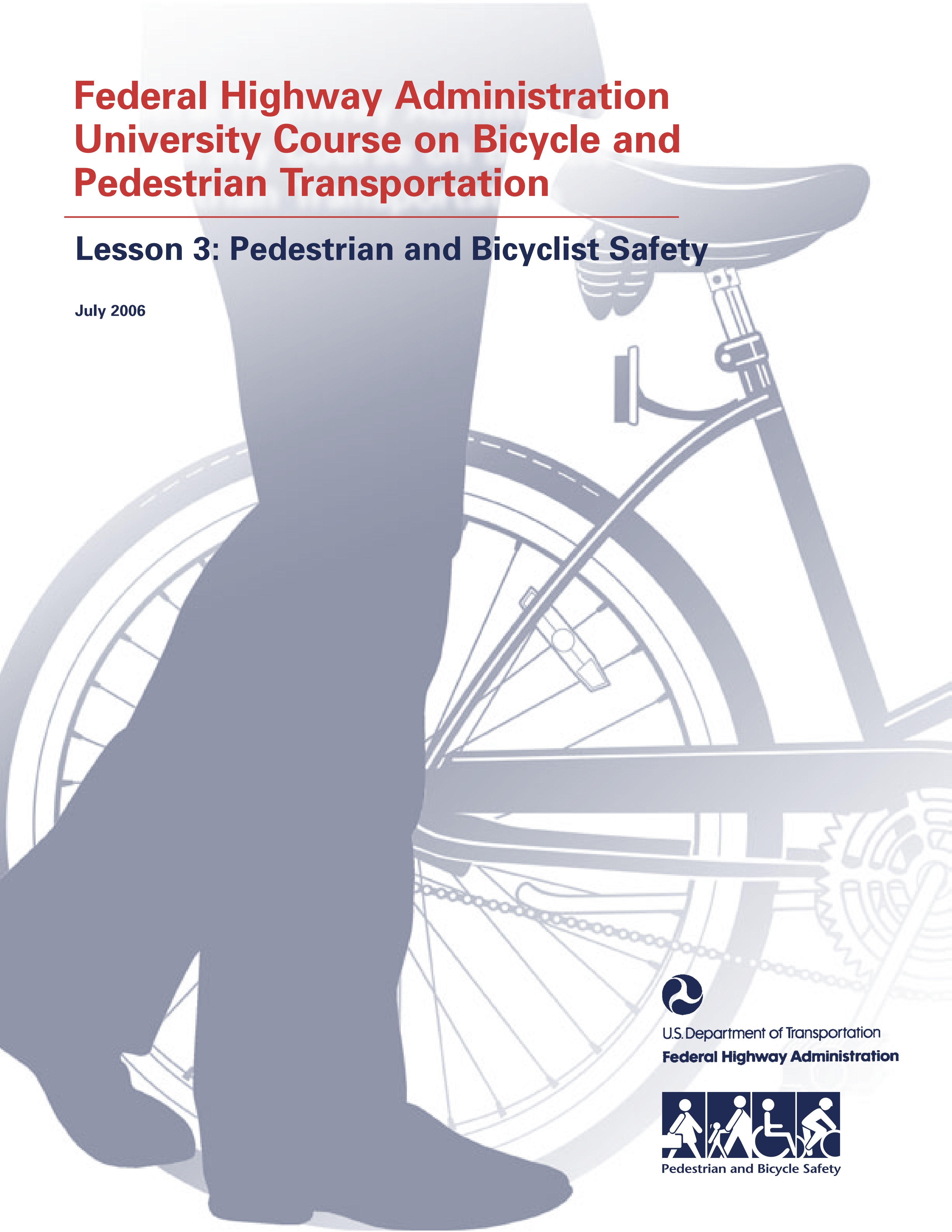
Federal Highway Administration University Course on Bicycle and Pedestrian Transportation

Lesson 3: Pedestrian and Bicyclist Safety

July 2006



U.S. Department of Transportation
Federal Highway Administration

Pedestrian and Bicycle Safety

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

Table of Contents

List of Figures

List of Tables

LESSON 3:

PEDESTRIAN AND BICYCLIST SAFETY

3.1 Introduction

Many professionals involved in pedestrian and bicycle programs have never received training that focuses on crash causation. Everyone—from traffic safety specialists to traffic engineers, planners, educators, and law enforcement personnel—can benefit from an understanding of how crashes occur and how to avoid them. It should be noted, however, that in some cases, the study of bicycle and pedestrian conflicts with vehicles may be more useful than crash analyses. Conflict analysis may be useful because bicycle and pedestrian crashes may be a rare occurrence on some facilities and may not be the best measure of operational analysis.

This lesson provides an understanding of crash characteristics, crash rates, exposure, crash typing, crash analysis, benefit-cost analysis, and associated countermeasures. The most significant crash types will be explained and associated with contributing factors and typical errors made. The concepts of corridor and site crash analysis and team problem solving will be emphasized. Discussion will include special conditions—especially nighttime crashes, those involving impaired drivers, pedestrians and bicyclists, and high-speed roadways. The major sections of the lesson are as follows:

- 3.1 Introduction.
- 3.2 What Is a Crash?
- 3.3 The Crash Avoidance Process.
- 3.4 Number of Bicycle and Pedestrian Crashes.
- 3.5 Summary of Bicycle and Pedestrian Crash Characteristics.
- 3.6 Common Pedestrian and Bicycle Crash Types.
- 3.7 Pedestrian and Bicycle Crash Analysis Tool (PBCAT).
- 3.8 Bike and Pedestrian Countermeasures.
- 3.9 Bike and Pedestrian Safety Goals.
- 3.10 Geographic Information System (GIS) Crash Frequency Analysis.
- 3.11 Benefit-Cost Analysis.
- 3.12 Student Exercise.
- 3.13 References and Additional Resources.

3.2 What Is a Crash?

The word "crash" may be new to some people as a way to describe the event in which a bicyclist or pedestrian collides with the ground, a motor vehicle, or any other solid object in a way that can result in bodily harm and/or property damage. Historically, these events were called accidents. The term accident implies heavy doses of chance, unknown causes, and the connotation that nothing can be done to prevent them.

Crashes are preventable. Bicyclist and pedestrian crashes are not random events. They fall into a pattern of recurring crash types and occur because the parties involved make mistakes. The mistakes can be identified and counteracted through a combination of education, skill development, engineering, and enforcement measures that can substantially reduce crash occurrences.

3.3 The Crash Avoidance Process

Whether you are a pedestrian, bicyclist, or motorist, you generally go through a similar sequence of actions leading from searching for and recognizing a potential crash situation to taking steps to avoid it. The steps in this sequence are described below. If either party overlooks any of these steps, a crash may result.

- Step 1: Search—Both driver and bicyclist or pedestrian scan their environment for potential hazards (see figure 3-1).
- Step 2: Detect—One or both parties (bicyclist, pedestrian, or motor vehicle) see the other.
- Step 3: Evaluate—The threat of collision is recognized, along with the need for action to avoid it.
- Step 4: Decide—Assess risk and select the actions necessary to avoid a collision. This may involve judging location, closing speed, direction of travel, position in traffic, likely behavior, and other factors.
- Step 5: Action—This step involves the successful performance of the appropriate action(s) to avoid a collision.

(This picture shows a bicyclist not wearing a helmet.
FHWA strongly recommends that all bicyclists wear helmets.)

Figure 3-1. Photo. Bicyclist scanning for potential hazards.

3.4 Number of Bicycle and Pedestrian Crashes

According to statistics from the National Highway Traffic Safety Administration (NHTSA), approximately 4,749 pedestrians and 622 bicyclists were killed in 2003 as a result of collisions with motor vehicles (see figure 3-2).[1,2] As a group, pedestrians and bicyclists comprise about 13 percent of all highway fatalities each year. There were more than 70,000 pedestrian injuries and 46,000 bicyclist injuries reported as well in 2003 (see figure 3-3).

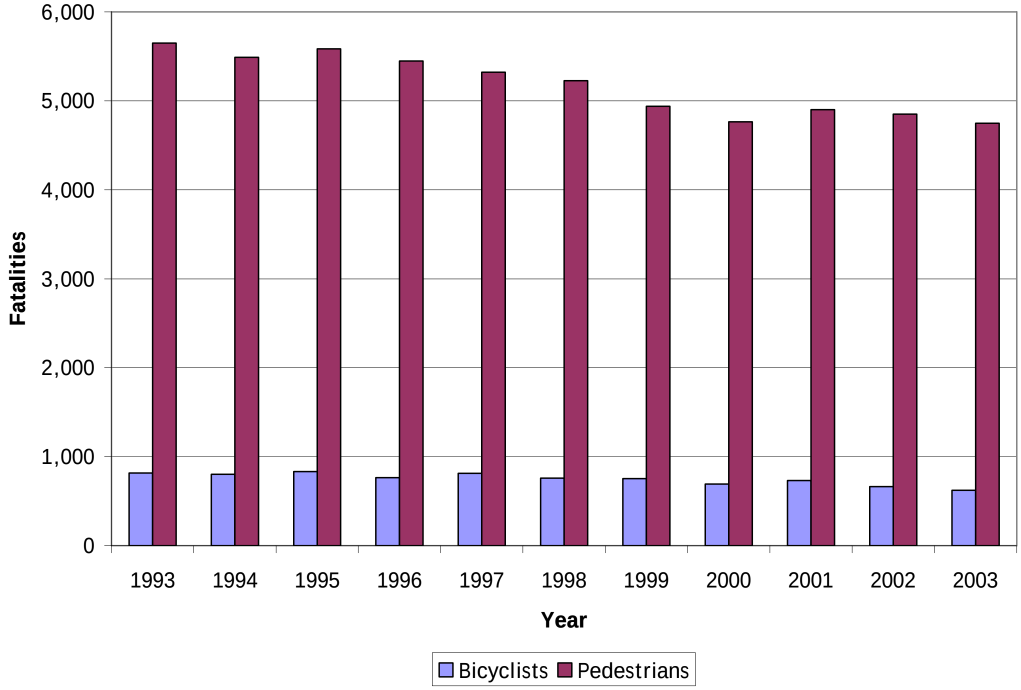


Figure 3-2. Graph. Trends in pedestrian and bicyclist fatalities.
Source: *NHTSA Traffic Safety Facts 2003*[1,2]

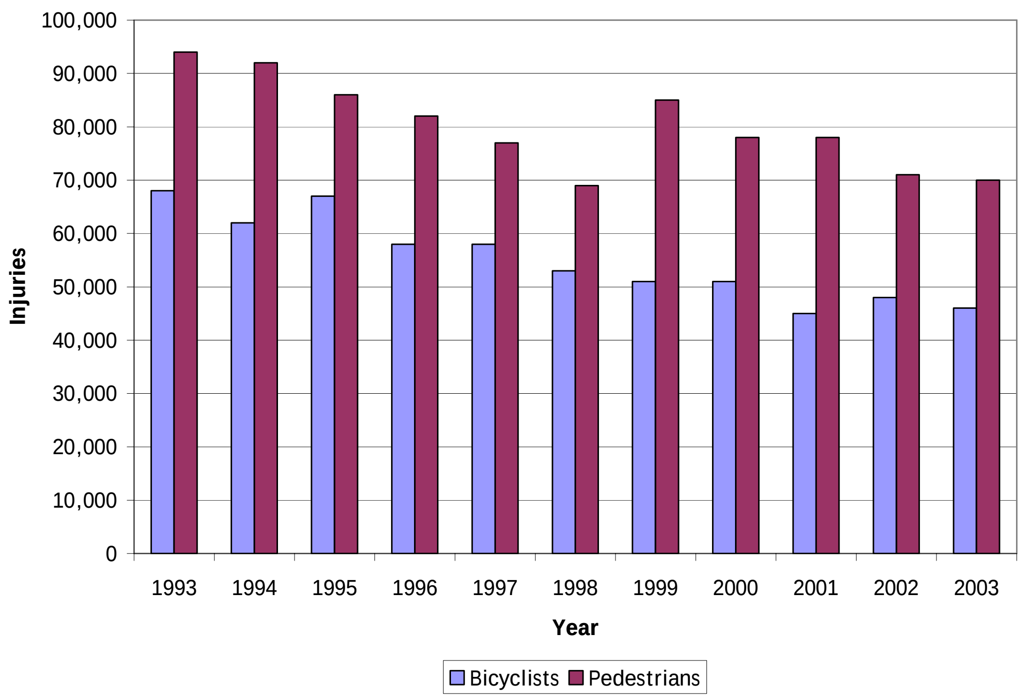


Figure 3-3. Graph. Trends in pedestrian and bicyclist injuries.
Source: *NHTSA Traffic Safety Facts 2003*[1,2]

The reported injuries are subject to significant undercounting; many more injuries were not reported to record-keeping authorities. A study by Hunter, et al., indicates that less than two-thirds of bicycle-motor vehicle crashes serious enough to require emergency room treatment were reported on State motor vehicle crash files.[3] Another study of emergency room records confirmed that there are numerous pedestrian and bicycle injuries that are never recorded by transportation authorities.[4] This may be due, in part, to the fact that the crashes didn't involve a motor vehicle (70 percent of reported bike injuries and 64 percent of pedestrian injuries) or that they occurred at nonroadway locations such as sidewalks, parking lots, or off-road trails (31 percent of bike injuries and 53 percent of pedestrian injuries). However, these crashes should not be overlooked or dismissed, as they still may have been caused by poor roadway facilities that could be improved by engineering or planning methods.

The number of pedestrian fatalities has dropped 16 percent from the 5,649 pedestrians killed in 1993, showing a steady decline in pedestrian-motorist crashes each year (see figure 3-2). The number of bicyclists killed in 2003 was 24 percent lower than the 816 fatalities reported in 1993. From 1993 to 2003, bicyclist fatalities per year have fluctuated, but they have not risen higher than the number reported in 1993 (see figure 3-2).

Of all nonmotorist traffic fatalities recorded in 2001, 85 percent were pedestrians, 13 percent were bicyclists, and the remaining 2 percent were inline skaters, skateboard riders, etc.

3.5 Summary of Bicycle and Pedestrian Crash Characteristics

Bicycle-Motor Vehicle Crashes

NHTSA provided the following statistics from 2003 that describe bicycle-motor vehicle crashes.[1]

Age

Sixty-two percent of bicyclists killed and 84 percent of those injured were between 5 and 44 years of age. In 2003, the average age of those killed was 35.8 years; the average age of those injured was 26.5 years. The proportion of bicyclists 25 years of age and older killed in motor vehicle crashes has risen since 1993. In 1993, 25 to 64-year-olds made up 41 percent of all bicyclist fatalities, while in 2001, that age group made up 57 percent.

At the same time, the proportion of bicyclists under age 16 involved in fatal crashes has declined since 1993. In 1993, young bicyclists (16 and younger) accounted for 38 percent of all bicyclists killed. In 2003, they accounted for 23 percent of all bicyclists killed and 37 percent of those injured. Twenty-three percent of the bicyclists killed in 2003 were between 5 and 15 years of age.

Gender

Most of the bicyclists involved in motor vehicle crashes in 2003 were males—88 percent of those killed and 78 percent of those injured. The male bicyclist fatality rate was almost eight times as high as the female rate, and the male injury rate was more than three times higher than the rate of injury for females.

Drug Impairment

Alcohol involvement, with either the driver or bicyclist, was reported in more than 33 percent of the fatal bicyclist crashes in 2003. In 32 percent of the fatal incidents, either the driver or the bicyclist was considered legally intoxicated (blood alcohol concentration of 0.08 grams per deciliter or greater). Lower alcohol levels were reported in an additional 7 percent of fatal bicycle-motor vehicle crashes. More than one-fourth of the bicyclists killed were intoxicated. This may be an emerging problem. Alcohol-drug crashes were more frequent on weekends and during hours of darkness.

Time of Day and Year

Almost one-third (31 percent) of the fatal bicyclist crashes occurred during late afternoon and early evening hours between 5 p.m. and 9 p.m. Bicyclist and pedestrian activity (i.e., exposure) is likely quite high during these hours, and visibility can be a problem. Thirty-five percent of all bicyclist fatalities occurred during the months of June, July, and August, months when bicycle riding peaks and exposure is high.

Location

About 69 percent of the fatal bicyclist crashes were categorized as urban, and 71 percent of the fatal crashes occurred at nonintersection locations. However, for nonfatal crashes, more collisions occurred at roadway intersections than nonintersection locations. Roads with narrower lanes, no shoulders, and higher speed limits were associated with more than their share of serious and fatal injuries to bicyclists.

Factors Contributing to Bicycle-Motor Vehicle Crashes

The 1996 Federal Highway Administration investigation studied 3,000 bicycle crashes in 5 States to determine factors contributing to the crashes.(3) Bicyclists were judged to be at fault in about half of these crashes with motor vehicles. Failure to yield, riding against traffic, stop sign violations, and safe movement violations were the bicyclist factors most frequently cited as contributing to crashes. Bicyclists need training about how to ride in traffic. The likelihood of the bicyclist being responsible for the crash was greatest for younger bicyclists. When the bicyclist involved in the crash was older, the motor vehicle driver was more likely to be at fault.

Motor vehicle drivers were judged to be solely at fault in 28 percent of the cases. Failure to yield, hit-and-run, and failure to see bicyclists were the driver factors most frequently cited as contributing to crashes.

Pedestrian-Motor Vehicle Crashes

NHTSA provided the following statistics that characterize pedestrian crashes:(2)

Age

Compared to their representation in the overall U.S. population, young persons (under 25 years of age) were overrepresented in pedestrian crashes with motor vehicles, whereas older adults (ages 50 to 69) and the elderly (age 70+) were underrepresented. However, elderly pedestrians who were involved in crashes were more likely to be killed. Older pedestrians (ages 70+) accounted for only 6 percent of pedestrians injured but 16 percent of pedestrians killed. Pedestrians aged 0 to 16, on the other hand, accounted for 27 percent of all pedestrians injured in 2003, but only 9 percent of those killed.

Gender

Sixty-nine percent of the pedestrian fatalities that occurred in 2003 were males. The male pedestrian fatality rate was more than double (2.27) the female pedestrian fatality rate; the pedestrian injury rate was considerably higher for males than females as well.

Drug Impairment

Alcohol is often a key factor in pedestrian-motor vehicle crashes that lead to fatalities. In 2003, 46 percent of the traffic crashes that resulted in pedestrian fatalities involved alcohol intoxication by either the driver or the pedestrian. Thirty-four percent of the total number of pedestrians involved in fatal crashes were considered legally intoxicated, while 13 percent of the drivers involved were intoxicated. Six percent of the fatal crashes involved both an intoxicated driver and pedestrian.

Time of Day and Week

Pedestrian crashes occurred most frequently during the late afternoon and early evening hours, times when exposure is probably highest and visibility may be a problem. Forty-four percent of the pedestrian fatalities under 16 years of age occurred between 3 p.m. and 7 p.m. Sixty-five percent of all pedestrian incidents occurred at night. Fatality counts also rose on weekends as well, with nearly one-half of all pedestrian fatalities occurring on a Friday, Saturday, or Sunday.

Location

About 72 percent of the crashes were categorized as urban. The elderly were overrepresented in commercial parking lot crashes, young adults in noncommercial parking lot crashes, and children under age 10 in collisions occurring in driveways, alleys, or yards.

Seventy-nine percent of the fatal pedestrian-motor vehicle crashes occurred at nonintersection locations. However, for nonfatal collisions, the percentage at nonintersection locations was significantly lowered, and more crashes occurred at roadway intersections. Serious and fatal injuries to pedestrians were directly proportional to speed limit and number of lanes.

Factors Contributing to Pedestrian-Motor Vehicle Crashes

In a 1996 study conducted by the Federal Highway Administration (FHWA), 5,000 pedestrian crashes in 5 States were studied extensively in order to determine contributing factors associated with the crashes.[3] The report judged that pedestrians were solely at fault in 43 percent of the crashes. Running into the road, failure to yield, alcohol impairment, stepping out from between parked vehicles, and walking or running in the wrong direction (with traffic) were the pedestrian factors most frequently cited as contributing to crashes. Younger pedestrians were more likely to be at fault.

Motor vehicle drivers were judged to be solely at fault in 35 percent of the crashes. Driver hit-and-run and failure to yield were the driver factors most frequently cited as contributing to crashes, followed by improper backing, safe movement violations, and exceeding safe speed. Only 3 percent of motor vehicle drivers striking pedestrians were judged to have been impaired by alcohol in the 1996 study.

3.6 Common Pedestrian and Bicycle Crash Types

This portion of the lesson presents information specific to the types and characteristics of pedestrian and bicycle crashes. The information on crash types was generated from a 1996 FHWA study and a study conducted by the Highway Safety Research Center (HSRC) at the University of North Carolina.[3,5,6] In the FHWA study, 8,000 pedestrian and bicycle crashes in 5 States were studied extensively in order to code crash types, determine the specific factors associated with the crash types, and identify how countermeasures could be used to reduce the frequency of crashes. The purpose of the HSRC study was to update 1970s era crash data to reflect more recent crash types, paying particular attention to roadway and locational factors so that designers can reduce crash frequency through engineering methods and other interventions.

Pedestrian Crash Types

The FHWA study concluded that more than three-fourths of pedestrian crashes fell into one of the following eight crash-type categories (see table 3-1):[(3)]

Table 3-1. Pedestrian crash types.

Crash-Type Category	Percent of Total Pedestrian Crashes
Midblock Dart/Dash	13.3
Other Midblock	13.2
Other Intersection	10.1
Vehicle Turn/Merge	9.8
Not in Roadway/Waiting to Cross	8.6
Walking Along Roadway	7.9
Intersection Dash	7.2
Backing Vehicle	6.9
Total	77.0

Source: *Pedestrian and Bicycle Crash Types of the Early 1990's*[(3)]

These major crash-type categories varied with respect to the pedestrian, driver, location/environmental, and roadway factors that characterized them. It is critically important for individual States and communities to develop a better understanding of the particular traffic situations endangering their residents. Figures 3-4 through 3-11 display the eight most common pedestrian crash types.

Bicycle Crash Types

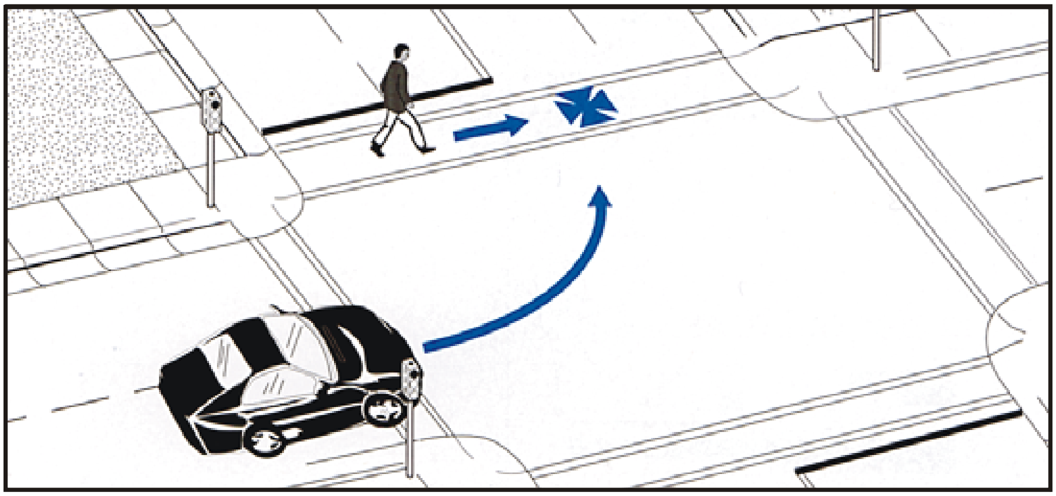
The FHWA study divided the bicycle-motor vehicle crashes into three general categories (see table 3-2):[(3)]

Table 3-2. Bicycle crash types.

General Crash-Type Category	Percent of Total Bicycle Crashes
Crossing-Path Events	57
Parallel-Path Events	36
Specific Circumstances	7
Total	100

Source: *Pedestrian and Bicycle Crash Types of the Early 1990's*[(3)]

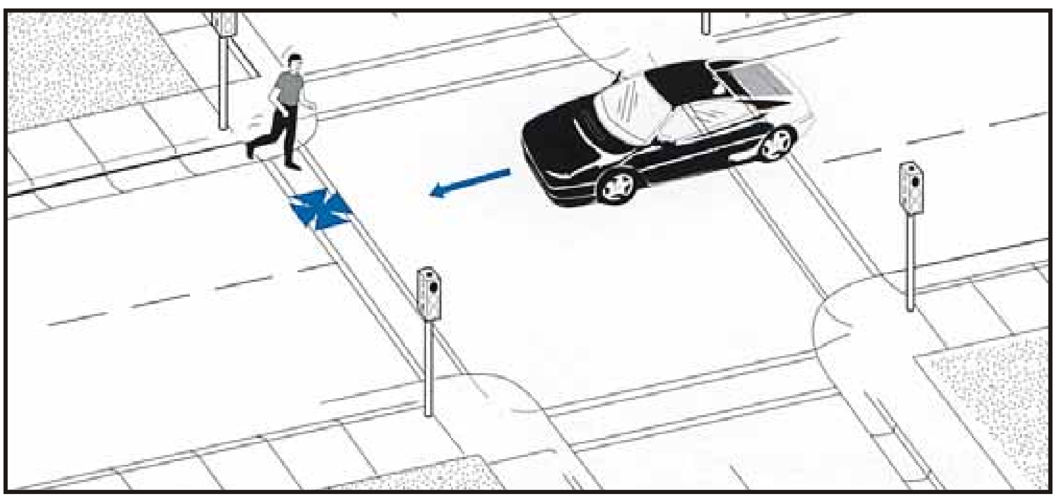
The most frequent parallel-path crashes were motorist turn/merge into bicyclist's path (12.2 percent), motorist overtaking the bicyclist (8.6 percent), and bicyclist turn/merge into motorist's path (7.3 percent). The most frequent crossing-path crashes were caused by motorist failure to yield to bicyclist (21.7 percent), bicyclist failure to yield at an intersection (16.8 percent), and bicyclist failure to yield midblock (11.8 percent). These six individual crash types accounted for almost 80 percent of all bicycle-motor vehicle crashes. Figures 3-12 through 3-19 show the eight most common bicycle crash types.



Frequency: 497 cases; 9.8% of all crashes
Severity: 18% resulted in serious or fatal injuries

Description: The pedestrian and vehicle collided while the vehicle was preparing to turn, in the process of turning, or had just completed a turn (or merge).

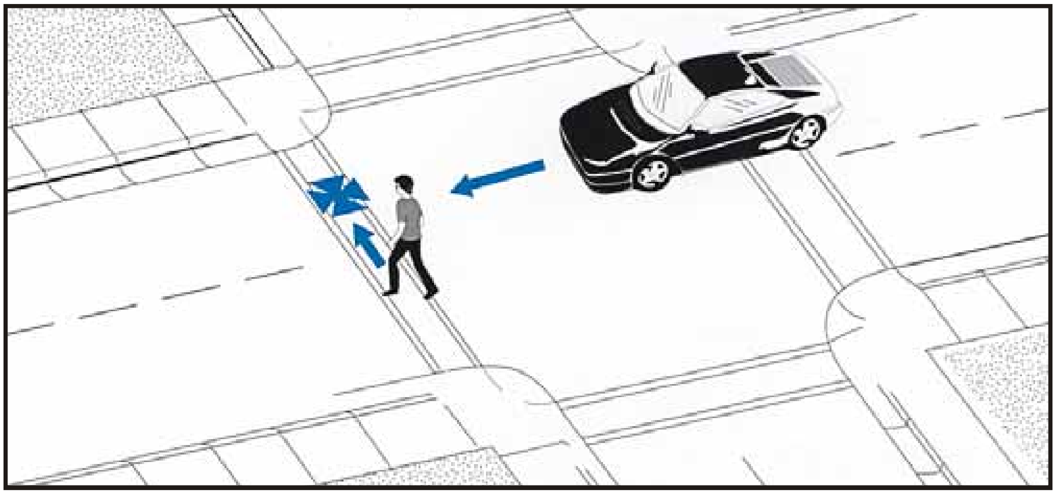
Figure 3-4. Illustration. Vehicle turn/merge.
Source: *Pedestrian Crash Types: A 1990's Informational Guide*[5]



Frequency: 363 cases; 7.2% of all crashes
Severity: 34% resulted in serious or fatal injuries

Description: The pedestrian was struck while running through an intersection and/or the motorist's view of the pedestrian was blocked before impact.

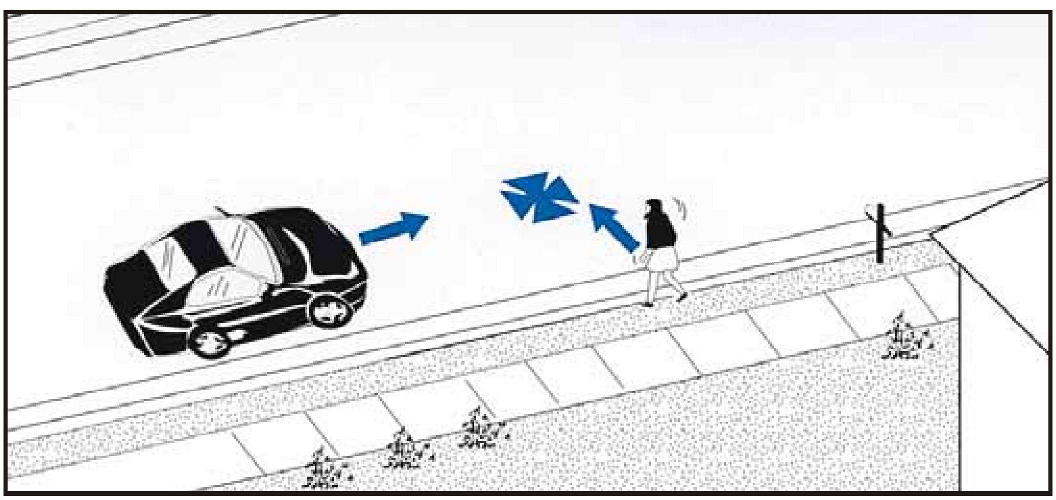
Figure 3-5. Illustration. Intersection dash.
Source: *Pedestrian Crash Types: A 1990's Informational Guide*[5]



Frequency: 364 cases; 7.2% of all crashes
Severity: 42% resulted in serious or fatal injuries

Description: The crash occurred at an intersection but does not conform to any of the specific crash types.

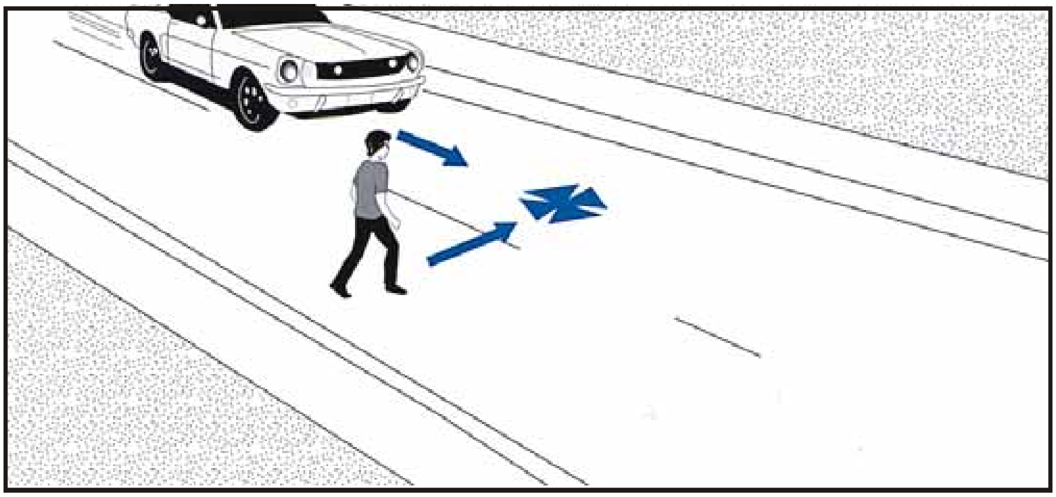
Figure 3-6. Illustration. Other intersection.
Source: *Pedestrian Crash Types: A 1990's Informational Guide*[5]



Frequency: 442 cases; 8.7% of all crashes
Severity: 37% resulted in serious or fatal injuries

Description: At midblock location, the pedestrian was struck while running and the motorist view of the pedestrian was not obstructed.

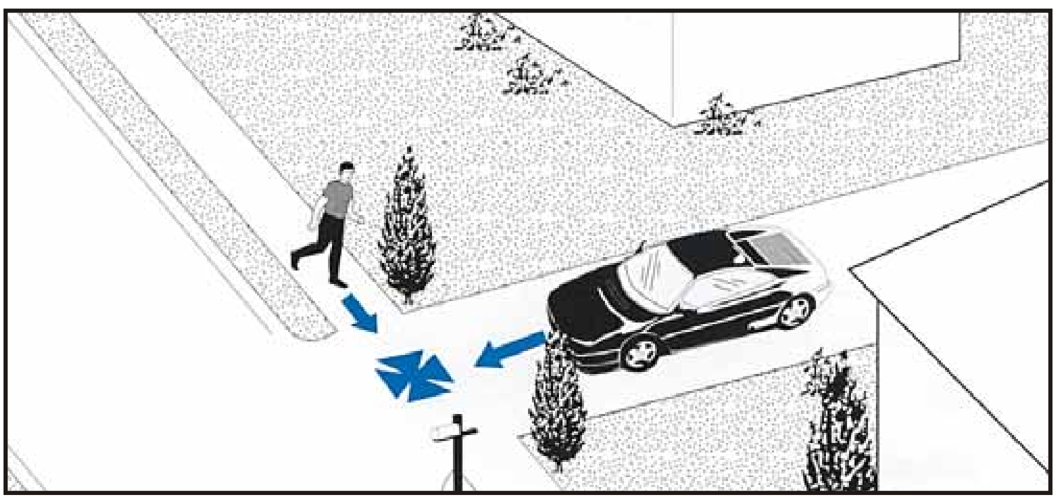
Figure 3-7. Illustration. Midblock dart/dash.
Source: *Pedestrian Crash Types: A 1990's Informational Guide*[5]



Frequency: 548 cases; 10.8% of all crashes
Severity: 49% resulted in serious or fatal injuries

Description: The crash occurred at midblock, but does not conform to any of the specific crash types.

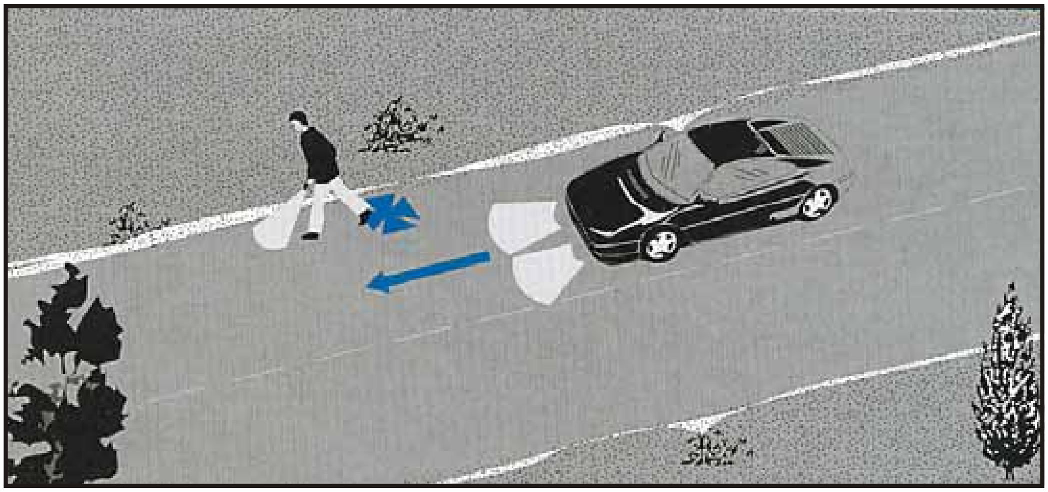
Figure 3-8. Illustration. Other midblock.
Source: *Pedestrian Crash Types: A 1990's Informational Guide*[5]



Frequency: 404 cases; 7.9% of all crashes
Severity: 28% resulted in serious or fatal injuries

Description: The pedestrian was struck when not in the roadway. Areas including parking lots, driveways, private roads, sidewalks, service stations, yards, etc.

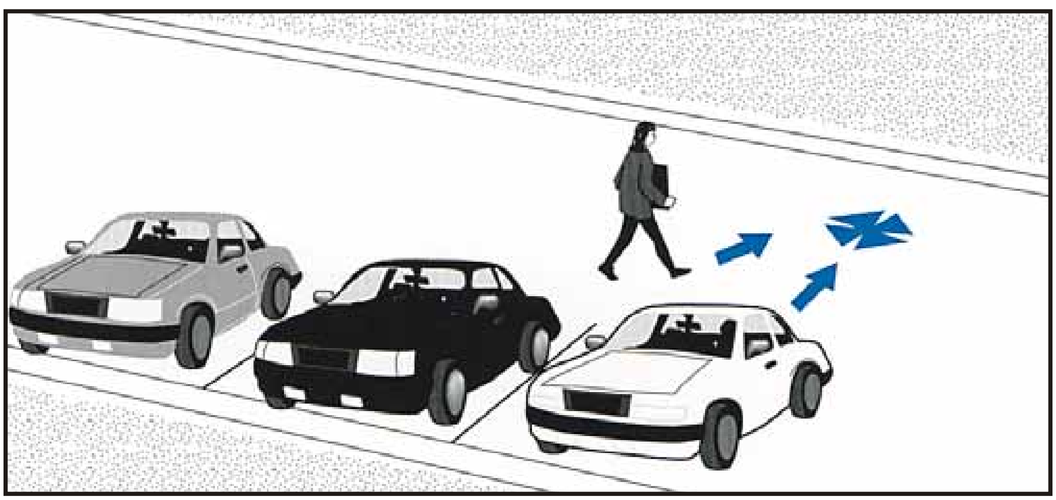
Figure 3-9. Illustration. Not in roadway/waiting to cross.
Source: *Pedestrian Crash Types: A 1990's Informational Guide*[5]



Frequency: 375 cases; 7.4% of all crashes
Severity: 37% resulted in serious or fatal injuries

Description: The pedestrian was struck while walking/running along a road without sidewalks. The pedestrian may have been: hitchhiking (15 cases), walking with traffic and struck from behind (257 cases) or from the front (5 cases), walking against traffic and struck from behind (76 cases) or from the front (7 cases), walking along a road, but the details are unknown (15 cases).

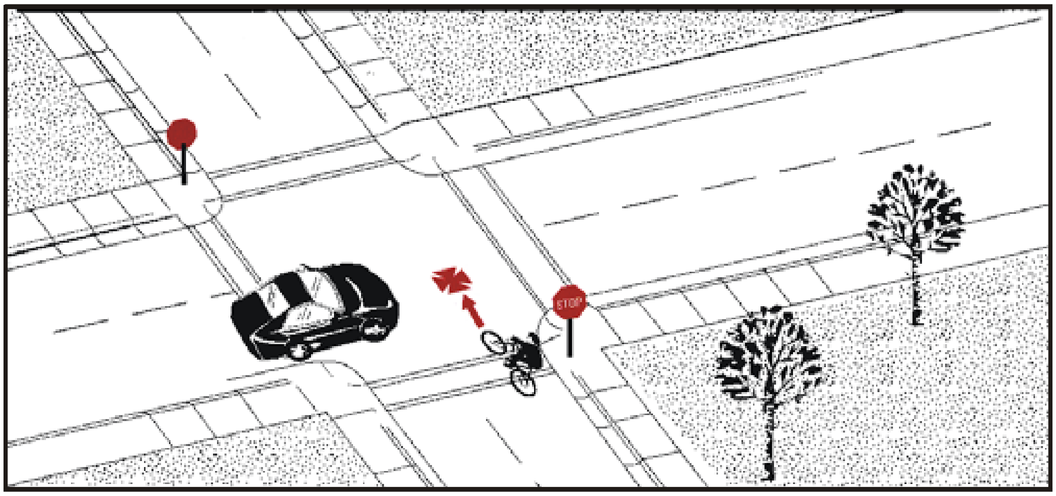
Figure 3-10. Illustration. Walking along roadway.
Source: *Pedestrian Crash Types: A 1990's Informational Guide*(5)



Frequency: 351 cases; 6.9% of all crashes
Severity: 23% resulted in serious or fatal injuries

Description: The pedestrian was struck by a vehicle that was backing.

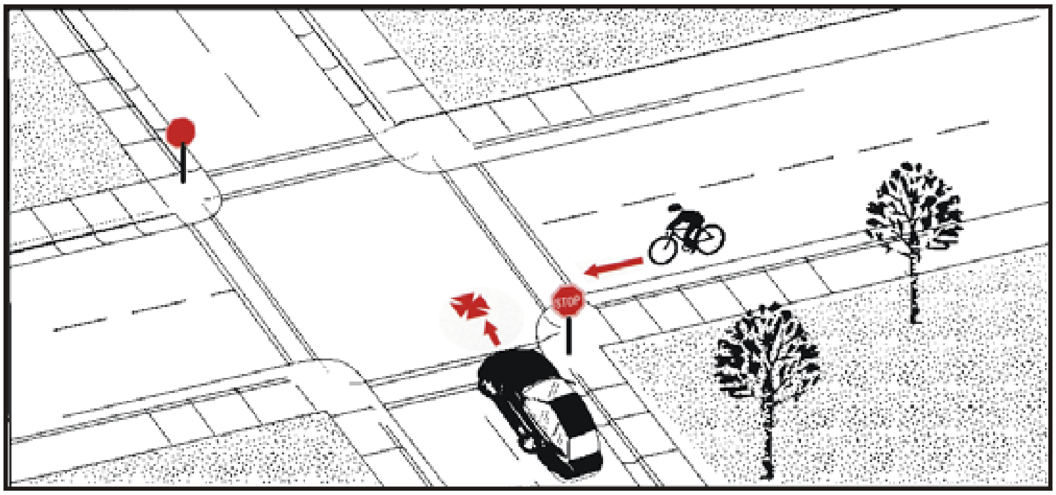
Figure 3-11. Illustration. Backing vehicle.
Source: *Pedestrian Crash Types: A 1990's Informational Guide*(5)



Frequency: 290 cases; 9.7% of all crashes
Severity: 23% resulted in serious or fatal injuries

Description: The crash occurred at an intersection at which the bicyclist was facing a stop sign or flashing red light.

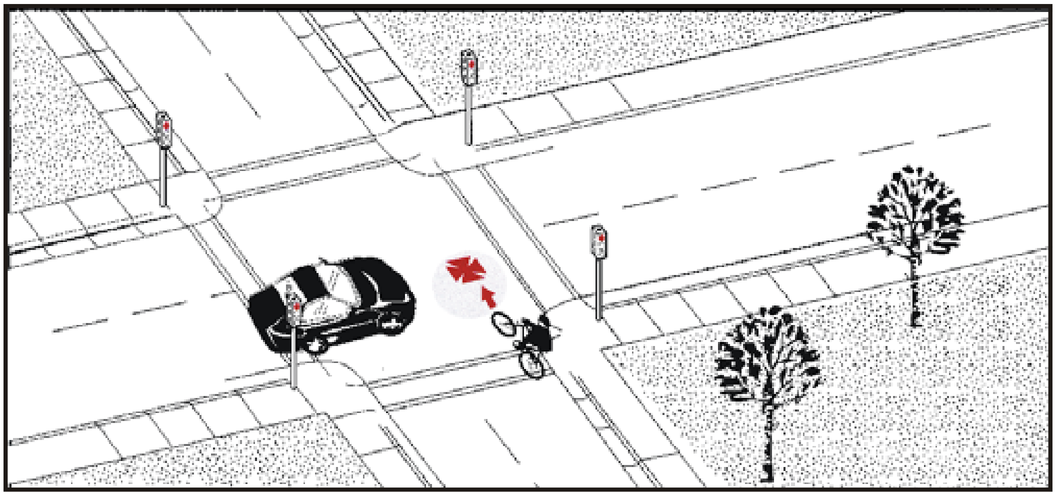
Figure 3-12. Illustration. Ride out at stop sign.
Source: *Bicycle Crash Types: A 1990's Informational Guide*(6)



Frequency: 277 cases; 9.3% of all crashes
Severity: 10% resulted in serious or fatal injuries

Description: The crash occurred at an intersection at which the motorist was facing a stop sign.

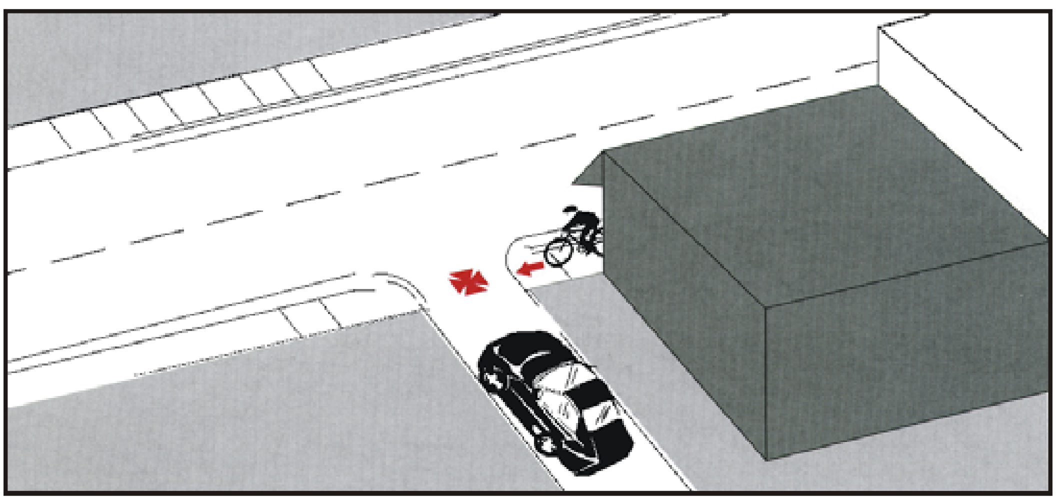
Figure 3-13. Illustration. Drive out at stop sign.
Source: *Bicycle Crash Types: A 1990's Informational Guide*(6)



Frequency: 211 cases; 7.1% of all crashes
Severity: 16% resulted in serious or fatal injuries

Description: The crash occurred at an intersection (signalized or uncontrolled) at which the bicyclist failed to yield.

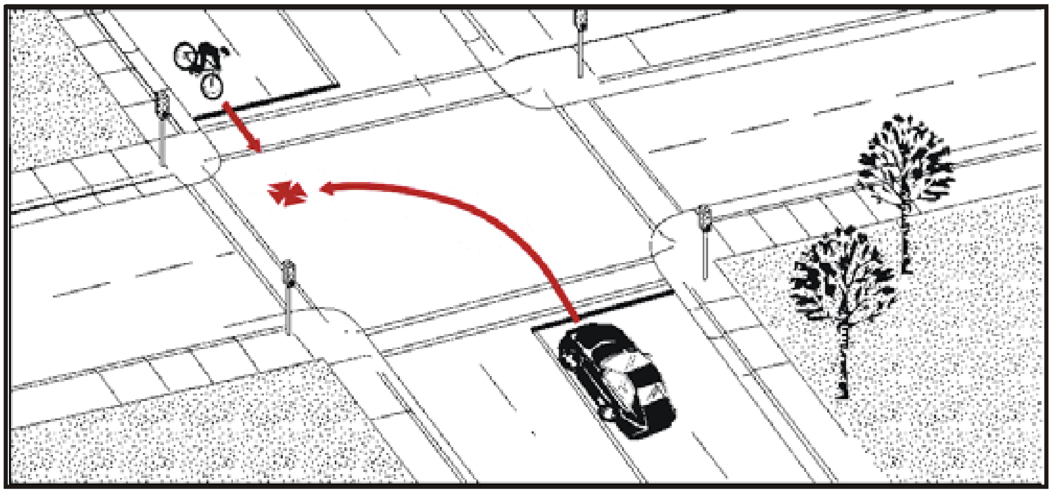
Figure 3-14. Illustration. Other ride out at intersection.
Source: *Bicycle Crash Types: A 1990's Informational Guide*(6)



Frequency: 207 cases; 6.9% of all crashes
Severity: 7% resulted in serious or fatal injuries

Description: The motorist was entering the roadway from a driveway or alley.

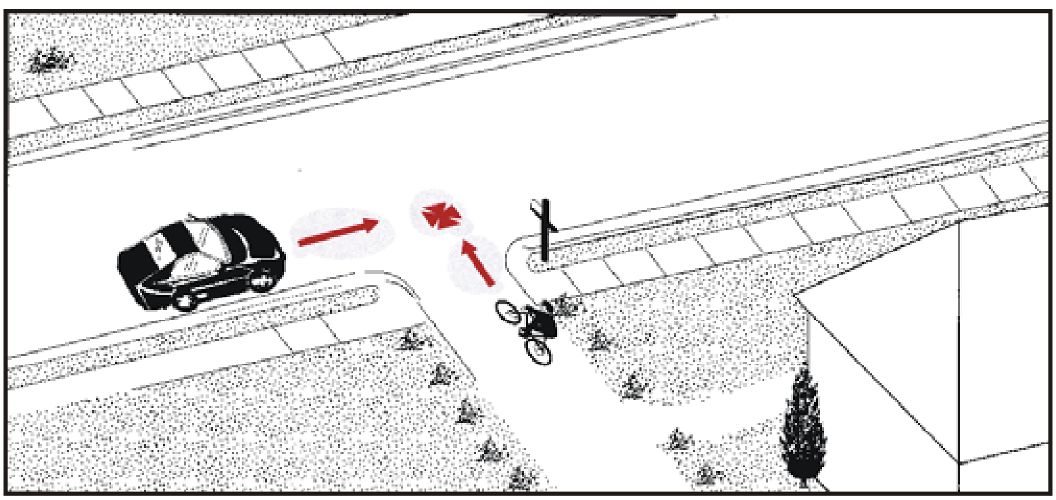
Figure 3-15. Illustration. Drive out at midblock.
Source: *Bicycle Crash Types: A 1990's Informational Guide*(6)



Frequency: 176 cases; 5.9% of all crashes
Severity: 24% resulted in serious or fatal injuries

Description: The motorist made a left turn while facing the approaching bicyclist.

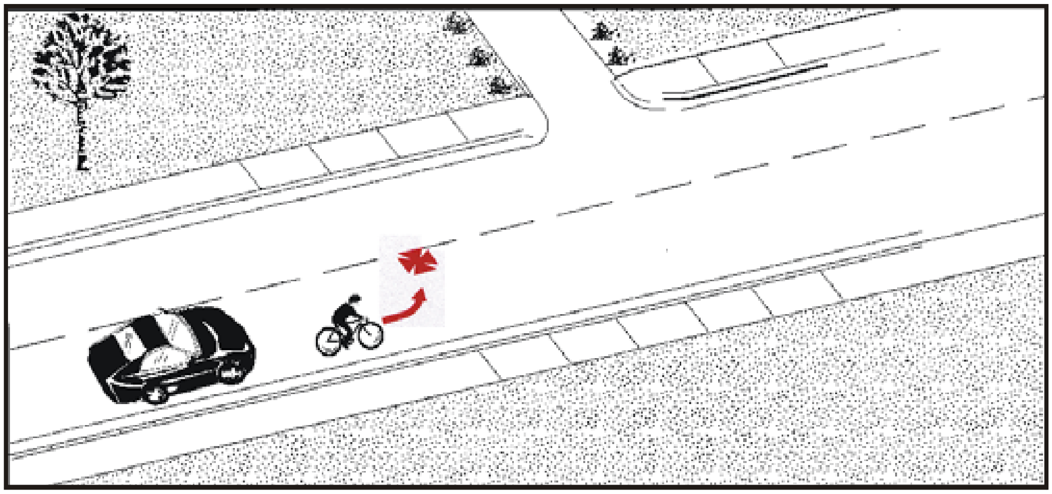
Figure 3-16. Illustration. Motorist left turn, facing bicyclist.
Source: *Bicycle Crash Types: A 1990's Informational Guide*[6]



Frequency: 153 cases; 5.1% of all crashes
Severity: 24% resulted in serious or fatal injuries

Description: The bicyclist entered the roadway from a driveway or alley.

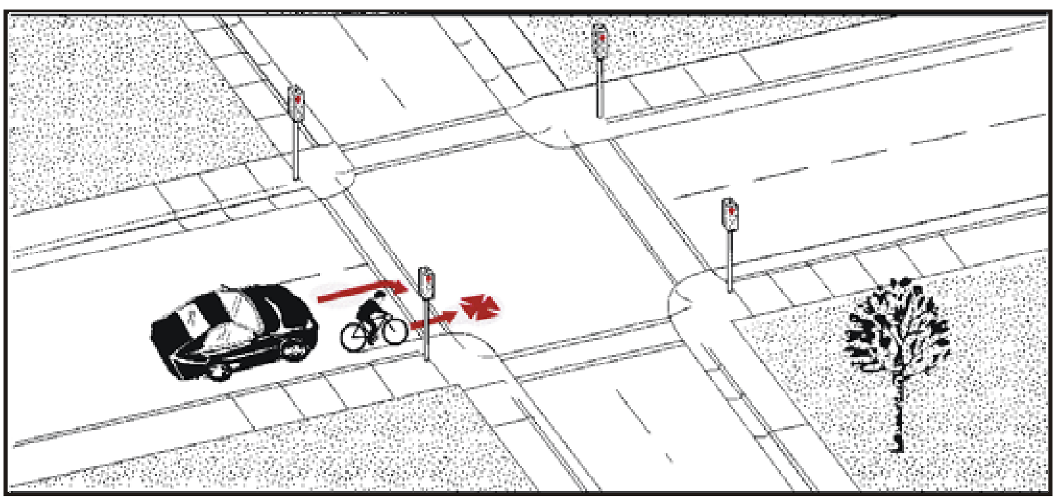
Figure 3-17. Illustration. Ride out at residential driveway.
Source: *Bicycle Crash Types: A 1990's Informational Guide*[6]



Frequency: 130 cases; 4.3% of all crashes
Severity: 28% resulted in serious or fatal injuries

Description: The bicyclist made a left turn in front of traffic traveling in the same direction.

Figure 3-18. Illustration. Bicyclist left turn in front of traffic.
Source: *Bicycle Crash Types: A 1990's Informational Guide*[6]



Frequency: 143 cases; 4.7% of all crashes
Severity: 11% resulted in serious or fatal injuries

Description: The motorist was making a right turn and the bicyclist was riding in either the same or opposing direction.

Figure 3-19. Illustration. Motorist right turn.
Source: *Bicycle Crash Types: A 1990's Informational Guide*[6]

3.7 Pedestrian and Bicycle Crash Analysis Tool (PBCAT)

FHWA, in cooperation with NHTSA, developed a Pedestrian and Bicycle Crash Analysis Tool (PBCAT) through the University of North Carolina HSRC. PBCAT is a user-friendly analysis tool that determines the crash type through a series of onscreen questions about the crash. It provides tabular and graphing functions of various factors (such as age, sex, light conditions, etc.) associated with the crash. The system also recommends countermeasures and related resources and reference information.

3.8 Bicycle and Pedestrian Countermeasures

Sections 3.6 and 3.7 discussed common crash types and how to determine these crash types by using PBCAT. This section provides a list of countermeasures that might be employed to offset a specific pedestrian crash type (see figure 3-20). Table 3-3 lists more than the general crash types previously provided and was adapted from the *Pedestrian Facilities Users Guide*.(7) Bike countermeasures may overlap with some pedestrian countermeasures. An exhaustive list of bike countermeasures can be found in the FHWA Bicycle Safety Tools and Technology page located on the FHWA Safety Web site. There, roadway countermeasures are listed for numerous types of bicyclist and motorist errors; these are organized by the type of entity that could implement the change.

Figure 3-20. Photo. A crosswalk can increase the visibility of a pedestrian path.
Source: Pedestrian and Bicycle Information Center (PBIC)
Image Library, http://www.pedbikeimages.org(8)

3.9 Bicycle and Pedestrian Safety Goals

Based on the data from the FHWA study, the following safety goals and research recommendations were made in 1996:[3]

1. Much of what is reported in this study seems strongly connected to basic walking, riding, and driving patterns—in other words, related to exposure. Future studies of pedestrians and bicyclists and related facilities should be planned with this need in mind.

2. As a measure of accountability, it is recommended that local and State pedestrian-bicycle coordinators continually track crashes in their jurisdictions. A simplified crash typing procedure that coordinators can easily use should be prepared and disseminated.

3. With the current increased interest in both bicycling and walking, crash investigators on the State and local levels should be urged to report completely on any bicyclist and pedestrian crashes, particularly for roadway-related variables.

4. A systemwide approach will be necessary to make safety gains as well as reach the goals of the National Bicycling and Walking Study, namely: (1) to double the number of trips made by bicycling and walking, and (2) to reduce by 10 percent the number of bicyclists and pedestrians injured or killed in traffic collisions. Engineering, education, and enforcement approaches are vital to improved safety. There is a continuing need to establish the mindset that bicyclists and pedestrians are worthy and viable users of our transportation system.

Table 3-3. Crash types and associated countermeasures.
Source: *Pedestrian Facilities Users Guide*[7]

Countermeasure	Midblock Dart/-Dash	Multiple Threat	Midblock Mailbox, etc.	Failure to Yield (Unsignalized)	Bus-Related	Turning Vehicle at an Intersection	Through Vehicle at Intersection	Walking Along Roadway	Working/Playing in Roadway	Not in Road	Backing Vehicle	Crossing Expressway
1. Sidewalk/-Walkway					•			•	•	•	•	
2. Curb Ramp				•	•	•	•	•				
3. Crosswalk Enhancements	•	•		•	•	•	•					
4. Transit Stop Treatments	•	•		•	•	•	•					
5. Roadway Lighting	•	•	•	•	•	•	•	•	•	•	•	•
6. Overpass/-Underpass	•	•		•		•	•					•
7. Street Furniture	•				•			•				
8. Bike Lane/-Shoulder	•	•	•	•	•			•	•	•		
9. Road/Lane Narrowing	•	•	•	•				•	•			
10. Fewer Lanes		•		•	•			•				
11. Driveway Improvements										•	•	
12. Raised Median	•	•	•	•		•	•					
13. One-Way Street						•	•					
14. Smaller Curb Radius				•		•				•		
15. Right-Turn Slip Lane						•						
16. Modern Roundabout						•	•					
17. Modified T-Intersection						•						
18. Intersection Median Barrier		•		•		•	•					
19. Curb Extension	•	•		•	•	•	•			•	•	
20. Choker	•			•								
21. Pedestrian Crossing Island	•	•		•	•	•	•					
22. Chicane	•		•	•					•			
23. Minicircle						•	•		•			
24. Speed Humps	•		•	•					•			
25. Speed Table	•	•	•	•					•			
26. Raised Intersection				•		•	•					
27. Raised Ped. Crossing	•	•		•	•	•	•				•	
28. Gateway	•		•	•					•			

Table 3-3. Crash types and associated countermeasures—*Continued*.
Source: *Pedestrian Facilities Users Guide*(7)

Countermeasure	Midblock Dart/Dash	Multiple Threat	Midblock Mailbox, etc.	Failure to Yield (Unsignalized)	Bus-Related	Turning Vehicle at an Intersection	Through Vehicle at Intersection	Walking Along Roadway	Working/Playing in Roadway	Not in Road	Backing Vehicle	Crossing Expressway
29. Landscape Options				•						•	•	
30. Paving Treatments				•		•	•					
31. Driveway Link/ Serpentine	•			•					•			
32. Woonerf	•								•			
33. Diverter	•					•	•		•			
34. Full Street Closure	•					•	•		•			
35. Partial Street Closure	•					•	•		•			
36. Pedestrian Street	•			•					•			
37. Traffic Signal	•	•		•	•	•	•					
38. Pedestrian Signal	•	•		•	•	•	•					
39. Pedestrian Signal Timing						•	•					
40. Signal Enhancement	•					•	•					
41. RTOR Restriction						•						
42. Advanced Stop Lines		•			•	•	•					
43. Sign Improvement	•	•	•	•	•	•	•	•	•	•		•
44. School Zone Improvement	•	•		•	•	•	•	•		•		
45. Identify Neighborhood	•		•	•				•	•			
46. Speed-Monitoring Trailer	•		•	•			•	•	•			
47. Park Enhancement	•		•	•	•	•	•			•	•	
48. Ped./Driver Education	•	•	•	•	•	•	•	•	•	•	•	•
49. Police Enforcement	•	•	•	•	•	•	•	•	•	•		•

3.10 Geographic Information System (GIS) Crash Frequency Analysis

Geographic information system (GIS) software turns statistical data (e.g., crashes) and geographic data (e.g., roads and crash locations) into meaningful information for spatial analysis and mapping. GIS is an invaluable tool being applied to many pedestrian and bicycle safety issues. It assists in mapping crashes to identify hot spots, planning the safest route to walk or bike based on roadway and traffic elements (sidewalk, curb lane width, crosswalk locations, traffic volume, etc.), and illustrating the relationships between land use, traffic patterns, and bicycle and pedestrian safety. This tool is valuable in helping visualize the data accumulated in crash and roadway databases.

3.11 Benefit-Cost Analysis

Once the crash types have been identified and the appropriate countermeasures selected, the resulting benefit-cost ratio can be calculated. A common formula used for this calculation is the Safety Improvement Index (SII), a formula developed by the Texas Department of Transportation (TxDOT) as part of the Federal Hazard Elimination and Safety (HES) Program to assess the attributes of a safety improvement project and convert it to an index ratio by which each project can be ranked or prioritized in order of importance.[9,10] In its most basic form, SII is a formula that computes the ratio of the potential reduction in crash costs (the "benefit") to the cost of implementing the countermeasure (the "cost"). This formulated value is weighted heavily on the percentage of the expected reduction in the number of crashes that occurred prior to the improvement. Reduction factors have been determined through previous studies, such as the TxDOT HES Program and a national survey of comparative crash reduction factors conducted by Texas Transportation Institute (TTI).[9,11] SII greater than or equal to 1.0 is considered to be cost effective. However, the ratio is not designed to measure the effectiveness of individual projects. Rather, it is a method by which many projects can be compared using the same set of criteria. By way of this comparison, a prioritization list of improvement projects can be formed. With this prioritized list, the projects can be funded beginning with the most important project, and each subsequent safety improvement project is then funded individually and sequentially thereafter.

Some of the other factors included in this index are:

- Percentage reduction factor (the potential a countermeasure has to reduce a crash type).
- Number of fatal and/or incapacitating injury crashes (weighted average cost of these per crash is $232,700).
- Number of nonincapacitating and/or possible injury crashes (weighted average cost of these per crash is $16,900).
- Number of property damage only crashes (weighted average cost of these per crash is $2,220).
- Number of years of crash data (usually 3 years is the minimum number required).
- Projected annual average daily traffic (AADT) at the end of the project service life (a 3–5 percent growth rate in traffic per year is to be expected).
- AADT during the year before the project is implemented.
- Project service life (the useful life of the improvement).

3.12 Student Exercise

The following ideas are suggested for student exercises.

Part 1

Design a program that specifically provides countermeasures aimed at reducing one (or more) common bicycle and/or pedestrian crash types. Countermeasures can include physical changes to the bicycle/pedestrian environment (engineered and constructed solutions), or education programs aimed at a particular audience that may be susceptible to certain crash types. Be specific about what the program would include, and how it would be implemented throughout a community. Include an explanation of how you would propose to evaluate the effectiveness of your program.

Part 2

Using the data provided for the case study location, Piedmont Park in Atlanta, GA, develop some conclusions regarding the crash data obtained through the Georgia Department of Transportation (DOT) for 1995, 1996, and 1997 (see figures 3-21 through 3-23 and tables 3-4 through 3-7). Cross-tabulations of crashes by time of day, location, and causation factors are helpful in gaining insight into safety problems and possible countermeasures. Data available for such evaluations are often limited due to the low percentage of reported pedestrian and bicycle crashes. However, important information can be obtained by a thorough analysis of available data.

For some general background on the case study location, the following descriptive information is provided:

- Piedmont Park is a large public park located approximately 4.8 kilometers (km) (3 miles (mi)) north of the central business district in the midtown area of Atlanta.
- The park is surrounded on all sides by densely populated residential neighborhoods.
- Very little parking is available within the park, and most park users arrive by foot, in-line skates, skateboard, or bicycle.
- The park has extensive walking, running, and bicycling trails, and these are the primary uses of the park. In addition, there are numerous festivals and special events.
- Access to the park from surrounding neighborhoods is via surface streets, most of which have narrow 1.2- to 1.5-meters (m)-wide (4- to 5-feet (ft)-wide) sidewalks.
- The park is bound on all sides by heavily traveled arterial roadways that commonly experience significant peak-hour congestion.
- Two transit stations are located within walking distance near the park and pedestrian access to and from the park links with the stations. Typical sidewalk and crosswalk treatments are used along surface streets (10th St. and 14th St.) to connect with the transit stations. Bicycles are allowed on transit fixed-rail vehicles during all operational periods.

For conducting a case study evaluation of pedestrian and bicycle conditions at Piedmont Park, the data provided include the following:

- Bicycle crash locations (year and location denoted by text boxes in figure 3-21).
- Pedestrian crash locations (year and location denoted by text boxes in figure 3-22).
- Site location map (figure 3-23).
- Tabulation of pedestrian crash data (table 3-4).
- Tabulation of bicycle crash data (table 3-5).
- Usage data collected at major park entrances (table 3-6).
- Summary of major roadways (table 3-7).

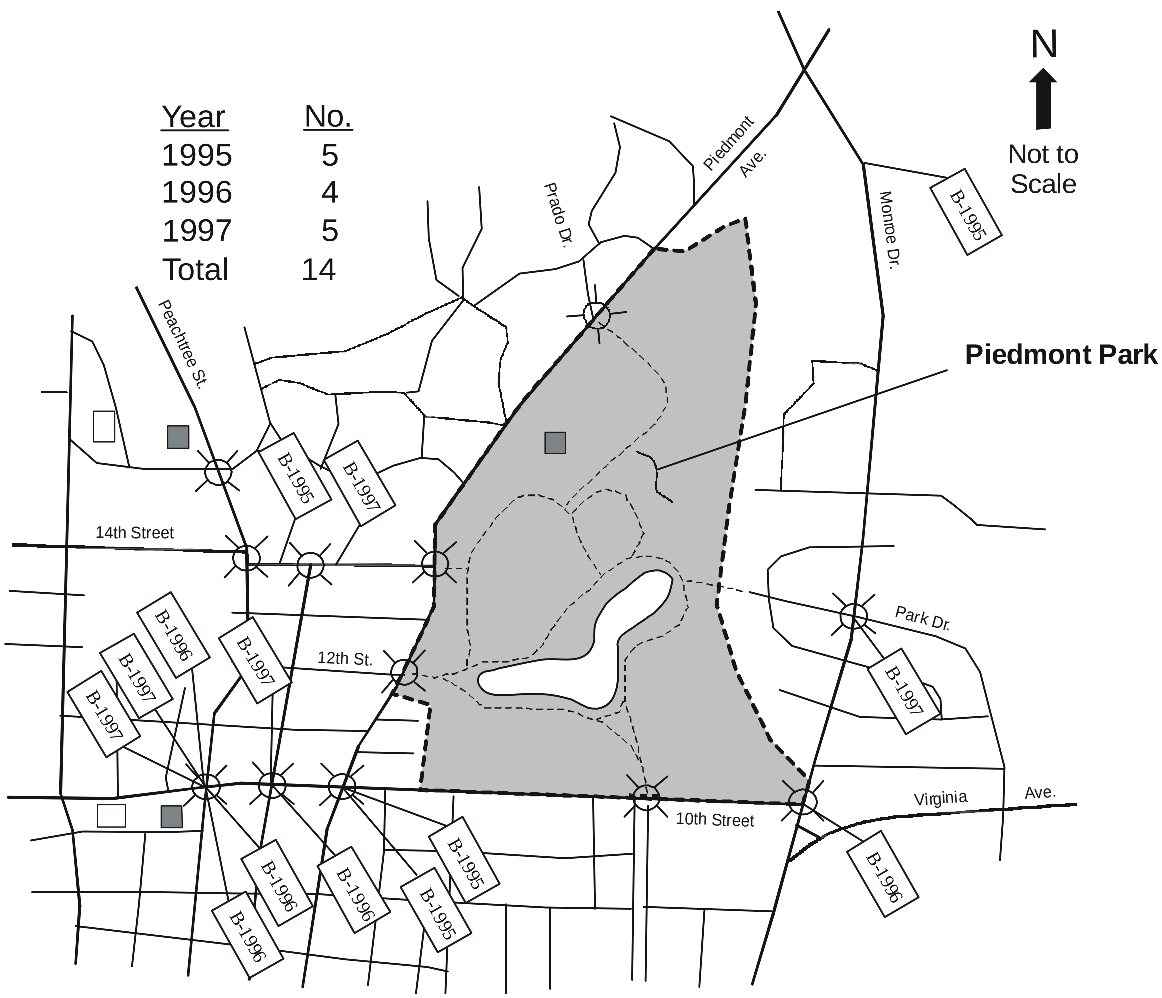


Figure 3-21. Illustration. Bicycle crash locations.

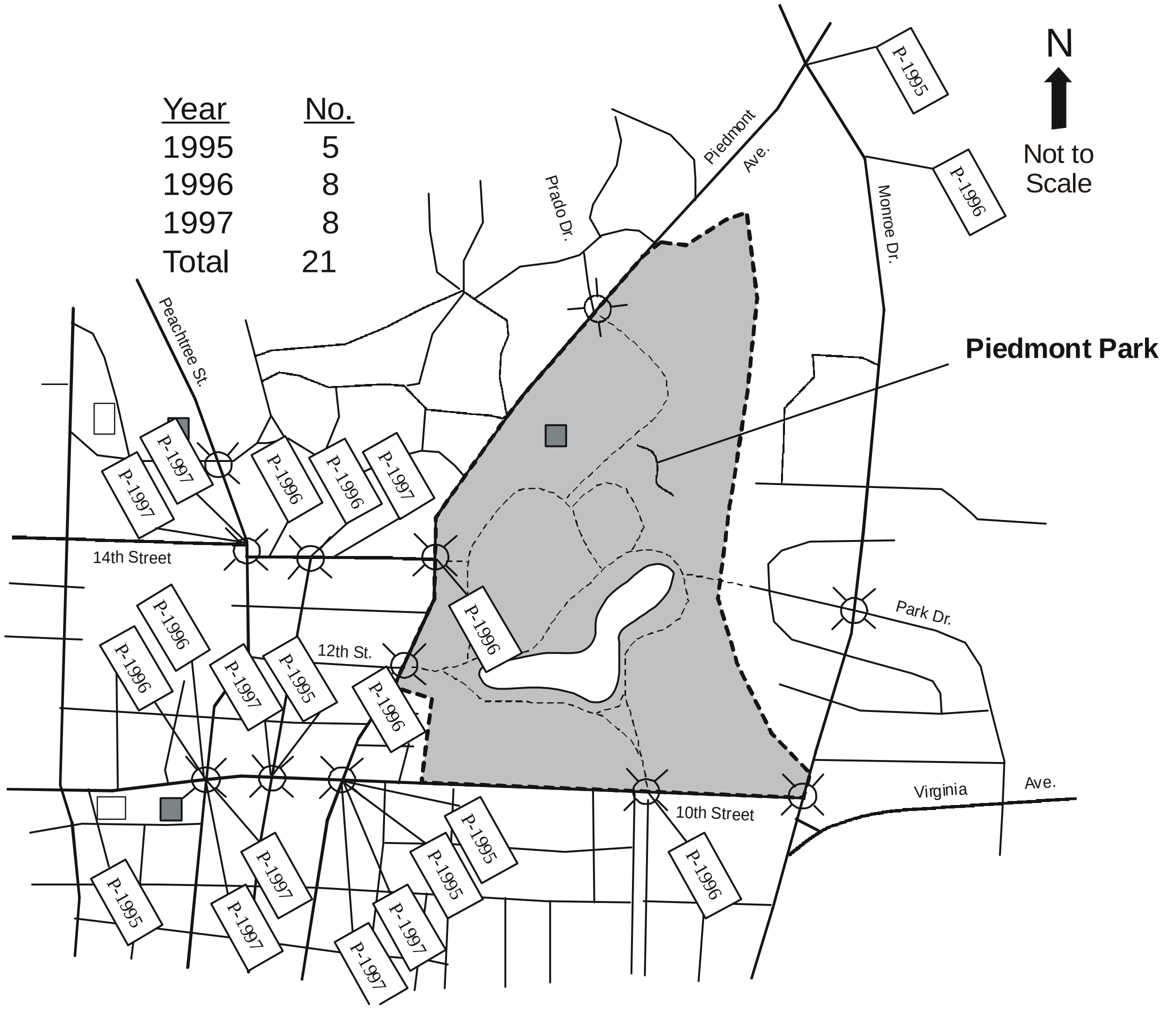


Figure 3-22. Illustration. Pedestrian crash locations.

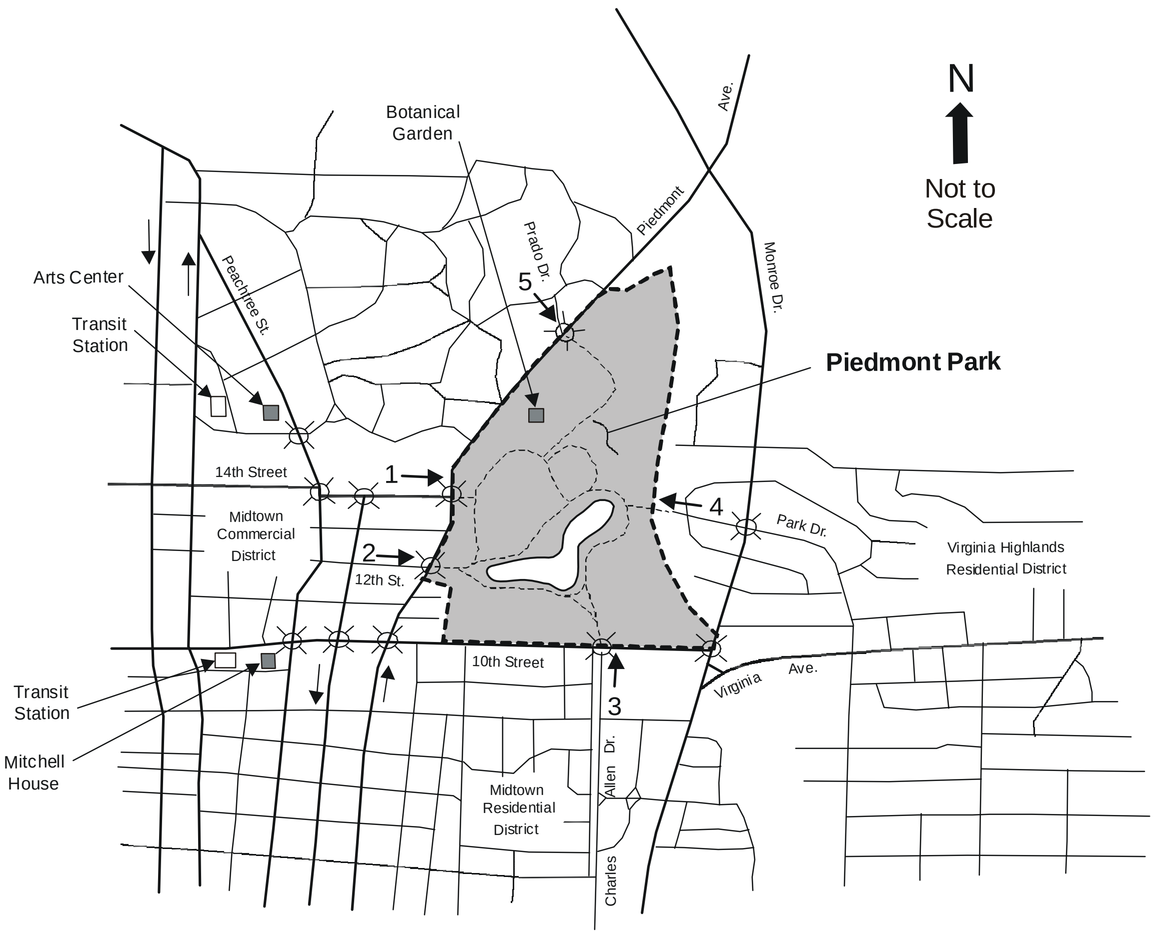


Figure 3-23. Illustration. Site location map.

Table 3-4. Tabulation of pedestrian crash data.

#	Route/-Road	Mile Post	Time	Month	Day	Year	Severity	Location	Type	Light Condition	Surface Condition
1	10th St	1.78	23:29	06	13	1997	Injury	Intersection	Pedestrian	Dk/Lighted	Dry
2	10th St	1.78	13:54	08	25	1997	Injury	Intersection	Pedestrian	Daylight	Dry
3	10th St	1.87	23:01	06	19	1997	Injury	Intersection	Pedestrian	Dk/Lighted	Dry
4	10th St	1.99	19:19	02	06	1997	Injury	Intersection	Pedestrian	Dk/Lighted	Dry
5	10th St	1.99	17:26	07	08	1997	Injury	Intersection	Pedestrian	Daylight	Dry
6	14th St	0.06	15:00	04	04	1997	Injury	Intersection	Pedestrian	Daylight	Dry
7	14th St	0.06	18:00	03	03	1997	Injury	Intersection	Pedestrian	Daylight	Dry
8	14th St	0.00	09:30	06	10	1997	Injury	Intersection	Pedestrian	Daylight	Dry
9	Monroe	5.71	16:12	09	21	1996	Injury	Road Segment	Pedestrian	Daylight	Dry
10	10th St	2.43	15:45	09	07	1996	Injury	Intersection	Pedestrian	Daylight	Dry
11	10th St	1.78	19:50	07	04	1996	Injury	Intersection	Pedestrian	Daylight	Dry
12	10th St	1.78	22:05	07	13	1996	Injury	Intersection	Pedestrian	Dk/Lighted	Dry
13	10th St	2.01	21:30	06	29	1996	Injury	Road Segment	Pedestrian	Dk/Lighted	Dry
14	14th St	0.00	17:10	08	05	1996	Injury	Intersection	Pedestrian	Daylight	Dry
15	14th St	0.06	13:00	03	13	1996	Injury	Intersection	Pedestrian	Daylight	Dry
16	Pied.	1.01	22:20	04	25	1995	Injury	Intersection	Pedestrian	Dk/Lighted	Dry
17	Monroe	5.97	23:06	02	10	1995	Injury	Intersection	Pedestrian	Dk/Lighted	Dry
18	10th St	1.64	18:20	01	11	1995	Injury	Road Segment	Pedestrian	Dusk	Dry
19	10th St	1.87	17:25	02	08	1995	Injury	Intersection	Pedestrian	Daylight	Dry
20	10th St	1.99	21:00	10	17	1995	Injury	Intersection	Pedestrian	Dk/Lighted	Dry
21	10th St	1.99	02:23	01	21	1995	Injury	Intersection	Pedestrian	Dk/Lighted	Dry

Table 3-5. Tabulation of bicycle crash data.

#	Route/-Road	Mile Post	Time	Month	Day	Year	Severity	Location	Type	Light Condition	Surface Condition
1	Monroe	5.14	19:00	09	17	1997	Injury	Intersection	Angle Intersecting	Daylight	Dry
2	10th St	1.78	12:20	03	14	1997	Injury	Intersection	Angle Intersecting	Daylight	Dry
3	10th St	1.78	17:32	08	29	1997	Injury	Intersection	Angle Intersecting	Daylight	Dry
4	10th St	1.87	17:43	03	11	1997	Injury	Intersection	Head On	Daylight	Dry
5	14th St	0.00	18:10	12	17	1997	Injury	Intersection	Angle Intersecting	Dk/Lighted	Dry
6	Monroe	4.85	01:15	05	05	1996	Injury	Intersection	Rear End	Dk/Lighted	Dry
7	10th St	1.78	15:33	12	18	1996	PDO	Intersection	Sideswipe Same Dir	Daylight	Dry
8	10th St	1.78	18:30	12	27	1996	PDO	Intersection	Angle Intersecting	Dk/Lighted	Dry
9	10th St	1.87	21:45	02	09	1996	PDO	Intersection	Angle Intersecting	Dk/Lighted	Dry
10	Monroe	5.81	17:15	09	02	1995	PDO	Road Segment	Angle Intersecting	Daylight	Dry
11	10th St	1.78	12:22	02	23	1995	Injury	Intersection	Angle Intersecting	Daylight	Dry
12	10th St	1.99	16:40	09	29	1995	Injury	Intersection	Angle Intersecting	Daylight	Dry
13	10th St	1.99	17:50	08	03	1995	Injury	Intersection	Angle Intersecting	Daylight	Dry
14	14th St	0.00	17:45	09	11	1995	Injury	Intersection	Rear End	Daylight	Dry

Note: PDO = property damage only crash

Table 3-6. Usage data collected at major park entrances.

No.	Entrance Location	Time of Day	Total for all interaction movements[1]			
			Bicyclists	In-line skaters[2]	Pedestrians[3]	Total HPT Activity
1[4]	Piedmont at 14th St	4:24–4:40 p.m.	3	2	22	27
1[4]	Piedmont at 14th St	5–5:15 p.m.	2	3	29	34
2	Piedmont at 12th St	4:40–4:55 p.m.	6	4	12	22
3	10th St at Charles Allen	5:20–5:35 p.m.	3	6	42	51
4	Park Avenue at Elmwood	5:40–5:55 p.m.	7	5	18	33

Notes:

(1) Conditions were sunny and clear, temperature approximately 32 degrees Celsius (90 degrees Fahrenheit). Count duration was for a total of 15 minutes for each spot count location.
(2) Count tabulations include occasional skateboarders.
(3) Count tabulations include joggers and people with baby strollers.
(4) Piedmont Avenue at 14th St was counted twice to evaluate peaking characteristics.

Table 3-7. Summary of major roadways.

No.	Roadway	Mileposts	No. of Lanes	Speed Limit km/h (mi/h)	1997 ADT	Total Length km (mi)
1	Piedmont					2.1 (1.3)
	Section 1	0.65–1.01	3 (one way)	56 (35)	11,700	
	Section 2	1.01–1.93	4	56 (35)	26,400	
2	10th St	1.56–2.68	4	56 (35)	20,420	1.8 (1.1)
3	14th St					0.5 (0.3)
	Section 1	0.00–0.23	4	56 (35)	22,400	
	Section 2	0.00–0.06	4	56 (35)	17,500	
4	Monroe	4.85–5.97	4	56 (35)	20,500	1.8 (1.1)

Part 3

Obtain pedestrian and bicycle crash data for an area of interest. You should obtain a minimum of three years of data to support your crash analysis. Although local city agencies sometimes maintain crash data, the State DOT is the most reliable source of available data. Most States maintain their crash data in a computerized database system and sorts of the data can be conducted on various field entries to list crashes associated with either pedestrians or bicycles. These types of crashes will only constitute a very small percentage of the total crashes occurring along a roadway and it may be useful to receive a full listing of all the crashes associated with your location of interest. DOTs may only maintain data along the more significant roadways and often do not include subdivision/residential streets.

Most DOT personnel are very helpful and willing to work to get you the data you need. You should clearly explain your intentions, location of interest, and type of data that you would like to obtain. Submitting a request in writing is typically required so that your data request can be efficiently processed through their system. In addition to the crash data, you may need other information that will allow you to decode the crash data and to physically link the crash to a location on the roadway network. A crash investigation manual is usually available that lists all of the coded entries used in creating aggregated crash tabulations. Also, a roadway features log is typically available to link milepost listings to physical map features such as intersections, bridges, and street names. In the initial phases of conducting an analysis of crashes, it is seldom necessary to access the actual crash reports. It is much more useful to utilize aggregated crash records that are available through the crash data system. Allow ample time for DOT personnel to accommodate your request within their day-to-day workload. Generally, data can be received in two to three weeks after submitting a request.

3.13 References and Additional Resources

The references for this lesson are:

1. *Traffic Safety Facts 2003: Pedalcyclists*, Technical Summary, Publication No. DOT-HS-809-768, National Highway Traffic Safety Administration, Washington, DC, 2004 (see http://www.nhtsa.gov/ for most recent statistics available).

2. *Traffic Safety Facts 2003: Pedestrians*, Technical Summary, Publication No. DOT-HS-809-769, National Highway Traffic Safety Administration, Washington, DC, 2004 (see http://www.nhtsa.gov/ for most recent statistics available).

3. Hunter, W.W., J.C. Stutts, W.E. Pein, and C.L. Cox, *Pedestrian and Bicycle Crash Types of the Early 1990's* [sic], Technical Summary, Publication No. FHWA-RD-95-163, Federal Highway Administration, Washington, DC, June 1996.

4. Stutts, J.C. and W.W. Hunter, *Injuries to Pedestrians and Bicyclists: An Analysis Based on Hospital Emergency Departmental Data*, Final Report, Publication No. FHWA-RD-99-078, Federal Highway Administration, Washington, DC, November 1999. Available online at http://www.tfhrc.gov/safety/pedbike/research/99078/99-078.htm.

5. Hunter, W.W., J.C. Stutts, and W.E. Pein, *Pedestrian Crash Types: A 1990's* [sic] *Informational Guide,* Publication No. FHWA-RD-96-163, Federal Highway Administration, Washington, DC, April 1997.

6. Hunter, W.W., J.C. Stutts, and W.E. Pein, *Bicycle Crash Types: A 1990's* [sic] *Informational Guide,* Publication No. FHWA-RD-96-104, Federal Highway Administration, Washington, DC, April 1997.

7. *Pedestrian Facilities Users Guide—Providing Safety and Mobility*, Federal Highway Administration, Publication No. FHWA-RD-01-102, McLean, VA, March 2002, available online at http://www.walkinginfo.org/pdf/peduserguide/peduserguide.pdf, accessed August 12, 2005.

8. Image Library, Pedestrian and Bicycle Information Center (PBIC), available online at http://www.pedbikeimages.org, accessed May 6, 2004.

9. Texas Department of Transportation, "Chapter 2—Hazard Elimination Program—Safety Improvement Index," *Traffic Operations Manual*, Austin, TX, 1999.

10. McFarland, William F. et al, "Benefit-Cost Analysis for Evaluating Safety Improvement Projects," Texas Transportation Institute, Houston, TX, Unpublished Report No. 1484, 2001.

11. "Appendix I: Summary of Accident Reduction Factors Used in Other States," *Houston East End Safety Study*, Final Report, Center for Transportation Safety, Texas Transportation Institute, Houston, TX, February 2004. Available online at http://www.h-gac.com/HGAC/Departments/Transportation/Safety/Safety.htm.

Additional resources for this lesson include:

- **http://safety.fhwa.dot.gov/ped_bike/bike/bike_tools.htm**. Has information on bicycle safety, PBCAT, and a bicycle safety resource guide and database of thousands of links to bicyclist information and safety countermeasures.

- **http://www.bicyclinginfo.org/**. Contains fact sheets, statistics, surveys, cost and ridership studies, and other bicyclist/ped links.

- **http://www.dot.state.tx.us/business/avgd.htm**. This is the Texas Statewide Average Low Bid Unit Price for construction and maintenance contracts Web page. It displays the average unit costs based on the previous year's competitive bid construction contracts. Bid items include everything from earth work to paint striping, traffic signals to landscaping. This information is useful in conducting SII benefit-cost calculations.

- **http://www.transtats.bts.gov/**. Click on the Bike/Pedestrian mode to explore databases like the Fatality Analysis Reporting System (FARS), or the Nationwide Personal Transportation Survey (NPTS) that provides data on the amount and nature of pedestrian travel.

- **http://www.walkinginfo.org/**. Offers a general overview of pedestrian safety, activities, design, etc.

- **http://www.walkinginfo.org/pedsafe/crashstats.cfm#locationtype**. Provides crash statistics, crash type analysis, and countermeasures.

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