of a wider and longer-term strategy to reduce dependence on private motor vehicles in towns and cities, and promote a modal shift in favor of walking, cycling and public transit.

The growing popularity of traffic calming is attributable to four perceived benefits:

- A significant reduction in road accidents and their severity.
- A greater feeling of security, particularly among vulnerable road users.
- Reclamation of roadway space for non-traffic activity such as play and social interaction.
- Improved visual and aesthetic environments created by landscaping and a reduction in the intrusive presence of motor vehicles.

b. Traffic Calming Techniques

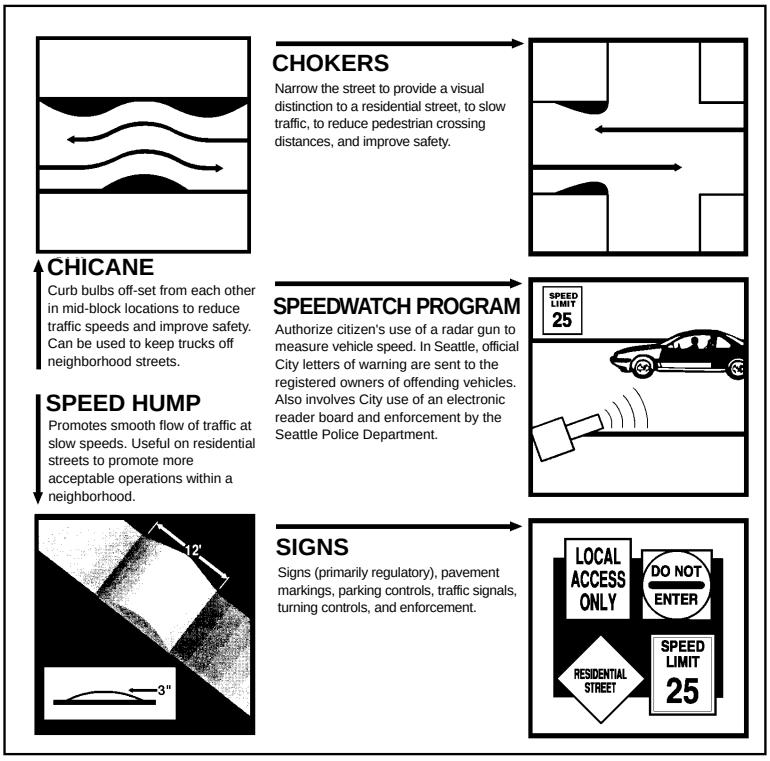
Three general observations should be noted from successful traffic-calming schemes that have been implemented:

- Where consistently low speeds, less than 30 km/h (20mph), are required, such as in residential areas, physical traffic-calming features should be positioned sufficiently closely together to deter unnecessary acceleration and braking.
- The use of appropriate signing is important to remind drivers that they are entering a traffic restraint area; public awareness campaigns facilitate the acceptance of lower speeds.
- Sympathetic speed limits, such as 30 km/h (20mph) in residential areas, are used to reinforce the physical speed control measures.

Examples of traffic calming techniques are listed and illustrated in Figures 33 through 39. Additional information can be found in the companion document to these guidelines, NJDOT Bicycle Compatible Roadways and Bikeways. These techniques are a selection of some current measures employed. Similarly, the descriptions of the various features are for illustrative purposes and should not be interpreted as rigid design criteria. It is recognized that the appropriate application of different traffic-calming techniques is dependent on the physical setting. As a result, the selection of appropriate techniques requires application of professional judgement and creativity.

Figure 33

Traffic Calming Techniques

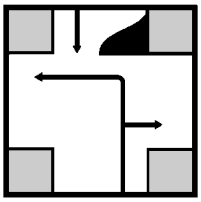


Neighborhood traffic control measures: Managing traffic in place.

Source: Design and Safety of Pedestrian Facilities, ITE, 1994

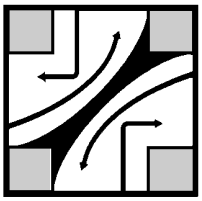
Figure 34

Neighborhood Traffic Control Measures



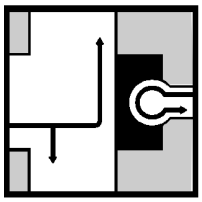
CURB BULB
Description: An extension of a curb built to block one half of the street.

Purpose: To stop vehicles from entering a neighborhood but allow egress.



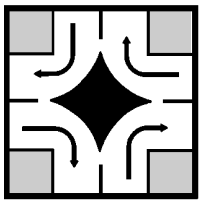
DIAGONAL DIVERTER
Description: An island built diagonally across an intersection.

Purpose: Discourages commuter traffic by forcing turns, returns streets to neighborhood/pedestrian use.



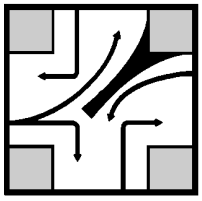
CUL-DE-SAC DIVERTER
Description: A complete street closure with a landscaped mini-park.

Purpose: To eliminate through traffic, separating land uses.



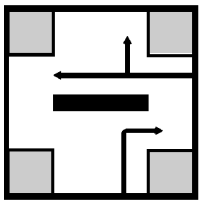
STAR DIVERTER
Description: A star-shaped island placed in an intersection.

Purpose: Discourages commuter traffic by forcing right turns.



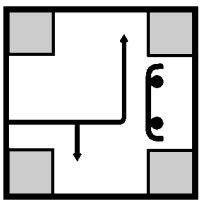
TRUNCATED DIAGONAL DIVERTER
Description: A diagonal diverter with one end open.

Purpose: Discourages commuter traffic by forcing turns.



CHANNELIZATION CURB DIVERTER
Description: Six-inch high curbing placed along the center line of an arterial.

Purpose: To prevent left turns from an arterial to a residential street.



GUARDRAIL CLOSURE
Description: Steel or timber rails on posts to close a street.

Purpose: To eliminate through traffic.

Source: Design and Safety of Pedestrian Facilities, ITE, 1994

Road Humps and Speed Tables

***Description*:** Raising the surface of the road over a short distance, generally to the height of the adjacent curb. Humps are longer than speed bumps and can be round or flat topped; the latter are known as "speed tables" and can extend over 3 to 9 meters (10 to 30 feet). Humps may extend curb-to-curb, or may be cut back at the curb with tapered sides to facilitate drainage and permit a bicycle bypass.

Figure 35
Speed Table

Source: Traffic Calming, CART, 1989, STOP, 1993

While generally employed on residential roads, humps are permitted on main roads subject to a speed limit of 50 km/h (30 mph) or less. On higher speed roads, these concepts may still be appropriate to call attention to important pedestrian crossings or areas of congestion. However, care must be taken in design to provide appropriate vertical transitions.

Speed tables frequently are coincident with a pedestrian crossing.

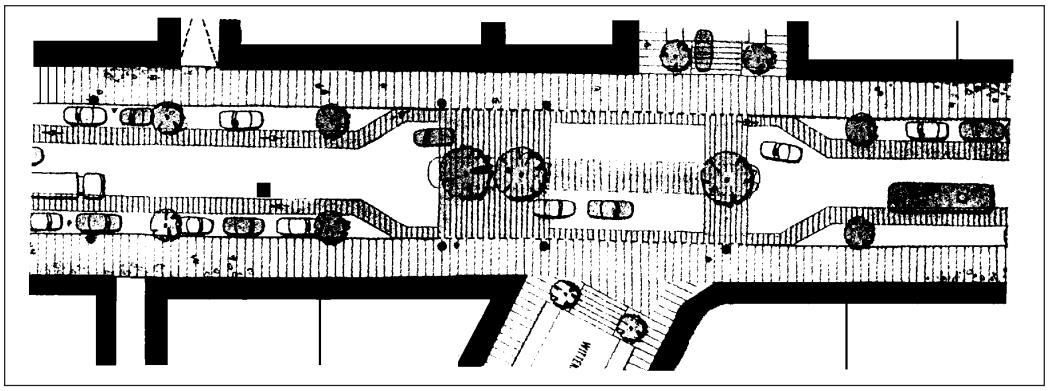
Design Considerations: To ensure the effectiveness of road humps while enabling bicyclists to negotiate them with a reasonable degree of comfort:

- gradients on the approach and exit slopes should not exceed 1:6 (16%);
- ramp faces should be clearly indicated;
- all materials employed should be skid resistant;
- the leading edge of ramps should be flush with the road surface;
- humps should be situated sufficiently far from an intersection to allow turning bicyclists to regain an upright position before they encounter the obstruction.

Where flat top humps (speed tables) are coincident with a pedestrian crossing they should extend from curb-to-curb.

Speed humps in the vicinity of bus stops should be designed to permit buses to either completely clear the raised roadway or to straddle the hump. (Bus passengers are particularly vulnerable to the adverse effects of humps.)

Figure 36
Mix of Traffic Calming Elements



Source: Traffic Calming, CART, 1989, STOP, 1993

Traffic Throttles/Chokers or Neck-downs

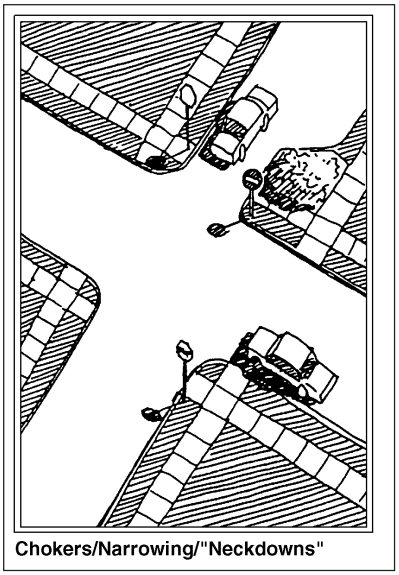
***Description*:** The narrowing of a two-way road over a short distance to a single lane. Sometimes these are used in conjunction with a speed table and coincident with a pedestrian crossing.

***Design Considerations*:** Throttles are generally only appropriate where traffic flows are less than 4-5,000 vehicles/day. Above this level considerable delays will occur in peak periods.

To reduce the risk of bicyclists being squeezed, throttles should generally be used in conjunction with other speed control measures, such as a speed table at the narrowing. Slower-moving drivers will be more inclined to allow bicyclists through before trying to pass. Where bicycle flows are high, consideration should be given to a separate right-of-way for bicyclists at the throttle point, possibly by means of a not-quite-central refuge.

Clear signing should indicate traffic flow priorities.

A textured surface such as blockwork may be used to emphasize pedestrian crossing movement. Substituting this for the normal roadway surface material may also help to impress upon motorists that lower speeds are intended.



Source: State of the Art Report: Residential Traffic Management, FHWA, 1980

Figure 37
Choker/Neckdown

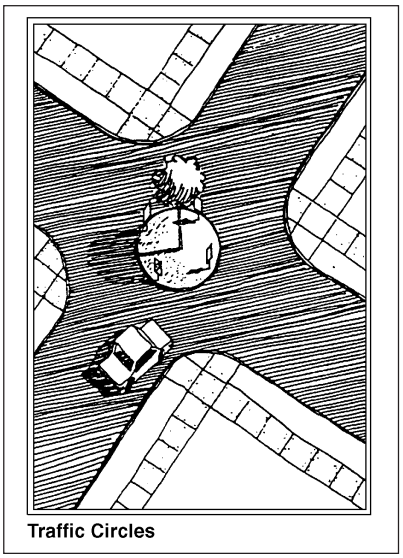
Nevertheless, such measures should not confuse pedestrians with respect to the boundary of the roadway area over which due care should still be taken, especially where a road is raised to the level of the adjacent walkway. As with all crosswalks, appropriate care must be taken to alert the blind and others with limited vision of the presence of a crossing. A tactile material should be provided at the approach which can be detected with long cane techniques. Similarly a contrasting color and texture should be provided for the benefit of the visually impaired.

Roundabouts or Traffic Circles

***Description*:** Small radius traffic circles located at street intersections or mid-block locations. Some have raised centers, others are little more than painted circles on the road.

Design Considerations: Roundabouts should preferably have sufficiently raised and highly visible centers to ensure that motorists use them correctly rather than over-running. Frequently, roundabouts with an interior area greater than 7 square meters (75 square feet) are planted. Small roundabouts may be only painted islands with a flexible barrier.

Complementary speed reduction measures, such as road humps on the approach to roundabouts can improve safety. Clear signing is essential.



Source: State of the Art Report: Residential Traffic Management, FHWA, 1980

FIGURE 38
Traffic Circle

The design of roundabouts must ensure that large radius vehicles will be able to negotiate the roadway, in particular, garbage trucks, fire engines, moving vans and school buses, all of which can be anticipated in residential areas. However, on low speed streets with AADT less than 2000, it is appropriate to assume that these large vehicles can encroach into the opposite lane when entering or exiting a roundabout.

Raised Intersections

Description: The roadway is raised at a street intersection with a visible roadway ramp on each approach. The platform created in the intersection is elevated to curb level and should have a distinctive surfacing.

Physical obstructions such as bollards or planters can be used to restrict the area to which vehicles have access.

Design Considerations: Roadway ramps should not exceed a maximum gradient of 1:6 (16%).

Distinctive surfacing materials should be skid resistant, particularly on inclines. Ramps should be clearly marked to enable bicyclists to identify and anticipate them, particularly in conditions of poor visibility.

As with all crosswalks, care must be taken to ensure that visually impaired people have adequate cues to advise them of the roadway area. Tactile strips may be appropriate and color variation will aid those who are partially sighted.

Plug "No-Entry" (with Bicycle Slip)

Description: A cul-de-sac created by blocking access in one direction at one point in the street to motor vehicles. Unlike a traditional cul-de-sac, a "plugged" street remains open for use by bicyclists and pedestrians.

Design Considerations: Bicycle exemption should be provided as a general rule, and designed to minimize the likelihood of obstruction by parked vehicles.

Signing should acknowledge the continued existence of the route as a through one for bicyclists.

Irregular or Textured Surfaces

Description: The use of non-asphalt roadway surfaces such as brick, paving blocks or blockwork, cobblestones to reinforce the concept of a "traffic restricted" area.

Design Considerations: Care must be taken in the choice of materials to ensure that they do not pose a danger or deterrent to bicyclists and pedestrians. Cobblestones present special difficulties and are particularly discouraging for bicyclists on steep slopes because they make it harder to maintain momentum when riding uphill. Similarly, paving stones with chamfered edges impair a bicyclist's stability and should be avoided.

Cobblestones or other rough surface should not be used along pedestrian routes since they represent both an obstacle and a danger for persons in wheelchairs, walkers or other devices.

In residential areas consideration must be given to the noise that might be generated from textured surface materials.

Tortuous Roads

Description: Roads designed to meander, occasionally turning sharply, reducing the image or perception of a straight and open road, thereby encouraging low vehicular speeds.

This technique is often used in new housing developments, incorporating courtyards or cul-de-sacs and thus removing through traffic.

Design Considerations: Tortuous roads are generally planned during the design of a new road rather than superimposed on an existing one. The siting of buildings may be used to accent the meanders.

Designers should be aware of the need to assure accessibility to residential properties, both in terms of emergency vehicles and service vehicles. Tortuous roads will not be viable if they severely restrict accessibility.

Source: Bicycle Federation of America

Figure 39
Woonerf

"Woonerf" or Shared Surfaces

Description: The traditional distinction between pedestrian space and vehicular space is removed and a "living courtyard" or common area is shared by both pedestrians and vehicles.

This technique is common in European communities and is created by narrowing the street entry on either end, typically on short, isolated residential streets, and installing obstacles such as planters, parking, etc., at irregular intervals to slow traffic.

Design Considerations: Woonerfs are generally acceptable for short distances only and should be used in conjunction with other physical speed control features such as textured pavement or posted 10 to 15 km/h (8 to 10 mph) speed limit signs.

c. Traffic Calming and Bicyclists

In areas subject to traffic restraint or low speed limits, special facilities for bicycles are not usually needed or provided since traffic calming offers many inherent benefits for bicyclists. Mixing with slower traffic, bicyclists can move around in comparative safety. Traffic calming also offers a more bicycle-friendly alternative to wholly pedestrianized streets. Some traffic calming measures may also be particularly appropriate on older and narrower streets, which are too narrow to allow for the provision of special bicycling facilities.

Nevertheless, poorly-designed traffic-calming facilities can inconvenience or even endanger bicyclists. Bicyclists are particularly susceptible to changes in surface height and texture, and may be put at risk by poorly-considered road narrowing. Speed-reducing measures should not be so "harsh" as to discourage bicyclists from using traffic-calmed areas. Design guidelines to accommodate bicyclists are discussed in the companion volume to this document, NJDOT Bicycle Compatible Roadways and Bikeways.

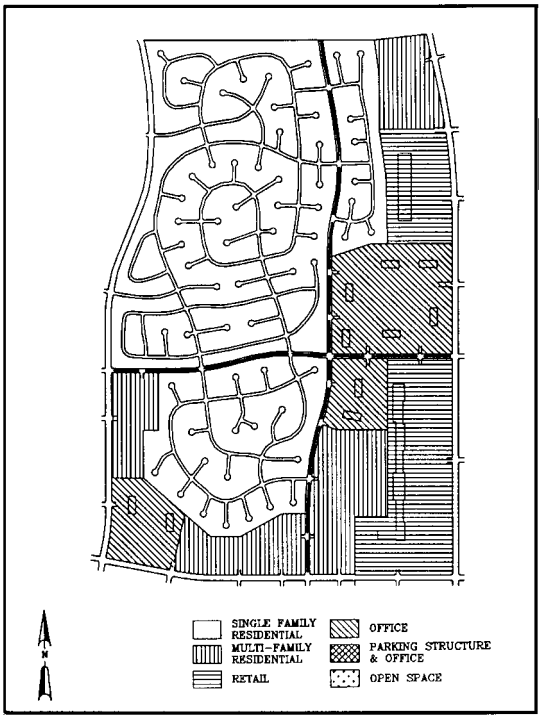
2. Traditional and Neo-Traditional Neighborhood Design

a. Background

Traditional or Neo-Traditional Neighborhood Design (TND or NTND) is a development or redevelopment concept which reflects principles and techniques that link land use with transportation choices. As an alternative to suburban sprawl, TND/NTND proposes a scale and mix of land use types and a transportation network for suburban communities, that differs from suburban development patterns of the recent past. Past development has been characterized primarily by suburban sprawl, cul-de-sacs, low-density and auto-oriented land use. TND/NTND communities are characterized by neighborhood centers and civic spaces within walking distance of one another, compact development patterns with a mix of housing choices and other land uses, connected street networks, typically in a grid pattern, design features that include narrow street pavement widths and pedestrian-scale improvements. These communities are often also integrated with transit through pedestrian linkages. See Figures 40 and 41.

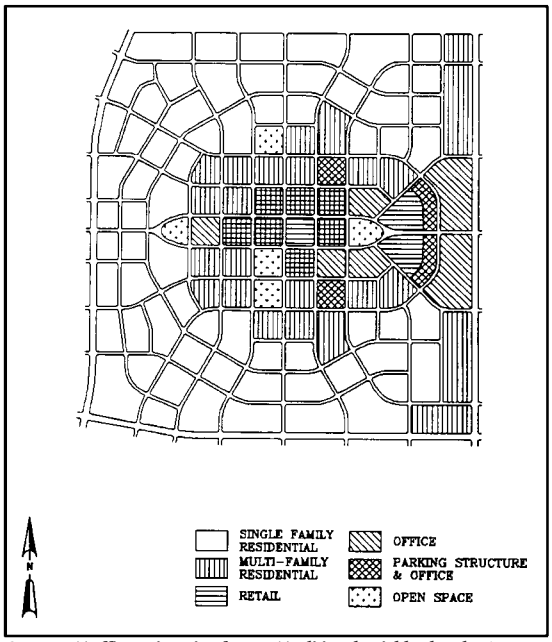
All of these elements contribute to creating a more pedestrian-friendly environment that will encourage walking trips. Application of TND/NTND transportation principles are described in the following section.

Figure 40
Suburban Land Use



Source: Traffic Engineering for Neo-Traditional Neighborhoods: An Informational Report, ITE Technical Committee 5P-8, 1993

Figure 41
Neo-Traditional Land Use



Source: Traffic Engineering for Neo-Traditional Neighborhoods: An Informational Report, ITE Technical Committee 5P-8, 1993

b. TND/NTND Transportation Principles and Techniques

TND/NTND type road guidelines reduce roadway width, horizontal curve radii and intersection of curb radii, as Figures 42 through 44 indicate. Suggested curb radii on local streets are 3.0 to 4.6 meters (10 to 15 feet) and on subcollectors, 4.6 to 6.1 meters (15 to 20 feet). In addition, TND site planning principles are very consistent with the SDRP "Communities of Place" concepts.

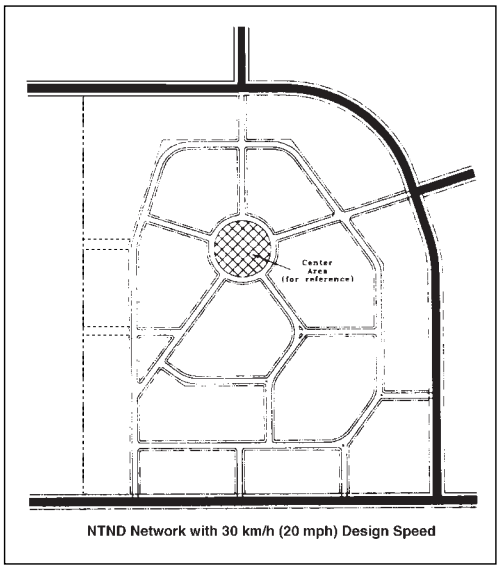


Figure 42

NTND Network with 30 km/h (20 mph) Design Speed

Source: Traffic Engineering for Neo-Traditional Neighborhoods: An Informational Report, ITE Technical Committee 5P-8, 1993

From an urban design perspective, a compact network of streets, with sharp turns and rectilinear road patterns as shown in Figure 42, will help create a strong visual identity and sense of place. This sense of place is further promoted by requiring buildings to front close to the street to create a sense of enclosure and to shorten the walking distances between destinations. These bounded spaces can allow for variations for special buildings or events which the pedestrian can appreciate at a walking pace. Thus, civic buildings such as meeting halls, theaters, churches and museums often open onto squares. Sometimes streets end at a civic building to accentuate their importance and provide aesthetic "vista terminations" which help to create this "sense of place" (Figure 45). These elements of design make for memorable views along streets and for neighborhood "legibility" that bland suburban designs cannot begin to emulate.

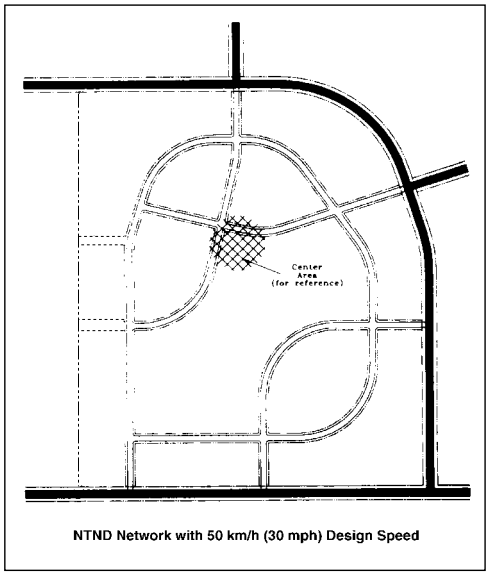


Figure 43

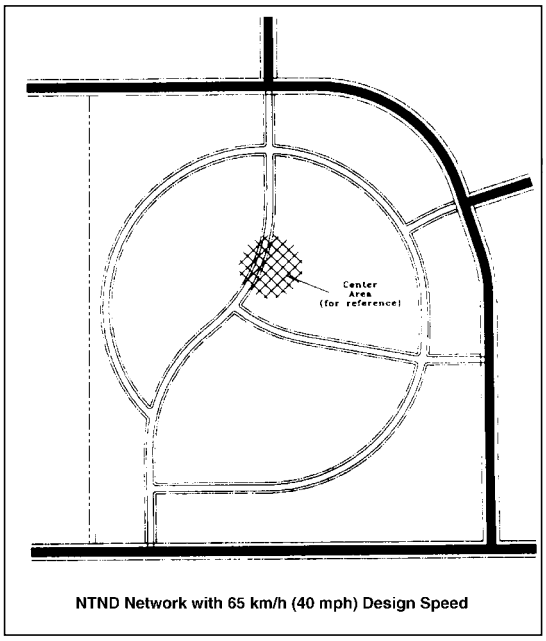
NTND Network with 50 km/h (30 mph) Design Speed

Source: Traffic Engineering for Neo-Traditional Neighborhoods: An Informational Report, ITE Technical Committee 5P-8, 1993

Grid patterns of narrow, well-designed streets improve community access in spite of low design speeds. The narrower streets provide smaller, more numerous intersections that disperse congestion. The gridded network of streets that is built into the TND plan disperses traffic from the major generators to a myriad of local streets. This is in direct contrast to the conventional hierarchical street system which focuses traffic from numerous generators onto single links of the arterial system (Figure 46). The gridded network that is built into the TND also disperses the turning-movement load onto a large number of intersections, rather than funneling a large number

Figure 44

NTND Network with 65 km/h (40 mph) Design Speed



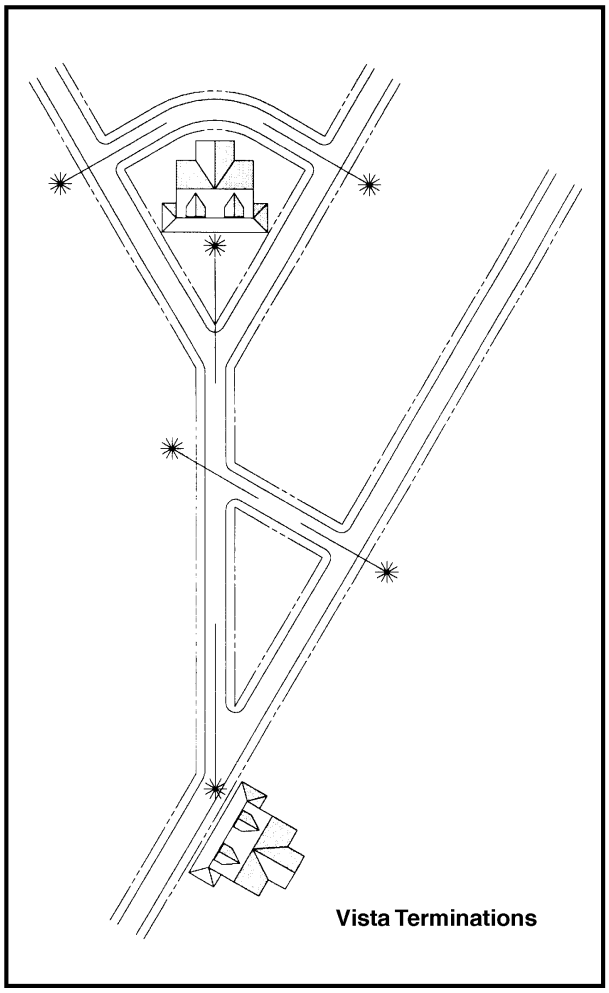
Source: Traffic Engineering for Neo-Traditional Neighborhoods: An Informational Report, ITE Technical Committee 5P-8, 1993

of turning movements into a single intersection.

A simple example illustrates the surprising amount of turning-movement capability that is gained in an intersection grid of streets, contrasted to a single multi-lane intersection (see computation on Figure 47).This example illustrates a fundamental point of network capacity: the total intersection capacity of a street system increases dramatically as the network expands.

Figure 45

Vista Terminations



Source: Traffic Engineering for Neo-Traditional Neighborhoods: An Informational Report, ITE Technical Committee 5P-8, 1993

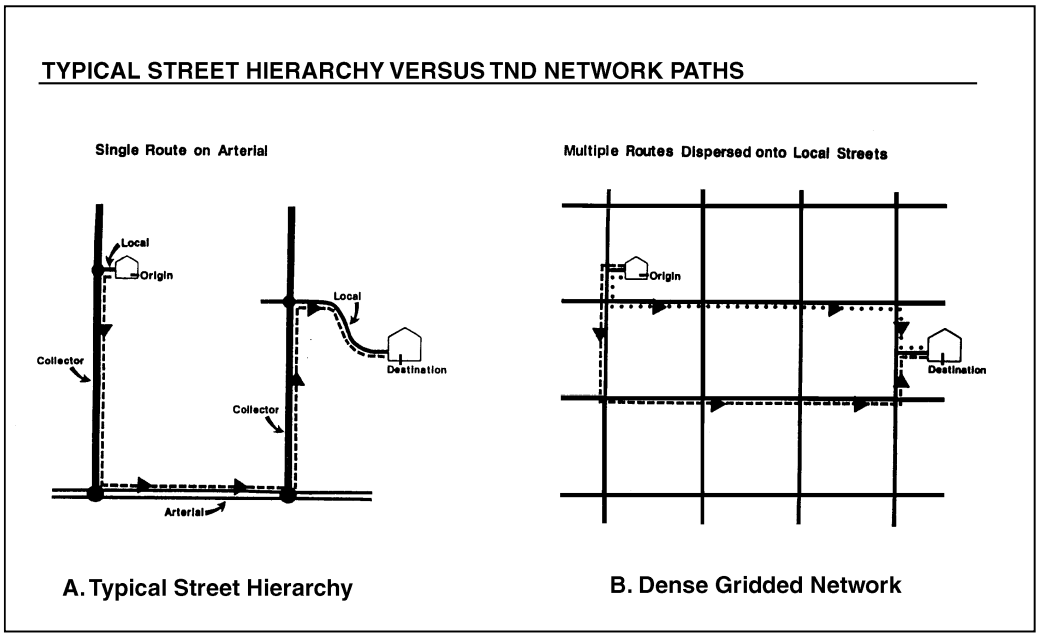


Figure 46

Typical Street Hierarchy Versus TND Network Paths

Source: Traditional Neighborhood Development, Will the Traffic Work?, Kulash, 1990.

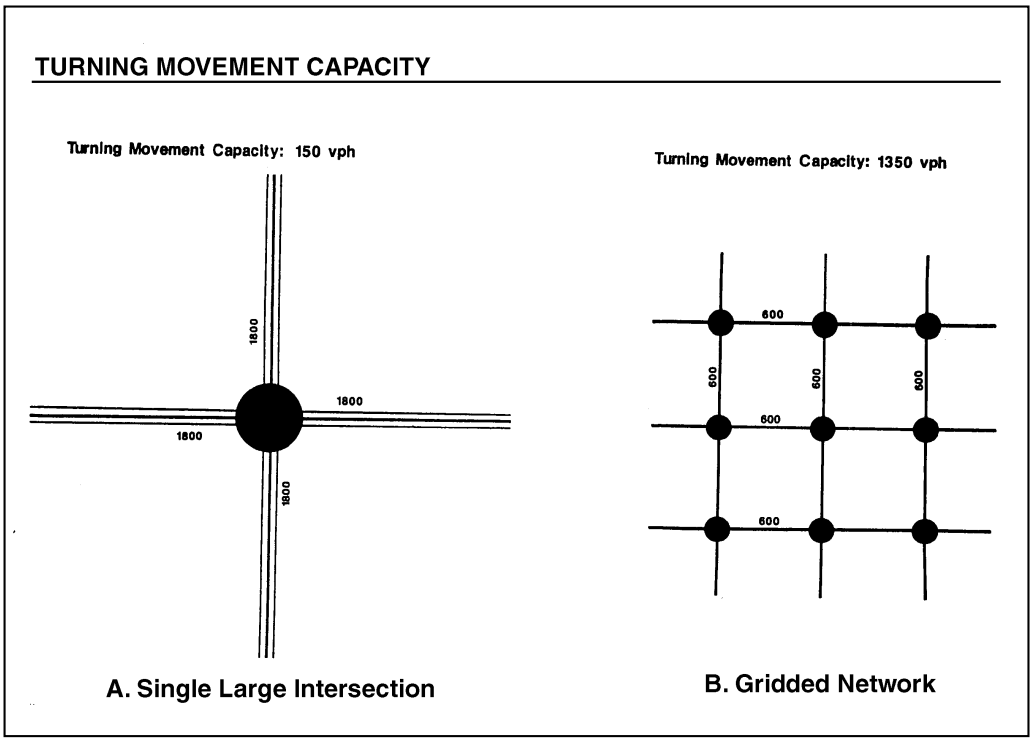


Figure 47

Turning Movement Capacity

Source: Traditional Neighborhood Development, Will the Traffic Work?, Kulash, 1990.

3. Pedestrian Linkages

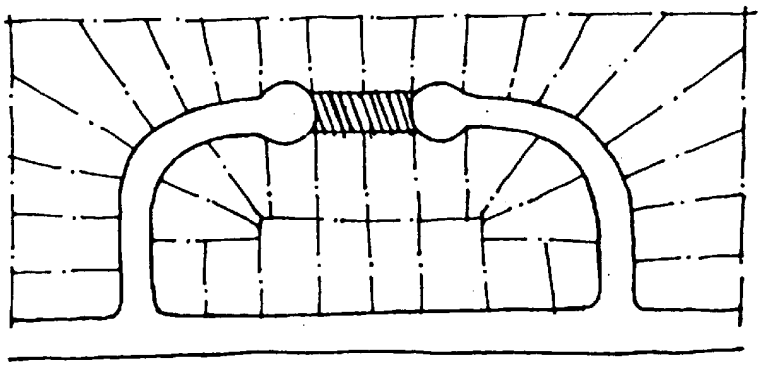
When a grid or other dense street network is not available, pedestrian linkages should be provided to maintain walking continuity. Cul-de-sacs, loop roads and similar treatments which disrupt pedestrian continuity should incorporate pedestrian linkages such as "cut-thrus" to adjoining developments. See Figure 48. These shortcuts enable pedestrians to travel by the most direct route between destinations. In most cases, routes will have fewer vehicular conflicts since the pedestrian does not have to use an arterial to get from one local street to another. Streets with a mid-block length greater than 180 meters (600 feet) should provide a mid-block pedestrian linkage to adjoining blocks.

Similarly, large lot commercial developments, such as office buildings or shopping centers, should provide numerous linkages with surrounding residential areas to permit nearby residents to walk to the site. Linkages should also be provided between adjoining commercial/ residential/office uses; for example, walkways connecting an office building parking area with an adjacent restaurant. It is not necessary to demonstrate that there is a latent demand for walking. The linkage is required to service even the single trip if it is generated.

Policy for linkages can be defined in the land use element of municipal master plans, in the circulation element of municipal master plans, and on the official map as provided in the Municipal Land Use Law.

Figure 48

Pedestrian Connections and Linkages



Source: Accommodating the Pedestrians, Untermann

Chapter 4

Operations and Maintenance of Pedestrian Facilities

1. Pedestrian Facilities in Traffic Work Zones

Construction activities can substantially disrupt sidewalks or other pedestrian walkways. As a result, it is essential that construction plans incorporate appropriate specifications assuring either that the pedestrian passage will be kept open and adequately maintained, or that an appropriate alternative route be established which is both convenient and accessible for all walkway users. In order to assure that adequate facilities for pedestrians have been provided, designers must document the nature of all existing pedestrian activity, including nighttime and week-end activity.

Construction occupying or disrupting the surface of a public sidewalk or path is a particular hazard to pedestrians with vision impairments if the work is not adequately protected by barriers. Persons who use long canes may not detect a tape or a series of widely spaced traffic cones placed around a construction site. Such marking does not provide sufficient warning to enable a visually impaired pedestrian to anticipate a hazard, nor does it provide an edge along which to travel around an obstruction.

Jurisdictions and their contractors should ensure that barriers establishing a temporary passage around public sidewalk and street construction meet the needs of all pedestrians. Scaffolding in the public right-of-way should be carefully designed in order to avoid creating protruding objects along the public sidewalk or pathway.

The removal, even for a short time, of a public sidewalk curb ramp or other accessible element may preclude access to buildings, facilities or areas for persons in wheelchairs or walking with crutches, pushing baby carriages, shopping carts or luggage carriers, or delivering goods on dollies. In some situations the removal of such a curb ramp may not preclude access but may force a lengthy and circuitous route to bypass the resulting barrier. As a result, it is essential that when a curb ramp or other accessible element is removed, an alternate route must be provided which is convenient and accessible for all public sidewalk users, and that route must be clearly marked to avoid extra travel distance.

Table 7 summarizes considerations required for planning, implementing and maintaining pedestrian accommodations at work zones. This table may be copied and, with appropriate notes, included in a project's file as an aid in safely accommodating pedestrians at work sites.

Table 7

Guidelines for Pedestrian Accommodations at Work Zones

Guidelines for Pedestrian Accommodations at Work Zones

Planning Considerations

1. **Consider origins, destinations and walking paths to determine where pedestrian access should be maintained and where it may be blocked and provided with 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, accessible route with necessary signs, signals, etc., which is as convenient and direct as possible.**

     The key is that the pedestrian must feel that his or her needs have been adequately met. Otherwise, pedestrians will choose their own "safe" route. Pedestrians should feel secure and not be subjected to undue risk. Adequate accommodations must be provided to meet the needs of all types of pedestrians, including school children, blind, elderly, or handicapped persons.

3. **Check for pedestrian generating land-use facilities - schools, senior citizen centers, facilities used by handicapped persons, shopping centers, recreation areas, and restaurants, etc., to determine if additional facilities will be required.**

4. **Consider needs for night time accommodation. In particular, consider the potential masking effect of barricade lights and high visibility work site markings.**

5. **To avoid blockage of the pedestrian pathway by construction material, equipment, and debris, establish a designated location for these items as a part of the construction contract and require in the contract that identified pedestrian routes be kept open.**

6. **Consider stage construction techniques when there is no acceptable alternate routing for pedestrians.**

Table 7
Continued

Information Needs

1. Advance Information

- Advance information is 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.
- In general, no advance information is needed for the following situations:
  - Where an accessible 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 accessible pedestrian pathway is maintained and the pathway itself is obvious to all pedestrians.
- Tailor sign messages to specific needs. Typical messages include: Sidewalk Closed Ahead, Sidewalk Closed — Use Other Side, and Pedestrian Detour — Follow Arrow. Signs should be located on barricades detectable to the blind.
- Where groups with special limitations are known to use the facility, public meetings should be held to describe the project, its duration, and its impact on users. In addition, a guide may be posted to alert these users during the initial period following the start of construction.

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: closely spaced cones, temporary marking tape, barricade — Type I or II, ropes or chains, wood railings, portable concrete barriers, etc. Use of tape, rope, chains or railings must take into account the needs and limitations of the visually impaired.

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: closely spaced cones, wooden railings, barricades, and portable concrete type barriers.

4. Exit Information

- No exit information is required if the existing pathway is used, or if the continuity of the accessible pathway is obvious to all pedestrians.
- In case of a bypass or detour, pedestrians need positive direction to return to the original path. Appropriate signing and other devices must be provided for this purpose.

Table 7
Continued

Pedestrian Pathway Considerations

1. Provide walkway widths consistent with original sidewalk width or sufficient to satisfy current pedestrian volumes.
2. Boundaries of the pathway should be clearly defined for all pedestrians.
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 pathways.
5. The transition into and out of redefined or relocated walkways should be clearly defined by markings, signs, or barricades to provide positive direction.
6. A physical barrier may be necessary to keep pedestrians from wandering into a traffic lane or the construction area.
7. Provide ramping where grade differential along the pathway is more than 13 millimeters (half an inch) between existing and temporary designated sidewalk. All ramping should be rigid and firmly secured for safety of wheelchair use, etc.
8. Do not allow changes in construction to block the pedestrian pathway. A periodic inspection and maintenance of the work zone area is desirable.
9. Physical separators between pedestrians and traffic should be selected based on duration of the project and space availability. In all cases, a separator should be used to confine pedestrians to a safe walkway space.
10. The interior of overhead protected (canopy type) pedestrian walkways should be properly illuminated for nighttime visibility.
11. All pathways must be kept clear of projecting items or other obstacles. A minimum vertical clearance of 2.9 meters (114 inches) shall be provided.
12. Evaluate potential impacts of drainage along all identified pedestrian routes and assure that water is effectively removed and that no ponding will occur.
13. If construction will be in place during the winter season, evaluate pedestrian routes to ensure that ice cannot readily form and that adequate space is available for snow removal and storage.

Intersection Crossings

1. If the original crosswalk is altered or removed, provide a clearly defined new crosswalk path using temporary marking tape. Make sure original crosswalk markings are not visible.
2. Keep the crosswalk clear of debris, mud, construction materials, construction equipment, and other devices.
3. Warn motorists if the pedestrian crossing is unexpected. Evaluate any possible need for pedestrian crossing signs, orange color. Special warning signing may be needed if the problem is severe.
4. Provide signing and/or markings to define the entrance to the crosswalk. Channelize pedestrians into the 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 an existing crossing is not to be used.

Table 7
Continued

7. Provide covers, or metal plates, over any cuts or ditches in the area for the entire width of the existing or modified crosswalk.
8. Consider lighting the area for nighttime visibility if the cut in pavement is deep or hazardous. This applies to sidewalk cuts as well.

Sidewalk Closure and Blockage

1. If existing sidewalk through a work zone is to be closed, two alternatives are possible:
   - Detour pedestrian traffic onto the other side where a sidewalk or a pedestrian path is available. Provide adequate signs and barriers for diverting pedestrian traffic onto 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 an arrow.
   - 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.
2. Sidewalk closure should be accomplished with a substantial barrier, Type III barricade. Use signs indicating sidewalk closure and pedestrian diversion.
3. If pedestrians have to cross the highway because of sidewalk closure, make sure that an adequate crossing is provided using signing, crosswalk markings, traffic signal modification, and pedestrian signs, if warranted. Curb ramps must be available.
4. For short-term utility operations, use less permanent devices, such as Type I or II barricades, or even closely spaced cones. Use signs and cones for delineation and channelization for safe walking around work zones.

Pedestrian Protection

1. Separators provided on both traffic and construction sides should be compatible with the level of hazard.
2. The type of separator used should not create a hazard itself.
3. A physical separator may be needed if the sidewalk on the construction side is to be closed and pedestrian traffic is to be diverted close to moving traffic.
4. If there is construction overhead, and the possibility of falling debris or wet concrete, overhead protection should be provided for walkways below.

Table 7
Continued

Inspection and Maintenance

1. **Check for compliance with the 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, sedimentation, debris, construction materials, and equipment.**
5. **Maintain signal equipment in operational condition. Check bulbs periodically.**
6. **Following rain or snow, check to assure that the pedestrian route is clear and accessible.**

Source: Planning, Design and Maintenance of Pedestrian Facilities, FHWA, 1989.

2. Pedestrian Facility Maintenance

Pedestrian facilities must be properly maintained if they are to be effective and durable. Poorly maintained pedestrian facilities may become serious hazards, pose a liability risk and will impact on a community's image. Maintenance of pedestrian facilities should address the following issues:

- Prompt removal of snow, mud, water or debris
- Periodic refurbishing of the facilities provided

Failure to properly maintain a pedestrian facility will likely compromise the original design objectives of the facility.

a. Sidewalk Repairs

Sidewalks and other pedestrian routes must be adequately maintained to assure that they are accessible to all pedestrians including persons in wheelchairs. Vertical movement and cracking are common problems affecting the accessibility and safety of sidewalks and paths. Vertical movement may result from tree root growth, soil heaving or settlement or loadings in excess of the pavement's design strength. Sidewalks and other routes should be repaired when cracks or vertical shifts exceed limits established by the Accessibility Guidelines for Buildings and Facilities.

A change in vertical elevation of less than 6 millimeters (1/4 inch) does not require any edge treatment. Greater changes in elevation must be corrected. Changes in elevation between 6 and 13 millimeters (1/4 and 1/2 inch) may be corrected using a bevel having a slope no greater than 1:2. For changes greater than 13 millimeters (1/2 inch) either a curb ramp should be provided meeting the requirements established in the federal regulations, or the sidewalk section should be repaired or reset In areas of high pedestrian activity, or in areas where physically impaired pedestrians or pedestrians using carts or carriages are con-

centrated, such as near nursing or rehabilitation homes, in downtowns or near transit terminals, resetting of sidewalk sections or other repairs should be considered in lieu of beveling even if the vertical change is less than 13 millimeters (1/2 inch).

b. Winter Season Maintenance Requirements

Continuity of pedestrian accessibility requires that sidewalks and other pedestrian routes remain open and accessible throughout the winter months. As a result, reasonable effort must be taken to keep pedestrian routes clear of obstruction from snow and free of hazards created by ice.

(1) Sidewalks. Snow storage for streets, highways, driveways or parking lots must not block sidewalks or other accessible pedestrian routes. The setback between a roadway's edge and a sidewalk will often provide sufficient space for snow storage. Where sufficient space is not available, however, snow, ice, snow melt and debris removed from the highway will occupy and block the pedestrian path. Where inadequate storage area is available, highway agencies should schedule and provide for snow removal or clearance as needed to assure that the pedestrian way is kept open.

Similarly, snow banks created by plowing frequently block pedestrian access to crosswalks. All intersections must be hand or machine shovelled to assure that crosswalks, both marked and unmarked, are accessible. To assure compliance with this requirement, highway agencies should maintain an inventory of crosswalk locations requiring clearance following storm events.

Snow melt can create ponds blocking access to sidewalks and especially crosswalks. Intersections and mid-block crosswalks should be designed to assure that drainage can be maintained through snow events. Where adequate design of street drainage has not been provided, plowed snow blocking stormwater inlets must be hand cleared following plowing. Because ponding and icing caused by blocked drainage facilities poses a hazard for both pedestrians and vehicles, effective storm drainage for snow melt must be reestablished as shortly following a storm as possible.

Responsibility for removing snow from sidewalks rests with the adjacent property owner. Municipalities should ensure that they have valid ordinances in place requiring prompt snow removal—usually defined as a requirement that sidewalks are cleared within 24 hours following the end of a storm event. In addition, property owners are responsible for either keeping ice from forming on their property or for applying appropriate traction materials such as sand to protect pedestrians once ice has formed.

Where sidewalks pass through publicly owned properties, for example along parks or adjacent or across highways or railroads, responsibility for snow clearance rests with the agency owning the property unless a jurisdictional agreement has established alternative responsibility.

Effective inspection and enforcement measures are required to ensure that sidewalk clearance responsibilities are met.

(2) Pathways. Paths, trails and linkages located on independent rights-of-way are generally not kept plowed during winter months. Instead, it is generally assumed that these routes during winter will only be used by able bodied persons, properly attired. As a results, these routes generally are trampled down by users rather than cleared.

However, in areas where disabled persons are known to use these paths, or can be expected, jurisdiction should be established to assure that the path is kept as clear as the sur-

rounding system of sidewalks. This requirement is especially important where a pedestrian path forms part of an accessible route required to provide access to a building, facility or site.

c. Inspection and Maintenance Programs

The adequate maintenance and repair of pedestrian facilities can best be assured through the adoption of a periodic inspection and maintenance program. Table 8 presents a sample inspection and maintenance checklist for pedestrian facilities, outlining possible maintenance and repair problems and appropriate activities to correct problems. The frequency with which facilities should be inspected, and maintenance activities conducted, depends upon the environment in which the facility is located and the nature of the maintenance activity.

Table 8
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 13 millimeters (1/2 inch).	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 and ponding from snow melt.	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 13 millimeters (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. Materials, signs, vending machines, etc. restricting effective sidewalk width.	7. Require responsible parties to remove obstructions.
	8. Low hanging tree limbs, bushes, weeds and other foliage 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 8

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 crosswalk.	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 6 millimeters (1/4 inch) 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 and ponding from snow melt.	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 13 millimeters (1/2 inch).	8. Fill joint with hardening expansion compound.
	9. Pedestrians do not have time to clear roadway prior to signal change.	9. Review pedestrian clearance/timing plan assuming a maximum speed of 1.1m (3.5 ft.) per second plus a tolerance of 2 seconds for reaction time. Add refuge island in middle of street. Extend sidewalk to edge of parking lane.
Shoulders	1. Debris, trash and loose sand on shoulder.	1. A maintenance program should be developed to provide for regular sweeping of shoulders.
	2. Snow and ice buildup.	2. A maintenance program should be developed to ensure snow and ice removal.
Overpasses and Underpasses	1. Falling objects from overpass.	1. Enclose overpass with chain-link fencing.
	2. Sparse pedestrian use of underpasses.	2. Underpass should be well lighted to provide a feeling of personal security.
	3. Worn step or ramp surfaces.	3. Overlay, replace or texturize to slip free and unbroken surface.
	4. Snow and ice buildup and ponding from snowmelt.	4. A maintenance program should be developed to ensure snow and ice removal.
	5. Section pop-up of vertical height greater than 13 millimeters (1/2 inch).	5. Replace defective section or provide temporary asphalt shim.

Table 8
Continued

Pedestrian Facility	Concern	Maintenance Activity
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. 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 foliage.
	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. Signs mounted on a wall should be mounted at a height between 1370 millimeters and 1675 millimeters (54 inches and 66 inches).
	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. • Refurbish, including lens cleaning and bulb replacement.

Source: Planning, Design and Maintenance of Pedestrian Facilities, FHWA, 1989.

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Excerpt From the NJDOT Guide to Metrication

CONVERSION FACTORS

ELECTRICAL ENGINEERING			
From English Units	To Metric Units	Metric Symbol	Multiply By
abampere	ampere	A	10.
abcoulomb	coulomb	C	10.
abfarad	farad	F	10^{9}
abhenry	henry	H	10^{-9}
abmho	siemens	S	10^{9}
abohm	ohm	Ω	10^{-9}
abvolt	volt	V	10^{-8}
ampere hour	coulomb	C	3 600.
EMU of capacitance	farad	F	10^{9}
EMU of current	ampere	A	10.
EMU of electric potential	volt	V	10^{-8}
EMU of inductance	henry	H	10^{-9}
EMU of resistance	ohm	Ω	10^{-9}
ESU of capacitance	farad	F	$1.112\ 650 \times 10^{-12}$
ESU of current	ampere	A	$3.335\ 6 \times 10^{-10}$
ESU of electric potential	volt	V	299.79
ESU of inductance	henry	H	$8.987\ 554 \times 10^{11}$
ESU of resistance	ohm	Ω	$8.987\ 554 \times 10^{11}$
faraday (based on carbon-12)	coulomb	C	96 487.0
faraday (chemical)	coulomb	C	96 495.7
faraday (physical)	coulomb	C	96 521.9
footcandle	lux	lx	10.763 91
footlambert	candela per square meter	cd/m^2	3.426 259
gamma	tesla	T	10^{-9}
gauss	tesla	T	10^{-4}
gilbert	ampere	A	0.795 774 7
horsepower (electric)	watt	W	746.0
kilowatt hour	joule	J	3 600 000.
lumen per square foot	lumen per square meter	lm/m^2	10.763 91
maxwell	weber	Wb	10^{-8}
mho	siemens	S	1
oersted	ampere per meter	A/m	79.577 47
ohm centimeter	ohm meter	Ω · m	0.01
ohm circular-mil per foot	ohm meter	Ω · m	$1.662\ 426 \times 10^{-9}$
statampere	ampere	A	$3.335\ 640 \times 10^{-10}$
statcoulomb	coulomb	C	$3.335\ 640 \times 10^{-10}$
statfarad	farad	F	$1.112\ 650 \times 10^{-12}$
stathenry	henry	H	$8.987\ 554 \times 10^{11}$
statmho	siemens	S	$1.112\ 650 \times 10^{-12}$
statohm	ohm	Ω	$8.987\ 554 \times 10^{11}$
statvolt	volt	V	299.792 5
unit pole	weber	Wb	$1.256\ 637 \times 10^{-7}$

Underlined factors in the table denote exact numbers.
Use the number of digits needed for the required accuracy.
When converting from metric units to English divide by the factor shown (multiply by the inverse).
Conversion values based on 1 inch = 25.4 millimeters unless otherwise shown.

CONVERSION FACTORS

GENERAL				
Quantity	**From English Units**	**To Metric Units**	**Metric Symbol**	**Multiply By**
Length	inch	millimeter	mm	25.4
	foot	millimeter	mm	304.8
	foot	meter	m	0.304 8
	foot (U.S. Survey) *	meter	m	0.304 800 6
	yard	meter	m	0.914 4
	mile	kilometer	km	1.609 344
Area	square inch	square millimeter	mm^2	645.16
	square foot	square meter	m^2	0.092 903
	square yard	square meter	m^2	0.836 127 4
	acre	square meter	m^2	4 046.856
	acre	hectare	ha	0.404 685 6
	square mile	square kilometer	km^2	2.590 000
Volume	fluid ounce	milliliter	ml	29.573 53
	quart	liter	L	0.946 352 9
	gallon	liter	L	3.785 412
	gallon	cubic meter	m^3	0.003 785 412
	cubic inch	cubic millimeter	mm^3	16 387.064
	cubic foot	cubic meter	m^3	0.028 316 85
	cubic yard	cubic meter	m^3	0.764 555
	acre-foot	cubic meter	m^3	1 233.482
Temperature	degree Fahrenheit	degree Celcius	°C	5/9 (°F-32)
Velocity	feet per second	meters per second	m/s	0.304 8
	miles per hour	kilometers per hour	km/h	1.609 344
Rate of application	gallon per square foot	liter per square meter	L/m^2	41.132 19
	gallon per square yard	liter per square meter	L/m^2	4.527 317
	gallon per acre	liter per hectare	L/ha	9.353 925
	gallon per acre	cubic meter per hectare	m^3/ha	0.009 353 925
	1 000 gallons per acre	cubic meter per hectare	m^3/ha	9.353 925
Slope	foot per foot	meter per meter	m/m	1.0
	foot per mile	meter per meter	m/m	0.000 189 4
Discharge	cubic foot per second	cubic meter per second	m^3/s	0.028 316 85

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- Use the number of digits needed for the required accuracy.
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- Conversion values based on 1 inch = 25.4 millimeters unless otherwise shown.
- * U.S. Survey Foot: In 1893, the U.S. foot was legally defined as 1200/3937 meters. In 1959, a refinement was made to bring the foot into agreement with the definition used in other countries, i.e., 0.304 8 meters. At the same time, it was decided that any data in feet derived from and published as a result of geodetic surveys within the U.S. would remain with the old standard, which is named the U.S. Survey foot. The new length is shorter by exactly two parts in a million.

CONVERSION FACTORS

CIVIL AND STRUCTURAL ENGINEERING				
Quantity	**From English Units**	**To Metric Units**	**Metric Symbol**	**Multiply By**
Mass	ounce pound ton (2,000 lb)	kilogram kilogram megagram	kg kg Mg	0.028 349 52 0.453 592 0.907 184
Mass per unit length	pound per inch pound per foot	kilogram per meter kilogram per meter	kg/m kg/m	17.857 97 1.488 16
Mass per unit area	pound per square foot ton (2,000 lb) per square foot	kilogram per square meter megagram per square meter	kg/m^2 Mg/m^2	4.882 43 9.764 856
Mass density	pound per cubic foot pound per cubic yard ton (2,000 lb) per cubic yard	kilogram per cubic meter kilogram per cubic meter megragram per cubic meter	kg/m^3 kg/m^3 Mg/m^3	16.018 46 0.593 276 1.186 554
Force	pound kip ton (2,000 lb)	newton kilonewton kilonewton	N kN kN	4.448 222 4.448 222 8.896 444
Force per unit length	pound per inch pound per foot kip per foot ton (2,000 lb) per foot	newton per meter newton per meter kilonewton per meter kilonewton per meter	N/m N/m kN/m kN/m	175.126 8 14.593 90 14.593 90 28.187 80
Force per unit area, pressure, stress, modulus of elasticity	pound per square inch kip per square inch kips per square inch pound per square foot kip per square foot	kilopascal megapascal gigapascal kilopascal megapascal	kPa MPa GPa kPa MPa	6.894 757 6.894 757 0.006 894 757 0.047 880 26 0.047 880 26
Bending moment, torque, moment of force	pound inch pound foot	newton meter newton meter	N · m N · m	0.112 984 8 1.355 818
Moment of mass	pound foot	kilogram meter	kg · m	0.138 255
Moment of inertia	inch to the fourth power	millimeter to the fourth power	mm^4	416 231.
Section modulus	inch cubed	millimeter cubed	mm^3	16 387.064

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