Safety Handbook for Oregon's Local Roads and Streets

Prepared for
Oregon Department of Transportation

Prepared by Mojie Takallou, Ph.D., P.E.,
University of Portland

April 2010

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FORWARD

Local governmental agencies (cities and counties) are responsible for constructing and maintaining the majority of Oregon's road mileage as well as insuring safe and efficient movement of traffic on local roads and streets. They are constantly faced with problems of limited funds and/or technical constraints in their task to properly identify, analyze and correct safety deficiencies on their roadway systems.

The purpose of this Handbook is to provide local roadway agencies with important information related to roadway safety features intended for use on roads and streets in rural and small urban areas. It will assist local road agency professionals in understanding the critical relationship between road users' behavior, traffic control devices, roadside safety features, traffic crashes, and roadway safety.

It is recognized that funds for construction, maintenance, and operation of local road and street systems are limited; therefore, the Handbook is aimed at providing a rational balance between maximum safety and minimum cost.

Familiarity with the Handbook will enable one to:

- Understand the types and causes of traffic crashes
- Recognize potential roadway safety problems and be able to suggest appropriate remedies
- Select the most promising roadway safety improvements
- Identify conditions which may make some existing safety features ineffective
- Use proper procedures for installation and maintenance of roadway safety features and traffic control devices.

The Handbook will be of value to engineers, public works directors, maintenance personnel, technicians, street superintendents, county road supervisors, city managers, elected officials, and other local officials with road and street safety responsibilities. It will answer many of the questions public roadway agency personnel, decision makers and other local officials may have regarding roadway safety.

NOTICE: This Handbook is disseminated under the sponsorship of the Oregon Department of Transportation in the interest of information exchange. The Handbook does not constitute a standard, specification, or regulation. Any trade or manufacturers' names that appear herein are included solely because they are considered essential to the object of the publication.

Every attempt was made to include the most up to date information in the preparation of this Handbook but readers are reminded that information contained in this Handbook may change over time and when possible readers should reference the applicable background documents for the latest guidance.

ACKNOWLEDGEMENT

The author wishes to thank both individuals and organizations which provided assistance in the preparation of this Handbook. Those providing significant contributions to the preparation of this Handbook are identified below:

All funds for the preparation and publication of this Handbook were provided by the Oregon Department of Transportation (ODOT), Transportation Safety Division and through grants from the U. S. Department of Transportation, Federal Highway Administration, and the National Highway Traffic Safety Administration (NHTSA).

The Oregon Department of Transportation's talented and knowledgeable team reviewed the manuscript draft and provided substantial, helpful comments and suggestions for finalizing this Handbook. Review of the manuscript was coordinated by Mr. Edward L. Fischer, State Traffic and Roadway Engineer. The entire team's effort and dedication to improving roadway safety throughout the State of Oregon is greatly appreciated.

I am grateful to the following individuals:

- Mr. Jim Huddleston, Executive Director, Asphalt Pavement Association of Oregon
- Mr. Scott Batson, City of Portland Transportation Office
- Dr. Robert Layton, Oregon State University
- John Oshel, Association of Oregon Counties

I am also indebted to several other individuals who assisted in providing information for the Handbook:

- Chris Brehmer, Kittelson and Associates, Inc
- Tim Burks, ODOT
- Debby Corey, ODOT
- Scott Cramer, ODOT
- Rich Crossler-Laird, ODOT
- Janice Gipson, ODOT
- Rodger Gutierrez, ODOT
- Kevin Haas, ODOT
- Elizabeth Hunt, ODOT
- Dale Huntington, Kittelson and Associates, Inc
- Katryn Johnson, ODOT
- Scott Jollo, ODOT
- Heather King, ODOT
- David Lanning, ODOT
- Sheila Lyons, ODOT
- Alvin Shoblom, ODOT
- Julie Yip, ODOT

I am also grateful to Ms. Anne Holder, Program Manager, Roadway Safety, Work Zones

& Safety Corridors of the Transportation Safety Division of the Oregon Department of Transportation for all of her assistance during the development of this Handbook.

Special thanks go to those who typed the manuscript and assisted with the graphics, printing, etc. Special thanks to Mr. Dale Frakes for formatting and working with me over many late evenings and weekends to get this book compiled and completed. He deserves my gratitude for his professional, dedicated, and tireless work. Special thanks to Ms. Erin Murray for editing the manuscript.

I would also like to thank Ms. Sue Safve, and Dr. Steven O'Halloran for assisting with the design of the cover page of this Handbook.

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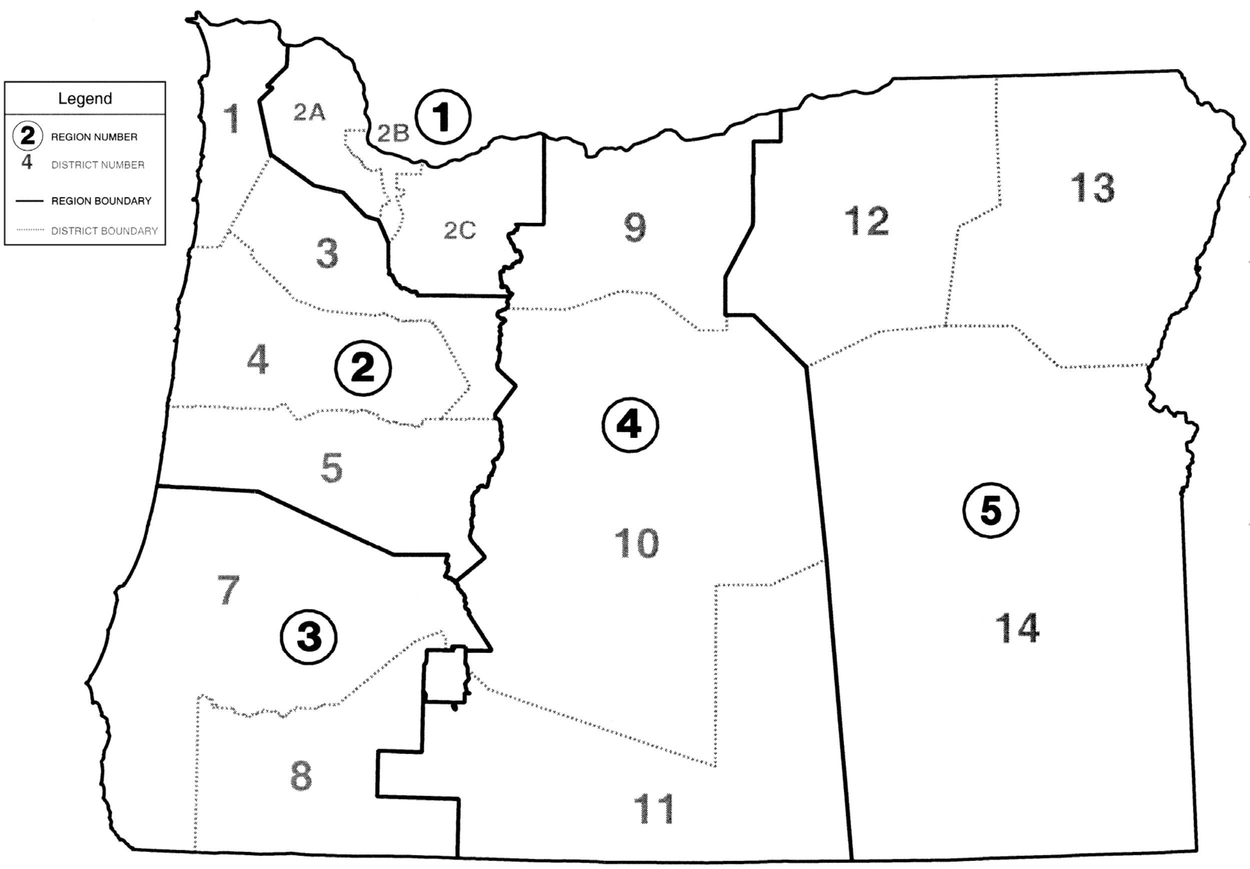
Engineering Assistance And Technical Information

Engineering assistance for the Roadway Safety and Traffic Control Practices for rural and smaller urban areas may be obtained from the regional offices, Oregon Department of Transportation, at the following locations:

Oregon Department of Transportation Regional Managers

Region 1 Portland, Oregon	Phone: (503) 731-8256
Region 2 Salem, Oregon	Phone: (503) 986-2631
Region 3 Roseburg, Oregon	Phone: (541) 957-3518
Region 4 Bend, Oregon	Phone: (541) 388-6191
Region 5 La Grande, Oregon	Phone: (541) 963-1327



Oregon Department of Transportation District Managers

DISTRICT 1 Astoria, Oregon	**REGION 2** Phone: (503-325-7222
DISTRICT 2A Portland, Oregon	**REGION 1** Phone: (503-229-5266
DISTRICT 2B Clackamas, Oregon	**REGION 1** Phone: (971) 673-6215
DISTRICT 2C Troutdale, Oregon	**REGION 1** Phone: (503) 665-4514
DISTRICT 3 Salem, Oregon	**REGION 2** Phone: (503) 986-2877
DISTRICT 4 Corvallis, Oregon	**REGION 2** Phone: (541) 757-4211
DISTRICT 5 Springfield, Oregon	**REGION 2** Phone: (541) 726-2552
DISTRICT 7 Roseburg, Oregon	**REGION 3** Phone: (541) 957-3586
DISTRICT 8 White City, Oregon	**REGION 3** Phone: (541) 774-6355
DISTRICT 9 The Dalles, Oregon	**REGION 4** Phone: (541) 296-2215
DISTRICT 10 Bend, Oregon	**REGION 4** Phone: (541) 388-6192
DISTRICT 11 Klamath Falls, Oregon	**REGION 4** Phone: (541) 883-5662
DISTRICT 12 Pendleton, Oregon	**REGION 5** Phone: (541) 276-1241
DISTRICT 13 La Grande, Oregon	**REGION 5** Phone: (541) 963-8406
DISTRICT 14 Ontario, Oregon	**REGION 5** Phone: (541) 889-9115

Regional Safety Coordinators As Of January 2010

Transportation Safety Division Main Office Salem, Oregon	Phone: (800) 922-2022
Roadway Safety / Work Zone Safety Program Manager, Safety Corridors, Commercial Vehicle Safety Anne Holder Salem, Oregon	Phone: (503) 986-4195 E-mail: Anne.P.Holder@odot.state.or.us
Region 1 KC Humphrey Portland, Oregon	Phone: (503) 731-4965 E-mail: Charles.Humphrey@odot.state.or.us
Region 2 Cindy Bradley Salem, Oregon	Phone: (503) 986-2763 E-mail: Cynthia.L.Bradley@odot.state.or.us
Region 3 Rosalee Senger Roseburg, Oregon	Phone: (541) 957-3657 E-mail: Rosalee.A.Senger@odot.state.or.us
Region 4 Debbie Miller Bend, Oregon	Phone: (541) 388-6429 E-mail: Debbie.A.Miller@odot.state.or.us
Region 5 Patricia McClure La Grande, Oregon	Phone: (541) 963-1387 E-mail: Patricia.J.McClure@odot.state.or.us

Chapter 1: Introduction To Roadway Safety

The purpose of this Handbook is to provide local roadway agencies with important information related to roadway safety features intended for use on roads and streets in rural and small urban areas. It will assist local road agency professionals in understanding the critical relationship between road users' behavior, traffic control devices, roadside safety features, traffic crashes, and roadway safety.

It is recognized that funds for construction, maintenance, and operation of local road and street systems are limited; therefore, the Handbook is aimed at providing a rational balance between maximum safety and minimum cost.

Familiarity with the Handbook will enable one to:

- Understand the types and causes of traffic crashes
- Recognize potential roadway safety problems and be able to suggest appropriate remedies
- Select the most promising roadway safety improvements
- Identify conditions which may make some existing safety features ineffective
- Use proper procedures for installation and maintenance of roadway safety features and traffic control devices.

The following chapters of the Handbook deal with each of the major subject areas pertaining to the regulation of motorists, pedestrians, and bicyclists. Each chapter will cover typical problems or questions relating to a specific subject and will discuss the techniques needed to analyze the problems and develop proper solutions. Those subjects to be covered include:

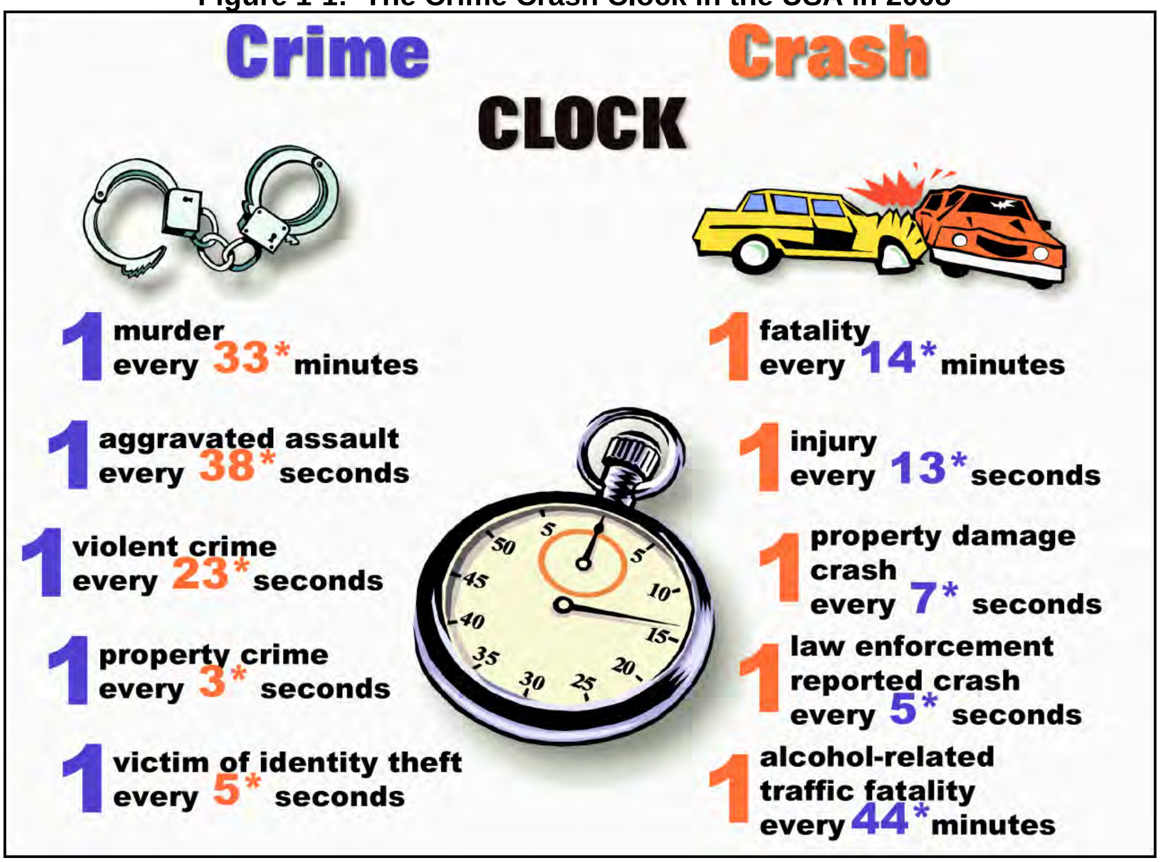
- Introduction To Roadway Safety
- Studies And Records
- Tort Liability And Risk Management
- Speed Limits
- Traffic Control Devices
- Low-Volume Roads
- Pavement Markings
- Sign And Mailbox Supports
- Flashing Beacons
- Traffic Signals
- Pedestrian Safety
- School Area Safety
- Bicycle Facilities
- Street Lighting
- Railroad Crossings
- Access Management And Driveways
- Parking
- Traffic Impact Analysis
- Traffic Calming
- Clear Zone, Sight Distance, and Vegetation Control
- Drainage Features
- Roadside Barriers
- Road Surface, Shoulder, And Pavement Management

It is important to indicate that the decision to use specific features and traffic control devices to improve safety at a particular location should be made on the basis of either an engineering study or the application of engineering judgment. Thus, while this Handbook provides important information related to roadway safety features, it should not be considered a substitute for engineering judgment. Engineering judgment should be exercised in the selection and application of roadway safety features and traffic control devices.

Statistical Traffic Crash Data For USA And Oregon

In Oregon, as of 01/01/2004, the law requires that any traffic crash on a public roadway which results in a fatality, bodily injury, or damage to one person's property in excess of $1,500 be reported to the DMV within 72 hours. Motor vehicle traffic crashes have been summarized by the Oregon Department of Transportation since 1941. The fatal crash rate is expressed as the number of fatalities per 100,000,000 vehicle miles traveled. Table 1-1 and Table 1-2 show motor vehicle crashes for the USA in 2006 and Oregon in 2007. Table 1-3 and Table 1-4 show persons killed and injured in motor vehicle crashes in the USA (2007) and Oregon (2007). Table 1-5 shows a comparison of motor vehicle fatality rates for the USA and Oregon. Figure 1-2 and Figure 1-3 show fatalities in Oregon (2007) and the USA (2007) by role.

Figure 1-1: The Crime Crash Clock in the USA in 2008[1]



[1] Source: NHTSA Traffic Safety Facts Data, 2008 and Department of Justice, FBI, Crimes In The United States, 2008

What Is The Crash Rate?

The crash rate represents the number of crashes that occur per one million vehicle miles traveled (VMT). Fatal and Serious Injury rates represent the number of crashes or casualties per 100 million VMT. VMT is calculated by multiplying the highway segment length, average annual daily traffic, and the number of days the segment was open for travel. The rate is computed using the following criteria, where:

- NUMBER OF CRASHES = the number of crashes that occurred on the given length of section during the current data year;
- SEGMENT LENGTH = the roadway length in miles, to the nearest one-hundredth;
- AADT = the average annual daily traffic for the length of section; and
- NUMBER OF DAYS = the number of days during the year that the roadway was open for travel.

The formula may be depicted two ways[2]:

$$\text{Crash Rate} = \frac{(\text{Number Of Crashes}) * 1{,}000{,}000}{(\text{Segment Length}) * (\text{AADT}) * (\text{Number Of Days})}$$

or

$$\text{Crash Rate} = \frac{(\text{Number Of Crashes}) * 1{,}000{,}000}{(\text{VMT})}$$

The fatality rate is depicted as:

$$\text{Fatality Rate} = \frac{(\text{Number Of Fatal Crashes}) * 100{,}000{,}000}{(\text{Segment Length}) * (\text{AADT}) * (\text{Number Of Days})}$$

or

$$\text{Fatality Rate} = \frac{(\text{Number Of Fatal Crashes}) * 100{,}000{,}000}{(\text{VMT})}$$

[2] Source: http://www.oregon.gov/ODOT/TD/TDATA/car/docs/2006_RateBook_web.pdf

Table 1-1: Motor Vehicle Crashes In The United States, 2008[3]

Population	**304,060,000**
Persons killed	37,261
Persons injured	2,346,000
Fatal crashes	34,017
Injury crashes	1,630,000
Property damage crashes	4,146,000
Registered vehicles	254,400,000
Persons killed per 100 million vehicle miles traveled	1.27
Persons killed per 100,000 population	12.25
Persons injured per 100,000 population	771
Alcohol related fatalities	32%
Speed related fatalities	31%
Passenger vehicle fatalities (restraint used)	45%
Passenger vehicle fatalities (restraint not used or unknown)	55%
Economic cost of motor vehicle traffic crashes in year 2006	$255.7 billion[4]

Table 1-2: Motor Vehicle Crashes In Oregon, 2008[5]

Population	**3,791,000**
Persons killed	416
Persons injured	26,805
Fatal crashes	396
Injury crashes	18,040
Property damage crashes	23,406
Vehicle miles traveled (in millions)	33,469
Registered vehicles	4,130,000
Licensed drivers	3,018,000
Persons killed per 100 million vehicle miles traveled	1.24
Persons injured per 100 million vehicle miles traveled	80.09
Persons killed per 100,000 population	10.97
Persons injured per 100,000 population	707
Alcohol related fatalities	41.1%
Speed related fatalities	50.5%
Passenger vehicle fatalities (restraint used)	56.9%
Passenger vehicle fatalities (restraint not used or unknown)	43.1%

[3] Source: US DOT, National Highway Traffic Safety Administration (NHTSA), Traffic Safety Facts 2008 Data
[4] Source: National Safety Council, Injury Facts, 2010
[5] Source: Oregon Department of Transportation, Oregon Traffic Safety Performance Plan For Fiscal Year 2010

Table 1-3: Persons Killed And Injured In Motor Vehicle Crashes, By Role In The United States, 2008[6]

Role	Persons Killed	Persons Injured
Large Trucks	677	23,000
Passenger Cars	14,587	1,319,000
Light Trucks	10,764	779,000
Motorcyclists	5,290	101,000
Pedestrians	4,378	69,000
Pedalcyclists	716	52,000
Other	849	3,000
TOTAL	37,261	2,346,000

Table 1-4: Persons Killed And Injured In Motor Vehicle Crashes, By Role In Oregon, 2008[7]

Role	Persons Killed	Persons Injured
Drivers, Passengers, and Others	310	24,755
Pedestrians	53	576
Motorcyclists	43	717
Bicyclists	10	757
TOTAL	416	26,805

Table 1-5: Comparison Motor Vehicle Deaths And Death Rates In Oregon[8] And The United States[9]

Year	Number of Deaths United States	Number of Deaths Oregon	Death Rates per 100,000,000 Vehicle Miles United States	Death Rates per 100,000,000 Vehicle Miles Oregon
2008	37,261	416	1.29	1.24
2007	41,059	455	1.37	1.31
2006	42,642	477	1.44	1.34
2005	43,510	487	1.46	1.38
2004	42,836	456	1.44	1.28
2003	42,884	512	1.48	1.46
2002	42,815	436	1.51	1.26
2001	41,945	488	1.51	1.42
2000	41,821	451	1.53	1.29
1999	41,717	414	1.55	1.19
1998	41,501	538	1.58	1.61
1997	42,013	524	1.64	1.66

[6] Source: Source: U.S.D.O.T., National Highway Traffic Safety Administration (NHTSA), Traffic Safety Facts 2008, DOT HS 811170

[7] Source: Oregon Department of Transportation, Oregon Traffic Safety Performance Plan For Fiscal Year 2010

[8] Source: Oregon Department of Transportation

[9] Source: Source: U.S.D.O.T., National Highway Traffic Safety Administration (NHTSA), Traffic Safety Facts 2008, DOT HS 811170

Figure 1-2: 2008 Oregon Fatalities[10]

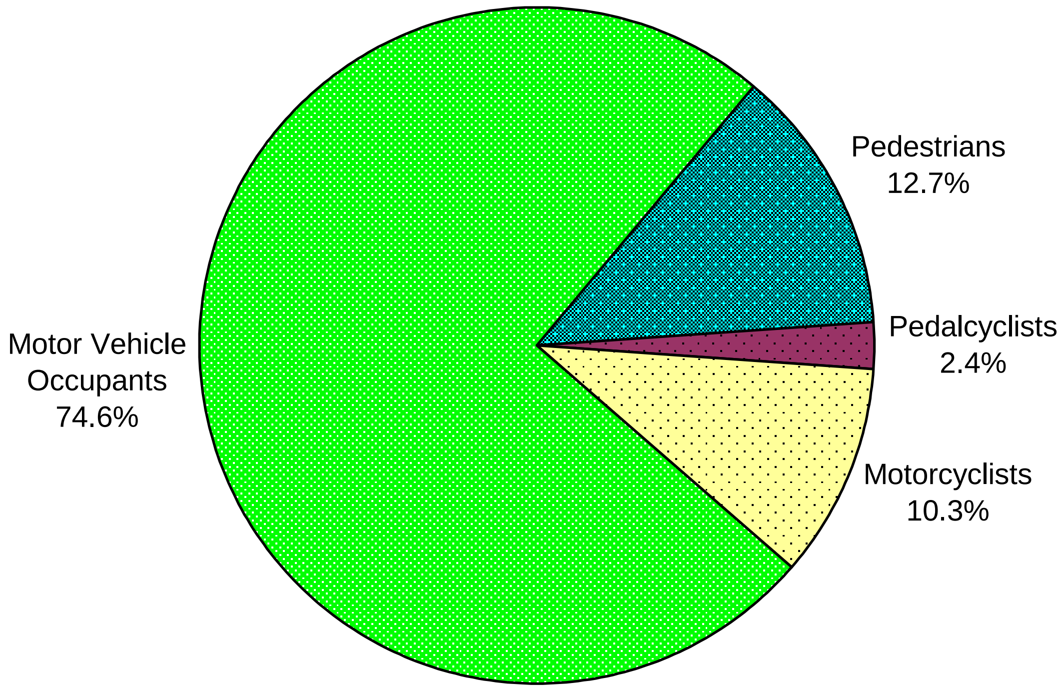
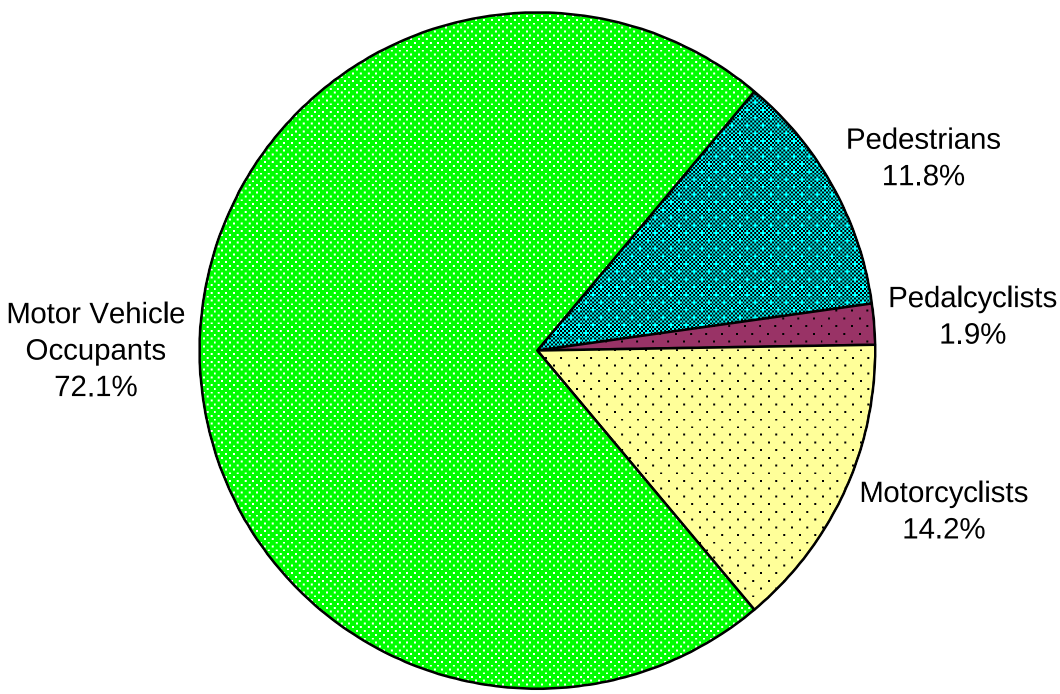


Figure 1-3: 2008 United States Fatalities[11]



[10] Source: Oregon Department of Transportation, Oregon Traffic Safety Performance Plan, Fiscal Year 2010
[11] Source: USDOT, National Highway Traffic Safety Administration (NHTSA), Traffic Safety Facts, 2008 Data

What Is The Cost Of Motor Vehicle Crashes?

There are two methods currently used to measure the costs of motor-vehicle crashes. One is the economic cost framework and the other is the comprehensive cost framework.

A. Economic costs may be used by a community or state to estimate the economic impact of motor-vehicle crashes that occurred within its jurisdiction in a given time period. It is a measure of the productivity lost and expenses incurred because of the crashes.

There are five economic cost components:

1. wage and productivity losses, which include wages, fringe benefits, household production, and travel delay;
2. medical expenses, including emergency service costs;
3. administrative costs of private and public insurance plus police and legal costs;
4. motor vehicle damage including the value of damage to property; and
5. employer costs for crashes to workers.

The following information shows the average economic cost in 2008 per death, per injury, and per property damage crash.

Table 1-6: Economic Costs, 2008[12]

Cause	Cost Per Person
Death	$1,300,000
Nonfatal disabling injury	$63,500
Incapacitating injury	$67,200
Non-incapacitating evident injury	$21,800
Property damage crash (including minor injuries)	$12,300
Total economic loss in Oregon	$2.23 billion
Economic loss per person in Oregon (2008)	$620

B. Comprehensive Costs include not only the economic cost components, but also a measure of the value of lost quality of life associated with the deaths and injuries, that is, what society is willing to pay to prevent them. The values of lost quality of life were obtained through empirical studies of what people actually pay to reduce their safety and health risks, such as through the purchase of air bags, etc. Comprehensive costs should be used for cost-benefit analyses.

The information below shows the comprehensive costs in 2006 on a per person basis.

Table 1-7: Comprehensive Costs, 2008[13]

Cause	Cost Per Person
Death	$4,200,000
Incapacitating injury	$214,200
Non-incapacitating injury	$54,700
Possible injury	$26,000
No injury	$2,400

[12] Source: National Safety Council, Injury Facts, 2010
[13] Source: National Safety Council, Injury Facts, 2010

How To Obtain Outside Technical Assistance To Evaluate The Safety Problems Of Small Local Jurisdictions

This Handbook attempts to cover as many of the typical problems or questions relating to roads and street safety, the use of traffic control devices, and traffic practices as is possible. In some cases where the problem is particularly complex, local agencies may wish to seek outside assistance to supplement the information presented. Such assistance is available from a number of sources.

The Oregon Department of Transportation has primary responsibility for the maintenance of all state highways. Therefore, highway safety related issues and traffic control problems on state highways should be referred to this agency for investigation. Local jurisdictions should contact the District Engineer of the Oregon Department of Transportation (ODOT) to seek assistance.

What Traffic Safety Resources And Highway Safety Short Courses Are Available For Local Jurisdictions?

The following traffic safety resources and highway safety short courses are available for local jurisdictions throughout the State of Oregon:

A. Traffic Engineering and Highway Safety Short Courses

Katharine M. Hunter-Zaworski
Transportation Research Institute,
Oregon State University, Corvallis, Oregon
Phone: (541) 737-4982
E-mail: hunterz@engr.orst.edu

Annually, the program offers several practical short courses on providing safe streets and roads. These short courses are designed for persons with responsibilities related to traffic and highway safety throughout Oregon. For additional information please visit the website: http://kiewit.oregonstate.edu/workshops.html

B. Improving Safety Features of Local Roads and Streets Workshop

Mojie Takallou, Ph.D., P.E.
University of Portland
Portland, Oregon
Phone: (503) 943-7437
E-mail: Takallou@up.edu

The University of Portland conducts a one-day workshop in your area free of charge. The workshop is designed for persons with responsibilities related to traffic and highway safety throughout Oregon. The workshop focuses on highway safety, tort liability, traffic control devices, clear zone, road surface, roadside barriers, speed limit and traffic calming, pedestrian safety and school crossings, parking, drainage, etc. For additional information please visit the website: http://www.up.edu/highwaysafety/.

C. Highway, Local Roads & Street Safety For Non-Engineers

Mojie Takallou, Ph.D., P.E.
University of Portland
Portland, Oregon
Phone: (503) 943-7437
E-mail: Takallou@up.edu

The University of Portland conducts two to six-hour workshops in your area free of charge. This workshop is designed for persons throughout Oregon with responsibilities related to traffic and highway safety. The workshop focuses mainly on the types, causes and costs of traffic crashes, the importance of the Engineering, Enforcement, and Education. The workshop also review proper use of traffic control devices, traffic calming, and the best safety practices in your region. Overall, the workshop will answer many of the questions that decision makers, traffic safety committee members, and public agencies personal may have regarding the roadway safety.

The workshop will be of value to elected officials, city councilors, traffic safety committee members, county commissioners, county road supervisors, street superintendents, and concerned citizens. The workshop introduces the latest developments in the field and is an opportunity for all concerned to exchange up-to-date information. Common road and street hazards are reviewed along with practical ways to improve road and street safety.

For additional information please visit the website: http://www.up.edu/highwaysafety/.

D. Challenges, Strategies & Obligations of Law Enforcement Agencies for the 21st Century

Mojie Takallou, Ph.D., P.E.
University of Portland
Portland, Oregon
Phone: (503) 943-7437
E-mail: Takallou@up.edu

The University of Portland conducts a four- to six-hour workshop in your area free of charge. This workshop presents the challenges, strategies, and obligations of law enforcement agencies in meeting 21st century demands and is designed for the entire patrol division of law enforcement agencies. The workshop focuses mainly on the types, causes and costs of traffic crashes, the importance of the 3Es (engineering, enforcement, and education) of highway safety, and the value of proactive traffic enforcement and looking beyond the traffic ticket in criminal apprehension. Overall, the workshop will answer many of the questions law enforcement personnel may have regarding the effectiveness of traffic enforcement and suggest strategies to maintain and improve traffic services as we enter the 21st Century.

For additional information please visit the website: http://www.up.edu/highwaysafety/.

E. Technology Transfer Center

Bob Raths
Oregon Department of Transportation

Salem, Oregon
Phone: (800) 544-7134
E-mail: Bob.Raths@odot.state.or.us

The Technology Transfer Center provides technical information and assistance to cities and counties on transportation topics, primarily streets and roads. Assistance includes low-cost workshops, a quarterly newsletter, a publications library, and an audio-visual lending library.

F. Alliance for Community Traffic Safety (ACTS)

Ruth Harshfield
Oregon City, Oregon
Phone: (503) 656-7207
E-mail: ruthh@actsoregon.org

ACTS provides information and assistance to counties' and cities' traffic safety commissions and efforts. Informational materials include a monthly newsletter on statewide traffic safety issues and programs, guides to working with the media and on starting a traffic safety commission, and an inventory of resources. ACTS is available to help set up a commission, conduct planning sessions, or to find a resource to meet your local traffic safety needs.

What Is The ODOT Highway Safety Program?

The Oregon Transportation Commission (OTC) has allocated approximately $28 to 29 million dollars a year to the ODOT Highway Safety Program for 2006 through 2009 for infrastructure improvements. These funds are primarily used for safety improvements on the state highway system. The mission of the Highway Safety Program at the Oregon Department of Transportation (ODOT) is to carry out highway safety improvement projects to achieve a significant reduction in traffic fatalities and serious injuries. For additional information regarding the ODOT Highway Safety Program, please visit the website:
http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/highway_safety.shtml

Traffic Roadway Section (TRS) Highway Safety Program Coordinator

Questions or comments about the Safety or HSIP Program not addressed in the ODOT Highway Safety Program Guide can be directed to:
Tim Burks, Highway Safety Engineering Coordinator
Traffic-Roadway Section
355 Capitol NE, 5th Floor
Salem, Oregon 97301
Voice: (503) 986-3572 Fax: (503) 986-4063
timothy.w.burks@odot.state.or.us

What Is The High Risk Rural Roads (HR3) Program?

The High Risk Rural Road Program (HRRR) in SAFETEA-LU (called HR3 in Oregon) is a sub-program of the Highway Safety Improvement Program (HSIP), a federally-funded program managed by the Oregon Department of Transportation (ODOT). Approximately one million dollars of federal funding is available each federal fiscal year in Oregon for High Risk Rural Roads.

The mission of the HR3 is to carry out safety improvement projects on rural roads, with identified safety issues, to achieve a significant reduction in traffic fatalities and serious injuries.

What Are The Eligibility Criteria For The High Risk Rural Roads (HR3) Program?

1. Roadways functionally classified as a rural major or minor collector or as a rural local road are eligible.
2. The roadway must have a crash rate for fatalities and incapacitating injuries (serious injury A) that exceeds the statewide average for those functional classes of roadways.
3. Roadways are also eligible if future traffic volumes are projected to increase causing a projected increase in the crash rate for fatalities and incapacitating injuries that exceeds the statewide average.
4. As long as the project will ultimately involve a construction or operational improvement which is identified as part of a State's HSIP process, funds from those set aside for high risk rural roads for preliminary engineering (including right-of-way, environmental approvals and final design) would be eligible for federal reimbursement.

Selected Eligibility Notes For The HR3 Program:

a. The intent of Oregon's implementation is to focus on County Roads, however, qualified State Highways or roads identified as public under 23 CFR 460.2, with a history of fatal or serious injury A crashes may apply for HR3 funding.
b. Projects in counties subject to loss of revenue due to reduction or elimination of Federal School Safety Net Funds may be given special consideration.
c. Eligible roadways with ADTs less than or equal to 400 will be given special consideration.
d. Roads with high crash rates, in addition to fatal crashes and serious injury A crashes, and having an assessment by the local engineer that indicates that there is potential for serious injury A crashes or fatal crashes to increase will be given special consideration.

Local Match Requirements

The Local Match requirement for HR3 projects is 7.78 percent of the total project cost.

Questions or comments about the High Risk Rural Roads (HR3) program can be directed to:

Marty Andersen
ODOT Local Government Section
Capitol St NE, Rm 326
Salem, OR 97301-3871
Phone: (503)986-3640
Fax: (503)986-3290
E-mail: martin.e.andersen@odot.state.or.us

Chapter 2: Studies And Records

A number of studies and records must be available for analysis in order to make the correct decisions about the operation of roadways. These include crash information, traffic data, and records that can also aid an agency in risk management and litigation.

Where Can Crash Information Be Obtained?

The Oregon Department of Transportation (ODOT), Transportation Development Division, Crash Analysis and Reporting Unit is the official repository for crashes reported on public roads in Oregon. Print-outs of crash data for communities are available from:

Sylvia Vogel
ODOT, Transportation Development Division
555 13th Street NE, Suite 2
Salem, OR 97301-4178
(503) 986-4240
sylvia.m.vogel@odot.state.or.us

Statewide Crash Rate Tables:
http://www.oregon.gov/ODOT/TD/TDATA/car/CAR_Publications.shtml

ODOT Maps:
http://www.oregon.gov/ODOT/TD/TDATA/gis/ODOTmaps.shtml

ODOT Highway Reports:
http://www.oregon.gov/ODOT/TD/TDATA/otms/OTMS_Highway_Reports.shtml

It is important that crash files on roadways be kept up-to-date and maintained. Spot maps and location files may be very useful for this purpose.

What Traffic Information Is Required?

Generally, the most important information needed is traffic volume. A tabulation of counts by time intervals of 15 minutes, 30 minutes, one hour, or one day of vehicles or pedestrians passing a specific point is collected.

The manual count is the most basic and generally the most useful of volume collection procedures. It includes data on travel direction and turning movements at intersections and can include a breakdown of vehicle types and sizes. Manual counts also may be taken by any time interval such as five minutes, signal cycle length, and so forth. Tabulation of other useful information including queue lengths, traffic signal violations, and any event contributing to vehicle delay may be noted.

Many traffic analyses such as those relating to capacity, design, channelization, and delay require traffic volumes during peak-hour conditions. Counts taken of traffic flow in the single heaviest hour of morning and evening traffic are generally used. Turning movements at intersections are also an important element of volume counts and can be used for design, channelization, lane marking, and application of traffic control devices.

How Are Manual Traffic Counts Taken?

Manual traffic counts are generally made by one or more persons depending on the data to be collected. This data may include vehicle classification, pedestrian volume, signal violations, queue lengths, and other items.

Most commonly, one person can record vehicle counts on both an intersection or non-intersection location using a watch, pencils, and a tablet. A field tabulation sheet is often used to simply record the data. For intersections, the equipment and forms used for traffic counts are:

a. Tally sheets. The simplest means of conducting manual counts is to record each observed vehicle with a tick mark on a prepared field form. Figure 2.1 shows a field sheet for a vehicle turning movement count.
b. Mechanical count boards. Mechanical count boards consist of various combinations of accumulating counters mounted on a board to facilitate the type of count being made. When the end of an interval is reached, the observer reads the counter, records the data on a field form, and resets the counter to zero. Figure 2.2 illustrates a field summary form for an intersection turning movement count.
c. Electric count board. Battery-operated, hand-held, electronic count boards are currently the most common device to aid in the collection of traffic count data. Many electronic count boards are capable of handling several types of common traffic studies, including turning movement, classification, gap, stop delay, stop sign delay, spot speed, and travel-time studies.

Counting Periods

Some of the more commonly used counting period intervals are:

a. 24-hour count normally covering any 24-hour period between noon Monday and noon Friday. If a specific day count is desired, the count should be from midnight to midnight.
b. 16-hour counts, usually 5:30 a.m. – 9:30 p.m., or 6:00 a.m. – 10:00 p.m.
c. 12-hour counts, usually 7:00 a.m. – 7:00 p.m.
d. Peak-period counts, usually 7:00 – 9:00 a.m. and 4:00 – 6:00 p.m.

The following should also be accomplished to check accuracy of data:

- If the count appears too low or too high, check for unusual circumstances such as new business in the area, adverse weather conditions, etc. If the count cannot be justified, recount it.
- If a counter has 15-minute increments, check individual periods. If it is noticed that any unusually high 15-minute volumes occur during non-peak hours, it is a good possibility someone has stopped and jumped on the hose or just driven back and forth to increase the volume.

- Compare the time period in doubt to the previous day for similarity and adjust accordingly.
- Keep historical data and compare previous ADT to new counts. This can be an editing tool, a way to develop growth factors, or just to create trends.

What Is A Peak-Hour Factor?

A peak-hour factor (PHF) is used to analyze traffic conditions for periods less than one hour, and it is a measure of the variability of traffic demand during the peak hour. It is the ratio of the volume during the peak hour to the maximum rate of flow during a given period within the peak hour. The Highway Capacity Manual suggests using 15 minutes flow of the peak hour for operational and design analyses. Operational studies of the peak-hour factor can be obtained by counting volumes on each approach separately for each 15-minute period of the peak hour and calculated as follows:

$$\textit{Peak-Hour Factor (PHF)} = \frac{\textit{Peak-Hour Volume}}{\textit{4 x (peak 15-minute Volume Within Peak Hour)}}$$

$$\textit{Design Hour Volume (DHV)} = \frac{\textit{Peak-Hour Volume}}{\textit{PHF}}$$

For example, the table that follows shows the 15-minutes volume counts during the peak hour on the approach of an intersection. Determine the Peak Hour Factor (PHF) and the Design Hour Volume (DHV) of the approach.

Time Period	**Volume**
6:00 – 6:15 A.M.	400
6:15 – 6:30 A.M.	450
6:30 – 6:45 A.M	500
6:45 – 7:00 A.M.	650

Total Volume During Peak Hour = (400 + 450 + 500 + 650) = 2000

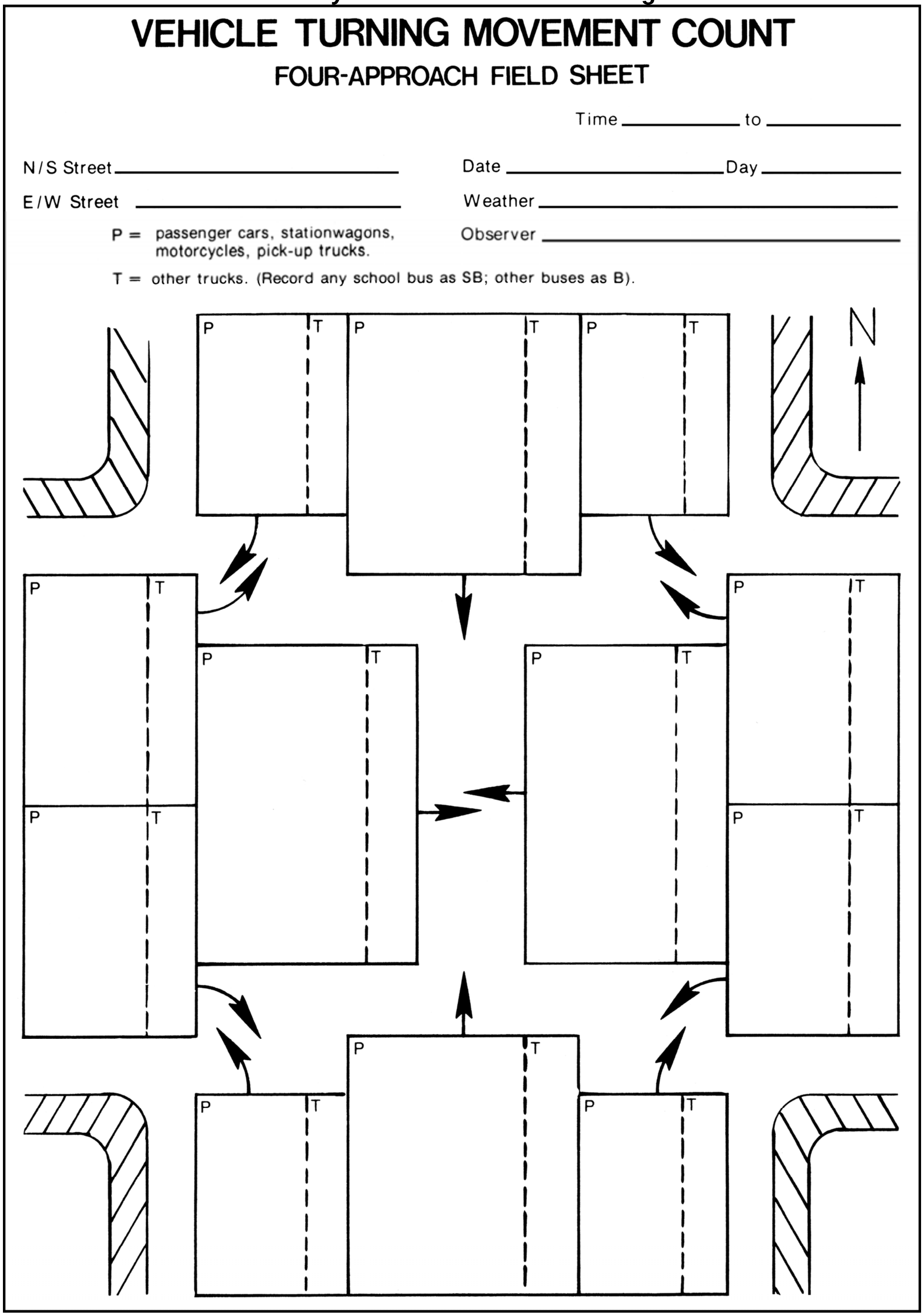
Volume During Peak 15-minutes = 650

$$\textit{PHF} = \frac{\textit{Peak-Hour Volume}}{\textit{4 x (peak 15-minute Volume)}}$$

$$\textit{PHF} = \frac{2000}{4 \times 650} = 0.77$$

$$\textit{Design Hour Volume (DHV)} = \frac{\textit{Peak-Hour Volume}}{\textit{PHF}} = \frac{2000}{0.77} = 2597$$

Figure 2-1: Intersection Field Tally Sheet For Vehicle Turning Movement Count[1]



[1] Source: Manual of Transportation Studies, Institute of Transportation Engineers, 1994

Figure 2-2: Tabular Summary Of Vehicle Counts[2]

TABULAR SUMMARY OF VEHICLE COUNTS

Observer ____________ Date ________ Day ________ City ____________

INTERSECTION OF ____________ AND ____________

R = Right turn
S = Straight
L = Left turn

TIME BEGINS	from NORTH				from SOUTH				TOTAL North South	from EAST				from WEST				TOTAL East West	TOTAL ALL
	R	S	L	Total	R	S	L	Total		R	S	L	Total	R	S	L	Total		

[2] Source: Manual of Transportation Studies, Institute of Transportation Engineers, 1994

Chapter 3: Tort Liability And Risk Management

The threat of lawsuits and liability is an inescapable fact of life for public agencies and their departments. Public officials and employees also have reason to be concerned. This is especially so for local government agencies and employees involved in street and sidewalk construction, maintenance, and repair.

According to the U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA), an estimated 2.35 million people were injured in motor vehicle crashes in 2008, and 37,261 were killed. There is a growing awareness, particularly among attorneys representing injured persons, that in many of these cases a legal claim can be made against the government entity responsible for designing, constructing, or maintaining the street or road where the crash occurred.

The purpose of this Chapter is to introduce public agencies maintenance officials and personnel to the general principles of tort liability and to show how those rules operate within the legal system to assign responsibility for crashes involving street and highway maintenance.

What Can Be Done To Eliminate The Possibility Of Being Sued?

There are no specific actions that can be taken to completely eliminate being sued. Since this is a fact of life, local public agencies must do the next best thing to minimize their liability exposure. A good risk management program serves as a preventive program and will assist in this effort. This program should be designed to anticipate the problems that local agencies frequently encounter in maintaining a reasonably safe road system. Frequent problems typically include malfunctioning traffic signals, sign defects, roadside hazards, guardrail and shoulder maintenance, road surfacing maintenance, intersection geometrics, removal of highway debris, and work zone signing. These problems are the most frequent target of lawsuits.

What Is The Meaning Of Tort Liability?

The word "tort" derives from a French word that means a "wrong" or an "injustice." Tort law comprises the legal rules that determine when one party should be required to pay money to compensate another party for personal injuries or property damage.

A public agency can be held liable for negligence or for any other wrongful conduct, including intentional torts committed by its employees within the scope of their employment. The two main purposes of tort law are to compensate injured people for the harm they have been caused and to deter unreasonably dangerous conduct.

Tort law, then, applies to lawsuits in which the person who brings a lawsuit (plaintiff) seeks to recover money to compensate for personal injuries or property damage that he claims was caused by the person, or roadway agencies, against whom a lawsuit is filed (defendant.)

What Is Negligence?

In order to recover money damages from a public agency in a negligence case, the plaintiff must prove the following four elements:

1. that the road authority owed him a duty;
2. that the conduct of a road authority employee acting in the scope of his employment breached that duty;
3. that the employee's conduct was the proximate cause of his harm; and
4. that the plaintiff was actually damaged.

These four elements are referred to as a prima facie case of negligence. Unless the plaintiff can establish all four of these elements, the case against the road authority will be dismissed. These four elements are described in the following paragraphs.

A. Duty

Initially, the plaintiff must show that the defendant owed the plaintiff a duty. A duty is a legal obligation that one party owes to another. The law imposes upon anyone carrying on activity that may cause harm to others the duty to exercise ordinary care to avoid that harm. The law requires that the road authority act reasonably under the circumstances; the failure to do so is negligence.

Example: A pedestrian falls on a sidewalk. The road authority is responsible to keep the sidewalks in "proper repair," which has been interpreted to mean "in a reasonably safe condition."

A road authority is only required to use due care and to prevent reasonably foreseeable occurrences that may cause injury. It is not an insurer, but the statute imposes a duty to keep the public way safe for ordinary use. There is also a duty to provide reasonable and continuing supervision over the streets, so the road authority can be aware of their condition and possible defects.

B. Breach of Duty

This element simply means that the plaintiff must produce evidence that the defendant failed to comply with a legal duty. There must be evidence that the defendant did not act reasonably under the circumstance, or evidence that the defendant violated an applicable statute. If the jury determines that the defendant's acts were unreasonable under the circumstances, then it can be said that the duty was breached. In many cases, expert testimony of a traffic engineer is necessary to establish a breach of duty.

Example: Plaintiff is injured in a two car collision at an intersection where maintenance work is being done by the city. He alleges in his complaint that the traffic control devices used to direct traffic around the work zone and through the intersection were improperly arranged and created an unreasonably confusing and dangerous condition. Because laymen are not qualified to determine whether the defendant was negligent, a traffic engineer will have to testify that the devices were placed improperly.

C. Proximate Cause

Because the consequences of a negligent act may be traced infinitely, proximate cause operates as a limitation on liability. It requires that there be a reasonably close connection between the defendant's negligence and the plaintiff's injury.

Example: Plaintiff is injured when her car leaves the roadway and goes down an embankment. She sues the road authority, alleging that it was negligent to fail to install a guardrail at that spot. The jury must be convinced that the guardrail's absence contributed to the plaintiff's injuries, i.e., that a guardrail would have eliminated or reduced her injuries.

D. Damages

A person to whom no harm has been done does not have a case. A city may be negligent in unreasonably delaying to repair a pot hole on a busy street, but until someone suffers some harm, there can be no liability. To recover, the injured party must have suffered some kind of personal injury or property damage. The purpose of the award is to put the injured parties back in the position in which they were prior to the crash, either to rehabilitate them, or to reimburse them for their monetary loss.

What Is Risk Management?

Risk management can be defined as an ongoing program of activities designed to minimize the possibilities of being sued as a result of an alleged deficiency in a roadway system. The goals of risk management are:

1. To reduce accidental injuries on roadways, streets and sidewalks;
2. To reduce incidents of carelessness on the part of city employees who can cause these injuries; and
3. To increase the road authority's ability to produce evidence that it acted reasonably, if a lawsuit is filed against it.

How To Reduce The Risk Of Liability

The following describes the factors to be taken into account for reducing the risk of liability.

A. Records

Good records can be extremely helpful in defending against a negligence lawsuit, especially when the plaintiff alleges that a dangerous condition was not repaired in a timely fashion. The road authority should be able to prevail in such an action if it can produce evidence that establishes timely repairs were done in a reasonable manner, or that adequate warnings were posted until repairs could reasonably be made. Good records can make the case.

The maintenance department should create a system that will document:

1. the information coming into the maintenance department regarding street conditions;
2. the procedures used to prioritize the repair work according to the risk presented; and
3. the action taken in making the repairs.

The road authority should develop a complaint form or data intake form for recording complaints and reports regarding street conditions. The forms should include the following information:

- the name, address, phone number of the complainant or the person reporting the information
- the date and time the complaint or report was made
- the time the complaint or report was received
- the time the complaint or report was given to the repair crew
- the time the crew responded to the scene
- the time the repair was completed
- a description of the conditions that the crew found
- the date and time the complainant contacted to inform the complainant of the action taken
- a description of the repair made and materials used.

A typical complaint form is shown in Figure 3-1.

B. Prioritize the Work

After information comes into the department, the next step is to prioritize the work. The priority of work assignments should be reviewed on a regular basis as new complaints or reports are received. It is very important that the persons responsible for assigning repair work be able to explain how their decisions are made.

With a system for receiving information about street conditions in place and a policy for prioritizing repair work, the road authority will have a record of when they were put on notice of a problem, when they responded to the problem, and what was done about the problem. The road authority will be in a position to effectively demonstrate that timely repairs were done in a reasonable manner, or that adequate warnings were posted until the repairs could reasonably be made.

Figure 3-1: Typical Complaint Form

Work Order

Complaint: Date: ____________

Time: ____________

Complainant: ____________

Address: ____________

Telephone: ____________

E-mail: ____________

Location: ____________

____

____

Description: ____________

____

____

Call Taken by: ____________

Corrective Action:

Priority: ____________

Assigned To: ____________

Date: ____________ Time: ____________

Action Taken: ____________

____

____

____

Completion Date: ____________ Time: ____________

Complainant Contacted: _____ Yes

_____ Requested not to be contacted

C. Inspections and Traffic Control Device Inventories

Liability for failure to correct a dangerous condition may be imposed if the road authority reasonably should have known of the condition, even if the road authority did not have actual notice of the condition. This is called "constructive notice." The better and more complete the information regarding street conditions, the less likely is the issue of constructive notice to arise. It is better to know than not to know. Of course, no department can hope to have complete, up-to-the-minute knowledge of the condition of all its streets and sidewalks. There will always be some hazard of which the road authority was unaware. Even in that case, a reasonable system of inspections may be the best defense against the plaintiff's claim that the road authority should have known about the hazard, if only they had acted reasonably to discover it.

Routine inspections for the purpose of gathering information and identifying dangerous conditions can complement the records system described above. If there are sufficient resources, a regular inspection program should be designed and implemented. Coverage should be as complete as possible, and the inspections should be done as often as is reasonable under the circumstances. Part of the inspection should include an inventory of traffic control devices to locate and identify those that are not in compliance with the Manual on Uniform Traffic Control Devices (MUTCD).

Some features, such as traffic signs and markings, need to be inspected both during the day and at night. Examples of reasonable inspection frequencies are:

- twice yearly for traffic signals;
- as needed for pavement markings, particularly in early spring;
- before the rainy season for drainage features; and
- daily for temporary traffic controls at work sites.

All employees should be trained to recognize and to report problems with signs, signals, pavement markings, road surfaces, shoulder conditions, and the like within the road authority's jurisdiction.

Construction and maintenance crews should be trained to do a general inspection of the area whenever they are sent out on a job.

Information should be collected on the forms described above. The forms should then be reviewed and prioritized as would any other complaint or report coming into the department. Of course, more frequent inspections or engineering evaluations may be necessary for areas where conditions are changing, repair work is being done, or construction is ongoing.

D. Crash Reports

It is good practice to work with local law enforcement to design a system for regular review of traffic crash reports. Evidence of repeat crashes at the same location, such as crash reports filed by police, may be sufficient to give the road authority constructive notice of a street maintenance problem, even if the maintenance department does not have actual notice of it. The system should ensure that the reports get to the right people in the traffic department.

Citizen input, articles, and editorials are other sources of information that need to be gathered and maintained. Once a problem has been covered by the citizens or in the press, it is assumed that all parties have been informed about it.

E. Emergency Maintenance

The department should establish procedures for dealing with emergency maintenance.

Many small towns in Oregon do not have 24-hour crews available to handle emergencies. If that is the case, be sure there is some procedure for other public agency departments to report major problems to someone who has both the knowledge and the authority to determine whether the problems need immediate attention. That person's name, address, and phone number must be distributed to those who would have the occasion to use it.

Be sure that the departmental procedure will permit the engineer, in case of emergency, to get the necessary people and equipment to the problem within a reasonable time.

Law enforcement officers are most often the ones who will first encounter and report such emergencies. Be sure police are trained on how to properly place temporary warning signs until the work crew arrives.

If a 24-hour crew is available, be sure they have full access to the materials and equipment they may need to make emergency repairs or post sufficient warnings of the hazard.

F. Public Relations, Public Information

Notice to the public of major construction work and repairs may reduce traffic in those areas and in turn reduce the risk of crashes. It makes sense to put the public on notice of conditions that could delay or detour their travel, alert them to hazards they are likely to confront in traveling through work zones, and suggest alternative routes.

Increased awareness and a heightened appreciation of the risks involved on the part of everyone can go a long way toward reducing the risk of crashes.

G. Minimizing Exposure When Dealing With Contractors

A road authority does not escape exposure to liability by hiring a contractor to perform repairs on city streets and sidewalks. The courts have held that a road authority's duty to keep the streets in reasonably safe condition is "non-delegable." That means the road authority can be liable if the contractor is negligent.

Taking effective action to reduce the road authority's exposure to liability from the acts of its contractor is a matter to be undertaken with the road authority's legal counsel. This section merely describes a few of the strategies that may be appropriate.

The road authority should require an indemnification or "hold harmless" agreement from the contractor. Such agreements require the contractor, in effect, to reimburse the road authority for any liability the city may incur as a result of the contractor's activities. Notice that such an agreement cannot prevent an injured person from suing the road authority.

The road authority should, of course, require the contractor to provide proof of sufficient liability and workers' compensation insurance as a condition to awarding the contract. In addition, the contractor's liability policy should name the road authority as the insured party.

H. Education and Training

All road authority employees who have any role in reducing the potential exposure to liability in this area should receive education and training as a part of an overall risk management program.

A good educational approach would include both initial training and periodic updating.

Studies have shown that frequent, brief training sessions are more effective than longer, occasional classes. Maintenance personnel could be taught to be alert to potential problems and to report information beyond the specific repair they have been sent to do through a series of short training sessions.

Should My Agency Conduct A Crash Investigation?

An agency may wish to conduct its own investigation of a crash. Reasons for separate investigation to supplement standard police reports are as follows:

- Police reports fulfill a different purpose and may be deficient with respect to information needed by a highway agency.
- If it appears that a claim may be forthcoming, additional information may be needed for the preparation of an adequate defense.
- In some instances, such as work area traffic control, corrective action may be in order before the police report is filed.
- An engineering evaluation of the situation may be required.
- The crash may establish notice of a potential problem or defect.
- Investigation enables personnel to testify firsthand as to findings.

What Information Should Be Obtained In An Agency Investigation?

Field Data

The following items of information are very important in any action that may ensue, but will typically be obtained by the investigating police officer:

- Identification of vehicle involved, operators, and other occupants
- Names and addresses of witnesses
- Paths and final positions of vehicles
- Location and length of skid marks
- Position of crash-related debris
- Sketch diagram of vehicle paths
- Weather conditions
- Posted speed.

The following items may or may not be recorded in the police report. Regardless, they are items with which police officers are not as familiar and for which independent observations are desirable.

- Pavement surface condition
- Type and location of all pertinent traffic control devices
- Type, size, condition, height, and lateral position of signs
- Type and condition of pavement markings
- Type and locations of traffic signal displays, controller type, settings, etc.
- Description of pertinent highway hardware and appurtenances
- Grades, cross-slopes, drop-offs, etc.
- Dimensions of roadway, shoulders, median, etc.
- Identification of agency personnel who witnessed the crash or who had firsthand knowledge of conditions at the site
- Photographs. Photographs should be obtained of the crash site, damage to the facility, and, when it can conveniently be done, the vehicles involved. The camera location, direction, elevation, and time of day and date, should be identified for each photograph. While some photographs may be made by investigating officers, they may not include information of importance to the agency; for example, warning signs located upstream of the crash site advising motorists of conditions ahead.

For more information about the Risk Management Program, please contact:

Risk Management
State Services Division
Department of Administrative Services
1225 Ferry Street SE U150
Salem, OR 97301-4287
Phone: 503-373-7475
Fax: 503-373-4287
Email: Risk.Management@state.or.us

Chapter 4: Speed Limits

Speed limits are one of the oldest strategies for controlling driving speeds. Connecticut imposed the first maximum speed limit of 8 mph (13 km/h) in cities in 1901. Since that time, primary responsibility for setting speed limits has remained with state and local governments. Nationally mandated speed limits such as the National Maximum Speed Limit (NMSL) are exceptions to the rule.

The current framework for speed regulation was developed in the 1920s and 1930s. Each state has a basic statute that requires drivers to operate vehicles at a speed that is reasonable and prudent for existing conditions.

Speed limits are important tools one can use to create and maintain a safe traffic environment. But as in all regulatory procedures, the limits imposed must be reasonable and appropriate to the situation. Most drivers tend to regulate their own speed according to traffic, road and weather conditions, and, as will be explained in this Chapter, it is the normal driver's speed which is used by traffic engineers as a guide in setting speed limits.

Other factors must be taken into account, of course, in setting appropriate speed regulations. School zones, for example, create especially hazardous conditions and require special consideration. The important point to remember is that the speed regulation informs the driver of the limits in which one can safely operate a vehicle under normal circumstances and within which the driver can be expected to safely react to driving problems. Setting speed limits at appropriate levels will create a reasonable flow of traffic, discourage violation of the law, and help keep streets and highways safe.

What Is The Primary Reason For Establishing Speed Zones And Speed Limits?

The primary reason for establishing speed zones and speed limits is safety. In setting speeds, decision-makers attempt to strike an appropriate balance between travel time and risk for the specific highway section. The posted speed should inform motorists of maximum driving speeds that are considered reasonable and safe for a highway section under favorable conditions.

Safe and reasonable highway speeds are determined through an engineering investigation. The investigation is based upon nationally accepted standards that include a full review of roadway characteristics. These characteristics include traffic volumes, crash history, highway geometry, roadside culture and density, etc.

The primary factor used in establishing speed zones is the 85^{th} percentile speed (the speed at or below which 85 percent of the vehicles are traveling). Most motorists drive in a reasonable and prudent manner, selecting their driving speeds so as to arrive at their destination safely. Regulatory signs are posted for those drivers who are unable to judge the capabilities of their vehicles (e.g., stopping, handling) and anticipate roadway geometry and roadside conditions sufficiently to determine appropriate driving speeds. Studies suggest posting speeds near the 85th percentile speed minimizes crash occurrence and provides favorable driver compliance.

The availability of enforcement for traffic speeds is an important consideration in establishing a posted speed. Appropriate speed zones coupled with consistent enforcement increases the safe operation of traffic by discouraging high risk behavior.

If Most Drivers Are Assumed To Be Capable Of Making Reasonable Judgments About Appropriate Driving Speeds, Why Are Speed Limits Even Necessary?

The primary reason for regulating individual choices is the significant risks drivers can impose on others. For example, a driver with a higher tolerance for risk may decide to drive faster, accepting a higher probability of a crash, injury, or even death in exchange for a shorter trip time. This driver's decision may not adequately take into consideration the risk his choices impose on the other road users.

Another reason for regulating speed derives from the inability of some drivers to correctly judge the capabilities of their vehicles (e.g., stopping, handling) and to anticipate roadway geometry and roadside conditions sufficiently to determine appropriate driving speeds.

A final reason for regulating speed, which is related to the issues of information adequacy and judgment, is the tendency of some drivers to underestimate or misjudge the effects of speed on crash probability and severity. This problem is often manifested by young and inexperienced drivers and may be a problem for other drivers.

The Safety Connection And The Role Of Speed Limits

Drivers' speed choices impose risks that affect both the probability and severity of crashes. Speed is directly related to injury severity in a crash. The probability of severe injury increases sharply with the impact speed of a vehicle in a collision, reflecting the laws of physics. The risk is even greater when a vehicle strikes a pedestrian, the most vulnerable of road users.

Speed is also linked to the probability of being in a crash, although the evidence is not as compelling because crashes are complex events that seldom can be attributed to a single factor. Many driver attributes and behavioral factors besides speed affect the probability of crashes—driving under the influence of alcohol or other drugs, age, attitudes toward risk, and experience of the driver—but speed has been shown to play an important role.

The primary purpose of speed limits is to enhance safety by reducing the risks imposed by drivers' speed choices. Speed limits enhance safety in at least two ways. By establishing an upper bound on speed, they have a limiting function; the objective is to reduce both the probability and the severity of crashes. Speed limits also have a coordinating function. Here the intent is to reduce dispersion in speeds (i.e., lessen differences in speed among drivers using the same road at the same time) and thus reduce the potential for vehicle conflicts.

In setting speed limits, decision makers attempt to establish a reasonable balance between risk (safety) and travel time (mobility) for a road class or specific highway section. Thus, the posted speed limit should inform motorists of maximum driving speeds under favorable conditions that decision makers consider reasonable and safe for a road class or highway section.

Role Of Enforcement And Sanctions For Managing Speeds

Managing speeds through speed limits requires a system of speed laws and a process for establishing reasonable speed limits as well as enforcement, sanctions, and public education, ideally all working together. Enforcement is an integral part of such a system.

The main difficulty with the traditional approach to speed enforcement—radar enforcement using a mobile or stationary police vehicle—is its short-lived temporal and spatial effect on deterring speeding. Maintaining the deterrence effect requires a level of enforcement intensity and expense that has proven difficult to sustain because of competing enforcement priorities and limited resources available for speed enforcement.

Targeted enforcement combined with focused publicity campaigns can boost the effectiveness of traditional enforcement methods. Alternatives to enforcement to achieve desired driving speeds on local roads include physical measures known as "traffic calming" (e.g., speed humps, roundabouts, and raised intersections). A proper mix of these approaches can enable police to leverage their resources and deploy them efficiently.

Traffic court judges are also important participants in effective speed enforcement. They may overturn speeding violations if they think the speed limits are unreasonable or reduce fines if they believe the sanctions are too harsh. If judges are lenient in their treatment of speeding offenses and routinely dismiss speeding citations, the incentive for the police to enforce the speed limits may be reduced. Thus it is important that traffic court judges -- as well as the police and motorists -- perceive that speed limits are reasonable and enforceable.

How Is A Speed Study Conducted?

Determining the 85th percentile speed is usually done by a spot speed check of vehicles on a given street. The speed of separately traveling vehicles, from the slowest to the fastest, is recorded. It is simple to determine that if 85 motorists out of 100 are driving at "X" miles per hour (km/h) or under, then "X" miles per hour (km/h) is the 85th percentile speed.

Electronic traffic counters are also available that can detect speeds and have the capability of being downloaded to a computer which will generate speed distribution graphs including the 85th percentile speed.

The following items describe the factors to be taken into account in a spot speed study.

A. Definition

A spot speed study is made by measuring the individual speeds of a sample of the vehicles passing a given point (spot) on a street or highway. These individual speeds are used to estimate the speed distribution of the entire traffic stream at that location.

B. Study Locations

The following factors should be considered in selecting a test site:

1. General location depends upon the purpose of the study. For determining speed trends, stations are usually established on open stretches of straight, rural highways or at mid-block locations on urban streets away from the influence of stop signs and signals.
2. The specific site is selected within the general location to reduce or eliminate the influence of the observer and measuring equipment on vehicle speed. Equipment should be concealed; the observer and his vehicle should be as inconspicuous as possible and onlookers must be kept from the area.
3. Variables which might influence the study should be minimized. Do not locate the site on curves, grades, rough stretches of road, or near construction unless the study requires these conditions. Other factors such as environment (weather, visibility, etc.) and excess traffic flow should be taken into consideration if these conditions are not normal.

C. Time of Study

Usually off peak hours are used in conducting a spot speed study, although the purpose of the study should determine the time. It is important that trend studies and "before and after" studies be made during the same hours under comparable conditions. Bad weather and unusual traffic volume conditions should be avoided.

D. Size and Selection of Sample

Normally, the speeds of at least 50, and preferably 100, vehicles should be obtained for any one location. Vehicles should be selected at random from the traffic stream to avoid bias in the results. Some other problems to avoid include:

1. Use only the speed of the lead vehicle in a platoon. Following cars tend to close in on the lead car and the results may be biased toward lower speeds.
2. Do not select too large a portion of trucks—their speeds may not be representative of the rest of the sample. Attempt to obtain about the same proportion of trucks in the sample that exists in the traffic stream. In most instances, 5 to 10 percent trucks are fairly representative.
3. The selection must be made at random, for example, every fourth vehicle's speed. Do not select too large a proportion of higher speed vehicles or the results will be biased toward the upper range of speeds. In low volume roads all of the vehicles are considered. (Untrained observers have been known to stop the measurement of a vehicle traveling at a normal speed in order to catch a high-speed vehicle or measure all higher speed vehicles to find the fastest car.)
4. Low volume roads with ADT under 400, the speed of at least 75 vehicles in each direction or the speed of vehicles for a minimum of three hours should be obtained for any locations.

E. Analysis

To make use of the data collected, the next step is the analysis. The best way to summarize the data is to chart the speeds collected on a frequency distribution table. The table used below, as an example, includes the speeds of 100 vehicles. The speeds are grouped into three mile increments with the second column indicating mid points for each three mile increment (or 4 km increment). The mid points are needed later for plotting a curve. All of the speeds collected in the example range from a low of 13.6 miles per hour (22 km/h) to a high of 49.5 miles per hour (81 km/h). The third column lists the number of vehicles observed operating within each of the speed groups.

The cumulative frequency (Column 4) is the total of each of the numbers (frequencies) in Column 3 added together row by row from the top down. The last column is a running percentage of the cumulative frequency from the top down (See Table 4-1).

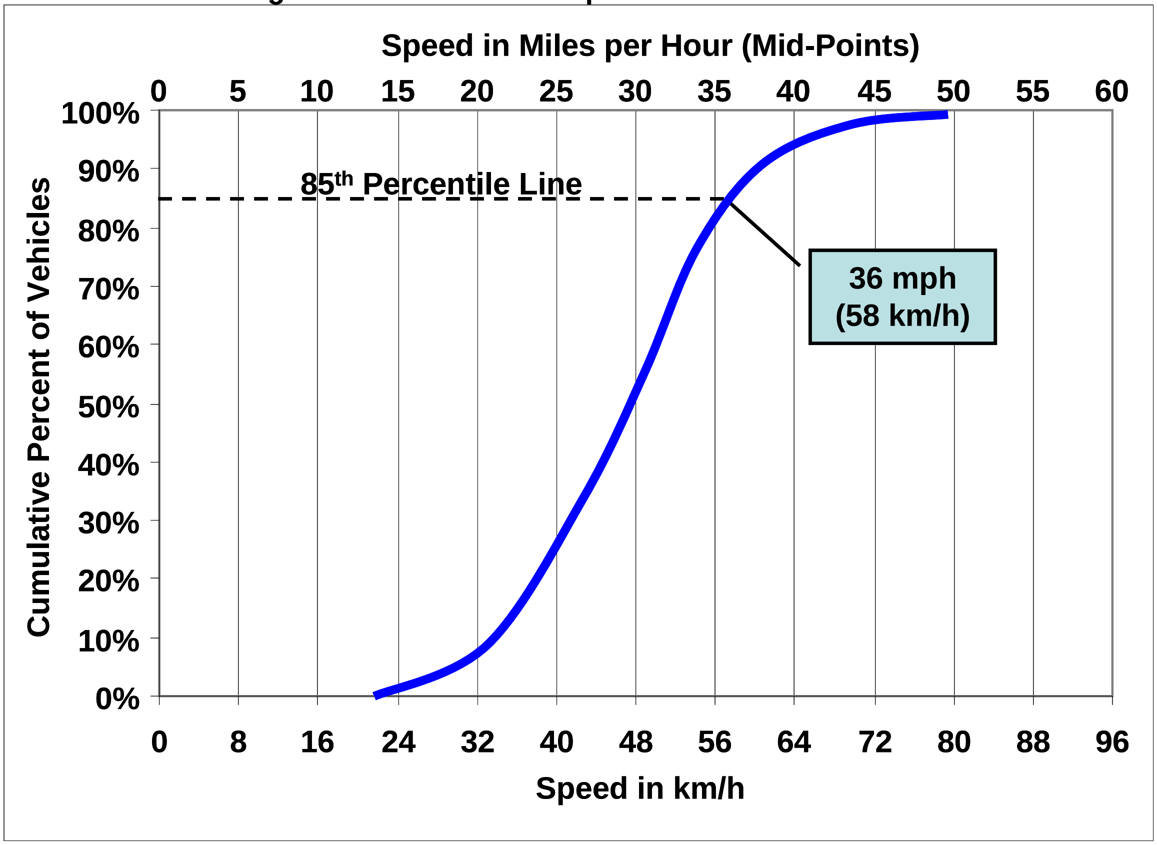
Once the frequency distribution table has been constructed, the best way to determine the 85th percentile is to plot the speed distribution on a graph. Take the mid point of each row (Column 2) and plot that speed on the graph where it corresponds with the cumulative percent of vehicles observed (Column 5).

Where the curve intersects the 85th percent line, that speed is the 85th percentile speed. In the example given above, the curve intersects at 36 miles per hour (58 km/h) (See Figure 4-1).

Table 4-1: Frequency Distribution Table

	1		2	3	4	5
Row	**Groupings of Speeds Observed**		**Mid-Point**	**Frequency of Vehicles**	**Cumulative Frequency**	**Cumulative Percent**
	mph	**km/h**				
1	13.6-16.5	22-26	15	1	1	1%
2	16.6-19.5	27-31	18	2	3	3%
3	19.6-22.5	32-36	21	6	9	9%
4	22.6-25.5	37-41	24	12	21	21%
5	25.6-28.5	42-46	27	13	34	34%
6	28.6-31.5	47-51	30	20	54	54%
7	31.6-34.5	52-56	33	18	72	72%
8	34.6-37.5	57-61	36	14	86	86%
9	37.6-40.5	62-66	39	6	92	92%
10	40.6-43.5	67-71	42	6	98	98%
11	43.6-46.5	72-76	45	1	99	99%
12	46.6-49.5	77-81	48	1	100	100%
				100 Vehicles		

Figure 4-1: Cumulative Speed Distribution Curve



Note: The actual speed limit posted should be the 85th percentile speed rounded off to the nearest five mile per hour increment, in this case 35 mph, or to the nearest 10 km/h, in this case 60 km/h.

Are There Other Factors Taken Into Account When Setting Speed Limits?

The 85th percentile speed is the first consideration used in establishing a speed zone. Other factors which should be considered are:

A. Crash Experience

A high frequency of crashes compared to other locations within the general area may indicate the need to re-evaluate the speed limit on a certain road or a portion of it. A recurring number of rear end collisions, turning crashes, or pedestrian-vehicle incidents, for example, would indicate that other factors such as driveways into commercial establishments are preventing a uniform flow of traffic. These factors may require vehicles to travel more slowly to allow for other vehicle and pedestrian maneuvers.

At the same time, a study of a roadway experiencing a high crash frequency may determine that a major contributing factor is too low a speed limit. Drivers may become impatient and pass when conditions are unsafe or dart in and out of lanes to get around slower-moving vehicles. A number of side-swipe or head-on collisions may indicate the need to increase the speed limit.

B. Traffic Volume

The higher the volume of traffic, the more important it is that most vehicles maintain about the same speed. Adjust the speed limit to a level which is acceptable to most motorists (the 85th percentile speed) thereby minimizing the number of passing maneuvers. In addition to the 85th percentile, the 10 mph pace limit is also used. This pace is the 10 mph range encompassing the greatest percent of the speed observation. If the pace limit is lower than the 85th percentile, the speed limit should be lowered.

C. Road Features

Lower speed limits can be used as a safety measure on roads with:

1. Frequent sharp curves
2. Extensive sight obstructions
3. Poor surface conditions
4. Long, steep downgrades
5. Driveways, parking and other roadside obstacles
6. School zones
7. Construction zones
8. Large numbers of pedestrians.

Who Can Establish Legal Speed Limits In Oregon?

The speed limits are set by human decisions and state regulations. Based on Oregon Administrative Rules OAR 734-020-0014 through 734-020-0017, speed limit decisions for most public roads are made jointly by the Department of Transportation and the road authority in Oregon.

By law, the Oregon Department of Transportation is responsible for establishing speed zones on all public roadways in Oregon. It requires that an engineering investigation be conducted to determine what the appropriate speed should be. The Traffic Roadway Section (TRS) is responsible for the overall administration of the program. Region traffic engineering staff conducts engineering investigations to determine recommendations for safe speeds on local roads and streets.

These recommendations are reviewed by the city, county, or other agency with road authority. If this agency agrees with the recommendations, the speed zone is established. If not, the Department reviews the road authority's objections and any additional information, and then if possible, revises the recommendation.

If no agreement can be reached, the speed zone decision is referred to a speed zone review panel that reviews the information and receives testimony from interested parties. The final decision is then made by the review panel. The panel has five members including representatives from the Transportation Safety Committee, the Oregon State Police, the Association of Oregon Counties, the League of Oregon Cities, and the Department of Transportation.

What Happens When A Speed Zone Change Is Requested?

When a city or county asks the Department of Transportation to review a speed zone, a study is started. The road is surveyed for widths, surface, lanes, shoulders, signals, and stop signs; number of intersections and other accesses; type and extent of roadside development; and other conditions such as allowed parking and bicycle lanes. The crash history is also reviewed.

Other tests are conducted that provide information such as the number and type of vehicles, pedestrians, and cyclists using the road. Spot speed checks are conducted, recording the speed of at least 75 vehicles in each travel direction, using laser. Recognizing that most of us are generally safe drivers, the speed at or below which 85 percent of the drivers travel is one nationally recognized factor proven by repeated studies as a fair and objective indication of safe and reasonable speeds.

When all the studies are completed, a report with photographs detailing the existing conditions and proposed changes is prepared. All of the above considerations are evaluated in deciding whether to propose a change or retain the posted speed zone. The report is then sent to the city or county for review.

Speed zoning used with an overall traffic plan helps traffic move more safely and efficiently. However, it doesn't provide a quick fix for land use problems or poor traffic patterns; instead, speed zoning reflects a reasonable balance between the needs of drivers, pedestrians and bicyclists using public roads for travel and those who live and work along these roads.

Is It True That Lowering Posted Speeds Will Mean Fewer Crashes?

Traffic studies show that traffic moving at a speed that is reasonable for the road and weather conditions results in few crashes. Drivers are more patient because a reasonable uniform speed allows progress with less passing, less delay and few rear-end collisions.

Many people believe that lowering posted speeds will mean fewer crashes, but studies do not prove this. Unrealistically low speeds frustrate many drivers, resulting in numerous speeding violations and unsafe driving, actually causing more crashes. Some motorists may try to make up time by taking a shortcut through residential or other areas that are not suited to higher speeds and increased number of cars. Drivers lose respect for the law, and police and courts are overloaded with increased traffic tickets.

What Are The Speed Zone Standards In Oregon?

By 1927, Oregon had basic speed rules and specific statutory speed limits. Various statutes give Oregon motorists the following designated speed zones:

- 15 mph (25km/h) – alleys, narrow residential roadways;
- 20 mph (30km/h) – business districts, school zones when children are present;
- 25 mph (40km/h) – residential districts, public parks, ocean shores;
- 55 mph (90km/h) – open and rural highways, trucks on interstate highways;
- 65 mph (105km/h) – passenger vehicles, light trucks, motor homes, and light duty commercial vehicles on interstate highways.

Posted speed zone signs, such as those that designate 35 mph (55km/h) or 45 mph (70km/h), override these statutory speeds.

However, designated and posted speeds are not the final word in Oregon, for all travel on public streets and highways is subject to the Basic Rule. The Basic Rule is both a safety valve and an acknowledgment that drivers are able to act independently, reasonably, and with good judgment.

The Rule states that a motorist must drive at a speed that is reasonable and prudent at all times by considering other traffic, road and weather conditions, dangers at intersections, and any other conditions that affect safety and speed. The Basic Rule does not allow motorists to drive faster than the posted speed, nor does it set absolute speeds designated for all conditions. Instead, the Rule expects drivers to be responsible for their own actions.

What Is The Procedure For Requesting A Speed Zone Investigation?

To request a speed zone investigation by ODOT personnel, city or county engineering department staff must make the request in writing to the State Traffic Engineer, including the suggested speed. The city or county engineering department staff should complete the Speed Zone Request form which is shown in Figure 4.2 and send it with a map of the roadway to:

Oregon Department of Transportation
State Traffic Engineer
355 Capitol St. NE
Salem, OR 97310
Phone: (503) 986-3568
Fax: (503) 986-4063
Website:
http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/speed_zone_program.shtml

When Should Speed Zone Investigations Be Requested?

When traffic patterns have changed, development has occurred, crashes have increased, or requests have been received from a number of area residents or businesses and roadway authority review panel supports a possible speed change.

Oregon law gives the State Department of Transportation the authority to establish speed zones on all roadways in Oregon. It also states that an engineering investigation will be done to determine what the appropriate speed should be.
(ORS 810.180)

The local roadway authority (the city or county) needs to complete the speed zone request form and submit it to ODOT to request an investigation. This form facilitates the request by providing ODOT with the pertinent local information needed to complete the investigation.

Further speed zoning information may be obtained from your local ODOT Region Traffic Office at the address below.

Region 1
123 NW Flanders
Portland, OR 97209-4037
Tel: (503) 731-8200
FAX: (503) 731-8259

Region 2
2960 State Street
Salem, OR 97310
Tel: (503) 986-2990
FAX: (503) 986-2630

Region 3
3500 NW Stewart Pkwy
Roseburg, OR 97470
Tel: (541) 440-6335
FAX: (541) 440-3547

Region 4
63055 N. Highway 97
PO Box 5309
Bend, OR 97708
Tel: (541) 388-6189
FAX: (541) 388-6231

Region 5
3012 Island Ave.
La Grande, OR 97850
Tel: (541) 963-3177
FAX: (541) 963-9079

The most up to date information regarding Speed Zoning please review the Speed Zone Manual, Oregon Department of Transportation, August 2009. The manual and other Speed Zoning information are available at the following website:
http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/speed_zone_program.shtml

Are There Other Ways To Control Speeding Vehicles?

1. **Advisory Speed Plate** – Advisory speed limit plates (in multiples of 5 miles per hour) (10 km/h) can be used on curves and at hazardous locations as the advisory maximum speed. Ball bank indicators, when used properly, are an effective means of establishing and checking advisory speed plate signs.
2. **Enforcement** – Consistent monitoring of a roadway by law enforcement agencies will lead to a reduction in speeding violations and other unsafe driving practices.
3. **Traffic Circles** – Traffic circles force vehicles to slow down by bending the direction of flow. All turning movement is still possible. Approaches require centerline markings to guide vehicles toward the right as they enter this intersection; warning signs are also necessary. Traffic circles should be only used on the roadways with a speed of 35 mph (55 km/h) or lower.
4. **Speed Bump** – Speed bumps are traffic management devices used for lowering the speed of motor vehicles along specific street sections. The speed bumps should be only used on the roadways with a speed of 35 mph (55 km/h) or lower. When using the speed bumps, the safety of emergency vehicles should be considered. The City of Portland, Bureau of Traffic Management, have established general standards and guidelines for speed bumps, which will be described in Chapter 19 of this Handbook.

Figure 4-2: Example Of Filled In Speed Zone Request[1]

Oregon Department of Transportation

Speed Zone Request

To request a Speed Zone Investigation by ODOT personnel, City or County Engineering Department staff should complete this form and send it - with a map of the roadway - to:

State Traffic Engineer
Oregon Department of Transportation
355 Capitol Street NE, Fifth Floor
Salem, OR 97301-3871

1. AGENCY NAME **City of Millersburg**	2. DATE **03/18/03**
3. CONTACT NAME AND TITLE **Barbara Castillo, City Recorder**	4. TELEPHONE NUMBER **541-928-4523**
5. E-MAIL ADDRESS **bcastillo@ci.millersburg.or.us**	6. FAX NUMBER **541-928-4524**

7. ADDRESS (POSTAL)
4222 Old Salem Road NE **Millersburg, OR 97321**

8. NAME OF ROADWAY
Millersburg Drive, NE

9. FROM **Morningstar Road**		10. TO **1.30 mile east of Morningstar Road (RR Xing)**
11. REQUESTED **40 MPH**	12. EXISTING POSTED SPEED - **None**	13. EXISTING SPEEDS OF ROADWAY ABUTTING THIS SECTION 14a. ENTERING - MPH: **55** 14b. EXITING - MPH: **55**

15. AVERAGE DAILY TRAFFIC VOLUME
600

16. ROADWAY CLASSIFICATION: ☐ LOCAL ☐ COLLECTOR ☒ ARTERIAL

17. Speed recommendation from City or County Engineering Department (***required per ORS 810.180***): **40** MPH
18. Reasons for this recommendation:
This is a rural residential area. There are 51 homes in a 1.24-mile stretch of road with many children living in the area. People are driving way too fast through this area.

19. Are curves in this section of roadway signed appropriately? ☒ YES ☐ NO
20. Is the recommended speed consistent with the speeds of similar roadways in the surrounding area? ☒ YES ☐ NO

21. Speed Recommendation from enforcement: **40** MPH
22. Reasons for this recommendation:
Safety

23. Are there special plans to enforce the proposed speed zoning? (explain):
Posted speed limit signs and extra police patrols

24. Speed Recommendation from local residents: **40** MPH
25. Reasons for this recommendation:
Safety issues. There are many people out walking, biking, etc. along Millersburg Drive. The density is too high for 55 MPH.

26. If more than one jurisdiction is involved, describe below (or furnish a map showing) where the city limits lines cross the roadway and where maintenance jurisdictional boundaries change. If there is more than one jurisdiction involved, this information must be furnished before the speed zone investigation can be done.

If you have questions on speed zones, contact the ODOT Traffic-Roadway Section in Salem at 986-3609, FAX 986-4063 or your local ODOT Region Traffic Office (see reverse for addresses).

(Filled In Example Request -Page 1)

Speed Zone Manual
7/24/09

[1] Source: Speed Zone Manual, Oregon Department of Transportation, 2009

Chapter 5: Traffic Control Devices

Traffic control devices are all signs, signals, markings, and other devices used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, highway, pedestrian facility, or bikeway by authority of a public agency having jurisdiction. The national standard for traffic control devices on all public roads open to public is **The Manual on Uniform Traffic Control Devices** (MUTCD). It is published by the Federal Highway Administration (FHWA) and contains all national design, application, and placement standards for traffic control devices.

The purpose of traffic control devices, as well as the principles for their use, is to promote highway safety and efficiency by providing for the orderly movement of all road users on streets and highways throughout the nation. They notify road users of regulations and provide warning and guidance needed for the safe, uniform, and efficient operation of all elements of the traffic stream.

The content of this Chapter is based on the following publications:

1. The Manual On Uniform Traffic Control Devices (MUTCD) 2003 Edition
2. Traffic Control Devices Handbook, published by the Institute of Transportation Engineers (ITE), 2001
3. Oregon Supplement to the Manual on Traffic Control Devices, 2003 Edition

Is Use Of The Manual On Uniform Traffic Control Devices Required By The State Of Oregon?

Traffic control devices installed on highways within the State of Oregon are required to conform to the Manual on Uniform Traffic Control Devices (MUTCD), published by the Federal Highway Administration (FHWA). The list of highways that are required to conform to the MUTCD includes all state highways and public roadways under the jurisdiction of cities and counties within the State of Oregon. This requirement is established by Oregon Revised Statute (ORS) (see ORS 810.200) and Oregon Administrative Rule (OAR) (see OAR 734-020-0005). To promote uniformity and understandability of traffic control devices, private property owners are also encouraged to conform to the MUTCD when installing devices on private property.

Traffic control devices installed or replaced on Oregon roadways shall conform to the current adopted MUTCD and Oregon Supplement to the MUTCD upon installation. Unless noted otherwise, existing devices that do not conform to the current adopted MUTCD shall be replaced at the end of their useful life.

The intent of the MUTCD is to enhance road safety and operation by requiring uniform, understandable, and effective traffic control devices on Oregon highways. The responsibility for the design, placement, operation, maintenance, and uniformity of traffic control devices shall rest with the public agency or the official having jurisdiction. The State of Oregon adopted the entire national manual with a few exceptions to the MUTCD 2003, found in the Oregon Supplement to the MUTCD 2003.

What Is The Purpose of the Oregon Supplement to the MUTCD?

Deviations to the MUTCD are published in the Oregon Supplement to the MUTCD and made for justifiable reasons such as instances where Oregon law deviates from the MUTCD. These deviations are adopted through the OAR process and by permission of the FHWA.

The Oregon Supplement to the MUTCD is available online in electronic format and can be downloaded at:
http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/Oregon_Supplement_MUTCD_2003_Edition.pdf

How to Use the Oregon Supplement to the MUTCD?

Both the Oregon Supplement and the MUTCD 2003 Edition need to be consulted when researching traffic control issues. The Oregon Supplement conforms to the organization and section numbering of the MUTCD. The two documents interact as follows:

- Unless otherwise noted, language in the Oregon Supplement is added to the end of the referenced MUTCD section.
- In other cases, the MUTCD language is deleted and/or the Oregon Supplement language inserted as directed by the instructions in italics.

Obtaining the MUTCD

The MUTCD is available online in electronic format (http://mutcd.fhwa.dot.gov/). Printed copies of the MUTCD 2003 Edition and cost information are available from the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the American Traffic Safety Services Association (ATSSA).

The Federal Highway Administration published the new MUTCD on December 2009. The State of Oregon will be reviewing the new MUTCD and it is expected to be adopted in the next two years. The MUTCD 2009 Edition is available online in electronic format at the following address: http://mutcd.fhwa.dot.gov/

Other Related Documents

Design details for signs and traffic signals are not included in the MUTCD. They are in the Oregon Department of Transportation (ODOT) Sign Policy and Guidelines, the ODOT Traffic Signal Policy and Guidelines, and the FHWA Standard Highway Signs manual. The ODOT Traffic Manual contains additional information on traffic engineering policies and practices for state highways.

How To Obtain Other ODOT Documents

The Oregon Supplement to the MUTCD and other ODOT traffic control device documents are available online in electronic format. The Web site also provides information on the latest updates to the ODOT Sign Policy and Guidelines. For more information abou other ODOT documents please visit the following website:
http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/publications_traffic.shtml

What Are The Basic Requirements Of Traffic Control Devices?

The Manual on Uniform Traffic Control Devices (MUTCD) 2003 Edition sets forth basic principles and guidelines that govern the design and usage of traffic control devices. To be effective, a traffic control device should meet five basic requirements:

A. **Fulfill a need** – A device is required to fulfill a need as long as it is in place. It is important to recognize that the need for traffic control devices changes as speeds, traffic volumes, or roadside development change. Therefore periodic functional evaluations of traffic control devices are required to ensure they continue to fulfill legitimate needs.
B. **Command attention** – This refers to the traffic control device's ability to be noticed by road users. Oversized signs, redundant devices, or flashing lights may be needed in areas with complex visual environments or at locations where traffic control devices are unexpected.
C. **Convey a clear, simple meaning** – Road users must be able to quickly understand the meaning of and proper response to the traffic control device. The uniform use of color, shapes, and legends helps facilitate quick, comprehensive understanding of traffic control devices.
D. **Command respect from road users** – Compliance to traffic control devices is increased when road users perceive the legitimacy of the regulation or warning.
E. **Give adequate time for proper response** – Traffic control devices must be visible far enough in advance to allow time for the road user to respond appropriately. Devices that are not adequately visible may cause delayed and erratic responses.

Traffic control devices should be designed so that:

- features such as size, shape, color, composition, lighting or retroreflection, and contrast are combined to draw attention to the devices;
- size, shape, color, and simplicity of message combine to produce a clear meaning;
- legibility and size combine with placement to permit adequate time for response; and
- uniformity, size, legibility, and reasonableness of the message combine to command respect.

What Are The Meanings Of "Standard", "Guidance", "Option", And "Support"?

The following category headings are used consistently throughout the MUTCD and it is essential that they be understood. The MUTCD defines the headings as follows:

A. **Standard**: a statement of required, mandatory, or specifically prohibitive practice regarding a traffic control device. All standards are labeled, and the text appears in bold large type in MUTCD. The verb "shall" is typically used. Standards are sometimes modified by Options.
B. **Guidance**: a statement of recommended, but not mandatory, practice in typical situations, with deviations allowed if engineering judgment or engineering study indicates the deviation to be appropriate. All Guidance statements are labeled and the text appears in large type in MUTCD. Guidance text is the same size as Standard text, but it is not bold. The verb "should" is typically used. Guidance statements are sometimes modified by Options.
C. **Option**: a statement of practice that is a permissive condition and carries no requirement or recommendation. Options may contain allowable modifications to a Standard or Guidance. All Option statements are labeled, and the text appears in small type in MUTCD. The verb "may" is typically used.
D. **Support**: an informational statement that does not convey any degree of mandate, recommendation, authorization, prohibition, or enforceable condition. Support statements are labeled, and the text appears in small type in MUTCD. The verbs "shall", "should", and "may" are not used in Support statements.

Maintenance Of Traffic Control Devices

Traffic control devices should be reviewed periodically to determine if they meet current traffic conditions. They should also be maintained to ensure that legibility is retained, that the device is visible, and that it functions properly in relation to other traffic control devices in the vicinity during both day and night conditions.

Placement And Operation Of Traffic Control Devices

Placement of a traffic control device should be within the road user's view so that maximum visual acuity is provided. To aid in conveying the proper meaning, the traffic control device should be appropriately positioned with respect to the location, object, or situation to which it applies. The location and legibility of the traffic control device should be such that a road user has adequate time to make the proper response in both day and night conditions.

Traffic control devices should be placed and operated in a uniform and consistent manner. Unnecessary traffic control devices should be removed. The fact that a device is in good physical condition should not be a basis for deferring needed removal or change.

What Is The Difference Between "Engineering Study" And "Engineering Judgment"?

A. **Engineering Judgment**: the evaluation of available pertinent information, and the application of appropriate principles, Standards, Guidance, and practices as contained in the MUTCD and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of a traffic control device. Engineering judgment shall be exercised by an engineer, or by an individual working under the supervision of an engineer, through the application of procedures and criteria established by the engineer. Documentation of engineering judgment is not required.

B. **<u>Engineering Study</u>**: the comprehensive analysis and evaluation of available pertinent information, and the application of appropriate principles, Standards, Guidance, and practices as contained in the MUTCD and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of a traffic control device. An engineering study shall be performed by an engineer, or by an individual working under the supervision of an engineer, through the application of procedures and criteria established by the engineer. An engineering study shall be documented.

When Should "Engineering Study" And "Engineering Study" Be Used?

The decision to use a particular traffic control device at a particular location should be made on the basis of either an engineering study or the application of engineering judgment. Thus, while the Manual provides Standards, Guidance, and Options for design and application of traffic control devices, the Manual should not be considered a substitute for engineering judgment.

Engineering judgment should be exercised in the selection and application of traffic control devices, as well as in the location and design of the roads and streets that the devices complement. Jurisdictions with responsibility for traffic control that do not have engineers on their staffs should seek engineering assistance from others, such as the Oregon Department of Transportation (ODOT), their county, a nearby large city, or a traffic engineering consultant.

It is also important to indicate that documentation is required for engineering studies. The use of engineering judgment does not need to be documented.

When Is A Traffic Control Device Needed?

Designers should imagine seeing the roadway through the eyes of a road user to determine traffic control device requirements. Is there information needed for the road user to properly use the transportation facilities? A road user normally drives a roadway that is familiar to the driver, with common operational characteristics, normal pavement markings and the usual signing. However, uncommon and, most importantly, unexpected situations, whether unusual geometrically or operationally, by their nature may result in failure by a driver to negotiate the roadway safely. In such situations, jurisdictions need to add traffic control devices to advise drivers of the changes, warn them about what they may encounter and regulate the operational factors so drivers can readily handle the roadway changes when they traverse them.

What Is A Road Safety Audit?

A road safety audit may be defined as the formal examination of a road to identify road safety deficiencies and, if appropriate recommendations aimed at removing or reducing the deficiencies. Suggested questions appropriate for the safety audit of traffic control devices are listed in Table 5-1.

Table 5-1: Suggested Road Safety Audit Questions For Traffic Control Devices[1]

1	Are road users using the roadway facilities as intended?
2	Is the roadway alignment, width, condition, and travel path apparent day and night?
3	Is the traffic control device needed?
4	Are there roadway features or traffic conflicts that are not readily apparent requiring warning signs or markings?
5	Do the roadway design, geometrics, and operations form a consistent pattern having broad usage or do they impose some unexpected operational problems?
6	Are interactions of vehicles and/or road users obscured by horizontal or vertical curves, vegetation, or other vehicles?
7	Is the application in conformance with the MUTCD or is it a unique application?
8	Is the device the appropriate shape, color, legend, and size?
9	Is the message clear and concise?
10	Is the device placement and spacing adequate to provide a reasonable time to read and react to the message? (Check vehicle speed, sign Legibility, pavement marking Location, and response time.)
11	Are the road users responding to the traffic control device in an appropriate manner?
12	Is the traffic control device frequently obscured by other vehicles?
13	Is the device Legible, at the appropriate time for the road user, both daytime and at night?
14	Are the signs, markings and signals consistent with each other?
15	Are advance warning signs or markings needed?
16	Would redundant signing or pavement legends be a benefit?
17	Are the route markers and destination and distance signing consistent?
18	Where a marked route turns, is advance signing provided with confirming route markers following the turn?
19	Are the signal heads visible from an adequate distance?
20	Are the signal phasing and timing reasonable to serve the traffic demand?
21	Does the traffic signal create unnecessary stops and excessive vehicle delay?
22	Are the pedestrian movements adequately accommodated without vehicle conflicts?
23	If there are bicycle facilities, are they appropriately marked and signed? Is the intersection treatment reasonable for the bicycle volume?
24	Are there special roadway uses (e.g., schools, elderly pedestrians, bus stops, right turn lanes) that require special signing?
25	Do the facilities meet the requirements of the Americans with Disabilities Act?

What Are The General Meanings Of The Color Codes For Use In Traffic Control Devices?

The following color code establishes general meanings for nine colors of a total of twelve colors that have been identified as being appropriate by the Federal Highway Administration (FHWA) for use in conveying traffic control information.

A. Yellow – warning
B. Red – stop or prohibition

[1] Source: Traffic Control Devices Handbook, Institute of Transportation Engineers (ITE), 2001

C. Blue – road user services guidance, tourist information, and evacuation route
D. Green – indicated movements permitted, direction guidance
E. Brown – recreational and cultural interest area guidance
F. Orange – temporary traffic control
G. Black – regulation
H. White – regulation
I. Fluorescent Yellow Green – pedestrian warning, bicycle warning, school bus and school warning
J. Purple – unassigned
K. Light Blue – unassigned
L. Coral – unassigned

What Are The Types Of Sign Sheeting?

Over time manufacturers have developed different types of sheeting to accomplish retroreflection, initially using small glass beads, but now more commonly using microprisms with various angular designs. Sheeting manufacturers have specific brand names for their materials. ASTM International has classified the different types of conformance to the retroreflectance properties, color, and durability. Some types of retroreflective sheeting in use for rigid surface highway signs are as follow:

Type I, also known as Engineer Grade:

Basic reflective sheeting, made up of very small glass beads enclosed in a translucent pigmented substrate. Has no distinctive identifying pattern, other than, of course, it reflects. Generally regarded to have a seven year service life. Type I is not recommended to be used for replacement of existing and new sign installation.

Type II, also known as Super Engineer Grade:

Similar to Type I, except it uses larger glass beads, providing about twice the level of reflectivity of Type I sheeting. Type II is not recommended to be used for replacement of existing and new sign installation.

Type III, also known as High Intensity:

This sheeting is know as an "encapsulated lens" sheeting, made of 2 layers - an outer translucent pigmented layer, and an inner reflective layer faced with glass beads. The two layers are connected by a lattice, hence its distinctive 'honeycomb' appearance, where the lattice pattern varies by manufacturer for easy identification. Cost is about twice that of Type I. Generally regarded to have a ten year service life.

Type IV:

This is also a multi-layer sheeting, except that the reflective layer is made of microscopic cube-corner reflectors instead of glass beads - known as a "microprismatic" layer. This sheeting can be distinguished by the pattern of small "squares" superimposed upon a hexagonal lattice grid.

This sheeting is about seven times as bright as Type I. Cost is comparable to type III. Generally regarded to have a ten year service life. Type IV is recommended for replacement of existing and new sign installations and is currently being used by cities and counties throughout Oregon.

Type VII, VIII, IX, X:

These are microprismatic sheetings with the differences related to varying angles of the microprisms. Cost is about 5 times that of Type I. Generally regarded to have a ten year service life. These types are recommended for replacement of existing and new sign installations on High Speed Roads.

What Are The Function And Classification Of Signs?

Traffic signs are the most commonly used traffic control devices. They provide directional, regulatory, and warning information to the motorist. The use of traffic signs should be limited to only those locations where they are warranted or where additional information is required. Signs are classified as follows:

A. Regulatory Signs

Regulatory signs shall be used to inform road users of selected traffic laws or regulations and indicate the applicability of the legal requirements.

Regulatory signs shall be installed at or near where the regulations apply. The signs shall clearly indicate the requirements imposed by the regulations and shall be designed and installed to provide adequate visibility and legibility in order to obtain compliance.

B. Warning Signs

Warning signs call attention to unexpected conditions on or adjacent to a highway or street and to situations that might not be readily apparent to road users. Warning signs alert road users to conditions that might call for a reduction of speed or an action in the interest of safety and efficient traffic operations.

C. Guide Signs

Guide signs are essential to direct road users along streets and highways, to inform them of intersecting routes, to direct them to cities, towns, villages, or other important destinations, to identify nearby rivers and streams, parks, forests, and historical sites, and generally to give such information as will help them along their way in the most simple, direct manner possible.

When Should A Stop Sign Be Used At An Intersection?

The STOP sign shall be an octagon with a white legend and border on a red background. If appropriate, a supplemental plaque (R1-3 or R1-4) shall be used to display a secondary legend.

At intersections where all approaches are controlled by STOP signs, a supplemental plaque (R1-3 or R1-4) shall be mounted below each STOP sign.

The ALL WAY (R1-4) supplemental plaque may be used instead of the 4-WAY (R1-3) supplemental plaque.

Standard Size
30” x 30”
(750 mm x 750 mm)
See MUTCD
page 2B-7

<u>R1-1</u>

Standard Size
12” x 6”
(300 mm x 150 mm)
See MUTCD
page 2B-7

<u>R1-3</u>

Standard Size
18” x 6”
(450 mm x 150 mm)
See MUTCD
page 2B-7

<u>R1-4</u>

For regulatory sign sizes, refer to page 2B.2 of the MUTCD.

STOP signs should not be used unless engineering judgment indicates that one or more of the following conditions exist:

1. Intersection of a less important road with a main road where application of the normal right-of-way rule would not be expected to provide reasonably safe operation.
2. Street entering a through highway or street.
3. Unsignalized intersection in a signalized area.
4. High speeds, restricted view, or crash records indicate a need for control by the STOP sign.

STOP signs shall not be installed at intersections where traffic control signals are installed and operating because the potential for conflicting commands could create driver confusion.

Portable or part time STOP signs shall not be used except for emergency and temporary traffic control zone purposes.

STOP signs should not be used for speed control.

STOP signs should be installed in a manner that minimizes the numbers of vehicles having to stop. At intersections where a full stop is not necessary at all times, consideration should be given to using less restrictive measures such as YIELD signs (See Section 2B.08 of the MUTCD).

Once the decision has been made to install two-way stop control, the decision regarding the appropriate street to stop should be based on engineering judgment. In most cases, the street carrying the lowest volume of traffic should be stopped.

A STOP sign should not be installed on the major street unless justified by a traffic engineering study.

What Is The Appropriate Location Of A Stop Sign

The following are considerations that might influence the decision regarding the appropriate street upon which to install a STOP sign where two streets with relatively equal volumes and/or characteristics intersect:

1. Stopping the direction that conflicts the most with established pedestrian crossing activity or school walking routes;
2. Stopping the direction that has obscured vision, dips, or bumps that already require drivers to use lower operating speeds;
3. Stopping the direction that has the longest distance of uninterrupted flow approaching the intersection; and
4. Stopping the direction that has the best sight distance to conflicting traffic.

The STOP sign shall be installed on the right side of the traffic lane to which it applies. When the STOP sign is installed at this required location and the sign visibility is restricted, a Stop Ahead sign (See Section 2C.26 of the MUTCD) shall be installed in advance of the STOP sign.

The STOP sign shall be located as close as practical to the intersection it regulates, while optimizing its visibility to the road user it is intended to regulate.

STOP signs and YIELD signs shall not be mounted on the same post.

Guidance:

Stop lines, when used to supplement a STOP sign, should be located at the point where the road user should stop (See Section 3B.16 of the MUTCD).

If only one STOP sign is installed on an approach, the STOP sign should not be placed on the far side of the intersection.

Where two roads intersect at an acute angle, the STOP sign should be positioned at an angle, or shielded, so that the legend is out of view of traffic to which it does not apply.

Where there is a marked crosswalk at the intersection, the STOP sign should be installed in advance of the crosswalk line nearest to the approaching traffic.

When Is It Necessary To Install A Multi-Way Stop Sign?

Multi-way stop control can be useful as a safety measure at intersections if certain traffic conditions exist. Safety concerns associated with Multi-way stops include pedestrians, bicyclists, and all road users expecting other road users to stop. Multi-way stop control is used where the volume of traffic on the intersecting roads is approximately equal.

The decision to install Multi-way stop control should be based on an engineering study. The following criteria should be considered in the engineering study for a Multi-way STOP sign installation:

1. Where traffic control signals are justified, the Multi-way stop is an interim measure that can be installed quickly to control traffic while arrangements are being made for the installation of the traffic control signal.
2. A crash problem, as indicated by five or more reported crashes in a 12 month period that are susceptible to correction by a Multi-way stop installation. Such crashes include right and left turn collisions as well as right angle collisions.
3. Minimum volumes:
    a. The vehicular volume entering the intersection from the major street approaches (total of both approaches) averages at least 300 vehicles per hour for any eight hours of an average day, and
    b. The combined vehicular, pedestrian, and bicycle volume entering the intersection from the minor street approaches (total of both approaches) averages at least 200 units per hour for the same eight hours, with an average delay to minor street vehicular traffic of at least 30 seconds per vehicle during the highest hour, but
    c. If the 85th percentile approach speed of the major street traffic exceeds 40 mph (65 km/h), the minimum vehicular volume warrants are 70 percent of the above values.
    d. Where no single criterion is satisfied, but where Criteria 2, 3b, and 3d are all satisfied to 80 percent of the minimum values. Criterion 3c is excluded from this condition.

Where multi-way stops are not justified, it may be desirable to place an intersection warning sign on the major street approach. It should be noted that placement of unwarranted STOP signs, as well as other unwarranted traffic control devices, tends to breed disrespect by drivers and possible disregard for traffic control devices in general.

There Is A Stop Sign In Town Which Drivers Either Seem To Miss Or Just Go Through. What Should Be Done About It?

It is possible that the STOP sign has been mounted in the wrong location or is insufficient in size to be properly visible. The instructions below are some guidelines to follow in selecting the proper size and location for these signs.

1. The standard size for the STOP sign is 30” x 30” (750 mm x 750 mm). For roads having a speed limit of 40 miles per hour (mph) (60 km/h) or greater, the signs should be increased to 36” x 36” (0.9 m x 0.9 m). All regulatory signs including STOP signs shall be reflectorized to show the same shape and color both by day and night.

2. The proper location for a STOP sign or other signs is illustrated in Figure 5-1 on the following page. The essential points to remember are:
    a. Lateral distance from edge of pavement is six to twelve feet (1.8 m to 3.6 m).
    b. Mounting height from the pavement to the bottom of the sign is seven feet (2.1 m) along roads where vehicles are likely to park or pedestrian activity occurs.
    c. The sign should be placed along the roadway at the point where the vehicle is to stop.
    d. Check nighttime visibility to assure reflective sheeting is not worn out.

If signs are of a correct size and in the proper location, it is possible that motorists are not being adequately warned of the need to stop. "STOP AHEAD" signs should be used where the speed limit exceeds 40 mph (60 km/h) and/or the curvature of the roadway prevents the motorist from seeing the STOP sign as they approach the intersection. On certain occasions, the sign's visibility may also be obscured by trees or shrubs. Table 5-2 gives the minimum distance from the intersection that the sign should be visible for different approach speeds.

Should Multi-Way Stop Signs Be Used As Speed Control?

No, according to the MUTCD, multi-way stop signs should not be used as speed control.

There have been numerous studies conducted to determine if multi-way stop signs are effective as speed control or traffic calming devices. An essay entitled "Multi-way Stops-The Research Shows the MUTCD is Correct!" written by W. Martin Bretherton Jr., summarizes the results of 70 technical papers with a collective 23 hypotheses regarding the relative effectiveness of multi-way stops as traffic calming devices.

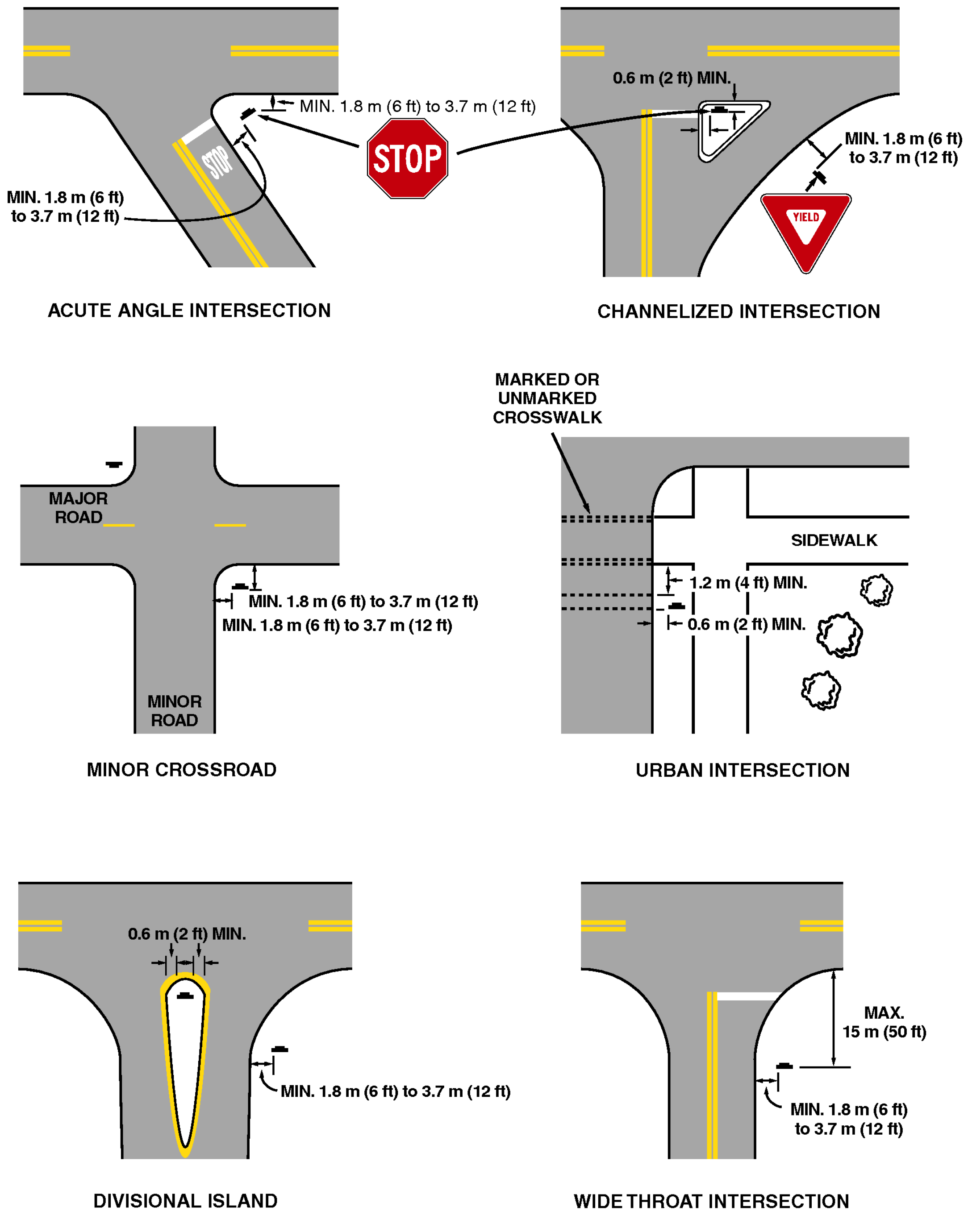
Bretherton points out that many elected officials, citizens, and some traffic engineering professionals believe that multi-way stops should be used as traffic calming devices, and as a result unwarranted stop signs are installed to control traffic. The MUTCD describes warrants (those listed above) for the installation of multi-way stop signs. There are many problems caused by unwarranted stop signs including liability issues, traffic noise, automobile pollution, traffic enforcement, and driver behavior.

Listed below is information presented in Bretherton's article regarding the effectiveness of multi-way stop signs as speed control in residential neighborhoods.

- Multi-way stop signs do not control speeds.
- Stop compliance is poor at unwarranted multi-way stop signs; drivers feel that the signs have no traffic control purpose.
- Before-After studies show multi-way stop signs do not reduce speeds on residential streets.
- Unwarranted multi-way stops increased speed between intersections; motorists are making up the time they lost at the "unnecessary" stop sign.
- Multi-way stop signs have high operating costs based on vehicle operating costs, vehicular travel times, fuel consumption and increased vehicle emissions.

- Safety of pedestrians is decreased at unwarranted multi-way stops; pedestrians expect vehicles to stop at the stop signs but vehicles have gotten in the habit of running the “unnecessary” stop sign.
- Speeding problems on residential streets are often associated with through traffic created by “outsiders,” however many times the problem is the person complaining or their neighbor.
- Stop signs increase noise in the vicinity of an intersection. Braking, acceleration, engine exhaust, tire, and aerodynamic noises all contribute to an increase in noise.
- Enforcement costs for multi-ways stops are cost prohibitive; many communities do not have the resources to effectively enforce compliance with the stop signs.
- Stop signs do not significantly change the safety of an intersection.
- Unwarranted multi-way stops have been successfully removed with public support and resulted in improved compliance at justified stop signs.
- Unwarranted multi-way stops reduce crashes in cities with intersection sight distance problems and at intersections with parked cars that restrict sight distance.

Figure 5-1: Typical Locations For Signs At Intersections[2]



Note: Lateral offset is a minimum of 1.8 m (6 ft) measured from the edge of the shoulder, or 3.7 m (12 ft) measured from the edge of the traveled way. See Section 2A.19 for lower minimums that may be used in urban areas, or where lateral offset space is limited.

[2] Source: Part II MUTCD, 2003 Edition

Sight Distance Requirements For Intersection Traffic Control Warning Signs

The signs used to warn of the type of intersection control include the following:

- STOP AHEAD (W3-1a for symbol version and W3-1 for word message version);
- YIELD AHEAD (W3-2a for symbol version and W3-2 for word message version);
- SIGNAL AHEAD (W3-3 for symbol version and W3-3a for word message version);
- BE PREPARED TO STOP (W4-3); and
- SIDE STREET TRAFFIC DOES NOT STOP

The MUTCD requires that these signs be used when the control devices (STOP, YIELD, or signal) is not visible for a sufficient distance to permit the road user to respond to the device. The visibility obstructions may be permanent or intermittent (such as summer foliage). Table 5-2 summarizes the sight distance requirements for warning signs that indicate the type of intersection control.

If the STOP sign is not visible for the minimum distance shown in Table 5-2, "STOP AHEAD" signs should be used. In rural areas, these signs should normally be placed about 750 feet (225 m) in advance of the STOP Sign. On high speed roads and particularly on freeways, advance warning distances may have to be as great as 1500 feet (450 m) or more. Where speeds are relatively low in urban areas, the advance distance should be only about 250 feet (75 m).

Table 5-2: Distances For Advance Traffic Control Warning Signs

Approach Speed (mph)	Required Sight Distance (ft.)		Advance Placement Distance (ft.)
	Stop/Yield Sign[3]	Traffic Signal[4]	2003 MUTCD[5]
20	115	175	N/A
25	155	215	N/A
30	200	270	N/A
35	250	325	N/A
40	305	390	125
45	360	460	175
50	425	540	250
55	495	625	325
60	570	715	400
65	645	N/A	475
70	730	N/A	550

Note: Metric converts as: 1 mile per hour = 1.61 km/h
NA indicates no suggested minimum distances are provided at these speeds

[3] Based on stopping sight distance from 2004 Policy on Geometric Design of Highways and Streets, 5th edition, 2004
[4] From Table 4D-1, 2003 MUTCD
[5] From Table 2C-4, 2003 MUTCD

Can A Stop Sign Or Yield Sign Be Used To Control Excessive Speed?

Even though STOP signs are the most frequently requested traffic control device in residential areas, they should not be used for speed or volume control. Many residents believe that the installation of STOP signs, or a series of STOP signs, at previously uncontrolled intersections will reduce both the speed and volume of cut-through traffic. Unfortunately, this is not the case. Numerous studies have indicated that STOP signs used solely to regulate speed may cause negative traffic safety impacts (noncompliance with the signs and more crashes).

When STOP signs are installed to slow speeders, drivers may actually increase their speeds between signs to compensate for the time they lost by stopping. Too many STOP signs can cause drivers to ignore the right-of-way rule, or some drivers may simply choose to ignore the STOP sign.

If cut-through residential traffic is the main reason for consideration of a STOP or YIELD sign (causing increased speeds and/or volumes), the engineer should consider traffic calming techniques rather than STOP or YIELD signs. The immediate purpose of traffic calming is to reduce the speed and volume of traffic to acceptable levels. Reductions in traffic speed and volume, however, are just means to other ends such as traffic safety and active street life. When reductions in speed and/or volumes are the main goal, the traffic calming practices listed in Table 5-3 should be considered rather than STOP or YIELD signs.

Table 5-3: Effective Traffic Calming Techniques[6]

Reduction of Speed	Reduction of Volume
• Full closures • Half closures • Semi diverters • Diagonal diverters • Median barriers • Forced turn islands	• Speed humps • Speed tables • Raised crosswalks • Raised intersections • Textured pavements • Neighborhood traffic circles • Roundabouts • Chicanes • Realigned intersections • Neckdowns • Center island narrowings • Chokers

For more information about these techniques, please refer to the publication titled: Traffic Calming: State of the Practice, FHWA RD 99 135, ITE/FHWA, Washington, DC, August 1999, and Chapter 19 of this Handbook.

[6] Source: ITE, Traffic Control Devices Handbook, 2001

Should A Stop Sign Be Used At A Railroad Crossing?

STOP signs may be used at highway rail grade crossings at the discretion of the responsible state or local agency for crossings that have two or more trains per day and are without automatic traffic control devices.

"Two or more trains per day" is interpreted to mean an average of two or more trains operating over the crossing each day for a period of one year prior to the installation of the STOP sign.

If a STOP sign is installed at a highway rail grade crossing, a STOP AHEAD advance warning sign must also be installed.

At A "T" Intersection, Traffic Crashes Are Occurring Due To Vehicles Approaching On The Leg Of The "T", Running The Stop Sign, And Driving Off The Road. What Signing Would Be Used In This Situation?

Install a STOP AHEAD sign to warn of the presence of the STOP sign, which either is not visible for sufficient distance or is not being observed. It may be helpful to install a double headed large arrow sign at the head of the "T", directly in line with the leg of the intersection.

When Should A Warning Sign Be Installed?

Warning signs call attention to unexpected conditions on or adjacent to a highway or street and to situations that might not be readily apparent to road users. Warning signs alert road users to conditions that might call for a reduction of speed or an action in the interest of safety and efficient traffic operations.

The use of warning signs shall be based on an engineering study or on engineering judgment.

The use of warning signs should be kept to a minimum as the unnecessary use of warning signs tends to breed disrespect for all signs. In situations where the condition or activity is seasonal or temporary, the warning sign should be removed or covered when the condition or activity does not exist.

Some typical uses of warning signs are:

- Changes in horizontal alignment
- Changes in vertical alignment
- Advance warning of traffic control devices
- Traffic flow
- Narrow roadways
- Changes in roadway design features
- Grades
- Roadway surface conditions
- Railroad-highway grade crossings
- Entrances and crossings
- Roadway obstructions

- Change in speed
- School areas
- Miscellaneous

Guidelines for the design and use of warning signs are contained in Chapter 2C of the 2003 edition of the MUTCD.

Where Should The Warning Sign Be Placed?

The longitudinal placement of warning signs should provide adequate time for a driver to see the warning sign, identify the intent of the warning sign, identify the potential hazard, decide what course of action should be taken and perform any maneuver necessary to respond to the potential hazard. Table 5-4, which is the same as Table 2C-4 of the MUTCD, suggests the minimum longitudinal placement requirements for warning signs. This table considers the speed of the vehicle, the speed of the required response and the type of judgment necessary to complete the response. These distances are minimum guidelines that may be exceeded when necessary.

Warning signs should not be placed too far in advance of the condition, as drivers might tend to forget the warning because of other driving distractions, especially in urban areas.

The effectiveness of the placement of warning signs should be periodically evaluated under both day and night conditions.

Table 5-4: Guidelines For Advance Placement Of Warning Signs[7]

Posted or 85th-Percentile Speed	Advance Placement Distance [1]								
	Condition A: Speed reduction and lane changing in heavy traffic[2]	Condition B: Deceleration to the listed advisory speed (mph) for the condition[4]							
		0[3]	10	20	30	40	50	60	70
20 mph	225 ft	N/A[5]	N/A[5]	—	—	—	—	—	—
25 mph	325 ft	N/A[5]	N/A[5]	N/A[5]	—	—	—	—	—
30 mph	450 ft	N/A[5]	N/A[5]	N/A[5]	—	—	—	—	—
35 mph	550 ft	N/A[5]	N/A[5]	N/A[5]	N/A[5]	—	—	—	—
40 mph	650 ft	125 ft	N/A[5]	N/A[5]	N/A[5]	—	—	—	—
45 mph	750 ft	175 ft	125 ft	N/A[5]	N/A[5]	N/A[5]	—	—	—
50 mph	850 ft	250 ft	200 ft	150 ft	100 ft	N/A[5]	—	—	—
55 mph	950 ft	325 ft	275 ft	225 ft	175 ft	100 ft	N/A[5]	—	—
60 mph	1100 ft	400 ft	350 ft	300 ft	250 ft	175 ft	N/A[5]	—	—
65 mph	1200 ft	475 ft	425 ft	400 ft	350 ft	275 ft	175 ft	N/A[5]	—
70 mph	1250 ft	550 ft	525 ft	500 ft	425 ft	350 ft	250 ft	150 ft	—
75 mph	1350 ft	650 ft	625 ft	600 ft	525 ft	450 ft	350 ft	250 ft	100 ft

Notes:

[1] The distances are adjusted for a sign legibility distance of 175 ft for Condition A. The distances for Condition B have been adjusted for a sign legibility distance of 250 ft, which is appropriate for an alignment warning symbol sign.

[2] Typical conditions are locations where the road user must use extra time to adjust speed and change lanes in heavy traffic because of a complex driving situation. Typical signs are Merge and Right Lane Ends. The distances are determined by providing the driver a PIEV time of 14.0 to 14.5 seconds for vehicle maneuvers (2001 AASHTO Policy, Exhibit 3-3, Decision Sight Distance, Avoidance Maneuver E) minus the legibility distance of 175 ft for the appropriate sign.

[3] Typical condition is the warning of a potential stop situation. Typical signs are Stop Ahead, Yield Ahead, Signal Ahead, and Intersection Warning signs. The distances are based on the 2001 AASHTO Policy, Stopping Sight Distance, Exhibit 3-1, providing a PIEV time of 2.5 seconds, a deceleration rate of 11.2 ft/second^2, minus the sign legibility distance of 175 ft.

[4] Typical conditions are locations where the road user must decrease speed to maneuver through the warned condition. Typical signs are Turn, Curve, Reverse Turn, or Reverse Curve. The distance is determined by providing a 2.5 second PIEV time, a vehicle deceleration rate of 10 ft/second^2, minus the sign legibility distance of 250 ft.

[5] No suggested distances are provided for these speeds, as the placement location is dependent on site conditions and other signing to provide an adequate advance warning for the driver.

[7] Source: Table 2C-4, MUTCD 2003

What Type Of Warning Signs Are Available?

Many standard warning signs are available, such as:

- Curve
- Turn
- Winding Road
- Dead End
- Signal Ahead
- Side Road
- STOP AHEAD
- Crossroad
- Railroad Crossing
- Slippery When Wet
- Hill
- Pedestrian Crossing

In addition, warning signs can be fabricated to meet other needs and symbol messages can be substituted for some word messages. Chapter 2C of the MUTCD should be consulted for this information.

In the following pages, some uses of the warning signs are described.

A. CROSS ROAD Sign (W2-1)

The CROSS ROAD sign is intended for use on a through highway to indicate the presence of an obscured crossroad intersection. The diagram for a crossroad intersection with a slight offset should indicate that the side roads are not opposite each other. If the crossroad occurs in the vicinity of a curve, the symbol may be modified appropriately.

Standard Size
30" x 30"
(750 mm x 750 mm)
See MUTCD 2003
page 2C-18

W2-1

B. SIDE ROAD Sign (W2-2, W2-3)

The SIDE ROAD sign, showing a side road symbol, either left or right, and at an angle of either 90 or 45 degrees, is intended for use in advance of a side road intersection according to the same warrants as set forth for the CROSS ROAD sign. If the side road occurs in the vicinity of a curve, the symbol may be modified appropriately.

Standard Size
30" x 30"
(750 mm x 750 mm)
See MUTCD 2003
page 2C-18

W2-2

W2-3

C. T SYMBOL SIGN (W2-4)

The T SYMBOL sign is intended for use to warn traffic approaching a T-intersection on the road where traffic must make a turn either to the left or the right. This sign should not generally be used on an approach where traffic is required to stop before entering the intersection. It may be desirable to place a double-headed LARGE ARROW sign or chevrons at the head of the T, directly in line with approaching traffic.

Standard Size
30" x 30"
(750 mm x 750 mm)
See MUTCD 2003
page 2C-18

W2-4

D. Y SYMBOL Sign (W2-5)

The Y SYMBOL sign is intended for use to warn traffic approaching a Y intersection on the road that forms the stem of the Y. The sign should not generally be used at a Y intersection that is channelized by traffic islands. It may be desirable to erect a double headed LARGE ARROW sign at the fork of the Y directly in line with approaching traffic.

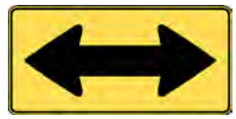
Standard Size
30" x 30"
(750 mm x 750 mm)
See MUTCD 2003
page 2C-18

W2-5

E. Two Direction Large Arrow Sign (W1-7)

If used, it shall be installed on the far side of a T intersection in line with, and at approximately a right angle to, approaching traffic. The Two Direction Large Arrow sign shall not be used where there is no change in the direction of travel such as at the beginnings and ends of medians or at center piers. The Two Direction Large Arrow sign should be visible for a sufficient distance to provide the road user with adequate time to react to the intersection configuration.

Standard Size
30” x 15”
(750 mm x 375 mm)
See MUTCD 2003
page 2C-20



W1-7

Advance Traffic Control Signs

The Advance Traffic Control symbol signs include the Stop Ahead (W3-1a), Yield Ahead (W3-2a), and Signal Ahead (W3-3) signs. These signs shall be installed on an approach to a primary traffic control device that is not visible for a sufficient distance to permit the road user to respond to the device (See Table 5-4). The visibility criteria for a traffic control signal shall be based on having a continuous view of at least two signal faces for the distance specified in Table 5-2.

Permanent obstructions causing limited visibility might include roadway alignment or structures. Intermittent obstructions might include foliage or parked vehicles.

Where intermittent obstructions occur, engineering judgment should determine the treatment to be implemented.

An Advance Traffic Control sign may be used for additional emphasis of the primary traffic control device, even when the visibility distance to the device is satisfactory.

A supplemental street name plaque may be installed be installed above or below an Advance Traffic Control sign.

A warning beacon may be used with a Signal Ahead (W3-3) sign.

A BE PREPARED TO STOP (W3-4) sign may be used to warn of stopped traffic caused by traffic control signals or in areas that regularly experience traffic congestion.

A. STOP AHEAD Sign (W3-1a)

Standard Size
30” x 30”
(750 mm x 750 mm)
See MUTCD 2003
page 2C-15

W3-1a

B. YIELD AHEAD Sign (W3-2a)

Standard Size
30” x 30”
(750 mm x 750 mm)
See MUTCD 2003
page 2C-18

W3-2a

C. SIGNAL AHEAD Sign (W3-3)

Standard Size
30” x 30”
(750 mm x 750 mm)
See MUTCD 2003
page 2C-18

W3-3

When Should Turn And Curve Signs Be Installed?

The TURN and CURVE warning signs inform a driver of a change in the horizontal direction of the roadway. Before the decision can be made to use this type of sign, and which specific sign to use, many factors must be taken into consideration. First, the higher of the operating approach speed (prevailing speed) or the established speed limit must be compared with the advisory safe speed of the curve in order to establish whether a TURN sign or a CURVE sign is necessary as well as to determine the need for an advisory speed plate. Other considerations include determining if the curve is consistent with the previous roadway alignment, and the classification of the road type with regard to driver expectancy. All Turn, Curve, Reverse Turn, and Reverse Curve signs shall have an Advisory Speed Plate when the comfortable safe speed on the curve is 10 mph or more below the posted speed.

What Types Of Turn And Curve Signs Are Available?

A. TURN Sign (W1-1)

The TURN sign (W1-1) is intended for use where engineering investigations of roadway, geometric, and operating conditions show the recommended speed of a turn to be 30 mph (50 km/h) or less, and this recommended speed is equal to or less than the speed limit established by law or by regulation for that section of highway. Where a TURN sign is used, a LARGE ARROW sign may be used on the outside of the turn. Additional protection may be provided by use of the ADVISORY SPEED plate.

Standard Size
30" x 30"
(750 mm x 750 mm)
See MUTCD 2003
page 2C-4

W1-1

B. CURVE Sign (W1-2)

The CURVE sign (W1-2) may be used where engineering investigations of roadway, geometric, and operating conditions show the recommended speed on the curve to be greater than 30 mph and equal to or less than the speed limit established by law or by regulation for that section of highway. Additional protection may be provided by use of the ADVISORY SPEED plate.

Standard Size
30" x 30"
(750 mm x 750 mm)
See MUTCD 2003
page 2C-4

W1-2

C. REVERSE TURN Sign (W1-3)

The REVERSE TURN sign is intended for use to mark two turns or a CURVE and a TURN in opposite directions as defined in the warrants for TURN and CURVE signs that are separated by a tangent of less than 600 feet (180 m). If the first turn is to the right, a RIGHT REVERSE TURN sign (W1-3R) shall be used and if the first turn is to the left, a LEFT REVERSE TURN sign (W1-3L) shall be used. For additional protection the ADVISORY SPEED plate may be used.

Standard Size
30” x 30”
(750 mm x 750 mm)
See MUTCD 2003
page 2C-4

W1-3

D. REVERSE CURVE Sign (W1-4)

The REVERSE CURVE sign is intended for use to mark two curves in opposite directions, as defined in the warrants for curve signs that are separated by a tangent of less than 600 feet (180 m). If the first curve is to the right, a RIGHT REVERSE CURVE sign (W1-4R) shall be used, and if the first curve is to the left, a LEFT REVERSE CURVE sign (W1-4L) shall be used. For additional protection the ADVISORY SPEED plate may be used.

Standard Size
30” x 30”
(750 mm x 750 mm)
See MUTCD 2003
page 2C-4

W1-4

E. WINDING ROAD Sign (W1-5)

The WINDING ROAD sign is intended for use where there are three or more turns or curves, as defined in the warrants for TURN and CURVE signs, separated by tangent distances of less than 600 feet (180 m). If the first turn or curve is to the right, a RIGHT WINDING ROAD sign (W1-5R) shall be used and if the first curve or turn is to the left. A LEFT WINDING ROAD sign (W1-5L) shall be used. If the WINDING ROAD sign is used it shall be erected in advance of the first curve. Additional guidance may be provided by the installation of road delineation markers and by use of the ADVISORY SPEED PLATE. The signs may include a mileage plaque indicating a distance.

Standard Size
30” x 30”
(750 mm x 750 mm)
See MUTCD 2003
page 2C-4

W1-4

F. COMBINATION HORIZONTAL ALIGNMENT/Advisory Speed Sign (W1-1d)

The Turn (W1-1) sign or the Curve (W1-2) sign may be combined with the Advisory Speed (W13-1) plaque to create a combination Horizontal Alignment/Advisory Speed (W1-9) sign.

When used, the combination Horizontal Alignment/Advisory Speed sign shall supplement other advance warning signs and shall be installed at the beginning of the turn or curve. The minimum size of the W1-9 sign shall be 48 inches x 48 inches (10.2 m x 10.2 m) for high speed facilities, and 36 inches x 36 inches (0.9 m x 0.9 m) for low speed facilities.

Standard Size
48” x 48”
(10.2 m x 10.2 m)
See MUTCD 2003
page 2C-7

W1-1d

G. Large Arrow Sign (W1-6)

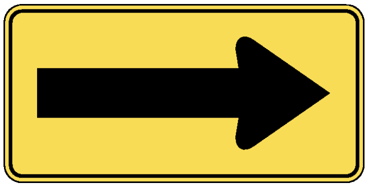
A One Direction Large Arrow (W1-6) sign may be used to delineate a change in horizontal alignment.

If used, the One Direction Large Arrow sign shall be installed on the outside of a turn or curve in line with and at approximately a right angle to approaching traffic.

The One Direction Large Arrow sign shall not be used where there is no alignment change in the direction of travel, such as at the beginnings and ends of medians or at center piers.

The One Direction Large Arrow sign should be visible for a sufficient distance to provide the road user with adequate time to react to the change in alignment.

Standard Size
48” x 24”
(10.2 m x 0.6 m)
See MUTCD 2003
page 2C-7



W1-6

H. Chevron Alignment Sign (W1-8)

The Chevron Alignment (W1-8) sign may be used to provide additional emphasis and guidance for a change in horizontal alignment. A Chevron Alignment sign may be used as an alternate or supplement to standard, delineators on curves or to the Large Arrow (W1-6) sign.

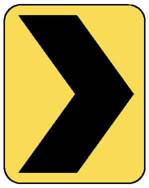
If used, Chevron Alignment signs shall be installed on the outside of a turn or curve, in line with and at approximately a right angle to approaching traffic.

A Chevron Alignment sign may be used on the far side of an intersection to inform drivers of a change of horizontal alignment through the intersection.

Spacing of Chevron Alignment signs should be such that the road user always has at least two in view, until the change in alignment eliminates the need for the signs.

Chevron Alignment signs should be visible for a sufficient distance to provide the road user with adequate time to react to the change in alignment.

Standard Size
18” x 24”
(450 mm x 0.6 m)
See MUTCD 2003
page 2C-78



W1-8

What Is A Comfortable Safe Speed On Horizontal Curves? (Ball Bank Indicator Method)

This speed value is determined by using a ball bank indicator and doing a series of trial runs around the curve(s) in question. To obtain a true reading, the speedometer must be calibrated to within one mile per hour, the indicator must be adjusted to a zero reading while on a level surface, such as a service station pump pad, and the car must be driven parallel with the centerline of the curve. The first trial run is made at a speed somewhat below the anticipated maximum safe speed. Subsequent trial runs are conducted in 5 mph speed increments as listed in the Table 5-5 until the ball bank indicator reading exceeds the value in the table or a speed is reached that is 5 mph below the posted general speed.

The comfortable safe curve speed to be placed on the curve sign rider is the speed that is 5 mph below the speed at which the ball bank indicator reading exceeds the table value. If the ball bank indicator reading has not exceeded the table value upon reaching 5 mph below the posted general speed, the curve sign and rider are not appropriate.

Table 5-5: Values For Determining Comfortable Safe Speeds On Horizontal Curves Using A Ball Bank Indicator[8]

Curve Speed in Miles per Hour	Ball Bank Reading Limiting Values in Degrees
15	13
20	13
25	13
30	13
35	10
40	10
45	10
50	10
55	10
60	7
65	7

Crossing Signs

Crossing (W11-1 through W11-4) signs may be used to alert road users to locations where unexpected entries into the roadway by pedestrians, bicyclists, animals, and other crossing activities might occur. These conflicts might be relatively confined, or might occur randomly over a segment of roadway.

Crossing signs shall be used adjacent to the crossing location. If the crossing location is not delineated by crosswalk pavement markings, the Crossing sign shall be supplemented with a diagonal downward pointing arrow plaque (W16-7P) showing the location of the crossing. If the crossing location is delineated by crosswalk pavement markings, the diagonal downward pointing arrow plaque shall not be required.

When a fluorescent yellow green background is used, a systematic approach featuring one background color within a zone or area should be used. The mixing of standard yellow and fluorescent yellow green backgrounds within a selected site area should be avoided.

Crossing signs should be used only at locations where the crossing activity is unexpected or at locations not readily apparent.

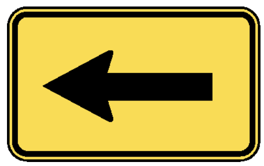
[8] Source: ODOT Sign Policy And Guidelines

W11-1

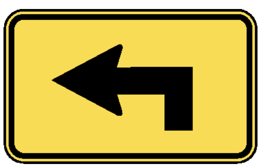
W11-2

W11-3

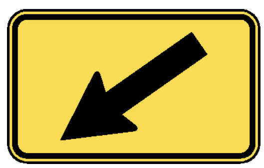
W11-4



W11-5



W16-6P



W16-7P

For additional information regarding WARNING SIGNS, refer to Chapter 2C of the MUTCD, 2003.

A Bridge Exists On Which It Is Difficult For Two Vehicles To Pass At The Same Time. How Would This Situation Be Signed?

A NARROW BRIDGE (W5-2) Word Message sign should be used in advance of any bridge or culvert having a two-way roadway clearance width of 16 to 18 feet (4.9 to 5.5 m), or any bridge or culvert having a roadway clearance less than the width of the approach travel lanes.

A NARROW BRIDGE Word Message sign may be used in advance of a bridge or culvert on which the approach shoulders are narrowed or eliminated.

A ONE LANE BRIDGE (W5-3) sign should be used on two-way roadways in advance of any bridge or culvert:

A. Having a clear roadway width of less than 4.9 m (16 feet), or
B. Having a clear roadway width of less than 5.5 m (18 feet) when commercial vehicles constitute a high proportion of the traffic, or
C. If the sight distance is limited on the approach to a structure having a clear roadway width of 5.5 m (18 feet) or less.

Additional emphasis should be provided by the use of object markers, delineators, and/or pavement markings for Narrow Bridges.

W5-2

W5-3

Shoulder Signs (W8-4, W8-9, W8-9a, And W8-11)

When used in temporary traffic control zones, the sign legend and border shall be black on an orange background. The SOFT SHOULDER (W8-4) word message sign may be used to warn of a soft shoulder condition.

The LOW SHOULDER (W8-9) word message sign may be used to warn of a shoulder condition where there is an elevation difference of less than 3 inches (75mm) between the shoulder and the travel lane.

The SHOULDER DROP OFF (W8-9a) sign should be used during construction and maintenance when a shoulder drop off exceeds 3 inches (75 mm) in height.

The UNEVEN LANES (W8-11) word message sign should be used during construction and maintenance operations that create a substantial difference in elevation between adjacent lanes.

Additional shoulder signs should be placed at appropriate intervals along the road where the condition continually exists.

W8-4

W8-9

W8-9a

W8-11

Guide Signs

Guide signs are essential to direct road users along streets and highways, to inform them of intersecting routes, to direct them to cities, towns, villages, or other important destinations, to identify nearby rivers and streams, parks, forests, and historical sites, and generally to give such information as will help them along their way in the most simple, direct manner possible.

Except where otherwise specified in the MUTCD for individual signs or groups of signs, guide signs on streets and highways shall have a white message and border on a green background. All messages, borders, and legends shall be retroreflective and all backgrounds shall be retroreflective or illuminated.

Lettering Style Of Guide Signs

Design standards for upper-case letters, lower-case letters, capital letters, numerals, route shields, and spacing shall be as provided in the "Standard Alphabets for Highway Signs and Pavement Markings."

The standard lettering for conventional road guide signs shall be all capital letters (Section 2A.14 of the MUTCD), or a combination of lower-case letters with initial upper-case letters. When a combination of upper- and lower-case letters are used, the initial upper-case letters shall be approximately 1.33 times the "loop" height of the lower-case letters.

Size Of Lettering For Guide Signs

Design layouts for conventional road guide signs showing interline spacing, edge spacing, and other specification details shall be as shown in the "Standard Highway Signs" book. The principal legend on guide signs shall be in letters and numerals at least 6 inches (150 mm) in height for all capital letters, or a combination of 6 inches (150 mm) in height for upper-case letters with 4.5 inches (113 mm) in height for lower-case letters. On low-volume roads (as defined in Section 5A.01 of the MUTCD), and on urban streets with speeds of 25 mph (40 km/h) or less, the principal legend shall be in letters at least 4 inches (0.1 m) in height. Sign panels shall be large enough to accommodate the required legend without crowding. The minimum lettering sizes specified herein should be exceeded where conditions indicate a need for greater legibility.

Are There Any Requirements For Street Name Signs?

Street Name (D3) signs should be installed in urban areas at all street intersections regardless of other route signs that may be present and should be installed in rural areas to identify important roads that are not otherwise signed. Lettering on Street Name signs should be at least 6 inches (150 mm) high in capital letters, or 6 inches (150 mm) upper-case letters with 4.5 inches (110 mm) lower-case letters. Larger letter heights should be used for street name signs mounted overhead. For local roads with speed limits of 40 km/h (25 mph) or less, the lettering height may be a minimum of 4 inches (100 mm).

Supplementary lettering to indicate the type of street (such as Street, Avenue, or Road) or the section of the city (such as NW) may be in smaller lettering, at least 3 inches (75 mm) high. The Street Name sign shall be retroreflective or illuminated to show the same shape and similar color both day and night. The legend and background shall be of contrasting colors.

Street name signs should be mounted a minimum of seven feet (2.1 m) above the pavement. In residential districts at least one sign is recommended at each intersection. In business districts or on major arteries, street name signs should be placed on diagonal corners so that they will be on the rear left hand and far right hand side of the intersection for traffic on the major street. Street name signs take on added importance particularly in rural areas where "911 systems" have been implemented. Generally, white on green street signs are used for public roads. Some agencies find it helpful to include the 100 block address on street name signs.

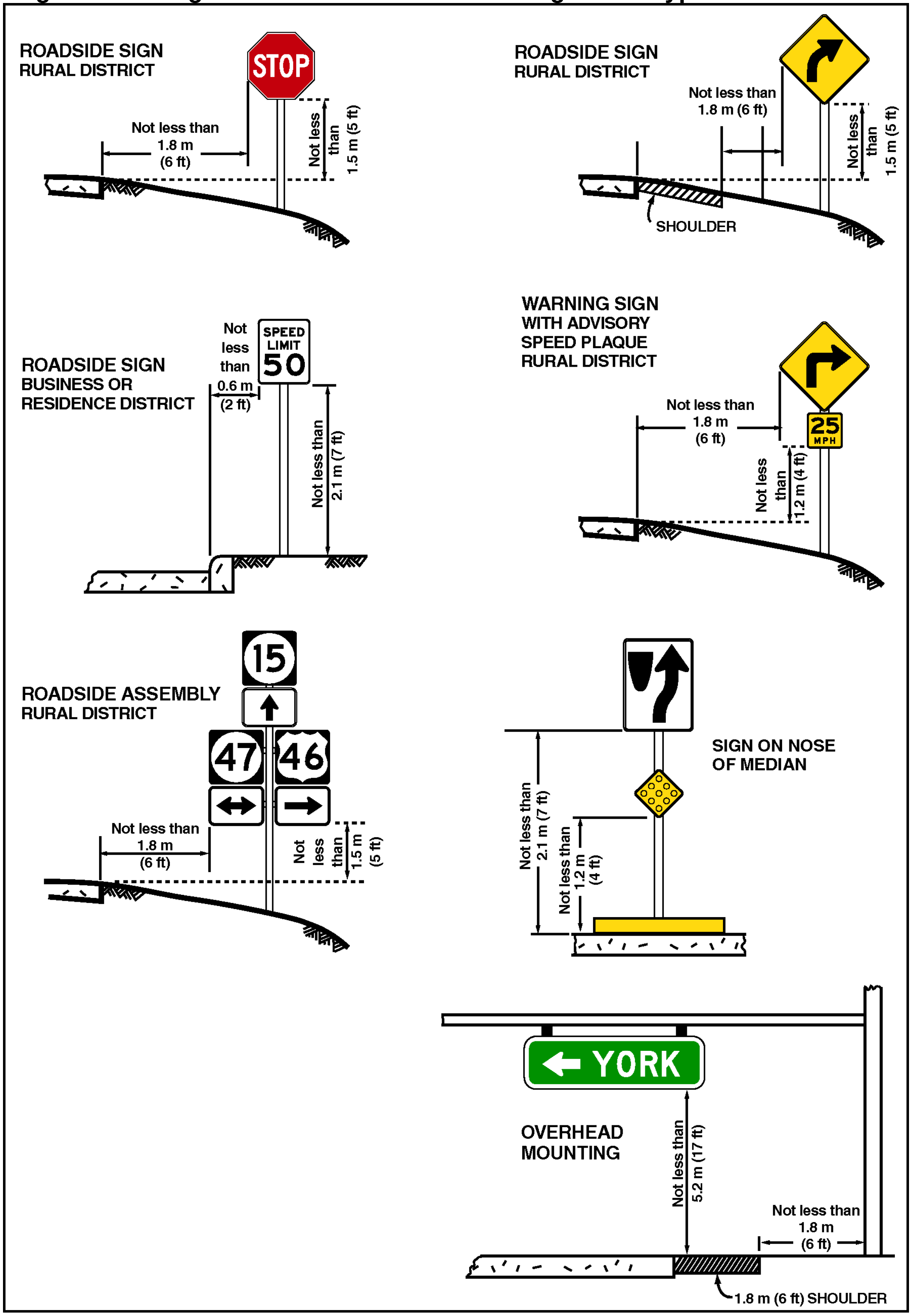
D3

Is There A Specific Mounting Height And Location For Signs?

The mounting height for signs in rural areas should be at least 7 feet (2.1 m) measured from the bottom of the sign to the near edge of the pavement. If more than one sign is mounted on a single post, the bottom of the sign assembly should be a minimum of 6 feet (1.8 m) measured from the bottom of the sign to the edge of the pavement. In other areas where there is possible pedestrian movement or on-street parking, the clearance to the bottom of the sign should be at least 7 feet (2.1 m). The 7-foot minimum height requirement may be waived for parking related signs where little or no interference with pedestrians exists.

Sign posts should be located as far as practical from the edge of the roadway. This distance should not be less than six feet (1.8 m) from the edge of the shoulder. In urban areas, as little as 1 foot (0.3 m) is permissible where the sidewalk width is limited; however, 2 feet (0.6 m) is desirable. For low-volume roads that have a traffic volume of less than 400 Average Annual Daily Traffic (AADT), a lateral offset of not less than 2 feet (0.6 m) from the roadside edge of the sign may be used where roadside features such as terrain, trees, etc. prevent the above lateral placement. Locations of typical signs are illustrated in Figure 5-2.

Figure 5-2: Height And Lateral Location Of Signs For Typical Installations[9]



[9] Source: Page 2A-9, MUTCD 2003

How Do You Conduct A Maintenance Check And Sign Inventory?

An ongoing maintenance system can be beneficial to a local jurisdiction by improving motorist safety as well as providing a greater degree of protection from liability claims. A maintenance system may include a sign inventory, a citizen complaint system, a method for rating maintenance priorities, and a routine inspection. The scope of the system will vary depending upon the size and complexity of the jurisdiction.

Some of the information which may be included in a sign inventory includes a record of:

1. type and size of sign'
2. time, date, and by whom the sign was installed or inventoried;
3. location of the sign;
4. condition of the sign, to include a note as to whether or not the sign is reflectorized; and
5. time, date, and by whom any maintenance was performed on the sign.

The record should be updated whenever a revision is made or maintenance is performed on the sign, and there should be a policy that establishes specified intervals for updating the records. Sign inventory card systems that are inexpensive, simple, and adaptable to all levels of roads, are available from commercial sources (example: 3M Corporation). In the following section, a citizen complaint system is discussed and a simple traffic control device inspection sheet is shown in Figure 5-3.

Figure 5-3: Traffic Control Devices Inspection Sheet[10]

County/Township ______________________

Road Identification ______________________

Location/Direction ______________________

Beginning Point ______________________

Ending Point ______________________

					Inspection Date (Note Condition)			
Odometer Reading	Side of Road	Sign No.	Sign I.D.	Sign Type	Date	Action Taken	Date	Action Taken
Inspector								

x - sign is OK

0 - needs attention

[10] Source: ITE, Traffic Control Devices Handbook, 2001

All signs should be checked periodically and local government employees should be instructed to watch for and report all problems.

How To Set Up A Complaint System

(This section is provided for those units which do not currently have a complaint system and are interested in starting one.)

All complaints should be made to one office. The office should be available to receive complaints or notices of problems concerning roadways and traffic control devices. The following action is suggested:

1. Record date and time of complaint;
2. Record name, address and telephone number of complainant;
3. Record location and description of problem;
4. Prioritize the problem according to an established priority system based upon potential criticality of having an accident (See Priority System Considerations);
5. Investigate, if necessary, in order to determine necessary corrective action;
6. Contact maintenance personnel and instruct them to take appropriate action, (action should be taken immediately in case of a high priority ranking);
7. Record time, date and to whom the corrective action instructions were assigned;
8. Ask for local law enforcement support at location, if necessary, until action can be taken;
9. Record date and time that corrective action was completed;
10. Upon completion of action, notify complainant about corrective action taken, and express appreciation for assistance;
11. Maintain a record system of all complaints, and file according to location; and
12. Provide for periodic review of records, noting recurring problems that may need special attention.

For additional information regarding the traffic control devices, refer to the Manual on Uniform Traffic Control Devices (MUTCD), available on line at:
http://mutcd.fhwa.dot.gov.

Chapter 6: Low-Volume Roads

Part 5 of the Manual on Uniform Traffic Control Devices (MUTCD), 2003 Edition specifically supplements and references the criteria for traffic control devices commonly used on low-volume roads.

A low-volume road shall be defined based on the MUTCD as follows:

A. A low-volume road shall be a facility lying outside of built-up areas of cities, towns, and communities, and it shall have a traffic volume of less than 400 Average Daily Traffic (ADT).
B. A low-volume road shall be classified as either paved or unpaved.

Low-volume roads typically include farm-to-market, recreational, resource management and development, and local roads. The needs of unfamiliar road users for occasional, recreational, and commercial transportation purposes should be considered.

For the minimum sizes for signs installed on low-volume roads refer to Part 5, Table 5A-1 of the MUTCD.

All signs shall be retroreflective or illuminated to show the same shape and similar color both day and night, unless specifically stated otherwise in other applicable Parts of this Manual. The requirements for sign illumination shall not be considered to be satisfied by street, highway, or strobe lighting. All markings shall be visible at night and shall be retroreflective unless ambient illumination ensures that the markings are adequately visible.

Guidelines For Geometric Design Of Low-Volume Roads

Nearly 80% of the roads in the United States have traffic volumes of 400 vehicles per day or less.

The geometric design of very low-volume roads presents a unique challenge because the very low traffic volumes and reduced frequency of crashes make designs normally applied on higher volume roads less cost effective. The Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400), address the unique needs of such roads and the geometric designs appropriate to meet those needs. These guidelines may be used in lieu of the guidance in A Policy on Geometric Design of Highways and Streets, also known as the "Green Book."

For more information please refer to:
Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400), The American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2001
Telephone: (800) 231-3475
Web: https://bookstore.transportation.org

A Policy on Geometric Design of Highways and Streets, The American Association of State Highway and Transportation Officials (AASHTO), 5th Edition, Washington, D.C., 2004
Telephone: (800) 231-3475
Web: https://bookstore.transportation.org

Who Can Establish Legal Speed Limits on Public Unpaved Roads in Oregon?

As mentioned in *Chapter 4: Speed Limits* of this Handbook, in Oregon the speed limits for most roads are made jointly by the Oregon Department of Transportation and the Road Authority.

Based on OAR 743-020-0017:

A. Establishing speed zones on unpaved roads is generally discouraged:

1. The risk with establishing a specific speed zone is that a "Speed Zone" sign creates an expectation by the driver that the roadway is safe to drive at the posted speed. Since unpaved roadway conditions can change rapidly depending on weather, season, traffic volumes and amount of road maintenance, establishing the appropriate speed limit for all conditions is difficult, if not impossible; and
2. Oregon's basic rule speed law requires drivers to adopt a reasonable and prudent speed. The driver should rely primarily on their visual observation of the roadway conditions, rather than a speed zone sign to determine the safe speed to drive a road.

B. Other factors that reduce the effectiveness of, or necessity for setting speeds on unpaved roads:

1. Enforcement is minimal on unpaved roads. There would be poor compliance with speed zoning without enforcement commitment; and
2. Risks of vehicle conflict are very low on these roads; most are used by travelers who are familiar with the roads and their condition.

For requesting a speed-zone investigation, please refer to Chapter 4: Speed Limits of this Handbook and Oregon Administrative Rule OAR 743-020-0017.

Location Of Traffic Control Devices On Low-Volume Roads

The traffic control devices used on low-volume roads shall be placed and positioned in accordance with the criteria contained in Part 5 of the MUTCD, and, where necessary, in accordance with the lateral, longitudinal, and vertical placement criteria contained in Part 2 of the MUTCD.

A lateral offset of not less than 2 feet (0.6 m) from the roadway edge to the roadside edge of a sign may be used where roadside features such as terrain, shrubbery, and/or trees prevent lateral placement in accordance with Section 2A.19 of the MUTCD. If located within a clear zone, roadside mounted sign supports shall be yielding, breakaway, or shielded with a longitudinal barrier or crash cushion as required in Section 2A.19 of the MUTCD.

Regulatory Signs

The purpose of a regulatory sign is to inform highway users of traffic laws or regulations and to indicate the applicability of legal requirements that would not otherwise be apparent.

STOP and YIELD Signs (R1-1 and R1-2)

STOP (R1-1) and YIELD (R1-2) signs should be considered for use on low-volume roads where engineering judgment or study indicates that either of the following conditions applies:

A. An intersection of a less-important road with a main road where application of the normal right-of-way rule might not be readily apparent.
B. An intersection that has restricted sight distance for the prevailing vehicle speeds.

R1-1

R1-2

Speed Limit Signs (R2 Series)

If used, Speed Limit signs shall display the speed limit established by law, ordinance, regulation, or as adopted by the authorized agency following an engineering study. It is important to indicate that all signs posting the designated speed or speed limit in Oregon, per ORS 811.105 and ORS 811.123, may omit the word limit.

R2-1

Warning Signs

The purpose of a warning sign is to provide advance warning to the road user of unexpected conditions on or adjacent to the roadway that might not be readily apparent. The criteria for warning signs are contained in Chapter 2C and in other Sections of this Manual. Criteria for warning signs that are specific to low-volume roads are contained in this Chapter.

A. Horizontal Alignment Signs (W1-1 through W1-8)

Horizontal Alignment signs include Turn, Curve, Reverse Turn, Reverse Curve, Winding Road, Large Arrow, and Chevron Alignment signs. Horizontal Alignment signs may be used where engineering judgment indicates a need to inform the road user of a change in the horizontal alignment of the roadway.

B. Intersection Warning Signs (W2-1 through W2-5)

Intersection warning signs include the crossroad, side road, T-symbol, and Y-symbol signs. Intersection warning signs may be used where engineering judgment indicates a need to inform the road user in advance of an intersection.

C. Stop Ahead and Yield Ahead Signs (W3-1a, W3-2a)

A Stop Ahead (W3-1a) sign shall be used where a STOP sign is not visible for a sufficient distance to permit the road user to bring the vehicle to a stop at the STOP sign. A Yield Ahead (W3-2a) sign shall be used where a YIELD sign is not visible for a sufficient distance to permit the road user to bring the vehicle to a stop, if necessary, at the YIELD sign.

D. Narrow Bridge Sign (W5-2)

The Narrow Bridge Word Message (W5-2) sign may be used on an approach to a bridge or culvert that has a clear width less than that of the approach roadway.

E. ONE LANE BRIDGE Sign (W5-3)

A ONE LANE BRIDGE (W5-3) sign should be used on low-volume roads in advance of bridges or culverts:

A. That have a clear roadway width of less than 16 feet (4.9 m); or
B. That have a clear roadway width of less than 18 feet (5.5 m) when commercial vehicles constitute more than ten percent of the traffic; or
C. Where the approach sight distance is limited on the approach to a bridge or culvert having a clear roadway width of 18 feet (5.5 m) or less.

Roadway alignment and additional warning may be provided on the approach to a bridge or culvert by the use of object markers and/or delineators.

F. Hill Sign (W7-1a)

An engineering study of vehicles and road characteristics, such as percent grade and length of grade, may be conducted to determine hill signing requirements. The use of the Hill sign on low-volume roads may be confined to roads where commercial or recreational vehicles are anticipated. Word messages (W7-1) may be used as alternates to symbols.

G. PAVEMENT ENDS Sign (W8-3)

A PAVEMENT ENDS (W8-3) sign may be used to warn road users where a paved surface changes to a gravel or earth road surface.

H. Motorized Traffic and Crossing Signs (W11 Series and W8-6)

Motorized Traffic signs should be used to alert road users to unexpected entries into the roadway by trucks, farm vehicles, fire trucks, and other vehicles. Such signs should be used only at locations where the road user's sight distance is restricted or the activity would be unexpected. If the activity is seasonal or temporary, the sign should be removed or covered when the crossing activity does not exist.

I. Advisory Speed Plaque (W13-1)

An Advisory Speed (W13-1) plaque may be mounted below a warning sign when the condition requires a reduced speed.

J. DEAD END or NO OUTLET Plaques and Signs (W14-1P, W14-2P, W14-1, and W14-2)

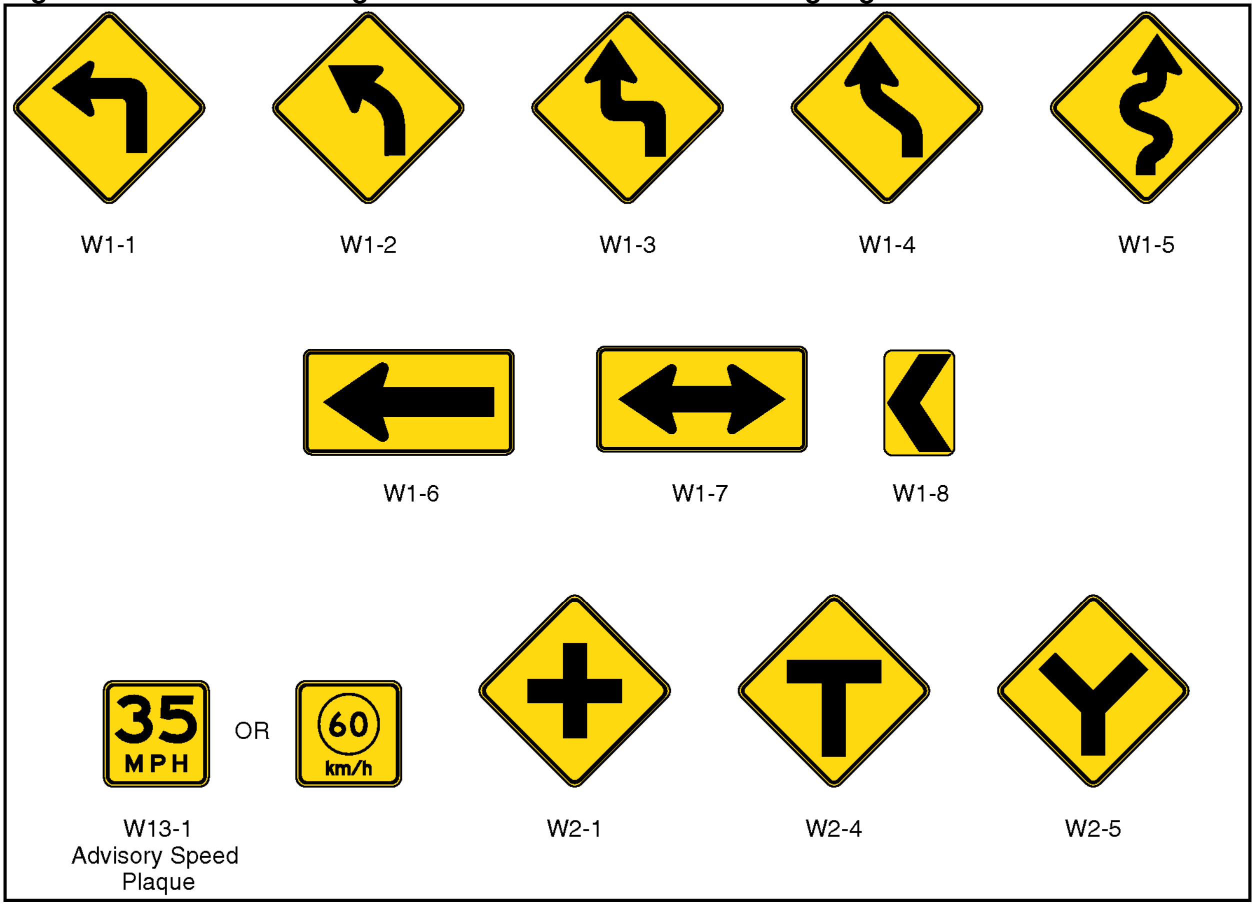
The DEAD END and NO OUTLET plaques and signs may be used to warn road users of a road that has no outlet or that terminates in a dead end or cul-de-sac.

K. NO TRAFFIC SIGNS Sign (W16-2)

A warning sign (W16-2) with the legend NO TRAFFIC SIGNS may be used only on unpaved, low-volume roads to advise users that no signs are installed along the distance of the road. If used, the sign may be installed at the point where road users would enter the low-volume road or where, based on engineering judgment, the road user may need this information. A supplemental plaque (W7-3a) with the legend AHEAD, XX FEET (XX METERS), or NEXT XX MILES (NEXT XX KM) may be installed below the W16-2 sign when appropriate.

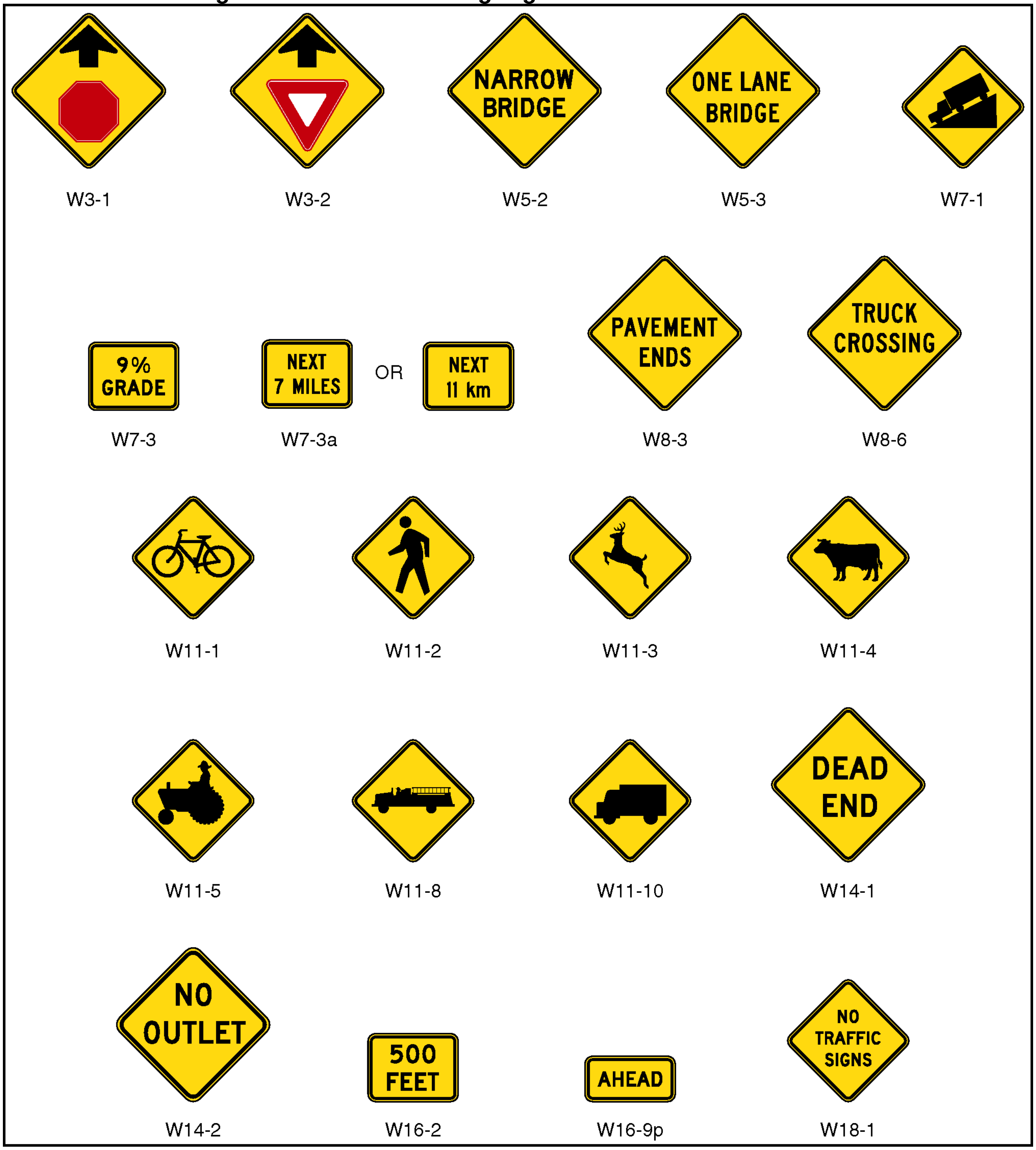
Typical warning signs for low-volume roads are illustrated in Figure 6-1 and Figure 6-2.

Figure 6-1: Horizontal Alignment And Intersection Warning Signs On Low-Volume Roads[1]



[1] Source: Part 5, MUTCD 2003

Figure 6-2: Other Warning Signs on Low-Volume Roads[2]



Guide Signs

The purpose of a guide sign is to inform road users regarding positions, directions, destinations, and routes. Criteria for guide signs that are specific to low-volume roads are contained in this Chapter. Low-volume roads generally do not require guide signs to the extent that they are

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[2] Source: Part 5, MUTCD 2003

needed on higher classes of roads. Because guide signs are typically only beneficial as a navigational aid for road users who are unfamiliar with a low-volume road, guide signs might not be needed on low-volume roads that serve only local traffic.

If used, destination names should be as specific and descriptive as possible. Destinations such as campgrounds, ranger stations, recreational areas, and the like should be clearly indicated so that they are not interpreted to be communities or locations with road user services.

Markings

The purpose of markings on highways is to provide guidance and information for road users regarding roadway conditions and restrictions. Criteria for markings that are specific to low-volume roads are contained in this Chapter.

A. Centerline Markings

Centerline markings should be used on paved low-volume roads where engineering judgment or an engineering study indicates a need for them.

B. Edge Line Markings

Edge line markings should be considered for use on paved low-volume roads based on engineering judgment or an engineering study. Edge line markings may be placed on highways with or without centerline markings. Edge line markings may be placed on paved low-volume roads for roadway features such as horizontal curves, narrow bridges, pavement width transitions, curvilinear alignment, and at other locations based on engineering judgment or an engineering study.

C. Delineators

The purpose of delineators is to enhance driver safety where it is desirable to call attention to a changed or changing condition such as abrupt roadway narrowing or curvature. Delineators may be used on low-volume roads based on engineering judgment, such as for curves, T-intersections, and abrupt changes in the roadway width. In addition, they may be used to mark the location of driveways or other minor roads entering the low-volume road.

D. Object Markers

The purpose of object markers is to mark obstructions located within or adjacent to the roadway, such as bridge abutments, drainage structures, and other physical objects. The end of a low-volume road should be marked with an end-of-roadway marker in conformance with Section 3C.04 of the MUTCD. A Type III barricade may be used where engineering studies or judgment indicates a need for a more visible end-of-roadway treatment (See Section 3F.01) of the MUTCD.

For additional information regarding traffic control devices for low-volume roads, refer to Part 5 of the MUTCD.

Chapter 7: Pavement Markings

Based on Section 3A.01 of the MUTCD 2003, markings on highways have important functions in providing guidance and information for the road user. Major marking types include pavement and curb markings, object markers, delineators, colored pavements, barricades, channelizing devices and islands. In some cases, markings are used to supplement other traffic control devices such as signs, signals, and other markings. In other instances, markings are used alone to effectively convey regulations, guidance, or warnings in ways not obtainable by the use of other devices.

Pavement markings have limitations. They may be covered by snow, may not be visible when wet, and may not be very durable when subjected to heavy traffic. In spite of these limitations, they have the advantage of conveying warnings or other information to drivers without diverting their attention from the roadway. Audible and tactile features, such as raised pavement markers, bars, or surface profile changes can be added to alert the road user that a line on the roadway is being crossed.

What Colors Can Be Used For Longitudinal Pavement Markings?

The colors of longitudinal pavement markings shall conform to the following basic concepts:

A. Yellow lines delineate:
   1. The separation of traffic traveling in opposite directions.
   2. The left edge of the roadways of divided and one-way highways and ramps.
   3. The separation of two-way left turn lanes and reversible lanes from other lanes.

B. White lines delineate:
   1. The separation of traffic flows in the same direction.
   2. The right edge of the roadway.

C. Red markings delineate roadways that shall not be entered or used.

D. Blue markings delineate parking spaces for persons with disabilities.

E. Black is not considered a marking color. It may only be used in combination with the four colors above where a light-colored pavement does not provide sufficient contrast with the markings.

What Materials Can Be Used For Pavement Markings?

1. Paint

The most common method of marking pavements, curbs, and objects is by means of paint. The average life of paint is about one year. According to the MUTCD, pavement markings, which must be visible at night, shall be reflectorized. Paint is categorized based on drying time, as follows:

- Conventional: requires more than 7 minutes to dry;

- Fast dry: requires 2 to 7 minutes to dry (hot-applied);
- Quick dry: requires 30 to 120 seconds to dry (hot-applied); and
- Instant dry: requires less than 30 sec. to dry (hot-applied).

Paint is also categorized by the base material used in the paint composition:

Alkyd (Oil-Based) And Modified Alkyd (Oleoresin) Paint

This is generally the cheapest and fastest-drying of common materials. These markings have relatively poor durability, lasting less than three months in adverse conditions. Many agencies restrict or prohibit their use for environmental concerns.

Waterborne Paint

Waterborne paint is being increasingly used because of environmental concerns about alkyd and modified alkyd paints. Standard pavement marking equipment must be modified to handle the waterborne paint. However, handling and cleanup is simplified. Drying time is about 2 minutes.

2. Hot-applied thermoplastics

Hot-applied thermoplastics are thick pavement marking materials consisting of a resin binder, glass beads, coloring agents, and an inorganic filler. The thermoplastic is transported to the job site as solid slabs or blocks or as granular powder. It is then heated and extruded or sprayed onto the pavement surface. Service lives of up to 10 years have been reported in areas where no snow plowing occurs.

Advantages of thermoplastics include:

- Long-lasting marking
- Wet-weather night visibility better than traffic paint

Disadvantages include:

- Snowplow damage due to thickness of lines
- Higher initial cost
- Bond failure due to surface contaminants
- Poor performance on Portland cement concrete
- Temperature must be carefully controlled
- High temperatures are hazardous to workers

3. Preformed tapes

Preformed tapes are cold-applied plastic pavement markings that are supplied in continuous rolls and in precut shapes to form letters or symbols. The tape is backed with adhesive and is bonded to the pavement using pressure or heat.

Advantages of preformed tapes include:

- Installation is simple, safe, and clean
- Surface adhesion is good, especially when inlaid into the pavement
- Initial retroreflectivity is good

Disadvantages include:

- Possible premature loss of retroreflectivity
- High initial cost; and Shifting or distortion under heavy turning traffic

4. Raised Pavement Marker (RPM)

A raised pavement marker is a device with a height of at least 10 mm (0.4 in) mounted on or in a road surface that is intended to be used as a positioning guide or to supplement or substitute for pavement markings.

RPM can provide better visibility over painted lines during wet weather conditions, especially at night. They also provide a tactile and auditory warning when vehicles cross over them. RPM should be considered for high seasonal traffic volumes for heavy rain and fog zones.

RPMs may be either nonretroreflective or retroreactive. Nonretroreflective markers are typically ceramic buttons about 4 inches (100 mm) in diameter and 0.75 inch (18 mm) thick. They are bonded to the pavement using an epoxy adhesive or a pressure-sensitive backing.

RPMs have the following advantages over standard pavement markings:

- Retroreflective markers provide increased visibility under wet weather conditions.
- RPMs are more durable than traffic paint.
- RPMs provide vehicle vibration and an audible tone when a vehicle crosses the lane line.
- Bi-directional retroreflective RPMs permit their use in conveying a wrong-way message to drivers.
- RPMs can be used to provide temporary lane and centerline markings in construction zones, then cleanly scraped from the pavement when work is finished.

The principle disadvantage of RPMs is their high initial cost. Their application is generally limited to roadways and pavements with a long remaining service life.

Based on the MUTCD, non-retroreflective raised pavement markers should not be used alone, without supplemental retroreflective or internally-illuminated markers, as a substitute for other types of pavement markings.

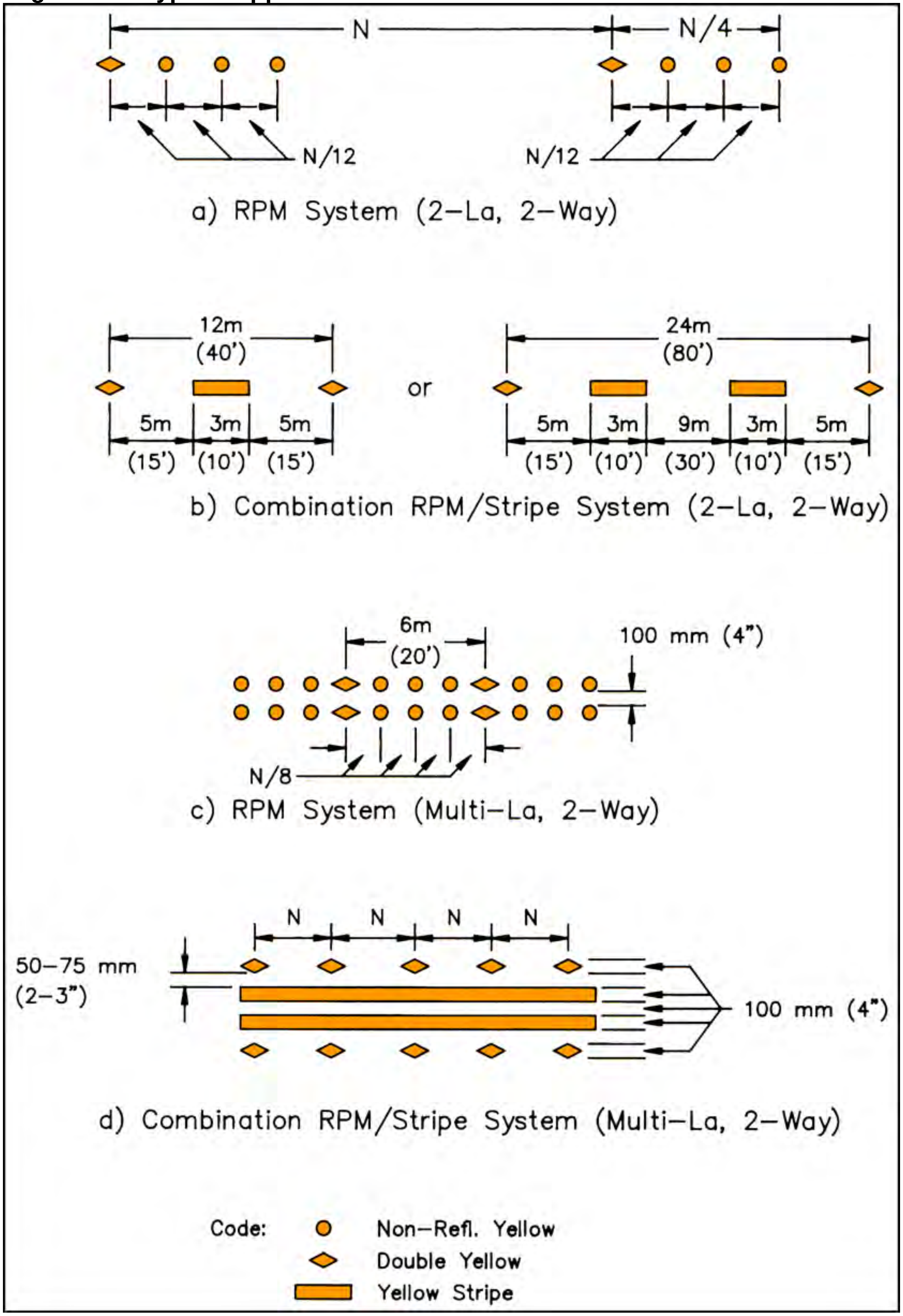
Figure 7-1 illustrates typical applications of raised pavement markers for centerline. A summary of the characteristics of pavement marking materials is shown in Table 7-1.

Table 7-1: Summary Characteristics Of Pavement Marking Materials[1]

Type	Lifetime (years)	Advantages	Disadvantages
1. Solvent-Borne Paint	1 - 1.5	Low cost Good visibility and retroreflectivity Fast drying Wet established	Possible health hazards Poor wet-night visibility Short lifetime Environmental concerns
2. Water-Based Paint	1 - 1.5	Low cost Good visibility and fair retroreflectivity Clean up with water	Poor wet-night visibility No-track time of 2-30 minutes Short lifetime Some weather restrictions on use
3. Thermoplastics	3.5 - 6	Relatively long service life Good visibility and retroreflectivity No-track time is short (0.5 to 1 min for sprayed stripes)	Special equipment needs For extruded strips no track time is 15 minutes
4. Tape And Performed Thermoplastic	1 - 3	Convenient to use Inlaid tape is snowplowable	High cost Variable night visibility Environmental concerns
5. Raised Pavement Markers	Variable	Durability is high Good visibility and retroreflectivity Need not be applied as a continuous marking	High cost Failed markers have to be replaced individually

[1] Source: Andrady, A.L., Pavement Marking: Assessing Environmental Friendly Performance, National Cooperative Highway Research Report 392, TRB, 1997

Figure 7-1: Typical Application Of Raised Pavement Markers For Centerline[2]



2 Source: Roadway Delineation Practices Handbook, FHWA, 1994

What Are The General Concepts Of The Longitudinal Pavement Markings?

Longitudinal pavement markings shall conform to the following basic concepts:

1. Yellow lines delineate the separation of traffic flows in opposing directions or mark the left edge of the travel lanes on divided highways and one-way roads.
2. White lines delineate the separation of traffic flows in the same direction or mark the right edge of the travel lanes.
3. Broken lines are permissive in character.
4. Solid lines are restrictive in character.
5. Width of line indicates the degree of emphasis.
6. Double lines indicate maximum restrictions.
7. Dotted lines provide guidance through breaks in line markings
8. Red markings delineate roadways that shall not be entered or used by the viewer of those markings.
9. Markings which must be visible at night shall be reflectorized unless ambient illumination assures adequate visibility.

Table 7-2: Typical Types Of Pavement Markings[3]

Description	Color	Min. Width	Application
Single broken	White	4 in.	Separation of lanes on which travel is in the same direction, with crossing from one to the other permitted, e.g., lane lines on multilane roadways
Single broken	Yellow	4 in.	Separation of lanes on which travel is in opposing directions and where overtaking (passing) is permitted, e.g., centerline on two-lane, two-way roadways
Single solid	White	4 in.	Separation of same-direction lanes where lane changing is discouraged, or separation of a lane and shoulder; e.g., Lane lines at intersection approaches or right edge lines
Single solid	White	8 in.	Separation of a motor vehicle lane from a bike lane
Single solid	White	8 in.	Separation of same-direction lanes where crossing is strongly discouraged, e.g., separation of special turn Lanes from through lanes, gore areas at ramp terminals, paved turnouts
Single solid	Yellow	4 in.	Delineation of left edge lines on divided highways, one-way roads and ramps
Double solid	White	4-4-4 in.*	Separation of same-direction lanes where crossing from one side to the other is prohibited, e.g., channelization in advance of an obstruction that may be passed on either side
Double solid	Yellow	4-4-4 in.*	Separation of opposing-direction lanes where passing is prohibited in both directions; Left turn maneuvers across these markings permitted; also used in advance of obstructions that may be passed only on the right side
Solid plus broken	Yellow	4-4-4 in.*	Separation of opposing-direction lanes where passing is permitted with care for traffic adjacent to the broken Line, but prohibited for traffic adjacent to solid line; used on two-way roadways with two to three lanes; also used to delineate edges of a two-way left-turn lane: solid lines on the outside, broken lines on the inside
Double broken	Yellow	4-4-4 in.*	Delineates the edge of reversible Lanes
Single dotted	Either	4 in.	Extension of Lane lines through intersections; color same as the Line being extended; also used to extend right edge of freeway shoulder Lanes through off-ramp diverging areas in problem locations
Wide dotted	White	8 in.	Separation of through lane and auxiliary lane or dropped Lane
Transverse	White	12 in.	Limit lines or STOP bars (to 24 in.); also crosswalk edge Lines (minimum 6 ft. apart)
Diagonal	White	12 in.	Cross hatch markings, placed at an angle of 45 degrees, at varying distances apart, on shoulders, gore areas, or channelization islands to add emphasis to these roadway features (optional chevron design in gores)

* 4-4-4 in. indicates typical width of stripes and gaps between them. This spacing may vary among states and Localities. (Some agencies increase this spacing to allow for raised pavement markers used as guidance devices.)

What Width And Spacing Requirements Are Used For Pavement Markings?

The widths and patterns of longitudinal lines shall be as follows:

[3] Source: Traffic Control Devices Handbook, Institute of Transportation Engineers (ITE), 2001

1. A normal width line is 4 inches to 6 inches (100 mm) wide.
2. A wide line is at least twice the width of a normal line (8 in or 200mm).
3. A double line consists of two normal width lines separated by a discernible space. Standard dimensions for the space are 4 inches (100 mm) for a narrow double line or 12 inches (350 mm) for a wide double line.
4. A broken line (skip line) is formed by 10 feet (3.0m) segments and 30 feet (9.0m) gaps, usually in the ratio of 1:3. Other dimensions in this ratio may be used as best suit traffic speeds and need for delineation.
5. A dotted line is formed by short segments, two feet (600mm) in length, and gaps, normally 6 feet (2.0m) or longer. Lane line extensions through intersections may be 4 inches (100mm) by 1 foot (300mm) at 4 feet (1.2m) to 15 feet (4.50m) centers. An 8" (200m) by 3 feet (0.90mm) dotted line at 15 feet (4.5m) centers may be used on bike lanes through intersections.

On Two-Lane Roadways, What Types Of Markings Are Used?

1. A broken yellow line is normally used to delineate the left edge of the travel path where travel on the other side of the line is in the opposite direction.
2. A normal solid white line when used delineates the edge of pavement.
3. A double line consisting of a normal broken yellow line and a normal solid yellow line delineates the separation between travel paths in opposite directions where overtaking and passing is permitted with care for motorists adjacent to the broken line and is prohibited for motorists adjacent to the solid line.

Based on the MUTCD 2003, centerline markings shall be placed on all paved urban arterials and collectors that have a traveled width of 20 feet (6.1 m) or more and an ADT of 6,000 vehicles per day or greater. Centerline markings shall also be placed on all paved two-way streets or highways that have three or more traffic lanes.

Based on the MUTCD 2003, centerline markings should be placed on paved urban arterials and collectors that have a traveled width of 20 feet (6.1 m) or more and an ADT of 4,000 vehicles per day or greater. Centerline markings should also be placed on all rural arterials and collectors that have a traveled width of 18 feet (5.5 m) or more and an ADT of 3,000 vehicles per day or greater. Centerline markings should also be placed on other traveled ways where an engineering study indicates such a need. Centerline markings may be placed on other paved two-way traveled ways that are 16 feet (4.9 m) or more in width.

Warrants For The Use Of Edge Lines

Based on Section 3B.07 of the MUTCD 2003, edge line markings have unique value as visual references to guide road users during adverse weather and visibility conditions. Edge line markings shall be placed on freeways, expressways, and rural arterials with a traveled way of 20 feet (6.1 m) or more in width and an ADT of 6,000 vehicles per day or greater. Edge line markings shall not be continued through intersections; however, edge line extensions (See Section 3B.08 of the MUTCD) may be placed through intersections.

Edge line markings should be placed on paved streets or highways with the following characteristics:

- Rural arterials and collectors with a traveled way of 20 feet (6.1 m) or more in width and an ADT of 3,000 vehicles per day or greater.
- At other paved streets and highways where an engineering study indicates a need for edge line markings.

Edge line markings:

- should not be placed where an engineering study or engineering judgment indicates that providing them would decrease safety.
- should not be broken for driveways.
- may be placed on streets and highways that do not have centerline markings.
- may be excluded, based on engineering judgment, for reasons such as if the traveled way edges are delineated by curbs, parking, bicycle lanes, or other markings.
- may be used where edge delineation is desirable to minimize unnecessary driving on paved shoulders or on refuge areas that have lesser structural pavement strength than the adjacent roadway.

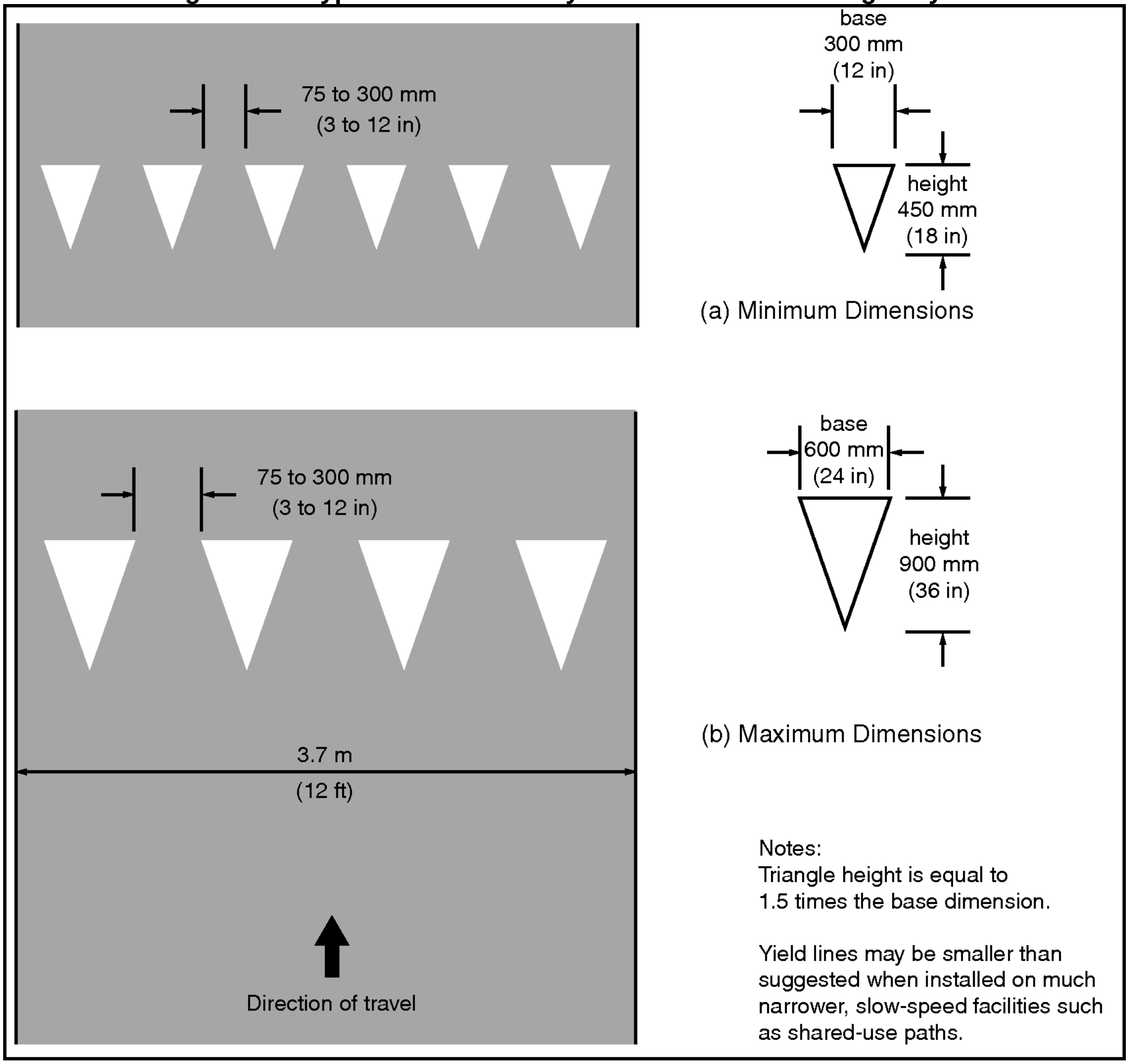
Stop And Yield Lines

Based on Section 3B.16 of the MUTCD 2003, if used, stop lines shall consist of solid white lines extending across approach lanes to indicate the point at which the stop is intended or required to be made. If used, yield lines shall consist of a row of isosceles triangles pointing toward approaching vehicles extending across approach lanes to indicate the point at which the yield is intended or required to be made (See Figure 7-2). Stop lines should be 12 to 24 inches (300 to 0.6 m) wide.

Stop lines should be used to indicate the point behind which vehicles are required to stop, in compliance with a STOP sign, traffic control signal, or some other traffic control device. Yield lines may be used to indicate the point behind which vehicles are required to yield in compliance with a YIELD sign.

If used, stop and yield lines should be placed 4 feet (1.2 m) in advance of and parallel to the nearest crosswalk line, except at roundabouts. In the absence of a marked crosswalk, the stop line or yield line should be placed at the desired stopping or yielding point, but should be placed no more than 30 feet (9 m) nor less than 4 feet (1.2 m) from the nearest edge of the intersecting traveled way. Stop lines should be placed to allow sufficient sight distance for all approaches to an intersection. Stop lines at mid-block signalized locations should be placed at least 40 feet (12 m) in advance of the nearest signal indication.

Figure 7-2: Typical Yield Line Layout For Streets And Highways[4]



Crosswalk Markings

Based on Section 3B.17 of the MUTCD 2003, crosswalk markings provide guidance for pedestrians who are crossing roadways by defining and delineating paths on approaches to and within signalized intersections, and on approaches to other intersections where traffic stops. Crosswalk markings also serve to alert road users of a pedestrian crossing point across roadways not controlled by traffic signals or STOP signs.

When crosswalk lines are used, they shall consist of solid white lines that mark the crosswalk. They shall be not less than 6 inches (150 mm) nor greater than 24 inches (0.6 m) in width. Marked crosswalks should not be less than 6 feet (1.8) wide.

[4] Source: Part III, MUTCD 2003

Crosswalk lines, if used on both sides of the crosswalk, should extend across the full width of pavement to discourage diagonal walking between crosswalks (See Figure 11-12).

Crosswalks should be marked at all intersections where there is substantial conflict between vehicular and pedestrian movements. Marked crosswalks also should be provided at other appropriate points of pedestrian concentration, such as at loading islands, mid-block pedestrian crossings, or where pedestrians could not otherwise recognize the proper place to cross.

Crosswalk lines should not be used indiscriminately. An engineering study should be performed before they are installed at locations away from traffic signals or STOP signs.

Motorists Have Not Been Yielding To Pedestrians At An Existing Crosswalk. What Solution Is Possible?

Motorists may be failing to yield to pedestrians at certain crosswalks because the crosswalk is not readily visible or it is unexpected. This usually occurs when a crosswalk is located in the middle of a block or on a narrow street with parked cars and other physical obstructions blocking the motorist's view.

Several solutions are possible, such as illumination. As mentioned above, the width of the lines could be increased up to 24 inches (0.6 m) and the area of the crosswalk marked with diagonal or longitudinal lines to make the walkway more visible (See Figure 11-12). Parking can be prohibited on both sides of the crosswalk for some distance in both directions and warning signs installed to alert motorists to the upcoming crosswalk. For more information about pedestrian crosswalks, please refer to *Chapter 11: Pedestrian Safety* of this Handbook.

When Is A No-Passing Zone At A Horizontal Or Vertical Curve Warranted?

Based on Section 3B.02 of the MUTCD 2003, where center lines are painted, a no-passing zone at a horizontal or vertical curve is warranted where the sight distance, as defined below, is less than the minimum necessary for safe passing. Passing sight distance on a vertical curve is the distance at which an object 3.50 feet (1.05m) above the pavement surface can be seen from a point 3.50 feet (1.05m) above the pavement (Figure 7-3). Similarly, passing sight distance on a horizontal curve is the distance measured along the centerline between two points 3.50 feet (1.05m) above the pavement on a line tangent to the obstruction that cuts off the view (Figure 7-3). Where no passing zones are warranted on horizontal curves or vertical curves, it should also be marked where the sight distance is equal to or less than the values shown in Table 7-3.

The beginning of a no-passing zone (point “a” Figure 7-3) is that point at which the sight distance first becomes less than that specified in the above table. The end of the zone (point “b”) is that point at which the sight distance again becomes greater than the minimum specified.

Table 7-3: Minimum Passing Sight Distances[5]

85th-Percentile or Posted or Statutory Speed Limit (km/h)	Minimum Passing Sight Distance (meters)
40	140
50	160
60	180
70	210
80	245
90	280
100	320
110	355
120	395

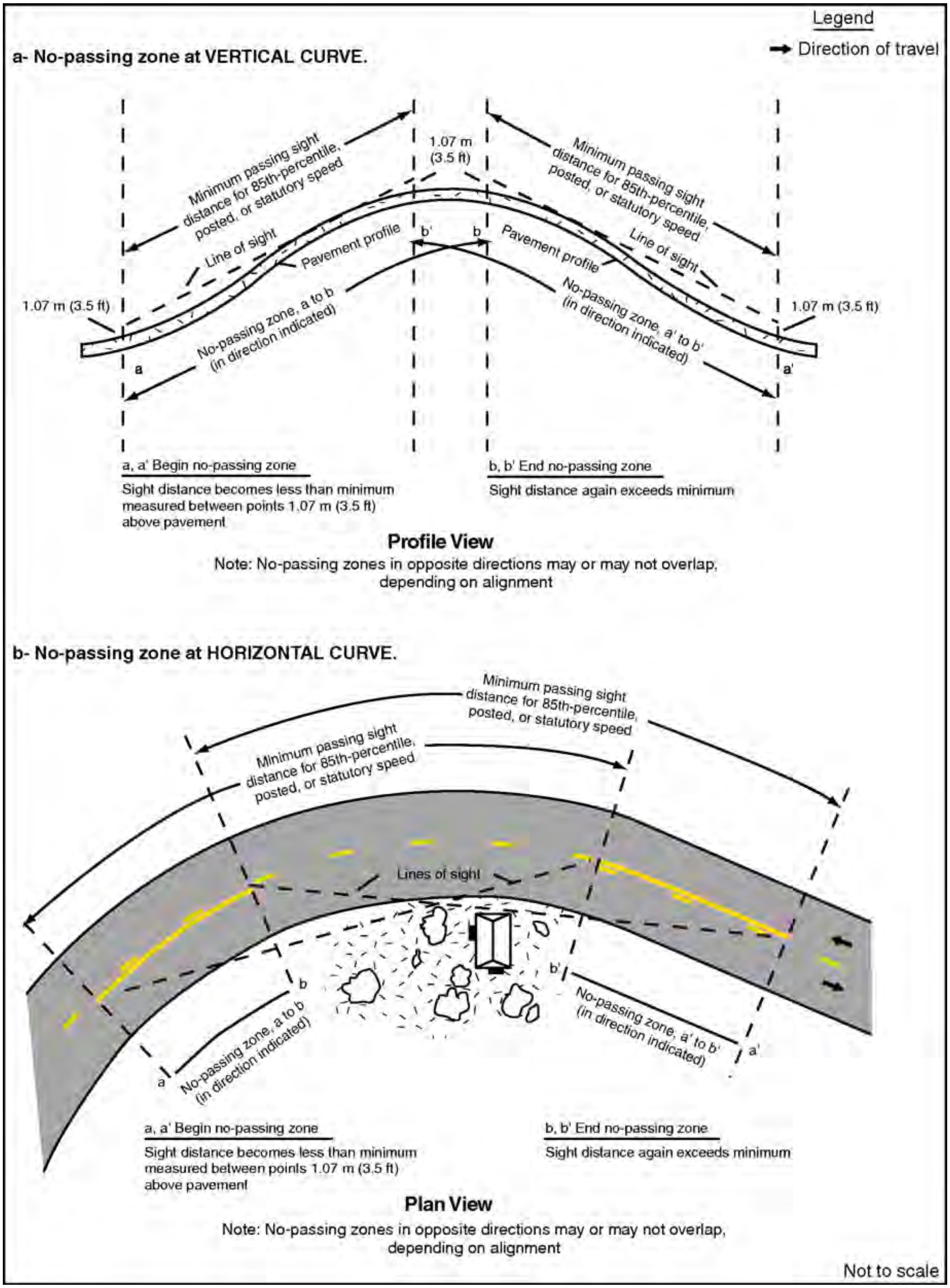
85th-Percentile or Posted or Statutory Speed Limit (mph)	Minimum Passing Sight Distance (feet)
25	450
30	500
35	550
40	600
45	700
50	800
55	900
60	1,000
65	1,100
70	1,200

How Should A No-Passing Zone Be Marked?

1. A no-passing zone shall be marked by either a one direction, no-passing marking or a two direction, no-passing marking as illustrated in Figures 8.5 and 8.6.
2. A 4-inch (100mm) space shall be used between the solid (barrier) line and a broken line. Double solid (barrier) lines typically have a 12-inch (300) space between lines, but a 4-inch (100mm) space may be used on narrow two-lane roads.
3. A broken line shall not be retraced or painted between the double solid lines.
4. The ends of no-passing zone barrier lines may be marked with white reference posts placed on the side of the roadway corresponding to the placement of the barrier line. Arrows on the posts indicate the beginning and ending of the barrier line (Figure 8.6).
5. On a three-lane highway where the single lane is being moved from one side of the road to the opposite side, a no-passing buffer zone shall be provided.
6. Where no-passing zone markings are warranted, they should generally be 500 feet (150m) or longer. Where necessary, the no-passing marking should be extended at the beginning of the zone to the 500 feet (150m) minimum.
7. Where the distance between successive no-passing zones is less than 400 feet (120m) the appropriate no-passing marking (one direction or two directions) should connect the zones.

[5] Source: Part III, MUTCD 2003

Figure 7-3: Method Of Locating And Determining The Limits Of No-Passing Zones At Curves[6]



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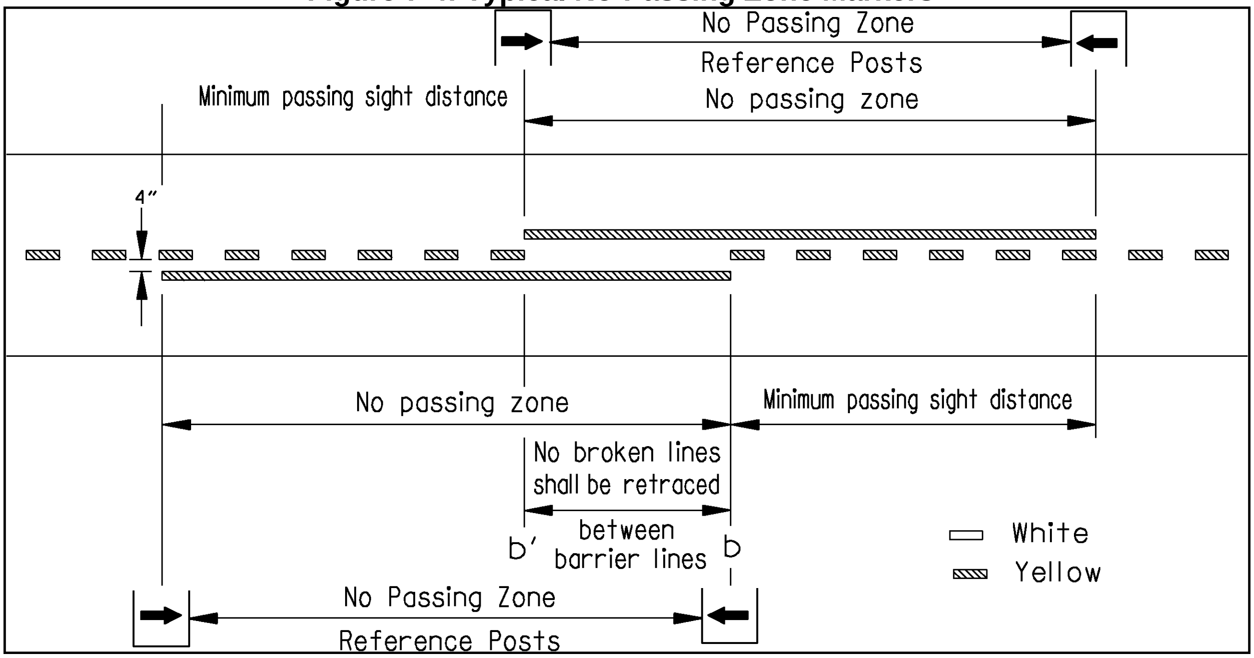
[6] Source: Part III, MUTCD 2003

Figure 7-4: Typical No-Passing Zone Markers[7]



How Should Channelization Lines And Islands Be Marked?

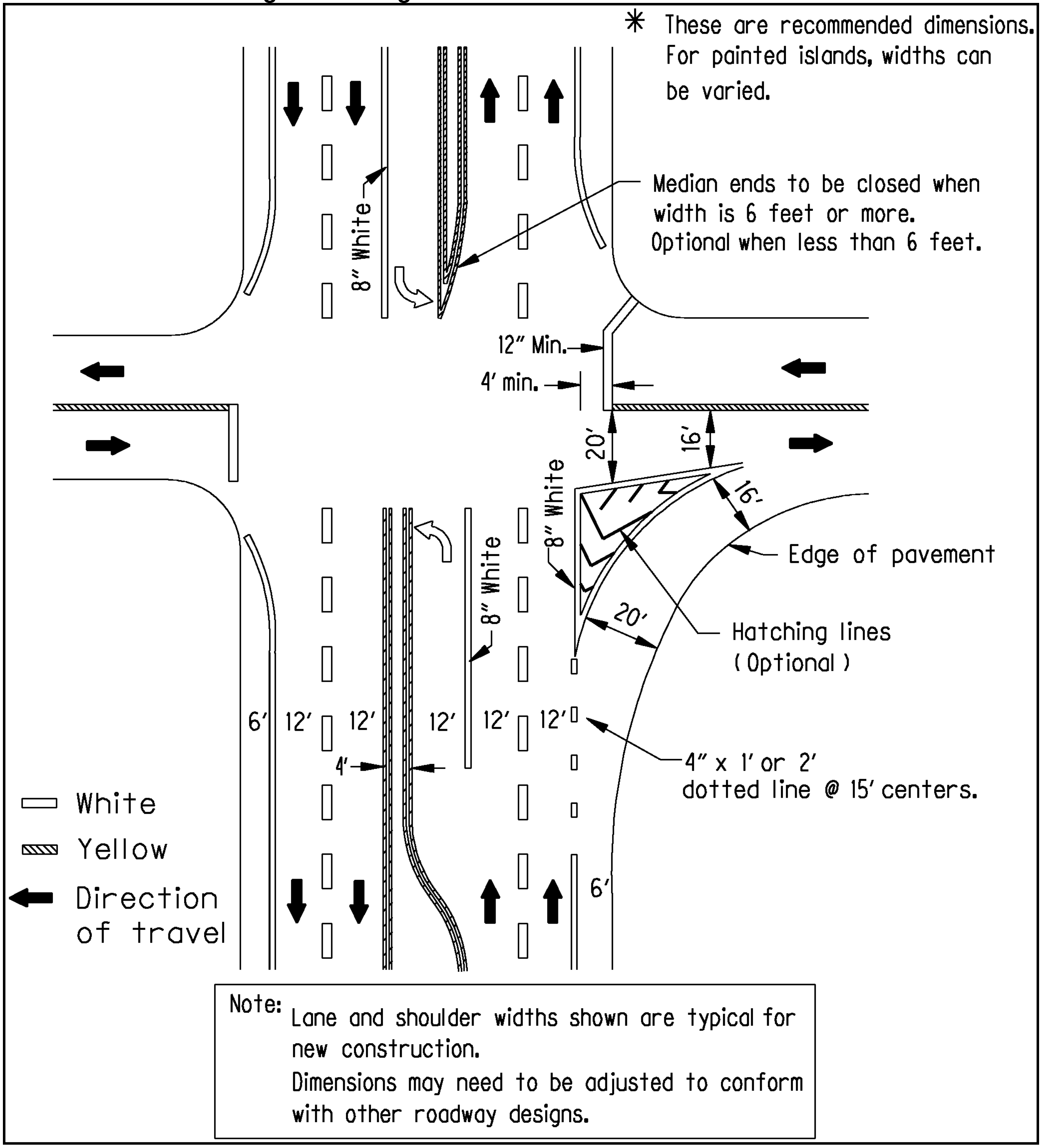
Channelizing lines should be 8-inch (200mm) solid white lines. They are used to limit sideways movements of traffic by discouraging crossing of this painted line. Included in this type of marking are painted islands with transverse lines or chevron markings where the traffic moves in the same direction on each side of the island (Figure 7-5). When painted, curbs on raised islands used to channelize traffic should also be white.

How Should A Median Island Be Marked?

All painted median islands 4 feet (1.2m) or greater in width are outlined by double yellow lines; islands less than 4 feet (1.2m) in width are outlined by single yellow lines (Figure 7-5). Where the median width is 6 feet (1.8m) or more and the median ends at an intersection the solid yellow stripes shall be joined. The stripes shall be joined as shown in Figure 7-5.

[7] Source: Traffic Line Manual, ODOT, 2003

Figure 7-5: Right Turn Lane With Painted Island[8]



How Should A Narrow Bridge Be Marked?

Figure 7-6 shows the typical pattern for painting a narrow bridge.

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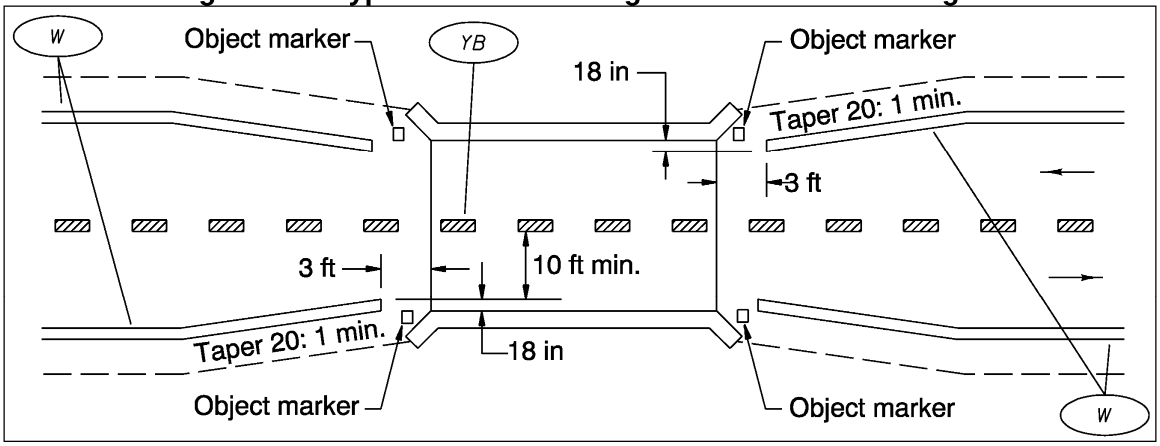
8 Source: Traffic Line Manual, ODOT, 2003

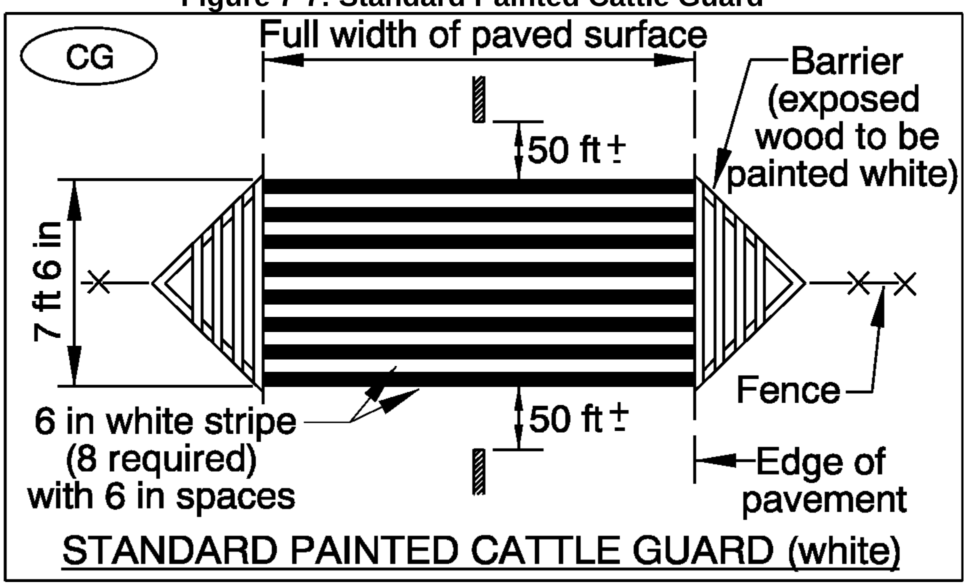
Figure 7-6: Typical Pavement Edge Line At Narrow Bridge[9]



How Should The Cattle Guards Be Marked?

Figure 7-7 shows the typical pattern for painting cattle guards. Prior to initial painting, the area to receive cattle guard should be paved from shoulder to shoulder as shown in Figure 7-7 so the painted cattle guard will extend completely across the roadway.

Figure 7-7: Standard Painted Cattle Guard[10]



When Should Object Markers Be Used?

Based on Section 3C.01 of the MUTCD 2003, when used, object markers shall consist of an arrangement of one or more of the following types:

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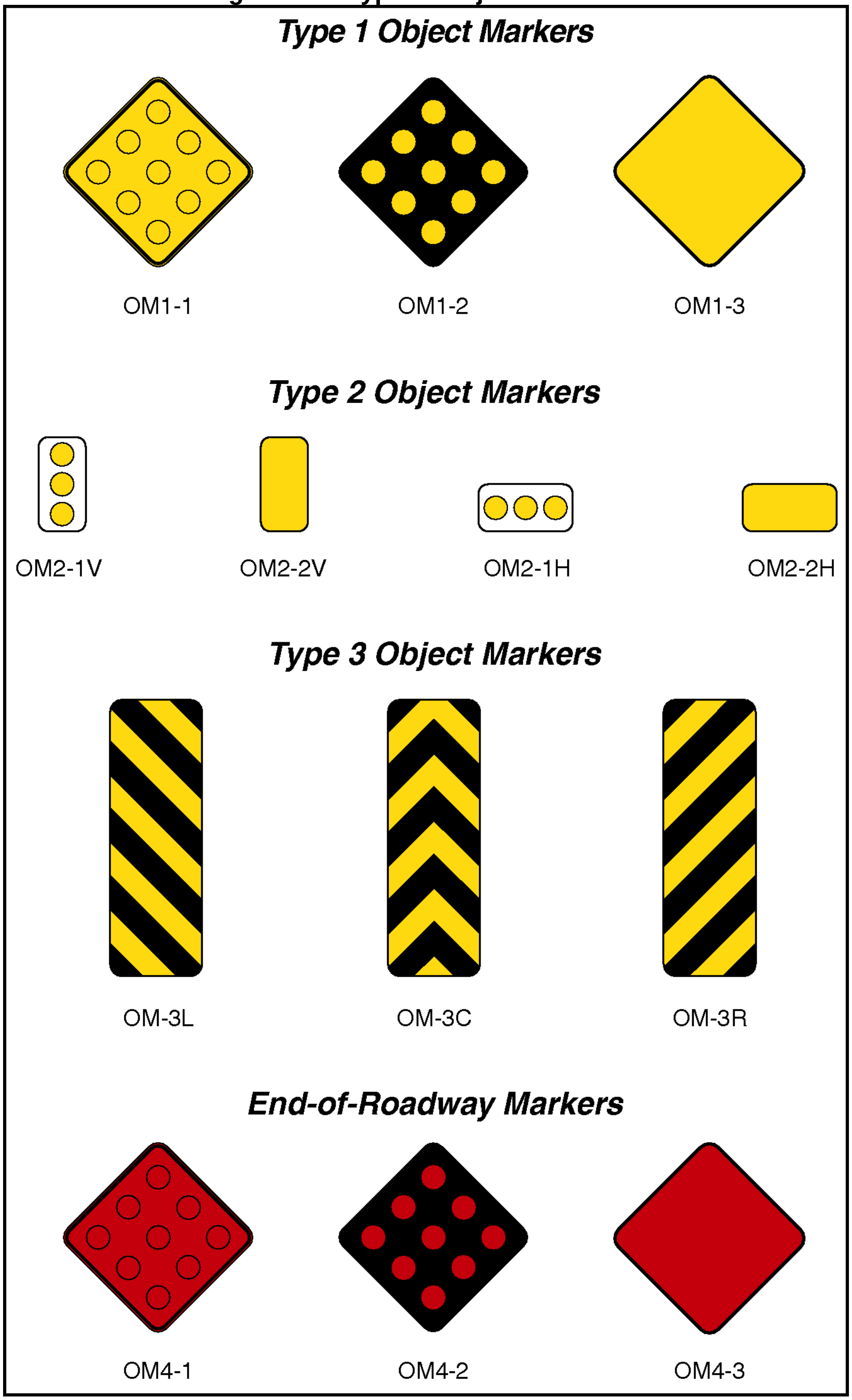
[9] Source: Traffic Line Manual, ODOT, 2007
[10] Source: Traffic Line Manual, ODOT, 2007

- **Type 1** - either a marker consisting of nine yellow retroreflectors, each with a minimum diameter of 3 inches (75 mm), mounted symmetrically on a yellow or black diamond panel 18 inches (450 mm) or more on a side; or on an all-yellow retroreflective diamond panel of the same size.
- **Type 2** - either a marker consisting of three yellow retroreflectors, each with a minimum diameter of 3 inches (75 mm), arranged either horizontally or vertically on a white panel; or on an all-yellow retroreflective panel, measuring at least 6 x 12 inches (150 x 0.3 m).
- **Type 3** - a striped marker, 12 x 36 inches (300 x 0.9 m), consisting of a vertical rectangle with alternating black and retroreflective yellow stripes sloping downward at an angle of 45 degrees toward the side of the obstruction on which traffic is to pass. The minimum width of the yellow stripe shall be 3 inches (75 mm).

The three types of object makers are shown in Figure 7-8.

Figure 7-8: Typical Object Markers[11]



[11] Source: Part III, MUTCD 2003

What Is The Mounting Height Of Object Markers?

Based on Section 3C.01 of the MUTCD 2003, when used for marking objects in the roadway or objects that are 8 feet (2.4 m) or less from the shoulder or curb, the mounting height to the bottom of the object marker should be at least 4 feet (1.2 m) above the surface of the nearest traffic lane.

When used to mark objects more than 8 feet (2.4 m) from the shoulder or curb, the mounting height to the bottom of the object marker should be at least 4 feet (1.2 m) above the ground.

When object markers or markings are applied to an object that by its nature requires a lower or higher mounting, the vertical mounting height may vary according to need.

What Type Of Markers Are Used For Marking Objects?

A. Markings for Objects in the Roadway

Obstructions within the roadway shall be marked with a Type 1 or Type 3 object marker. In addition to markers on the face of the obstruction, warning of approach to the obstruction shall be given by appropriate pavement markings (See Section 3C.02 of the MUTCD 2003).

To provide additional emphasis, large surfaces such as bridge piers may be painted with diagonal stripes, 12 inches (0.3 m) or greater in width, similar in design to the Type 3 object marker.

B. Markings for Objects Adjacent to the Roadway

Objects not actually in the roadway are sometimes so close to the edge of the road that they need a marker. These include underpass piers, bridge abutments, handrails, and culvert headwalls. In other cases there might not be a physical object involved, but other roadside conditions exist, such as narrow shoulders, drop-offs, gores, small islands, and abrupt changes in the roadway alignment, that might make it undesirable for a road user to leave the roadway, and therefore would create a need for a marker (See Section 3C.03 of the MUTCD 2003).

If Type 2 or Type 3 object markers are used, the inside edge of the marker shall be in line with the inner edge of the obstruction.

End-Of-Roadway Markings

The end-of-roadway marker is used to warn and alert road users of the end of a roadway in other than construction or maintenance areas. The end-of-roadway marker may be used in instances where there are no alternate vehicular paths.

The end-of-roadway marker shall be one of the following: a marker consisting of nine red retroreflectors, each with a minimum diameter of 3 inches (75 mm), mounted symmetrically on a red or black diamond panel 18 inches (450 mm) or more on a side; or a retroreflective red diamond panel 18 inches (450 mm) or more on a side (See Section 3C.04 of the MUTCD 2003).

The minimum mounting height of an end-of-the-roadway marker shall be 4 feet (1.2 m), and the appropriate advance warning sign should be used. In Oregon, red and white barricades are placed at the end of the roadways.

When Should Delineators Be Used?

Based on Section 3D.01 of the MUTCD 2003, delineators are particularly beneficial at locations where the alignment might be confusing or unexpected, such as at lane reduction transitions and curves. Delineators are effective guidance devices at night and during adverse weather. An important advantage of delineators in certain locations is that they remain visible when the roadway is wet or snow covered.

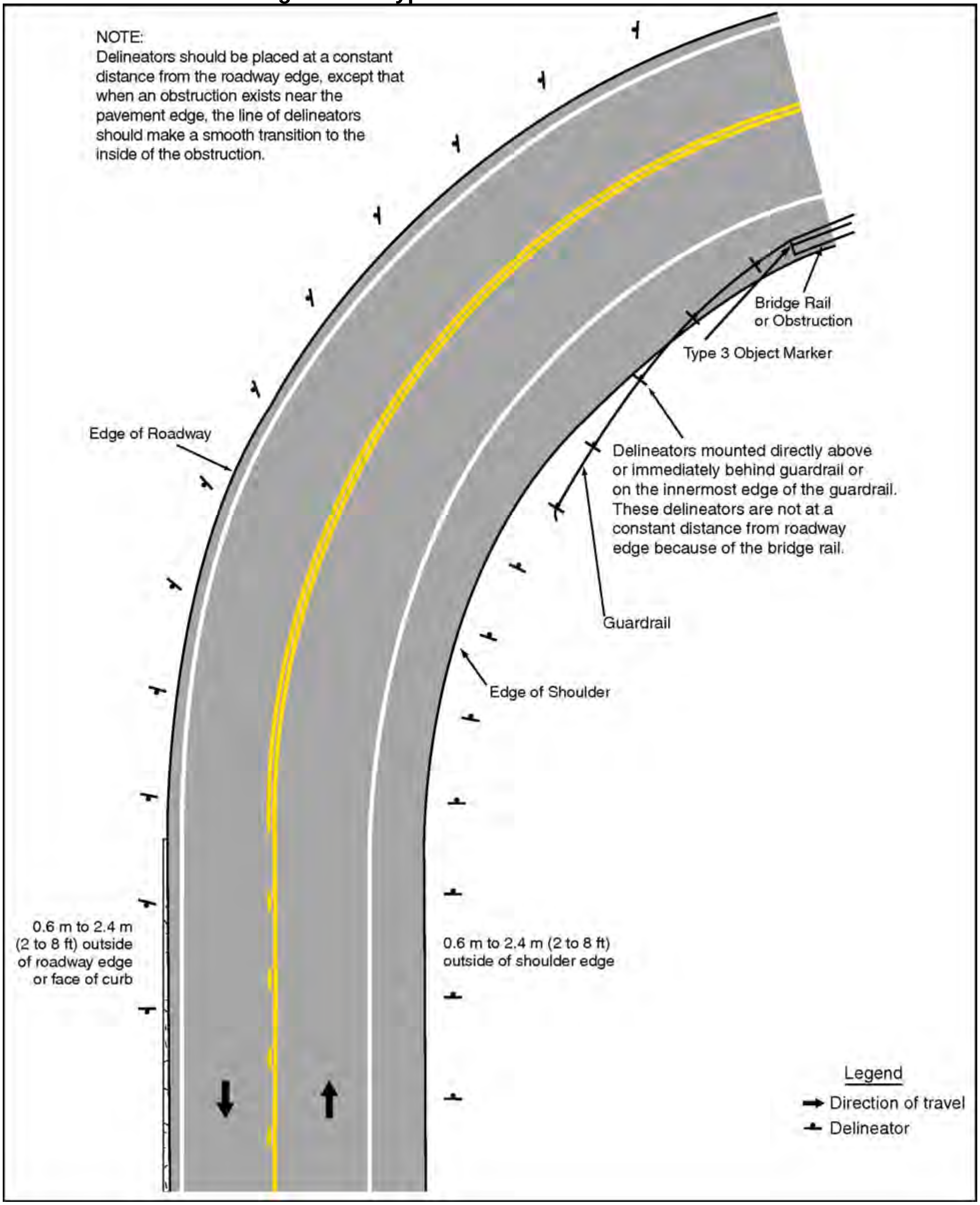
Delineators shall be retroreflective devices mounted above the roadway surface and along the side of the roadway in a series to indicate the alignment of the roadway. Delineators shall consist of retroreflector units that are capable of clearly retroreflecting light under normal atmospheric conditions from a distance of 1,000 feet (300 m) when illuminated by the high beams of standard automobile lights. Retroreflective elements for delineators shall have a minimum dimension of 3 inches (75 mm). The color of delineators shall conform to the color of edge lines.

Delineator Placement and Spacing

Delineators should be mounted on suitable supports so that the top of the highest retroreflector is 4 feet (1.2 m) above the near roadway edge. They should be placed 2 to 8 feet (0.6 to 2.4 m) outside the outer edge of the shoulder, or if appropriate, in line with the roadside barrier that is 8 feet (2.4 m) or less outside the outer edge of the shoulder.

Delineators should be placed at a constant distance from the edge of the roadway, except where a guardrail or other obstruction intrudes into the space between the pavement edge and the extension of the line of the delineators. In such a case, the delineators should be transitioned to be in line with or inside the innermost edge of the obstruction (See Figure 7-9).

Figure 7-9: Typical Delineator Installation[12]



[12] Source: Part III, MUTCD 2003

Markings For Roundabouts

Based on Section 3B.24 of the MUTCD 2003, roundabouts are distinctive circular roadways that have the following three critical characteristics:

A. A requirement to yield at entry which gives a vehicle on the circular roadway the right-of-way;
B. A deflection of the approaching vehicle around the central island; and
C. A flare or widening of the approach to match the width of the circular roadway.

Typical markings for roundabouts are shown in Figure 7-10. A yellow edge line may be placed around the inner (left) edge of the circular roadway. A white line should be used on the outer (right) side of the circular roadway as follows: a solid line along the splitter island and a dotted line across the lane(s) entering the roundabout. Edge line extensions should not be placed across the exits from the circular roadway.

Where crosswalk markings are used, these markings should be located a minimum of 25 feet (7.6 m) upstream for the yield line, or, if none, from the dotted white line. Lane lines may be used on the circular roadway if there is more than one lane.

Speed Hump Markings

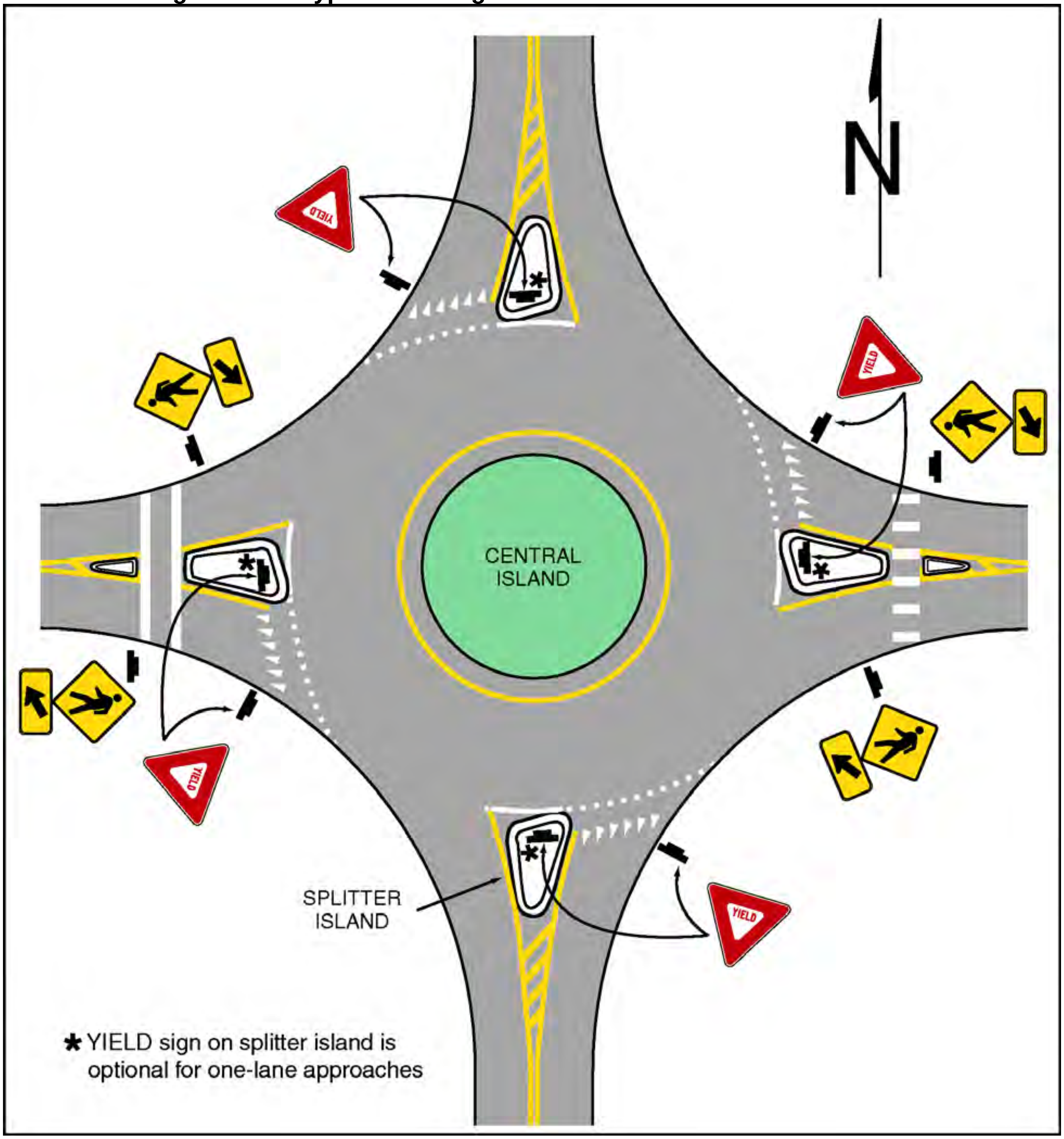
Based on Section 3B.26 of the MUTCD 2003, if used, speed hump markings shall be a series of white markings placed on a speed hump to identify its location. Speed humps, except those used for crosswalks, may be marked in accordance with Figure 7-11. The markings shown in Figure 7-12 may be used where the speed hump also functions as a crosswalk or speed table.

Advance Speed Hump Markings

If used, advance speed hump markings shall be a special white marking placed in advance of speed humps or other engineered vertical roadway deflections such as dips.

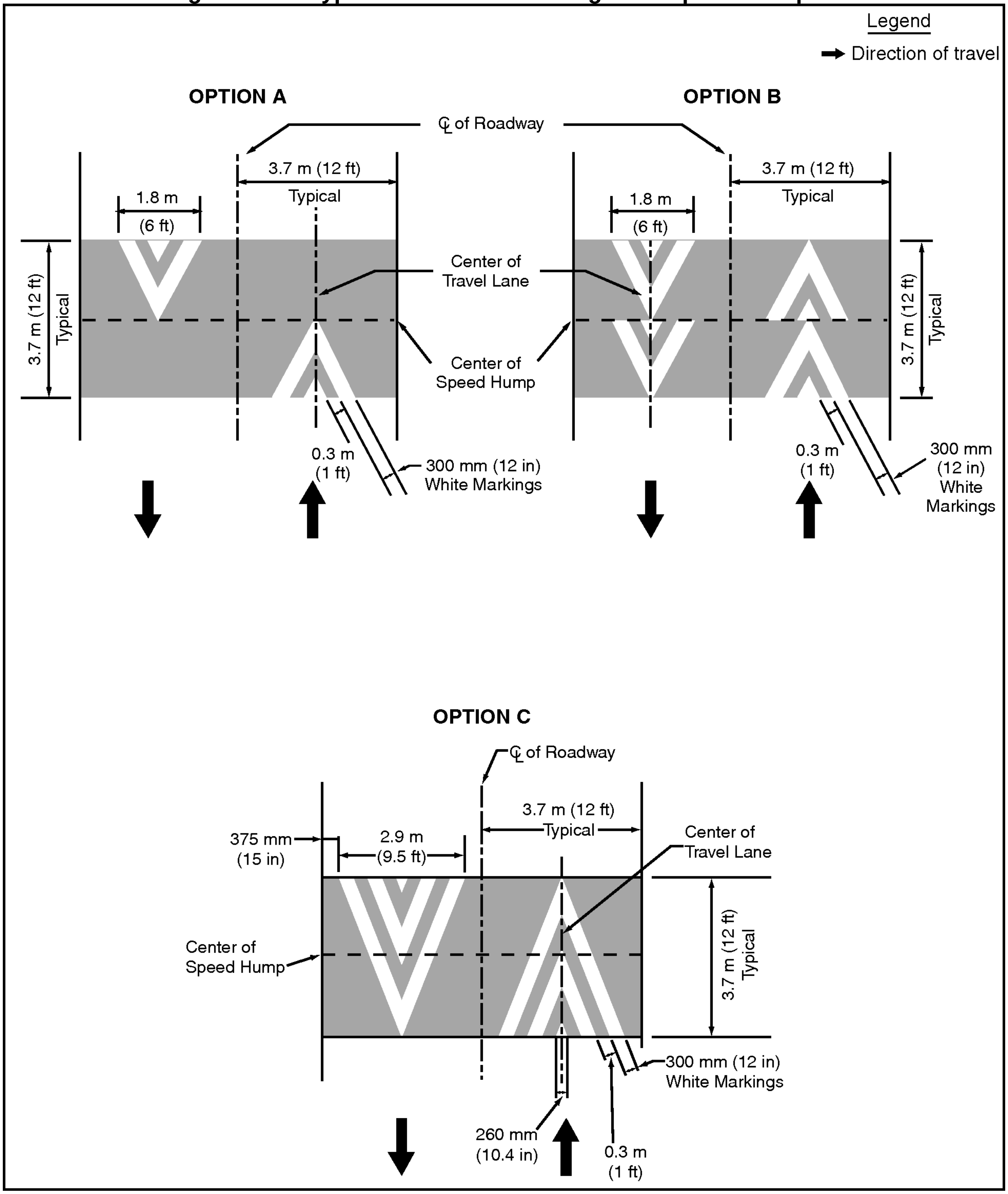
Advance speed hump markings may be used in advance of an engineered vertical roadway deflection where added visibility is desired or where such deflection is not expected (See Figure 7-13).

Figure 7-10: Typical Markings For Roundabouts With One Lane[13]



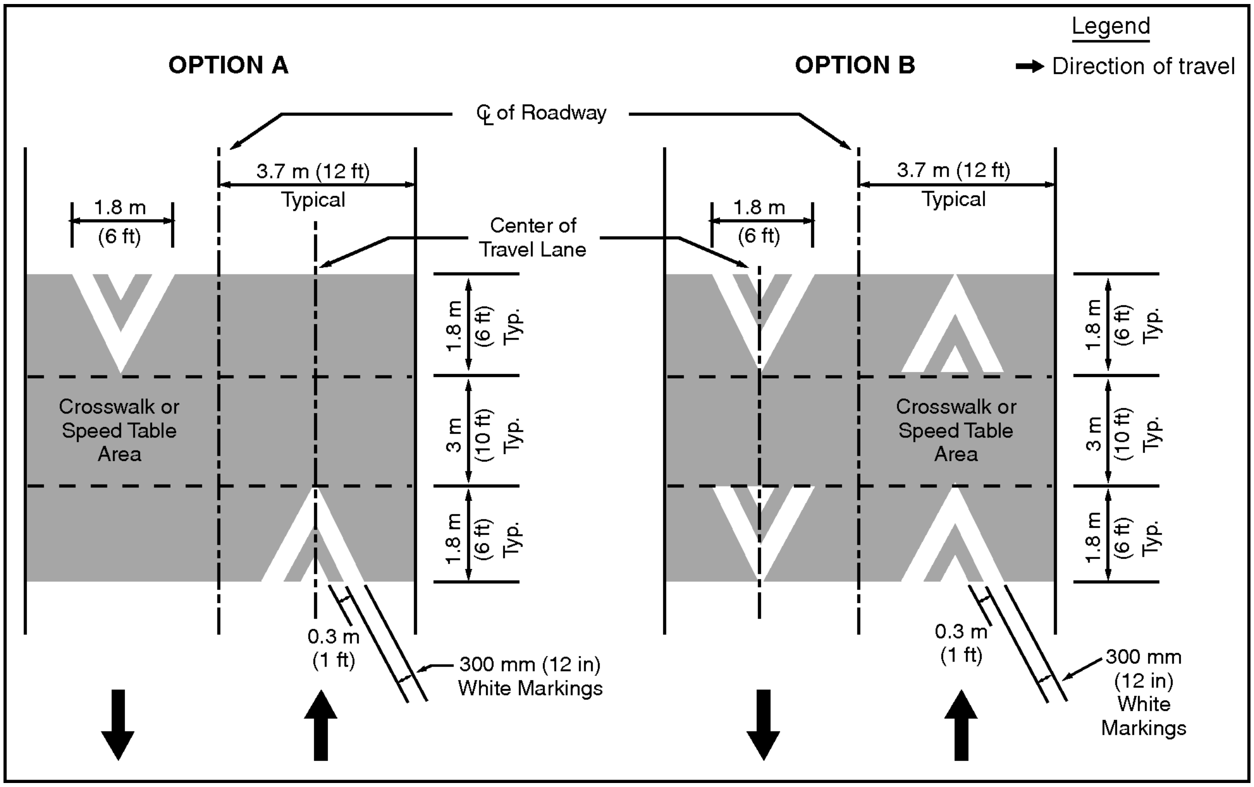
[13] Source: Part III, MUTCD 2003

Figure 7-11: Typical Pavement Markings For Speed Humps[14]



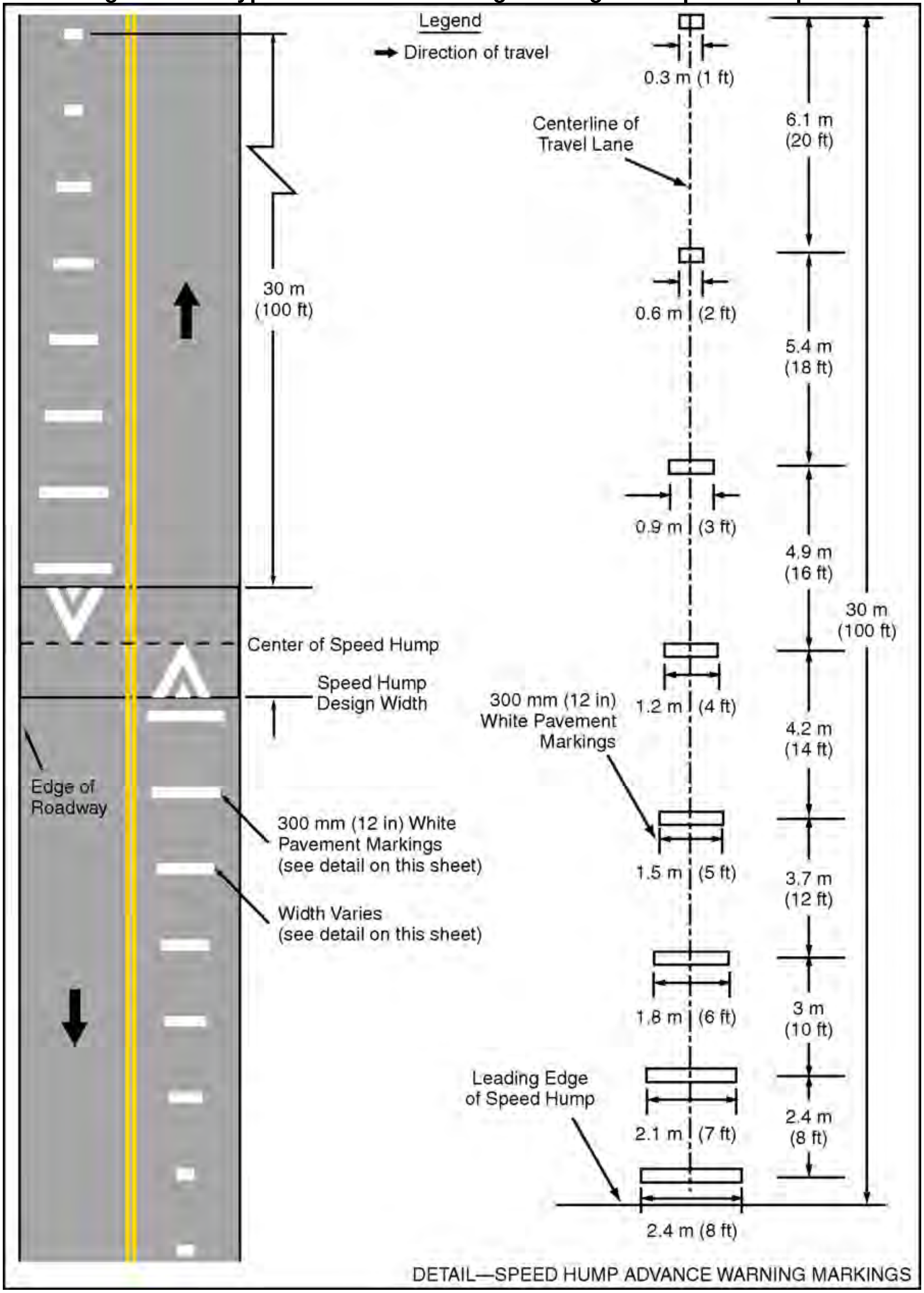
[14] Source: Part III, MUTCD 2003

Figure 7-12: Typical Pavement Markings For Speed Tables Or Speed Humps With Crosswalks[15]



[15] Source: Part III, MUTCD 2003

Figure 7-13: Typical Advance Warning Markings For Speed Humps[16]



[16] Source: Part III, MUTCD 2003

What Are Rumble Strips?

Rumble strips are devices used to alert the driver of a change in conditions ahead. Strips can consist of sawed grooves in the pavement, a series of transverse grouped thermoplastic strips, or some other means of creating a tire rumble effect. Successful applications have been in advance of sharp curves when motorists tend to approach too fast for existing conditions. Other applications are on approaches to stop signs, toll-booths, lane drops, and between opposing travel lanes (centerline). Rumble strips are also used to discourage use of shoulders and traversable medians.

How Are Rumble Strips Constructed?

There are three possible ways to construct rumble strips: rolled, milled, or formed. ODOT uses rolled-in and milled-in construction techniques to install rumble strips; milled-in construction techniques have been successfully installed by ODOT on many miles of highway. It is the preferred technique because studies have shown that this design is the very effective and uses less shoulder width for installation than other designs.

Shoulder Rumble Strips (SRS)[17]

Shoulder rumble strips are used to reduce the occurrence of run-off-road crashes by alerting drivers to lane departures. They are a possible countermeasure to fatigue and inattention. Their effectiveness on rural interstates has been demonstrated and documented in engineering studies, however they will not eliminate all run-off-road crashes especially those caused by excessive speed, sudden turns to avoid head-on collisions, or high angle encroachments.

Where is the most effective placement of SRS?

They should be installed near the edge line adjacent to relatively wide shoulders. This location provides motorists leaving the roadway at a shallow angle time and space to steer back onto the roadway safely.

Guidelines For Shoulder Rumble Strips Installation

All installations on new or existing bituminous shoulders shall be continuous milled-in SRS. To retrofit SRS on existing bituminous pavement, it must be in sufficiently good condition to effectively accept the milling process without raveling or deteriorating.

- Installations of SRS should leave approximately 4 feet (1.2 m) of useable paved shoulder for bicycle use as measured from the outside edge of the rumble strip to the shoulder edge.
- Input from the ODOT Bicycle-Pedestrian Program Manager will be requested on all proposed installations, especially in high bicycle use areas.

Do not install SRS:

- On bridge decks;
- Where the distance between the fog line and obstructions such as barrier or guardrail is 4 feet (1.2 meters) or less;

[17] Source: ODOT Traffic Manual, December 2007

- In sections with horizontal curvature except where the data indicate a significant single vehicle run-off-road collisions; or
- Within 200 feet in advance of an intersection with a public road or 50 feet after the intersection

Centerline Rumble Strips (CLRS)[18]

Centerline Rumble Strips (CLRS) are used to prevent head-on and sideswipe crashes where a median barrier is not feasible.

Do CLRS prevent crashes?

Experiences by other states indicate that CLRS are effective at reducing head-on and sideswipe crashes, however they will not eliminate all crossover crashes. Crashes caused by excessive speed, loss of control, and most weather related crashes would, most likely, not be eliminated. CLRS are intended to alert drivers that are drifting into on coming traffic due to fatigue, inattention, and other similar impairments.

Guidelines for CLRS installation on rural highways with or without medians:

- Crash history indicates a large number of head-on or sideswiping crashes that would be treatable with CLRS.
- Pavement improvement may be needed if the pavement is not capable of withstanding milled-in construction without deteriorating.
- Median width requirements:
    - A minimum median width of 4 feet is need for rumble strip installation.
    - Rumble strips should be installed at the center of medians that are 4 feet in width.
    - Rumble strips should be placed 12 inches inside each median stripe for medians greater than 4 feet in width.

Do not install CLRS on:

- Bridge decks
- In the area of intersections with public roads. Stop CLRS 25 feet (7.5 m) in advance of intersections
- CLRS should not be placed in areas with short distances between access points

Removal of rumble strips shall not be considered unless there is a clear and documented problem. Noise impacts to residential areas should be considered when installed on rural highways without medians.

Transverse Rumble Strips[19]

Transverse Rumble Strips are placed perpendicular to the travel direction in the travel lane. Their primary purpose is to enhance other traffic control devices to warn drivers of an unusual situation. Judgment should be exercised to ensure that transverse rumble strips are not overused.

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[18] Source: ODOT Traffic Manual, December 2007
[19] Source: ODOT Traffic Manual, December 2007

In what situations should transverse rumble strips be used?

They should be used to warn drivers on the approaches to intersections with poor compliance with STOP signs. They should be limited to areas that have a documented history of crashes and where more conventional treatments have proved ineffective. Transverse rumble strips are not effective as speed control and should not be used as speed control devices.

For more information about pavement marking please refer to the following publications:

1. Traffic Line Manual, ODOT, 2007, available at: http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/traffic_line_manual_web.pdf
2. Manual on Uniform Traffic Control Devices, available at: http://mutcd.fhwa.dot.gov/

Chapter 8: Sign And Mailbox Supports

Sign posts and their foundations should be so constructed as to hold the sign in a proper and permanent condition that resist mild displacement or vandalism. On the other hand, the post must be constructed in such a way that it will yield or break away after being hit even by a small vehicle.

There are three basic categories of sign support systems.

1. **Fixed-based supports** may be used when signs are placed in a shielded area or beyond the clear zone.
2. **Knock-down supports** can be used for small signs.
3. **Breakaway supports** are used with large and small signs and luminaires (poles for highway lighting systems).

Signs are classified as small or large:

Small roadside signs are those with a panel area of less than 50 square feet (4.65 square meters), supported by one or two posts less than six feet (1.8 m) apart. It is assumed that all supporting posts may be struck by an impacting vehicle. Most of the signs used on local roads are in this category.

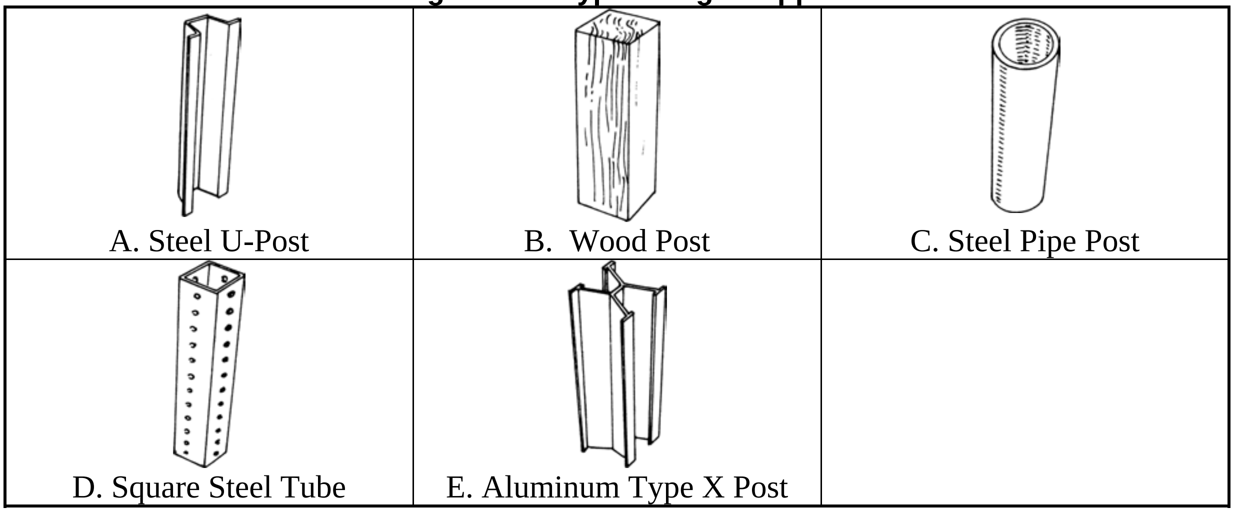
Large roadside signs are those with a panel area of 50 square feet (4.65 square meters) or more. They may be supported by up to three posts. When less than seven feet (2.1 m) of clearance is provided between posts, it must be realized that a vehicle could easily strike two adjacent posts. During a crash the sign supports must break away upon impact.

Oregon Department of Transportation (ODOT) has developed important drawings and design manuals for signs, signals, and mailbox supports. These publications include, “Oregon Standard Drawings, ODOT, 2008” and “ODOT Traffic Structures Design Manual, ODOT, 2009” The website for these publications is listed at the end of this chapter.

What Are The Various Types Of Sign Supports?

The wood post is the most widely used support in Oregon. Other commonly used types are the steel U-Post (also known as the flanged channel post), the steel pipe post and the square steel tube. An extruded aluminum type X post is also being used to a limited degree. Cross-sectional views of these five types of sign supports are shown in Figure 8-1.

Figure 8-1: Typical Sign Supports[1]



What Are Fixed-Base Supports?

Fixed-base supports are those that do not breakaway, bend over, or fracture safely when struck by a vehicle. They are usually imbedded in or rigidly attached to a foundation. These sign supports are rigid obstacles, and should not be used within the clear recovery zone unless protected by a guardrail or other type of barrier.

What Are Satisfactory Knock-Down And Breakaway Supports?

A. Knock-Down Supports

The knock-down post is a common type of support for small signs. These include various perforated square tubular supports, U-shape perforated supports, and wooden posts. The small-sized metal posts will break off or bend over, depending on the type of footing used; the wood supports will break. Because of the small size and flexibility of the posts, there is usually only minor damage to an automobile when it strikes one of these sign supports. However, a severe crash may occur if the driver loses control of the vehicle after impact.

Knock-down supports shall be designed for wind forces as stated in section 12 of the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.

B. Breakaway Supports

Breakaway supports are designed so that they can resist wind loads, yet fail at a pre-selected point when they are struck by an automobile. In this design, the post separates from the base. Some of the most popular sign supports are listed below.

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[1] Source: Traffic Control Devices Handbook, US DOT, FHWA, 1983

1. Wood Posts

Type of Wood Post	Maximum Size
Single wood post with no breakaway or weakening devices	4 x 4 inches (89 mm x 89 mm)
Dual wood post with 1.5 inches (38 mm) drilled holes	4 x 4 inches (89 mm x 89 mm)
Single wood post with 1.5 inches (38 mm) drilled holes	4 x 6 inches (89 mm x 140 mm)
Single wood post with 2 inches (50 mm) drilled holes	6 x 6 inches (140 mm x 140 mm)
Single wood post with 3 inches (75 mm) drilled holes	6 x 8 inches (140 mm x 190 mm)

Notes:

A. Wood post systems are grade 2 southern yellow pine.

B. All the metric units shown are actual lumber sizes, while the English units are nominal sizes for dressed lumber. The actual dimensions for the post lumber in English units are one half inch less than the values shown.

C. Drilled holes for the wood posts should be 4 inches (100 mm) and 18 inches (450 mm) above the groundline perpendicular to the roadway centerline.

D. If multiple support posts are used, they must be spaced 7 feet (2.10 m) or more apart.

Figure 8-2 illustrates the field installation of a typical wood post.

2. U-Channel Steel Post

The U Channel rolled steel post is the second most common small sign support. It is considered breakaway since it will bend, break, or pull out of the ground when it is hit.

Post Support

The post should be driven into the ground and not encased in concrete. Drive posts into the ground no more than 3.5 feet (1.05 m) to make it easier to pull out damaged posts.

Breakaway Devices

Splices can be installed at ground level. They allow the post to break off on impact. These devices improve safety when the post is hit. An alternate installation is to set a stub post in the concrete with a 4-inch (100 mm) length available to bolt the sign post as a base connection.

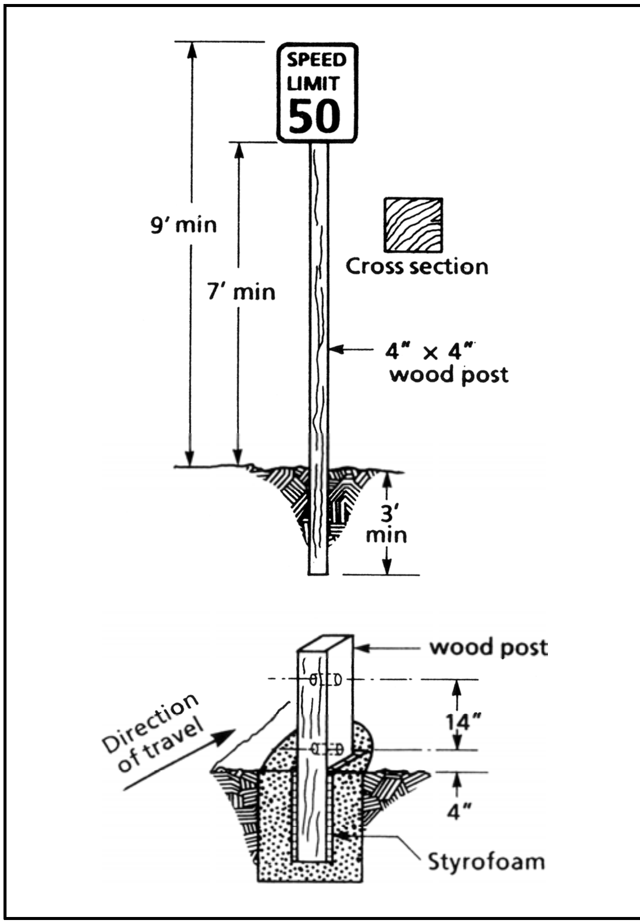
Common sizes used are:

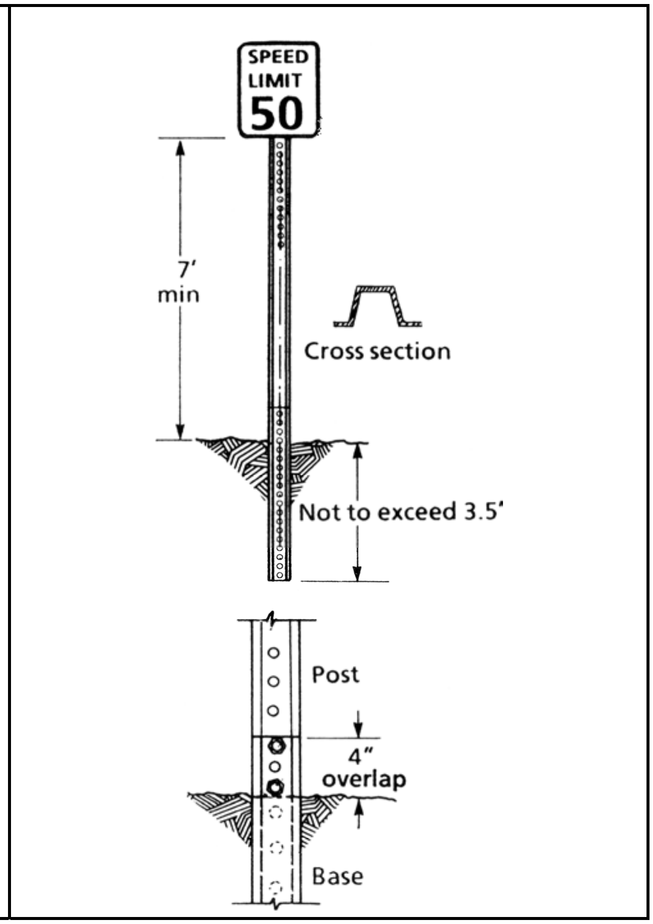
- 3 lb/ft (4.5 kg/m) and less, direct burial
- 3 lb/ft (4.5 kg/m) and less with 6-inch (150 mm) splice
- 4 lb/ft (4.5 kg/m) and less with 6-inch (150 mm) splice

Figure 8-3 illustrates the field installation of a typical U-Channel steel post.

Figure 8-2: Field Installation Of Wood Posts[2]

Figure 8-3: Field Installation Of U-Channel Steel Posts[3]





3. Steel Pipe Post

Steel pipe posts are used less frequently than wood or U channel posts, but are often used in cities to support small signs. Standard steel pipe, schedule 40, galvanized, should be used.

Post Support

Steel pipe posts can be driven directly into the ground to a depth of at least 3.5 feet (1.05 m). A steel plate (earth plate) measuring 4 inches X 12 inches X 0.25 inches (0.1 m x 300 mm x 4 mm) should be welded or bolted to the pipe (See figure) to keep the sign from rotating in the wind and to help in driving the post.

Breakaway Devices

A collar assembly (See Figure 7.4) is recommended if the sign is likely to be hit. A collar assembly consists of a concrete footing, usually 2.5 feet deep X 1 foot diameter (750 mm x 0.3 m), a 2 foot (0.6 m) pipe base (usually one pipe size larger than the post), and a pipe reduction

[2] Source: Maintenance of Small Traffic Signs, USDOT, FHWA, 1991
[3] Source: Maintenance of Small Traffic Signs, USDOT, FHWA, 1991

collar. When the pipe post is hit, the post usually shears off just above the collar. This speeds repair and replacement by installing a new collar. Often the pipe post can be reused.

Maximum Size:
Inside Diameter (ID) 2 inches (50 mm) without collar design
Inside Diameter (ID) 2.5 inches (62 mm) with collar design

Figure 8-4 illustrates the field installation of a typical pipe post.

4. Square Steel Tube (Perforated)

Another sign post is the square steel tube design. It is used in many localities.

Post Support

Posts can be driven into the ground. Do not place concrete around the post. A broken or damaged post is easier to remove if it is not driven or set into the ground more than three feet.

Breakaway Devices

Sleeve assemblies like the one shown in the lower drawing will increase the safety of a sign when it is hit and make it easier to repair. After the sign has been hit, the broken stub of the post can be removed from the base sleeve and a new sign post put back in place.

Maximum Size: 2.25 x 2.25 x 0.105 inches (57 x 57 x 2.67 mm)

Figure 8-5 illustrates the field installation of the square steel tube post.

Figure 8-4: Field Installation Of Steel Pipe Posts[4]

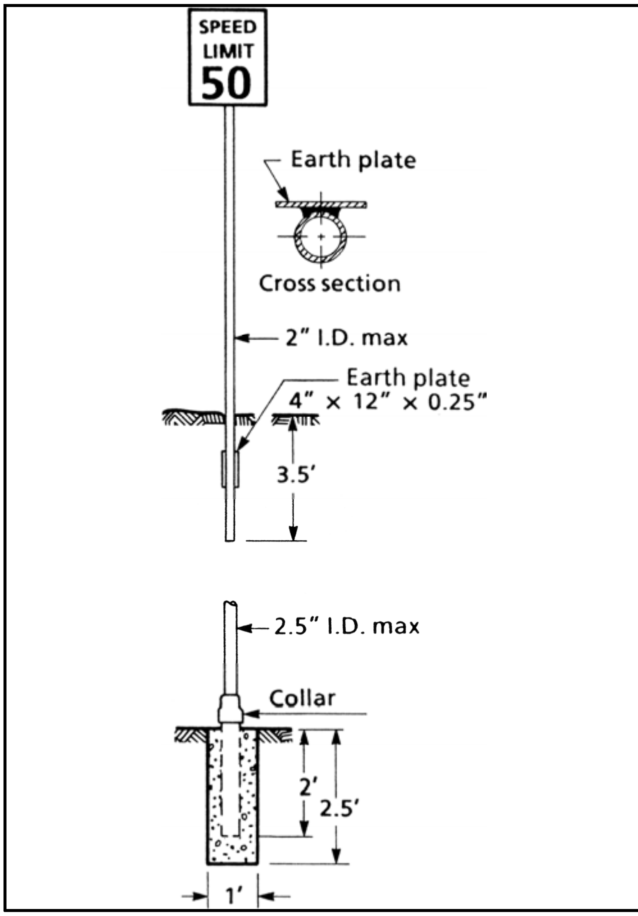
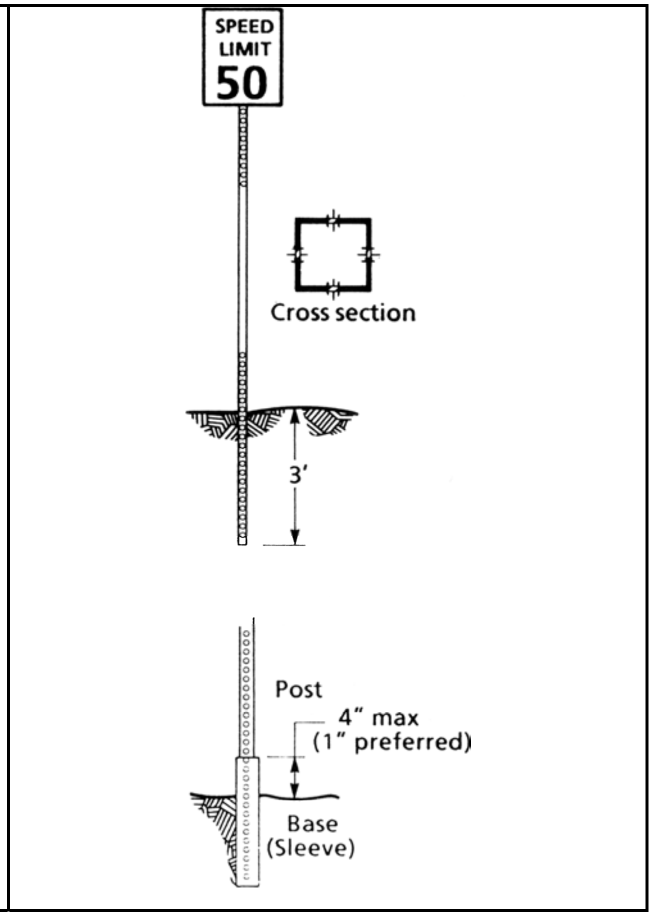


Figure 8-5: Field Installation Of Steel Tube Posts[5]



What Factors Should Be Considered For The Replacement Of Sign Supports?

A. Lateral Clearance

Lateral clearance for roadside signs is the distance from the edge of the traveled way to the nearest edge of the sign. All signs, regardless of size, constitute a potential hazard for the motorist due to the potential for collision with the sign support. Therefore, signs are normally located as far from the traveled way as practical while still providing good conspicuity. The following should be considered when determining the lateral clearance of signs:

- When possible, the larger signs should be located behind existing roadside barriers. Care should be taken to ensure that the sign support is outside the anticipated maximum deflection of the barrier.
- Based on the MUTCD, sign supports should be placed at least 6 feet (1.8 m) from the edge of the shoulder, or, if there is no shoulder, at least 6 feet (1.8 m) from the edge of

[4] Source: Maintenance of Small Traffic Signs, USDOT, FHWA, 1991
[5] Source: Maintenance of Small Traffic Signs, USDOT, FHWA, 1991

the traveled way. Unfortunately, on many local roads, it is often necessary to put the signs closer to the roadway so that they can be seen easily. In no case, however, should permanent signs be located within a shoulder area. At least 2 feet (0.6 m) of clearance should always be provided. Vegetation should be trimmed back to provide better lateral location and visibility.

- On urban streets, a lesser clearance may be necessary. Although 2 feet (0.6 m) is still recommended as a minimum, a clearance of 1 foot (0.3 m) from the face of the curb is permissible where sidewalk width is limited or where signs are mounted on existing poles close to the curb.

B. Longitudinal Placement

Where two or more signs are needed at approximately the same location, the order of priority that should be followed is: Regulatory signs first, then Warning signs, then Guide signs.

C. Ditches

Sign posts should not be placed in ditch areas. Out-of-control vehicles are often guided down the ditch line, directly into the sign post which will cause serious safety problems.

D. Side Slopes

Supports placed on cut slopes are generally safer than those placed on fill slopes. On fill slopes, a vehicle can become airborne as it crosses the hinge point.

Supports placed on roadside slopes must not allow impacting vehicles to snag on either the foundation or any substantial remains of the support. Surrounding terrain must be graded to permit vehicles to pass over any non-breakaway portion of the installation that remains in the ground or rigidly attached to the foundation. Figure 8-6 adopted from the AASHTO Standard Specifications for structural Supports for Highway Signs, Luminaires and Traffic Signals, illustrates the method used to measure the required 4-inch (100 mm) maximum stub height.

E. Curbs

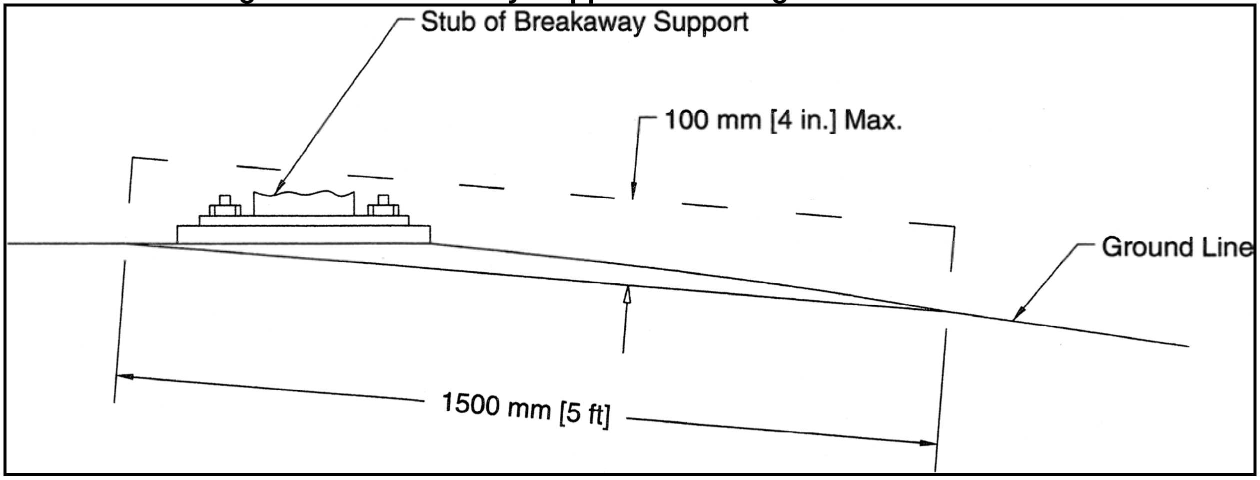
Ideally, since curbs are not considered to be traffic barriers, sign supports should not be located within 8 to 11 feet (2.4 to 3.0 m) of a curb face.

F. Soil Erosion

The loss of soil from around the base can result in stub posts and pedestals that are higher than the desirable 4-inch (100 mm) maximum height. Suggestions to avoid this problem are:

- Avoid placement of signs on steep slopes.
- Design post foundations to have only two inches of exposure, to provide a factor of safety.
- Pave or stabilize the area around the post foundation.

Figure 8-6: Breakaway Support Stub Height Measurements[6]



What Are Some Of The Common Problems With The Placements Of The Signs?

All locations for signs should be carefully checked before installing the sign to assure that there is no sight obstruction between the sign location and its intended point of observation by the motorist. Some of the common problem placements to be avoided are:

- Dips in the roadway;
- Beyond the crest of a hill;
- Where a sign could be obscured by parked cars;
- Where a sign would create an obstruction for pedestrians, joggers, or bicyclists;
- Where a sign would interfere with the driver's visibility of hazardous locations or objects;
- Where sign visibility would be impaired due to existing overhead illumination;
- Where signs are vulnerable to roadside splatter or to being covered with snow by plowing operations; and
- Too close to trees or other foliage that could cover the sign face or could grow and cover the sign face.

When Should An Overhead Sign Be Used?

Signs placed directly over the travel lanes to which they apply can be of great assistance in increasing communications with the driver. Their principal applications are on multilane, heavily traveled highways. Overhead signs are generally used:

- Where the message is applicable to a particular lane(s) over which the sign is placed.
- Where traffic or roadway conditions are such that an overhead mounting is necessary for adequate visibility.
- At, or just in advance of, a divergence from a heavily traveled roadway.
- Where narrow right-of-way does not provide adequate width for a sign installation.
- Where ground-mounted placement would create an undue roadside hazard.

[6] Source: AASHTO Roadside Design Guide, AASHTO, 2002

- Where, because of hazardous conditions, particularly effective guidance is need for the unfamiliar driver.

ODOT specifies for all overhead signs a vertical clearance from the pavement to the bottom of a sign to be 18 feet (5.4 m). Overhead signs are frequently placed on overcrossing structures. This reduces the cost of the installation. When the sign is mounted on an overcrossing structure, the vertical clearance to the sign need not exceed the vertical clearance of the structure. If the structure is less than 15 feet (4.50 m), a low clearance sign (W12-2) shall be used.

What Is The Priority For Sign Placement?

Some regulatory signs necessarily must be placed at a particular location, such as intersection traffic control devices (STOP or YIELD signs), and therefore have the highest priority. Warning signs, because of their critical impact on safety, take priority over other, more general regulatory signs. The location of guide signs is usually the least critical. An appropriate order of priority for signs is as follows:

- Location-critical regulatory signs (STOP, YIELD, Turn Prohibition, etc.)
- Warning signs
- Non-location-critical regulatory signs (speed limit, weight limit, etc.)
- Guide signs
- Motorist information signs.

The principles of “timing” and “primacy” suggest that signs be separated longitudinally so that drivers need only receive and respond to one message at a time. Different-purpose signs should not be located closer together (in feet) than 5 to 7 times the speed limit in mph if it can be avoided. However, in urban areas these guidelines cannot always be met, and as a minimum signs should be spaced at least three times the speed limit in mph. On freeways and expressways a minimum spacing of 800 feet (250 m) between all large guide signs should be maintained.

Is It Acceptable To Group Signs To Eliminate Extra Support?

While it is preferable to install signs individually (except where one sign supplements another or where guide signs must be grouped), it is sometimes advantageous to group signs to eliminate extra supports. Examples of acceptable sign groupings include:

- street name signs installed above STOP signs;
- a DIVIDED HIGHWAY sign or SIDE STREET TRAFFIC DOES NOT STOP sign installed below a STOP sign;
- ONE WAY signs on the sides of a post with a DO NOT ENTER sign; and
- a street name sign below an intersection related warning sign.

How Should Signs Be Oriented?

Signs are normally installed at approximately right angles to the direction of and facing the traffic that they are intended to serve. Parking signs are an exception to this rule. Some parking signs may be installed at an angle of between 30 to 45 degrees to the direction of traffic. Except for parking signs, post mounted signs located close to the traveled way should be turned slightly away from the roadway to avoid glare reflection of headlights off the sign face directly back into the driver's eyes. An angle of about 93 degrees to the line of approaching traffic has been found satisfactory for sign locations from 12 to 14 feet (3.6 to 4.2 m) from the pavement edge. On curved alignments, the angle should be determined by the course of approach traffic, rather than by the roadway edge at the point where the sign is located. On grades it may be desirable to tilt a sign forward or back from the vertical to improve the viewing angle. The face of all overhead signs should be tilted upward about 3 (degrees) to reduce specular glare (mirror reflection), enhancing nighttime readability.

What Should Be The Mounting Height For Post-Mounted Signs?

To ensure good visibility, the vertical clearance from the bottom of the sign to the surface of the roadway should be as specified in the MUTCD. A minimum clearance of 7 feet (2.1 m) to the bottom of any sign panel must be provided in locations where pedestrians are likely to frequent or in locations where parked cars or vehicles in adjacent lanes may block the view of the sign. Oregon requires that signs in rural areas be installed at a minimum height of 7 feet (2.1 m) measured from the bottom of the sign to the near edge of pavement. Advisory plaques may be installed below the primary sign at a 6 feet (1.8 m) height.

When the sign is within the clear zone and not shielded by a crashworthy barrier, the AASHTO Roadside Design Guide indicates that posts of sufficient length should be used so that the top of the sign panel is at least 9 feet (2.7 m) above the adjacent terrain to ensure that the top of the sign does not penetrate the windshield of an impacting vehicle. A minimum of 7 feet (2.1 in) of clearance above the terrain should also be provided to the bottom of large roadside signs with multiple support posts to allow the safety mechanism (e.g., breakaway, slip base, yielding) of the support system to function properly.

What Factors Should Be Considered For Mailbox Supports?

There may be as many as 20 million mailboxes on rural roads and streets and another 10 to 15 million on suburban streets. The AASHTO's 2001, issue of **A Guide for Erecting Mailboxes on Highways (Mailbox Guide)** contains information on mailbox supports, and their location on the roadside. Briefly, the following guidelines should be used for mailbox supports:

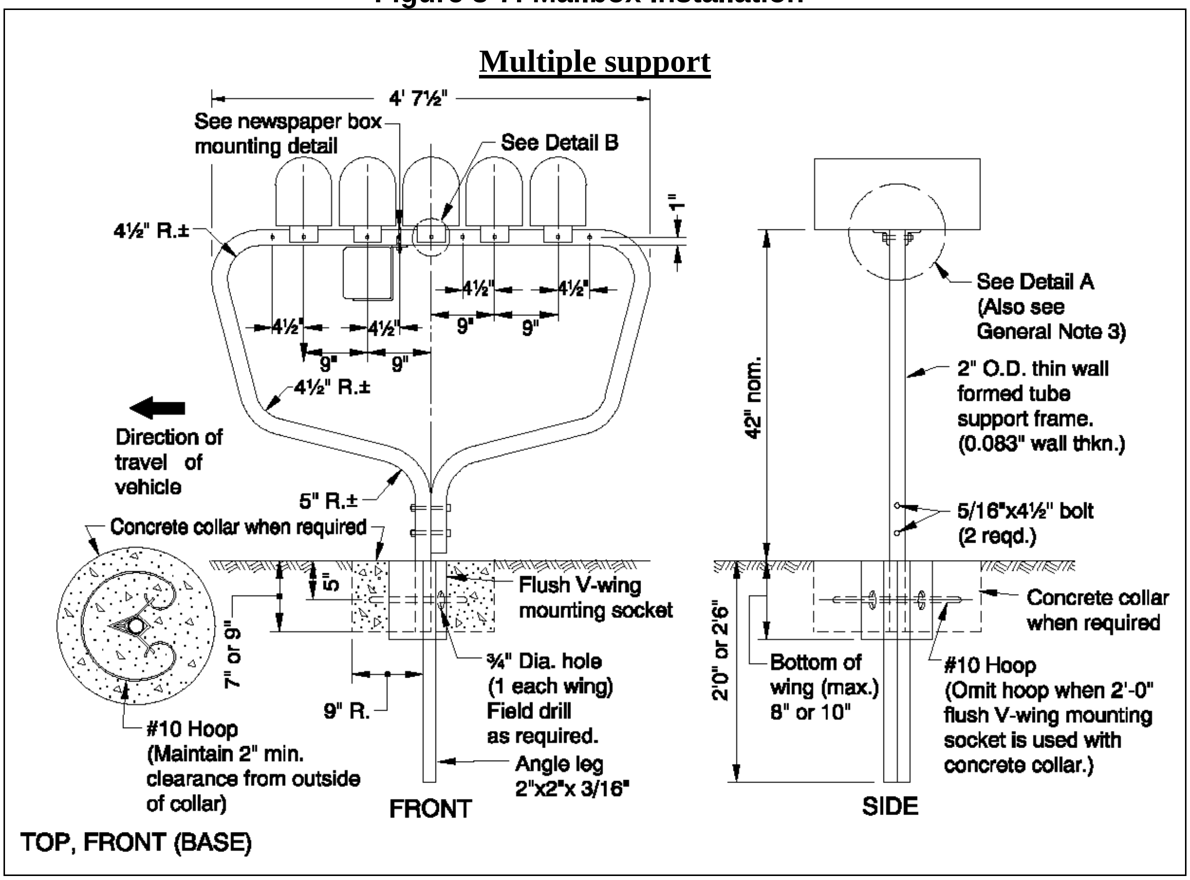
- Mailbox supports are nominal 4 x 4-inch (100 x 100 mm) or 4.5-inch (112 mm) diameter wood posts or metal posts with no greater than a 2-inch (50 mm) diameter standard strength steel pipe, with a height of 42 inches (1.05 m) to the bottom part of box, embedded no more than 24 inches (0.6 m) into the ground with a lateral distance of 30 inches (0.75 m) from the edge of pavement. For example, a single 2 pound per foot U-channel support would be acceptable under this structural limitation. Mailbox supports should not be set in concrete unless the support design has been shown to be safe by crash tests.
- Mailbox-to-post attachments should ideally prevent mailboxes from separating from their supports under vehicle impacts. The mailbox guide contains information on attachments that prevent their separation.
- Multiple mailbox installations should meet the same criteria as single mailbox installations. Multiple support installations should have their supports separated a

minimum distance of 4 feet (1.20m) above ground. This distance is 12 inches (0.3 m) for the single support. This will reduce interaction between adjacent mailboxes and supports.

Neighborhood delivery and collection box units are owned by the postal service and are a specialized type of multiple mailbox installation that should be located outside the clear zone, particularly on high speed or heavily traveled highways. It is incumbent upon local highway officials and local postal officials to communicate with each other to ensure that this type of installation does not become a safety hazard to the motorist.

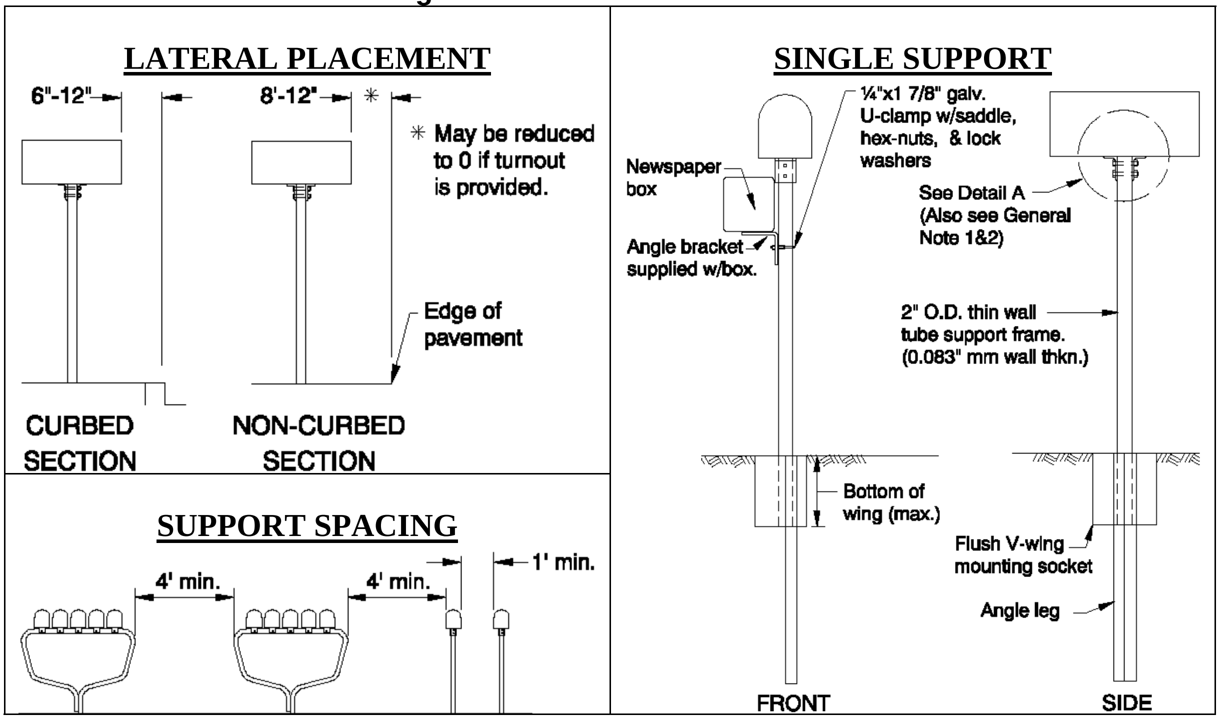
Figure 8-7 shows the mailbox installation guidelines for the single support and the new ODOT approved multiple metal support.

Figure 8-7: Mailbox Installation[7]



7 Source: ODOT, Standard Drawings

Figure 8-8: Mailbox Installation[8]



Best Practice For Selection And Maintenance Of Utility Poles

Fixed object collisions account for approximately 25% of all motor vehicle fatalities. Utility poles are the second most frequently struck fixed object resulting in approximately 1100 to 1200 fatalities per year. In addition to fatalities, it is estimated that 65,000 to 110,000 individuals are injured each year from utility pole collisions.

Utility poles are massive fixed objects that are frequently placed relatively close to the traveled way. Their huge mass and proximity to the roadway results in utility pole crashes having the highest probability of injury, and accounts for more than 50% of all single vehicle run-off roads injury crashes. The magnitude of utility pole crashes has resulted in efforts to reduce both the frequency and severity of utility pole crashes. Corrective actions that have been taken to alleviate the problem include the following:

- Increasing the lateral separation, or offset, between poles and traffic flow.
- Placing the utilities carried by the poles underground.
- Placing longitudinal barriers in the vicinity of utility poles.
- Reducing the number of poles by allowing multiple use and increased spacing.
- Reducing crash potential by improved roadway alignment, skid resistance pavement, improved delineation and pole placement on the inside of horizontal curves.
- Undergrounding utilities, though expensive to install

[8] Source: ODOT, Standard Drawings

Summary Of Breakaway Utility Pole Selection

Identify utility pole locations with either a history or a high probability of vehicle impacts. This identification requires the inspection of crash summaries, individual crash reports, site review and contacting local personnel.

- Site characteristics with a higher-than-average pole crash history or high accident potential are candidates for utility pole crashes. Site characteristics which increase crash potentials include poles located on the outside of horizontal curves, along long straight roadway segments, and on the right side of downgrades.
- Only consider the installation of a breakaway timber utility pole when preferred alternatives such as pole removal or relocation have been investigated and found to be impractical.
- Do not replace poles which provide service across the roadway, have mounted transformers, are located in an area of pedestrian activity, have insufficient recovery area, or are adjacent to other fixed objects.

For more information about sign supports and utility poles, please refer to the AASHTO Roadside Design Guide, 2002.

For more information about sign supports and design, please refer to the following ODOT publications:

1. Oregon Standard Drawings, ODOT, 2008, http://www.oregon.gov/ODOT/HWY/ENGSERVICES/traffic_drawings.shtml#Traffic_600___Supports
2. ODOT Traffic Structures Design Manual, 2009, http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/Traffic_Structures_Design_Manual_May_2009.pdf

Chapter 9: Flashing Beacons

Flashing beacons are used as a supplement to other traffic control devices and shall consist of one or more signal sections of a standard traffic signal face with a flashing CIRCULAR YELLOW or RED signal indication in each signal section. Their most common use is at an intersection. This Chapter information deals with the use and installation of flashing beacons.

A complete discussion on the subject of flashing beacons will not be presented in this Handbook. Additional information is available in Part IV, Chapter 4K of the **Manual on Uniform Traffic Control Devices (MUTCD), 2003 Edition**.

What Are Typical Applications Of Warning Beacons?

Typical applications of Warning Beacons include the following:

1. At intersections where warning is required but where traffic and physical conditions do not justify conventional signals. A flashing yellow display is provided to the major roadway, and a flashing red is provided to the minor roadway, supplementing its normal STOP sign control.
2. To warn motorists of a particularly hazardous condition, such as a sharp curve or turn, an obstruction in or immediately adjacent to the roadway, a narrow bridge or underpass, or an intersection ahead hidden from view because of a vertical curve.
3. Flashing beacons can be used in advance of isolated signalized intersections such as the approach to the first signal encountered when entering an urban area from a high-speed rural roadway.
4. As supplement to advance warning signs.
5. In school zones where reduced speed limits may be enforced during specific times of certain days.
6. As emphasis for mid-block crosswalks.
7. As a special warning to specific drivers, such as low-clearance bridge.
8. As supplements to regulatory signs, except STOP, YIELD, DO NOT ENTER, and SPEED LIMIT signs.
9. A Warning Beacon shall be used only to supplement an appropriate warning or regulatory sign or marker. The beacon shall not be included within the border of the sign except for SCHOOL SPEED LIMIT sign beacons.
10. Warning Beacons, if used at intersections, shall not face conflicting vehicular approaches.
11. If an obstruction is in or adjacent to the roadway, illumination of the lower portion or the beginning of the obstruction or a sign on or in front of the obstruction, in addition to the beacon, should be considered.

Warning Beacons should be operated only during those hours when the condition or regulation exists.

Can A Flashing Beacon Be Used To Provide Better Visibility For An Intersection?

A flashing beacon will provide better identification of an intersection. It should be remembered that a flashing beacon should be used to supplement other traffic control devices when these devices, by themselves, do not prove effective. One of the more common locations for using this device is at an intersection that is hidden from the view of approaching motorists. In this situation a flashing yellow beacon would be displayed to traffic entering from the cross street. By reserving the use of flashing beacons for select locations, they will serve a useful function. If they are used at locations where they are not warranted, they will soon lose much of their effectiveness because of overuse.

What Is An Intersection Control Beacon?

An Intersection Control Beacon shall consist of one or more signal faces directed toward each approach to an intersection. Each signal face shall consist of one or more signal sections of a standard traffic signal face, with flashing CIRCULAR YELLOW or CIRCULAR RED signal indications in each signal face. They shall be installed and used only at an intersection to control two or more directions of travel.

Application of Intersection Control Beacon signal indications shall be limited to the following:

1. Yellow on one route (normally the major street) and red for the remaining approaches.
2. Red for all approaches (if the warrant for a multi-way stop is satisfied).
3. Flashing yellow signal indications shall not face conflicting vehicular approaches.
4. A STOP sign shall be used on approaches to which a flashing red signal indication is shown on an Intersection Control Beacon.
5. An Intersection Control Beacon should not be mounted on a pedestal in the roadway unless the pedestal is within the confines of a traffic or pedestrian island.
6. Supplemental signal indications may be used on one or more approaches in order to provide adequate visibility to approaching road users.
7. Intersection Control Beacons may be used at intersections where traffic or physical conditions do not justify conventional traffic control signals but crash rates indicate the possibility of a special need.
8. An Intersection Control Beacon is generally located over the center of an intersection; however, it may be used at other suitable locations.

What Is The Size Of The Flashers And How Should They Be Mounted?[1]

1. Each signal unit lens shall have a visible diameter of not less than 8 inches (0.2 m). Where two lenses are used, they shall have not less than 8-inches (0.2 m) visible diameter size, aligned vertically and flashed alternately. When a single lens is used, it can either be 8 inches (0.2 m) or 12 inches (0.3 m) in diameter.

[1] Source: Part 4, MUTCD 2003

2. If a beacon used to identify a hazard is used alone and located at a roadside, the bottom of the beacon unit shall be at least 8 feet (2.4 m) and no more than 12 feet (3.6 m) above the pavement.
3. An Intersection Control Beacon is generally suspended over the center of the intersection. The minimum distance above the pavement shall be at least 15 feet (4.5 m) and less than 19 feet (5.7 m). If pedestal mounting is used, the bottom of the signal head shall be at least 8 feet (2.4 m) but no more than 15 feet (4.5 m) above the pavement.
4. Beacons shall be flashed at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall not be less than one-half and not more than two-thirds of the total cycle.
5. If a 150-watt lamp is used in a 12-inch (0.3 m) lens yellow flashing beacon and the lamp is so bright it causes excessive glare during night operation, an automatic dimming device may be used to reduce the brilliance of flashing yellow signal indications during night operation.
6. If a Beacon Signal is used to supplement a warning or regulatory sign, the edge of the beacon signal housing should normally be located no closer than 12 inches (0.3 m) outside of the nearest edge of the sign.

Can A Flashing Beacon Be Used To Control Excessive Speed?

Installation of a yellow flashing beacon will not necessarily cause motorists to reduce their speed. If reduced speed is necessary for safety, some other type of solution should be considered. If the location has poor visibility, consideration should be given to a change in the roadway alignment, relocation of the road, or removal of the sight obstruction.

What Information Is Necessary To Determine If A Flashing Beacon Is Warranted?

1. A Field Observation should be made on all approaches to the intersection to determine visibility and the location of any sight distance obstructions.
2. The crash history of the intersection should be reviewed to determine the nature of any crashes that have occurred. A flashing beacon may be considered on high-speed roads:
    a. If four or more right angle plus left turn crashes occur in a year.
    b. If six or more right angle plus left turn crashes occur in two years.

What Are Other Uses For Flashing Beacons?

In addition to intersection and warning sign applications, flashing beacons are used for:

1. Speed Limit Sign Beacons – intended for use with fixed or variable speed limit signs. The flashing speed limit beacon may be used to indicate that the speed limit shown is in effect. The beacon can be included within the border of a School Speed Limit Sign.
2. Stop Sign Beacon – mounted above the STOP sign, this beacon provides added visibility and emphasis. The bottom of the signal housing of a Stop Beacon shall be not less than 12 inches (0.3 m) nor more than 24 inches (0.6 m) above the top of a STOP sign.
3. Obstructions – flashers can be mounted on traffic islands to warn of a hazard located in or adjacent to the roadway.

4. Barricade Warning Lights – barricade lights at highway construction sites are portable, lens directed, enclosed lights and yellow in color, they can either be flashing or be steadily burning.

For more information about flashing beacons, please refer to Part IV, Chapter 4K of the MUTCD 2003.

Chapter 10: Traffic Signals

This Chapter contains information concerning warrants and data for the installation and operation of traffic signals. The main purpose of a traffic signal is to allocate right-of-way at an intersection by alternately directing traffic to stop and proceed. A well designed and installed signal will provide for orderly traffic movement, reduce certain types of crashes, and permit motorists to safely cross or enter the traffic stream.

A complete discussion on the subject of traffic signals will not be presented in this Handbook. Additional information is available in Part IV of the **Manual on Uniform Traffic Control Devices (MUTCD), 2003 Edition**, the ODOT Traffic Signal Policy And Guidelines, 2006, the ODOT Signal Design Manual, 2007, and other related publications that are listed at the end of this chapter.

A careful analysis of traffic operations and other factors at a large number of signalized and unsignalized intersections, coupled with the judgment of experienced engineers, have provided a series of warrants that define the minimum conditions under which signal installations may be justified.

Traffic signals can not be installed unless one of the warrants specified by the MUTCD has been satisfied. These warrants are based on a number of factors including: vehicular volume, pedestrian volume, school crossing, crash experience, vehicular speeds, population of the city, and number of traffic lanes. **The satisfaction of a warrant or warrants is not in itself justification for a signal. A traffic engineer study must be conducted coupled with engineering judgment to determine if the traffic signal should be installed.**

What Are The Advantages Of Traffic Control Changes?

When properly used, traffic control signals are valuable devices for the control of vehicular and pedestrian traffic. Warranted traffic control signals that are properly designed, located, operated, and maintained will have one or more of the following advantages:

- They provide for the orderly movement of traffic.
- They increase the traffic handling capacity of the intersection.
- They reduce the frequency and severity of certain types of crashes, especially right angle collisions.
- They are coordinated to provide for continuous or nearly continuous movement of traffic at a definite speed along a given route under favorable conditions.
- They are used to interrupt heavy traffic at intervals to permit other traffic, vehicular or pedestrian, to cross.

What Are The Disadvantages Of Traffic Control Changes?

The following factors can result from an improper or unwarranted signal installation:

- Excessive delay may be caused. Even the best designed and operated signals usually increase delay when compared to unsignalized intersections.
- Disobedience of the signal indications is encouraged.
- The use of less adequate routes may be encouraged in an attempt to avoid such signals.
- Crash frequency can be significantly increased at unwarranted signals or at locations where installation was not based on sound engineering analysis. Crashes related to unwarranted signals are rear-end collisions and drivers either willfully or unintentionally running the red light.

What Are The Alternatives To Traffic Control Changes?

Based on Part IV of the MUTCD 2003, since vehicular delay and the frequency of some types of crashes are sometimes greater under traffic signal control than under STOP sign control, consideration should be given to providing alternatives to traffic control signals even if one or more of the signal warrants has been satisfied.

These alternatives may include, but are not limited to, the following:

- Installing signs along the major street to warn road users approaching the intersection;
- Relocating the stop line(s) and making other changes to improve the sight distance at the intersection;
- Installing measures designed to reduce speeds on the approaches;
- Installing a flashing beacon at the intersection to supplement STOP sign control;
- Installing flashing beacons on warning signs in advance of a STOP sign controlled intersection on major and/or minor street approaches;
- Adding one or more lanes on a minor street approach to reduce the number of vehicles per lane on the approach;
- Installing roadway lighting if a disproportionate number of crashes occur at night;
- If the warrant is satisfied, installing multiway STOP sign control;
- Installing a roundabout.

What Are The Costs Of Traffic Signals?

Traffic signals are much more costly than is commonly realized, even though they represent a sound public investment when justified. A modern signal can cost taxpayers between $200,000 and $500,000 to install depending on the complexity of the intersection and the characteristics of the traffic using it.

On top of this, there is a perpetual cost which is almost never considered – the cost of the electrical power consumed in operating a signalized intersection 24 hours a day, and the associated maintenance costs. These costs can be $3,000 to $5,000 a year.

What Are The Studies And Factors To Justifying Traffic Control Signals?

An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.

Based on Part IV of the MUTCD 2003, the investigation of the need for a traffic control signal shall include an analysis of the applicable factors contained in the following traffic signal warrants and other factors related to existing operation and safety at the study location:

- Warrant 1, Eight-Hour Vehicular Volume.
- Warrant 2, Four-Hour Vehicular Volume.
- Warrant 3, Peak Hour.
- Warrant 4, Pedestrian Volume.
- Warrant 5, School Crossing.
- Warrant 6, Coordinated Signal System.
- Warrant 7, Crash Experience.
- Warrant 8, Roadway Network.

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.

A traffic control signal should not be installed unless an engineering study indicates that installing a traffic control signal will improve the overall safety and/or operation of the intersection.

A traffic control signal should not be installed if it will seriously disrupt progressive traffic flow.

When performing a signal warrant analysis, bicyclists riding in the street with other vehicular traffic are usually counted as vehicles and bicyclists who are clearly using pedestrian facilities are usually counted as pedestrians.

What Data Must Be Collected For An Engineering Study Of Traffic Signal Installations?

Engineering study data may include the following:

A. The number of vehicles entering the intersection in each hour from each approach during 12 hours of an average day. It is desirable that the hours selected contain the greatest percentage of the 24-hour traffic volume.
B. Vehicular volumes for each traffic movement from each approach, classified by vehicle type (heavy trucks, passenger cars and light trucks, public-transit vehicles, and, in some locations, bicycles), during each 15-minute period of the two hours in the morning and two hours in the afternoon during which total traffic entering the intersection is greatest.
C. Pedestrian volume counts on each crosswalk during the same periods as the vehicular counts in Item B above and during hours of highest pedestrian volume. Where young,

elderly, and/or persons with physical or visual disabilities need special consideration, the pedestrians and their crossing times may be classified by general observation.

D. Information about nearby facilities and activity centers that serve the young, elderly, and/or persons with disabilities, including requests from persons with disabilities for accessible crossing improvements at the location under study. These persons might not be adequately reflected in the pedestrian volume count if the absence of a signal restrains their mobility.
E. The posted or statutory speed limit or the 85th-percentile speed on the uncontrolled approaches to the location.
F. A condition diagram showing details of the physical layout, including such features as intersection geometrics, channelization, grades, sight-distance restrictions, transit stops and routes, parking conditions, pavement markings, roadway lighting, driveways, nearby railroad crossings, distance to nearest traffic control signals, utility poles and fixtures, and adjacent land use.
G. A collision diagram showing crash experience by type, location, direction of movement, severity, weather, time of day, date, and day of week for at least 1 year.

What Warrants Must Be Satisfied For Traffic Signal Installation?

Based on Part IV, Section C of the MUTCD 2003, traffic signals should not be installed unless one or more of the following warrants are met.

Warrant 1, Eight-Hour Vehicular Volume

The Minimum Vehicular Volume, Condition A, is intended for application at locations where a large volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

The Interruption of Continuous Traffic, Condition B, is intended for application at locations where Condition A is not satisfied and where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or conflict in entering or crossing the major street.

It is intended that Warrant 1 be treated as a single warrant. If Condition A is satisfied, then the criteria for Warrant 1 is satisfied and Condition B and the combination of Conditions A and B are not needed. Similarly, if Condition B is satisfied, then the criteria for Warrant 1 is satisfied and the combination of Conditions A and B is not needed.

Table 10-1: Warrant 1, Eight-Hour Vehicular Volume[1]

Condition A—Minimum Vehicular Volume

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1................	1................	500	400	350	280	150	120	105	84
2 or more...	1................	600	480	420	336	150	120	105	84
2 or more...	2 or more ...	600	480	420	336	200	160	140	112
1................	2 or more	500	400	350	280	200	160	140	112

Condition B—Interruption of Continuous Traffic

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1................	1................	750	600	525	420	75	60	53	42
2 or more...	1................	900	720	630	504	75	60	53	42
2 or more...	2 or more ...	900	720	630	504	100	80	70	56
1................	2 or more	750	600	525	420	100	80	70	56

[a] Basic minimum hourly volume.
[b] Used for combination of Conditions A and B after adequate trial of other remedial measures.
[c] May be used when the major-street speed exceeds 70 km/h or exceeds 40 mph or in an isolated community with a population of less than 10,000.
[d] May be used for combination of Conditions A and B after adequate trial of other remedial measures when the major-street speed exceeds 70 km/h or exceeds 40 mph or in an isolated community with a population of less than 10,000.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that one of the following conditions exist for each of any eight hours of an average day:

A. The vehicles per hour given in both of the 100 percent columns of Condition A in Table 10-1 exist on the major street and the higher-volume minor street approaches, respectively, to the intersection; or
B. The vehicles per hour given in both of the 100 percent columns of Condition B in Table 10-1 exist on the major street and the higher-volume minor street approaches, respectively, to the intersection.

[1] Source: Part 4, MUTCD 2003

In applying each condition the major street and minor street volumes shall be for the same eight hours. On the minor street, the higher volume shall not be required to be on the same approach during each of these eight hours.

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph (70 km/h), or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 70 percent columns in Table 10-1 may be used in place of the 100 percent columns.

Guidance:

The combination of Conditions A and B is intended for application at locations where Condition A is not satisfied and Condition B is not satisfied and should be applied only after an adequate trial of other alternatives that could cause less delay and inconvenience to traffic has failed to solve the traffic problems.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that both of the following conditions exist for each of any eight hours of an average day:

1. The vehicles per hour given in both of the 80 percent columns of Condition A in Table 10-1 exist on the major street and the higher-volume minor street approaches, respectively, to the intersection; and
2. The vehicles per hour given in both of the 80 percent columns of Condition B in Table 10-1 exist on the major street and the higher-volume minor street approaches, respectively, to the intersection.

These major street and minor street volumes shall be for the same eight hours for each condition; however, the eight hours satisfied in Condition A shall not be required to be the same eight hours satisfied in Condition B. On the minor street, the higher volume shall not be required to be on the same approach during each of the eight hours.

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph (70 km/h), or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 10-1 may be used in place of the 80 percent columns.

Warrant 2, Four-Hour Vehicular Volume

The Four-Hour Vehicular Volume signal warrant conditions are intended to be applied where the volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that, for each of any four hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor street approach (one direction only) all fall above the applicable curve in Figure 10-1 for the existing combination of approach lanes. On the minor street, the higher volume shall not be required to be on the same approach during each of these four hours.

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph (70 km/h) or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 10-2 may be used in place of Figure 10-1.

Figure 10-1: Warrant 2, Four-Hour Vehicular Volume[2]

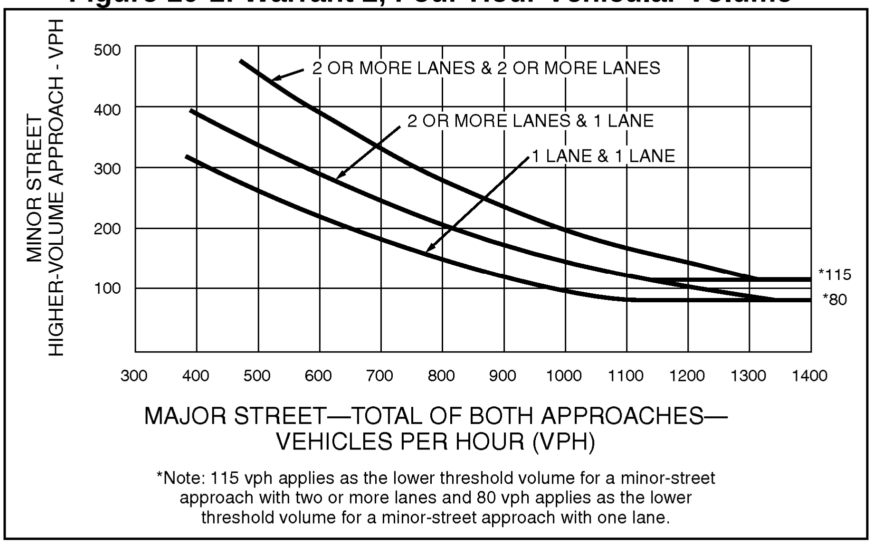
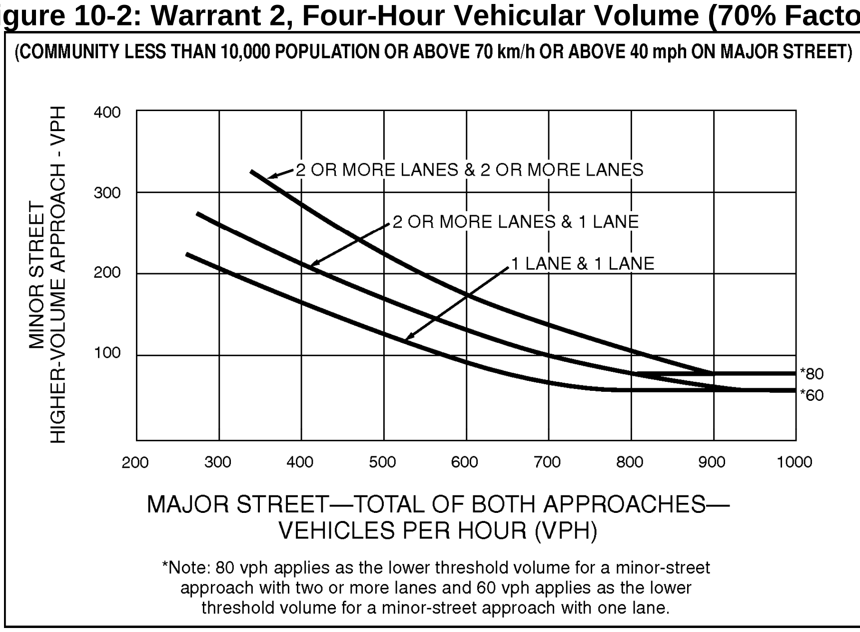


Figure 10-2: Warrant 2, Four-Hour Vehicular Volume (70% Factor)[3]



[2] Source: Part 4, MUTCD 2003
[3] Source: Part 4, MUTCD 2003

Warrant 3, Peak Hour

The Peak Hour signal warrant is intended for use at a location where traffic conditions are such that for a minimum of one hour of an average day the minor street traffic suffers undue delay when entering or crossing the major street.

Standard:

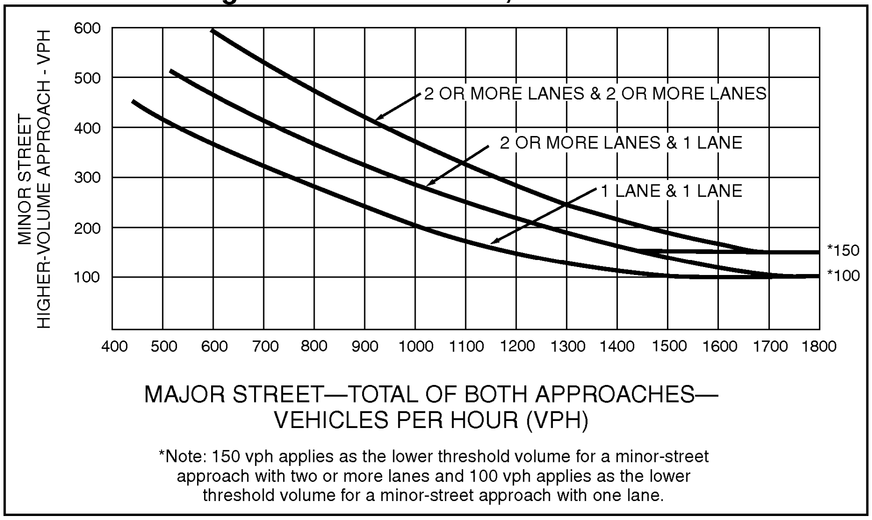
This signal warrant shall be applied only in unusual cases, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.

The need for a traffic control signal shall be considered if an engineering study finds that the criteria in either of the following two categories are met:

A. If all three of the following conditions exist for the same one hour (any four consecutive 15-minute periods) of an average day:
   a. The total stopped time delay experienced by the traffic on one minor street approach (one direction only) controlled by a STOP sign equals or exceeds: four vehicle-hours for a one-lane approach; or five vehicle-hours for a two-lane approach, and
   b. The volume on the same minor street approach (one direction only) equals or exceeds 100 vehicles per hour for one moving lane of traffic or 150 vehicles per hour for two moving lanes, and
   c. The total entering volume serviced during the hour equals or exceeds 650 vehicles per hour for intersections with three approaches or 800 vehicles per hour for intersections with four or more approaches.

B. The plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor street approach (one direction only) for one hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 10-3 for the existing combination of approach lanes.

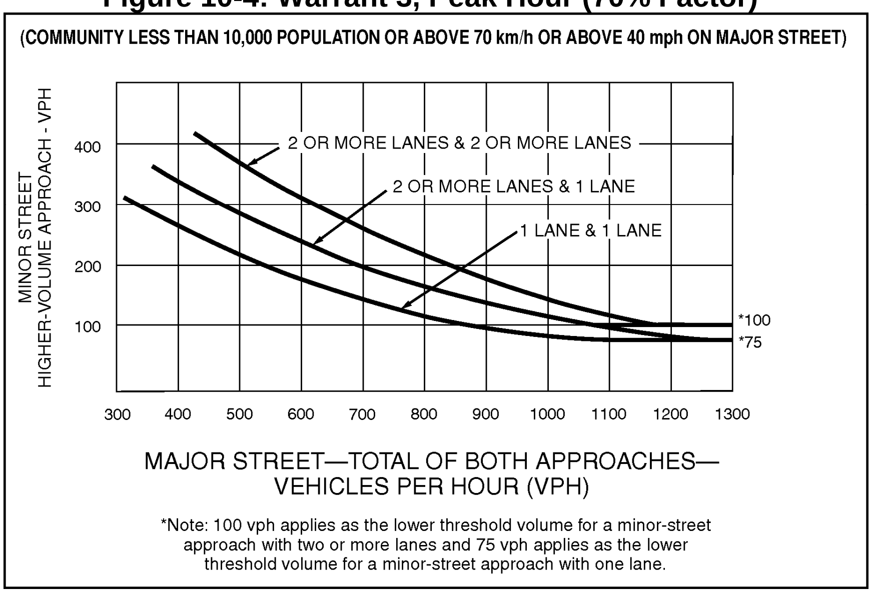
Figure 10-3: Warrant 3, Peak Hour[4]



Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph (70 km/h), or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 10-4 may be used in place of Figure 10-3 to satisfy the criteria in the second category of the Standard.

Figure 10-4: Warrant 3, Peak Hour (70% Factor)[5]



Warrant 4, Pedestrian Volume

The Pedestrian Volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street.

[4] Source: Part 4, MUTCD 2003
[5] Source: Part 4, MUTCD 2003

Standard:

The need for a traffic control signal at an intersection or midblock crossing shall be considered if an engineering study finds that both of the following criteria are met:

A. The pedestrian volume crossing the major street at an intersection or midblock location during an average day is 100 or more for each of any four hours or 190 or more during any one hour; and
B. There are fewer than 60 gaps per hour in the traffic stream of adequate length to allow pedestrians to cross during the same period when the pedestrian volume criterion is satisfied. Where there is a divided street having a median of sufficient width for pedestrians to wait, the requirement applies separately to each direction of vehicular traffic.

The Pedestrian Volume signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 90 m (300 feet), unless the proposed traffic control signal will not restrict the progressive movement of traffic.

If this warrant is met and a traffic control signal is justified by an engineering study, the traffic control signal shall be equipped with pedestrian signal heads conforming to requirements set forth in Chapter 4E of the MUTCD.

Guidance:

If this warrant is met and a traffic control signal is justified by an engineering study, then:

A. If at an intersection, the traffic control signal should be traffic-actuated and should include pedestrian detectors.
B. If at a nonintersection crossing, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 100 feet (30 m) in advance of and at least 20 feet (6.1 m) beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.
C. Furthermore, if installed within a signal system, the traffic control signal should be coordinated.

Option:

The criterion for the pedestrian volume crossing the major roadway may be reduced as much as 50 percent if the average crossing speed of pedestrians is less than 4 feet/sec (1.2 m/sec).

A traffic control signal may not be needed at the study location if adjacent coordinated traffic control signals consistently provide gaps of adequate length for pedestrians to cross the street, even if the rate of gap occurrence is less than one per minute.

Warrant 5, School Crossing

The School Crossing signal warrant is intended for application where the fact that school children cross the major street is the principal reason to consider installing a traffic control signal.

Standard:

The need for a traffic control signal shall be considered when an engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of school children at an established school crossing across the major street shows that the number of adequate gaps in the traffic stream during the period when the children are using the crossing is less than the number of minutes in the same period (See Section 7A.03 of the MUTCD) and there are a minimum of 20 students during the highest crossing hour.

Before a decision is made to install a traffic control signal, consideration shall be given to the implementation of other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing.

The School Crossing signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 300 feet (90 m), unless the proposed traffic control signal will not restrict the progressive movement of traffic.

Guidance:

If this warrant is met and a traffic control signal is justified by an engineering study, then:

A. If at an intersection, the traffic control signal should be traffic-actuated and should include pedestrian detectors.
B. If at a nonintersection crossing, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 100 feet (30 m) in advance of and at least 20 feet (6.1 m) beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.
C. Furthermore, if installed within a signal system, the traffic control signal should be coordinated.

Warrant 6, Coordinated Signal System

Progressive movement in a coordinated signal system sometimes necessitates installing traffic control signals at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that one of the following criteria is met:

A. On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.
B. On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.

Guidance:

The Coordinated Signal System signal warrant should not be applied where the resultant spacing of traffic control signals would be less than 1,000 feet (300 m).

Warrant 7, Crash Experience

The Crash Experience signal warrant conditions are intended for application where the severity and frequency of crashes are the principal reasons to consider installing a traffic control signal.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that all of the following criteria are met:

A. Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency; and
B. Five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; and
C. For each of any eight hours of an average day, the vehicles per hour (vph) given in both of the 80 percent columns of Condition A in Table 10-1 or the vph in both of the 80 percent columns of Condition B in Table 10-1 exists on the major street and the higher-volume minor street approach, respectively, to the intersection, or the volume of pedestrian traffic is not less than 80 percent of the requirements specified in the Pedestrian Volume warrant. These major street and minor street volumes shall be for the same eight hours. On the minor street, the higher volume shall not be required to be on the same approach during each of the eight hours.

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph (70 km/h), or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 10-1 may be used in place of the 80 percent columns.

Warrant 8, Roadway Network

Installing a traffic control signal at some intersections might be justified to encourage concentration and organization of traffic flow on a roadway network.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that the common intersection of two or more major routes meets one or both of the following criteria:

A. The intersection has a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has five-year projected traffic volumes, based on an engineering study, that meet one or more of Warrants 1, 2, and 3 during an average weekday; or

B. The intersection has a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any five hours of a non-normal business day (Saturday or Sunday).

A major route as used in this signal warrant shall have one or more of the following characteristics:

A. It is part of the street or highway system that serves as the principal roadway network for through traffic flow;
B. It includes rural or suburban highways outside, entering, or traversing a city; or
C. It appears as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study.

How Can The Agencies Prioritize The Installation Of The Warranted Signals?

Many agencies are faced with a number of locations where signalization is warranted. There are seldom sufficient funds or other resources to signalize all warranted locations. Consequently, it is necessary to decide the order in which installation will be scheduled.

To assure that the most critical locations are installed first, agencies generally rely on a priority ranking system. The criteria used and the weighting values assigned to each criteria vary among agencies according to local situation. A typical list of priority criteria and commonly used considerations ranking is shown in Table 10-2.

Table 10-2: Typical Elements In Signal Priority Ranking System[6]

Satisfaction of volume warrants	Additional points for the number of hours a warrant is met.
Satisfaction of warrants	Additional points for the number of warrants met.
Crashes	Additional points given for the number of crashes above the minimum and/or the severity of crashes.
Coordination	Additional points if signal fits into an arterial progression or grid system. Reduction in points if signal does not lend itself to coordination.
School crossing proximity	Additional points if intersection is a school crossing or is proximate to school crossing.
Pedestrian Volume	Additional points if intersection has a moderate to high pedestrian activity associated with it, or serving physically or visually challenged individuals
Intersection geometrics	Reduction in points for "T" intersections. Additional points for higher speed locations, sight-distance restrictions, vertical or horizontal curvature conditions.

[6] Source: ITE, Traffic Control Devices Handbook, 2001

Who Can Design And Maintain The State Highway Signalized Intersections With County Roads Or City Streets? [7]

<u>Standard Procedure:</u>

A. Design by State
B. Contract and inspection by State
C. Maintenance performed by State
D. Power initially paid by State (if State shares power cost)
E. Signal timing by State

<u>Optional Procedure:</u>

A. Design by others with State review
B. Contract by others using State plans and specifications with State inspector if State is to perform maintenance
C. Maintenance performed by City or County under some circumstances
D. Power initially paid by City or County (if they maintain and share power cost)
E. Signal timing by City or County with State concurrence

What Is The Minimum Visibility For A Traffic Signal?

Minimum visibility for a traffic signal is defined as the distance from the stop line at which a signal should be continuously visible for various approach speeds. Table 10-3 includes minimum visibility distances and desired visibility distances. If these visibility requirements cannot be accommodated, an advance warning sign must be installed to alert approaching drivers. The sign may be supplemented by a warning beacon as described in Section 4K.03 of the MUTCD, 2003.

How Can One Determine If 8-Inch (200 mm) Or 12-Inch (300 mm) Indications Are Appropriate?

8-inch (0.2 m) lenses may be used. However, the MUTCD states that 12-inch (0.3 m) shall be used:

1. For signal indications for approaches where drivers view both traffic control and lane use control signals simultaneously.
2. Where the nearest signal face is between 120 feet (36 m) and 150 feet (45 m) beyond the stop line unless a supplemental near side signal indication is being used.
3. For signal faces located more than 150 feet (45 m) beyond the stop line.
4. All signal approaches where minimum visibility requirements cannot be met as indicated in Table 10-3.

[7] Source: ODOT, Traffic Signal Policy And Guidelines, May 2006

Table 10-3: Minimum Visibility At Signal Approaches[8]

85th Percentile Speed (mph)	Minimum Visibility Distance (feet)	Desirable Visibility Distance (feet)
20	175	265
25	215	325
30	270	405
35	325	480
40	390	570
45	460	660
50	540	760
55	625	870
60	715	980

In addition, 12-inch (300 mm) lenses should be used for all signal indications for:

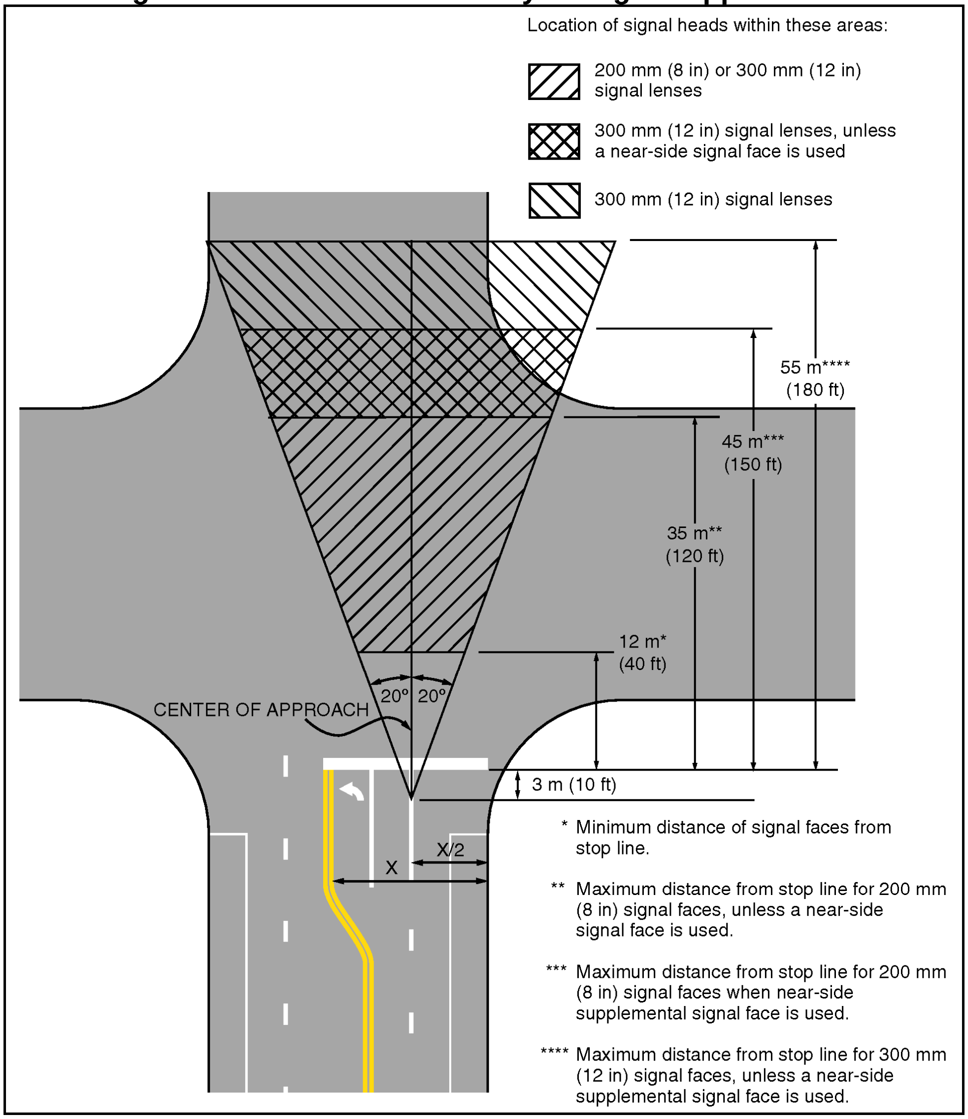
A. Approaches with 85th percentile approach speeds exceeding 40 mph (65 km/h).
B. Approaches where signalization might be unexpected.
C. Arrows.
D. All approaches with rural cross section where only post mounted signals are used.

How Is The Number And Location Of Signal Faces Determined?

1. There shall be a minimum of two signal faces for through traffic and they must be visible according to the minimum distances shown in Figure 10-5.
2. Signal faces shall be located not less than 40 feet (12 m) nor more than 180 feet (55 m) beyond the stop line for 12-inch (0.3 m) signal lenses.
3. If both faces are post-mounted, then they shall be mounted on the far side of the intersection.
4. The two signal faces shall each be within a 20 degree cone with one side of the cone being the center of the approach lane (See Figure 10-5).
5. The mounting height of a post-mounted signal face shall not be less than 8 feet (2.4 m) or more than 19 feet (5.8 m) above the pavement above the sidewalk, or if there is no sidewalk, above the pavement grade at the center of the roadway, in addition, the AASHTO Standard for Traffic Structures requires the minimum mounting height over the roadway to be 1 foot higher than the minimum bridge height for the road system.
6. The bottom of the signal face housing suspended over a roadway shall not be less than 15 feet (4.6 m) nor more than 25.6 feet (7.8 m) above the pavement center of the roadway.

[8] Source: ITE, Traffic Control Devices Handbook, 2001

Figure 10-5: Minimum Visibility At Signal Approaches[9]



A Signal Installation Is Planned For An Intersection Within The City. Should A Pre-Timed Or Traffic Actuated Controller Be Used To Operate The Intersection?

This decision should be made using traffic volume data as well as field observations of the traffic patterns at the intersection. A traffic-actuated signal should be considered under the following situations:

1. Low, fluctuating or unbalanced traffic volumes.
2. High side-street traffic volumes and vehicle delays during peak hours only.
3. Locations where only a single warrant is satisfied, such as at school crossings.
4. Non-intersection locations (mid-block pedestrian and fire station signals).

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[9] Source: Part IV, MUTCD 2003

Pre-timed controllers use a regularly repeated sequence with predetermined timing values based on average traffic volumes. Normally, the cost of pre-timed equipment is significantly less than traffic-actuated equipment. In addition, pre-timed equipment is easier to maintain.

What Signal Cycle Length Should Be Selected?

The shortest practical cycle lengths are the most desirable. Cycle lengths longer than necessary to accommodate the existing traffic volume produce higher average delays.

The cycle length is the total time required for the complete sequence of phases. This time includes the sum of the green phases and yellow clearance intervals. For simple right angle intersections with moderate traffic volumes, the cycle length will be in the range of 45 to 60 seconds. For a heavier volume intersection, the cycle length may run 60 to 90 seconds.

How Is The Signal Phasing Determined?

The number of traffic phases used depends upon the volume and direction of traffic flow and the number of approaches to the intersection. It should be remembered that the number of phases controls the cycle length. When additional traffic phases are used, longer cycle lengths are required. LEFT TURN BAYS significantly improve the operation of a traffic signal, but the addition of a left turn arrow in phasing creates a major need for a left turn bay.

Types of Phasing

1. Two-Phase – normally used at four-way right angle intersections. Provides for most efficient operation if left turn and pedestrian volumes are not excessive.
2. Three-Phase – used at intersections having a concentrated volume of left turns. More than three phases may be used for more complex intersections.
3. Exclusive Pedestrian Phase – used at intersections where there is a serious conflict between turning vehicles and heavy pedestrian volumes.
4. Split Phase – leading or lagging green, used where there is an unbalanced direction of traffic flow.

What Is The Desirable Length For The Yellow Clearance Interval?

The yellow clearance interval advises the motorist that the red interval is about to commence. It should be of sufficient length to permit the motorist to bring his vehicle to a safe stop or, if he has already entered the intersection, sufficient time to clear the point of conflict. The yellow interval is a function of approach speed. Excessively short or long yellow intervals encourage driver disrespect. The MUTCD states that the yellow change intervals should range between 3.0 and 6.0 seconds. The longer intervals should be reserved for use on approaches with higher speeds.

When longer yellow intervals are required, it is usually better to use a yellow of 3 to 6 seconds and use an all-red clearance interval of 2 to 3 seconds before the start of green for the opposing traffic. A red clearance interval should have a duration not exceeding 6 seconds (See Table 10-4).

Table 10-4: Suggested Yellow Change Intervals For Level Grades[10]

85th Percentile Speed		Yellow Change Interval
MPH	km/h	(seconds)
20	30	3.0
25	40	3.0
30	50	3.2
35	55	3.6
40	65	3.9
45	70	4.3
50	80	4.7
55	90	5.0
60	95	5.4

For additional important information regarding traffic signals, please refer the ODOT Traffic Signal publications at the website: http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/publications_traffic.shtml and specifically the following publications:

1. Traffic Signal Policy And Guidelines, ODOT, 2006, http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/Traffic_Signal_Policy_and_Guidelines.pdf
2. ODOT Traffic Manual, ODOT, 2009, http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/Traffic_Manual_09.pdf
3. ODOT Signal Design Manual, ODOT, 2007, http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/Signal_Design_Manual.pdf
4. ODOT Traffic Signal Loop Layout Examples, ODOT, 2006, http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/Signal_Loop_Layout_Examples.pdf
5. Current Traffic Signal Standard Drawings, ODOT, http://egov.oregon.gov/ODOT/HWY/ENGSERVICES/traffic_drawings.shtml#Traffic_400___Signals
6. Traffic Signal Detailed Drawings, http://egov.oregon.gov/ODOT/HWY/ENGSERVICES/details_traffic.shtml#Signals
7. Part IV of the Manual on Uniform Traffic Control Devices (MUTCD), http://mutcd.fhwa.dot.gov/

[10] Source: Traffic Control Devices Handbook, Institute of Transportation Engineers (ITE), 2001

Chapter 11: Pedestrian Safety

Collisions between pedestrians and motor vehicles are a serious problem in the United States and many other countries. A total of 4,378 pedestrians were reported killed in motor vehicle collisions in the United States in 2008[1]. These deaths accounted for 12 percent of the 37,261 motor vehicle deaths nationwide. An estimated 69,000 pedestrians were injured in motor vehicle collisions. On average, a pedestrian is killed in a traffic crash every 120 minutes and injured in a traffic crash every eight minutes. Although a drop in pedestrian fatalities has occurred in recent years, a serious problem continues to exist in the U.S. relative to pedestrian deaths and injuries.

Most pedestrian fatalities in 2006[2] occurred in urban areas (74%), at non-intersection locations (79%), in normal weather conditions (90%), and at night (69%), and more than two-thirds (70%) of the pedestrians killed in 2006 were males. In Oregon, 53 pedestrians were reported killed and 576 pedestrians were injured in 2008[3].

Location Of Pedestrian Crashes[4]

In terms of crash location, 65 percent of crashes involving pedestrians occur at non-intersections. This is particularly true for pedestrians under age nine, primarily because of dart-outs into the street. For ages 45 to 65, pedestrian crashes are approximately equal for intersections and non-intersections. Pedestrians age 65 and older are more likely to be injured or killed at intersections (59 percent) compared to non-intersections.

Speeding

Speeding is a major contributing factor in crashes of all types. In 2008, speeding was a contributing factor in 31 percent of all fatal crashes and 11,674 lives were lost in speeding related crashes[5]. Speeding has serious consequences when a pedestrian is involved. A pedestrian hit at 40 mph (64.4 km/hr) has an 85 percent chance of being killed; at 30 mph (48.3 km/hr), the likelihood goes down 45 percent, while 20 mph (32.2 km/hr), the fatality rate is only 5 percent. [6]

In Oregon, 51% of all traffic fatalities involved speeding (210 of 416 traffic fatalities). Over 72% of all 2008 traffic fatalities in Oregon (including speed-related events) occurred on the rural state highway system. Speed-related crashes cost Oregonians an estimated $685,000,000 in total economic costs in 2007[7].

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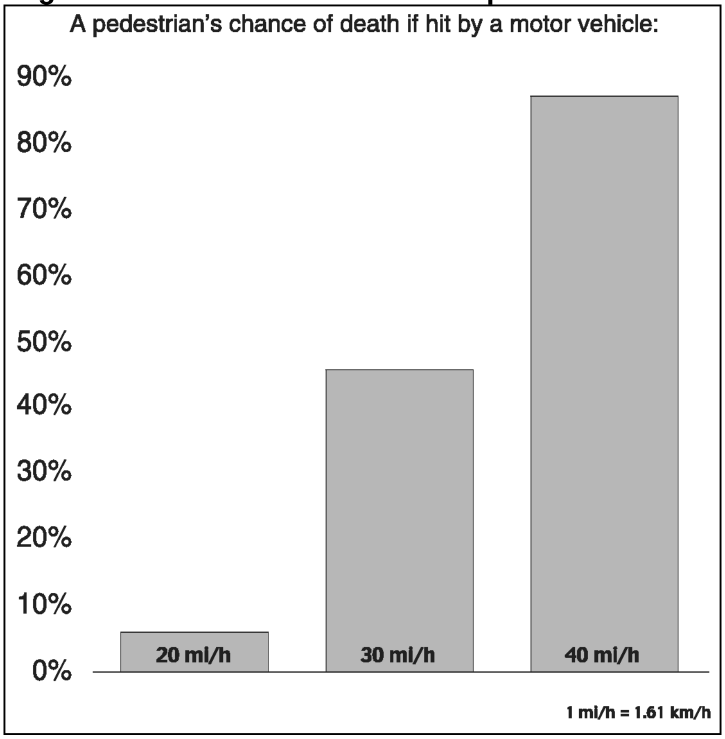
[1] Source: NHTSA, Traffic Safety Facts, 2008, DOT HS81170
[2] Source: NHTSA, Traffic Safety Facts, 2006 Data, DOT 4S81010
[3] Source: ODOT, Oregon Traffic Safety Performance Plan, Fiscal Year 2010
[4] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System, 2004
[5] Source: NHTSA, Traffic Safety Facts, 2008, DOT HS81170
[6] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System, 2004
[7] Source: ODOT, Oregon Traffic Safety Performance Plan, Fiscal Year 2010

Figure 11-1: Fatalities Based On Speed of Vehicle[8]



Identification Of High-Crash Locations

A first steep in the problem-solving process of improving pedestrian safety and mobility is to identify locations or areas where pedestrian crash problems exist and where engineering, education, and enforcement measures will be most beneficial. Mapping the locations of reported pedestrian crashes in a neighborhood or city is a simple method of identifying sites for improving walking safety.

What Types Of Crashes Are Most Common?[9]

Statistics show that in every area of the country, several specific situations are especially more threatening to pedestrians. Most pedestrian crashes—in fact, more than 90 percent—occur when a pedestrian is involved in the following situations:

A. Dart/Dash

The pedestrian walked or ran into the roadway at an intersection or midblock location and was struck by a vehicle. The motorist's view of the pedestrian may have been blocked until an instant before the impact, as illustrated in Figure 11-2.

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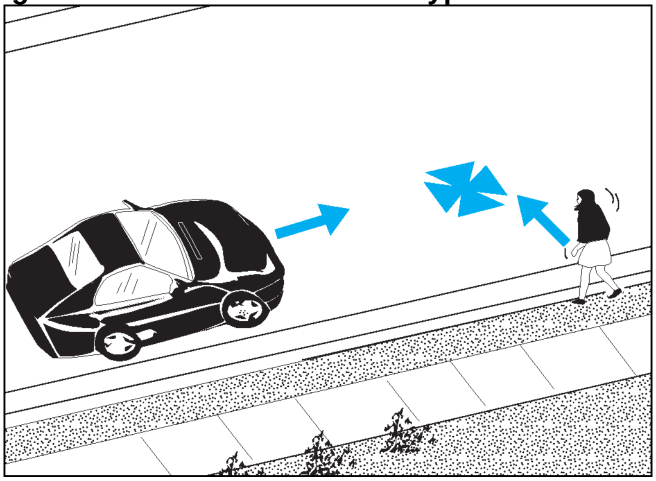
[8] Source: UK Department of Transportation, Killing Speed and Saving Lives, London, 1987
[9] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasure System, 2004

Figure 11-2: Pedestrian Crash Type – Dart/Dash[10]



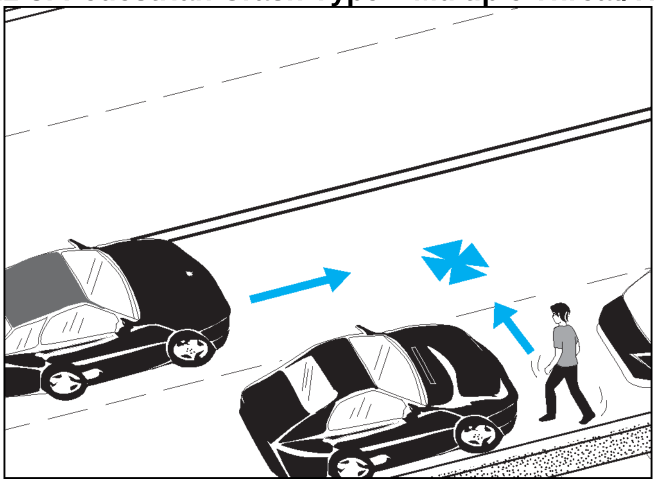
General Countermeasures

a. Provide adequate nighttime lighting
b. Narrow travel lanes
c. Provide curb extensions
d. Implement traffic-calming measures such as chicanes, speed humps, or speed tables
e. Provide a raised pedestrian crossing

B. Multiple Threat/Trapped

The pedestrian entered the roadway in front of stopped or slowed traffic and was stuck by a multiple-threat vehicle in an adjacent lane after becoming trapped in the middle of the roadway, as illustrated in Figure 11-3.

Figure 11-3: Pedestrian Crash Type – Multiple Threat/Trapped[11]



[10] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasures System, 2004
[11] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasures System, 2004

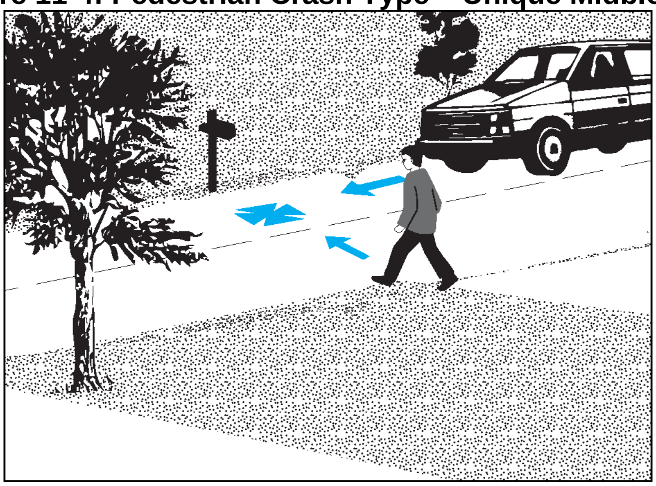
General Countermeasures

a. Improve roadway lighting
b. Provide midblock or intersection curb extensions
c. Install traffic-calming devices such as speed tables or raised pedestrian crossings on local or other neighborhood streets
d. Provide raised crosswalks to improve pedestrian visibility
e. Install flashers or advance warning signs
f. Recess stop lines 30 feet (9.1 m) in advance of crosswalk
g. Reduce roadway width. For example, add sidewalks and bike lanes to a roadway by narrowing four-lane undivided roadways to two through lanes plus a center two-way left-turn lane or wide raised median.

C. Unique midblock (mailbox, ice-cream vendor, parked vehicle)

The pedestrian was struck while crossing the road to/from a mailbox, newspaper box, or ice-cream truck, or while getting into or out of a stopped vehicle, as illustrated in Figure 11-4.

Figure 11-4: Pedestrian Crash Type – Unique Midblock[12]



General Countermeasures

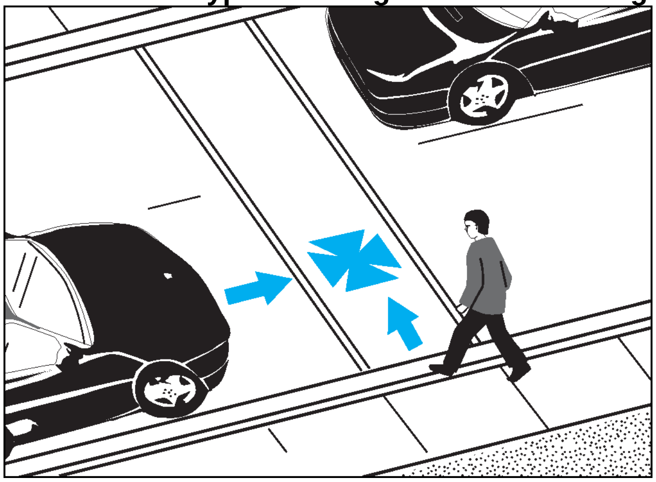
a. Improve lighting
b. Provide raised median on multi-lane arterial street
c. Provide traffic-calming measures (e.g.chicanes or raised devices on residential streets)
d. Implement driver education program
e. Implement pedestrian education program
f. Relocate mailboxes to safer crossing area or provide safer crossings at existing locations

D. Through vehicle at unsignalized location

The pedestrian was stuck at an unsignalized intersection or midblock location. Either the motorist or the pedestrian may have failed to yield, as illustrated in Figure 11-5.

[12] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasures System, 2004

Figure 11-5: Pedestrian Crash Type – Through Vehicle At Unsignalized Location[13]



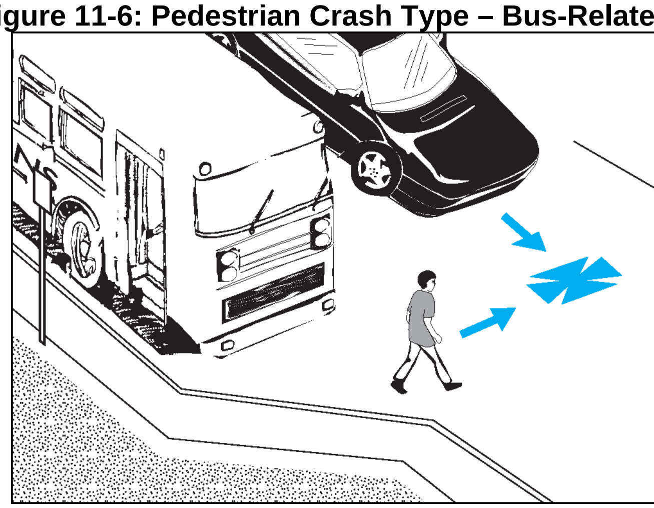
General Countermeasures

a. Improve crosswalk marking visibility
b. Improve roadway lighting
c. Reduce curb radius to slow vehicle speeds
d. Install curb extensions or choker
e. Construct raised pedestrian crossing island
f. Install speed humps, speed tables, raised intersections, or raised crosswalks

E. Bus-related

The pedestrian was struck by a vehicle while: (1) crossing in front of a commercial bus stopped at a bus stop; (2) going to or from a school bus stop; or (3) going to, from, or waiting near a commercial bus stop, as illustrated in Figure 11-6.

Figure 11-6: Pedestrian Crash Type – Bus-Related[14]



[13] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasures System, 2004
[14] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasures System, 2004

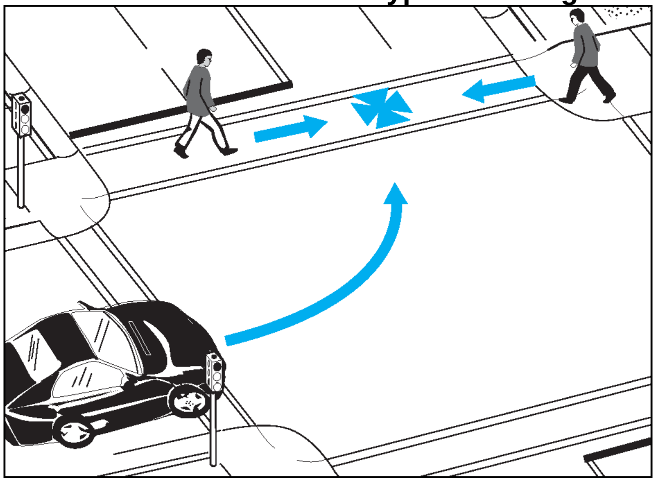
General Countermeasures

a. Install crosswalk marking to encourage pedestrians to cross in the crosswalk behind the bus
b. Move bus stop to far side of intersection or crosswalk
c. Consider an alternative bus stop location
d. Mark bus stop area with pedestrian warning signs
e. Install or improve roadway lighting
f. Install pedestrian crossing medians or raised crosswalk
g. Install curb extensions
h. Remove parking in areas that obstruct the vision of motorists and pedestrians

F. Turning vehicle

The pedestrian was attempting to cross at an intersection, driveway, or alley and was struck by a vehicle that was turning right or left, as illustrated in Figure 11-7.

Figure 11-7: Pedestrian Crash Type – Turning Vehicle[15]



General Countermeasures

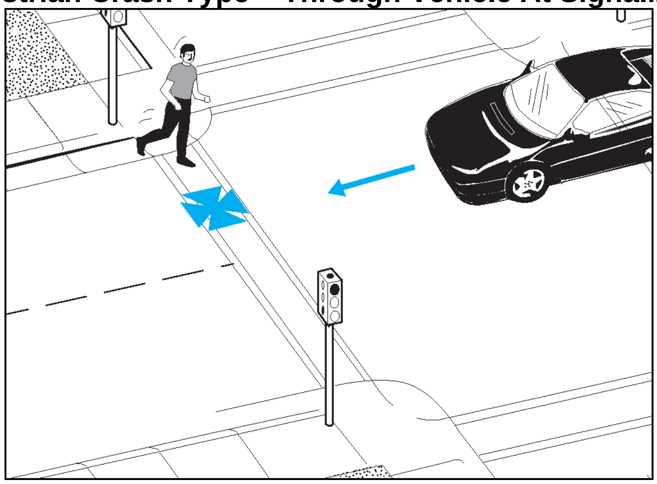
a. Add curb extensions
b. Install raised median and pedestrian crossing island
c. Convert to one-way street network (if justified by surrounding area-wide pedestrian and traffic volume study)
d. Use traffic-calming devices, such as a raised intersection or raised pedestrian crossing, to reduce vehicle speeds
e. Provide separate left-turn and WALK/DON'T WALK signals
f. Prohibit left turns
g. Provide leading pedestrian interval if signalized
h. Provide countdown pedestrian signal

[15] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasures System, 2004

G. Through vehicle at signalized location

The pedestrian was struck at a signalized intersection or midblock location by a vehicle that was traveling straight ahead, as illustrated in Figure 11-8.

Figure 11-8: Pedestrian Crash Type – Through Vehicle At Signalized Intersection[16]



General Countermeasures

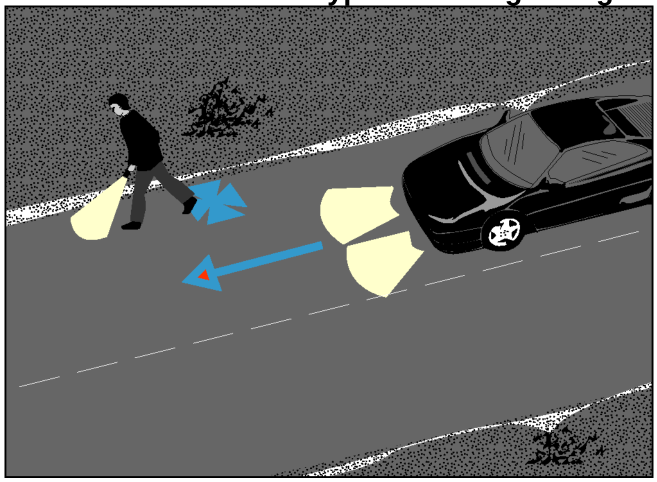
a. Provide pavement markings and school zone signs
b. Provide curb extensions to reduce crossing distance
c. Use traffic-calming devices such as mini-circle or raised intersection to reduce vehicle speeds
d. Provide a raised pedestrian crossing
e. Provide advanced stop lines
f. Provide leading pedestrian interval
g. Provide countdown pedestrian signal

H. Walking along roadway

The pedestrian was walking or running along the roadway and was struck from the front or from behind by a vehicle, as illustrated in Figure 11-9.

[16] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasures System, 2004

Figure 11-9: Pedestrian Crash Type – Walking Along Roadway[17]



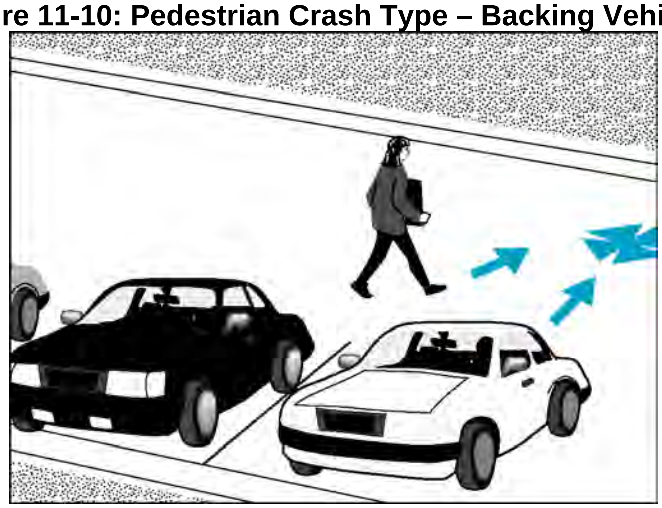
General Countermeasures

a. Provide a sidewalk for the road
b. Provide an asphalt path or paved shoulder
c. Provide lighting
d. Remove obstacles in sidewalk
e. Build missing sidewalk segments
f. Provide raised pavement marking. This must be balanced against bicycle access as raised pavement marking can be a hazard for bicyclists.

I. Backing vehicle

The pedestrian was struck by a backing vehicle on a street, in a driveway, on a sidewalk, in a parking lot, or at another location, as illustrated in Figure 11-10.

Figure 11-10: Pedestrian Crash Type – Backing Vehicle[18]



General Countermeasures

[17] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasures System, 2004
[18] Source: USDOT, FHWA, PEDSAFE: Pedestrian Safety Guide and Countermeasures System, 2004

a. Provide clearly delineated walkways for pedestrians in parking lot
b. Relocate pedestrian walkways
c. Improve nighttime lighting
d. Remove unneeded driveways and alleys
e. Provide curb extensions or raised pedestrian crossings to improve the visibility of pedestrians to backing motorists

Does a crosswalk always increase the safety of pedestrians?[19]

There is conflicting evidence as to the effectiveness of marked crosswalks on motorist behavior and pedestrian safety. Numerous studies (San Diego, 1972; Long Beach, 1986; Brigham Young, 1996; Santa Anna, 1999) have shown that marking crosswalks at uncontrolled intersections can increase crash risk for pedestrians. In contrast, some studies show higher rates of motor vehicle yielding to pedestrians at marked crosswalks.

Recent studies (Zeeger, 2002)[20] suggest that wider (multi-lane) or higher volumes (above 10,000 ADT) roadways contribute to higher crash risk for marked crosswalks vs. unmarked crosswalks. The study also found that the presence of a raised median was associated with a lower crash risk.

From the pedestrian's point of view, a crosswalk is large and clearly marked. Crosswalks are far less visible to the drivers than to the pedestrians. It is important to ensure that the crosswalk markings and pedestrians are highly visible to motorists.

Marked crosswalks are routinely requested to increase the safety of crossing the highway. The function of the marked crosswalk is to provide guidance to the proper crossing location and to serve to alert motorists of a pedestrian crossing point. But, unjustified or poorly located crosswalks may not increase safety. Marking crosswalks unnecessarily or in locations where there are few pedestrians may lead motorists to disrespect the marking.

A driver who passes over crosswalks marked at every intersection or a location that rarely has pedestrians may be conditioned to not expect pedestrians and thus loses respect for crosswalk markings. These crosswalks may increase the crashes risk to pedestrians and motorists alike.

Most experts agree that on a busy roadway, marking a crosswalk alone is rarely an effective safety measure and in some cases may actually increase the pedestrian's crash risk. Other measures such as median refuge islands, curb extensions and illumination should be considered before a crosswalk is marked. Other improvements include improving sight distance, better access management to reduce conflict with driveways, pedestrians signs, etc. Consideration should also be given to the overall environment in which the pedestrian crossing occurs, beyond the immediate vicinity of the proposed crosswalk, i.e. sign clutter and visual distraction.

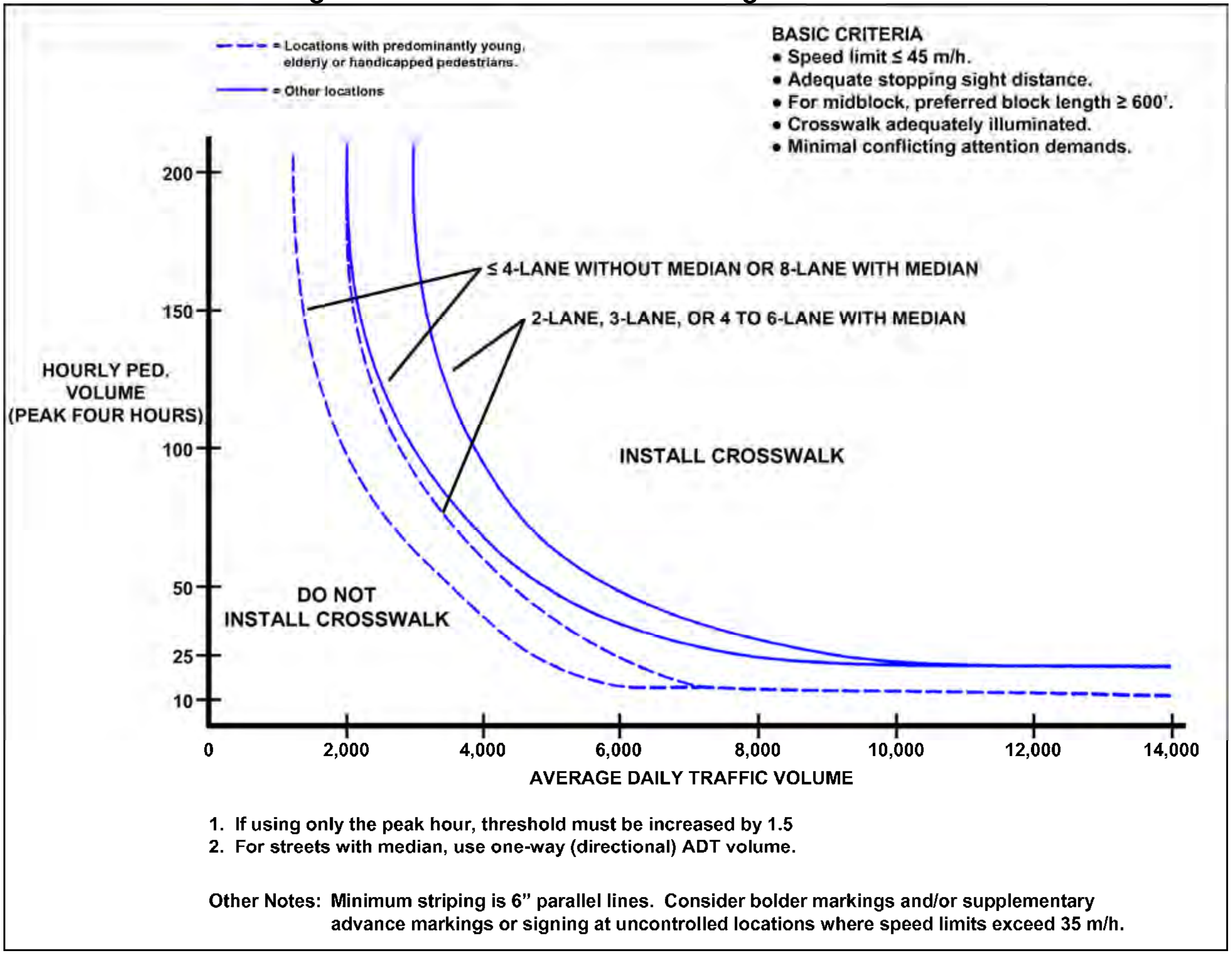
[19] Source: ODOT, Traffic Manual, December 2006
[20] Source: Zeeger C.V., Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations, FHWA-RD-01-075, 2002

Guidelines For Marking Crosswalks For Local Streets

In general, follow these guidelines to determine where to install marked crosswalks:

- All intersections that have pedestrian signals.
- Anywhere a school crossing guard is normally stationed to help children cross the street.
- Anywhere there are high volumes of pedestrians crossing.
- Anywhere it is necessary to mark the preferred crossing area, including places where pedestrians might be confused about where the proper crossing area is.
- All intersections and mid-block crosswalks that meet the basic criteria of Figure 11-11, as well as the minimum volume standards for vehicles and pedestrians. This figure analyzes each crosswalk according to approach leg, showing when a crosswalk is warranted on one or all sides of an intersection. The figure uses volume averages. If you are using volume figures that are based on peak hours, then you must increase your threshold. For streets with medians, refer to the figure. Of the elements that are based on peak hours, the most important ones are the basic criteria. Following them will prevent you from installing marked crosswalks at locations that would be extremely hazardous to the pedestrian. When using the figure, you should reduce your volume thresholds for locations where young, elderly, or handicapped pedestrians are a significant proportion of the pedestrian population. A value of 50 percent or more is suggested, but this is best left to your engineer's judgment.
- Do not install marked crosswalks in places where it may be dangerous for pedestrians to cross the street, such as locations with high-speed motor vehicle traffic, with poor sight distances, or that have poor lighting.
- Because it is costly to install and maintain crosswalks, you should only install them at places where their benefits will outweigh their costs.
- In areas with many vehicles or vehicles traveling at high speeds, use advance warning signs and, in some cases, advance warning pavement markings.
- Use marked crosswalks selectively. An extensive use of crosswalks decreases the overall effectiveness of them all.

Figure 11-11: Criteria For Installing Crosswalks[21]



Criteria For Marking Crosswalks At Uncontrolled Approaches And Intersections For State Highways[22]

Marked crosswalks are one tool to get pedestrians safely across the street. When considering marked crosswalks at uncontrolled locations, the question should not simply be: "Should I provide a marked crosswalk or not?" Instead, the question should be: "Is this an appropriate tool for getting pedestrians across the street?"

Generally marked crosswalks are discouraged at uncontrolled approaches due to a concern that they may not improve safety and may, if inappropriate, put a pedestrian more at risk.

Marked crosswalks should only be considered at uncontrolled approaches when an engineering study demonstrates their need and the location meets the following required criteria:

[21] Source: Federal Highway Administration, Walk Alert, National Pedestrian Safety Program Guide, FWHA, 1994
[22] Source: ODOT, Traffic Manual, December 2007

1. There is good visibility of the crosswalk from all directions, or it can be obtained. Stopping sight distance is at a minimum.
2. There is no reasonable alternative crossing location.
3. There is established pedestrian usage.
4. Posted speeds should be 35 mph or less.
5. Traffic volumes should be less than 10,000 ADT or if above 10,000 ADT raised median islands should be included.
6. On multi-lane highways, pedestrians crossing enhancements (curb extensions and/or pedestrians refuges) should be considered.
7. High pedestrian volume in Central Business District (CBD)

Criteria For Marking Crosswalks At Mid-Block Locations For State Highways[23]

Mid-block crosswalks often do not get good compliance from motorists. In most cases, Mid-block marked crosswalks are best used in combination with other treatments (e.g. curb extensions, raised crossing islands, enhanced overhead lighting, traffic calming measures, etc.) . Consider mid-block crosswalks when an engineering study demonstrates their need and the location meets the following required criteria:

1. There is good visibility of the crosswalk from all directions, or it can be obtained. Stopping sight distance is at a minimum.
2. Posted vehicular speed limits should be 35 mph or less.
3. There is not a reasonable alternative at a stop controlled intersection.
4. There is established pedestrian usage.
5. Locations should be more than 300 feet to nearest crossing or marked crosswalk.
6. Traffic volumes should be less than 10,000 ADT or if above 10,000 ADT raised median islands should be included.
7. Pedestrian crossing enhancements (curb extensions and/or pedestrian refuges) should be considered.

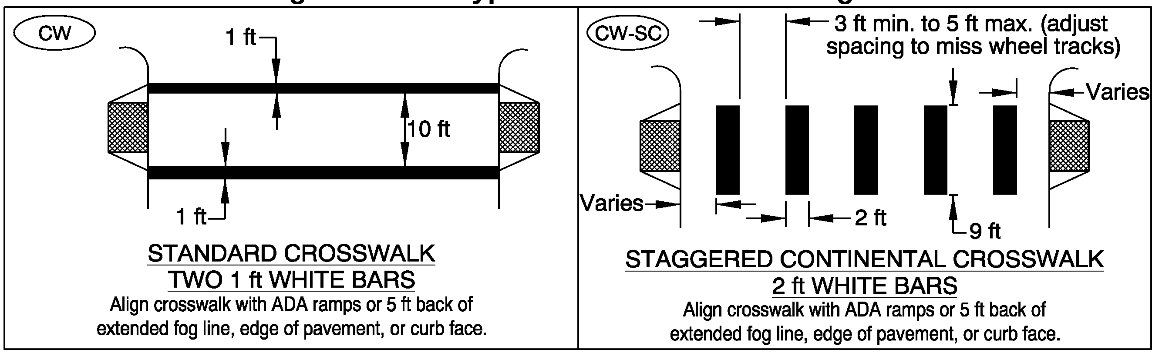
Types Of Crosswalk Markings

As shown in Figure 11-12, crosswalks can be drawn one of two ways:

A. Continental (or Longitudinal) Crosswalk marking is a series of uniform, parallel solid white longitudinal lines that mark the pedestrian's path with transverse lines (see Figure 11-12).
B. Standard Crosswalk marking is a set of parallel solid white transverse lines that mark both edges of the pedestrian crosswalk (see Figure 11-12).

[23] Source: ODOT, Traffic Manual, December 2007

Figure 11-12: Types Of Crosswalk Markings[24]



Crossing Strategies[25]

The need for convenient, practical and safe pedestrian crossings of highways is a high priority for virtually all cities.

There are many reasons pedestrians have difficulty crossing a highway:

- High traffic volumes
- Lack of adequate gaps
- High traffic speeds
- Long crossing distances
- Multiple travel lanes
- Poor visibility

High traffic volumes and lack of adequate gaps are difficult obstacles to resolve with a simple crossing strategy, but there are several ways to mitigate the other factors. The following measures should be instituted before a crosswalk is marked at a location other than a traffic signal:

A. Traffic Speeds

The most conventional “traffic-calming” methods are not appropriate on state highways, but there are measures a jurisdiction can undertake to alert drivers they are entering an area with expected pedestrian activity. These include, but are not limited to, sidewalks, street trees, median islands, bike lanes, visually narrowing the cross-section with better lane definition, bringing buildings closer to the back of sidewalks, maintaining on-street parking, etc.

B. Long Crossing Distances

Using good design practices, the roadway cross-section can be reduced by selectively narrowing or even eliminating unnecessary roadway elements (i.e. travel lanes, turning lanes, or parking). Where on-street parking is present, curb extensions should be considered.

[24] Source: ODOT, Traffic Line Manual, 2007
[25] Source: ODOT, Traffic Manual, December 2007

C. Multiple Travel Lanes

Assessing a safe and adequate gap in traffic becomes more difficult as the number of travel lanes increases. Islands can break up the crossing into discrete steps, so the pedestrian has to deal with fewer conflicts at a time. If the crossing point is at an intersection with a right-turn lane, an island between the right-turn lane and the through lanes enables the pedestrian to cross just the turning lane first. This breaks the crossing into more manageable parts.

The most important island to provide is in the median. This enables a pedestrian to cross traffic in only one direction at a time, in two easy steps. It can be up to 5 to 7 times easier to cross a four-lane road in two steps than all at once.

D. Poor Visibility

Pedestrians rarely knowingly step in front of moving traffic, and drivers don't purposely hit a pedestrian they could see and react to in time. Measures to address visibility include removal or relocation of obstructions (signs, signal boxes, etc), installation of curb extensions (where on-street parking is present), and illumination. Curb extensions allow pedestrians to better see on-coming traffic, and drivers to better see pedestrians about to cross. Approximately 60 percent of pedestrian crashes occur at night, which is out of proportion to exposure. Illumination should be provided at all designated crossing points.

Note: providing visibility should not be carried to extremes; for example, removing all on-street parking, trees and other vertical elements may have the negative effect of increasing travel speeds, which is potentially a greater hazard to safe crossing.

Table 11-1 shows some of the possible strategies for addressing some pedestrian facility deficiencies on the transportation system.

Table 11-1: Objectives And Strategies For Addressing Pedestrian Deficiencies[26]

Objective	Strategies
Reduce Pedestrian Exposure to Vehicular Traffic	Provide Sidewalks/Walkways and Curb Ramps
	Install or Upgrade Traffic and Pedestrian Signals
	Construct Pedestrian Refuge Islands and Raised Medians
	Provide Vehicle Restriction/Diversion Measures
	Install Overpasses/Underpasses
Improve Sight Distance and/or Visibility Between Motor Vehicles and Pedestrians	Provide Crosswalk Enhancements
	Implement Lighting/Crosswalk Illumination Measures
	Eliminate Screening by Physical Objects
	Signals to Alert Motorists That Pedestrians Are Crossing
	Improve Reflectorization/Conspicuity of Pedestrians
Reduce Vehicle Speed	Implement Road Narrowing Measures
	Install Traffic Calming Devices
	Provide School Route Improvements
Improve Pedestrian and Motorist Safety Awareness and Behavior	Provide Education, Outreach, and Training
	Implement Enforcement Campaigns

[26] Source: NCHRP Report 500, Volume 10, A Guide For Reducing Collisions Involving Pedestrians

What Are The Guidelines For Installing Sidewalks?

Sidewalks separate pedestrians from vehicles and, therefore, are effective in reducing the potential for a crash. Sidewalks also provide paved places for children to play, which helps keep them out of the street.

Before installing new sidewalks, review the publication titled "Guide for the Planning, Design, and Operation of Pedestrian Facilities", published by the American Association of State Highway And Transportation Officers (AASHTO), July 2004. In addition, the Americans with Disabilities Act (ADA) should be addressed.

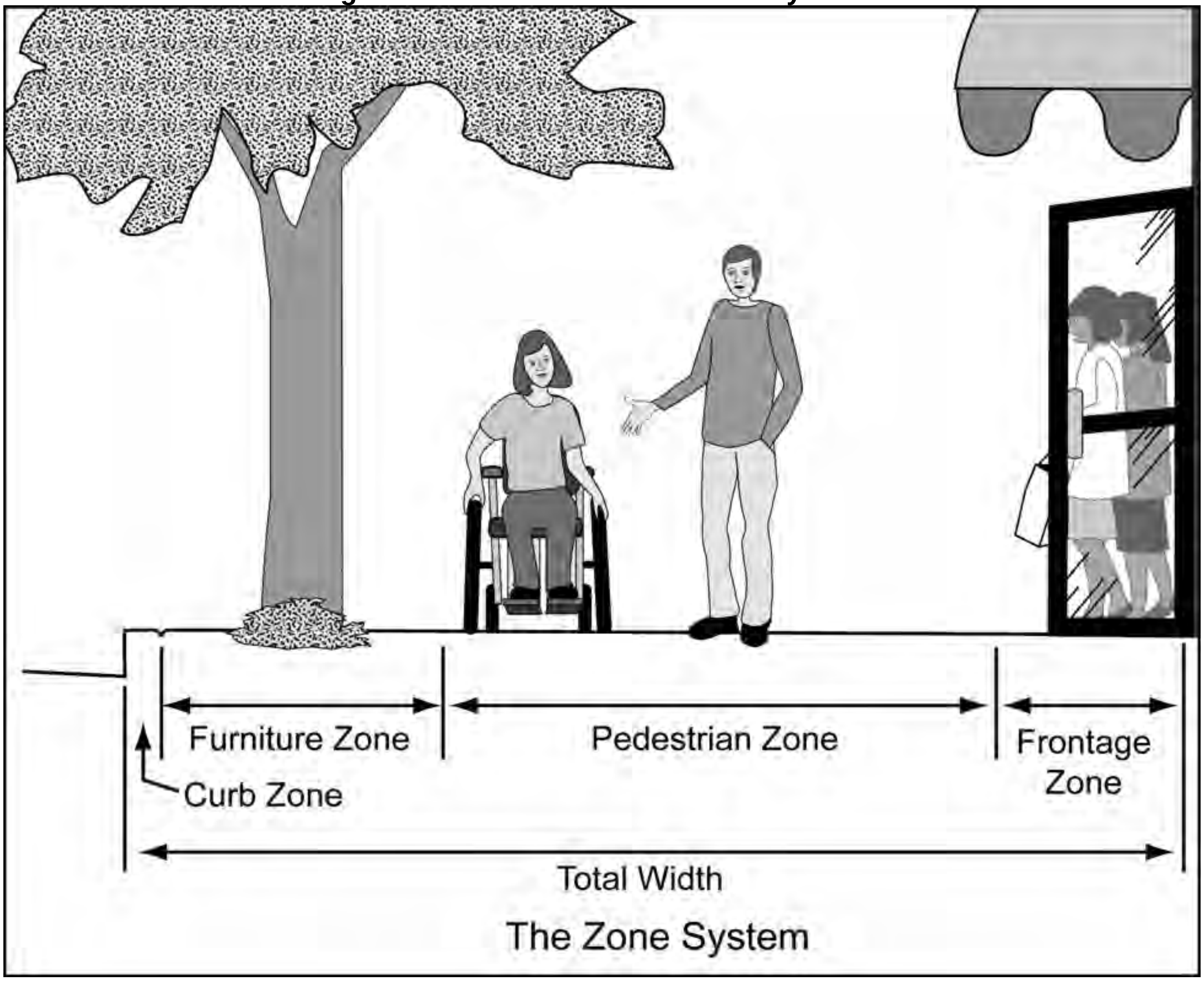
The Sidewalk Zone System

The best way to achieve the goal of a clear walking area is to design sidewalks using the zone system. Each zone is a distinct sidewalk area; the four zones are:

1. The curb zone
2. The furniture (or planter) zone
3. The pedestrian (or walking) zone
4. The frontage zone.

Each zone has its function, and omitting a zone compromises the quality of the walking experience. The zone system makes it easier to meet the basic ADA requirements for a continuous, smooth, and level sidewalk free of obstructions. Figure 11-13 illustrates the Sidewalk Zone System.

Figure 11-13: The Sidewalk Zone System[27]



A. The Curb Zone:

Most urban streets with sidewalks are typically curbed. A vertical (barrier) curb channelizes drainage and prevents people from parking their cars on the sidewalk (See Figure 11-13).

B. The Furniture Zone/Planter Strip:

The furniture zone is located between the curb and pedestrian zones (See Figure 11-13). When landscaped it is referred to as the planter strip. It's easier to meet ADA sidewalk requirements with separated sidewalks. The furniture zone has many functions:

- Pedestrians are separated from traffic, increasing a walker's sense of security and comfort;
- Street furniture and obstructions (bicycle parking, poles, posts, mailboxes, parking meters, fire hydrants, etc.) can be placed out of the walking zone (these objects should not reduce visibility of pedestrians, bicyclists, and signs);
- Room for street trees and other landscaping;
- The sidewalk can stay level across driveways;

[27] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

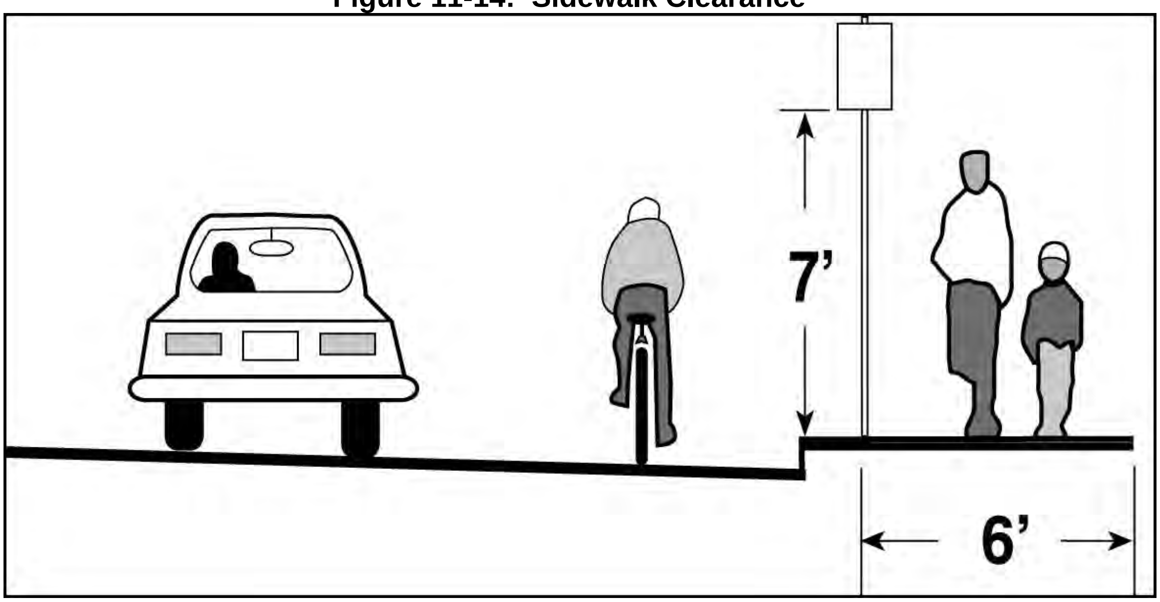
- Ramps can be placed correctly: sidewalks, curb cuts, and crosswalks line up at intersections.
- Improved drainage: decreased runoff water, decreasing overall drainage requirements; prevents water in puddles from splashing onto pedestrians; creates a place to store snow removal during the winter

The furniture zone/planter strip should be 5 feet (1.7 m) wide or more. Narrower furniture zones (2 feet min (0.6 m)) offer some of the advantages listed above. Where constraints preclude the use of the same width throughout a project, the planter strip can be interrupted and resumed where the constraint ends.

C. The Pedestrian Zone:

This is where people walk. All planning, design and construction documents should clearly state the walking zone dimension is to be clear of obstructions. The ODOT standard pedestrian zone width is 6 feet (1.8 m). This width allows two people (including wheelchair users) to walk side by side or to pass each other comfortably (See Figure 11-13). Where it can be justified and deemed appropriate, the minimum width may be 5 feet (1.5 m), such as on local streets, with adequate separation from the roadway. Clearance to vertical obstructions (signs, tree limbs, etc.) must be at least 7 feet (2.1 m) (See Fitur 11-13). At no point should the pedestrian zone be less than 4 feet (1.2 m) wide at pinch points, such as around poles (See Figure 11-14).

Figure 11-14: Sidewalk Clearance[28]



The pedestrian zone should be either straight or parallel to the adjacent road when the road naturally curves.

Cars parked perpendicular or diagonally to sidewalks can reduce the sidewalk width if there is excessive overhang. Wheel stops should be used to prevent narrowing the usable sidewalk width.

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[28] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Sidewalks must not be placed directly adjacent to a high-speed travel lane (45 mph (70 km/h) and above); they should be buffered with a planting strip, a parking lane, or a bike lane. In the absence of any separation, sidewalks next to high-speed roadways should be at least 8 feet (2.7 m) wide, as the outer 2 feet (0.6 m) are used for poles, sign posts etc. This results in an effective 6-foot (1.8 m) wide walking space.

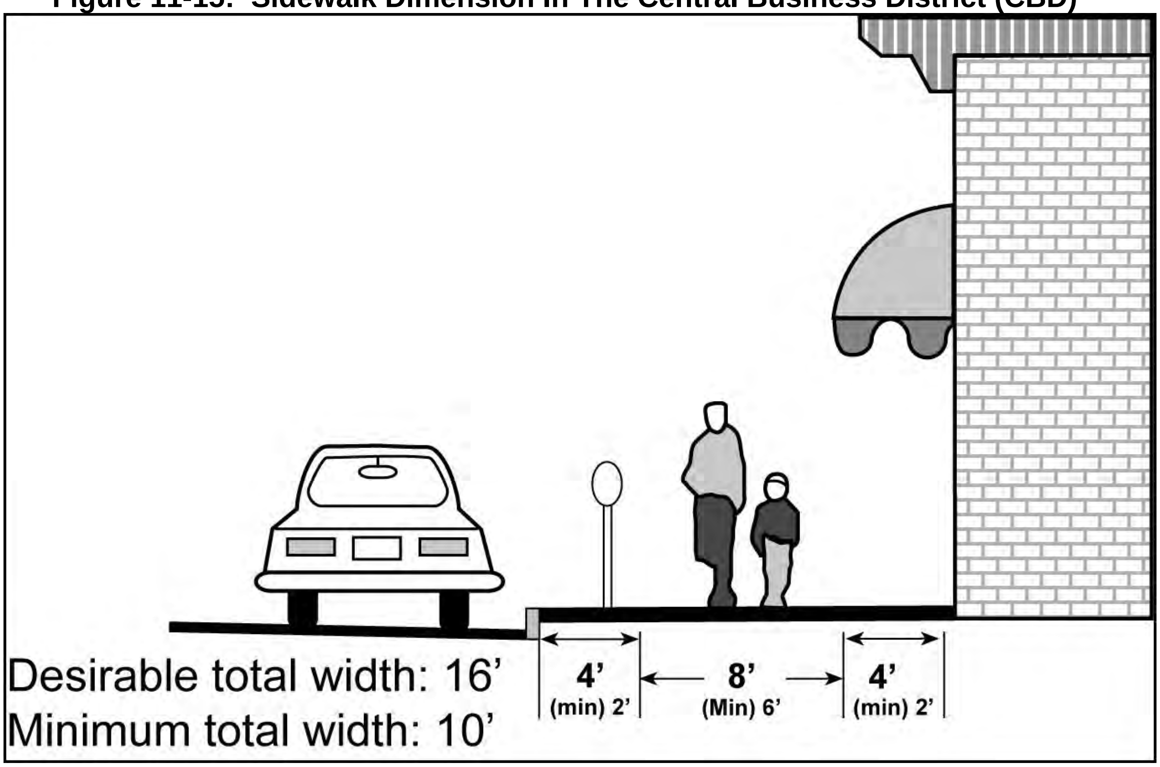
D. The Frontage Zone:

The frontage zone is located between the pedestrian zone and the right-of-way (See Figure 11-13). It is where sandwich boards, bike racks and other street furniture are placed; it is used by window shoppers, and it is where people enter and exit buildings.

The recommended width for the frontage zone is 2 feet (0.6 m) or greater. An absolute minimum of 1 foot (0.3 m) is needed for practical purposes, for example to ensure that adjacent property owners don't erect a fence at the back of walk, or for maintenance personnel to make sidewalk repairs. A shy distance of 2 feet (0.6 m) is needed from vertical barriers such as buildings, sound walls, retaining walls, and fences.

In Central Business Districts the frontage zone should be 4 feet (1.2 m) or wider to provide space for sandwich boards, sidewalk cafés, and opening doors (See Figure 11-15).

Figure 11-15: Sidewalk Dimension In The Central Business District (CBD) [29]



[29] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Accommodating People With Disabilities[30]

The Americans with Disabilities Act (ADA) requires that transportation facilities accommodate the disabled. For most practical purposes, pedestrians with mobility- and vision-impairments need greater attention.

The Americans with Disabilities Act Accessibility Guidelines for the Public Right-of-Way (ADAAG) and ODOT Standard Drawings should be used to construct curb cuts, driveways, accessible signals, and other facilities designed for pedestrians with disabilities.

The US Access Board website has the latest guidelines:
http://www.access-board.gov/prowac/draft.htm

The ODOT Bicycle and Pedestrian program website has links to the Oregon standard drawings:
http://www.oregon.gov/ODOT/HWY/BIKEPED/

The general guidelines for the ADA requirements are described below:

A. WIDTH

The 6-foot (1.8 m) standard sidewalk width exceeds the ADA minimum passage requirements of 4 feet (1.2m). At pinch points, such as at poles, or other obstructions in a sidewalk, a width of 4 feet (1.2m) is acceptable. The ADA minimum clearance width is not an acceptable continuous sidewalk width.

B. GRADES

ADA requires that the grade of pedestrian accessible routes may not exceed 5% and must have a level (2% drainage cross-slope allowed) every 30 feet (9 m). Ramps, provided to transition from the sidewalk to the street, must be no steeper than 1/12 (8.33%), with a 4-foot square level landing at the top (see Figure 11-16). Also see ODOT Standard Drawing D 755 for details on when the ramp can be steeper than stated above.

C. CROSS-SLOPE

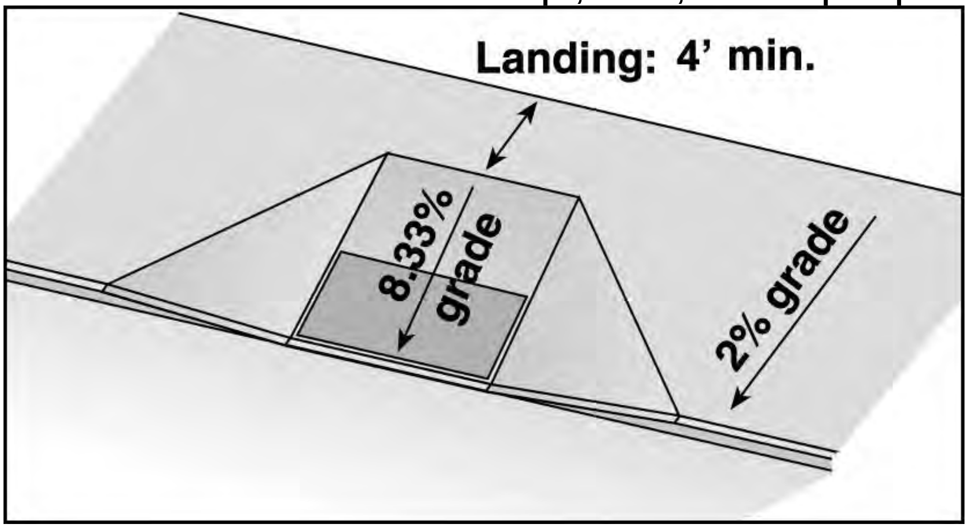
The maximum allowable cross-slope (needed for drainage) for the pedestrian access route portion of a walkway is 2%. Across driveways, curb cuts, and road approaches (in crosswalks, marked or unmarked), a 4-foot (1.3 m) minimum wide area must be maintained at 2% (See Figure 11-16).

D. RAMPS

ADA recommends two ramps per corner at intersections for new construction, as a single diagonal ramp may direct users into the travel way. A single ramp is allowable on retrofit projects where circumstances prohibit the installation of two ramps; however, in most cases two ramps can and should be accommodated even on retrofit projects. A 4-foot (1.2 m) wide passage with a cross slope of 2% must be maintained behind ramps (See Figure 11-16).

[30] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Figure 11-16: ADA Dimensions For Cross-Slope, Grade, And Ramp Requirements[31]



How To Use Physical Barriers To Separate Pedestrians And Vehicles

You can also use physical barriers, such as chains, fences, plants, or other devices to separate pedestrians and vehicles. At intersections these barriers can direct pedestrians to and keep them within crosswalks. In the middle of a block, they can be especially effective in keeping people from darting into the roadway. However, when used near high schools or college campuses, physical barriers are often less effective because people simply maneuver over or under them. An effective use of barriers is a divider between two lanes of traffic, preventing pedestrians from crossing the roadway and keeping wandering vehicles from the median.

When Should The Pedestrian Signals Be Used?

Often people assume that using WALK and DON'T WALK signals is a way to reduce pedestrian crashes. Yet studies have found that intersections with standard-timed pedestrian signals (those where pedestrians have a WALK signal while the vehicles parallel to them are moving and turning right or left across the pedestrians' path) are not any safer than intersections with no pedestrian signals. There are fewer crashes when exclusive-timed pedestrian signals are used - signals that stop all traffic and allow pedestrians to cross in any direction. However, exclusive-time signals greatly delay motor vehicle traffic.

The MUTCD contains four recommendations for the installation of pedestrian signal indications. They are:

- When traffic signals are installed based on meeting the minimum pedestrian volume or school crossing warrants.
- When an exclusive pedestrian interval is provided, i.e., with all conflicting vehicular traffic being stopped.
- When the vehicle signals are not visible to pedestrians (such as at one-way streets or "T" intersections).
- At signalized intersections within established school crossing locations.

[31] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Pedestrian signal indications are recommended: when there are multiphase signals, where there is complex geometry (more than four legs, wide streets, refuge islands), in areas where compliance is high, in areas where older adults or young children are present, and/or where pedestrian push-buttons are in use. The MUTCD recommend at least a 4 to 7 second walk interval be used.

For more information about pedestrian safety, please refer to the following publications:

- A Guide for Reducing Collisions Involving Pedestrians, NCHRP Report 500, Volume 10, Transportation Research Board, Washington, D.C., 2004,
- Guide for the Planning, Design and Operation of Pedestrian Facilities, AASHTO, 2004
- Traffic Manual, ODOT, December 2007
- PEDSAFE: Pedestrian Safety Guide and Countermeasure Selection System, USDOT, FHWA, September 2004, http://www.walkinginfo.org/pedsafe/
- Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations Final Report and Recommendation Guidelines, FHWA-RD-04-100, USDOT, FHWA, February 2005, http://www.tfhrc.gov/safety/pubs/04100/

For the most up to date information about the "Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines" (which is currently being updated by the Oregon Transportation Commission and should be finished in 2010), please visit the website: http://www.oregon.gov/ODOT/HWY/BIKEPED/

For the most current information about pedestrian safety, please contact:
Sheila Lyons, PE
Bicycle and Pedestrian Program Manager
Oregon Department of Transportation
355 Capitol Street NE
Salem, Oregon, 97301
Phone: 503-986-3555
E-mail: sheila.a.lyons@odot.or.us
http://www.oregon.gov/ODOT/HWY/BIKEPED/

Chapter 12: School Area Safety

School area safety can be an emotionally and politically charged topic. There are many aspects that make the design and use of school traffic control devices challenging. Parents often have concerns about their children's safety and school age children have limited judging capabilities. In addition, the mix of traffic modes (buses, private autos, pedestrians, bicyclists, etc.) and the extreme peaking characteristic of traffic at schools present unique challenges. The multiple parties involved in the decision making process regarding the appropriate traffic control devices (TCDs), the low cost of TCDs, which makes them an attractive solution that may not be warranted, and the limited amount of information exchanged nationwide contribute to the politically charged atmosphere that can build around the use of school traffic control devices.

Part VII of the MUTCD 2003 was developed to provide standards and guidance for the use of school traffic control devices in hopes of providing balanced emotional, political, and technical engineering solutions to traffic situations surrounding schools.

The Traffic Control Device Handbook published by the Institute of Transportation Engineers (ITE), 2001 presents six basic responses to school traffic situations. These responses are listed below. Some of these responses will be discussed in further detail in this Chapter. Most of the information presented in this Chapter is based on the publication titled, "A Guide To School Area Safety", Oregon Department of Transportation, August 2006.

1. Education Programs
2. Crossing Guards
3. Safe "School Route Plans"
4. School Bus Transportation Programs
5. Grade-Separated Crossings
6. Land Use Planning

What Is The Safe Routes To School Program?[1]

The Safe Routes to School Program is administered in Oregon by ODOT's Transportation Safety Division. You can find the latest information, contacts, and guidance for Oregon on Transportation Safety's web site at http://www.oregon.gov/ODOT/TS/saferoutes.shtml.

The goal of the Safe Routes to School Program is to assist communities in identifying and reducing barriers and hazards to school children, grades K-12, in walking or bicycling within two miles of the school. Safe Routes to School (SRTS) is a multi-national effort to encourage and enable more youth to walk and bike to school.

[1] Source: A Guide To School Area Safety, ODOT, August 2006

The program works with the five Es as the key to a solution: Engineering, Enforcement, Education, Encouragement, and Evaluation. SRTS brings together school administrators, teachers, support staff, parents, students, neighbors, police, and community service providers in School Teams and Community Task Forces. The School Teams and Community Task Forces study why more kids aren't walking and biking to school. Then they develop strategies to increase safety and the number of kids walking and biking to school. These strategies are based on a balanced and integrated approach of enforcement, engineering, encouragement, education, and evaluation.

What Agencies Are Responsible For Developing A Safe Route To School Plan (SRTS)? [2]

Development of a SRTS plan is the responsibility of the local school district, in cooperation with the local road and policing jurisdictions. Schools work in cooperation with local public works staff, engineering staff, traffic safety committees, parents, and law enforcement officers to complete their plan.

What Is A School Zone? [3]

A school zone is a section of roadway adjacent to a school or a school crosswalk where signs designating a school are present. The signs marking a school zone may include any words or symbols that give notice of the presence of a school zone. Some traffic fines double in a school zone regardless of whether a school speed zone is posted or not.

What Is A School Speed Zone? [4]

A school speed zone is a special 20 mph speed zone for schools allowed by statute and defined by school speed signs. The school speed zone begins at the SCHOOL SPEED LIMIT 20 sign and ends at the END SCHOOL SPEED ZONE sign or other posted speed sign (See Figure 12-1).

ORS 811.111 describes school zone limits. School speed zones are defined for the two types of school zone areas: those adjacent to school grounds (Condition A) and crosswalks not adjacent to school grounds (Condition B). If the school zone is in Condition A, adjacent to school grounds, the school speed is in effect when a flashing light indicates when children are coming to or leaving the school or, if there is no flashing light, between the hours of 7 a.m. and 5 p.m. on a day when school is in session. For Condition B, at a crosswalk not adjacent to school grounds, the school speed is in effect with either the flashing light or when children are present as described in ORS 811.124.

School speed zones should begin 100 to 200 feet (30 to 60 m) from the school property line or school crosswalk, whichever is determined to be most appropriate. Ideally, school speed zones should be kept short to enhance driver compliance. When school property frontage along the roadway is lengthy and/or fenced, consider focusing the school speed zone on the school crosswalk, potential crossing areas or exposed/unfenced portions.

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[2] Source: A Guide To School Area Safety, ODOT, August 2006
[3] Source: A Guide To School Area Safety, ODOT, August 2006
[4] Source: A Guide To School Area Safety, ODOT, August 2006

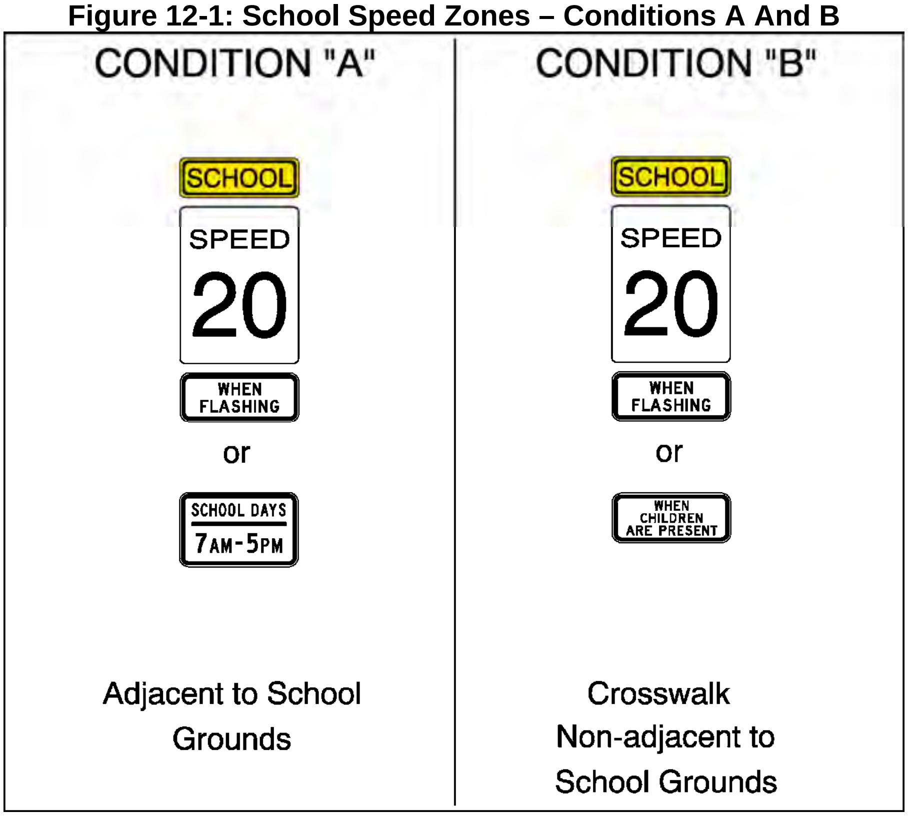
What Is Not A School Speed Zone? [5]

Not all school crossings or school areas are posted with a SCHOOL SPEED LIMIT 20 sign. There may be areas adjacent to school grounds where the need for reduced school speeds may be deemed unnecessary. For instance, residential streets on the side or back of a school may not need a reduced speed if travel speeds are already slow. A high school with good traffic control or a school with no students who walk to school may have no need of a reduced speed. A school crosswalk away from the school controlled by a traffic signal may have no need of a reduced speed. Unless a school area or crossing has SCHOOL SPEED LIMIT 20 signs, the area is not considered a school speed zone.

Who Determines That A School Speed Zone Is Appropriate? [6]

Each road authority (state, county, or city) determines, for roadways under their jurisdiction, where school speed zones are located. Locations and limits for school speed zones should be determined on the basis of an engineering study. The school speed zone should be established as per the applicable sections of the Manual on Uniform Traffic Control Devices. The road authority is encouraged to use these guidelines to help determine the need for a school speed zone. A local jurisdiction that does not have the expertise to do an engineering study is encouraged to contact their local Region ODOT Traffic office for assistance or hire a consulting engineer. School districts and local traffic safety committees can request a school speed zone study through the local road authority.

Figure 12-1: School Speed Zones – Conditions A And B



[5] Source: A Guide To School Area Safety, ODOT, August 2006
[6] Source: A Guide To School Area Safety, ODOT, August 2006

School Crosswalks[7]

Purposes:

1. Crosswalks show pedestrians where to cross and concentrate them in a specified area. The concentration makes the pedestrians more visible to drivers and the frequency of pedestrians may improve general driver expectancy of pedestrian activity in the area.
2. Sight of the marked crosswalk may cause some drivers to be more alert as they approach.

Note: Detailed information regarding marked and unmarked crosswalks is contained in Chapter 11 of this Handbook.

General Considerations For The Installation Of School Crosswalks

In conjunction with the considerations and recommendations presented in Chapter 11 of this Handbook, prior to the installation of a school crosswalk a school route plan should be developed.

What Is A School Route Plan?

School route plans should be developed for each school within a jurisdiction. They define the most appropriate route for students in a given area to walk or bike to and from school. These plans require time to develop, review, and update on an annual basis.

What Should Be Included In A School Route Plan?

- It should consist of a map showing streets, the school, existing traffic controls, established school walk routes, and established school crossings.
- The type(s) of school area traffic control devices used, either warning or regulatory, should be related to the volume and speed of vehicular traffic, street width, and the number and age of the students using the crossing.
- School area traffic control devices should be included in a school traffic control plan.

How Should A School Route Plan Be Developed?[8]

For each kindergarten and elementary school child, plan a route in which the child must:

1. Walk on sidewalks or, if sidewalks are not available, walk on paths that are not in the roadway.
2. Walk only a very short distance on roadways that have neither sidewalks nor wide shoulders.
3. Walk facing traffic on roadways where sidewalks or wide shoulders are not available.
4. Avoid high-speed roadways, major intersections without crosswalks or signals, and railroad crossings.
5. Cross the fewest number of streets possible to reduce the child's contact with traffic.
6. Become part of a group of other children along the way to help ensure that motorists see them.

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[7] Source: A Guide To School Area Safety, ODOT, August 2006
[8] Source: Part VII of MUTCD 2003

7. Have available crossing guards, school safety patrols, and traffic control devices such as stop signs and traffic signals to help protect them.

When deciding which places are safest for children to cross roadways, consider five factors:
1. the speed of approaching traffic;
2. the number of vehicles and pedestrians that are usually at the crossing at that time of day;
3. whether the curve of the road, trees, or other obstructions prevent children from seeing approaching traffic;
4. whether the crossing is in a residential, commercial, or industrial area; and
5. whether the children will have crossing guards, school patrols, or traffic control devices, such as crossing signs or crosswalks, to help them cross.

To map a safe route to school, start with the street at the outermost walking boundaries of the school and work in toward school. Because existing traffic control devices might not be the safest route, don't try to make the route fit the existing boundaries. Instead, focus on plotting the safest route possible.

Involve the children in the selection of the safe route program. A safety program will be most effective when the children have a chance to shape it. Not only will children feel that they are a part of the process, but they will learn how to discriminate between safe and unsafe behaviors.

After the maps are complete, meet with any group that was not involved in the plan for whatever reason—school principals, local police, parents, care facility operators, etc.—to be sure that all groups understand and agree to the purpose of the safest route to school. During these meetings, give parents and children a list of rules for walking safely. Also encourage parents to:

1. work with administrators to find the safest route for walking between home or school and the bus stop.
2. plan the safest route to other places where the child might walk unsupervised, such as to the store, daycare, playground, or to a friend's house.
3. walk the chosen route with the child. If there is a shorter, less safe route, explain to the child why the longer route is better.
4. leave home about the same time each day. As parents, they should plan their time so the child won't be late or too early.
5. teach the child that traffic signs, crosswalks, traffic signals, or adult crossing guards do not necessarily make the crossing safer. The child must learn to stop, to look left for approaching vehicles, look right, and then look left again, and to cross only when no car or other moving vehicle is approaching.

After you distribute the maps to the school children and their parents, send teams out to observe the children on their routes to find out whether the map and instructions are being used properly. Because children learn more by example than by words, encourage parents to practice safe pedestrian habits.

How Should School Crosswalk Signs Appear?

A school crosswalk shall be accompanied by two sign assemblies:

1. The sign shown in Figure 12-2 shall be installed in advance of the crosswalk.
2. The sign depicted in Figure 12-3 shall be installed at the crosswalk.

Figure 12-2: Advance Warning Assembly[9]

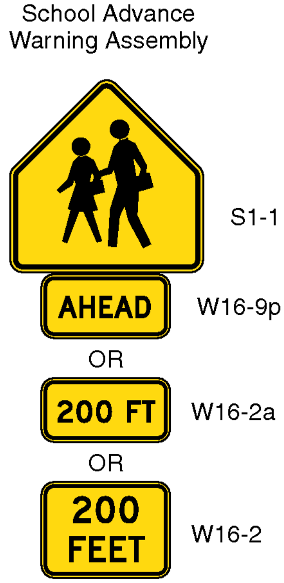
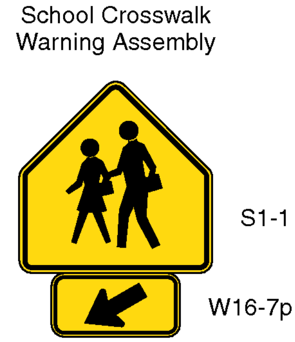


Figure 12-3: Location Warning Assembly[10]



Note: Vehicles turning right on red may come into conflict with pedestrians; some municipalities have found that signs reading "NO RIGHT TURN ON RED WHEN CHILDERN ARE PRESENT" an acceptable solution.

How Can One Tell If A School Crossing Is Unsafe?

When the delay time between adequate traffic gaps is excessive, or in other words, when gaps are less frequent than one per minute, it is an indication that some form of traffic control is needed to create gaps. An adequate gap is determined by dividing the width of the roadway by the average walking speed (4 feet per second) (1.2 m/sec). For example, if a roadway is 48 feet wide (14.4 m), an adequate gap would be 12 seconds (48 feet divided by 4) or (14.4 m divided by 1.2 m).

What Is The Recommended Sight Distance On Approach To A School Bus Stop?[11]

The sight distance should be 500 feet (150 m) on approach to a school bus stop where students are picked up or dropped off. If 500 feet (150 m) of sight distance is not available, the jurisdiction should consider moving the location of the bus stop. The MUTCD also allows the installation of the sign SCHOOL BUS STOP AHEAD (S3-1).

Note: Flashing lights on a school bus are typically more visible to approaching drivers than a roadside sign.

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[9] Source: Part VII, MUTCD 2003
[10] Source: Part VII, MUTCD 2003
[11] Source: Part VII, MUTCD 2003

Figure 12-4: School Bus Stop Ahead (S3-1) [12]

Where Should School Zones Begin?

School zones should begin 100 feet to 200 feet (30 to 60 m) in advance of school property or school crosswalk. The school zones should be kept a short distance to enhance driver compliance. The SCHOOL SPEED 20 sign (See Figure 12-5) should mark the beginning of a school zone and the END SCHOOL ZONE sign (See Figure 12-6) or other posted speed limit should mark the end of a school zone.

Figure 12-5: School Speed 20 (S4-3/R2-1) [13]

S4-3

R2-1

Figure 12-6: End School Zone (S5-2) [14]

S5-2

What Should The Engineering Study Include? [15]

An engineering study is required for the establishment of a school speed zone. They are a documented analysis and evaluation of available pertinent information using engineering principles and standards.

The following information should be considered in an engineering study for establishing school speed zones:

1. Crash history
2. Traffic volumes
3. Gap Study
4. Number of bicyclists riding to school

[12] Source: Part VII, MUTCD 2003
[13] Source: Part VII, MUTCD 2003
[14] Source: Part VII, MUTCD 2003
[15] Source: A Guide To School Area Safety, ODOT, August 2006

5. Number of pedestrians using the school crossing
6. Speed Study for all directions of travel at the proposed location
7. Examination of conditions adversely affecting pedestrian and bicycle safety
8. Examination of the school's drop-off and pick-up operations (includes on street parking controls and off-street parking facilities)
9. Examination of the school's Safe Routes to School Plan (includes review of planned adult crossing guards)
10. Input and participation by the school district, traffic safety committees, and other community representatives

What Are The Potential Improvements To Safety Beyond The School Zone Signing And Speed Zone?

When assessing the safety of the immediate area surrounding the school building, it is important to consider visibility and site design issues.

- Are there sight obstructions that should be corrected by restricting or removing parking or by trimming trees and shrubs?
- What accommodations have been made for children riding to school on bikes?
- Are the designated loading and unloading zones free from conflicts with other traffic?
- Are sidewalks needed to improve safety?

What Are Pedestrian Crossing Enhancements? [16]

Pedestrian crossing enhancements include:

A. Pedestrian enhancements

Pedestrian enhancements are encouraged to increase the safety of crossings near and along the route to school. Marked crosswalks may include enhancements such as curb extensions, median islands, and roadway illumination. The use of pedestrian refuges and curb extensions shorten the exposure time of the pedestrian. Other considerations include improving sight distance and better access management to reduce conflicts, as well as traffic calming to reduce speeds.

B. Pedestrian refuges and curb extensions

Pedestrian refuges and islands allow students to use existing gaps in traffic to split the crossing of the roadway into manageable parts. This is especially important where there are multiple travel lanes in each direction.

The use of curb extensions (bulb-outs) can reduce crossing distances. These extensions also have the effect of increasing the visibility of the pedestrian. Where on-street parking is present, curb extensions should be considered.

C. Textured/colored crosswalks

ODOT's practice is to not install textured or colored crosswalks. It is sometimes, however, a wish of a local road authority to install them. The perception is often times that the texturing or

[16] Source: A Guide To School Area Safety, ODOT, August 2006

coloring crosswalks alone will be more visible than standard crosswalk marking. But often times that is not the case; textured or colored crosswalks can actually be less visible than conventional marked crosswalks (also, red brick tends to fade to black, especially at times of low visibility).

D. In-roadway lights

In-roadway warning lights at crosswalks provide additional warning to motorists of their approach to a marked crosswalk. The usefulness of these lights is limited during daylight hours because they are sometimes difficult to see under normal daylight conditions. School crossings may not be the best location since most activity in school crossings is typically during daylight hours.

The in-roadway lights should only be considered after proven pedestrian safety measures such as median refuge islands, curb bulb-outs, and roadway illumination are in place.

What Standard Signs Should Be Used?

The following are the guidelines for the use of school signs in Oregon:

A. Sign Sheeting

ODOT reserves the use of the fluorescent yellow-green (strong yellow-green) sheeting exclusively for yellow background school-related signs. Fluorescent yellow-green sheeting is the preferred color for these signs. The mixing of standard yellow and fluorescent yellow-green background within a school area should be avoided. All school area signs should use high intensity sheeting or better.

B. School Zone Signs

School zones can be defined with signs other than school speed zone signs. The school advance warning assembly consists of the school advance sign supplemented with the “AHEAD” plaque. The school advance warning assembly is used in advance of school grounds, school crossings, and school zones. An alternative plaque “XXX feet” may be substituted in lieu of the AHEAD plaque.

The school crosswalk warning assembly consists of a school advance sign supplemented with a diagonal downward pointing arrow. The school crosswalk warning assembly may be used at school crossings, whether adjacent to schools and those on established school pedestrian routes. It can be used at signalized crossings but may not be used at crossings controlled by stop signs.

If used overhead at a marked crosswalk the School Advance Warning sign may be installed alone. The overhead sign should be located at the crosswalk facing both directions of traffic and must be accompanied by ground mounted school crosswalk warning assemblies with the arrow plaque. When used overhead, the minimum size should be 48" x 48".

C. School speed signs

When a school zone is established, the school speed sign or assembly shall be used. The beginning of the school zone is indicated by the school speed sign, which consists of a top plaque with the legend “SCHOOL”(S4-3), a “SPEED LIMIT 20” sign (R2-1), and a bottom plaque indicating when the school zone is in effect

As per the Oregon Revised Statute 811.111, possible bottom plaques include one of the following: SCHOOL DAYS/ 7 AM to 5 PM; WHEN CHILDREN ARE PRESENT; or WHEN FLASHING . The different categories of school zones for determining which bottom plaque to use are shown below:

- Areas adjacent to the school. In these areas the school speeds are 20 mph:
  - between 7 AM and 5 PM; or
  - when lights are flashing (school beacons)

.

- Crosswalks not adjacent to school grounds. In these areas the school speeds are 20 mph:
  - when children are present; or
  - when lights are flashing (school beacons).

D. End School Speed Zone Sign

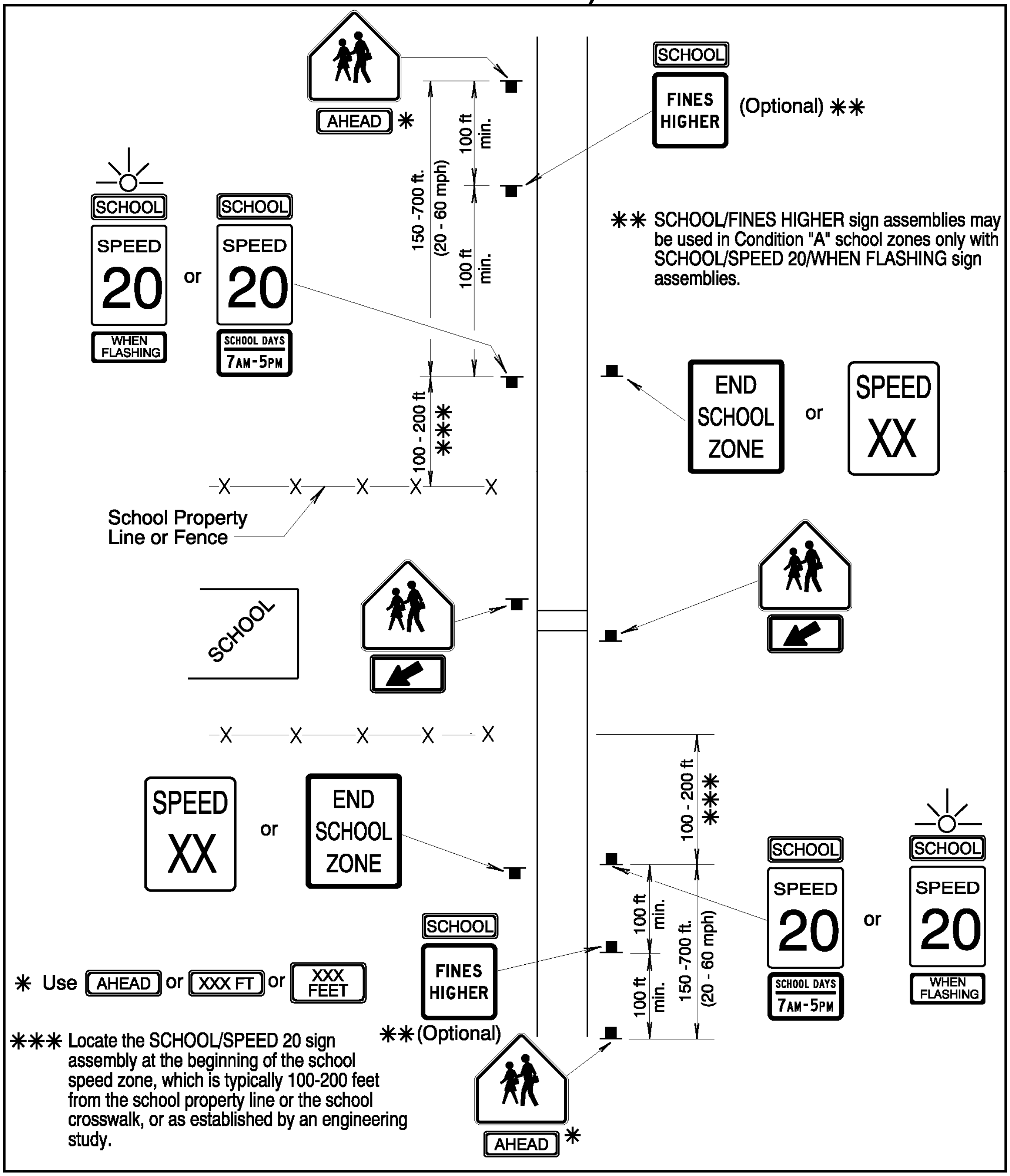
The end of a school speed zone must be marked with an "END SCHOOL SPEED ZONE" sign or a standard speed limit sign showing the speed limit for the section of roadway that follows.

E. School bus stop ahead sign

School bus stop ahead signs are used in advance of locations where school buses that are stopping to pick up or discharge passengers are not visible for a minimum distance of 500 feet and there is no opportunity to relocate the bus stop to a location with better visibility. The sign shall have a minimum 30" x 30" size.

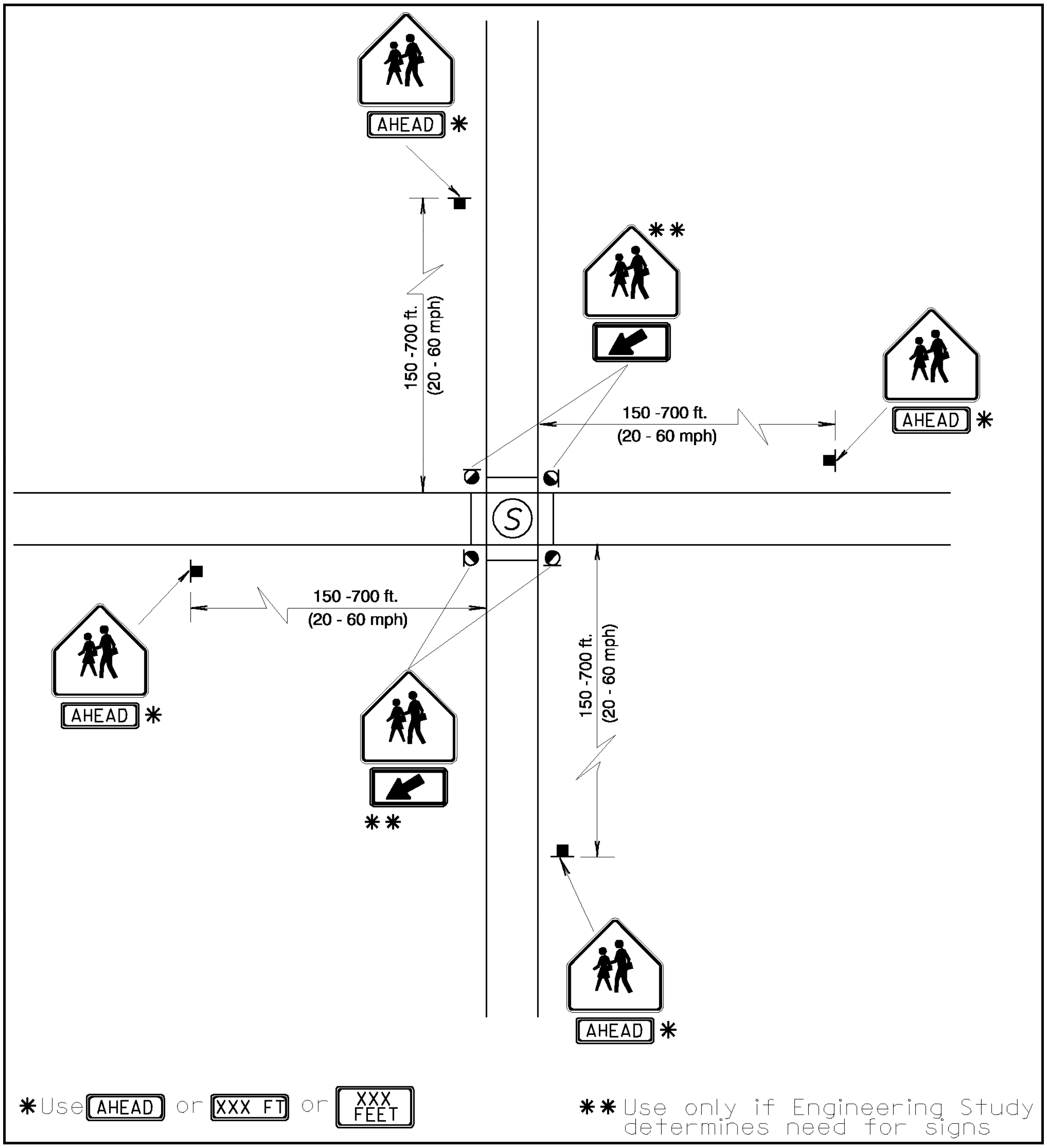
Figure 12-7 through Figure 12-9 show the location of standard signs at school crossings.

Figure 12-7: School Signing – Condition "A" With School Crosswalk (*Adjacent To School Grounds) [17]



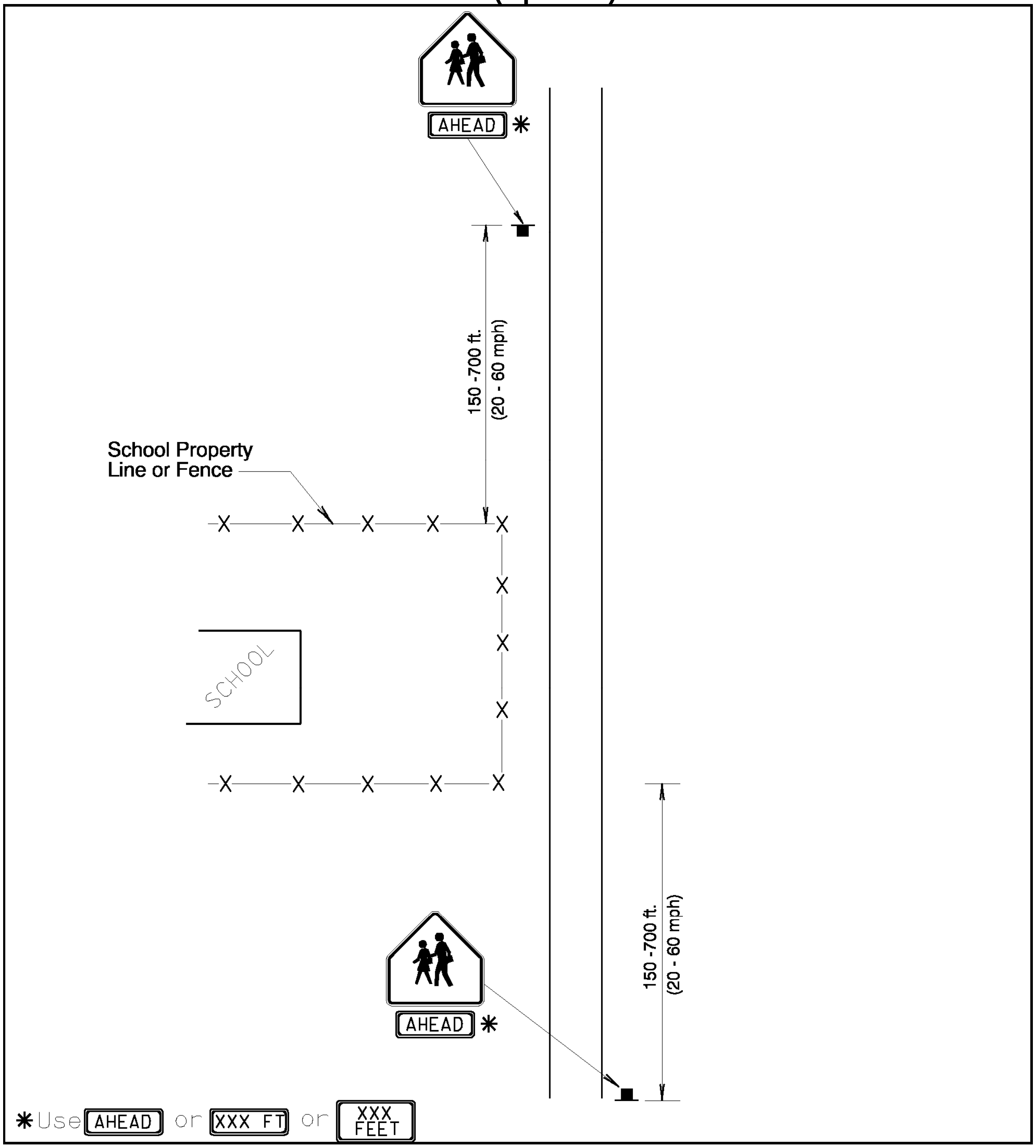
[17] Source: Sign Policy And Guidelines For The State Highway System, ODOT, 2008

Figure 12-8: School Signing – School Crosswalk Away From School At Signalized Intersection[18]



[18] Source: Sign Policy And Guidelines For The State Highway System, ODOT, 2008

Figure 12-9: School Signing – School Building Away From Highway Or School Grounds Fenced (Optional) [19]



What Types Of Pavement Markings Should Be Used At A School Intersection?

Pavement markings can be used in conjunction with traffic signals and signs or used solely as a crossing safeguard. One should be aware, however, that pavement markings have limitations because they can be hidden by snow, are often difficult to see when wet, and may be worn off by heavy traffic. The following are typical applications of pavement markings at school crossings.

[19] Source: Sign Policy And Guidelines For The State Highway System, ODOT, 2008

A. Crosswalk Lines – As was described above, crosswalk lines are solid white parallel lines marking the edge of the crosswalk. They are a minimum of six inches (150 mm) in width, spaced not less that six feet (1.8 m) apart, and extend from curb to curb. Where no advance stop line is provided, where vehicle speeds exceed 35 miles per hour (60 km/h), or where crosswalks may be unexpected, it is desirable to increase the widths of the lines to 24 inches (0.6 m).

B. Stop Lines – Stop lines are solid white lines, normally 12 to 24 inches (0.3 m to 0.6 m) wide which extend across all approach lanes and indicate the point at which vehicles should stop in compliance with a stop sign or traffic signal. Stop lines should ordinarily be placed four feet (1.2 m) in advance of and parallel to the nearest crosswalk line.

C. Curb Markings – Curb markings are used to restrict parking near school crossings in order to allow both drivers and pedestrians adequate sight distance. Curb markings are normally yellow and should be used in conjunction with signs.

D. Words and Symbol Markings – Words and symbol markings (like STOP or SCHOOL) on the pavement should be white in color and 8 feet (2.4 m) or more in height.

When Should Traffic Signals Be Used At A School Crossing?

School signals are standard traffic control signals used to create adequate gaps in the traffic stream for pedestrian crossings. Signals can be used in place of signs if the signals are warranted and the costs are not prohibitive. When initial and operating costs are considered, school signals over a period of years may be more economical than a combination of signs and guards.

A school sign may be warranted at an established school crossing when a traffic engineering study (of pedestrian group size and available gaps in the vehicular traffic stream) indicates that the number of adequate gaps in the traffic stream during the period when the children are using the crossing is less than the number of minutes in that same time period (Sec 7A-3, MUTCD 2003).

What Are Effective Educational And Enforcement Programs For Safe Routes To School? [20]

A. Education and encouragement programs

Educational programs are needed to supplement the engineering and enforcement efforts to effectively promote school area safety. A number of materials and programs are in existence. These programs include school curriculum, banners, reader boards, internet resources, work with local media and neighborhoods, and special events and promotions, such as International Walk to School Day. These efforts should be continuous throughout the year, but especially strong at the beginning of the school year.

[20] Source: A Guide To School Area Safety, ODOT, August 2006

B. Enforcement programs

Law enforcement can take a leading role in improving public awareness of existing traffic laws (e.g. stopping for pedestrians in marked crosswalks, not speeding in school areas, obeying parking controls, and stopping for school buses).

Where Is Additional Information About School Route Plans?

Table 12-1 contains information regarding where additional information can be obtained about school route plans.

Table 12-1: Sources For Additional Information – School Route Plans

Organization	Program Name	Source of Information
National Center for Safe Routes To School	National Clearing House for State Routes To School	www.saferoutesinfo.org
Institute of Transportation Engineers (ITE)	School Trip Safety Program Guidelines	www.ite.org
National Highway Traffic Safety Administration (NHTSA)	Safe Routes to School	www.nhtsa.dot.gov
Oregon Department of Human Services	Oregon Supplement to Safe Routes to School	www.dhs.state.or.us
Clackamas County	Our Children Are Our Future – A Guide to Developing Safe Routes To School	www.co.clakamas.or.us
City of Portland	Community and School Traffic Safety Partnership	www.SafeRoutesPortland.org

Another important reference is: A Guide to School Area Safety, ODOT, August 2006. The guidebook is available at the website: http://www.ODOT.state.or.us/traffic/publicat.htm.

For the most current information about safe routes to school and traffic safety and education, please contact:

Julie Yip
Oregon Safe Routes to School Program
Transportation Safety Section
Oregon Department of Transportation
Phone: 503-986-4196
E-mail: Julie.A.Yip@odot.state.or.us

Chapter 13: Bicycle Facilities

ORS 366.514 requires that the state, cities and counties expend a reasonable amount (minimum 1%) of their State Highway Funds on footpaths and bicycle trails. The statute also requires that footpaths and bicycle trails shall be provided wherever a highway, road or street is being constructed, reconstructed, or relocated. Footpaths and trails are not required if scarcity of population or other factors indicate an absence of any need, if costs appear excessively disproportionate to need or probable use, or where public safety is compromised. The current terminology for such facilities is bikeways and walkways.

The design of bikeways shall be based on the standards provided in the following publications:

1. "Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines", latest edition and related references, and
2. AASHTO, "Guide for the Development of Bicycle Facilities, 1999"

What Are The Types Of Bikeways?

A bikeway exists on any road that has the appropriate design treatment to accommodate bicyclists, based on motor vehicle traffic volumes and speed. The basic design treatments used for bicycle travel on roads are shared roadway, shoulder bikeway, or bike lane. A shared-use path is a facility separated from the roadway.

Bikeway types (listed with no implied order of preference):
A. Shared Roadway – Bicyclists and motorists ride in the same travel lanes. There are no specific dimensions for shared roadways. They are usually narrow, so a motorist has to cross over into the adjacent travel lane to pass a cyclist. Shared roadways are common on neighborhood residential streets, rural roads, and low-volume highways.
B. Bicycle Boulevards – The operation of a local street is modified to function as a through street for bicyclists while maintaining local access for automobiles. Traffic calming devices control traffic speeds and discourage through trips by automobiles. Traffic controls limit conflicts between automobiles and bicyclists and give priority to through bicycle movement.
C. Shoulder Bikeway – A shoulder bikeway is a paved shoulder that provides a suitable area for bicycling, reducing conflicts with faster moving motor vehicle traffic. Most bicycle travel on the rural state highway system, as well as on many county roads, is accommodated on shoulder bikeways.
D. Bike Lane – A portion of the roadway designated for preferential use by bicyclists. Bike lanes are appropriate on busy urban thoroughfares. They may be used on other streets where bicycle travel and demand is substantial. Bike lanes are marked to call attention to their preferential use by bicyclists.
E. Shared-Use Path (formerly called bike path or multi-use path) – A facility separated from motor vehicle traffic by an open space or barrier, either within the roadway right-of-way or

within an independent right-of-way. These are typically used by pedestrians, joggers, skaters and bicyclists.

What Are The Design Standards For Shared Roadway Bikeways?

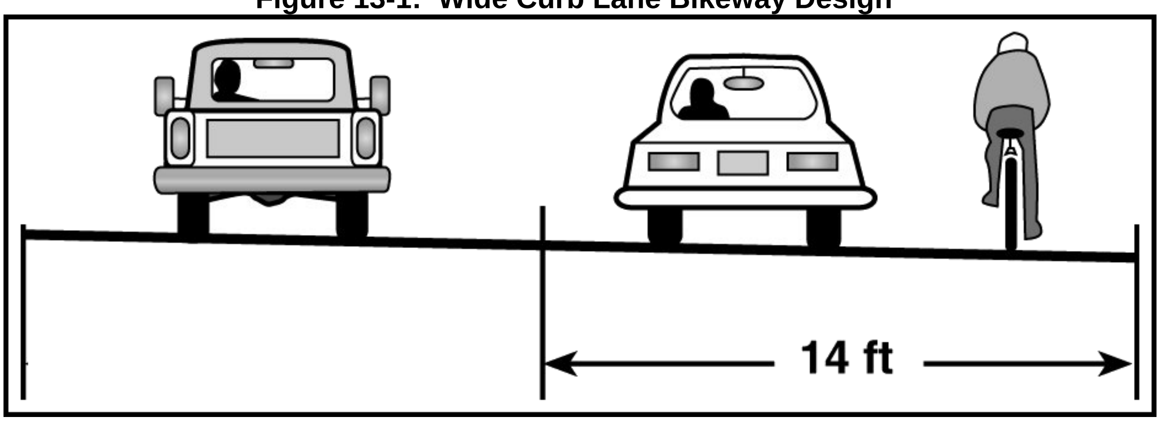
Shared roadways are the most common bikeway type. There are no specific bicycle standards for most shared roadways. Most are fairly narrow; they are the roads as constructed.
Shared roadways are suitable in urban areas on streets with slow speeds (25 mph (40 km/h) or less) or low traffic volumes (under 3,000 to 5,000 ADT, depending on speed and adjacent land use).

In rural areas, the suitability of a shared roadway decreases as traffic speeds and volume increases, especially on roads with poor sight distance.

A wide curb lane may be provided where there is inadequate width to provide the required bike lanes or shoulder bikeways.

To be effective, a wide curb lane is recommended for facilities with speed of 35 mph (50 km/h) and under and must be at least 14 feet (4.2 m) to 15 feet (4.5 m) wide. Usable width is normally measured from curb face to the center of the lane stripe, but adjustments need to be made for drainage grates, parking and the ridge between the pavement and gutter. Widths 16 feet (4.8 m) or greater encourage the undesirable operation of two motor vehicles in one lane. In this situation, a bike lane should be striped. A wide curb lane bikeway design is shown in Figure 13-1.

Figure 13-1: Wide Curb Lane Bikeway Design[1]



What Are The Design Recommendations For Shoulders Bikeways?

When providing shoulders for bicycle use, a width of 6 feet (1.8 m) is recommended. This allows a cyclist to ride far enough from the edge of pavement to avoid debris, yet far enough from passing vehicles to avoid conflicts where no curb is present. If there are physical width limitations, a minimum 4 feet (1.2 m) shoulder may be used.

[1] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

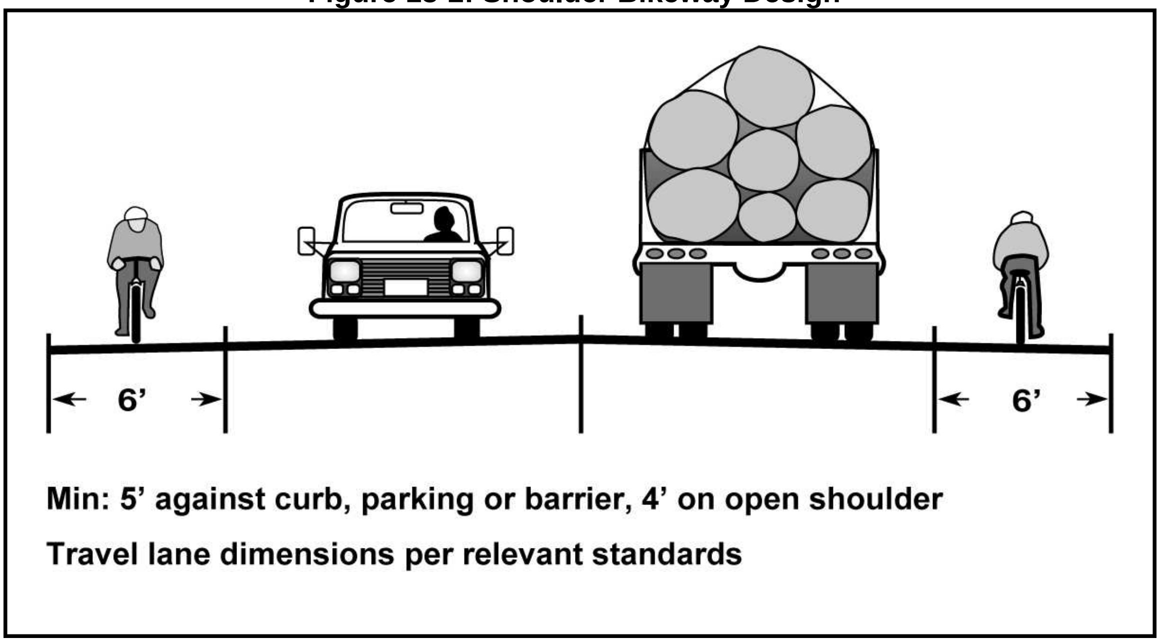
Shoulders adjacent to a curb face, guardrail, or other roadside barrier must be 5 feet (1.5 m) wide, as cyclists will “shy” away from a vertical face. Shoulders adjacent to a curb should have 4 feet (1.2 m) of pavement from the longitudinal joint at the gutter pan. Curbed sections usually indicate urban conditions, where shoulders should be striped as bike lanes.

On steep uphill grades, it is desirable to maintain a 6-foot (1.8 m) (minimum 5 feet (1.5 m)) shoulder, as cyclists need more space for maneuvering.

Note: many rural roads are 28 feet (8.4 m) wide, with fog lines striped at 11 feet (3.3 m) from centerline. The remaining 3 feet (0.9 m) should not be considered a shoulder bikeway (minimum 4 feet (1.2 m)); these are shared roadways, as most cyclists will ride on or near the fog line. But they provide an enjoyable riding experience where traffic volumes are low to moderate.

Shoulder bikeway design is shown in Figure 13-2.

Figure 13-2: Shoulder Bikeway Design[2]



Pavement Design And Gravel Driveways And Approaches For Shoulder Bikeways

Pavement Design

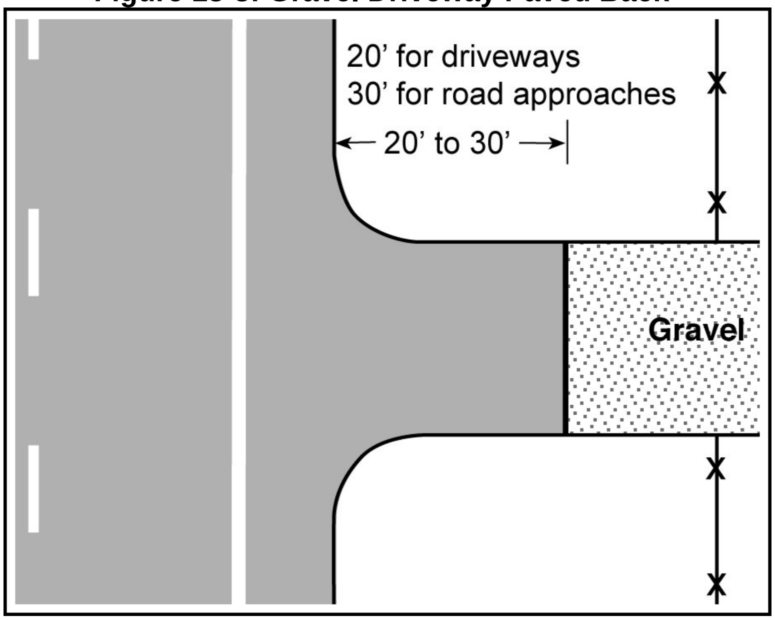
Many existing gravel shoulders have sufficient width and base to support shoulder bikeways. Minor excavation and the addition of 3 to 4 inches (75 to 100 mm) of asphaltic concrete is often enough to provide shoulder bikeways.

[2] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Gravel Driveways and Approaches

Wherever a highway is constructed, widened, or overlaid, all gravel driveways and approaches should be paved back to prevent loose gravel from spilling onto the shoulders. ODOT standards are 20 feet (6.1 m) for driveways and 30 feet (9 m) for public road approaches. A gravel driveway paved back is shown in Figure 13-3.

Figure 13-3: Gravel Driveway Paved Back[3]



What Are The Advantages Of Bike Lanes?

Bike lanes enable cyclists to ride at a constant speed, even when traffic in the adjacent travel lanes speeds up or slows down, for example at intersections.

Bike lanes enable bicyclists to position themselves where they will be visible to motorists.

Bike lanes encourage cyclists to ride on the streets rather than the sidewalks.

What Are The Design Standards For Bike Lanes?

Bike lanes are a portion of the roadway designated for preferential use by bicyclists, and are provided on busy urban and suburban streets (arterials and some major collectors).

Bike lanes may also be provided on rural roadways near urban areas, where there is high potential bicycle use.

Bike lanes are generally not recommended on high-speed rural highways; at channelized intersections, the speeds are too high to place a through bike lane to the left of right-turning

[3] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

vehicles. Shoulder bikeways, striped with a 4 inches (100 mm) fog line, are the appropriate facility for these roads.

Bike lanes should always be provided on both sides of a two-way street. One exception may be on steep hills where topographical constraints limit the width to a bike lane on one side only; in these cases, a bike lane in the uphill direction is acceptable as cyclists ride slower uphill. They can ride in a shared lane in the downhill direction.

The standard width of a bike lane is 6 feet (1.8 m), as measured from the center of stripe to the curb or edge of pavement.

The minimum bike lane width is 4 feet (1.2 m) on open shoulders or 5 feet (1.5 m) from the face of a curb, guardrail, or parked cars. A 4-foot (minimum 3 feet) (1.2 m, minimum 0.9 m) wide smooth asphalt surface should be provided to the left of a longitudinal joint between asphalt pavement and the concrete gutter section. It is preferable to pave the bike lane to the curb face to avoid a longitudinal joint in the bike lane.

Shoulders wider than 6 feet (1.8 m) may be marked as bike lanes in areas of very high use, on high-speed facilities where wider shoulders are warranted, or where they are shared with pedestrians. Standard bike lane dimensions are shown in Figure 13-4.

A bike lane must be marked with pavement stencils and an 8-inch (200 mm) stripe. This width increases the visual separation of a motor vehicle lane and a bike lane. If on-street parking is permitted, the bike lane must be placed between parking and the travel lane, and be at least 5 feet (1.5 m) wide.

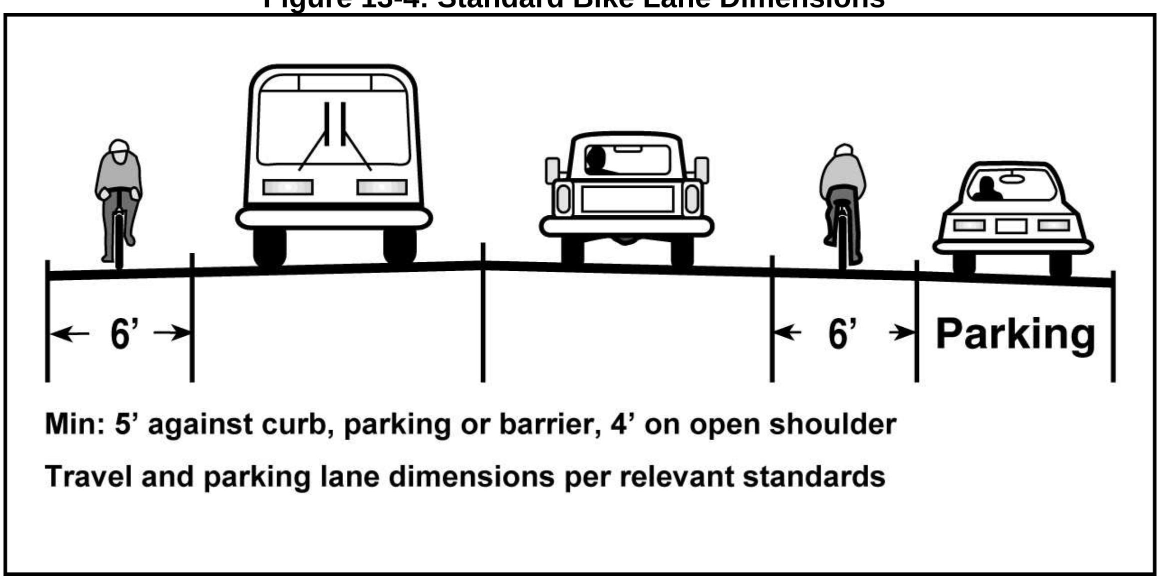
Bikeway and walkway standards of metric conversion are shown in Table 13-1.

Table 13-1: Bikeway And Walkway Standards Quick Reference Table And Metric Conversion[4]

BIKEWAYS	"ENGLISH"		METRIC	
Bike lane	6	feet	1.8	meters
Shoulder bikeway	6	feet	1.8	meters
Wide lane	14-15	feet	4.2-4.5	meters
Multi-use path	10	feet	3	meters
(high use)	12	feet	3.6	meters
Bike lane stripe	8	inches	200	millimeters
Shoulder stripe	4	inches	100	millimeters
Vertical clearance	10	feet	3	meters
WALKWAYS	**"ENGLISH"**		**METRIC**	
Sidewalk*	6	feet	1.8	meters
(on bridge)	7	feet	2.1	meters
(high use)	8	feet	2.4	meters
Shy distance	2	feet	0.6	meters
Sign height	7	feet	2.1	meters

** Clear dimensions, exclusive of curb and obstructions*

Figure 13-4: Standard Bike Lane Dimensions[5]



[4] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007
[5] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

What Practices Must Be Avoided When Designing Bikeways?

The Oregon Department of Transportation has over 30 years of experience designing bikeways, and has also learned from local city and county experiences; some have proven to be poor practices.

A. Sidewalk Bikeways

Sidewalks are not suited for cycling for several reasons:

- Cyclists face conflicts with pedestrians;
- There may be conflicts with utility poles, sign posts, benches, etc.;
- Bicyclists face conflicts at driveways, alleys, and intersections. A cyclist on a sidewalk is generally not visible to motorists and emerges unexpectedly; and
- Bicyclists are put into awkward situations at intersections where they cannot safely act like a vehicle but are not in the pedestrian flow either, creating confusion for other road users.

Cyclists are safer when they are allowed to function as roadway vehicle operators, rather than as pedestrians.

B. Extruded Curbs

Extruded curbs create an undesirable condition when used to separate motor vehicles from cyclists; either one may hit the curb and lose control, with the motor vehicle crossing onto the bikeway or the cyclist falling onto the roadway.

Extruded curbs make bikeways difficult to maintain and tend to collect debris. They are often hit by motor vehicles, causing them to break up and scatter loose pieces onto the surface of the road and bikeway.

C. Reflectors and Raised Pavement Markings

Reflectors and raised pavement markings can deflect a bicycle wheel, causing the cyclist to lose control. If pavement markers are needed for motorists, they should be installed on the motorist's side of the stripe, and have a beveled front edge.

D. Two-Way Bike Lane

A two-way bike lane creates a dangerous condition for bicyclists. It encourages illegal riding against traffic.

E. Surface Treatments

Rough surfaces and imperfections such as joints can cause a rider to loose control and fall. Debris such as gravel and glass are also problems that can be addressed through maintenance. Adequate drainage is critical to cyclists, as they ride in the area where water collects when drains get clogged or surface irregularities prevent water from entering drain grates.

F. Surface Types

The preferred roadway surfacing for bicycling is a finely graded asphaltic concrete. Rough open-graded mixes are very uncomfortable for cyclists, as they cause vibrations and increased rolling resistance, contributing to greater cyclist fatigue.

G. Chip Seals

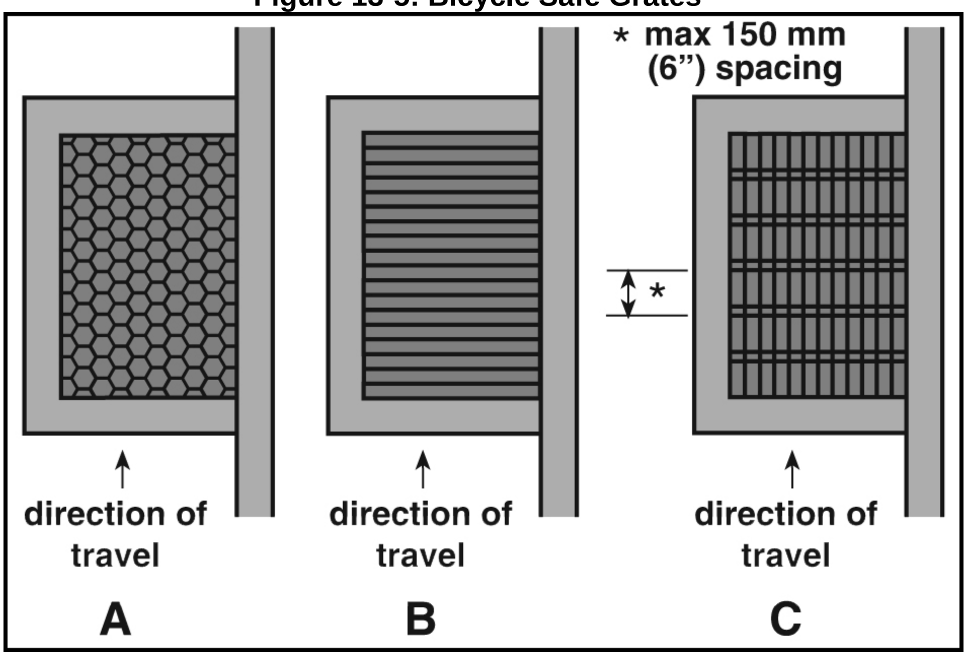
Chip-sealed surfaces are particularly unpleasant to ride on and should be avoided when possible. Where used, chip seals should be limited to the travel lanes on roads and highways with paved shoulders: the shoulders should NOT be chip-sealed. On roads with no shoulders (where cyclists ride in the travel lanes), chip seals should use a fine mix and be covered with a fog or slurry seal.

What Type Of Drainage Grates Are Bicycle Safe?

Care must be taken to ensure that drainage grates are bicycle safe, as required by ORS 810.150. If not, a bicycle wheel may fall into the slots of the grate causing the cyclist to fall. Replacing existing grates (A, B, preferred methods) or welding thin metal straps across the grate perpendicular to the direction of travel (C, alternate method) is required. These should be checked periodically to ensure that the straps remain in place. Bicycle safe grates are shown in Figure 13-5.

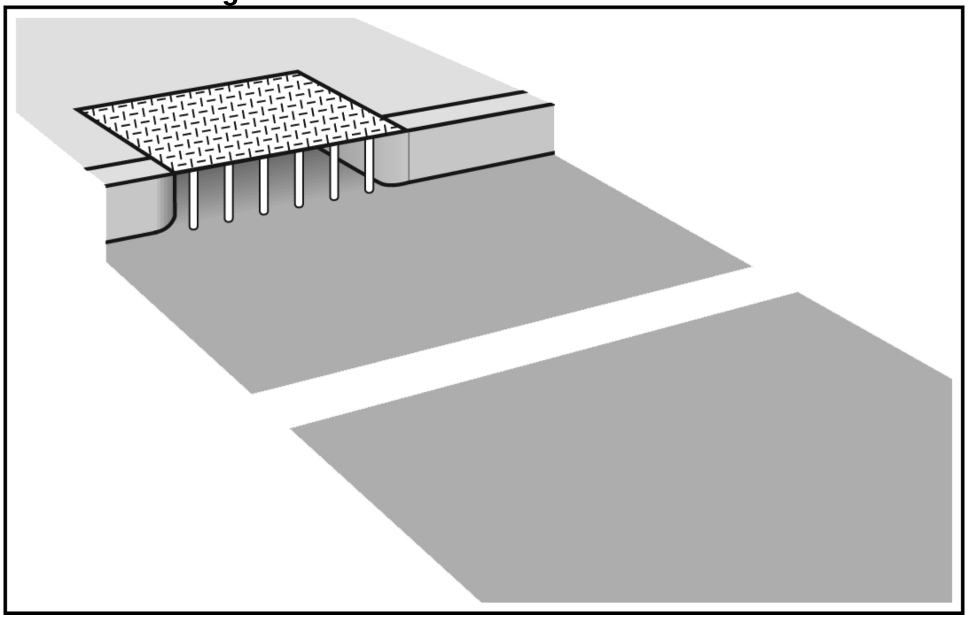
The most effective way to avoid drainage-grate problems is to eliminate them entirely with the use of inlets in the curb face (type CG-3), as shown in Figure 13-6.

Figure 13-5: Bicycle Safe Grates[6]



[6] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Figure 13-6: Inlet Flash In The Curb Face[7]



What Are The Design Considerations For Railroad Crossing?

The most important improvements for bicyclists are crossing surface smoothness, angle of crossing, and flange opening.

By statute, all public highway, bikeway, shared-use path, and sidewalk crossings of a railroad in Oregon are regulated by the Rail Division of the Department of Transportation. The Rail Division must approve, by issuance of an Order, the construction of new crossings or alterations to existing crossings to include the approaches to these crossings.

A. Crossing Surface Smoothness

The four most commonly used materials, in descending order of preference, are:

- Concrete: Concrete performs best under wet conditions and, when laid with precision, provides a smooth ride.
- Rubber: Rubber provides a ridable crossing when new, but they are slippery when wet and degrade over time.
- Asphalt: Asphalt pavement must be maintained in order to prevent a ridge buildup next to the rails.
- Timber: Timbers wear down rapidly and are slippery when wet.

B. Crossing Angle

The risk of a fall is kept to a minimum where the roadway (or bikeway portion of the roadway) crosses the tracks at 90 degrees. If the skew angle is less than 45 degrees, special attention should be given to the bikeway alignment to improve the angle of approach, preferably to 60

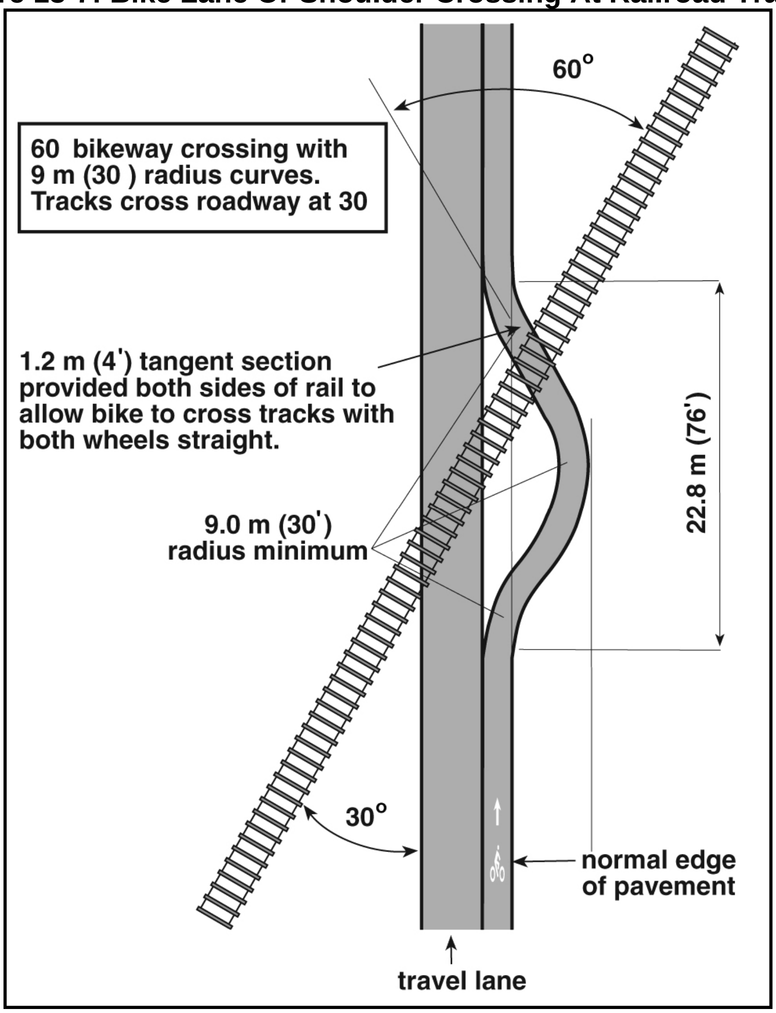
[7] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

degrees or greater, so cyclists can avoid catching their wheels in the flange and losing their balance.

C. Flange Opening

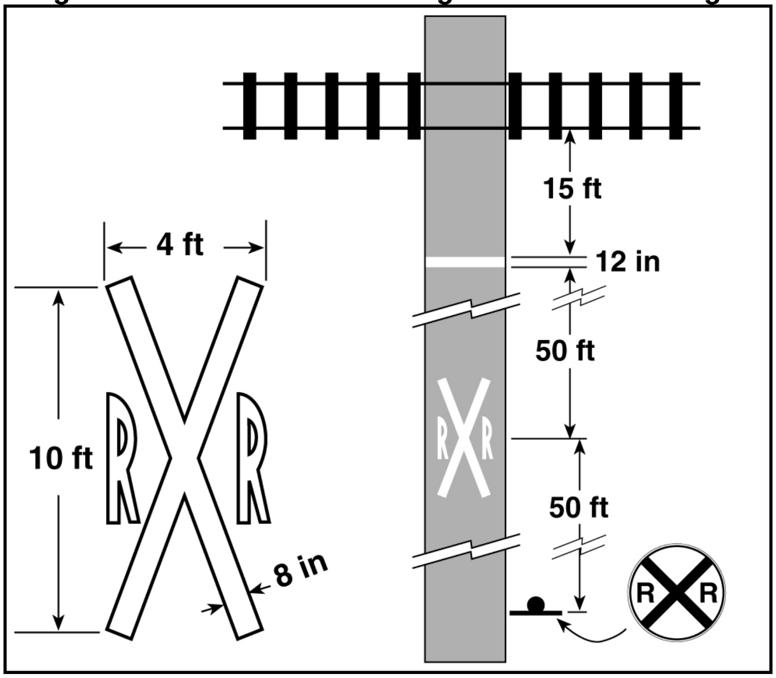
The open flange area between the rail and the roadway surface can cause problems for cyclists, since it can catch a bicycle wheel and cause the rider to fall. Flange width must be kept to a minimum. Figure 13-7 shows the bike lane or shoulder crossing at railroad tracks and Figure 13-8 shows the railroad crossing pavement markings.

Figure 13-7: Bike Lane Or Shoulder Crossing At Railroad Tracks[8]



[8] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Figure 13-8: Railroad Crossing Pavement Markings[9]



Can Sidewalk Ramps On Bridges Be Used By Cyclists?

These can be used by cyclists if the bridge sidewalks are wide enough for bicycle use (minimum 4 feet (1.2 m)). They should be provided where motor vehicle traffic volumes and speeds are high, the bridge is fairly long, and the outside traffic lanes or shoulders on the bridge are narrow. Where bicyclists are allowed to use bridge sidewalks. The recommended bridge railing height is 4 feet (1.2 m) where the bicyclist is riding parallel to the railing and 4.5 feet (1.4 m) where a bicyclist could "vault over" the railing such as on a curve or down-slope.

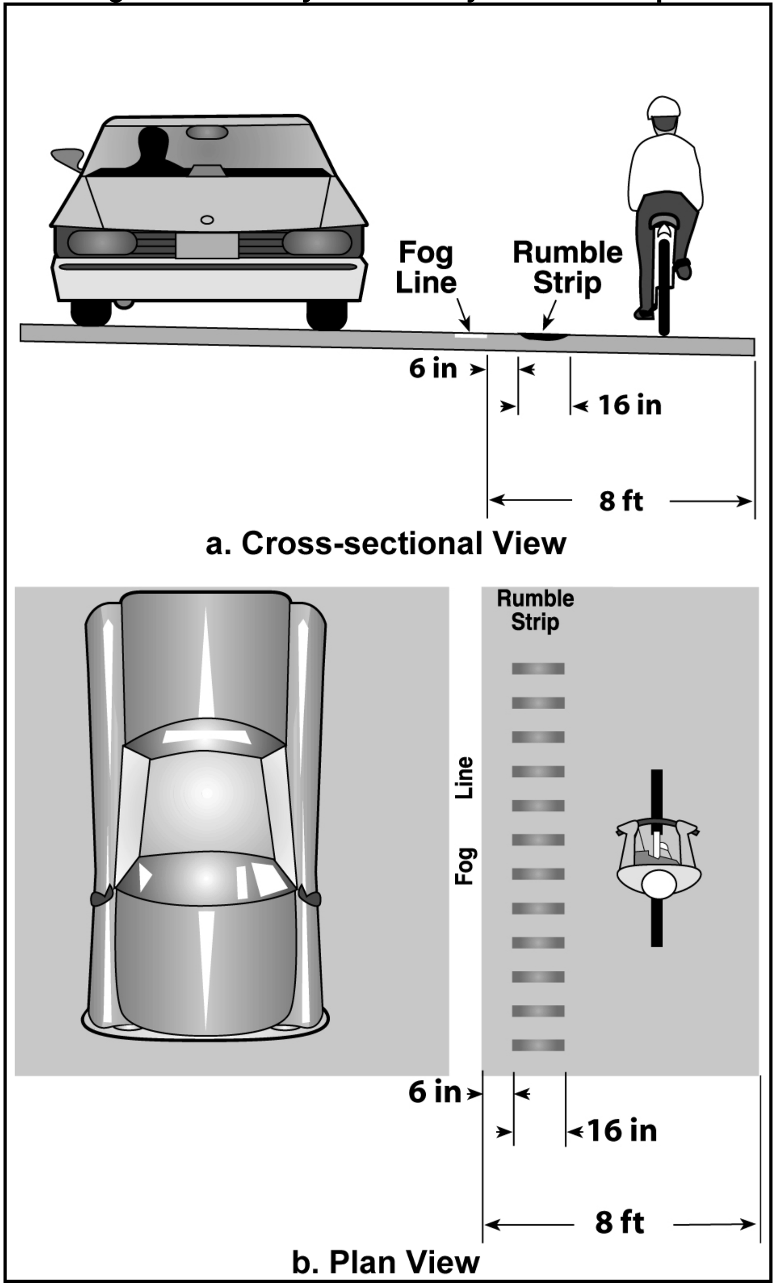
Can Rumble Strips Be Used For Bikeways?

Rumble strips are provided to alert motorists that they are wandering off the roadway. Rumble strips should not extend across the entire width of the shoulder, because they create an unridable surface for bicyclists. Rumble strips should not be used if they leave less than 4 feet (1.2 m) of ridable space.

A more bicycle-friendly rumble strip design is 16-inch (400 mm) grooves cut into the shoulder, 6 inches (150 mm) from the fog line. On an 8-foot (2.4 m) shoulder, this leaves 6 feet (1.8 m) of usable shoulder for bicyclists. Rumble strips can also be cut directly at the fog line, leaving the entire shoulder available for cycling. Figure 13-9 shows a bicycle-friendly rumble strip.

[9] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Figure 13-9: Bicycle-Friendly Rumble Strip[10]



How Can Existing Roadways Be Modified And Restriped To Accommodate Bike Lanes?

Bike lanes can be retrofitted onto existing urban roadways by:

1. Marking and signing existing shoulders as bike lanes;
2. Widening the roadway to add bike lanes; or
3. Restriping the existing roadway to add bike lanes.

[10] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

In most cases, the existing curb-to-curb width allows only restriping to be considered. These guidelines illustrate how a roadway can be restriped for bike lanes without negatively affecting the safety and operation of the roadway.

It is important to use good judgment, and to consider context. Each project should be approved by a traffic and/or roadway engineer to ensure that capacity and safety are not compromised. ORS 366.215 prohibits reducing capacity on certain freight routes.

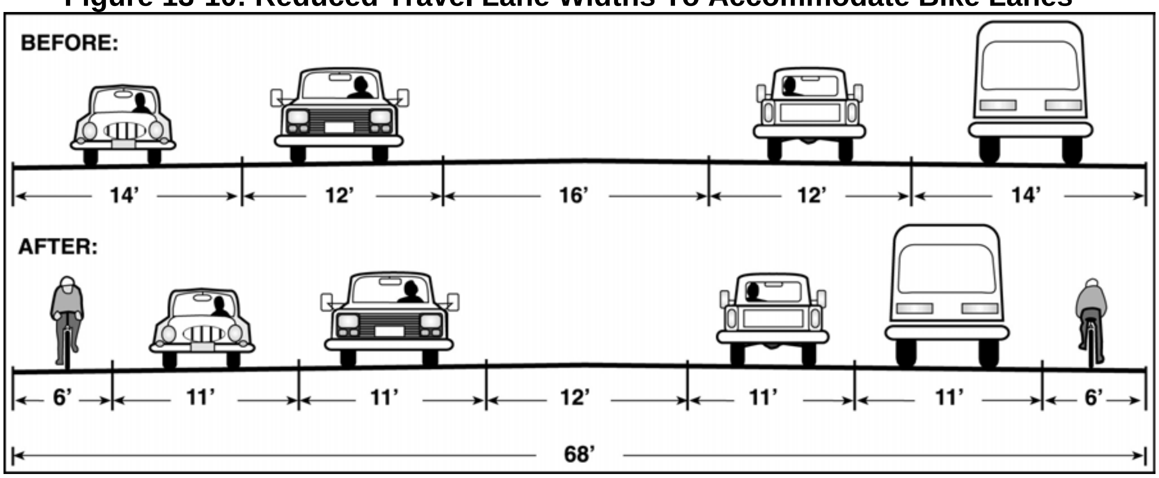
A. Reduce Lane Widths

Commonly used lane widths are: 14-foot (4.2 m) center turn lanes, 12-foot (3.6 m) travel lanes, 6 (1.8 m) bike lanes, and 8-foot (2.4 m) parking lanes; under many conditions these can be narrowed to:

- 25 mph (40 km/h) or less: lanes can be reduced to 10 feet (3 m) or 11 feet (3.3 m).
- 30 to 40 mph (50 to 65 km/h): 11-foot (3.3 m) travel lanes and 12-foot (3.6 m) center turn lanes are acceptable, even desirable.
- 45 mph (70 km/h) or greater: 12-foot (3.6 m) outside travel lanes and a 14-foot (4.2 m) center turn lane if there are high truck volumes.

Dimensions should take into account the combination of speeds, volumes, trucks, context, and desired outcome. Figure 13-10 shows reduced travel lane widths to accommodate bike lanes.

Figure 13-10: Reduced Travel Lane Widths To Accommodate Bike Lanes[11]



B. Reduce On-Street Parking

On-street parking is usually beneficial to business and pedestrians. Removing parking for bike lanes requires careful negotiation with the affected businesses and residents.

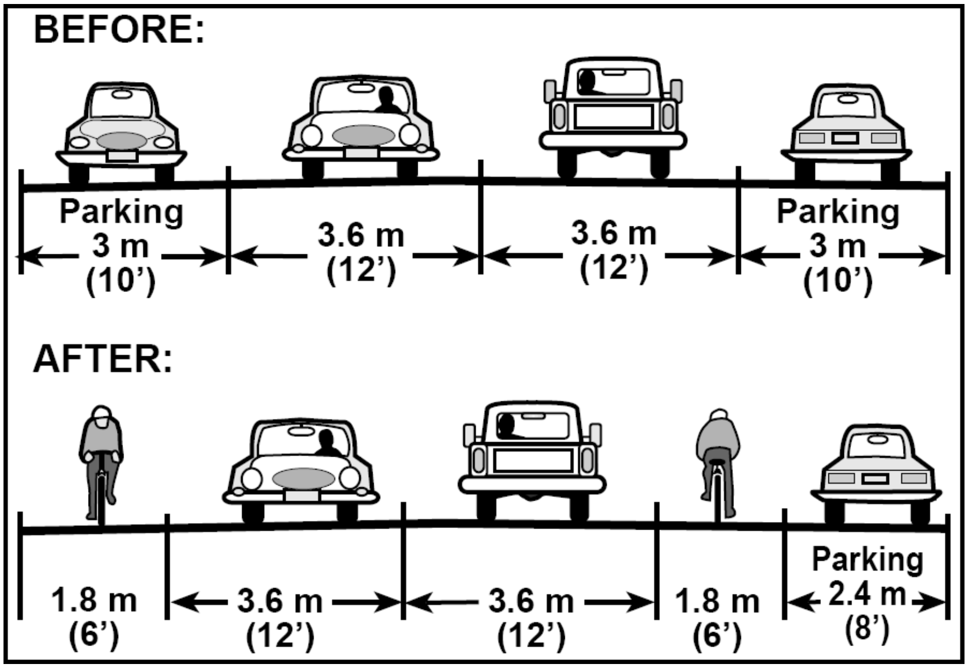
C. Remove Parking on One Side

On most streets with parking on both sides, removal of all on-street parking is not necessary: removing parking from one side creates enough space for two bike lanes, with some additional

[11] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

lane narrowing. Parking may be needed on only one side to accommodate residences and/or businesses with no off-street parking. Figure 13-11 shows parking removed on one side of a two-way street to accommodate bike lanes.

Figure 13-11: Parking Removed On One Side Of The Street To Accommodate Bike Lanes[12]

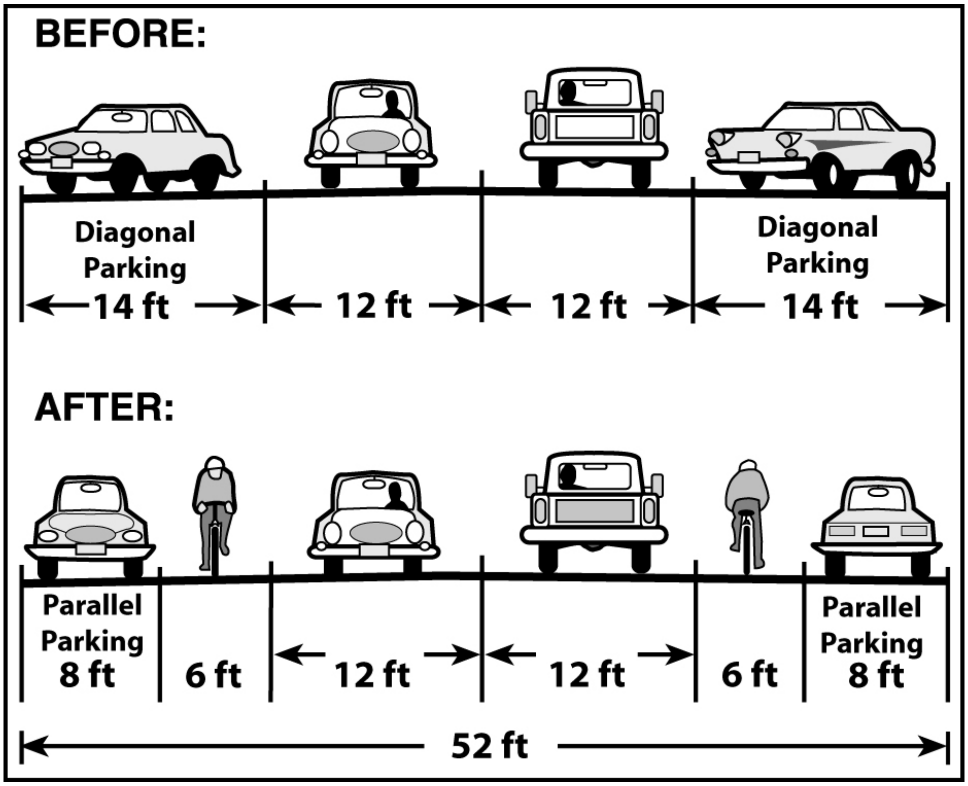


D. Change From Diagonal to Parallel Parking

Changing to parallel parking on one side only is usually sufficient; this reduces total parking availability of a street segment by less than one-fourth. Figure 13-12 shows changing from diagonal to parallel parking on a two-way street to accommodate bike lanes.

[12] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Figure 13-12: Changing From Diagonal To Parallel Parking On A Two-Way Street To Accommodate Bike Lanes[13]

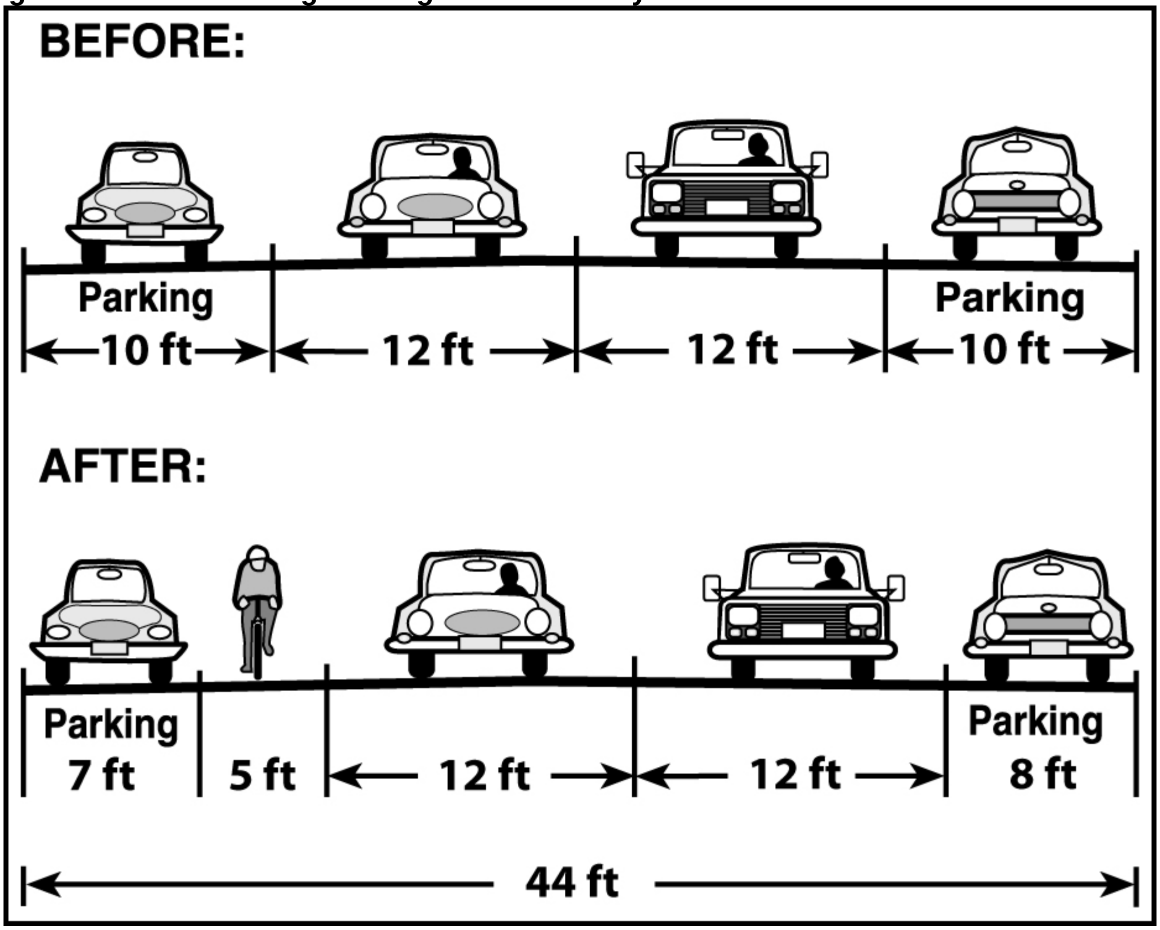


E. Narrow Parking Lanes

Parking can be narrowed to 7 feet (2.1 m), particularly in areas with low truck parking volumes. On a one-way street, only one bike lane needs to be provided, so narrowing both parking lanes a little bit creates enough room for one bike lane (See Figure 13-13).

[13] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Figure 13-13: Narrowing Parking On A One-Way Street To Accommodate Bike Lanes[14]



F. Reduced Number Of Travel Lanes

Many roads were built wider than needed to accommodate existing or projected traffic volumes, or traffic conditions have changed since the road was built, and the number of travel lanes can be reduced. This concept is generally referred to as a "road diet." In most cases the road diet results in enough space to stripe bike lanes.

The most common road diet takes a four-lane undivided highway and redistributes the roadway to one travel lane in each direction, a center turn lane, and two bike lanes. The safety benefits of the four to three lane road diet include:

- Fewer rear-end crashes: motorists wait to make a left turn in a dedicated turn lane, not in a through lane;
- Fewer sideswipe crashes: motorists no longer swerve around a vehicle waiting to turn left in a through lane;
- Fewer left turn crashes;
- Reduced speeds; and

[14] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

- Easier and safer pedestrian crossings, especially with a median island in the center turn lane.

Operational benefits of the four to three lane road diet include:

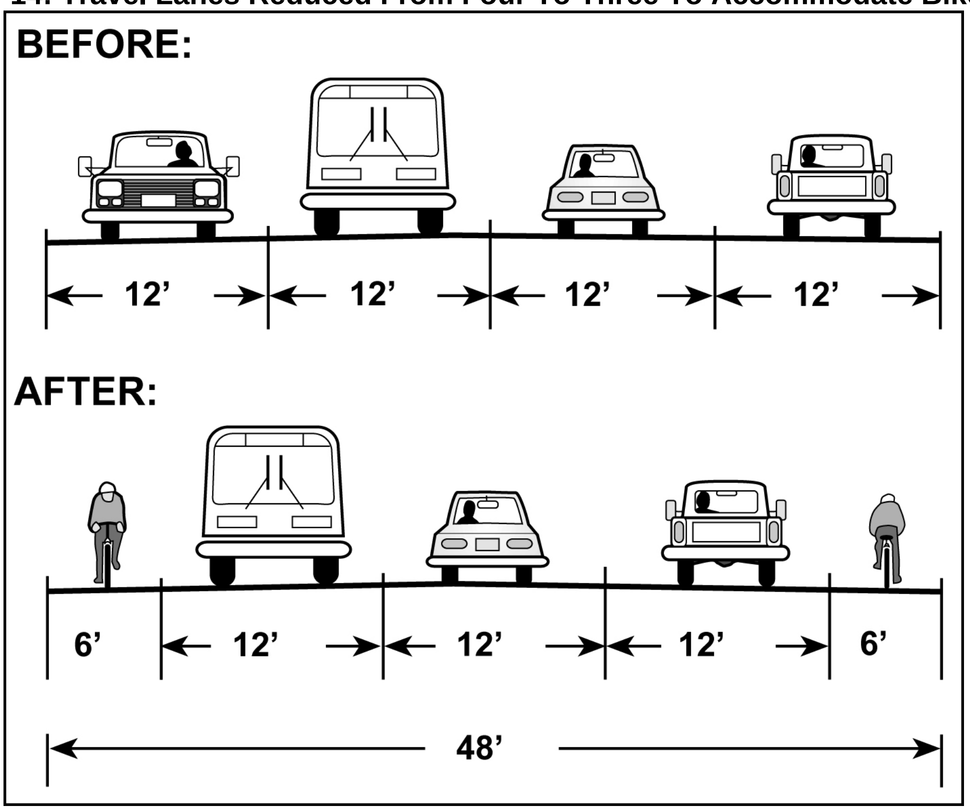
- Fewer delays from traffic stacked behind a car waiting to turn left;
- Easier negotiation of right turns, as the curb lane is offset from the curb; and
- Higher carrying capacity where many left turns obstruct the inside lane on a 4-lane section.

The livability benefits of a road diet include:

- Greater separation from moving traffic for pedestrians;
- Room for street furniture and landscaping; and
- More people using bicycles for transportation.

Figure 13-14 shows travel lanes reduced from four to three to accommodate bike lanes.

Figure 13-14: Travel Lanes Reduced From Four To Three To Accommodate Bike Lanes[15]



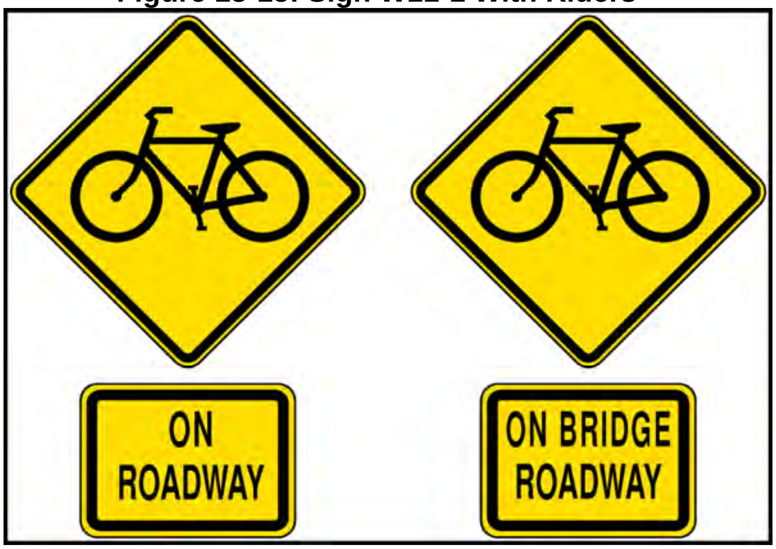
[15] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

What Are The Signing And Marking Requirements For The Bikeways?

A. Shared Roadway and Shoulder Bikeways

1. Signing – In general, no signs are required for these two types of bikeways. On a narrow rural road that is heavily used by cyclists, it may be helpful to install bike warning signs (W11-1) with the rider ON ROADWAY or ON BRIDGE ROADWAY (See Figure 13-15) where there is insufficient shoulder width for a significant distance. This signing should be in advance of the roadway condition. Bike boulevards are usually shared roadways, but are characterized by special signing and marking that are not addressed in this Handbook.

Figure 13-15: Sign W11-1 With Riders[16]



2. Marking – A normal 4-inch (100 mm) wide fog line strip is used on shoulder bikeways.

B. Bike Lanes

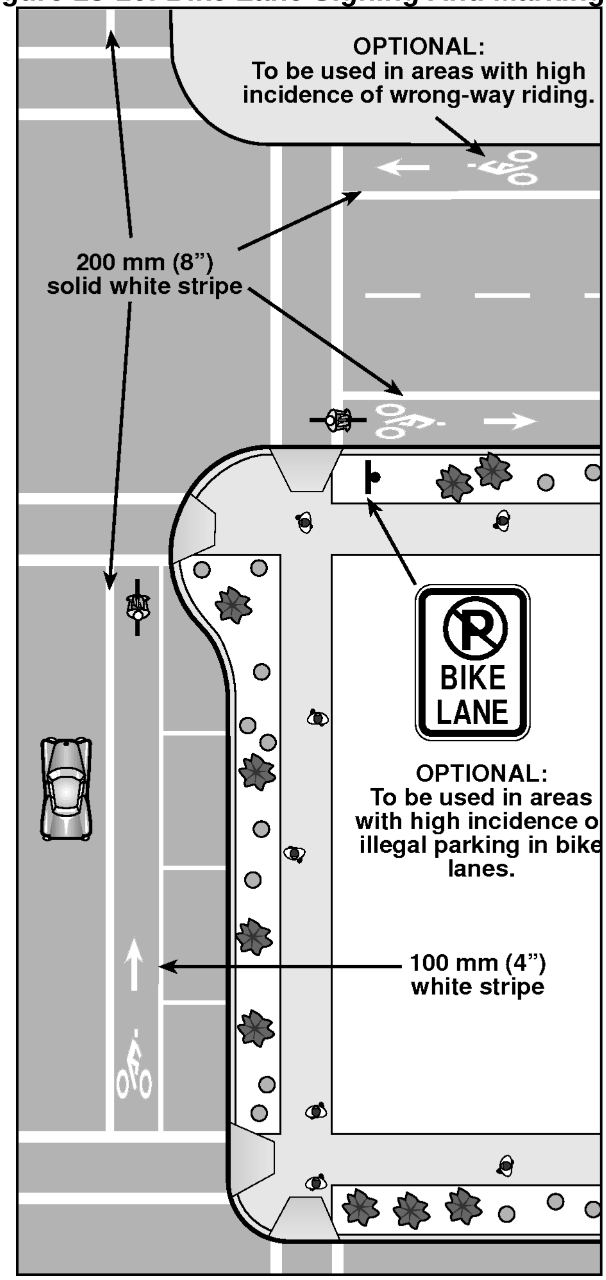
1. Bike Lane Designation – Bike lanes are officially designated to create an exclusive of preferential travel lane for bicyclists with the following markings:

- An 8-inch (200 mm) white stripe; and
- Bicycle symbol and directional arrow stencils on pavement.

Figure 13-16 shows bike lane signing and markings.

[16] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Figure 13-16: Bike Lane Signing And Markings[17]



2. Stencil Placement – Stencils should be placed after every intersection where a parking lane is present between the bike lane and the curb.

Supplementary stencils may also be placed at the end of a block to warn cyclists not to enter a bike lane on the wrong side of the road.

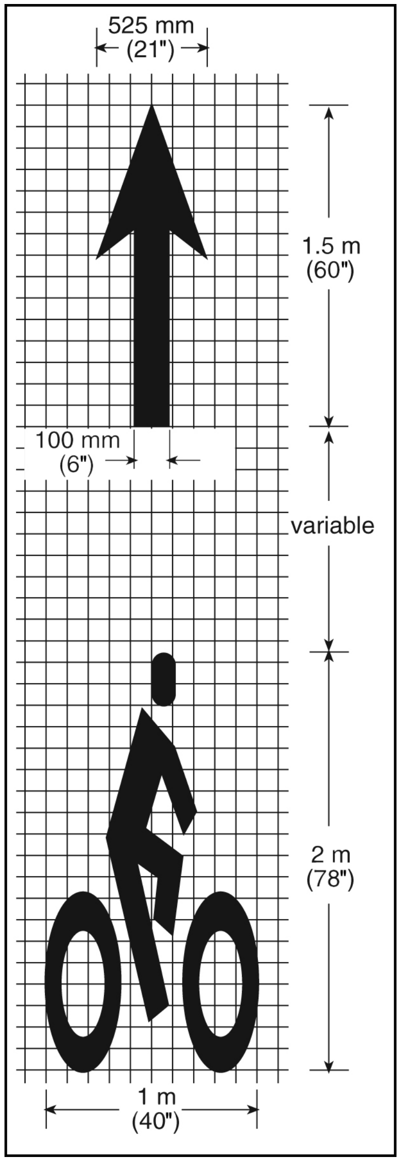
Additional stencils may be placed on long sections of roadway with no intersections. A rule of thumb for appropriate spacing is to multiply the designated travel speed (in mph) by 40. For

[17] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

example, in a 35 mph (55 km/h) speed zone, stencils may be placed approximately every 1400 feet (420 m).

Care must be taken to avoid placing stencils in an area where motor vehicles are expected to cross a bike lane - usually driveways and the area immediately after an intersection. Bike lane stencil dimensions are shown in Figure 13-17.

Figure 13-17: Bike Lane Stencil Dimensions[18]



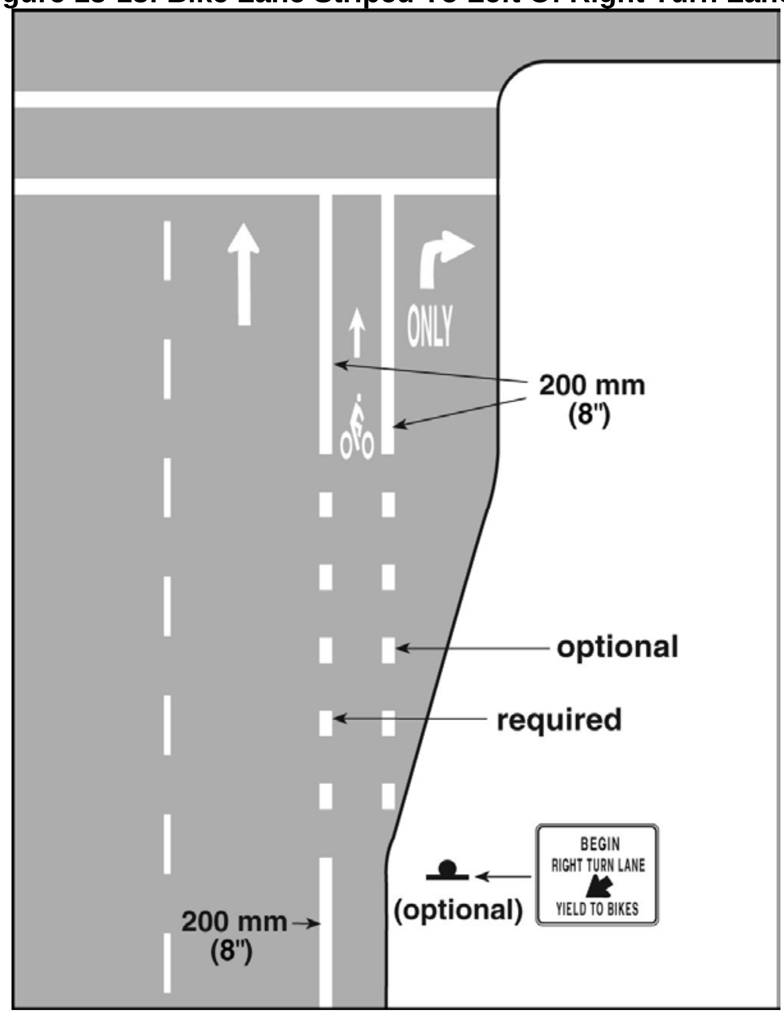
3. Right Turn Lanes at Intersections - The through bike lane to the left of a right-turn lane must be striped with two 8-inch (200 mm) stripes and connected to the preceding bike lane with a dotted line (8 inches x 2 feet on 8-foot centers (6-foot gaps) (200 mm x 0.6 m on 2.4 m centers

[18] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

(1.8m gaps)). This allows turning motorists cross the bike lane. A stencil must be placed at the beginning of the through bike lane.

Sign R4-4, BEGIN RIGHT TURN LANE, YIELD TO BIKES, may be placed at the beginning of the taper in areas where a through bike lane may not be expected, for example on sections of roadway where bike lanes have been added where there weren't any previously. Figure 13-18 shows the bike lane striped at the intersection.

Figure 13-18: Bike Lane Striped To Left Of Right Turn Lane[19]

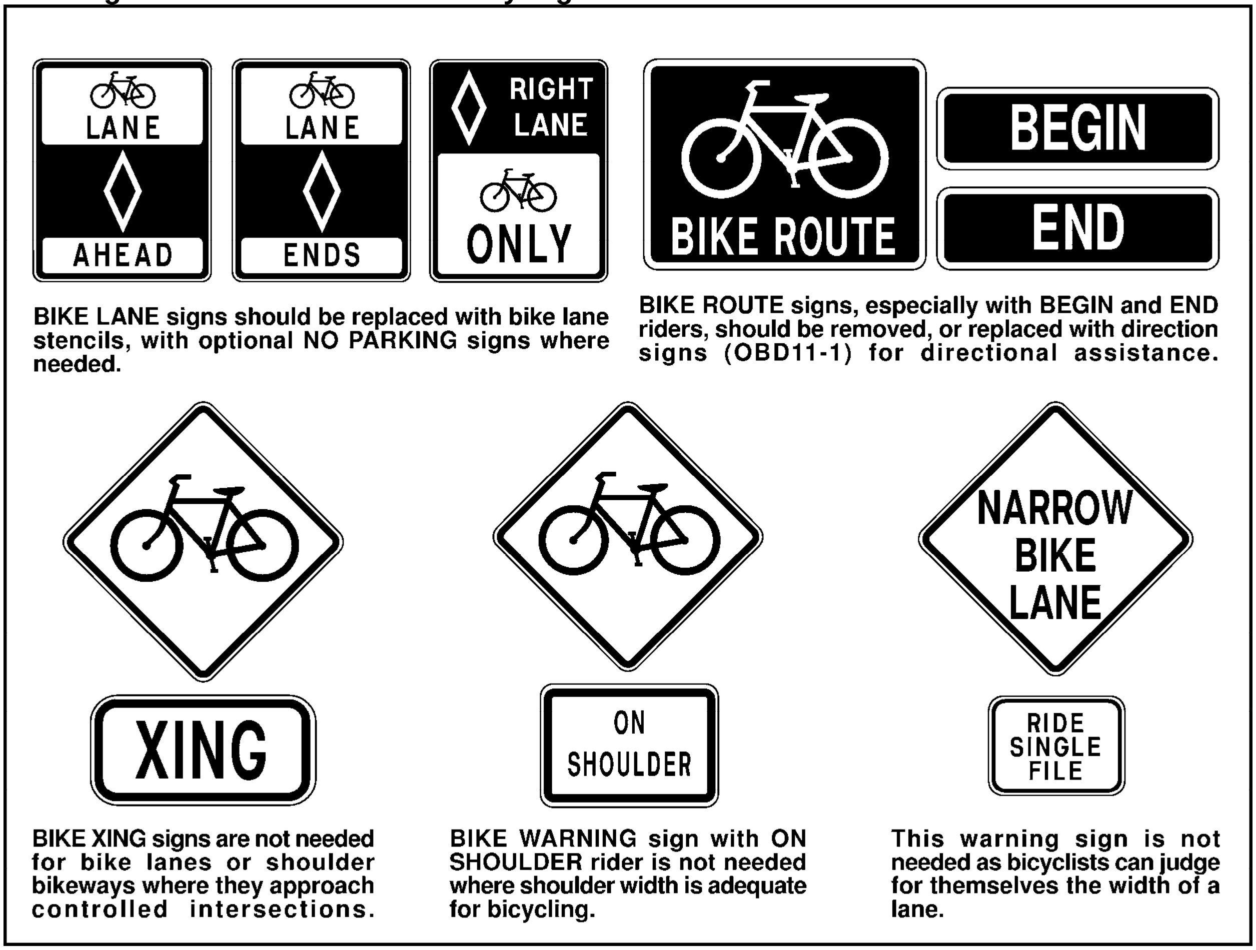


What Are The Existing Bikeway Signs That ODOT Recommends For Removal?

Many bikeways are signed and marked in a manner that is not consistent with current standards and practices. ODOT recommends periodic review of existing signs to upgrade and standardize bikeway signing. Figure 13-19 are the bikeway signs that ODOT recommends for removal.

[19] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Figure 13-19: Obsolete Bikeway Signs That ODOT Recommends For Removal[20]



For the most up to date information about the "Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines" (which is currently being updated by the Oregon Transportation Commission and should be finished in 2010), please visit the website: http://www.oregon.gov/ODOT/HWY/BIKEPED/

For the most current information about pedestrian safety, please contact:
Sheila Lyons, PE
Bicycle and Pedestrian Program Manager
Oregon Department of Transportation
355 Capitol Street NE
Salem, Oregon, 97301
Phone: 503-986-3555
E-mail: sheila.a.lyons@odot.or.us
http://www.oregon.gov/ODOT/HWY/BIKEPED/

[20] Source: Oregon Bicycle and Pedestrian Plan Design Standards and Guidelines, Final Draft, 2007

Chapter 14: Street Lighting

This Chapter will cover the use and benefits of street lighting. Roadway lighting provides for the safe movement of traffic during darkness, reduces nighttime crashes, and reduces nighttime crime in urban areas.

In most small municipalities, street lighting is installed either by the public agency, utility company, or a private electrical contractor. Information in this Chapter will assist local officials in determining the type and amount of lighting recommended.

When lighting is desired on a section of roadway maintained by Oregon Department of Transportation, the District Engineer of ODOT should be contacted before proceeding with any work. The District Engineer will advise the local governmental agency as to the specific requirements for lighting installations on a state right-of-way.

In 2000, the Illuminating Engineering Society established new standards for pavement surface luminance values. The function of the roadway usually defines the lighting needs. The average level of luminance of the roadway surface is usually obtained with the maintenance factor involved, which means expressed in average candelas (c.d.)/ft.^{2} or c.d./m^2. A candela (c.d.) is the unit of luminous intensity. The criteria shown in Table 14-1 should be used as the standard.

Table 14-1: Recommended Luminance Values[1]

Roadway Classification	Pedestrian Conflict Area		
	High	Medium	Low
Expressway	1.0 cd/m^2	0.8 cd/m^2	0.6 cd/m^2
Major	1.2 cd/m^2	0.9 cd/m^2	0.6 cd/m^2
Collector	0.8 cd/m^2	0.6 cd/m^2	0.4 cd/m^2
Local	0.6 cd/m^2	0.5 cd/m^2	0.3 cd/m^2

Metric converts as follows:
1.0 c.d./m^2 .... 0.0929 c.d./ft.^{2}

The values shown in Table 14-1 are expressed in candelas per square meter and are measured with an optical instrument. In addition, the average to minimum pavement luminance ratio should be between 3:1 and 4:1 for all roadways except local streets, which should have a ration not exceeding 6:1.

The area classification of the Table 14-1 are as follows:

[1] Source: Roadway Lighting (RP-8-00), 2000, USDOT-FHWA

1. High Pedestrian Conflict Areas: Commercial areas in urban environments may have high night pedestrian activities. It is important to provide visibility for a driver to create a reasonably safe environment for the pedestrian and cyclist.
2. Medium Pedestrian Conflict Areas: Intermediate areas have moderate night pedestrian activities. These areas may typically be those near community facilities such as libraries and recreation centers. Safety for the pedestrian as well as providing guidance to primary travel ways are key elements in the design of a lighting system in these areas.
3. Low Pedestrian Conflict Areas: Residential areas in urban environments may have low night pedestrian activities. These areas include single-family homes and small apartment buildings. Safety for the pedestrian as well as providing guidance to primary travel ways are key elements in the design of a lighting system in these areas.

What Mounting Heights Should Be Used?

The mounting height is determined by lamp output, desired pavement luminance, and uniformity of light distribution. Light sources of 200 watt high pressure sodium or less are normally mounted at 30 feet (9 m) and light sources of 250 watt to 400 watt high pressure sodium are normally mounted from 30 to 45 feet (9 m to 13.7 m). For ornamentary/historical lighting, ODOT recommends a 12-foot (3.6 m) minimum mounting height and a maximum of 150 watt high pressure sodium lamp.

The mounting height of luminaires should be limited to 40 feet (12 m) for Oregon's local roads and streets since the bucket trucks most agencies use/own typically cannot service a 45 feet (13.7 m) mounting height.

What Luminaire Spacing Should Be Used?

Luminaire optical designs have been created for luminaries to be located over the pavement edge or at some distance off the roadway (for post-top luminaire). Typical spacing configurations are shown in Table 14-2 with the spacing(s) defined as the distance between luminaries along the centerline of roadway.

Staggered spacing is the preferred spacing arrangement. Opposite spacing would be appropriate where the width of the street exceeds twice the mounting height. One-side spacing should only be used on narrow roadways or where economy dictates this type of installation.

Table 14-2 shows the recommended luminaire spacing for typical roadways and is based upon the more commonly used luminaire wattages.

Table 14-2: Recommended Luminaire Spacing For Typical Roadways[2]

Pedestrian Conflict	Traffic Class	Average cd/m^2	Unif. Ratio	Road Width	Mounting Height	Wattage	Recommended Spacing (Feet)
Low	Local	0.3	6:1	30(9 m)	30(9 m)	175	110(33 m)
				40(12 m)	30(9 m)	175	90(27 m)
				30(9 m)	30(9 m)	250	140(43 m)
				40(12 m)	30(9 m)	250	120(36 m)
	Collector	0.4	3:1	30(9 m)	30(9 m)	250	100(30 m)
				40(12 m)	30(9 m)	250	80(24 m)
				30(9 m)	30(9 m)	400	160(49 m)
				40(12 m)	30(9 m)	400	150(46 m)
	Major	0.6	3:1	40(12 m)	30(9 m)	400	100(30 m)
				60(18 m)	30(9 m)	400	70(21 m)
Medium	Local	(USE LOW COLLECTOR)					
	Collector	0.6	3:1	30(9 m)	30(9 m)	400	120(36 m)
				40(12 m)	30(9 m)	400	110(33 m)
	Major	0.9	3:1	40(12 m)	30(9 m)	400	70(21 m)
				60(18 m)	40(12 m)	400	50(15 m)
High	Local	(USE LOW COLLECTOR)					
	Collector	0.8	3:1	40(12 m)	30(9 m)	400	80(24 m)
	Major	1.2	3:1	40(12 m)	30(9 m)	1000	120(36 m)

What Problems Are Caused By Glare?

Glare reduces visibility and causes eye discomfort. Glare can be diminished by reducing luminaire brightness, increasing mounting height, and increasing the effective luminaire area.

What Type Of Routine Maintenance Is Required For Lighting Installations?

Proper maintenance of the system ensures continued levels of illumination at the original design value. It also minimizes repair cost and protects the capital investment.

The responsible department or agency should establish a cleaning and washing schedule. Based upon the surrounding conditions, glassware should be washed at least one or two times per year.

It is also necessary to set up an inspection system to ensure replacement of burned out lamps. When luminaries are approaching the life expectancy of the lamp, it is a good practice to begin group replacement of all lamps.

An Existing Intersection Has Experienced Several Nighttime Crashes. Is Lighting Warranted?

Lighting should be considered when four or more night crashes susceptible to correction by safety lighting have occurred in one year or six night crashes have occurred in two years.

What Types Of Crashes May Be Correctable By Street Lighting?

Street lighting will assist in preventing nighttime crashes involving:

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[2] Source: Roadway Lighting (RP-8-00), 2000, USDOT, FHWA

1. Obstacles located within the roadway (islands, medians, bridge piers);
2. Single vehicle crashes at locations where the geometrics of the road (or intersection) may contribute to the cause of the crash (“T” intersection, curve, poor horizontal alignment); and
3. Right angle collisions.

For more information about illumination or street lighting please refer to the following publications:

Oregon Department of Transportation, “Lighting Policy and Guidelines”, Salem, Oregon, 2003: http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/Lighting_Policy_and_Guidelines.pdf

Oregon Department of Transportation, “Traffic Lighting Design Manual”, Salem, Oregon, January 2003:
http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/Traffic_Lighting_Design_Manual.pdf

For the most up to date information about illumination and street lighting please contact:

Ernest Kim
Illumination Specialist
Oregon Department of Transportation
Traffic Roadway Section
355 Capitol St., 5th Floor
Salem, OR 97301-3871
Phone: (503) 986-3587
E-mail: Ernest.C.Kim@state.or.us

Chapter 15: Railroad Crossings

There are approximately 140,000 public railroad crossings in the United States; approximately 53 percent of which have active warning devices (flashing-light signals with or without automatic gates). In Oregon, there are approximately 2,442 public crossings. Approximately 1,986 of the crossings are at grade; 868 of which have active warning devices.

Since early 2008, all passively signed public grade crossings in Oregon have been upgraded by installation of railroad crossbuck assemblies. Each crossbuck assembly includes new highly reflective crossbuck signs on new support posts with new vehicle STOP signs or YIELD signs attached to the same post. Each post has reflective tape on the front and back sides.

Oregon uses federal funds to upgrade 6 to 8 at-grade crossings annually from passive to active warning devices. The average cost of installing flashing-light signals and automatic gates at an at-grade is $250,000 to $350,000.

Although train-vehicle collisions may not occur frequently, they often result in fatalities. This chapter will assist in understanding Oregon crossing regulations.

What Factors Are Considered in Evaluating Railroad Crossing Safety?

The following factors are considered:

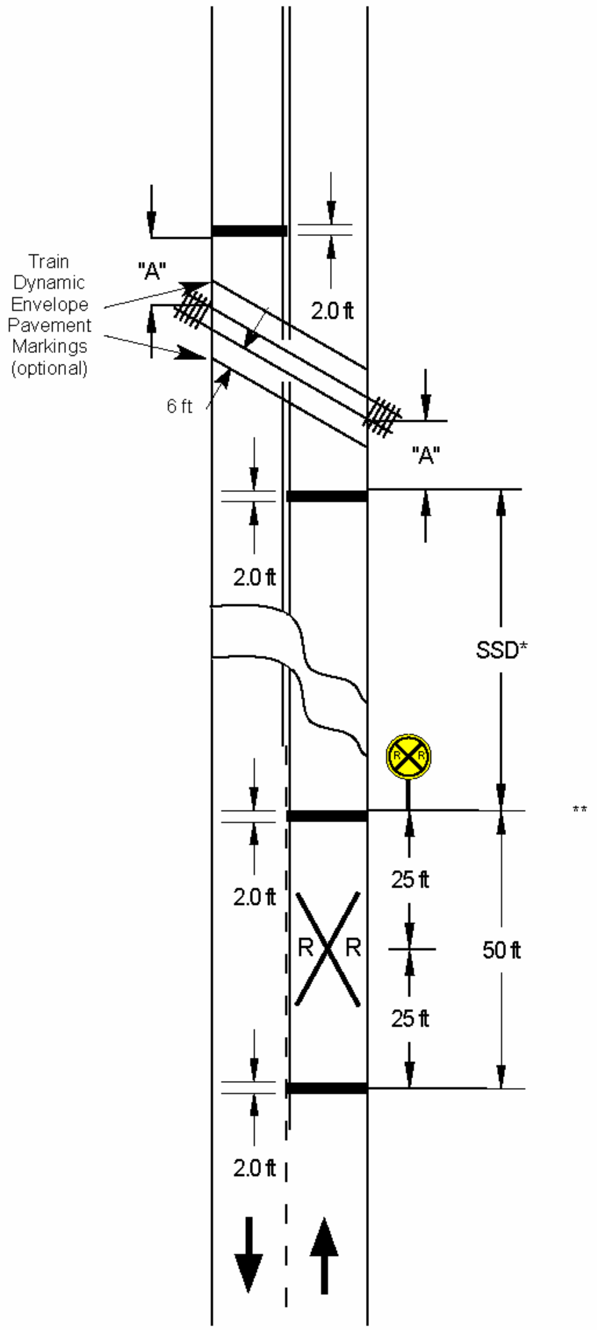
- The history of train/vehicle collisions and the potential for train/vehicle or train/person conflicts.
- Physical characteristics of crossings, including the geometry, topography, roadway and track alignments, the number and type of tracks, the speed, length and frequency of trains, the average daily vehicle traffic and speed of vehicles, sight distances, proximity of adjacent highways, and the potential for vehicles to queue on the tracks.
- Driver behavior
- Warning devices

What Passive Warning Devices Are Used To Warn Motorists Of A Railroad Crossing?
The minimum warning devices are:

- Highway-Rail Grade Crossing Advance Warning Signs
- Highway-Rail Grade Crossing Pavement Markings
- Stop Lines (stop clearance lines)
- Railroad Crossbuck Assemblies

Figure 15-1 provides direction on the proper placement of warning signs and pavement markings at railroad grade crossings.

Figure 15-1: Example of Placement of Warning Signs and Pavement Markings at Highway-Rail Grade Crossings[1]



A three-lane roadway should be marked with a centerline for two-lane approach operation on the approach to a crossing

On multi-lane roads, the transverse bands should extend across all approach lanes, and individual RXR symbols should be used in each approach lane.

** When used the toe of the pavement marking should be directly opposite the Advanced Warning Sign (W10-1). If needed, supplemental pavement marking symbol(s) may be placed between the Advance Warning Sign and the crossing, but should be at least 50 ft. from the stop line.

"A" Stop clearance line location is 12ft minimum from the nearest rail or 1ft in advance of the location where an automatic gate arm crosses the roadway

Note:
In an effort to simplify the figure to show warning sign and pavement marking placement, not all required traffic control devices are shown.

*Safe stopping distances (SSD) based on vehicle speed approaching grade crossings:

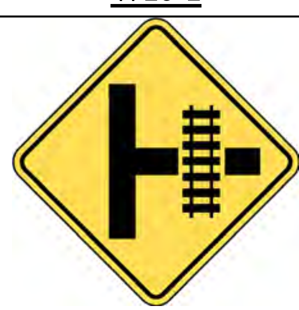
SPEED MPH	SSD FEET
15	80
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645

Legend
→ Direction of travel

[1] Source: Oregon Supplement to the Manual on Uniform Traffic Control Devices 2003 Edition, adopted July 2005

Highway-Rail Grade Crossing Advance Warning signs shall be used on each roadway approach to every grade crossing. On divided highways and one-way roads, it is desirable to install an additional sign on the left side of the roadway. If the distance between the railroad tracks and a parallel highway is less than 100 feet (30 m), W10-2, 3 and 4 signs shall be installed on each approach of the parallel highway to warn a motorist making a turn that a railroad crossing is ahead. Where there is 100 feet (30 m) or more between the railroad and the parallel highway, a W10-1 sign shall be installed in advance of the railroad crossing in lieu of W10-2, 3 or 4 signs on the parallel highway. (See Figure 15-2).

Figure 15-2: Railroad-Highway Warning Signs[2]

Standard Size 36" diameter (0.9 m diameter) See MUTCD page 8B-4  **W10-1**	Standard Size 30" x 30" (750 mm x 750 mm) See MUTCD page 8B-4  **W10-2**
Standard Size 30" x 30" (750 mm x 750 mm) See MUTCD page 8B-4  **W10-3**	Standard Size 30" x 30" (750 mm x 750 mm) See MUTCD page 8B-4  **W10-4**

What Are The Standards For Highway-Rail Grade Crossing Pavement Markings?

Unless otherwise authorized by crossing Order, grade crossing pavement markings for approaches to railroad crossings shall

- Be installed at all crossings and conform to the specifications set forth in the crossing Order
- Include no-passing markings on two-lane roadways
- On multi-lane roads, the transverse bars shall extend across all approach lanes and individual RxR symbols shall be used in each approach lane on all paved approaches (including bicycle lanes)

[2] Source: Chapter 8B, MUTCD 2003; OAR 741-110-0040(10)

- Include a 24-inch wide stop line at least 12 feet (3.6 m) from the nearest rail or 1 foot (.3 m) in advance of where the gate arm crosses the roadway. Stop lines shall be perpendicular to the roadway. (See Figure 15-1).

NOTE: See OAR 741-110-0030(5)(d)

What Is The Safe Stopping Distance (SSD) For Railroad Crossings?

The safe stopping distance (SSD) is based on the posted vehicle speed approaching grade crossings. It is measured 12 feet minimum from the nearest rail as shown in Table 15-1.

Table 15-1: Safe Stopping Distances (SSD)[3]

Vehicle Approach Speed (mph)	Safe Stopping Distance (feet)
15	80
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
SSD is measured 15 feet (4.5 m) from nearest rail	

What Active Warning Devices Are Used At A Railroad Crossing?

Active warning devices include flashing-light signals and/or flashing-light signals and automatic gates activated by railroad control circuitry to provide a minimum of 20 seconds advance warning of approaching trains. If the crossing has more than one track, a Number of Tracks (R15-2) sign shall be attached to the mast of the active warning devices. Flashing-light signals may be mounted on overhead structures and additional flashing lights may be used where needed.

If a parallel highway is within 200 feet of the railroad crossing, the active warning devices at the crossing shall be interconnected with the vehicle traffic signals at the adjacent highway-highway intersection to provide advance and simultaneous preemption of traffic signal operations for the safety of highway and railroad crossing users.

Who Is Responsible For Signs, Signals, and Maintenance Of Traffic Control Devices at A Railroad Crossing?

The Rail Division of the Oregon Department of Transportation has exclusive jurisdiction under ORS 824.202 over all public railroad crossings including where vehicles can cross, construction or elimination of crossings, their use, and the warning devices at the crossing. An inventory has been made of all crossings in the state.

[3] Source: OAR 741-100-0020

Federal funds for crossing improvements are available through the Crossing Safety Section. Crossings that qualify for upgrade may be improved with 100% federal funding. No local match is required.

The railroad is responsible for installing and maintaining flashing-light signals, automatic gates, activation circuitry, and Crossbuck Assemblies. The road authority (city, county, or state highway) is responsible for installation and maintenance, and the cost thereof, for all other passive warning devices and protective guardrails or curbs adjacent to active warning devices.

Who Has Responsibility For Installation And Maintenance Of Protective Devices at Railroad Crossings?

Table 15-2 shows the party responsible for the installation and maintenance of protective devices at grade crossings.

Table 15-2: Party Responsible for Installation and Maintenance of Standard Protective Devices at Railroad Crossings[4]

Standard Protective Device	Party Responsible for Installation and Maintenance	MUTCD Reference	Rule Reference
Advance EXEMPT sign	Public Authority	Sign W10-1a Section 8B.05	
Advance Warning Pavement Markings	Public Authority	Section 8B.20	
Advance Warning sign	Public Authority	W10 series signs Section 8B.04	
Automatic gate	Railroad	Section 8D.04	741-110-0030(3)(d)
Cantilevered Flashing-light signal	Railroad	Section 8D.03	741-110-0030(3)(b)
Crossbuck sign	Railroad	Sign R15-1 Section 8B.03	
Crossbuck/STOP sign assembly	Railroad		741-110-0030(2)(a) 741-110-0040(10)
Crossbuck/YIELD sign assembly	Railroad		741-110-0030(2)(b) 741-110-0040(10)
DO NOT STOP ON TRACKS sign	Public Authority and Railroad	Sign R8-8 Section 8B.07	
EXEMPT sign	Public Authority and Railroad	Sign R15-3 Section 8B.04	
Flashing-light signal	Railroad	Section 8D.02	741-110-0030(3)(a)
Guardrail	Public Authority		741-110-0030(6) 741-110-0040(7) Oregon Standard Drawing No. RD445
HIGH LEVEL WARNING DEVICE	Public Authority		741-115-0040(1)(b) Figure 3
Illumination	Public Authority and Utility Companies	Section 8C.01	741-110-0030(2)(e) 741-110-0040(9) Figure 7
Multi-use Path Advance Warning sign	Public Authority	Sign W10-1 (15" diameter) Chapter 9B, Table 9B-1	
NO TURN ON RED sign	Public Authority	Signs R10-11, or 11a Section 8D.07	
Number of Tracks sign	Railroad	Sign R15-2 Section 8B.03	
Pedestrian	Railroad		741-110-0030(3)(c)

[4] Source: OAR 741-115-0030

Standard Protective Device	Party Responsible for Installation and Maintenance	MUTCD Reference	Rule Reference
flashing-light signal			741-110-0040(2) Figure 2
Railroad STOP sign	Railroad		741-110-0030(2)(c) 741-110-0040(3) Figure 1
Skewed Angle Bicycle Warning sign	Public Authority		741-110-0030(5)(b) Figure 9
Standard Curb	Public Authority		741-110-0030(7) 741-110-0040(8) Oregon Standard Drawing No. RD700 Figure 6
STOP AHEAD sign	Public Authority	Sign W3-1 or 1a Section 2C.29	741-110-0040(6)
Stop Clearance Line	Public Authority	Stop Line Section 8B.21	741-110-0040(4)
STOP HERE ON RED sign	Public Authority	Sign R10-6 Section 2B.40	
Traffic Signal Preemption Control	Public Authority and Railroad	Section 8D.07	741-110-0030(3)(g) 741-115-0040
Train-activated Advance Warning Device	Public Authority and Railroad		741-110-0030(5)(a) 741-110-0040(6) Figure 5
Turn Restriction Devices During Train Preemption	Public Authority and Railroad	Sign R10-11a, 11b or 11c in Section 2B.45 and Section 8B.06	
Vehicle STOP sign	Public Authority	Sign R1-1 Section 2B.04	
YIELD AHEAD sign	Public Authority	Sign W3-2 or 2a Section 2C.29	741-110-0030(5)(b) 741-110-0040(6)

At traffic signal interconnections where responsibility is shared between the railroad and the public authority, the railroad shall install and maintain the circuitry located on the track and inside the railroad signal case. The railroad shall provide appropriate electrical contacts to the public authority, which shall install and maintain all other signs, signals and circuitry located outside the railroad signal case to assure safe operations during railroad preemption of the vehicle traffic signals.

Which Party is Responsible for Repairing Crossing Surfaces and the Roadway Approaches to a Railroad Crossing?

Oregon Administrative Rules, Chapter 741, Division 120 addresses these issues:

- The roadway or multi-use path at all new or altered grade crossings used by motor vehicles, bicycles, or pedestrians shall be constructed to conform to or exceed nationally recognized and commonly used construction standards.

- The width of the crossing surface, including sidewalks, at the crossing shall be not less than the width of the roadway approaches to the crossing.
- The surface of the roadway shall be in the same plane as the top of rails for a distance of at least two feet outside the rails, and not more than three inches higher nor three inches lower than the top of the nearest rail at a point thirty feet from the rail, measured at right angles thereto, unless authorized by Order from the Department.
- The surface of each grade crossing shall conform to the plane of the top of the rails and be constructed and maintained in a reasonably smooth condition.
- Railroads shall notify the public authority at least two weeks in advance of the date it intends to raise or lower the elevation of one or more tracks at a crossing.
- Public authority(s) shall notify the railroad at least two weeks in advance of the date it intends to raise or lower the elevation of its roadway on the roadway approach to the crossing.
- When a railroad desires to close a railroad crossing temporarily, it shall provide at least two weeks advance notice of its intent to close the crossing to the public authority.
- If the temporary closure is needed for emergency circumstances, railroads may provide the road authority less than two weeks advance notice of its intent to temporarily close the grade crossing. See Section 8A.05 of the MUTCD.

Upon notification by the Department of a condition that does not conform to the requirements of sections (1) through (5) of OAR 741-120-0020, the railroad or the public authority, within 30 days of such notification, unless any party requests a hearing, shall bring its portion of the crossing into compliance with the provisions of OAR 741-120-0020, unless a time extension is granted in writing by the Department.

Additional important information regarding railroad crossings can be found in Oregon Administrative Rules, Chapter 741, which is available online at:

http://arcweb.sos.state.or.us/rules/OARS_700/OAR_741/741_tofc.html

For more information or assistance about railroad crossings contact:

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Rail Division
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Chapter 16: Access Management And Driveways

This Chapter provides an overview of access management for both state highways and local roads. The information presented in this Chapter is a selective summary of the information contained in the ODOT Local Agency Guidelines, Section A, Oregon Administrative Rule Division 51 (OAR 734-051) and Transportation Research Board Access Management Manual and Studies. Access to state highways is under the authority of the Oregon Department of Transportation unless an intergovernmental agreement has provided otherwise.

Access management is the careful planning and management of the location, design, and operation of driveways, median openings, interchanges, and street connections. Roadways serve two primary and important purposes—mobility and access.

Mobility is the efficient and safe movement of people and goods. Mobility is achieved through the elimination of congestion, providing adequate capacity, maintaining reasonable and uniform speeds, and through reducing the need for through traffic to stop.

Access is the ability for people and goods to safely reach specific properties adjacent to the roadway. Access is achieved through on-street parking, driveways, and unsignalized and signalized intersections.

Since no roadway can provide both high levels of mobility and high levels of access, balancing mobility and access to maintain the roadway function based on its classification is one of the key objectives of effective access management.

Ten access management principles as described on the Transportation Research Board's Access Management Manual are[1]:

1. Provide a Specialized Roadway System—Different types of roadways serve different functions. It is important to design and manage roadways according to the primary functions that they are expected to serve.
2. Limit Direct Access to Major Roadways—Roadways that serve higher volumes of regional through traffic need more access control to preserve their traffic movement function.
3. Promote Intersection Hierarchy—An efficient transportation network provides appropriate transitions from one classification of roadway to another.
4. Locate Signals to Favor Through Movements—Long, uniform spacing of intersections and signals on major roadways enhances the ability to coordinate signals and to ensure continuous movement of traffic at the desired speed.

[1] Source: Access Management, Transportation Research Board, 2003

5. Preserve the Functional Area of Intersections and Interchanges—The functional area of an intersection or interchange is the area that is critical to its safe and efficient operation. This is the area where motorists are responding to the intersection or interchange, decelerating, and maneuvering into the appropriate lane to stop or complete a turn.
6. Limit the Number of Conflict Points—Drivers make more mistakes and are more likely to have collisions when they are presented with the complex driving situations created by numerous conflict points.
7. Separate Conflict Areas—Drivers need sufficient time to address one set of potential conflicts before facing another.
8. Remove Turning Vehicles from Through Traffic Lanes—Turning lanes allow drivers to decelerate gradually out of the through lane and wait in a protected area for an opportunity to complete a turn.
9. Use Non-Traversable Medians to Manage Left-Turn Movements—Medians channel turning movements on major roadways to controlled locations. Therefore, non-traversable medians and other techniques that minimize left turns or reduce the driver workload can be especially effective in improving roadway safety.
10. Provide a Supporting Street and Circulation System—Well-planned communities provide a supporting network of local and collector streets to accommodate development, as well as unified property access and circulation systems.

What Are The Benefits Of Access Management?[2]

A. As reported in Chapter 1 of the Transportation Research Board's Access Management, national studies have shown that an effective access management program may achieve the following:

- reduce crashes as much as 50 percent;
- increase roadway capacity by 23 to 45 percent; and
- reduce travel time and delay as much as 40 to 60 percent.

B. Appropriate access management can prevent or reduce the following adverse consequences listed in the Transportation Research Board's Access Management Manual:

- an increase in vehicular crashes;
- collisions involving pedestrians and bicyclists;
- accelerated reduction in roadway efficiency;
- unsightly commercial strip development;
- degradation of scenic landscapes;
- cut-through traffic in residential areas due to overburdened arterials;
- homes and businesses adversely affected by a continuous cycle of widening roads; and
- increased commute times, fuel consumption, and vehicular emissions as numerous driveways and traffic signals intensify congestion and delays along major roads.

C. Some of the benefits to businesses of access management:
Access management not only improves roadway safety, it also helps reduce the growing problem of traffic congestion. Frequent access and closely spaced signals increase congestion on major

[2] Source: ODOT Local Agency Guidelines, Section A, 2007

roads. As congestion increases, so does delay, which is bad for the economy and frustrating to your customers.

Criteria For ODOT Access Management

Criteria for access management policies and guidelines are covered in the Oregon Highway Plan and Chapter 734, Division 51 of the Oregon Administrative Rules. Division 51 addresses the process for requesting an approach to the state highway. Items such as the use of medians and access control are covered in the Oregon Highway Plan.

OAR 734 Division 51 provides state regulations and requirements for highway approaches and spacing standards. The purpose of Division 51 rules is "…to provide a safe and efficient transportation system through the preservation of public safety, the improvement and development of transportation facilities, the protection of highway traffic from the hazards of unrestricted and unregulated entry from adjacent property, and the elimination of hazards due to highway grade intersections." These rules establish procedures and criteria used by the Department to govern highway approaches, in compliance with statewide planning goals and in a manner compatible with acknowledged comprehensive plans and consistent with Oregon Revised Statutes (ORS), Oregon Administrative Rules (OAR), and the 1999 Oregon Highway Plan.

What Is The Role Of ODOT Region Access Management Engineers?

Region Access Management Engineers (RAMEs) play a key role in many individual projects and the development review process. Each of ODOT's five Regions has a RAME that provides technical support for reviewing approach road applications and participating in project development. The RAMEs provide a communication link between central staff and region staff. They also act as an ODOT advisory group to central staff on access management in the development of policies, standards, and administrative rules. They serve as subject matter experts in appeals procedures and are responsible for approving deviations from access management spacing standards..

Private Approaches

Private approaches are privately-owned roads which connect buildings, parking lots and other areas with public roads and highways. Although approaches are essential to providing access to these facilities, they can produce hazardous highway conditions. Engineering studies have shown that as entry and exit to commercial establishments become more frequent along a public road, crash rates, and congestion often increase. The objective, therefore, is to regulate the design and frequency of driveways and other private access roads so as to minimize the incidence of crashes and maintain a reasonable traffic flow along the highway.

The people of Oregon have an enormous investment in their state highway system. At one time highways could link the state's activity centers to each other and serve as "Main Streets" for communities, facilitating roadside development. This is no longer the case. Highways are costing more to construct, and poor access management in the past has made it necessary to build new bypasses when old bypasses have become congested because of new development along the route.

The Oregon Department of Transportation (ODOT) recognized the importance of an effective access policy in Goal 3 of the Oregon Highway Plan, entitled "Access Management". The Transportation Commission adopted comprehensive administrative rules in 2000 that govern the standards and procedures for access management in planning, project delivery and permitting of public and private approach roads.. Therefore, ODOT developed the Access Management Manual in 1991. The purpose of this manual is to provide the relevant documents to those who are working in access management.

What Agency Has Legal Authority For Permitting Approach Roads To The State Highway System?

ORS 374.305 requires that anyone wishing to construct an approach to a state highway must first obtain written permission from the Department of Transportation. The department issues approach road permits to document permission for another party to construct the facilities on state highway right-of-way to serve the abutting property. ORS 374.310(1) provides that: “no permit can be issued... where no rights of access exist between the highway and abutting real property....” That is, where the department has acquired rights of access, through purchase or other means, no access can be allowed unless the department approves "grant of access" as described below. If the property owner has a right of access, decisions on issuance of the permit are based on the criteria and factors of OAR 734-051, which include safety, spacing, and roadway classification.

How To Request For Grant Of Access From Oregon Department Of Transportation.

A grant of access is defined in OAR 734-051 as “... a specific right of access at a location where an abutting property currently does not have that specific right of access.” The following paragraph describes the process for grant or indenture of access from ODOT.

The applicant for the grant completes the ODOT grant applicant and submits it to the applicable ODOT District Manager. If the City or county receives the application, they should assist the applicant in determining the appropriate ODOT District office to submit the application. After receiving the request from a property owner, the cities and counties should send the request to the district manager of the ODOT. The District Manager and the Region Engineer review the application and decide to approve or deny the request, then it is sent to a Statewide Grant Review Committee that makes a recommendation to the Chief Highway Engineer whether to approve or deny the application. If the application is approved, then it is sent to Right-of-Way Property Management Unit to appraise the value of the grant. Once the price of the grant is agreed to and paid by the applicant, Right of Way prepares and records final legal documents. Right-of-Way will then send a copy of the fully executed document to the district. No other review will be done by Salem offices. Complete instructions and grant application materials are available online at http://www.oregon.gov/ODOT/HWY/ACCESSMGT/.

What Are The Major Factors A Municipality Should Take Into Account In Providing Guidelines For Driveway Construction And Operation?

Driveways accessing major highways require more stringent requirements than those accessing secondary roads or streets. Standards for all driveways, however, should minimize potential crashes and conflicts between through vehicles and those entering and leaving the driveway. Some of the objectives to be achieved through the use of proper driveway design standards are:

1. Minimize the speed differential between through vehicles and those using the driveway.
2. Eliminate encroachment of turning vehicles on adjacent lanes.
3. Prohibit motorists from using the road or highway as a means of circulating between parking rows.
4. Provide sufficient space between driveways to reduce interference from traffic using adjacent driveways.
5. Discourage motorists from parking on streets or backing out onto the highway or road.
6. Preserve the original intent of the roadway, pedestrian walkway and drainage facilities.
7. Provide adequate sight distance of on-coming traffic for motorists exiting the driveway.

What Are The Proper Design Standards For A Driveway?

Cities and counties should regulate the driveways as to width of entrance, placement with respect to property lines and streets, angle of entry, vertical alignment, and number of entrances to a single property to provide for traffic safety and maximum use of curb space for parking where permitted. Sight distance is a significant design control, and driveways should be avoided where sight distance is insufficient. In general, access to lower order roadways is preferred over access to higher order roadways to enhance mobility and safety. Sight distance requirements for intersections are contained in *Chapter 20: Clear Zone, Sight Distance, and Vegetation Control* of this Handbook.

Driveways should be situated as far away from intersections as practical, outside of the influence area of an intersection, particularly if the local street intersects an arterial street. Many cities and counties have developed standards for driveways. The Transportation Research Board's Access Management Manual provides additional guidance on intersection influence areas.

Access spacing and design standards for state highways are contained in Oregon Administration Rules, Chapter 734, Division 51, and the Highway Design Manual.

What Factors Do I Consider In Locating a Driveway?

When considering a proposed driveway, the following criteria should be used in determining that its construction will not endanger lives and property.

1. Locate the driveway where motorists using the proposed drive and abutting road will have adequate sight distance, and where grade and alignment conditions are favorable.
2. Reduce or eliminate conflicts that interfere with the free and safe movement of highway traffic.
3. The safety and convenience of pedestrians and other users of the

4. Driveways serving commercial, industrial and high density residential developments can affect the efficiency and safety of the street or highway onto which they enter and exit. Perhaps the single most important factor in developing a safe access plan for these developments is a determination of the potential traffic volumes generated (reference Chapter 17).
5. Research the crash history in the vicinity of the driveway. Evaluate ways to reduce approach related crashes, especially those associated with left turn (left turns tend to result in the most severe crashes).
6. Minimize conflicts points between through traffic and vehicles entering and exiting driveways.
7. Avoid driveways in the influence area of an intersection.

Can A Driveway Be Jointly Shared By Two Adjacent Property Owners?

State and local jurisdictions generally support shared driveways by adjacent property owners if the properties have or develop any easements necessary for joint use, usually an easement agreement. The only barrier to allowing such a driveway would be the safety and traffic flow issues already addressed in this Chapter. In order to minimize traffic conflicts on the public road, internal (cross drives) may be appropriate.

Are There Special Conditions For Driveways Entering And Exiting Specific Kinds Of Establishments?

Along with traffic volumes, other critical factors to be examined include the number of entrances, the size of the parking area, the length of storage lanes for traffic entering and leaving these establishments, and the internal traffic circulation pattern. Different kinds of developments also demand special conditions. Following are a few general guidelines for different types of land use, but a traffic impact study should be considered to identify problems that may develop with under the specific site conditions and design parameters of a development.

1. **Office Space**—The exit driveway facility should be designed to accommodate heavy traffic during peak hours.
2. **Drive-In Service Establishments**—The layout and design of all driveways must ensure that no queues of vehicles develops on the highway waiting to enter the site.
3. **Drive-In Theaters**—A storage area between the ticket booths and the highway shoulders should be provided for an equivalent of 10 percent of the rated vehicle capacity of the theater.

What Are Driveway Permits?

Most cities and counties regulate construction of driveways and other improvements in the public right-of-way. Such permits, sometimes called “driveway permits” or “encroachment permits,” may be required for achieving better access management solutions on public streets within the city and county, or only on those streets maintained by that jurisdiction. ODOT is responsible for issuing all road permits to state highways unless an agreement with the city or county states otherwise.

What Is The Function Of Site And Design Review?

In recent years, several cities and counties have established site plan policies, rules, and procedures in addition to the more traditional zoning and subdivision controls and building codes. These communities almost unanimously agree that this review has helped to improve access management. It provides greater flexibility and allows the city or county to place conditions upon the approval of a proposed development to mitigate the impact of traffic safety and operations. Among many benefits that such a review provides are:

- It is possible to avoid problem situations that could not easily be addressed in specific standards of the zoning ordinance.
- It provides the opportunity for coordination with adjacent developments, including the use of shared curb cuts of frontage roads. ODOT has produced a Development Review Guideline manual that covers most of the issues involved in these processes, including extensive guidance on state and local collaboration.

What Are The Three Types Of Land Divisions?

There are three types of land divisions recognized under Oregon state statute: subdivisions, major partitions, and minor partitions. Briefly, a subdivision is a division of land into four or more lots with or without the creation of a road or street. A partition is a division of land into three or fewer lots. A major partition includes the creation of a road or street while a minor partition does not.

The layout of subdivisions should ensure connectivity of the road system. Minor partition generally have less impact on arterial roadways than a subdivision, however the aggregate impact of individual partitions can be substantial.

Additional information about access policies and procedures, as well as links to resources for local government access management are available on the internet at:
http://www.oregon.gov/ODOT/HWY/ACCESSMGT/

Chapter 17: Parking

Parking is one of the essential elements of any workable transportation system. Parking characteristics normally are influenced by the size of the city, the other modes of transportation available to commuters, and the size and importance of the Central Business District.

This Chapter provides basic information on how to determine parking needs, the dimensions of parking spaces, and appropriate signs. As with all traffic management questions, one should take advantage of professional advice and utilize proper reference materials for assistance in developing the best possible system for a municipality.

When Should On-Street Parking Be Prohibited?[1]

The need for on-street or curb parking must be balanced with the need for a safe and adequate traffic flow. When there is a need for using the entire street for traffic movement, on-street parking should be prohibited.

A local one-way street with a width of less than 16 feet (4.8 m) requires prohibition of parking on both sides. A width range of 17 to 24 feet (5.2 to 7.3 m) parking should be prohibited on one side.

A local two-way street with a width of less than 26 feet (7.8 m) should have parking prohibited on both sides. A width range of 27 to 31 feet (8.2 to 9.4 m), parking should be prohibited on one side.

When Can Angle Parking Be Allowed?

Angle parking requires more street width than does parallel parking. However, it does provide more spaces than parallel parking for a given length of curb space. The main advantage of angle parking is the ease with which drivers can maneuver into and out of a parking space. Conversely, its biggest disadvantage is the fact a driver's vision is somewhat impaired when the driver vacates the parking space. Many communities have eliminated angle parking because of associated traffic crash problems.

Are There Certain Places Where Parking Should Always Be Prohibited?[2]

Prohibit parking in the following locations:

1. on a sidewalk;
2. in front of a public or private driveway;
3. within an intersection;
4. within 15 feet (4.5 m) of a fire hydrant;

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[1] Source: Institute of Transportation Engineers, Traffic Engineering Handbook, 5th Edition, 1999
[2] Source: Institute of Transportation Engineers, Traffic Engineering Handbook, 5th Edition, 1999

5. on a crosswalk;
6. within 20 feet (6.0 m) of a crosswalk at an intersection;
7. within 30 feet (9.0 m) on the approach to any flashing light, stop sign, or traffic control signal located at the side of a roadway;
8. within 50 feet (15.0 m) of the nearest rail or a railroad crossing;
9. within 20 feet (6.0 m) of the driveway entrance to any fire station and on the side of the street opposite the entrance to any fire station within 75 feet (22.5 m) of said entrance (when properly posted);
10. alongside or opposite any street excavation or obstruction when stopping, standing, or parking would obstruct traffic; and
11. on any bridge or other elevated structure on a highway or within a highway tunnel.

How Much Space Is Needed For Each Curb Parking Stall?

A. Parallel Curb Parking

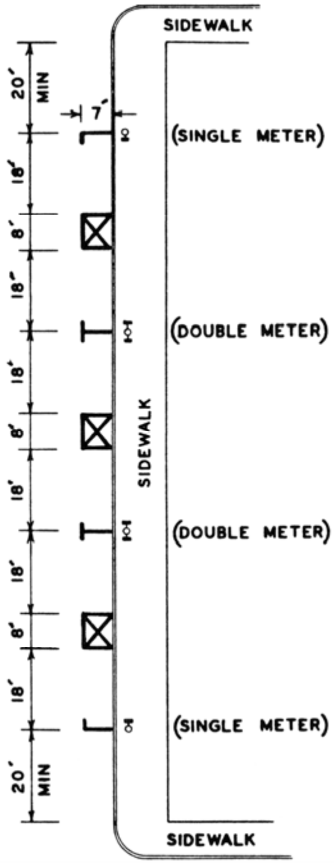
Three kinds of stalls are used when allocating space for vehicles parking along city streets: end stalls, interior stalls, and paired parking stalls. Since a vehicle can be driven into and out of an end stall, only the length of the vehicle (about 18 feet (5.4 m)) needs to be accommodated. Interior stalls require room for a car to maneuver. Therefore, these spaces should be approximately 22 feet (6.6 m) in length.

"Paired" parking has stall layouts such that two vehicles are parked bumper to bumper with the pair of stalls separated by a maneuver area. Stall lengths of 18 feet (5.4 m) are recommended with maneuver areas of about 8 feet (2.4 m) (See Figure 17-1).

B. Angle Curb Parking

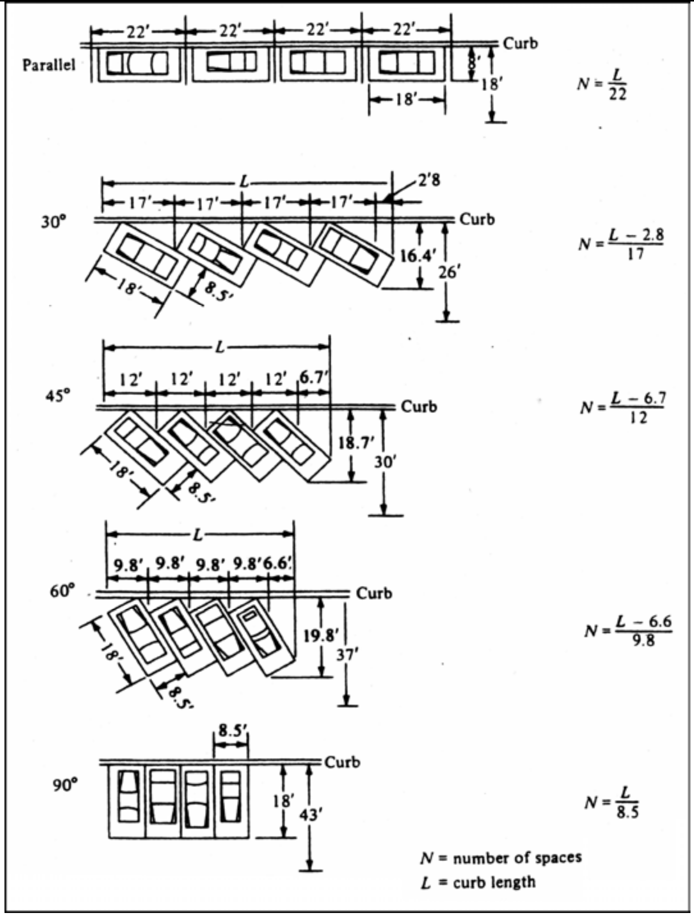
Angle parking uses considerably more street width. Therefore, parallel parking is preferred over angle parking where the movement of traffic takes priority over the temporary storage of vehicles, and vice versa. It is also important to indicate that angle parking is potentially more hazardous than parallel parking because of impaired visibility for the unparking driver. Figure 17-2 shows the curb parking spaces at various angles.

Figure 17-1: Example Of Paired Parking Meter Layout[3]



Note: Metric converts as follows:
1 foot = 0.3048 m

Figure 17-2: Curb Parking Spaces At Various Angles[4]



What Are The Advantages And Disadvantages Of 90 Degree Parking?[5]

Several advantages of 90 degree parking include the following:

- Parking type is the most common and understandable.
- 90 degree parking is generally most efficient if the site is sufficiently large.
- Two-way movement is used, which can allow short, dead-end aisles.
- Unparking can be accomplished in either direction, minimizing travel distance and internal conflict
- Wide aisles can provide room to pass stopped vehicles waiting for an unparked vehicle.
- Wide aisles increase separation between pedestrians walking in the aisle and moving vehicles.
- Wide aisles increase clearance from other traffic in the aisle during unparking maneuvers.
- 90 degree parking results in fewer total aisles, which makes locating a parked vehicle easier.

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[3] Source: Parking Principles, Special Report 125, Highway Research Board, 1971
[4] Source: W.S. Hamburger and J.H. Kell, Fundamentals of Traffic Engineering, 12th Edition, 1989
[5] Source: Institute of Transportation Engineers, Traffic Engineering Handbook, 5th Edition, 1999

Several advantages of angle parking (usually 45 to 75 degrees), include the following:

- This type of parking is the easiest in which to park.
- It can be adapted to almost any width of site by varying the angle.
- It requires slightly deeper stalls but much narrower aisles and modules.

Disadvantages of angle parking include the following:

- Drivers must unpark and proceed in original direction, hence producing greater out-of-way travel and conflict.
- Additional cross aisles for one-way travel are required to avoid long travel, which adds to gross area used per parking stall.
- It is difficult to sign one-way aisles.

When Is It Necessary To Mark Stalls For Curb Parking?

Curb parking stalls should be marked:

- where high turn over is expected;
- where parking is not parallel to the curb line;
- where parking meters are used;
- where absence of markings will cause inefficient use of available space; and
- to define spaces for the handicapped.

What Colors Are Used For Parking Stall Markings?[6]

White is the standard color for marking stall lines in most communities, with yellow used only to delineate areas of NO PARKING. Yellow cross-hatching is most effective, if other lines are white.

Some liability issues need to be recognized. Paint can become slippery when wet. While not usually a problem with ordinary stall lines, wider stop bars or crosswalk lines may pose a problem if on a significant grade. This can be treated by use of abrasives mixed into the paint. Plastic “buttons” have been used to delineate parking stalls at a few locations. These devices form pavement irregularities and can be a trip-and-fall hazard along direct pedestrian paths to and from parked vehicles.

When Is It Necessary To Establish Time Limits For The Curb Parking?

Time limits should be established only after studies have shown a demand for additional short time parking in the immediate area. Time limits are usually selected as follows:

- One hour for the central business district (CBD).
- Two hours in areas adjacent to one hour zones to accommodate persons who desire to park longer, but are willing to walk further.
- Ten to thirty minutes near special establishments, such as banks and post offices, to accommodate demand for short time parking.
- Three to five hours in residential areas adjacent to major generator of all day parking.

[6] Source: Institute of Transportation Engineers, Traffic Engineering Handbook, 5th Edition, 1999

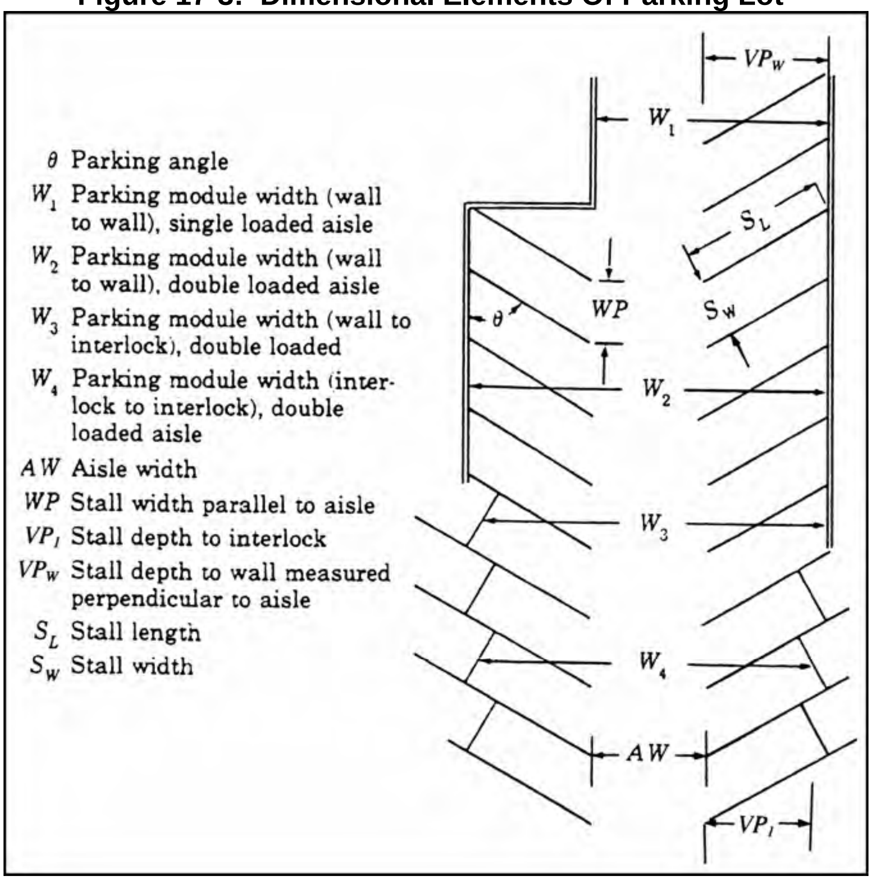
How Much Space Is Needed For Off-Street Parking?

Although the trend during the past decade has been toward smaller vehicles, the suggested dimensions discussed below will accommodate today's largest models. Over the next few years, new vehicles will probably be slightly smaller.

The recommended stall width is 8.5 feet (2.6 m) for self-parking of long duration. For higher turnover self-parking, for example at supermarkets where shoppers generally have large packages, the minimum recommended width is 9.0 feet (2.7 m), with 9.5 to 10.0 feet (2.9 to 3.0 m) desirable. Stall lengths of 18.5 feet (5.6 m) should be sufficient to accommodate most cars using the parking spaces. Refer to Figure 17-2 for or stall dimensions for varying degrees of angle parking.

Attempts to get by with narrower aisles and stalls is not the answer to increasing a parking facility's capacity. Drivers will simply tend to encroach on more than one parking stall, and the end result being a loss of actual parking spaces. Refer to Table 17-1 for stall width classification, Table 17-2 for parking layout dimension, and Figure 17-3 for dimensional elements of parking lots.

Figure 17-3: Dimensional Elements Of Parking Lot[7]



[7] Source: Institute of Transportation Engineers, Guidelines for Parking Facility Location and Design, 1994

Table 17-1: Stall Width Classification[8]

Class	Width (ft)*	Typical Turnover: Low	Medium	High	Typical Uses
A	9.00			X	Retail customers, banks, fast foods, other very high turnover
B	8.75		X	X	Retail customers, visitors
C	8.50	X	X		Visitors, office employees, residential, airport, hospitals
D	8.25	X			Industrial, commuter, university

*For large-size vehicle, measured at right angles to stall.

1 ft = 0.305 m

Table 17-2: Parking Layout Dimension Guidelines[9]

1	2 - S_w	3 - WP	4 - VP_w	5 - VP_i	6 - AW	7 - W_2	8 - W_4
						Modules	
Parking Class	Basic Stall Width (ft)	Stall Width Parallel to Aisle (ft)	Stall Depth to Wall (ft)	Stall Depth to Interlock (ft)	Aisle Width (ft)	Wall to Wall (ft)	Interlock to Interlock (ft)
		Two-Way Aisle — 90 Degrees					
A	9.00	9.00	17.5	17.5	26.0	61.0	61.0
B	8.75	8.75					
C	8.50	8.50					
D	8.25	8.25					
		Two-Way Aisle — 60 Degrees					
A	9.00	10.4	18.0	16.5	26.0	62.0	59.0
B	8.75	10.1					
C	8.50	9.8					
D	8.25	9.5					
		One-Way Aisle — 75 Degrees					
A	9.00	9.3	18.5	17.5	22.0	59.0	57.0
B	8.75	9.0					
C	8.50	8.8					
D	8.25	8.5					
		One-Way Aisle — 60 Degrees					
A	9.00	10.4	18.0	16.5	18.0	54.0	51.0
B	8.75	10.1					
C	8.50	9.8					
D	8.25	9.5					
		One-Way Aisle — 45 Degrees					
A	9.00	12.7	16.5	14.5	15.0	48.0	44.0
B	8.75	12.4					
C	8.50	12.0					
D	8.25	11.7					

Notes: In general, these dimensions are subject to slight reductions by local agencies under high-cost conditions (such as garages) or slight increases in areas subject to special needs (such as extensive snowfall). Aisle width may be narrowed by about 1 ft without a major increase in congestion and accessibility of parking stalls (particularity in structures where high construction cost is a factor). A one-step trade-off can be made between stall and aisle width. A decrease of 2 ft in the module can be compensated for by a 0.5-ft increase in stall width for the appropriate class.

Columns 5, 8 — May also apply to boundary curb where bumper overhang is allowed.
Column 6 — To vehicle corner.
Columns 6 to 8 — Rounded to nearest foot.
1 ft = 0.305 m

[8] Source: Institute of Transportation Engineers, Guidelines for Parking Facility Location and Design, 1994
[9] Source: Institute of Transportation Engineers, Guidelines for Parking Facility Location and Design, 1994

How To Design And Locate Access Driveways For Parking Lot Facilities[10]

Access driveways serving large facilities should be located to provide appropriate entrance and exit storage (reservoir) space and should be an adequate distance from controlled intersections. Combined entry/exit points should preferably be located mid-block. At pay facilities, it is desirable to locate entry and exit points together so that attendants can monitor both in and out traffic from the same point.

The basic or nominal design width for a two-way access driveway serving a commercial land use is 30 feet (9.1 m) with 15 feet (4.6 m) radii. With greater volumes (such as for a community shopping center), a 36-foot (11 m) driveway may be appropriate, marked with two exit lanes that are 10 or 11 feet (3.0 or 3.3 m) wide and a single entry lane 14 to 16 feet (4.3 to 4.6 m) wide to accommodate the off-tracking path of an entering vehicle.

What Are The Design Elements Related To Operations Of Parking Facilities?[11]

The design of a parking facility is strongly influenced by its intended operation. Design elements and their operations features follow in successive steps:

1. Vehicular access from the street system (an entry driveway).
2. Search for a parking stall (circulation and/or access aisles).
3. Maneuver space to enter the stall (access aisle).
4. Sufficient stall size to accommodate the vehicle's length and width plus space to open car doors wide enough to enter and leave the vehicle (stall dimensions).
5. Pedestrian access to and from the facility boundary (usually via the aisles) and vertically by stairs, escalators, and elevators in multi-level facilities.
6. Maneuver space to exit from the parking stall (access aisle).
7. Routing to leave the facility (access and circulation aisles).
8. Vehicular egress to the street system (exit driveway).
9. Any revenue control system (may involve elements of entry, exit or both).

What Factors Should Be Considered For The Design Of Off-Street Parking Lots?

For the design of an off-street parking lot the following design factors should be considered:

1. Surfacing or paving. The minimum requirements are drainage, grading (1% for asphalt and 0.5% for concrete), and dust prevention.
2. Marking and signing. These affect efficiency of operation.
3. Illumination. This is affected for lots which are used during the hours of darkness.
4. Landscaping. This may be necessary to remove visual problems in some areas as well as for aesthetic reasons.
5. Raised pedestrian sidewalks. Used in large parking lots to separate rows of cars and to provide more favorable walking conditions.

[10] Traffic Engineering Handbook, 5th Edition, 1999
[11] Source: Traffic Engineering Handbook, 5th Edition, Institute Of Transportation Engineers, 1999

6. Boundary barrier. Where a parking lot abuts a public sidewalk, it is usually necessary to provide some type of boundary barrier. This can be wheel stops, curbing, guardrails, low walls, or fencing.
7. Boundary controls. Boundary controls that are higher than about 24 inches (0.6 m) should not be allowed on streets that have exit driveways or near intersections unless an 8-foot (2.4 m) boundary setback from the public walk is used.

What Are The Steps For Geometric Design Of Off-Street Parking Lots?

A. Preliminary steps

Make an accurate drawing of the area at a scale of 1 inch = 20 feet (25 mm = 6 m) and include:

1. Location of any nearby parking generator which the lot is intended to serve.
2. Determine the possibility which would give access to a second street or to an alley and permit a better circulation pattern.
3. If a pay lot, determine the method of fee collection as this would affect the location of entrances and space needed to accommodate meters.
4. Consult local building codes and zoning ordinances for restrictions as to size, curb cuts, fencing or screening, drainage, lighting, hours of operation, and signing.

B. Space layout principles

1. As a general rule, 90 degree parking, where feasible, is the most economical use of space.
2. Irrespective of parking angle, aisle parking to the longest dimension of the lot gives the most efficient arrangement.
3. Exits and entrances should be planned for locations as far from street intersections as possible to avoid left turns or crossing movements. If both the entrance and exit are located on a two-way street, they should be separated as far as possible and in such a way that paths of inbound and outbound cars would not cross.
4. Inbound circulation should permit parkers to pass each vacant stall at least once without having to leave the parking lot.
5. Raised islands are used to serve pedestrian traffic, for locating meters, bumpers, and lighting, and for landscaping where space permits. Pedestrian walkways should be at least 4 feet wide if raised after allowing for car overhang.
6. Make an estimate of the maximum number of stalls that can be provided with combinations of several of the parking angles. Select the alternative which provides a balance between maximum safety, good circulation patterns, and maximum number of stalls.

How Much Parking Space Is Needed For Special Purpose Vehicles?[12]

Parking stalls or spaces for specific purposes should be defined with white lines which extend perpendicular from the curb for a distance of about 7 feet (2.1m) and with signs posted to specify the use.

A. Truck Loading Zones are generally from 30 to 60 feet (9.0m to 18.0m) in length. Trucks can be allowed additional maneuvering space by placing the zones next to no parking areas.

[12] Source: A Policy On Geometric Design Of Highways And Streets, AASHTO, 2004

B. Taxi Zones require about 20 feet (6.0m) for each stall plus an additional 5 feet (1.5m) on each end for a maneuvering area.

C. Bus Loading Zones should allow for passenger pick-ups without any backing maneuvers by the driver. This requires about 50 feet (15.0m) for one space and 25 feet (7.5m) for each additional space with a stall width of 12 feet (3.6 m).

D. Handicap Parking Zones are accessible parking spaces for disabled persons that must be at least 8 feet (2.4 m) wide and must be signed with the international symbol of accessibility. Pavement marking and signs associated with handicapped parking are blue on white.

A minimum access aisle of at least 5 feet (1.5m) wide and 20 feet (6.0 m) long adjacent and parallel to the parking space must be provided.

E. Motorcycles require 8 feet (2.4 m) of stall length and 5 feet (1.5 m) of width.

F. Bicycles typically measure 5.5 to 6 feet (1.6 to 1.8 m) in length, with handle bars spanning about 17 to 27 inches (43 to 69 cm). A very broad selection of parking racks, posts and lockers have been manufactured. For a basic layout, a 2 by 6 feet (0.6 by 1.8 m) long stall is appropriate, served by a 5 feet (1.5 m) wide aisle.

What Types Of "No Parking" Signs Can Be Used?

Each parking situation may require a specific kind of sign, but the following signs are examples of what is typically used (See Figure 17-4). To minimize the number of parking signs, blanket prohibitions and/or restrictions which apply can be posted at municipal boundary lines. The signs must conform to the MUTCD in shape, color, location and use. The information on the sign should be in the following order:

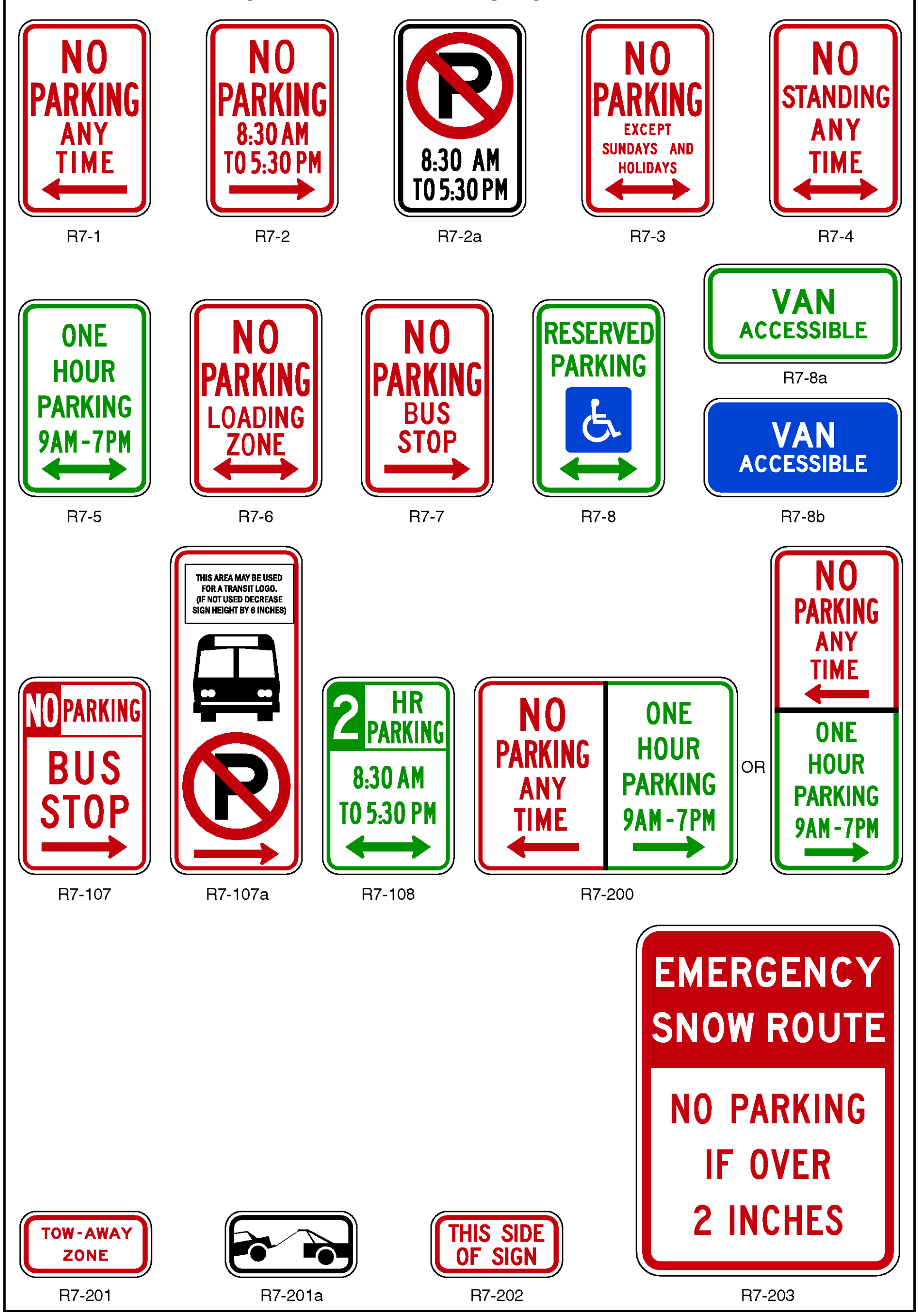
1. Restriction or prohibition.
2. Time of day it is applicable, if not all hours.
3. Days of week it is applicable, if not all days.

Where parking is prohibited at all times or at specified times, the parking signs shall have red letters and borders on a white background (parking prohibition signs). Where only limited time parking or parking in a particular manner is permitted, the signs shall have green letters and borders with a white background (parking restriction signs).

Parking signs with arrows are used to indicate the restricted zone. The signs should be set at an angle of not less than 30 nor more than 45 degrees with the line of traffic flow so that they are visible to approaching drivers. If the zone is unusually long (a block or longer), signs with a double arrow should be set at intermediate points within the zone.

Figure 17-4: Standard Regulatory Signs[13]

Figure 2B-16. No Parking Signs (R7 Series)



Note: all above signs minimum 12"x18" (300mm x 450mm) in urban areas.

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[13] Source: Part II, MUTCD, 2003

What Are Parking Signs For Rural Areas?

In rural districts, signs that prohibit stopping, parking or standing on highways and heavily traveled secondary roads should conform to other standards. The standard size for rural "NO PARKING" signs is 24 by 30 inches (600mm x 750mm), although on secondary roads 18 by 24 inches (450mm x 600mm) is permitted. The words or numerals are red in color on a white background.

The simple legend NO PARKING prohibits any parking along a given highway (See Figure 17-5). Other typical signs include NO PARKING ON PAVEMENT, NO PARKING EXCEPT ON SHOULDERS (where the highway has a shoulder), and NO STOPPING. As within city limits, if the sign applies to only a limited area arrows or supplemental messages should be added to indicate the restrictions.

Figure 17-5: No Parking Sign (R8-3)[14]

Standard Size 24" x 30" (0.6 m x 750 mm) See MUTCD page 2B-37	

What Are The Liability Issues Of Parking Lots?[15]

Many lawsuits allege defects in parking lots. These occur in two general categories: (1) pedestrian falls, and (2) vehicle collisions, including fixed objects and pedestrians. Issues relate to design, operation, or maintenance. The following lists include elements typical of claims that have been made in the United States. They are arranged in three groups: pedestrian slip or trip-and-fall hazards, vehicle hazards, and hazards common to both collisions and falls.

A. Pedestrian slip or trip-and-fall hazards include the following:

- Wheel stops located in direct pedestrian paths, creating a trip-and-fall hazard.
- Side slopes of handicapped ramps placed along sidewalks, where the slope ratio exceeds the desirable one in ten and/or where the surface has not been painted with a yellow, skid resistant surface.
- Inadequate lighting to allow view of surface defects such as holes, cracks, or other fixed objects, as well as for personal security issues.
- Inadequate drainage and depressions which can retain water and freeze into ice in northern climates.
- Barriers between parking modules, such as ropes or cables, creating hazards for pedestrians or bicycle riders.

[14] Source: Part II, MUTCD, 2003
[15] Source: Traffic Engineering Handbook, 5th Edition, Institute of Transportation Engineers, 1999

- Lack of building entrance crosswalks painted across building frontage roadways where pedestrian concentrations occur.
- Inadequate boundary controls or setbacks to prevent vehicle bumper overhang across public sidewalks adjacent to the site, which can be a hazard to pedestrians.
- Use of paint which can become slippery when wet, especially on sloping surfaces.
- Lack of contrast between walk surfaces or edges of steps and adjacent pavement to give pedestrians notice of a step down.
- Use of “buttons” instead of paint to form parking stall lines.
- Stairways in garages.
- Inadequate maintenance to keep surface clean of trash, excessive oil drips, snow, and ice.

B. Collision hazards to drivers of vehicles include the following:

- Lack of reflectorization of traffic control devices.
- Inadequate reflective marking for night visibility of fixed objects such as fire hydrants, utility poles, light pole bases, or sign posts in the driving path.
- Lack of traffic controls at major driveways intersecting access streets, such as the need for traffic signals where warrants are met.
- Substandard driveway radii, causing vehicle encroachment inside a facility or excessive slowing down to enter site.
- Lack of separate left turn lanes at major driveway entry points.
- Lack of proper internal traffic control devices to regulate major conflicting flows.
- Inadequate boundary controls adjacent to abrupt drop-offs as needed to reasonably restrain vehicles.
- Lack of end islands to open up sight distance at parking row intersections in larger facilities such as at ring roads in shopping centers.
- Inadequate maintenance of traffic controls: signs, signals, pavement markings.

C. Hazards common to both collisions and falls include the following:

- Sight obstruction at driveways or aisle intersections formed by bushes, low-growing trees, ground-mounted signs, or building walls.
- Speed bumps creating both a vehicular hazard and a pedestrian trip-and-fall condition.
- Yellow stall markings instead of white, which depreciate the value of yellow when used to mark curbing, steps, or fixed-object hazards.
- Inadequate maintenance of light components.

What Are The Standards For Disabled Parking Spaces?[16]

The number of spaces open to the public shall comply with Oregon Transportation Commission, Standards For Accessible Parking Places, April 2008, as shown in Table 17-3.

An accessible parking space consists of a 9 feet (2.7 m) wide parking space with a 6 feet (1.8 m) wide access aisle. An accessible parking space designated as “van-accessible” or reserved for wheelchair users only consists of a 9 feet (2.7 m) wide parking space with an 8 feet (2.4 m) wide access aisle. Figure 17-6 through Figure 17-8 show example layouts, ADA ramp, and slope

[16] Source: Oregon Transportation Commission, Standards For Accessible Parking Places, April 2008

design. The access aisle must be located on the passenger side of the parking space (See Figure 17-6) except that two adjacent accessible parking spaces may share a common access aisle (See Figure 17-7).

Access aisles adjacent to accessible spaces shall be 6 feet (1.8 m) wide minimum with the following exceptions:

- One in every eight accessible spaces, but not less than one, shall be served by an access aisle 8 feet (2.4 m) wide minimum and shall be designated "van accessible" (See Figure 17-6 and Figure 17-7).
- Where five or more parking spaces are designated accessible, any space that is designated “van accessible” shall be reserved for wheelchair users.

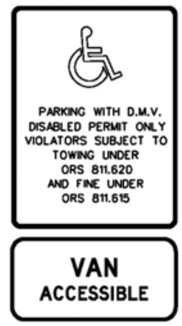
At outpatient facilities, 10 percent of the total number of parking spaces at the facility shall be accessible. At facilities that specialize in treatment or services for persons with mobility impairments, 20 percent shall be accessible.

For additional information about parking please refer to the following publications:
Edwards, John, “The Parking Handbook For Small Communities”, Institute of Transportation Engineers, Washington, D.C., 1994

Urban Land Institute, “The Dimensions of Parking”, Fourth Edition, Washington, D.C., 2000.

For further information and requirements on disabled facilities check the state building code (Chapter 11) and Oregon Transportation Commission, Standards For Accessible Parking Places, April 2008, which is also available online at:
http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/standards_for_accessible_parking_places.pdf.

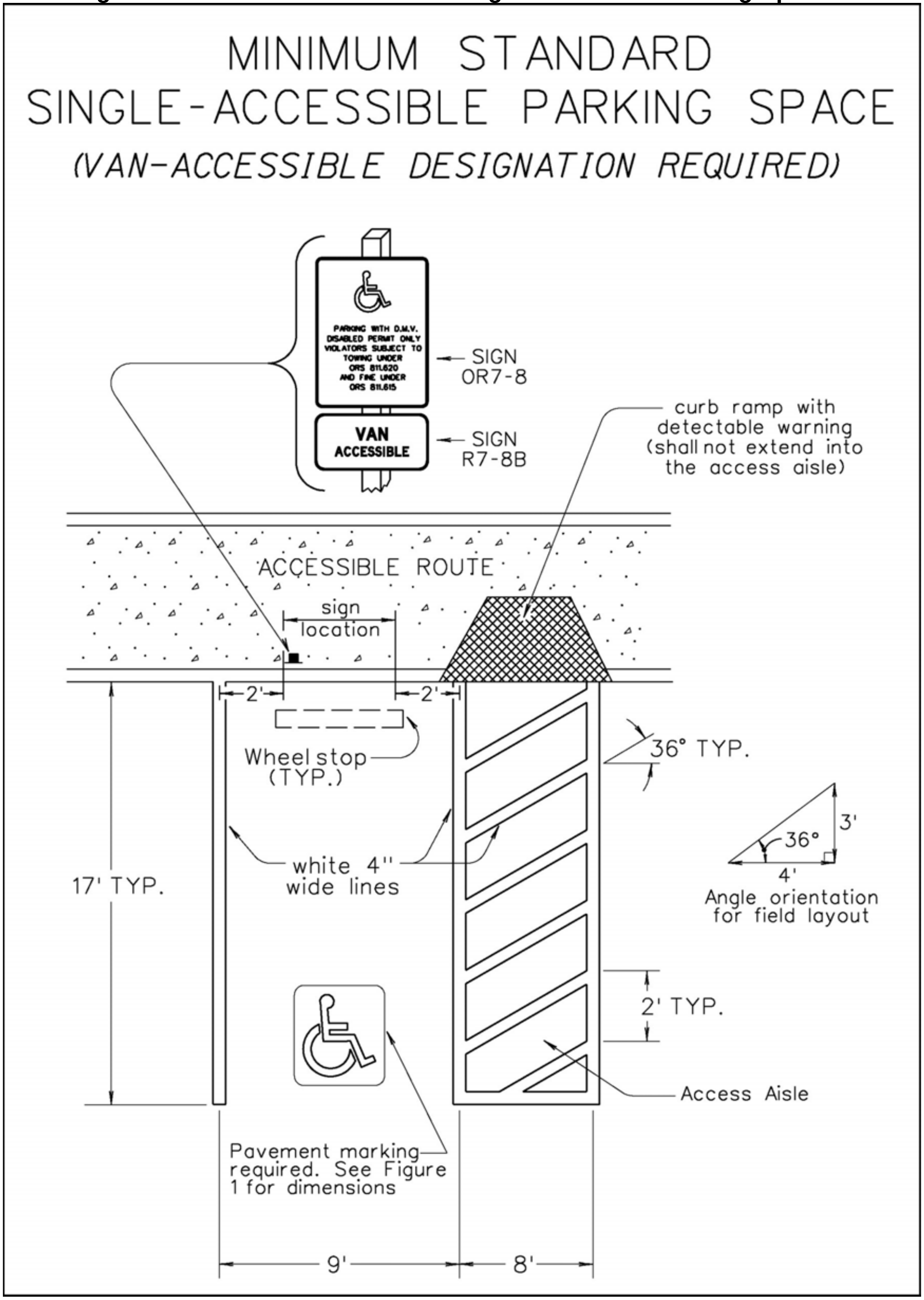
Table 17-3: Number Of Accessible Parking Spaces By Lot Size[17]



Total Parking in Lot	Required Minimum Number of Accessible Spaces	Required Minimum Number of "Van Accessible" Spaces	Required Number of "Wheelchair User Only" Spaces
1 to 25	1	1	-
26 to 50	2	1	-
51 to 75	3	1	-
76 to 100	4	1	-
101 to 150	5	-	1
151 to 200	6	-	1
201 to 300	7	-	1
301 to 400	8	-	1
401 to 500	9	-	2
501 to 1000	2% of total	-	1 in every 8 accessible spaces or portion thereof
1001 and over	20 plus 1 for each 100 Over 1000	-	

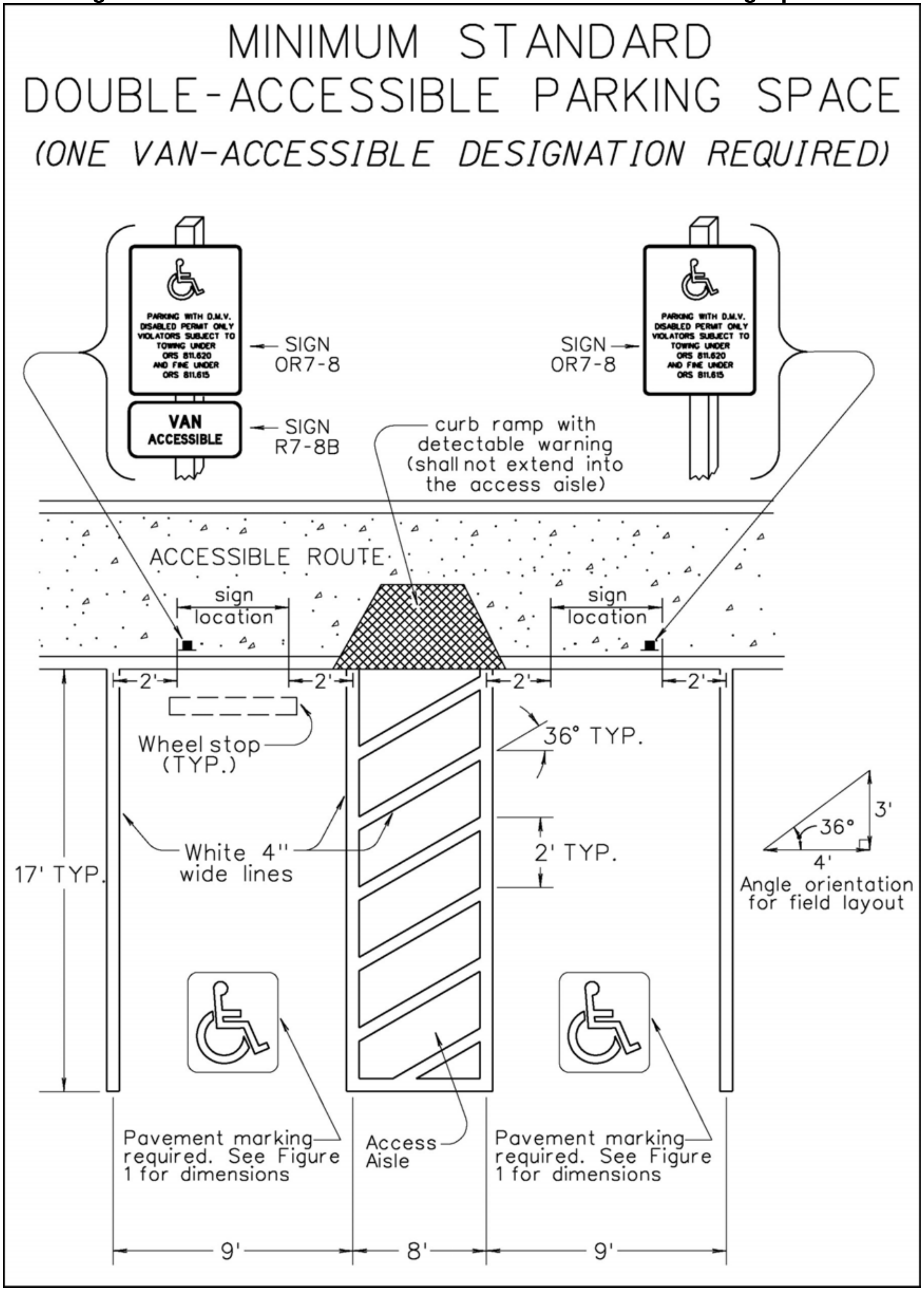
[17] Source: Oregon Transportation Commission, Standards For Accessible Parking Places, April 2008

Figure 17-6: Minimum Standard Single-Accessible Parking Space[18]



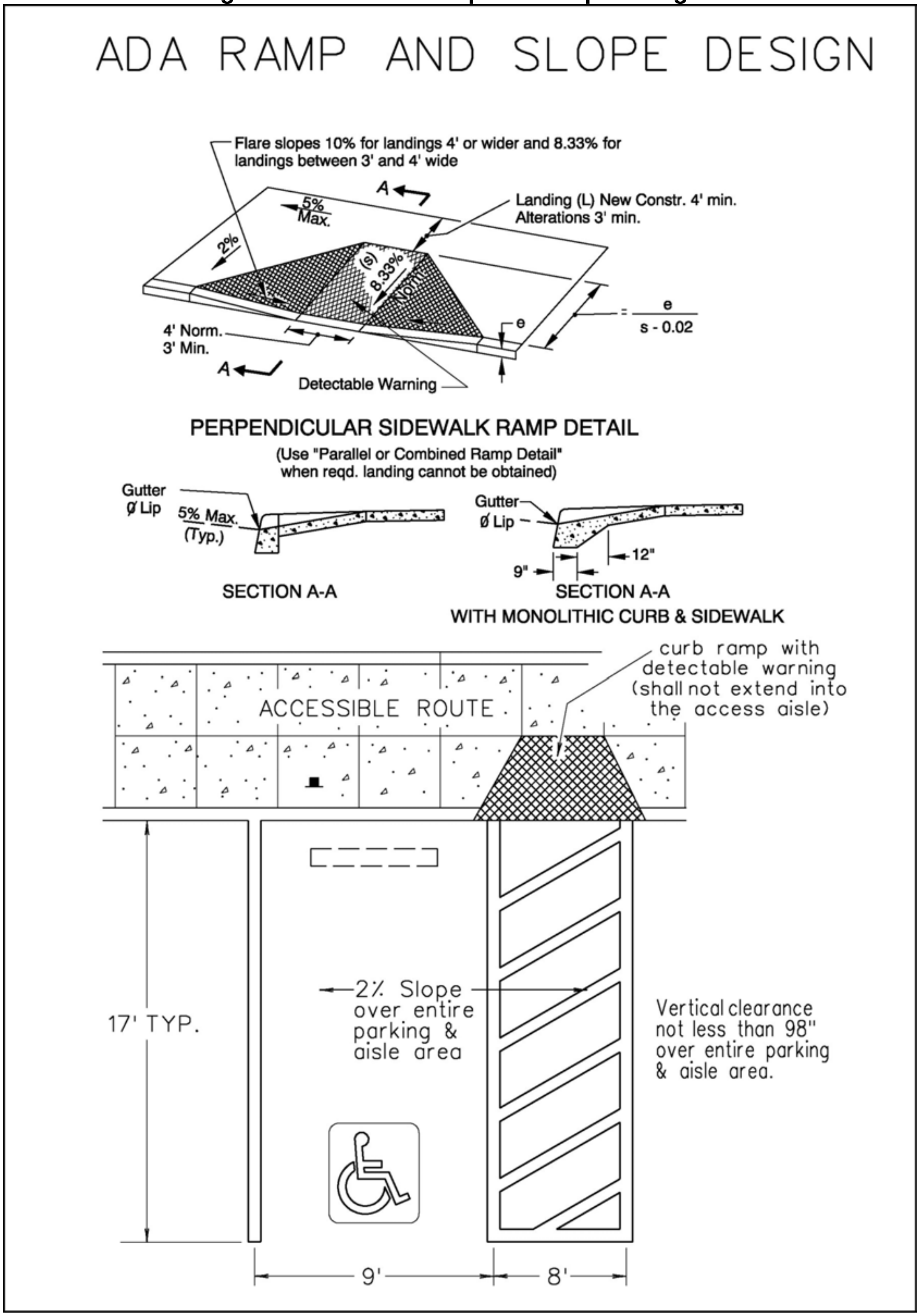
[18] Source: Oregon Transportation Commission, Standards For Accessible Parking Places, April 2008

Figure 17-7: Minimum Standard Double-Accessible Parking Space[19]



[19] Source: Oregon Transportation Commission, Standards For Accessible Parking Places, April 2008

Figure 17-8: ADA Ramp And Slope Design[20]



[20] Source: Oregon Transportation Commission, Standards For Accessible Parking Places, April 2008

Chapter 18: Traffic Impact Analysis

Understanding the demands placed on the community's transportation network by development is an important dimension of assessing the overall impacts of development. All development generates traffic, and it may generate enough traffic to create congestion and to compel the community to invest more capital into the transportation network, whether it is in the form of new roads, traffic signals, or turn lanes. Traffic congestion results in a number of problems, including economic costs due to delayed travel times, air pollution, and crashes. As one roadway becomes congested, drivers may use other roads that are not necessarily intended for through traffic. As a result, traffic impact analyses are becoming more common as a planning tool to forecast demands on the transportation network and to mitigate any negative impacts. Understanding traffic impacts becomes even more important as budgets for public facility and infrastructure improvements become increasingly strained.

What Is A Traffic Impact Analysis (TIA)?

A traffic impact analysis is a study which assesses the effects that a particular development will have on the transportation network in the community. These studies vary in their range of detail and complexity depending on the type, size, and location of the development. Traffic impact studies should accompany developments which have the potential to impact the transportation network. They are important in assisting public agencies in making land use decisions. These studies can be used to help evaluate whether the development is appropriate for a site and what type of transportation improvements may be necessary.

Traffic impact studies help communities to:

1. Forecast additional traffic associated with new development based on accepted practices.
2. Determine the improvements that are necessary to accommodate the new development.
3. Assist communities in land use decision making.
4. Assist in allocating scarce resources to areas which need improvements.
5. Identify potential problems with the proposed development which may influence the developer's decision to pursue it.
6. Allow the community to assess the impacts that a proposed development may have.
7. Help to ensure safe and reasonable traffic conditions on streets after the development is complete.
8. Reduce the negative impacts created by developments by helping to ensure that the transportation network can accommodate the development.
9. Provide direction to community decision makers and developers of expected impacts.
10. Protect the substantial community investment in the street system.

When Is A Traffic Impact Analysis Necessary?

A traffic impact study is not necessary for every development. Those developments that are unlikely to generate significant traffic generally do not need a traffic impact assessment. One approach that can be used to determine whether a traffic impact analysis should be required for a proposed development is the use of trip generation data. The trip generation of a proposed development is the number of inbound and outbound vehicle trips that are expected to be generated by the development during an average day or during peak hour traffic.

The Institute of Transportation Engineers (ITE) recommends that a Traffic Impact Analysis (TIA) be prepared whenever a development is expected to generate 100 or more new inbound or outbound trips during the peak hours or 750 trips in an average day, or when a development is likely to cause other significant traffic flow impact. Developments containing about 150 single-family homes, 220 multi-family units, 55,000 square feet of general office space, or a 15,500 square foot shopping center would be expected to generate this level of traffic and require a complete traffic impact analysis. A number of local agencies in the Portland and Southwest Washington area require a preliminary traffic assessment for any development generating up to 10 peak hour trips and a full traffic impact study for any development generating more that 100 peak hour trips.

The trip generation process provides an estimate of the number of trips that will be generated due to the new development. Trip generation rates are then applied to the various land uses within the development.

The ITE Trip Generation Manual is based on hundreds of trip generation surveys nationwide for a range of land use types. It is the most commonly accepted data source for trip generation rates[1]. Generally, examining those numbers based on the peak-hour conditions are used in traffic assessments. An analysis of peak-hour conditions results in a more accurate identification of site traffic impacts.

Table 18-1: Threshold Levels For Traffic Impact Analysis (ITE Recommendations)[2]

Land Use	100 Peak Hour Trips	750 Daily Trips
Single Family Homes	100 homes	100 homes
Apartments	245 units	120 units
Mobile Home Park	305 units	150 units
Shopping Center	15,500 sq. feet	2,700 sq. feet
Fast Food Restaurant	5,200 sq. feet	1,200 sq. feet
Hotel/Motel	250 rooms	90 rooms
General Office	55,000 sq. feet	45,000 sq. feet
Light Industrial	115,000 sq. feet or 8 acres	115,000 sq. feet or 11.5 acres
Manufacturing	250,000 sq. feet	195,000 sq. feet

Communities may wish to use their own thresholds. Thresholds may need to be lower for corridors which are already experiencing congestion.

[1] The Institute of Transportation Engineers publishes updated versions of *Trip Generation* approximately every five years based on data submitted by members, public agencies, and other sources. The 8th Edition of *Trip Generation* was released in December 2008.

[2] Source: Trip Generation Manual, 7th Edition, Institute of Transportation Engineers (ITE)

Is A Traffic Impact Analysis Necessary For Development That Does Not Meet The Threshold Requirements?

Even if the development does not generate the threshold level of trips, a traffic analysis may still be necessary under the following conditions:

1. High traffic volumes on surrounding roads that may affect movement to and from the proposed development.
2. Lack of existing left turn lanes on the adjacent roadway at the proposed access drive.
3. Inadequate sight distance at access points or nearby intersections.
4. The proximity of the proposed access points to other existing drives or intersections.
5. A development that includes a drive-thru operation.
6. Known safety issues need to be addressed.

General Process For A Traffic Impact Analysis

1. Prepare study scope
    - Jurisdiction requirements (ODOT, city, county)
2. Conduct existing conditions assessment
    - Traffic counts, site visit, safety review
3. Assess future conditions with and without site development
    - Review measures of effectiveness
4. Prepare and submit traffic impact study report
5. Jurisdiction review and comment period
6. Jurisdiction decision and approval process
    - Staff review/public hearings
    - Appeal period
7. Conditions of approval issued

Technical Steps For A Traffic Impact Analysis

There is a basic four-step process that engineers use in assessing transportation impacts. These sequential steps involve assessing how many trips will be generated, where they are beginning and ending, what mode of travel is used, and finally, how the trips are assigned to the transportation network. In industry parlance, engineers often refer to these four steps as trip generation, trip distribution, mode split, and trip assignment.

When generating a Traffic Impact Analysis, an engineer will usually start with trip generation. Trip generation is the process of estimating the number and type of trips a new development will generate on the transportation system.

How are 'Trips Generated' calculated?

Trips may be estimated from standard rates based on previous projects, standards from similar locations by the same developer, surveys of sites in comparable areas, or from ITE Trip Generation Manual, latest edition.

Trip generation according to the Trip Generation Manual

Jurisdictions are often asked to consider new development opportunities. As an example of a typical scenario, a large commercial development might be proposed for a site. One of the first questions an engineer will be asked is, "How much traffic will it generate?"

Because of the many variables affecting traffic generation, it is difficult to predict the precise amount of traffic that will be generated by a given project. However, transportation studies have quantified, in general terms, the volume of traffic generated for different types of projects. Most agencies rely on the standard industry reference *Trip Generation* to develop trip estimates.

Table 18-2 presents a tabulation of generation values which may be expected for both residential and commercial developments. Daily a.m. and p.m. peak hour forecasts are given for each type of project.

In addition, as was mentioned before, many communities require the developer to have a traffic impact study prepared, submitted, and approved for large residential, commercial, office, and industrial developments. The developer also may be required to pay all or at least a share of roadway improvement costs necessitated by the development.

Table 18-2: Summary Of Trip Generation Rates By Average Weekday Vehicle Trip Ends[3]

Land Use	**Average Daily Traffic (ADT)**	**A.M. Peak Hour**	**P.M. Peak Hour**
Residential			
Single Family Unit	9.57 per unit	0.75 per unit	1.01 per unit
Apartment	6.72 per unit	0.51 per unit	0.62 per unit
Mobile Home Park	4.99 per unit	0.44 per unit	0.59 per unit
Condominiums	5.86 per unit	0.44 per unit	0.52 per unit
Office			
General Office	11.01/1000 GFA	1.55/1000 GFA	1.49/1000 GFA
Medical Office	36.13/1000 GFA	2.48/1000 GFA	3.72/1000 GFA
Office Park	11.42/1000 GFA	1.74/1000 GFA	1.50/1000 GFA
Retail			
Supermarket	102.24/1000 GFA	3.25/1000 GFA	10.45/1000 GFA
Convenience Market	737.99/1000 GFA	67.03/1000 GFA	52.41/1000 GFA
Discount Market	96.82/1000 GFA	2.74/1000 GFA	8.90/1000 GFA
Home Improvement	29.80/1000 GFA	1/20/1000 GFA	2.45/1000 GFA
Gasoline/Service Station	168.56/1000 GFA	12.07/1000 GFA	13.86/1000 GFA
Restaurant			
Fast Food with Drive-Thru Window	496.12/1000 GFA	53.11/1000 GFA	34.63/1000 GFA
High Turnover (Sit Down) Restaurant	127.15/1000 GFA	11.52/1000 GFA	10.92/1000 GFA

Notes:
- A trip end is one either entering or exiting the development.
- GFA = Gross Floor Area of the building.
- 1000 $feet^2$ = $92.9m^2$

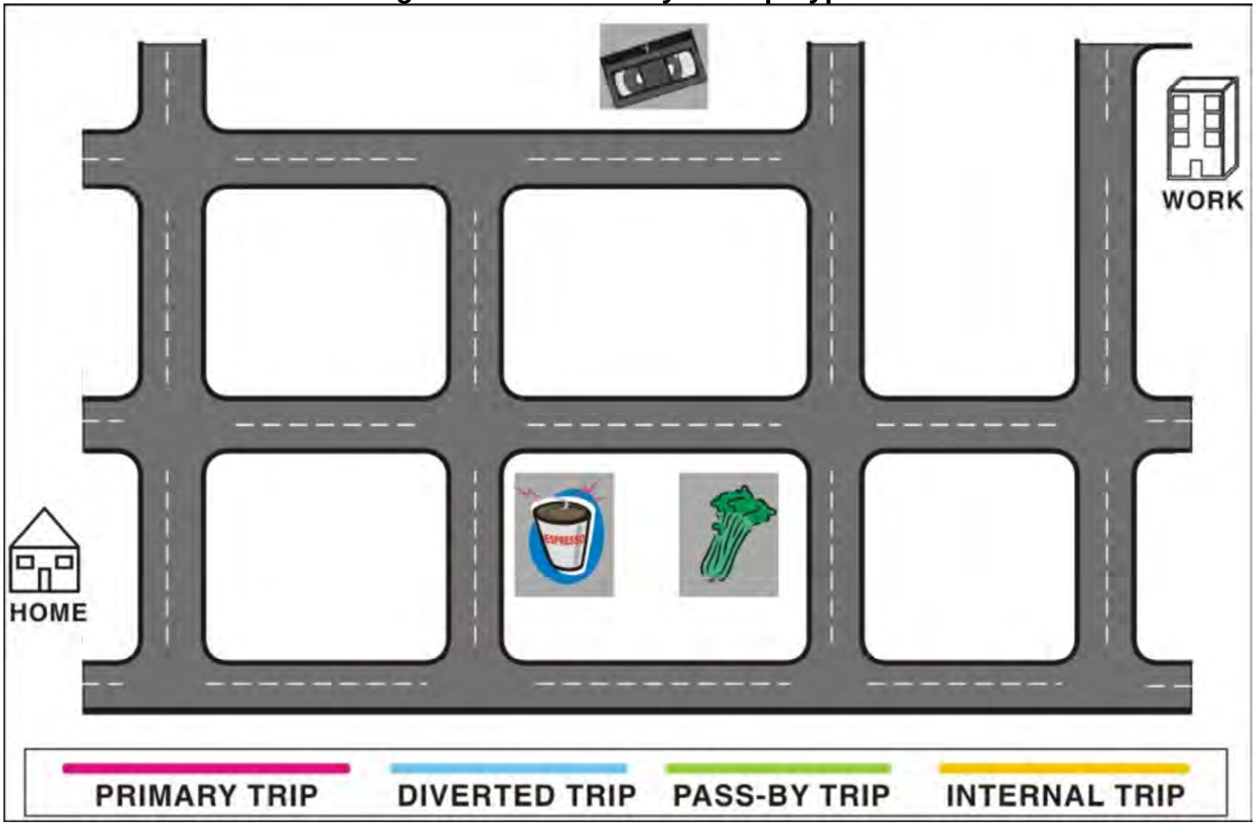
The second part of trip generation is to determine the kind of trips being made to and from the new development. According to ITE, there are four different kinds of trips:

1. A primary trip, which is made for the specific purpose of visiting the primary destination.
2. A diverted trip occurs when the trip is on the transportation system and travels a short distance out of direction to the site.
3. A pass-by trip enters the site while on another trip on an adjacent transportation system.
4. An internal trip occurs between two or more land uses without using the roadway outside the site.

These four types of trips are further explained with Figure 18-1.

[3] Source: Trip Generation Manual, 7th Edition, Institute Of Transportation Engineers (ITE)

Figure 18-1: Summary Of Trip Types[4]



After the types of trips are determined, the engineer assesses how the trips will be distributed on the transportation system, called trip distribution. This step determines origins of trips to the development, typically considering factors such as existing travel patterns, local travel demand model data, market studies, census data, and/or engineering experience.

Next, the engineer determines the modes of transportation available on the system, and the number of trips serviced by each mode. This takes into consideration modes of transportation including, but not limited to, automobile, rail, bus, bike, and walking.

Finally, the engineer places the new trips generated by the development on transportation facilities. This takes into account the trip generation, trip distribution and mode split. This final step helps determine the impact on the transportation system.

What is the Impact?

For new development traffic impact studies typically address the following questions:

1. How does the transportation system function today?
2. How will the transportation system operate in the future?
3. How will the transportation system operate with the proposed project?
4. Is mitigation necessary?

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[4] Source: Figure courtesy of Kittelson and Associates, Inc.

How Is The Impact Assessed?

Traffic impact studies typically measure pedestrian, bicycle, motorist, and other users' quality of service such as speed, travel time, delay, conflicts, and safety. The system performance is then assessed by comparing these quality of service measures with adopted standards.

What Is Mitigation?

Mitigation is the process of improving the operational or safety performance of a transportation system to alleviate capacity deficiencies and meet jurisdictional standards. Mitigation may include improvements such as making changes to intersections, roadways, and pedestrian facilities.

What types of mitigation treatments are used?

A. Geometric Treatments

- Adding additional lanes or re-designing the existing lanes
- Increasing/decreasing lane widths
- Vertical and/or horizontal realignment
- Additional acceleration and deceleration lengths
- Channelization of specific movements
- Median and access management treatments

B. Traffic Control Treatments

- Signalize a stop-controlled intersection
- Convert a stop-controlled signalized intersection to a roundabout
- Improve traffic control devices
- Improve signal timing and phasing

In some situations, capacity-based mitigations may not be deemed appropriate. For example, in downtown areas, there is often a desire to maintain a walkable community feeling and simply widening roadways to create more vehicular capacity is not considered acceptable. Further, right-of-way implications or cost to make improvements may exceed the benefit achieved.

As a result, it is important for traffic studies and agency standards to consider providing alternative mitigation options. For example, some agencies allow a waiver to operating standards on some routes if pedestrian/bicycle facilities and transit services are in place (or can be provided by a development) in lieu of adding more lanes. Another tool sometimes considered is requiring development and implementation of transportation demand management (TDM) plans that encourage carpooling, transit pass subsidies, provision of transit amenities, and/or other means that reduce single-occupant vehicle trips.

Measures Of Effectiveness

Most agencies with traffic impact study requirements have defined minimum operation standards for intersections based on measure of effectiveness such as level of service and/or volume-to-capacity ratios.

What Is Level-Of-Service?

Level-of-service is a qualitative measure describing operational condition within a traffic stream that is based on service measures that include the following:

1. Speed
2. Travel time
3. Freedom to maneuver
4. Traffic interruptions
5. Comfort
6. Convenience

What Are The Level-Of-Service Criteria For Signalized Intersections?

The level-of-service criteria for signalized intersections defined by the *2000 Highway Capacity Manual* are given in terms of average control delay per vehicle during an analysis period of 15 minutes. The criteria for the six levels-of-service are described below.

Table 18-3: Level of Service Criteria For Signalized Intersections[5]

Level-of Service	Average Control Delay Per Vehicle (sec)
A	$\leqslant$ 10
B	> 10 and $\leqslant$ 20
C	> 20 and $\leqslant$ 35
D	> 35 and $\leqslant$ 55
E	> 55 and $\leqslant$ 80
F	> 80

What Is The Capacity Of Two-Lane Highways?

- 1,700 passenger cars per hour for each direction of travel
- 3,200 passenger cars per hour for both directions of travel

What Are The Level-Of-Service Criteria For Two-Lane Highways?

The level-of-service criteria for two lane highways that function as primary arterials or daily commuter routes are given in terms of the average percentage of time that vehicles are traveling behind slower vehicles and average travel speed. The criteria for the six levels-of-service are described below.

[5] Source: Highway Capacity Manual, HCM 2000, Transportation Research Board, Washington, D.C., 2000

Table 18-4: Threshold Levels For Traffic Impact Analysis[6]

Level-of-Service	Percent Time-Spent-Following	Average Travel Speed (Miles/Hour)
A	⩽ 35	> 55
B	> 35 and ⩽ 50	> 50 and ⩽ 55
C	> 50 and ⩽ 65	> 45 and ⩽ 50
D	> 65 and ⩽ 80	> 35 and ⩽ 50
E	> 80	⩽ 40

Volume-To-Capacity Ratio

In addition to delay, many jurisdictions assess the volume-to-capacity (v/c) ratio of intersections. The *Highway Capacity Manual 2000* defines capacity as "the maximum number of vehicles that can pass a certain point during a specified period under prevailing roadway, traffic, and control conditions." V/C operating standards are typically evaluated for signalized intersections as a function of the overall critical v/c ratio of the intersection, while individual turn movement v/c ratios are considered at unsignalized intersections.

The Oregon Department of Transportation (ODOT) now evaluates intersection performance exclusively on the basis of v/c ratio; level of service is not considered by ODOT. ODOT has defined v/c ratios for different operating conditions and facility types. Generally speaking, ODOT's v/c standards are more stringent for high-speed, high importance facilities and are more stringent in rural areas as compared to metropolitan areas (where drivers tend to tolerate more congestion).

How Many Access Drives Are Needed To Accommodate This Development?

Access requirements will depend upon the volume of traffic on the main road, the number of trips generated by the development, existing roadway conditions, property dimensions, etc. One rule of thumb, which can be used as a guideline, is that the volume of traffic in the predominant direction of travel along the adjacent highway (measured in vehicles per lane per hour) plus that existing from the development (vehicles per lane per hour) should not exceed 1,200. When this volume is exceeded, additional lanes (or additional access points) should be considered. As a practical point, it is generally a good policy to provide two access driveways if the size of the commercial development exceeds 25,000 square feet (708 m^2).

The following are other guidelines which should be considered:

1. Access driveways should generally be designed with two exiting lanes when the left turn volume exceeds 100 vehicles per hour.
2. A left-turn storage lane should be provided along the adjacent highway when left turning movements into the site exceed 100 vehicles per hour at any given location.
3. Where at all possible, align the proposed access drives directly opposite existing driveways or streets so that offset intersections can be avoided.

[6] Source: Highway Capacity Manual, HCM 2000, Transportation Research Board, Washington, D.C., 2000

How Closely Can Driveways Be Spaced And How Should They Be Designed?

For information on driveway design, see Chapter 16. Secondary driveways off the access driveways should be a minimum of 100 feet (30.0 m) from the public roadway to prevent interference with the operation of the access driveway at the public roadway.

Will This Development Require Additional Traffic Lanes Along The Adjacent Street?

The critical lane analysis is useful in determining if additional traffic lanes will be needed. Count peak hour volumes on the adjacent street. If the volume of traffic in the heaviest direction of travel (expressed in vehicles per lane per hour) plus that exiting from the access road to the development (vehicles per lane per hour) exceeds 1200, additional lanes or an alternative mitigation treatment will likely be required.

Example:

A. Main Street

- Has two traffic lanes (one in each direction)
- Peak hour traffic volume

B. Driveway to the Proposed Development

- Has two traffic lanes (one in each direction)
- Peak hour exiting traffic volume - 500

C. Critical Lane Analysis

- Main Street 800 Vehicles per lane per hour
- Driveway 500 Vehicles per lane per hour
- Total Volume 1,300 Vehicles per lane per hour

The total volume exceeds 1,200 vehicles per hour. Therefore, additional lanes will likely be required on Main Street or additional exiting lanes (or driveways) should be considered to serve the proposed development.

For the most up to date information about the process of developing a Traffic Impact Analysis (TIA), please refer to the publication titled, "Community Guide To Development Analysis," Edwards, Mary, University of Wisconsin, Madison, Wisconsin, 2000, , also available online at: http://www.lic.wisc.edu/shapingdane/facilitation/all_resources/impacts/CommDev.pdf

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Chapter 19: Traffic Calming

Local streets are designed to serve local residential traffic and provide access to adjacent land uses. Generally, traffic volumes and speeds along local streets are low and the users are those from nearby residences or buildings. However, in some neighborhoods, especially those with grid street patterns, traffic using the streets is not local traffic, but is instead using the neighborhood streets as a short cut between larger arterials. When nearby arterial streets experience congestion, drivers may use local residential streets to cut through the area, often at high speeds. The cut through traffic changes the intent of the local street by adding traffic volume and increasing the speeds, as well as adding noise and pollution. Traffic calming can be used to mitigate the problem described above.

What Is Traffic Calming?[1]

Definitions of traffic calming vary, but they all share the goal of reducing vehicle speeds, improving safety, and enhancing quality of life. Some traffic calming measures focus on what are known as the three Es: Education, Enforcement, and Engineering. Other forms of traffic calming include all kinds of engineering measures, while others focus only on engineering measures that compel drivers to slow down, excluding those that use barriers to divert traffic.

Based on the Institute of Transportation Engineers (ITE), "Traffic Calming: State of Practice" report, "Traffic calming involves changes in street alignment, installation of barriers, and other physical measures to reduce traffic speeds and/or cut-through volumes, in the interest of street safety, livability, and other public purposes."[2]

Traffic calming measures are distinctly different from other traffic measures such as road modification, traffic control devices, and streetscaping. Rather than being a regulatory measure that is enforced, such as a STOP sign or a speed limit, traffic calming measures are "self-enforcing," meaning that the driver makes a conscious decision to change his or her behavior.

What Are Traffic Calming Goals? [3]

While the need for traffic calming along a roadway may be apparent, many factors should be considered before implementing a particular calming measure. Along with vehicular traffic, bicycles, pedestrians, and transit are other modes of transportation that can be greatly impacted by traffic calming. The type of calming measure should be chosen not only based on the intended purpose of the measure, but also the type of environment and roadway location. In order to implement an appropriate and effective device, which contributes to the users and aesthetics of the area, public input and concerns should be considered and addressed. If all necessary factors have been considered and an appropriate traffic calming measure has been

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[1] Source: http://www.trafficcalming.org
[2] Source: Traffic Calming: State of the Practice, ITE/FHWA, August 1999
[3] Source: http://www.trafficcalming.org

selected, then the overall goals of traffic calming can be achieved. Traffic calming goals, as described by the Institute of Transportation Engineers (ITE), are to:

- Increase the quality of life;
- Incorporate the preferences and requirements of the people using the along streets or at intersections;
- Create safe and attractive streets;
- Help to reduce the negative effects of motor vehicles on the environment; and
- Promote pedestrian, cycle and transit use.

What Are The Objectives Of Traffic Calming? [4]

The most apparent purpose of traffic calming is to reduce speed and volume to an acceptable level appropriate for the type of facility and environment. The desired outcome of the traffic calming device can be used to determine the type of measure implemented in a particular area. While some devices are intended to slow traffic, others may be intended to reduce traffic volumes along a specific roadway. Although each calming measure may serve particular tasks, the overall objectives traffic calming are to:

- Encourage citizen involvement in the traffic calming process by incorporating the preferences and requirements of the citizens;
- Reduce vehicular speeds;
- Promote safe and pleasant conditions for motorists, bicyclists, pedestrians, and residents;
- Improve the environment and livability of neighborhood streets;
- Improve real and perceived safety for nonmotorized users of the streets;
- Discourage use of residential streets by non-resident cut through vehicular traffic; and
- Reduce the need for police enforcement.

Traffic calming is a process that involves implementing or changing the physical features of the roadway in order to reduce the negative effects that motor vehicles can have in a neighborhood or any urban environment. When the original intent of the roadway is being altered by cut through traffic or high speeds, traffic calming may be a necessary option for improving the overall quality of life throughout that area.

Traffic Calming Measures

Due to the wide range of issues that arise when mitigating a traffic problem, there have been a variety of traffic calming treatments developed, each with advantages and disadvantages, and each with a primary objective. The following section describes traffic calming measures that are available and outlines the purposes, advantages, and disadvantages of each.

Speed Control Measures

Speed control measures are of three types:

- vertical measures—use forces of vertical acceleration to discourage speeding. Examples include speed humps and speed tables
- horizontal measures—use forces of lateral acceleration to discourage speeding. Examples include traffic circles, roundabouts, chicanes, and lateral shifts.

[4] Source: http://www.trafficcalming.org

- narrowings—use a psycho-perceptive sense of enclosure to discourage speeding. Examples include curb extensions, center island narrowings, and chokers.

Because physical forces are more compelling, vertical and horizontal devices tend to be more effective in reducing speeds.

Speed Humps (Speed Bumps)

Speed humps are rounded raised areas of pavement placed across the roadway. They are typically 14 feet (4.2 m) in length and 3 inches (75 mm) high and are often placed in a series spaced 300 to 600 feet (90 to 180 m) apart. The profile of a speed hump is generally circular, parabolic, or sinusoidal and tapered on each end towards the curb to allow unimpeded drainage. Speed humps are usually placed mid-block and are not appropriate near intersections or on roadways with a grade greater than 8 percent. This type of calming measure is designed for areas where slow speeds are desired, such as a residential neighborhood street, and is not appropriate for major roadways or primary emergency response routes. Figure 19-1, Figure 19-2, and Figure 19-3 show typical speed humps (speed bumps).

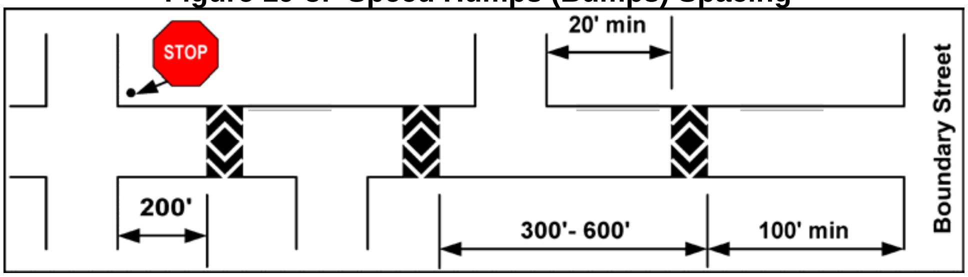
Figure 19-1: Typical Speed Humps

Beaverton, Oregon Portland, Oregon

Figure 19-2: Typical Rubber Speed Humps

Kaiser Medical Center, Clackamas, Oregon

Figure 19-3: Speed Humps (Bumps) Spacing[5]



Advantages

Speed humps have proven to reduce the average travel speed of vehicles by 20 to 25 percent and are relatively inexpensive to install. Although bicyclists often prefer that the speed humps do not extend into the bike lane, this traffic calming measure has shown to be easily traversed by all modes of transportation. Traffic volumes are often reduced depending on alternative nearby routes and the number of collisions has also been shown to decrease.

Disadvantages

Although speed humps are inexpensive, due to their complex shape these traffic calming devices can be difficult to construct. The shape and placement of speed humps can create an uncomfortable ride for drivers and passengers, and usually require additional pavement marking or signage to warn drivers of the obstacle. The braking and acceleration necessary to traverse the speed humps can increase noise and air pollution. These devices cause delays in emergency vehicle response and travel time.

Design Guidelines For Speed Humps (Bumps)[6]

The following are selected general standards and guidelines developed by the City of Portland Bureau of Traffic Management that apply to speed humps (bump) applications.

A. Prevailing Speed – 14-foot (4.2 m) speed humps should not be placed on streets with 85th percentile speeds exceeding 40 mph (65 k/ph).
B. Street Classification – 14-foot (4.2 m) speed humps shall only be placed on local service streets.
C. Street Grade – All speed humps may be installed on street sections with a longitudinal grade of up to 8%.
D. Proximity To Curve – Before placing Speed Humps on a curved roadway, an engineering evaluation should be conducted to determine that the Speed Hump installation, in conjunction with the posted speed of the curve, will accommodate safe vehicle passage. Speed humps shall not be placed on horizontal curves with radii of less than 100 feet (30 m). Special attention shall be paid to the placement of speed humps on crest vertical curves.
E. Street Condition – The Maintenance Department should inspect all streets prior to any proposed speed hump construction. The Maintenance Bureau will determine if the existing street

[5] Source: Traffic Manual, City of Portland
[6] Source: Traffic Manual, City of Portland

pavement material is adequate to support speed humps or if any pavement maintenance is required.

F. Unimproved Streets – Speed humps may be installed on paved streets without curbs that are maintained by the city unless otherwise prohibited by these guidelines. After construction on streets without curbs the engineer may consider the installation of roadside delineators to deter a confirmed problem with driver circumnavigation of a speed hump.

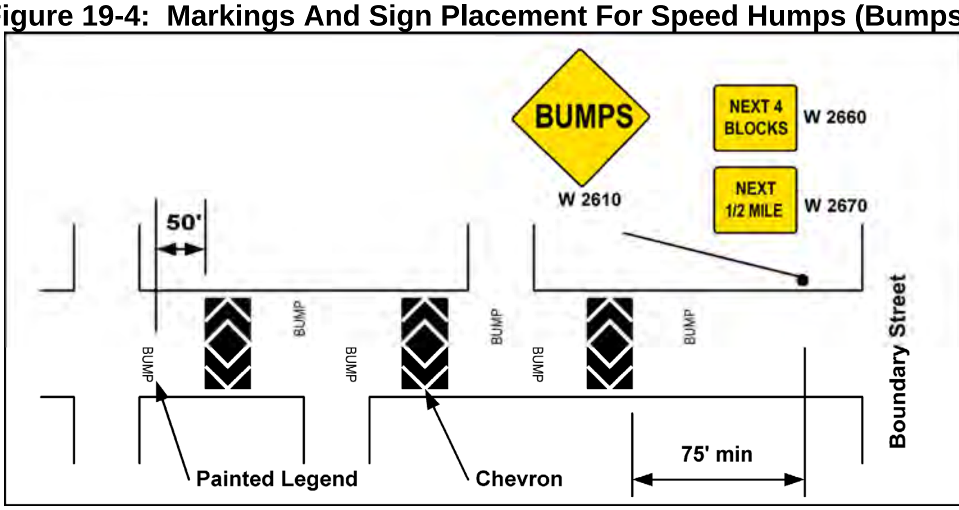
G. Travel Lanes – Speed humps should not be placed on streets with more than two automobile through travel lanes.

H. Spacing – Speed humps are typically spaced at least 300 feet (90 m) apart. Speed humps spaced more than 600 feet (180 m) apart have significant less affect on driver speeds. The standard spacing for speed humps is 400 to 500 feet (120 to 150 m) apart (See Figure 19-3) with closer spacing chosen for more severe speeding problems. 14-foot (4.2 m) speed humps at standard spacing will typically reduce the average 85th percentile vehicle speed along the length of the project street to 25 mph (40 km/h).

I. Shape – The size or length of a speed hump is measured along the centerline of the street. Both 14-foot (4.2 m) speed humps and 22-foot (6.6 m) speed tables are constructed to a maximum height of 3 inches (75 mm) above the existing street surface.

J. Pavement Markings – Each speed hump shall be marked with white chevron markings (See Figure 19-4). Chevron markings shall be centered on the painted street centerline when such a centerline exists and shall not be placed where a marked bike lane exists. For each speed hump installed, a BUMP legend shall be painted in each approaching travel lane 50 feet (15 m) upstream of the speed hump. Existing double yellow centerlines and bike lanes shall be installed on top of any speed hump that covers those markings.

Figure 19-4: Markings And Sign Placement For Speed Humps (Bumps)[7]



K. Driveways - Speed humps shall not be constructed so as to block driveways. Speed hump locations shall be chosen to maintain driveway access, with the minimum clearance from a driveway throat being 5 feet (1.5 m).

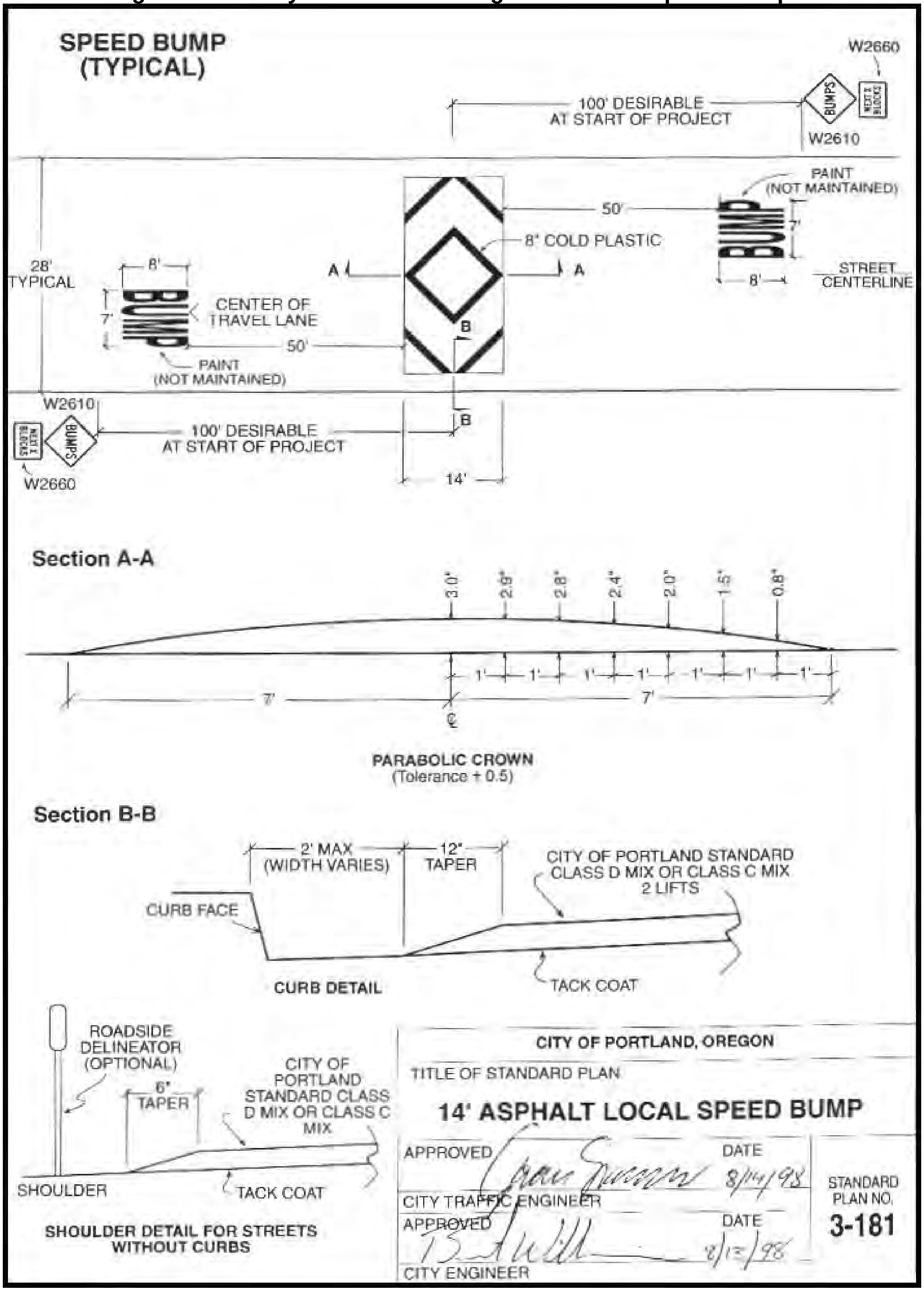
L. Parking Removal – Parking removal is not required at standard 14-foot (4.2 m) speed humps.

[7] Source: Traffic Manual, City of Portland

M. Utilities – Speed humps shall not be placed closer than 20 feet (6 m) adjacent to underground utility access points. Speed humps should be located to avoid placement over water, sewer and natural gas service connections.

Figure 19-5 shows the City of Portland design of 14-foot (4.2 m) speed humps (bumps).

Figure 19-5: City Of Portland Design Of 14-Foot Speed Humps[8]



[8] Source: City of Portland, Bureau of Traffic Management, TRAFFIC MANUAL, 1994

Speed Tables (Trapezoidal Humps, Speed Platforms)

Speed tables are long raised speed humps with a flat top and ramps on the ends (See Figure 19-6). The flat section of the speed table is more gently sloped than a speed hump and is sometimes long enough for the entire wheel base of a vehicle. Often these calming measures are constructed with brick or textured material on the flat section. The textured material not only adds to the aesthetics of the calming measure, but also draws the attention of the driver, thus enhancing safety and speed reduction. Typically, speed tables are installed along local and collector streets or main roads through small communities. The purpose of the speed table is to slow vehicle speeds and allow a smoother ride for larger vehicles, while reducing the likelihood of diversion on higher volume street projects. Speed tables often work well with textured crosswalks and curb extensions and can include a cross walk. The most common type of speed table is 3 to 4 inches (75 to 100 mm) high and 22 feet (6.6 m) long in the direction of travel, with 6-foot (1.8 m) ramps at the ends and a 10-foot (3 m) field on top.

Figure 19-6: Speed Table Examples

Speed Table With Center Island, Beaverton, Oregon

Speed Table With Curb Extension, Beaverton, Oregon

Speed Table With Crosswalk, Beaverton, Oregon

Speed Cushion, Beaverton, Oregon

Advantages

Speed tables are effective in reducing the vehicle speeds and are smoother on large vehicles such as buses or fire trucks. Depending on alternative nearby routes, traffic volumes are often reduced and the number of collisions has also been shown to decrease. The design of the raised crosswalk allows for more pedestrian visibility and there is a better chance that a driver may yield to a pedestrian in a raised crosswalk. Speed tables are usually preferred by emergency vehicles due to less of a delay during emergency response.

Disadvantages

Due to the gentler slope of the design, speed tables are not as effective in speed reduction as speed humps. The textured material that is typically used can add to the aesthetics, but can also add to the expense of the calming device. The braking and acceleration necessary to traverse the speed humps can increase noise and air pollution.

How To Design 22-Foot (6.6 M) Speed Bump

Shape

The 22-foot (6.6 m) long vertical cross- section of the 22-foot (6.6 m) speed bump, measured in the direction of traffic flow, shall consist of a 10-foot (3 m) horizontal platform, 3 inches (75 mm) in height which transitions at both ends to existing pavement level by way of 6-foot (1.8 m) parabolic curves, as detailed in Figure 19-7.

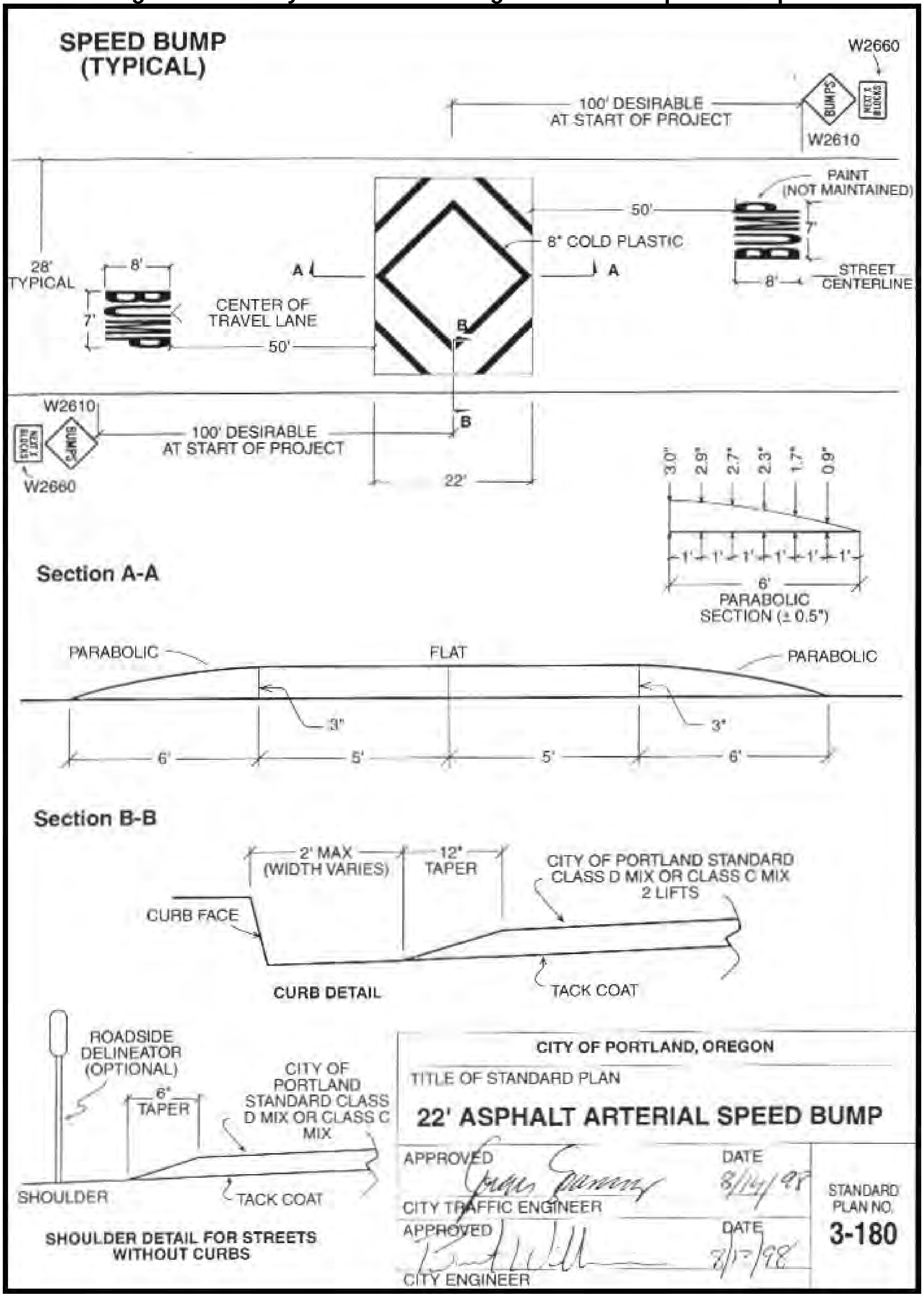
Signing and Pavement Markings

22-foot (6.6 m) speed bumps shall be accompanied by appropriate signing and pavement markings as detailed in Figure 19-7.

Placement of 22-Foot (6.6 m) Speed Bump

Where possible, 22-foot (6.6 m) speed bumps should be located at least 100 feet (30 m) from the closest intersection curb or pavement edge line.

Figure 19-7: City Of Portland Design Of 22-Foot Speed Humps[9]



[9] Source: City of Portland, Bureau of Traffic Management, TRAFFIC MANUAL, 1994

City Of Portland Speed Hump (Bump) Purchase Projects

The following summary describes the City of Portland approval process for speed hump (bump) purchase projects.

1. Neighborhood Request – City receives written request from neighborhood resident(s) and determines eligibility for a proposed project.
2. Eligibility Verification – City determines eligibility for proposed project based on the following criteria:
    a. Emergency Response Route Designation – street will not be considered for speed reduction measures (speed bumps or traffic circles) if it is designated a Major Emergency Response Route.
    b. Street Classification – speed bumps are allowed on two street types, Local Service and Neighborhood Collector, with at least 75 percent residential land use.
    c. Traffic Speeds and Volumes – this criteria is based on street classification: Speed: 85th percentile speed is at least 5 mph above posted limit (85th percentile speed of 30 mph based on 25 mph limit (40 km/h)).
3. Preliminary Project Area – City defines preliminary Project Area for proposed project street, and informs neighborhood resident(s) of eligibility status. City commits to best effort to complete this task within 30 days of receipt of initial neighborhood request.
4. Neighborhood Interest Petition – City receives neighborhood interest petition from residents within Project Area demonstrating reasonable support to evaluate their street for a Speed Bump Project. This petition must be signed by at least 33 percent of the Project Area properties. City ends project if the neighborhood interest petition does not meet the minimum 33 percent support requirement.
5. Draft Project Summary – City works with residents in Project Area neighborhood to develop a Draft Project Summary that defines:
    a. Project Area
    b. Potentially Impacted Area
    c. Project Cost
    d. Project Design
6. Public Meeting Announcement – City announces public meeting for review of Draft Project Summary.
7. Public Meeting – City facilitates public meeting to discuss proposed project where residents from the Project Area and the Potentially Impacted Area can provide feedback/input.
8. Project Support Petition – City provides a project support petition at the public meeting to be circulated by neighborhood residents that must be signed by at least 67 percent of the Project Area properties.
9. Support Petition Deadline – Project support petition must be completed and returned to City no more than 60 days from date of public meeting. City verifies petition completeness and accuracy.
10. Neighborhood Association Presentation – Following successful completion of the Project Support Petition step, City staff and area project sponsor(s) present project summary and

petition results at the next meeting(s) of all Neighborhood Associations covering Potentially Impacted Area.

11. Neighborhood Association Endorsement Letter – All Neighborhood Associations covering Potentially Impacted Area have up to 60 days to consider project and vote on endorsement.
12. Administrative Approval – City administratively approves proposed project based on completion of Steps 1-11.
13. City Council – Proposed project proceeds to City Council as a Resolution for consideration and final approval.
14. Project Funding – City received/collects funding for approved project through:
    a. Residential Purchase Program (via voluntary financial contributions)
    b. Urban Renewal Areas
    c. Grants
15. Project Construction – City constructs approved speed bump project after full funding has been received.

Table 19-1: Speed Bump Purchase Program Scoring Criteria Review[10]

Scoring Criteria Review

Criteria	Point Range	Basis for Points	Discussion
Traffic Speed	0-50 points	5 points for each mile per hour that the highest 85th percentile speed exceeds the lowest posted speed limit by 5 mph.	Uses posted speed as gauge of violation. Accounts for newly created permanent 20-mph school zones
High Speeders	0-15 points	50-99 speeders: 5 points 100-199 speeders: 10 points 200 or more: 15 points	Speed bumps have greatest effect on most egregious speeders.
Traffic Volume	0-30 points	500 or less vpd: 0 points 500-1500 vpd: (Volume-500)/50 1500-2500 vpd: 30 points	A large number of lower speed speeders is commensurate with a few egregious speeders
City Walkway or Pedestrian District	5 points	If designated in the Transportation System Plan 5 points are given.	Adds value based on multi-modal designation of street, acknowledging more vulnerable users. Supports City transportation goals related to concentrating pedestrian activity.
City Bikeway	5 points	If designated in the Transportation System Plan 5 points are given.	Adds value based on multi-modal designation of street, acknowledging more vulnerable users. Supports City transportation goals related to concentrating bicycle activity.
Sidewalks	0, 10 or 20 points	100% sidewalks on both sides = 0 points 100% sidewalks on one side = 10 points Lack of 100% one side = 20 points	Considers the importance a lack of sidewalks plays in street safety for pedestrians.
Maximum	125 points		

- For Local Service Streets only that are not designated as Major Emergency Response Routes and serve 2500 or fewer vehicles per day.
- It is proposed that the City's 60% subsidy initially be offered to project segments that achieve 30 total points. This would place approximately 150 projects on the subsidy list.

[10] Source: City of Portland, Bureau of Traffic Management

Raised Intersection

(Raised Junctions, Intersection Humps, or Plateaus)

Raised intersections are flat raised areas covering an entire intersection, with ramps on all approaches and often with brick or other textured materials on the flat section (See Figure 19-8). The area is usually raised to the level of the sidewalk or slightly below to provide a lip that is detected by those visually impaired. The raised level of the intersection allows the crosswalks and pedestrians to be more easily seen by motor vehicles. Raised intersections are effective in areas with high pedestrian volumes and areas where loss of parking due to traffic calming devices would be unacceptable.

Figure 19-8: Raised Intersection

City of Bend, Oregon   City of Bend, Oregon

Advantages

Raised intersections have proven to be effective in reducing the speeds of through vehicles at intersections, as well as in reducing midblock speeds by approximately 10 percent. The design of this calming measure improves safety for both motorists and pedestrians. The raised area extends over the entire intersection, thus calming two roads at a time. When textured material or brick is used this type of traffic calming measure can add to the aesthetic appearance of the environment.

Disadvantages

Due to the large raised area, this type of traffic calming measure is expensive and requires more extensive construction with careful consideration for drainage. Raised intersections are less effective in speed reduction than speed tables or humps. However, the speeds of emergency vehicles are decreased by approximately 15 miles per hour (22 km/h).

Street Closures

(Full Closures: Cul-De-Sacs, Dead Ends; Half Closures: Partial Closures, Entrance Barriers)

Full street closures are barriers placed across a street to completely close the street to through traffic (See Figure 19-9). Half closures are barriers that block travel in one direction for a short distance on otherwise two-way streets (See Figure 19-10 and Figure 19-11). In both cases the pedestrian and bicycle connections are maintained. These types of calming measures are used when faced with extreme traffic volume problems and several other measures have proven to be unsuccessful.

Advantages

Street closures are able to maintain access for pedestrian and bicycles, while being effective in reducing traffic volumes. This type of measure can be successful in minimizing cut through traffic by making travel through neighborhoods more circuitous, in which through movements are possible but less attractive than alternative routes. Street closures have also been used as a crime prevention tool.

Disadvantages

Certain legal procedures are required for street closures on public streets in most jurisdictions. The circuitous route caused by the closure can be inefficient for residential and local traffic, as well as emergency vehicles. This type of calming measure can significantly impact the street network connectivity and parallel local streets that may receive the diverted traffic. Depending on the location of the street closure, business access can also be affected.

Figure 19-9: Full Closure (Cul-De-Sac)

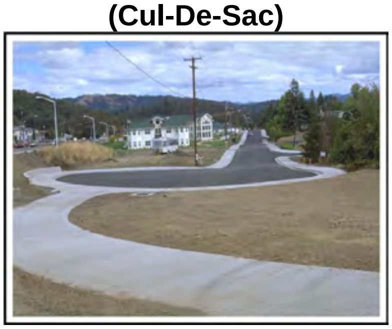


Figure 19-10: Partial Closure

Lake Oswego, Oregon

Figure 19-11: Partial Closure

Portland, Oregon

Neighborhood Traffic Circle

A Traffic Circle is an intersection treatment that uses roadway geometry and traffic signing to control vehicle interaction and improve intersection safety (See Figure 19-12). Traffic Circles slow auto traffic by requiring drivers to alter their course to drive around the Traffic Circle. Traffic Circles reduce right angle vehicle collisions by eliminating crossing movements (Figure 19-13). Trees placed in Traffic Circles break uninterrupted views of long straight street sections and help to focus driver attention on local surroundings. Traffic Circles are distinguished from Roundabouts in that Traffic Circles are small, do not have raised splitter islands, and usually have STOP control on one of the intersecting streets.

Figure 19-12: Traffic Circle Examples

Gresham, Oregon

Lincoln City, Oregon

Lake Oswego, Oregon

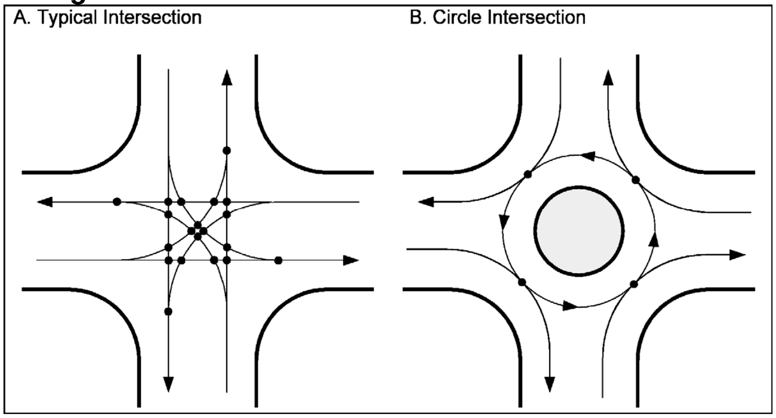
Advantages

Traffic circles have shown to effectively reduce the speeds of vehicles traveling through the intersection, as well as reduce midblock speeds by approximately 10 percent. The reduction in speeds improves pedestrian safety. The center island eliminates intersection conflict points, thus decreasing the number and severity of collisions. Landscaping on the center island can add aesthetic value to the neighborhood if designed correctly.

Disadvantages

Traffic circles can be difficult for large trucks or buses to maneuver around. Large vehicles may need to turn left in front of the circle, which could be unsafe at higher volumes and may require legislation to legally permit this movement. The narrow travel lanes, characteristic of traffic circles, can result in bicycle/vehicle conflicts within the intersection. Traffic circles may also require elimination of some on-street parking.

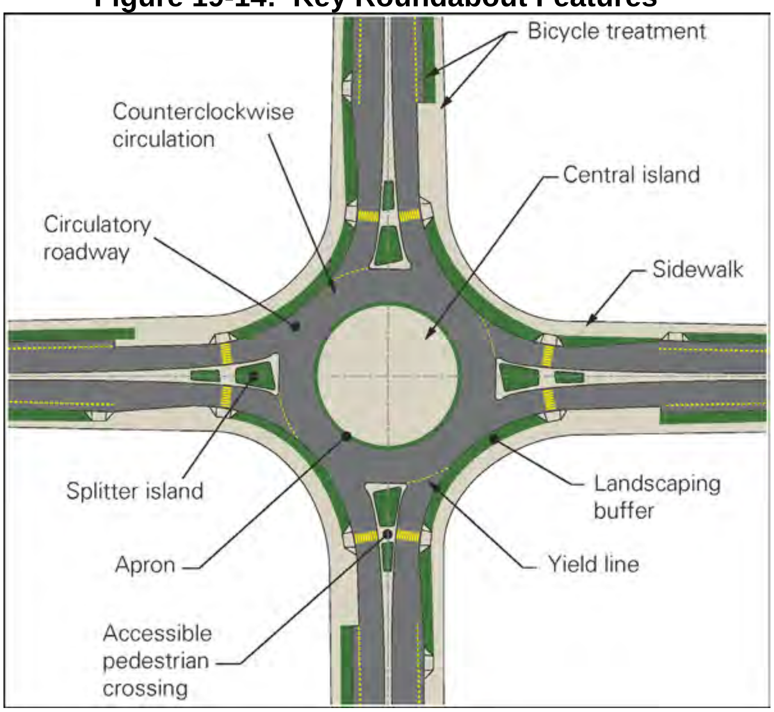
Figure 19-13: Traffic Circle Auto Conflict Points[11]



Roundabouts

Roundabouts are circular intersections with design and traffic control features such as yield control of all entering traffic, channelized approaches, and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less than 30 mph (45 km/h) (See Figure 19-14 and Figure 19-15). Roundabouts can have multiple lane entrances and traffic circulating the roundabout always travels in a counterclockwise direction. Roundabouts and traffic circles are often mistaken for being the same type of traffic calming device. Therefore, the differences between these types of treatments, as described in the FHWA document on Roundabouts: An Informational Guide, are described below:

Figure 19-14: Key Roundabout Features[12]



[11] Source: Traffic Manual, City of Portland
[12] Source: Roundabouts An Informational Guide, USDOT, FHWA

Figure 19-15: Urban Single-Lane Roundabout Examples

City of Bend, Oregon

Sherwood, Oregon

Corvallis, Oregon

Table 19-2: Features Of Roundabouts Vs. Traffic Circles

Roundabouts	Traffic Circles
Yield control on all entries; the circulatory roadway has no control.	Some traffic circles use stop control or no control on one or more entries.
Circulating vehicles have the right-of-way.	Some traffic circles require circulating traffic to yield to entering traffic.
Pedestrian access is allowed only across the legs of the roundabout, behind the yield line.	Some traffic circles allow pedestrians to access the center island.
No parking is allowed within the circulatory roadway or at the entries.	Some traffic circles allow parking within the circulating roadway.
All vehicles circulate counterclockwise and pass the right of the central island.	Some neighborhood traffic circles allow left-turning vehicles to pass the left of the central island.

Roundabouts are typically located at intersections with a history of crashes or in areas where queues need to be minimized. This type of traffic calming measure is often used at intersections with irregular geometry, intersections with a high proportion of U-turns, or areas with an abundant amount of right-of way.

Advantages

Roundabouts provide an inexpensive traffic control in terms of maintenance compared to the installation and maintenance of a traffic signal. The circular shape and placement of the island causes deflection in the vehicle's path of travel, therefore requiring drivers to reduce speeds. The reduction in speeds at roundabouts can improve the safety of all users of the roadway. Typically roundabout have vehicle crash reductions of 50% compared to a signalized intersection serving a similar traffic volume. The center island eliminates intersection conflict points, thus decreasing the number and severity of collisions. The yield control at the entrance of the roundabout can decrease the queues and decrease delays at the intersection more efficiently than traffic signals. Landscaping on the center island can add aesthetic value to the neighborhood if designed correctly.

Disadvantages

Due to the large center island as well as splitter islands at the entrances, roundabouts can be difficult for large trucks or buses to maneuver around. The narrow travel lanes, characteristic of traffic circles, can result in bicycle/vehicle conflicts within the intersection. Roundabouts may also require elimination of some on-street parking. Landscaping may require on-going maintenance to ensure vegetation does not create sight distance issues.

Chicanes

(Deviations, Serpentines, Reversing Curves, Twists, and Staggerings)

Chicanes are series of curb extensions that alternate from one side of the street to the other, forming S-shaped curves (See Figure 19-16). These types of traffic calming devices can also be created by alternating on-street parking between one side of the street and the other. Each parking bay can be created either by restriping the roadway or by installing raised, landscaped islands at the ends of each parking bay. Chicanes are most appropriate for midblock locations and are most effective with roadways of equivalent volumes of traffic on both approaches. Chicanes are often installed where speeds are a problem but policy or noise associated with speed humps or related calming measures would not be acceptable.

Figure 19-16: Chicane Example

Lincoln City, Oregon

Advantages

Chicanes discourage high speeds by forcing vehicles to make horizontal deflections. This type of traffic calming device is easily negotiable by large trucks, buses and emergency vehicles, except under heavy traffic conditions.

Disadvantages

Chicanes must be designed in a way to discourage vehicles from deviating out their appropriate lane, thus not being effected by the deflection and not reducing their speeds. The cost of curb realignment, landscaping and modifications to drainage can be expensive. This type of calming measure can also eliminate some of the on-street parking.

Chokers

Chokers are curb extensions that narrow a street by widening the sidewalk or planting strip (See Figure 19-17). Chokers that are marked as crosswalks are known as safe crosses. Two-lane chokers leave the street cross section with two lanes that are narrower than the normal cross section. One-lane chokers narrow the width to allow travel in only one direction at a time, operating similarly to one-lane bridges. Chokers are most typically used on local and collector streets at pedestrian crossings. Sometimes they are used on main roads through small communities. This type of traffic calming device works well with speed humps, speed tables, raised intersections, textured crosswalks, curb radius reductions, and raised median islands.

Figure 19-17: Choker Examples

Chokers Combined With Speed Table
Beaverton, Oregon

Chokers Combined With Speed Table
Beaverton, Oregon

Chokers Combined With Center Island and
Textured Crosswalk, Beaverton, Oregon

Advantages

Chokers reduce both speeds and volumes of traffic and are easily maneuvered by large trucks and buses. Speeds have typically been reduced on average by 4 percent for two-lane chokers and 14 percent for one-lane chokers. Chokers reduce pedestrian crossing width and increases visibility between pedestrians and motorists. This type of treatment is preferred by many fire department and emergency response agencies to most other traffic calming measures.

Disadvantages

The effectiveness of chokers in terms of speed reduction is limited by the absence of any vertical or horizontal deflection. Chokers can possibly impact parking and driveway access, and also may require the elimination of some on-street parking. This treatment may require bicycles to merge with vehicular traffic.

Neckdowns (Bulbouts)

Neckdowns (Bulbouts) are curb extensions at intersections that reduce the roadway width from curb to curb (See Figure 19-18). This type of traffic calming device improves pedestrian safety by shortening crossing distances for pedestrians to cross the intersection and increase the visibility of pedestrians to motor vehicle operators and of motor vehicles to pedestrians by moving pedestrians closer to the street centerline before entering the roadway. Neckdowns may also tighten the curb radii at the corners, therefore reducing the speeds of turning vehicles. This type of treatment is appropriate for intersections with high pedestrian activity and in areas where vertical traffic calming measures would be unacceptable due to noise.

Figure 19-18: Neckdown (Bulbout) Examples

Gresham, Oregon

Medford, Oregon

Gresham, Oregon

Advantages

Neckdowns (Bulbouts) improve pedestrian areas, as well as safety, by decreasing the crosswalk distance. The tighter radii of the curb results in a reduction of speeds for turning vehicles at the intersection, thus increasing safety for pedestrians. Both through and left-turning movements are easily negotiable by large trucks or buses. The curb extension of a neckdown creates protected on-street parking.

Disadvantages

Although there is a reduction in speeds for right turning vehicles, the effectiveness of neckdowns is limited by the absence of vertical or horizontal deflections. Emergency vehicles making a right turn typically are forced to reduce speed and cause delay. Neckdowns may require the elimination of some on street parking near the intersection. The curb extension into the intersection may require bicyclists to briefly merge with vehicular traffic.

Diagonal Diverters

Diagonal diverters are barriers placed diagonally across an intersection, blocking through movements (See Figure 19-19 and Figure 19-20). This diverter creates two separate streets, with an L-shape. Like half closures, diagonal diverters are often staggered to create circuitous routes through the neighborhood as a whole, discouraging non-local traffic while maintaining access for local residents.

Figure 19-19: Diagonal Diverter[13]

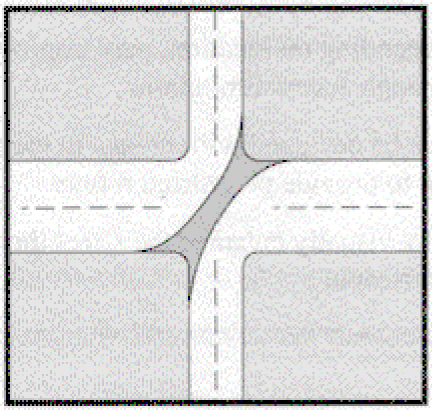


Figure 19-20: Diagonal Diverter in Portland, Oregon

Advantages

Diagonal diverters do not require a complete closure of a street, only a redirection of existing streets. This type of traffic calming measure is able to maintain full pedestrian and bicycle access. Diagonal diverters reduce traffic volumes, such as cut-through traffic from congested arterials.

Disadvantages

Diagonal diverters cause circuitous routes for local residents and emergency services. Some types of diverters may be expensive, depending on the design, and may require reconstruction of corner curbs.

Center Island Narrowing

(Midblock Medians, Median Slowpoints, Median Chokers)

A center island narrowing is a raised island located along the centerline of a street that narrows the travel lanes at that location. These treatments are often landscaped to provide a visual amenity (See Figure 19-21 and Figure 19-22). If a center island narrowing is placed at the entrance to a neighborhood, and combined with textured pavement, they may be called a "gateway island." Center islands that are fitted with a gap to allow pedestrians to walk through at

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[13] Source: http://www.portlandonline.com/TRANSPORTATION/INDEX.CFM?a=83901&c=38760

a crosswalk are often called "pedestrian refuges." This type of traffic calming device is very effective when used with crosswalks.

Figure 19-21: Center Island Narrowing Examples

Center Island Combined With Speed Table
Beaverton, Oregon

Center Island Combined With Crosswalk and Bicycle Crossing, Benton County, Oregon

Center Island Combined With Crosswalk
Corvallis, Oregon

Advantages

Center island narrowing increases pedestrian safety by reducing the width of the crossing area. This type of traffic calming device has proven to reduce traffic volumes. When designed well, with landscaping features, this type of treatment can have a positive aesthetic value.

Disadvantages

The speed reduction effect of a center island narrowing is somewhat limited by the absence of any vertical or horizontal deflection. Center island narrowing may require the elimination of on-street parking and driveway access. This treatment may require bicycles to merge with vehicular traffic, thus increasing conflicts.

Figure 19-22: Center Island Narrowing Examples

Center Refuge Island Combined With Crosswalk and Choker

Center Refuge Island Combined With Crosswalk Tualatin, Oregon

Center Refuge Island Combined With Crosswalk City of Bend, Oregon

Textured Crosswalks[14]

A textured crosswalk features a surface material at a crosswalk such as brick, concrete pavers, or stamped asphalt, which is installed to produce small, constant changes in vertical alignment and to aesthetically enhance the crosswalk. A colored crosswalk features a pavement marking or proprietary product at a crosswalk, which is installed to contrast with adjoining paved areas and to aesthetically enhance the crosswalk (See Figure 19-23).

ODOT practice is to not install textured or colored crosswalks. It is sometimes, however, a wish of a local road authority to install them. The perception is often times that the textured or colored crosswalk alone will be more visible than standard crosswalk marking. But often times that is not the case, textured or colored crosswalks can actually be LESS visible than conventional marked crosswalks (red brick tends to fade to black, especially at times of low visibility).

[14] Source: ODOT, Traffic Manual, 2009

Textured crosswalks can be rough, impeding the movement of pedestrians with wheelchairs and walkers. They can become uneven, presenting a tripping hazard to pedestrians, especially the sight impaired. Textured or colored crosswalks are typically higher maintenance and some materials can become slick creating a slipping hazard. Installation costs are also high in comparison to conventional marked crosswalks.

Figure 19-23: Textured Pavement Examples

Milwaukie, Oregon

Beaverton, Oregon

Lake Oswego, Oregon

Additional Traffic Calming Resources

For additional information about Traffic Calming please refer to:

- "Traffic Calming: State of the Practice", by Reid Ewing, written for the Institute of Transportation Engineers with funding from the Federal Highway Administration. August 1999.
- "A Practical Guide to Traffic Calming", by the Traffic Calming Group at Fehr & Peers Transportation Consultants. www.trafficcalming.org
- "Traffic Calming Library", by the Institute for Transportation Engineers. www.ite.org/traffic
- "Traffic Manual", Office of Transportation, City of Portland. www.portlandonline.com/transportation

Chapter 20: Clear Zone, Sight Distance, and Vegetation Control

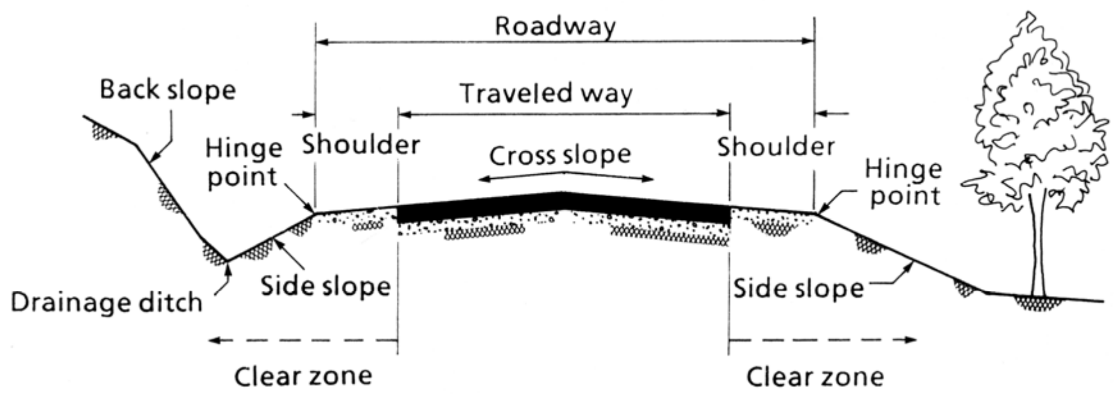
The term "clear zone" refers to the desirable unobstructed area available for the recovery of vehicles that have left the traveled way, and is measured from the edge of the traveled way as illustrated in Figure 20-1. When possible, there should be no physical obstructions such as utility and light poles, tress, boulders, etc. within the clear zone area. The ground should be relatively flat and gently graded. Once a clear zone is built, commitment must be made to maintain it by keeping it free from fixed objects or hazardous slopes. If the obstructions cannot be removed, then engineering judgment must be used to determine if the obstruction should be shielded by a longitudinal barrier or a crash cushion.

Barriers should only be installed if they can be expected to reduce the severity of potential crashes. Since the severity of potential crashes is not directly related to the probability or frequency of run-off-road crashes, it is often difficult to determine when a barrier should be installed. Some agencies determine barrier need by comparing the costs associated with the barrier (installation cost, maintenance cost and crash cost) to those associated with the unshielded obstacle. The cost analysis should be performed to evaluate three options:

1. remove the obstacle
2. install an appropriate barrier
3. leave the obstacle unshielded.

The third option is usually cost effective only on low speed, low volume roadways where engineering studies indicate a low probability of crashes.

Figure 20-1: Clear Zone Illustration[1]



Hinge Point	Point where the slope rate changes.
Clear Zone	That area along the side of the traveled way including the shoulder that is available for recovery of an errant vehicle.

What Factors Should Be Considered For Determining The Width Of Clear Zones

On high speed highways, a width of 30 feet (9 meter) or more from the edge of the traveled way permits about 80 percent of the out of control vehicles leaving a roadway to recover. Many obstacles located within this clear zone should be removed, relocated, redesigned, or shielded by traffic barriers or crash cushions. On most low volume or low speed facilities, a 30-foot (9 meter) clear zone distance is excessive.

The 1977 AASHTO Guide for Selecting, Locating and Designing Traffic Barriers introduced variable clear zone distances based on traffic volumes and speeds and roadside geometry. Table 20.1 or Figure 20.2 can be used to determine the suggested roadside recovery area or clear zone for selected design average daily traffic volume (ADT) and speeds. The AASHTO publication Roadside Design Guide, 2002 Edition may be referenced for additional clear zone discussion.

[1] Source: Vegetation Control For Safety, US DOT, FHWA

Table 20-1: Clear Zone Distances (In Feet From Edge Of Driving Lane)[2]

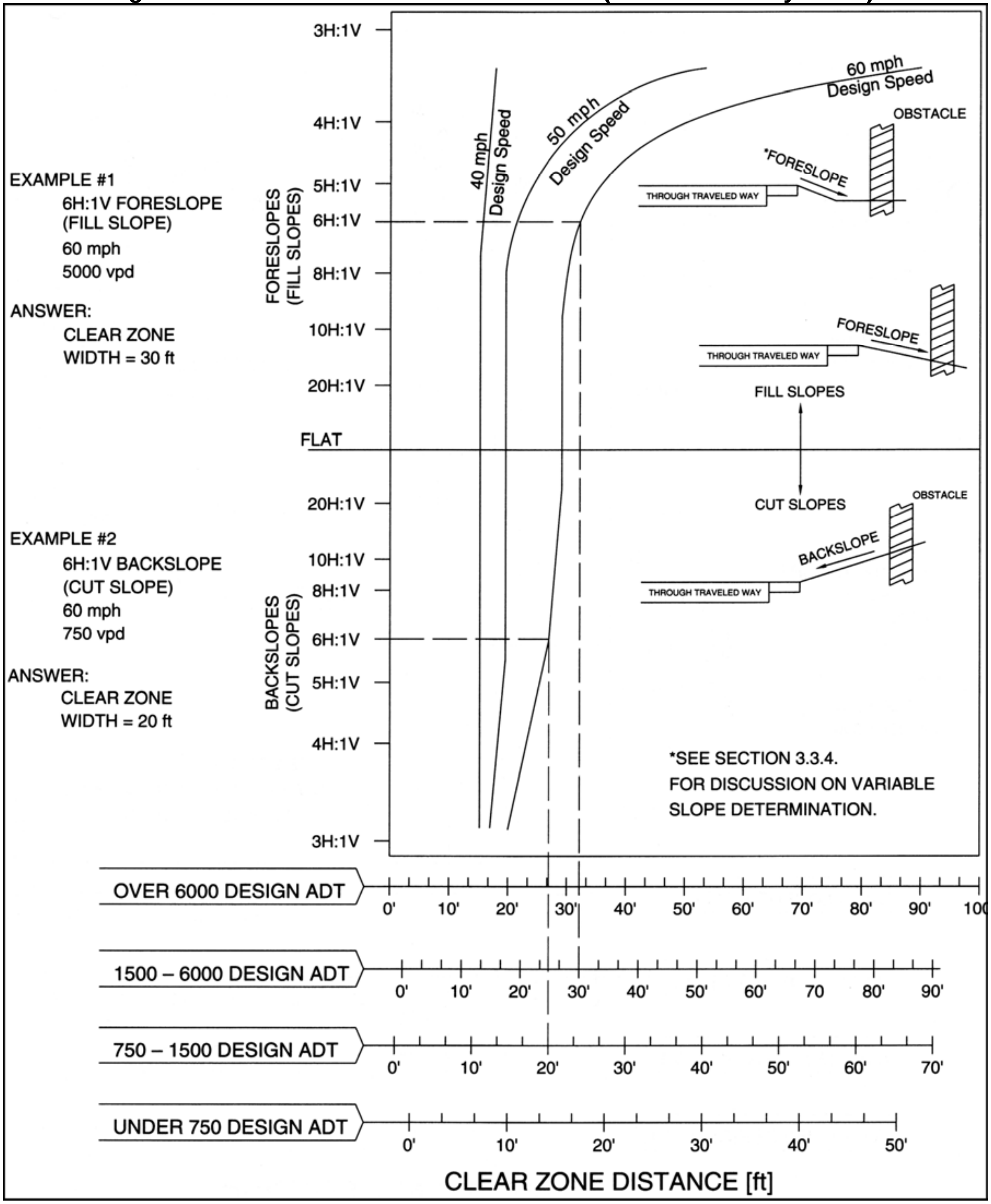
DESIGN SPEED	DESIGN ADT	FORESLOPES			BACKSLOPES		
		1V:6H of flatter	1V:5H TO 1V:4H	1V:3H	1V:3H	1V:5H TO 1V:4H	1V:6H or Flatter
40 mph or less	UNDER 750	7 – 10	7 – 10	**	7 – 10	7 – 10	7 – 10
	750 – 1500	10 – 12	12 – 14	**	10 – 12	10 – 12	10 – 12
	1500 – 6000	12 – 14	14 – 16	**	12 – 14	12 – 14	12 – 14
	OVER 6000	14 – 16	16 – 18	**	14 – 16	14 – 16	14 – 16
45–50 mph	UNDER 750	10 – 12	12 – 14	**	8 – 10	8 – 10	10 – 12
	750 – 1500	12 – 14	16 – 20	**	10 – 12	12 – 14	14 – 16
	1500 – 6000	16 – 18	20 – 26	**	12 – 14	14 – 16	16 – 18
	OVER 6000	18 – 20	24 – 28	**	14 – 16	18 – 20	20 – 22
55 mph	UNDER 750	12 – 14	14 – 18	**	8 – 10	10 – 12	10 – 12
	750 – 1500	16 – 18	20 – 24	**	10 – 12	14 – 16	16 – 18
	1500 – 6000	20 – 22	24 – 30	**	14 – 16	16 – 18	20 – 22
	OVER 6000	22 – 24	26 – 32 *	**	16 – 18	20 – 22	22 – 24
60 mph	UNDER 750	16 – 18	20 – 24	**	10 – 12	12 – 14	14 – 16
	750 – 1500	20 – 24	26 – 32 *	**	12 – 14	16 – 18	20 – 22
	1500 – 6000	26 – 30	32 – 40 *	**	14 – 18	18 – 22	24 – 26
	OVER 6000	30 – 32 *	36 – 44 *	**	20 – 22	24 – 26	26 – 28
65–70 mph	UNDER 750	18 – 20	20 – 26	**	10 – 12	14 – 16	14 – 16
	750 – 1500	24 – 26	28 – 36 *	**	12 – 16	18 – 20	20 – 22
	1500 – 6000	28 – 32 *	34 – 42 *	**	16 – 20	22 – 24	26 – 28
	OVER 6000	30 – 34 *	38 – 46 *	**	22 – 24	26 – 30	28 – 30

* Where a site specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear-zone distances greater than the clear-zone shown indicated. Clear zones may be limited to 30 ft for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

** Since recovery is less likely on the unshielded, traversable 1V:3H slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope.

[2] Source: AASHTO, 2002 Roadside Design Guide

Figure 20-2: Clear Zone Distance Curves (U.S. Customary Units)[3]



Types Of Run-Off-Road Hazards[4]

The three types of run-off-road hazards are roadside objects, roadside hazards, and slopes.

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[3] Source: ASSHTO, 2002 Roadside Design Guide
[4] Source: Road Safety Fundamentals, US DOT, FHWA

Roadside objects include fixed objects that could punch through the vehicle into the passenger compartment. Fixed objects are relatively unyielding obstacles such as utility poles, tress and boulders. Other common fixed objects include:

- Culvert headwalls and bridge walls or railings.
- Large mailboxes or multiple single mailboxes placed close together.
- Tress 4 inches (100 mm) or more in diameter or smaller trees less than 7 feet (2.1 m) apart.
- Cross culverts 3 feet (0.9 m) or more across.
- Parallel culverts (driveway or crossroad pipes) 2 feet (0.6 m) or more wide.
- Other objects more than 4 inches (100 mm) high.

Groups of mailboxes mounted on flat boards are hazards because the board is at the same height as most vehicle windshields. When hit, the mailbox can break free from the support posts and crash through the vehicle windows at about the head height, causing severe, often fatal injuries.

Roadside hazards such as rock cuts and guardrail can extend along the road for a distance.

Slopes are hazardous as they can cause a vehicle to roll over or be launched into the air. Side slopes such as ditch slopes or embankment slopes run parallel to the road. Transverse slopes slant at an angle to the road and include creek beds and embankments for other roads, driveways, and railroads.

The three categories of side slopes indicate how steep they are:

- **Recoverable slopes** are flatter than 4:1 (horizontal:vertical). A driver has a good chance to chance to regain vehicle control and return to the roadway.
- **Nonrecoverable slopes** are between 4:1 and 3:1. A vehicle on a nonrecoverable slope will probably stay upright, but the slope is too steep to allow return to the roadway and the vehicle will end up at the bottom of the slope.
- **Critical slopes** are steeper than 3:1. When possible, avoid or shield these slopes because they dramatically increase the chances of a severe rollover crash.

Except for new construction or full reconstruction of a road, you can retain 2:1 slopes less than 5 feet (1.5 m) high without guardrail. But then not much fill material is needed to flatten a low, steep slope to 3:1 when right-of-way or adjacent landowners allow.

Treatment Of Roadside Hazards[5]

Ask yourself the following questions as you consider what to do with a hazard that reduces the available clear zone distance:

- Is the possible hazard dangerous?
- Can you remove the hazard?
- Can you relocate the hazard to a place where it is less likely to be hit?
- Can you reduce crash severity if the hazard is hit?

[5] Source: Road Safety Fundamentals, US DOT, FHWA

- If you can't remove, relocate, or modify the hazard, will adding guardrail make the road safer?
- Would delineation help guide drivers around the hazard?

Is the Potential Hazard Dangerous? [6]

When you know something on the roadside is a hazard, do something about it. To decide how dangerous the hazard is to drivers, ask yourself:

- Is there a fixed object in the clear zone?
- Is there an object in the clear zone that could punch into the passenger compartment when struck?
- Is there a critical slope near the road?
- Is there a fixed object at or near the bottom of a nonrecoverable slope?

Can You Remove the Hazard?

Your best option is to eliminate the hazard. For example, a vehicle running off the roadway can pass safely over a tree stump cut flush with the ground.

Can You Relocate It to a Place Where It is Less Likely to be Hit?

Moving an object farther from the road or from the outside of a curve to the inside can reduce the chances that the hazard will be hit. You can extend cross culverts to move the culvert end out of the clear zone, and move utility poles farther from the traffic.

Can You Reduce Crash Severity? [7]

If you can't remove or relocate the hazard, then try to reduce the severity of the crash. There are three main ways to do this:

- Install signposts, light and utility poles on breakaway bases to reduce collision forces. Breakaway hardware is designed to separate in a controlled way when hit, allowing the vehicle is able to pass under or over it.
- Upgrade drainage features so that vehicles leaving the roadway can drive over them. For example, placing grates over culvert ends allow a vehicle to drive over the opening rather than fall into it.
- Flattening ditch foreslopes and backslopes making them safer for a vehicle leaving the roadway.

Will Guardrails Improve Road Safety? [8]

Remember that striking guardrail can cause injuries, so install it only where crashing into the hazard would be worse than striking the guardrail.

If a potential hazard is located in the clear zone and you can't reasonably remove, relocate, or modify it to be crashworthy, then consider installing guardrail. For a fatal-at-any-speed hazard

[6] Source: Road Safety Fundamentals, US DOT, FHWA
[7] Source: Road Safety Fundamentals, US DOT, FHWA
[8] Source: Road Safety Fundamentals, US DOT, FHWA

(body of water, large propane tank), it is reasonable to assume than an errant vehicle could reach it, provide a strong barrier system to shield it such as strong-post W-beam guardrail or box beam.

Would Delineation Guide Drivers Around the Hazard? [9]

Signs, pavement markings, rumble strips, and post-mounted delineators are a good way to define the edge of the road or mark hazardous conditions. Delineation helps guide careful drivers around obstacles, although it does not help drivers who lose control of their vehicles. Examples of delineation include chevrons on curves and object markers at narrow bridges.

If you can't remove, relocate, modify, or shield a hazard with guardrail, then install signs and delineation to warn drivers that they need to be alert for the hazard. Installing these devices is especially helpful where crash records show frequent nighttime run-off-road crashes.

Delineation can also be used to make guardrail more visible to drivers.

Delineation can be a low-cost temporary solution when installing guardrail is necessary but will be delayed by limited budget, time, or personnel. Just make sure the temporary measure doesn't become permanent when guardrail is truly needed.

Is the Solution Feasible and Cost-Effective?

This is probably the hardest question. At what point is the cost of an improvement more than the crash cost savings you can expect from it? Because guardrails need a clear deflection zone behind them, it may be impossible to install guardrail without narrowing the road. On low-volume roads, the deflection distance of some guardrail systems may exceed the available clear zone width.

Summary Of Clear Zone Concept

1. A basic understanding of the clear zone concept is necessary for its proper application. The numbers obtained from Table 20.1 or Figure 20.2 imply a degree of accuracy which does not exist. The clear zone distances are, therefore, neither absolute nor precise. They are intended to provide a safe roadside.
2. The first preference is to remove or relocate all obstacles that are within the right-of-way. However, in most cases this is not practical because of economic or physical constraints. In some cases it is reasonable to leave an obstacle within a clear zone. In other cases an object beyond the clear zone distance may require removal or shielding. The use of an appropriate clear zone distance is a compromise between maximizing safety and minimizing construction cost.
3. The designer should not use the clear zone distances as boundaries for introducing obstacles such as non-breakaway sign supports, utility poles, or landscape features. These should be placed as far from the roadway as is practical.
4. For new construction the volumes used for determining clear zone distances should be design year ADT's. For two-way roadways, such as divided highways and ramps, the directional ADT should be used.

[9] Source: Road Safety Fundamentals, US DOT, FHWA

5. The clear zone should not vary with small variations in highway features. For roadways on new location, the clear zone should be consistent for as much of the length of the project as practical.
6. On curbed roads, locate obstructions such as utility poles or fire hydrants as far beyond the curb as is practical. Curbs won't prevent a car from leaving the road. At medium to high speeds, a vehicle hitting the curb can cause a driver to lose control. Rather than keeping the vehicle away from the sidewalk, hitting the curb can actually turn a vehicle toward the sidewalk. Because curbing will not protect pedestrians, try to add a buffer area between the sidewalk and the curb more than 1.5 feet (0.5 m) beyond the curb when possible.
7. Traffic speeds are generally higher on rural roads, so try to include wider clear zones. The clear zones should be wider where the roadside slopes down and away from the edge of the road, and on the outside of curves. Don't neglect the inside of curves. Vehicles do run off the road on the inside of curves, and fixed objects on the inside of curves can also restrict driver sight distance.
8. On rural local roads, try to include clear zones of 10 feet (3.0 m) from the lane edgeline. Consult the 2002 AASHTO Roadside Design Guide for recommended clear zones on collector and arterial roadways.

What Are Roadside Vegetation Management Guiding Principles? [10]

These guiding principles are designed to address the breadth of roadside concerns and reflect the differing types of activities within the roadside. These guiding principles are intended to make the most efficient and effective use of public resources. The roadside vegetation management guiding principles are described in the following subsections.

A. Maintain Public Safety

The safety of people is the first priority in designing and maintaining the roadside. This includes such things as: maintaining the errant vehicle recovery zone, known as the "Clear Zone"; removal of vegetation that could be used as 'hide-out' along bike paths and sidewalks; proper use of chemicals; removal of obstacle trees or branches that might fall during wind or ice storms; proper warning for motorists in roadside work areas; and more.

B. Statutes

Federal, state, and local regulations significantly influences and control activities along roadsides. ODOT, cities, and counties have obligations under a variety of inter-jurisdictional and individual agreements as well as applicable mandates, policies, administrative rules, easements, and commitments. When making roadway vegetation decisions, ODOT, city, and county maintenance personnel must comply with pertinent ordinances and honor agreements between the agencies that are affected.

C. Stewardship

1. Manage Vegetation Using Integrated Roadside Systems

[10] Source: Roadside Vegetation Management Principles and Guidelines, ODOT

Recognizing that some roadside uses may conflict, ODOT, cities, and counties are obligated to provide a balanced response as it performs its stewardship responsibilities. Systematically managing the roadside as a multipurpose resource will benefit ODOT, cities, counties, motorists, adjacent landowners, special interest groups, and local communities.

2. Integrate Vegetation with its Surroundings

Oregon's roadways pass through urban, rural, agricultural, forest, riparian, and open range environments. Roadside treatments and vegetation will vary to blend with and reinforce the natural and cultural character of the surrounding areas. Views from and of the roadway must be considered in the roadside projects, particularly where scenic issues have a high level of importance.

3. Manage Vegetation for Both Sustainability and Cost Efficiency

Roadside development must be designed and managed to be sustainable and cost-efficient. Sustainable landscaping may be defined as vegetation that is appropriate for the existing climate and soil, and sufficiently hardy to withstand stresses without needing excessive maintenance.

Safety Considerations Of Landscaping And Vegetation Control

Carefully planned landscaping and vegetation design can help to provide a safe, stable and visually pleasing roadway facility. Benefits derived from proper landscaping and vegetation control include:

- Providing soil stability and prevention of erosion of the roadbed, roadside, and drainage ditches.
- Providing a visually pleasing facility to roadway users and neighbors.
- Potential use as a noise barrier to mitigate the undesirable effects of traffic noise and screen the noise source from view.
- Potential alleviation of driver fatigue brought about by long stretches of roadway that, with no visual enhancement, would call for no change in eye focus.

Vegetation Control Goals

The primary goal of vegetation control is to increase traffic safety. Due to the different characteristics of both the vegetation and traffic, there are different concerns between urban and rural situations. The following discussion presents common vegetation problems and, where appropriate, urban and rural situations.

- Overhanging trees and bushes can obscure traffic signs.
- Tall grasses can hide the presence of obstructions and obstacle markers.
- Vegetation-covered ditches can experience restricted water flow by the presence of vegetation which is too tall and inappropriate.
- Encroaching vegetation can cause reduced lane width and vertical clearance.
- Vegetation can cause sight restrictions at intersections, railroad grade crossings, and horizontal curves.
- Mowing operations are not only expensive, but expose maintenance crews to obstacles. Slopes steeper than 3:1 increase the probability of mowers to overturning.

Sight Distance

Drivers approaching an intersection need a clear line of sight along crossroads early enough to see any conflicting vehicles, pedestrians, and bicyclists to avoid a collision. Drivers also need an unobstructed line of sight to any roadside signs or obstacles far enough in the distance to allow them to react safely to each decision.

Sight Distance Requirements For Traffic Control Devices

Look for signs and other traffic control devices blocked by brush trees, grass, or weeds when on routine maintenance patrol.

Often a small branch from an overhanging tree or some bush near the sign is all that needs to be cut back. If vegetation along the ditch or shoulder blocks a driver's view of a sign, then cut enough to allow a driver sufficient time to see the sign and respond to its message. If your agency has a policy on how far from a sign vegetation has to be cleared for a safe view, then follow that policy. If you do not have such a policy, use Table 20-2, which shows suggested distances for advance traffic control warning signs.

Table 20-2: Distances For Advance Traffic Control Warning Signs

Approach Speed (mph)	Required Sight Distance (ft.)	
	Traffic Signs*	Traffic Signal**
20	N/A	175
25	N/A	215
30	N/A	270
35	N/A	325
40	125	390
45	175	460
50	250	540
55	325	625
60	400	715

* from Table 2C-4, 2003 MUTCD
** from Table 4D-1, 2003 MUTCD
N/A: No suggested distances are provided for these speeds, as the placement location is dependent on site conditions and other signing to provide an adequate advance warning for the driver.

Sight obstructions to traffic control devices can be identified by drive through inspections, observations of employees, and complaints of citizens. Maintaining visibility requires constant attention during the growing season. Vegetation cut back in the spring can grow back later in the season. Urban areas often have signs mounted higher that rural areas to allow visibility of signs over parked vehicles. This requires additional attention to ensure that the signs are not blocked by overhanging trees.

Watch especially for overhead power lines and electrified farm fence when cutting brush. Never touch a wire farm fence when an electrical storm is in the vicinity of your work.

Intersection Sight Distance[11]

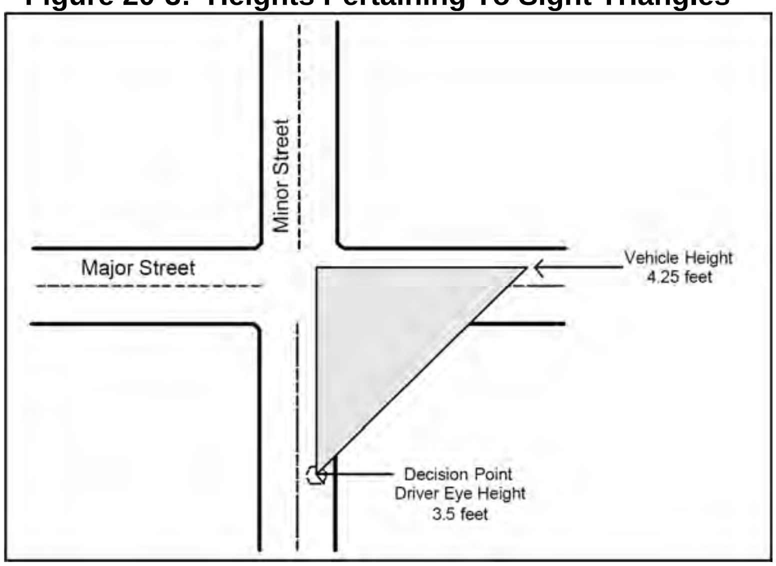
The driver of a vehicle approaching or departing from an intersection should have an unobstructed view of the intersection, including any traffic control devices, and sufficient lengths along the intersecting highway to permit the driver to anticipate and avoid potential collisions. These unobstructed views form triangular areas known as sight triangles.

Sight triangles are the specified areas along an intersection's approach legs and across the included corners (See Figure 20-3 for an illustration). These areas should be clear of obstructions that might block a driver's view of conflicting vehicles or pedestrians.

Obstructions Within Sight Triangles

To determine whether an object is a sight obstruction, consider both the horizontal and vertical alignment of both roadways, as well as the height and position of the object. For passenger vehicles, it is assumed that the driver's eye height is 3.5 feet and the height of an approaching vehicle is 4.25 feet above the roadway surface, as illustrated in Figure 20-3. At the decision point, the driver's eye height is used for measurement.

Figure 20-3: Heights Pertaining To Sight Triangles[12]



Any object within the sight triangle that would obstruct the driver's view of an approaching vehicle (4.25 feet in height) should be removed or modified or appropriate traffic control devices should be installed as per the Manual on Uniform Traffic Control Devices (MUTCD). Obstructions within sight triangles could be buildings, vehicles, hedges, trees, bushes, tall crops, walls, fences, etc.

[11] Source: Handbook Of Simplified Practice For Traffic Studies, Iowa State University, CTRE, 2002
[12] Source: Handbook of Simplified Practice For Traffic Studies, IOWA State University , CTRE, 2002

Uncontrolled Intersections[13]

For uncontrolled intersections, the drivers of both approaching vehicles should be able to see conflicting vehicles in adequate time to stop or slow to avoid a crash. The required sight distance for safe operation at an uncontrolled intersection is directly related to the vehicle speeds and the distances traveled during perception, reaction, and braking time. Table 20-3 lists the minimum recommended sight distances for specific design speeds. For example, if a vehicle is traveling 30 mph, a sight distance of 140 feet is the minimum recommended stopping sight distance.

Table 20-3: Minimum Recommended Sight Distances At Intersections With No Traffic Control[14]

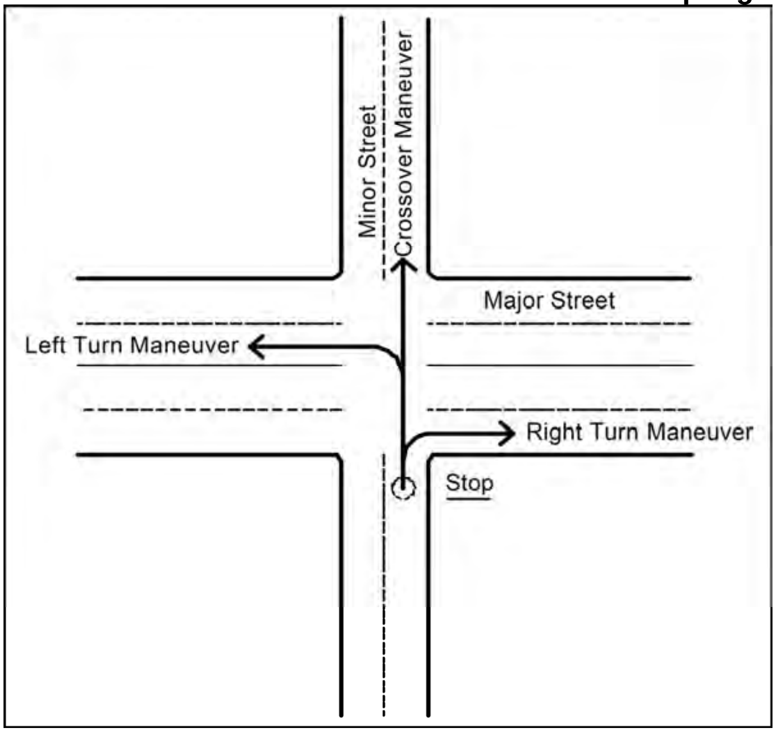
Vehicle Speed (mph)	Stopping Sight Distances (feet)
15	70
20	90
25	115
30	140
35	165
40	195
45	220
50	245
55	285

Vehicle Maneuvers At Intersections With Stop Sign Control

Three maneuvers can be completed for vehicles stopped at an intersection: crossing maneuver, left-turn maneuver, and right-turn maneuver (See Figure 20-4).

[13] Source: Handbook of Simplified Practice For Traffic Studies, IOWA State University , CTRE, 2002
[14] Source: AASHTO, A Policy On Geometric Design Of Highways And Streets, 2004

Figure 20-4: Three Maneuvers At An Intersection With Stop Sign Control[15]



Crossing Maneuver from the Minor Roadway

When a driver is completing a crossing maneuver, there must be sufficient sight distance in both directions available to cross the intersecting roadway and avoid approaching traffic. Table 20-4 lists the recommended sight distances for this maneuver based on design speeds.

Turning Left From the Minor Roadway

The left maneuver requires first clearing the traffic on the left, then entering the traffic stream on the right. Table 20-4 lists the recommended sight distances for this maneuver based on design speeds.

Turning Right from the Minor Roadway

The right turn maneuver must have sufficient sight distance to permit entrance onto the intersecting roadway and then accelerate to the posted speed limit without being overtaken by approaching vehicles. Table 20-4 lists the minimum recommended sight distances for this maneuver based on design speeds.

[15] Source: Handbook of Simplified Practice for the Traffic Studies, IOWA State University, CTRE, 2002

Table 20-4: Design Intersection Sight Distance Based on Vehicle Maneuver [16]

Vehicle Speed (mph)	Intersection Sight Distance For Passenger Cars To Turn Left Onto A Two-Lane Highway With No Median (feet)	Intersection Sight Distance For Passenger Cars To Turn Right Onto Or Cross A Two-Lane Highway With No Median (feet)
15	170	145
20	225	195
25	280	240
30	335	290
35	390	335
40	445	385
45	500	430
50	555	480
55	610	530

Key Steps To A Sight Distance Study At An Intersection With Stop Control[17]

A sight distance study at an intersection with stop control includes the following steps:

A. Determine the Minimum Recommended Sight Distances

Determine the minimum sight distance for each maneuver and speed (See Table 20-4).

B. Obtain Sighting and Target Rods

The target rod should be 4.25 feet tall to represent the vehicle height and the sighting rod should be 3.5 feet tall to represent the driver's eye height. The sighting rod and target rod are used in measuring sight distance.

C. Measure Current Sight Distances and Record Observations

The observer with the sighting rod stands at the center of the approaching lane and 10 feet back from the stop bar or aligned with the stop sign. The observer's eye should be at the top of the sighting rod.

The assistant walks away from the observer along the intersecting roadway toward approaching traffic. The assistant should stop periodically and place the target rod. This process should continue until the top of the target rod can no longer be seen. The point where the target rod disappears is the maximum sight distance along that leg and should be recorded from the observer's sight.

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[16] Source: AASHTO, A Policy On Geometric Design Of Highways And Streets, 2004

[17] Source: Handbook of Simplified Practice for the Traffic Studies, IOWA State University, CTRE, 2002

D. Perform Sight Distance Analysis

The analysis of intersection sight distance consists of comparing the recommended sight distance to the measured available sight distance. If the measured sight distance is less than the recommended sight distance some mitigation may be required. Some mitigation measures are as follows:

- Remove/modify obstruction
- Reduce Speed
- Install traffic control devices (if warranted by the MUTCD).

Urban Intersection Concerns And Tree Trimming

Intersections formed by residential streets frequently have private property which comes up to the street corner. Intersection sight obstructions will frequently be the result of vegetation growing on private property. Public work crews are usually not allowed to work outside the right-of-way lines. Many cities have enacted an ordinance that establishes a sight distance easement. Hedges, trees or shrubs which pose sight obstructions can be requested to be trimmed to the ordinance specifications.

Tree branches should be trimmed so that there is a minimum of 9 feet (3 m) of clear space above the street and/or sidewalk. Consideration for pedestrians and bicyclists also require that bushes, which obstruct sidewalks, be trimmed back so that there is at least 1 foot (0.3 m) between the bush and sidewalk. The tree trimming is illustrated in Figure 20-5.

Trimming the vegetation away to a distance of at least 25 feet (8 meters) from the intersecting pavement edge lines will, in most cases, provide sufficient sight distance for stop controlled intersections. Some government agencies require a 50-foot (16 meters) clear area to ensure a clear of sight for motorists at the stop bar.

The sight distance requirements for street corners with and without walkways are illustrated in Figure 20-6 and Figure 20-7.

Figure 20-5: Tree Trimming[18]

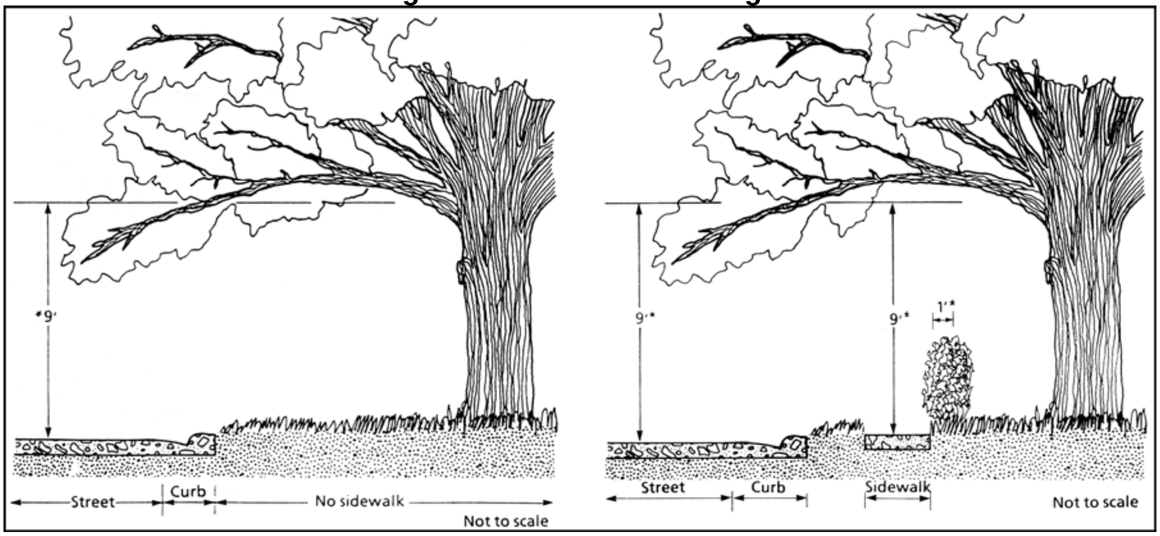
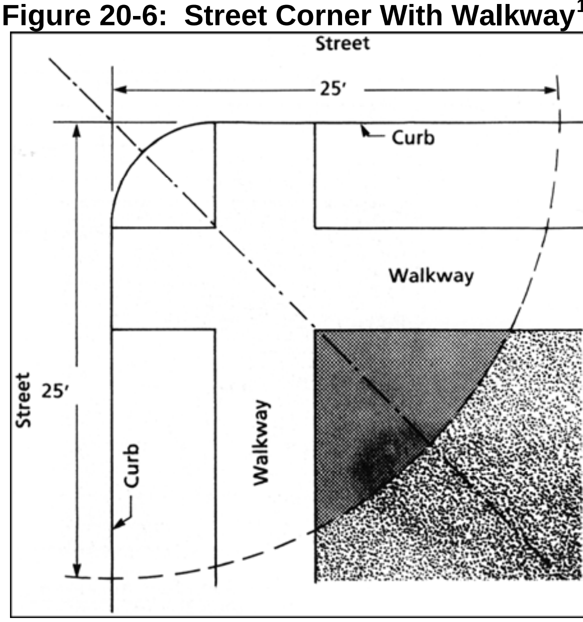
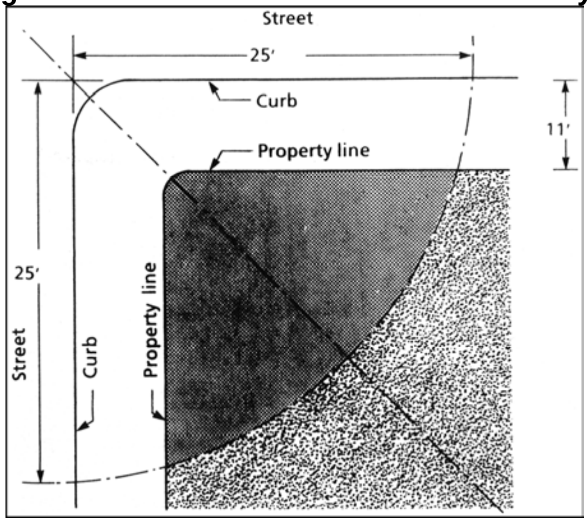


Figure 20-6: Street Corner With Walkway[19]



[18] Source: Vegetation Control Safety, USDOT, FHWA
[19] Source: Vegetation Control Safety, USDOT, FHWA

Figure 20-7: Street Corner Without Walkway[20]



Railroad Crossings Of Highways And Streets

At-grade crossings are a special case of intersections. The most important thing to do in vegetation maintenance at railroad crossings is to make sure the signs and signals for the crossing can be clearly seen by drivers, bike riders, and others approaching the crossing.

- Clear vegetation to the railroad crossing signs and the advance warning signs to provide good sight distance.
- Clear vegetation to provide good sight distance of all flashing signals when a crossing has signals.
- The suggested safe stopping distance, which is measured 15 feet (4.5 m) from the nearest rail based on OAR-100-0020 at rail crossings in Oregon, are shown in Table 20-5.

The next most important thing to do is cutting vegetation to give the driver a clear view of any train coming from either side. This clear view is labeled the "approach sight triangle" shown in Figure 20-8. Brush and vegetation along the road should be cut back so the clear view distance extends back from the railroad track as far as possible. This is the distance labeled "stopping sight distance" in the figure. Vegetation along the railroad right-of-way may be a significant part of the problem. DO NOT ENTER THE RAILROAD RIGHT-OF-WAY TO CUT VEGETATION UNLESS YOU ARE UNDER THE SUPERVISION OF PROPER RAILROAD EMPLOYEES and have been authorized to do so by your maintenance supervisor. When you cut the vegetation, trim it enough so that normal growth will not reach a height of 3 feet for at least one month.

[20] Source: Vegetation Control Safety, USDOT, FHWA

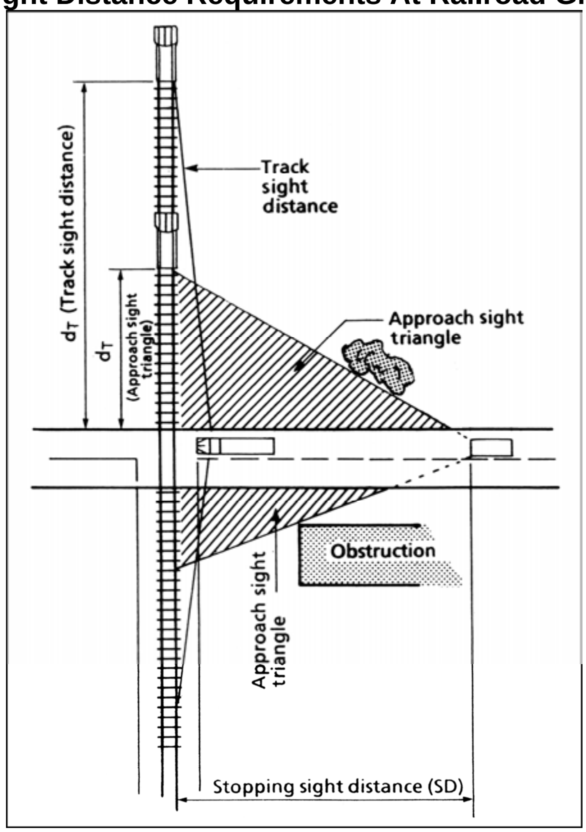
Table 20-5: Safe Stopping Distances (SSD)[21]

(The SSD is measured 15 feet from nearest rail)

(OAR 741-100-0020)

Vehicle Approach Speed	SSD
15 mph	80 feet
20 mph	115 feet
25 mph	155 feet
30 mph	200 feet
35 mph	250 feet
40 mph	305 feet
45 mph	360 feet
50 mph	425 feet
55 mph	495 feet
60 mph	570 feet
65 mph	645 feet

Figure 20-8: Sight Distance Requirements At Railroad Grade Crossing[22]



[21] Source: Based on AASHTO, A Policy On Geometric Design Of Highways And Streets, 2004, OAR741-100-0020

[22] Source: Vegetation Control for Safety, USDOT, FHWA

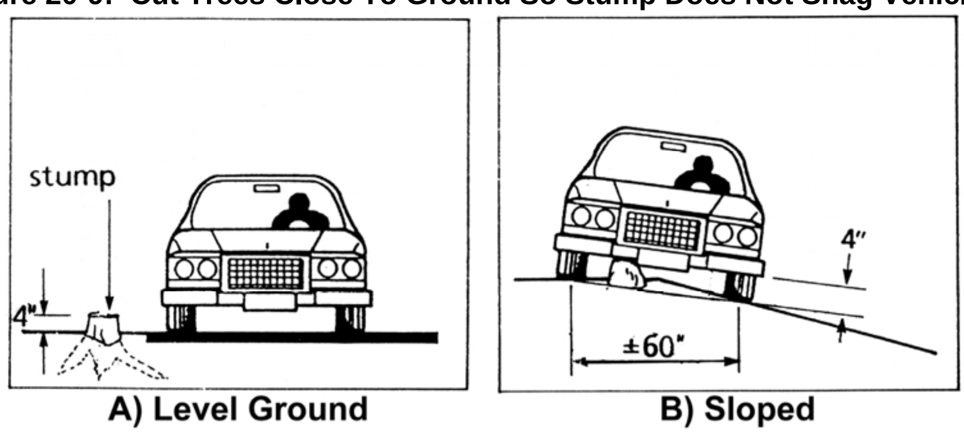
Maintenance Practices For The Trees In Clear Zone[23]

Trees growing in a clear zone are a special problem. Evergreen trees or trees in full leaf in the highway right-of-way block the driver's sight distance for signs and intersections. Trees with trunks larger than the posts used to support signs typically 4 inches (100 mm) in diameter can be an obstacle to any vehicle hitting them.

On roadways the goal is to keep the roadside clear of trees and other obstructions for a distance of up to 30 feet (9 m) if there is that much room in the right-of-way. A clear zone gives a driver who runs off the road a good chance to bring the vehicle under control without a crash. In removing the trees in the right-of-way to maintain this clear zone there are two things to remember:

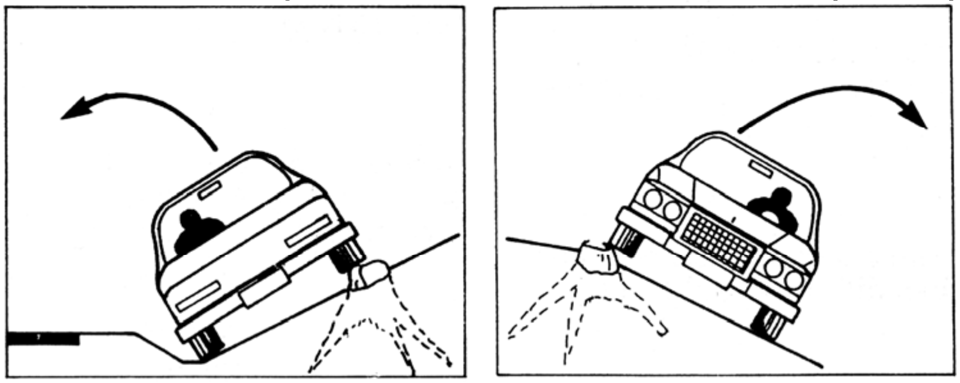
1. Cut trees close to the ground or remove the stump so that it does not become an obstacle. If the stump is not removed, then trees should be cut flush with the ground. Tree stumps protruding more than 4 inches (100 mm) above the ground can result in vehicle snagging on a level surface, as presented in Figure 20-9A. If the stump is on a slope, as in Figure 20-9B, snagging can occur even if the stump is less than 4 inches (100 mm). In addition to snagging, protruding stumps on slopes can result in vehicle rollover as presented in Figure 20-10.
2. All trees within the clear zone should be cut while they are still small saplings rather than small trees. At that time they are easily cut to the ground and cause no stump problems. Also, no one will be tempted to try to save a beautiful but hazardous tree in the highway clear zone.

Figure 20-9: Cut Trees Close To Ground So Stump Does Not Snag Vehicles[24]



[23] Source: Vegetation Control Safety, USDOT, FHWA
[24] Source: Vegetation Control for Safety, USDOT, FHWA

Figure 20-10: Possibility of Vehicle Rollover Due To Tree Stump on Slope[25]



Private Property Owner Agreement

Most private property owners are willing to cooperate in improving traffic safety. They should be required to keep all bushes and shrubs at a height of 3 feet (0.9 m) or lower and to trim all tree and hanging branches to a minimum height of 9 feet (2.7 m). Figure 20-11 is a sample letter and form suggested as a way of contacting private property owners to ask them to remove vegetation blocking the intersection sight distance. If notice is provided and homeowners do not respond in a reasonable time, most public agencies have regulatory powers to remove the designated vegetation at the homeowner's expense. Check with your supervisor for more information.

[25] Source: Vegetation Control for Safety, USDOT, FHWA

Figure 20-11: Sample Letter For Contacting Private Property Owners[26]

(Month/day/year)

(Property Owner)
(Address)
(City, State Zip)

In a recent survey of your area, street maintenance workers observed the following problems that exist on your property.

(Code #) ____ Your shrubs and bushes on the corner are obstructing drivers' views and must be cut down to not more than ____ feet high. (See attached drawing.)

____ A tree branch hanging over the street or sidewalk limits view or access and must be cut to ____ feet above the surface of the widewalk or street. (See attached drawing.)

____ A bush is obstructing the sidewalk or street and must be cut back to 12 in. from the edge of the sidewalk or curb. (See attached drawing.)

____ Bushes less than 25 ft from the intersection block the driver's view. (See attached drawing.)

If you have questions please call ____________. If you need help correcting the problem, the City will do the work and bill you for the cost. To obtain a cost estimate and authorize the City to do the work, call ____________ during business hours.

We will inspect your property again in ______ days to check on the work unless you have arranged for the City to do the work before then.

Sincerely,

(____________________), Director

Include Figure 20-5 to Figure 20-7 with the letter for contacting the private property owner.

Mowing Operation Maintenance Practices[27]

DON'T:

1. Mow too often – This wastes money, exposes mowing crews to traffic obstacles more than needed, and can damage the vegetation.
2. Mow at the wrong time – Good timing reduces the frequency of mowing required by cutting the vegetation at the right stage of growth.

[26] Source: Vegetation Control for Safety, USDOT, FHWA
[27] Source: Vegetation Control for Safety, USDOT, FHWA

3. Mow too short – Leaving the proper height helps maintain the stand of vegetation and keeps small litter objects hidden.
4. Mow steep slopes if you don't need to – Steep slope operations increase risk of mower crashes.
5. Mow patterns inconsistently and mow a regular area incompletely – Drivers watch the safety of a mowed area to help understand the safety of an area. Consistent mowing of similar areas helps drivers evaluate the safety of the roadway.
6. Mow when wet – This is hard on equipment.
7. Operate equipment carelessly and scar trees and shrubs – Mowing is tedious, but care must be taken to avoid crashes and preserve valuable plantings.

DO:

1. Avoid mowing slopes steeper than 2.5:1 with a regular mower unit.
2. Mow slopes steeper than 2.5:1 with a side-mounted mower on a boom if the tractor unit remains on flatter surfaces while mowing.
3. Operate side-mounted or boom mower units on the uphill side of the tractor to limit the possibility of overturning the tractor.
4. Replace broken or lost chain guards to deflect debris immediately. Using flail type mowers reduces the amount of debris thrown.
5. Cover all v-belts, drive chains, and power takeoff shafts.
6. Raise the mower when crossing driveways or roadways.
7. Shut off power before checking any mower unit. Block a mower before changing, sharpening, or replacing a blade. Any blade being re-installed should be checked for cracks or damage that will lead to failure.
8. Use flashing signals and slow-moving-vehicle signs on all mower units.
9. Use signs to warn traffic, such as MOWING AHEAD, MOWING AREA, ROAD WORK AHEAD, or similar legends. Signs should not be more than one to two miles ahead of the mowing. Signs saying MOWING NEXT _____ MILES may be used in advance of the operation if your agency wants, but the distance limits should not be shorter than two miles nor longer than five miles.

Suggested Mowing Limits:

Table 20-6 lists suggested limits on how far to mow in different roadway situations. Your individual agency may have different standards, but if it does not, use these as a starting point.

Table 20-6: Suggested Moving Limits[28]

(Measured Along Surface of Slopes)

	On slopes 2.5:1 or less	On slopes more than 2.5:1 up to 1:1 within 20′ outside of pavement edge	More than 1:1 slopes within 10′ outside of pavement edge
Backslopes	Mow 15′ outside of pavement edge	With side-mounted units mow one swath width past slope that does not exceed 2.5:1	Mow brush and as required for sight distance
Foreslopes	Mow 15′ or entire width up to 25′ outside of pavement edge or one pass on the backslope to maintain drainage	With side-mounted units mow one swath width past slope that does not exceed 2.5:1	Mow brush up to 15′ or entire width and as required for sight distance
Downslopes	Mow 15′ outside of pavement edge	With side-mounted units mow one swath width past slope that does not exceed 2.5:1	Mow brush and as required for sight distance
Median Areas	Mow 15′ outside of pavement edge or entire width if less than 50′	With side-mounted units mow one swath width past slope that does not exceed 2.5:1	Mow brush and as required for sight distance
Interchange Areas	Mow 15′ from pavement edge and any areas that obstruct sight distances or areas used for snow storage or entire area in urban areas	With side-mounted units mow one swath width past slope that does not exceed 2.5:1	Mow brush and as required for sight distance
Guardrail	Mow 3′ behind guardrail	Mow brush for 3′ behind guardrail and as required for sight distance	Mow brush for 3′ behind guardrail and as required for sight distance

Note – Metric converts as follows: 1 foot = 0.3048 m

Summary Of Safety Tips For Vegetation Control[29]

1. Wear the proper personal safety equipment when conducting vegetation control.

2. Turn on rotating yellow beacons when operation mower units.

3. Display a slow moving vehicle symbol (reflective triangle) on the rear of a mower unit moving down the road. If the tractor has flashing lights, operate them to warn traffic that you are moving slowly with respect to normal traffic flow.

4. Be alert for signs marking areas requiring limited mowing and vegetation control because of wildlife habitat. If you think these "no-mow" areas are becoming a safety problem, report it to your supervisor for review.

5. Face oncoming traffic as much as possible when cutting vegetation around obstacle marker panels and other signs or safety hardware near the edge of the roadway. Be alert at all times for a vehicle out of control or being driven too close to you.

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[28] Source: Vegetation Control for Safety, USDOT, FHWA

[29] Source: Vegetation Control for Safety, USDOT, FHWA

For more information about roadside vegetation management please contact:

Will Lackey
Vegetation Management Coordinator
Oregon Department of Transportation
Salem, Oregon 97310
Telephone: (503) 986-3010
Email: William.Lackey@odot.state.or.us

Chapter 21: Drainage Features

Effective drainage is one of the most critical elements in roadway design. Proper drainage prevents roadway flooding, prevents vehicle hydroplaning, and helps controls erosion. However, drainage features must be constructed and maintained properly to ensure proper hydraulic efficiency and roadside safety.

One engineering need that itself has a direct impact on safety is providing adequate drainage. Roadways are constructed as crowned, rotated or superelevated sections to remove water from the road surface. Adequate drainage facilities are required to channel this water away from the roadway to prevent drainage to the road bed and surface ponding. In addition to hydraulic concerns, drainage features must be designed with proper consideration of their consequences on roadside safety.

This Chapter addresses the design concerns associated with curbs, pipes and culverts, headwalls, and drop inlets. In general, the following alternatives, listed in order of preference, are applicable to all drainage features.

What Is The Primary Function Of The Drainage Ditch?

Ditches are present on the majority of rural roadsides. Their primary function is to collect and distribute the roadway surface water away from the roadbed. Ditches are designed to accommodate runoff from heavy rain storms with minimal highway flooding or damage. Deep ditches constructed close to the roadway are the most efficient in removing and retain the water from the roadway surface. Deep ditches close to the roadway are, however, an obstacle to errant vehicles. Proper ditch design requires considerations of roadside safety as well as hydraulic efficiency.

Typical ditches can be classified by whether they are designed with abrupt or gradual slope changes. Abrupt slope change designs include vee ditches, rounded ditches with a bottom width less than 8 feet (2.4 m), and trapezoidal ditches with bottom widths less than 4 feet (1.2 m). Gradual slope change ditches include rounded ditches with bottom widths of 8 feet (2.4 m) or more and trapezoidal ditches with bottom widths equal to or greater than 4 feet (1.2 m). Diagrams of typical ditches are presented in Figure 21-1.

Vehicles leaving the roadway and encroaching on a ditch face three obstacle areas:

- **Ditch front slope** – If the front slope is 4:1 or steeper, the majority of vehicles entering the ditch will be unable to stop and can be expected to reach the bottom.
- **Ditch bottom** – Abrupt slope changes can result in errant vehicles impacting the ditch bottom.
- **Ditch backslope** – Vehicles traveling through the ditch bottom or becoming airborne from the front slope can impact the backslope.

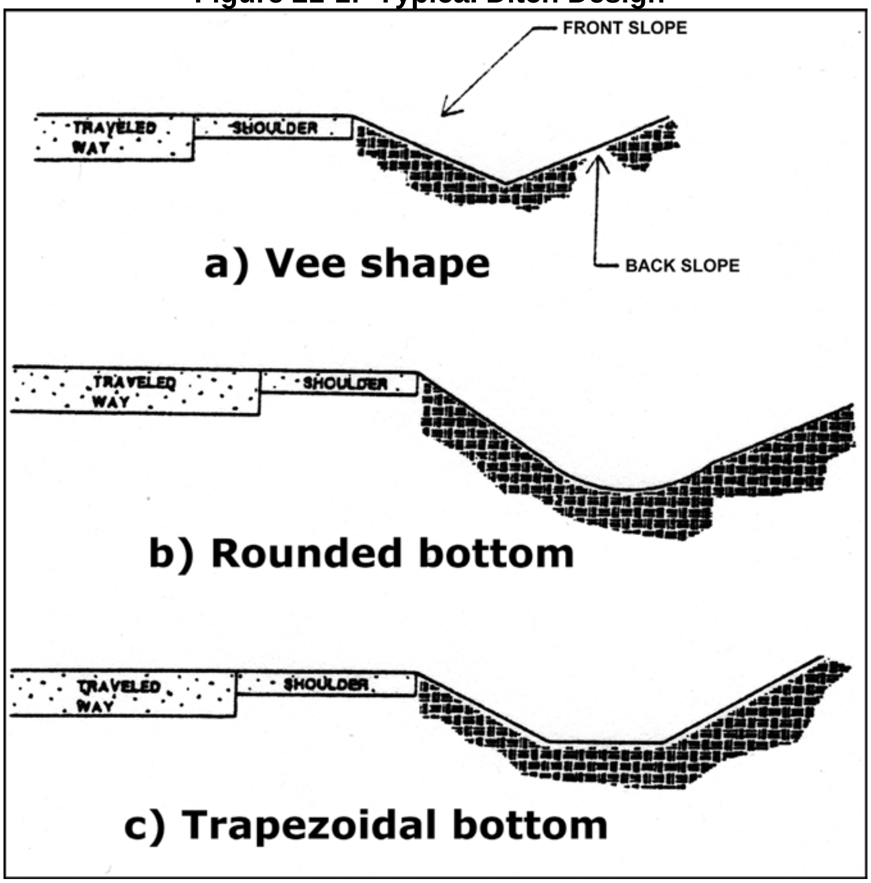
Figure 21-2 and Figure 21-3 present the preferred designs for abrupt and gradual change slopes, respectively. Preferred ditch design cross sections, which fall within the shaded region of each of these figures, are considered traversable.

Ditch sections which fall outside the shaded area of Figure 21-2 and Figure 21-3 are considered non-traversable. As a general rule, they should be located beyond the clear zone, reshaped, converted to a closed system (culvert or pipe), or, in some cases, shielded with a traffic barrier.

If the ditch bottom and slopes are free of any fixed objects, then non-preferred ditch sections may be acceptable for projects having restrictive right-of-way, rugged terrain, or resurfacing, restoration or rehabilitation (RRR) construction projects or on low volume, low speed roadways.

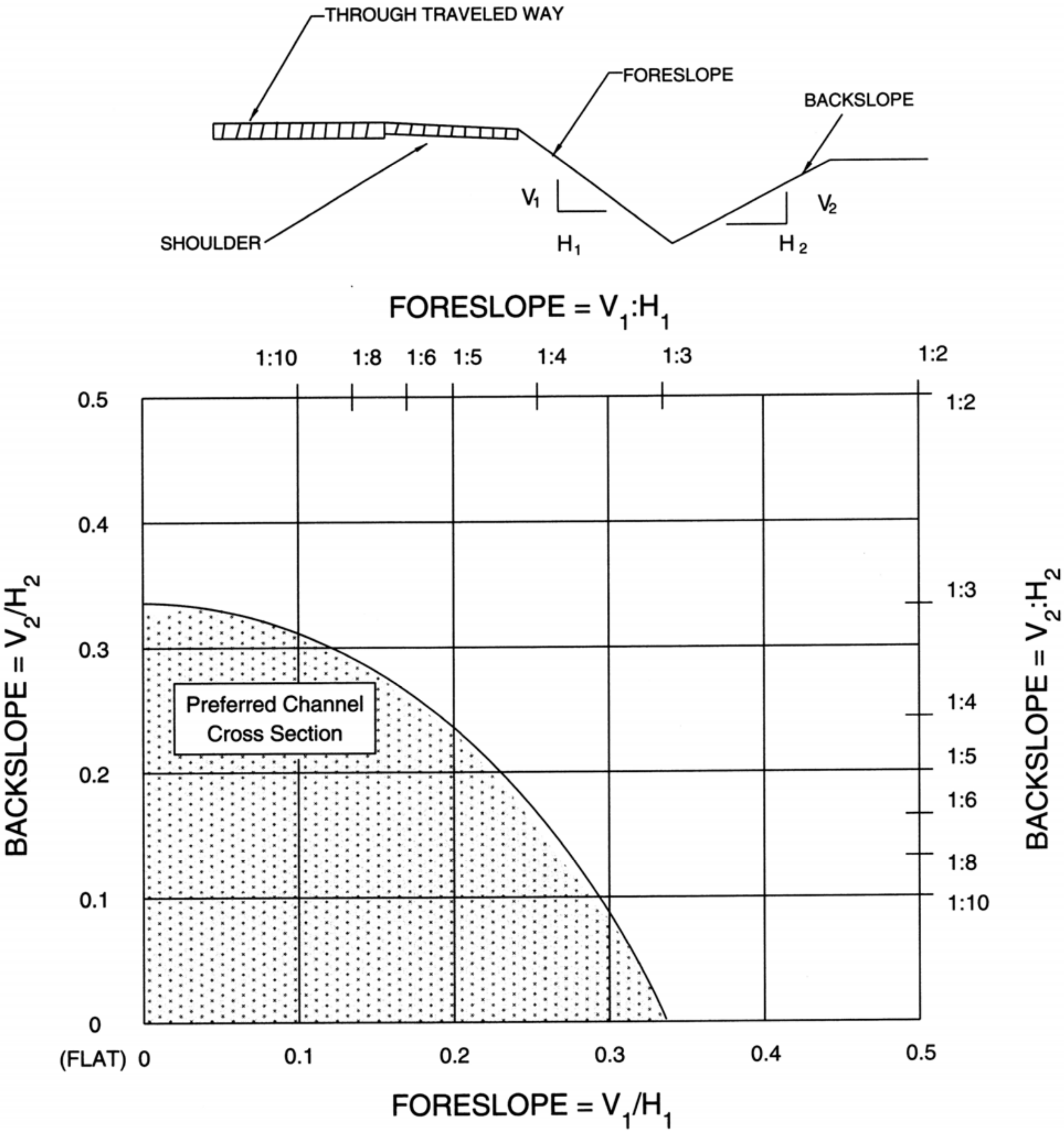
Ditches, both abrupt and gradual slope designs, can funnel a vehicle along the ditch bottom. This increases the probability of impact with any fixed objects present on the slopes or ditch bottom. Breakaway hardware may not operate correctly if the vehicle is airborne or sliding sideways when contact is made. For these reasons non-yielding, fixed objects should not be located on ditch slopes or ditch bottoms.

Figure 21-1: Typical Ditch Design[1]



[1] Source: Design Construction and Maintenance of Highway Safety Features and Appurtenances, FHWA, 1997

Figure 21-2: Preferred Cross Sections For Ditches With Abrupt Slope Changes[2]



*This chart is applicable to all Vee ditches, rounded channels with a bottom width less than 2.4 m [8 ft] and trapezoidal channels with bottom widths less than 1.2 m [4 ft].

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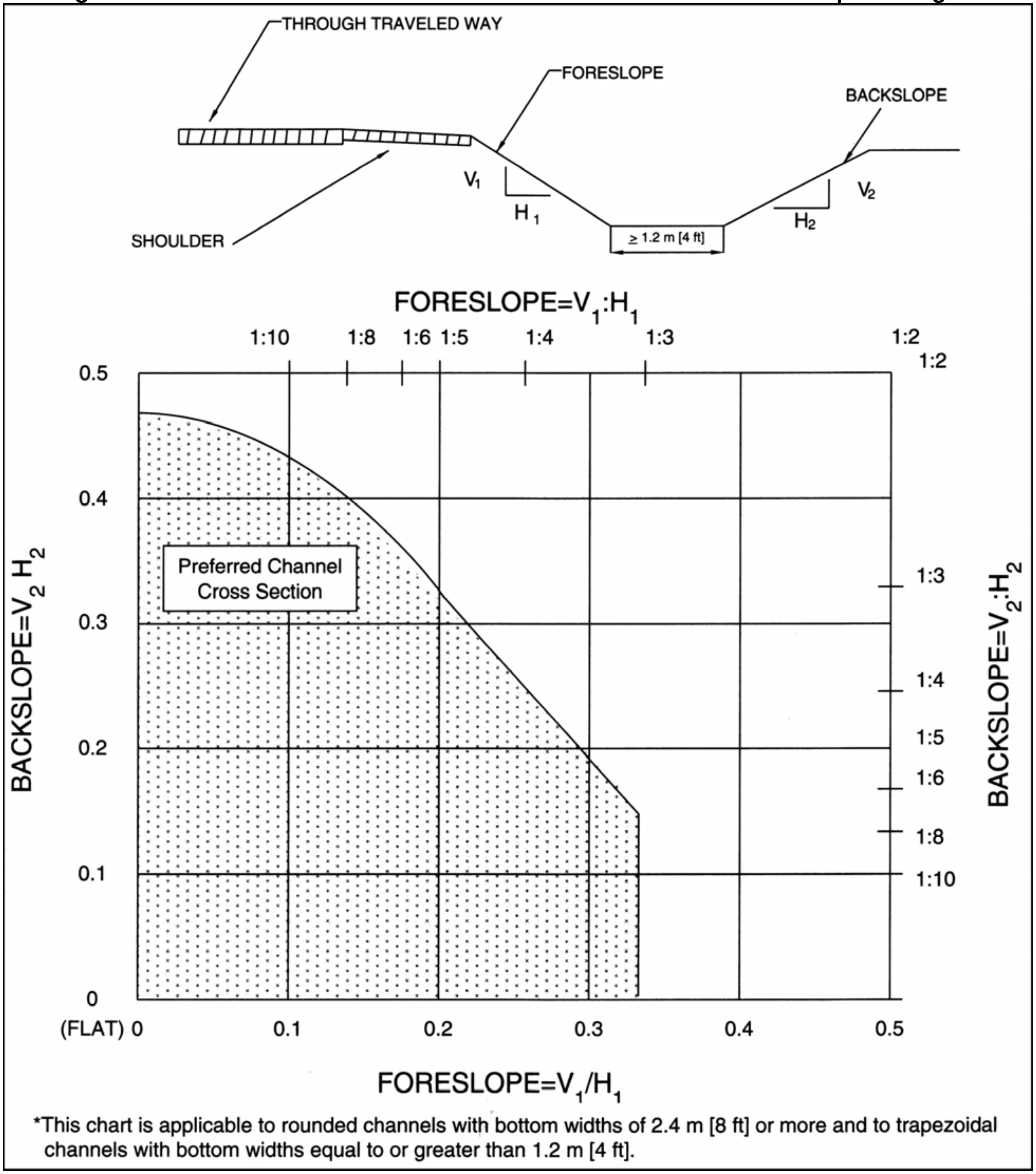
[2] Source: 2002 AASHTO, Roadside Design Guide

Figure 21-3: Preferred Cross Sections For Ditches With Gradual Slope Changes[3]



What Are The Various Types Of Curbs?

Curbs are often believed to have the sole purpose of separating the roadway from the roadside. Curbs are also installed to reduce maintenance operations, provide pavement edge support and to

[3] Source: 2002 AASHTO, Roadside Design Guide

assist in drainage control. While curbs are frequently used on all types of urban roadways, their use on rural roadways should be exercised with caution. Curbs should not be used on rural, high speed roadways when the same objective for their installation can be obtained by another method. If curbs are used, they should be removed after they are no longer necessary.

Curbs are classified into the general categories of vertical and sloping. Each category has numerous types and design details. Improperly designed drainage facilities on curbed roadways can result in vehicles hydroplaning on the roadway surface water.

A. Vertical Curbs

Vertical curbs are designed to inhibit or at least discourage vehicles from leaving the roadway. As shown in Figure 21-4A, the curb exposure height ranges from 6 to 8 inches (150 to 0.3 m) in height. A sloping face is desirable, but generally the face batter does not exceed about 1 inch per 3 inches (25 per 75 mm) of height. The upper corner may be rounded on a radius from 0.5 to 1 inch (12 to 25 mm). Vertical curbs should not be used where design speeds exceed 40 mph (65 km/h). When impacted at high speeds, it is difficult for the operator to retain control of the vehicle. In addition, vertical curbs are not adequate to prevent a vehicle from leaving the roadway.

Generally, vertical curbs should not be used with traffic barriers. Curbs may contribute to vehicle vaulting of all types of traffic barriers and they are not compatible with yielding traffic barriers. An exception to the rule of not using barrier curbs with the traffic barriers may be made on low-speed streets where curbs may be used in conjunction with sidewalks placed on the traffic side of railings on structures.

Vertical curbs introduced intermittently along streets should be offset 2 feet (0.6 m) from the edge of pavement; where continuous, as along a median, barrier curbs should be offset at least 1 foot (0.3 m) and preferably 2 feet (0.6 m).

B. Sloping Curbs

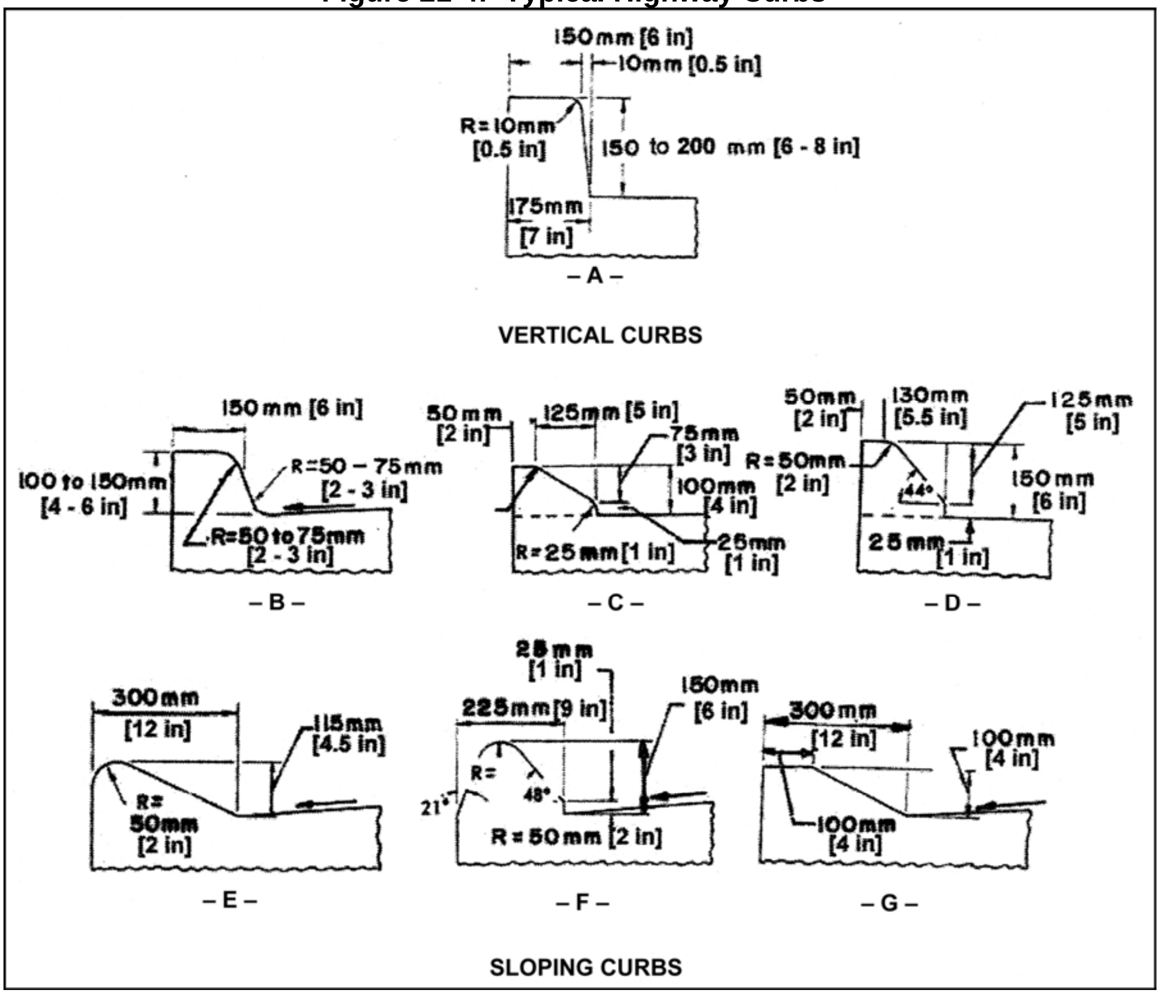
Sloping curbs are designed so that vehicles can easily cross them as shown in Figure 21-4. Sloping curbs designed with 2:1 or flatter ratios should have a height limit of 6 inches (150 mm) to prevent snagging of the vehicle undercarriage. When the face slope is 1:1, the height of sloping curbs should not exceed 4 inches (100 mm). The curbs shown in Figure 21-4B, Figure 21-4C, and Figure 21-4D are considered to be mountable under emergency conditions.

In general, sloping curbs should be used on roadways where design speeds exceed 40 mph (65 km/h). When impacted at high speeds, curbs do not prevent a vehicle from leaving the roadway and can cause vehicle rollover if impacted while vehicle is spinning or slipping sideways.

Sloping curbs are not designed in front of traffic barriers since they can result in unpredictable post impact trajectories. The best practice is to avoid using curbs in the vicinity of guardrails. If a curb must be used, its effect can be minimized by using a maximum curb height of 4 inches (100 mm), placing it so that the face of the curb is at or behind the face of the barrier, and stiffening the beam to reduce deflection. This requires the barrier post to be driven immediately behind the back of the curb. If barriers must be placed behind the curb then they should be a distance of at least 12 feet (3.6 m) from the curb to the barrier. This distance allows the vehicles, which have been vaulted by the curb, to return to ground level prior to impacting the barrier.

To encourage proper use of the shoulders, any sloping curbs should preferably be placed at or beyond the outer shoulder edge. For low-speed street conditions, sloping curbs may be placed at the edge of a through lane, although it is preferable that the curbs be offset 1 to 2 feet (0.3 to 0.6 m). For more information regarding drainage curbs refer to ODOT Standard Drawings Number RD700.

Figure 21-4: Typical Highway Curbs[4]



What Are On-Roadway Drainage Inlets?

On-roadway drainage inlets are usually located near or on the curb or shoulder of a roadway. They are designed to collect and remove the runoff from the road surface. On-roadway inlets include grated inlets, curb opening inlets, slotted drain inlets, or a combination of these basic designs. Proper design of on-road inlets requires:

[4] Source: 2004 AASHTO, A Policy on Geometric Design of Highways and Streets

- That they pose no obstacle to errant motorists. This is usually not a problem since they are installed either flush with the roadway surface or into the curb face.
- Surface inlets must be capable of supporting vehicle wheel loads and present no obstacle to pedestrian and bicycle traffic.
- There are trade-offs involved in the loss of hydraulic efficiency versus an increase in safety. Hydraulic engineers should evaluate the hydraulic design needs, considering the amount of flow, expected debris and grate inlet performance.

What Are Off-Road Inlets?

Off-road drop inlets are designed to collect runoff and are often located in the median of divided roadways and in roadside ditches. Their obstacle to errant motorists can be minimized, and their hydraulic efficiency maximized by constructing them flush with the ditch bottom or slope on which they are located. The opening should be treated to prevent a vehicle wheel from dropping into it, but, unless pedestrians are a concern, the openings do not need to be as small as required for on-pavement grates.

What Are Cross-Drainage Structures?[5]

Cross-drainage structures are designed to carry water underneath the roadway embankment and vary in size from 18-inch (450 mm) pipes of various materials to multi-barreled concrete box culverts or structural plate pipes with clear spans of 10 feet (3 m) or more. Typically, their inlets and outlets consist of concrete headwalls and wingwalls for the larger structures and beveled end sections for the smaller pipes. While these types of designs are hydraulically efficient and minimize erosion problems, they may represent an obstacle to motorists who run off the road. This type of design may result in either a fixed object protruding above an otherwise traversable embankment or an opening into which a vehicle can drop, causing an abrupt stop. The options available to a design engineer to minimize these obstacles are:

- Use a traversable design.
- Moving the drainage structures away from the traveled way.
- Shield the structure.

Installation Of A Traversable Drainage Feature

The inlets and outlets of cross drainage structures can generally be located on the foreslope of parallel ditches. If the foreslope is 3:1 or flatter, it is preferred to extend, or shorten the cross drainage structure to match the face of the embankment slope. Matching the structure to the slope results in a traversable design, reduces obstacle area, reduces erosion problems, and simplifies mowing operations. Matching the faces of the drainage structure with the embankment could also be accomplished by warping the embankment in or out to match the drainage opening. This latter method is not recommended, however, since it will cause discontinuities in the slope resulting in possible vehicle control problems and increased erosion.

Matching the drainage structure to the slope of the embankment is all that is required when the slope is 3:1 or flatter and the culvert has a single round pipe of 36 inches (0.9 m) or less. Pipes

[5] Source: 2002 AASHTO, Roadside Design Guide

greater than 36 inches (0.9 m) can be made traversable for passenger vehicles by using grates or pipes to reduce the clear opening width. Crash tests indicate that automobiles can cross culvert end sections on slopes as steep as 3:1 at speeds as low as 20 mph (30 km/h) and as high as 60 mph (100 km/h) when steel safety pipes are placed on 30-inch (750 mm) centers for cross drainage structures.

Extension Of Drainage Structures

Extending a cross drainage structure whose inlets and outlets cannot be made traversable beyond the clear zone reduces the possibility of the pipe end being impacted; however, it does not eliminate the possibility. The desirable clear zone is not an exact distance and engineering judgment is required. For example, if after extension the culvert headwall is the only significant obstacle at the edge of a traversable clear zone, then the extension may not be the best alternative. This is particularly true on high-speed roadways, controlled access facilities and specific locations with a high probability run-off-the-road occurrence. The preferred treatment is redesigning the inlet/outlet so that it is traversable and no longer an obstacle.

Shield Drainage Structures

When either making the inlet/outlet of cross drainage structures traversable or extending beyond the clear zone are not possible or cost effective, then a shield is the last alternative. Shielding with an appropriate traffic barrier can often be the most effective method of decreasing accident severity.

What Are Parallel Drainage Structures?[6]

Parallel drainage culverts are those which continue the flow of parallel ditches under driveways, intersection roadways, and median crossovers. Parallel drainage features present a significant safety obstacle because they can be struck head on by impacting vehicles. Effective treatments for improving the safety of parallel drainage features, in order of preference, include:

- Eliminating the structure
- Moving the structure away from the traveled way
- Installing a traversable design
- Shield the structure.

These treatments are described below:

A. Eliminate the Structure

Eliminating parallel drainage structures is the preferred choice for increasing roadside safety. This can be accomplished by developing an overflow section and by converting an open ditch to a storm drain.

Connecting an open ditch to a storm drain is the ideal solution but is also expensive. The costs are reasonable and cost effective at proper locations. Rural roadways with closely spaced residential driveways are good candidates for converting an open ditch to a storm drain.

[6] Source: 2002 AASHTO, Roadside Design Guide

B. Relocate Parallel Structure

Where sufficient right-of-way exists at intersections, the parallel drainage structure can be moved further from the main roadway edge. Although the structure is further removed from the main roadway, it is still recommended that the inlet and outlet match the embankment slope.

C. Traversable Designs

The designer should try to provide the flattest side slopes as is practical in each situation, particularly in areas where the embankment has shown a high probability of being struck head-on by a vehicle. Cross slopes of 10:1 or flatter are suggested, with slopes of 20:1 desirable when possible. Once this has been done, parallel drainage structures should match the selected sideslope and should be safety treated if possible when they are located in a vulnerable position relative to main road traffic.

As a general rule, parallel drainage structures with 24-inch (0.6 m) or less diameter pipe do not require a grate. For parallel drainage structures the use of safety pipes set on 24-inch (0.6 m) centers will significantly reduce wheel snagging.

D. Shielding of Parallel Drainage Structures

Shielding the obstacle with a traffic barrier may be necessary when the parallel drainage structure cannot be made traversable, cannot be relocated or eliminated, or is too large to be treated effectively.

Construction Of Drainage Features

Some important items to remember while constructing the drainage features include the following:

- Inlets and outlets of drainage structures should be removed from the clear zone, made traversable, or shielded.
- Inlets and outlets can be made traversable by matching the slope of the structure to the embankment, when the slope is 3:1 or flatter, and the culvert has a single round pipe of 3 feet (0.9 m) or less.
- Pipes greater than 3 feet (0.9 m) can be made traversable for passenger vehicles by using safety grates or pipes to reduce the clear opening width. Oregon state specifications should be followed on the spacing of the safety pipes.
- No part of the drainage feature should extend more than four inches (100 mm) above the surrounding terrain.
- Depressions deeper than four inches may trap a vehicle wheel, causing loss of steering control or rollover, and should be avoided.
- Culvert openings should follow the force of the slope. Headwalls above the opening should be avoided, and structurally adequate grates should be used to cover large culvert openings.

Grate Design Patterns

- Grates in ditch lines and gutters should have bars parallel to the roadway centerline.
- Grates on roadway slopes should have bars at right angles to the roadway. Special precautions must be taken in urban areas to assure that cycle tires will not pass through

grates placed in the roadway. In this case crossbars or diagonal bars must be used. Grates at the ends of culverts crossing the roadway at a right angle should conform to the slopes involved.

- For culverts parallel to the roadway, the incline angle of the grate at the ends of the culvert is extremely critical.
- Guidelines for design and installation are:
    - Slopes of 20:1 or flatter are recommended (a maximum slope of 10:1 can be used near low-speed roadways)
    - Downward slopes of 6:1 or greater may produce vehicle pitch-over, and possibly end-to-end rollovers.
    - Upslopes of 6:1 or greater may cause vehicles to become completely airborne for several car lengths, if speeds are high.

Maintenance Practices For Drainage

Many factors that adversely affect the safety and water removal performance of drainage structures can be identified during routine maintenance. Some of these can be readily corrected and others may require extensive redesign. Listed below are factors that should be addressed during routine maintenance for the best results.

A. Drainage Structure

1. Bent or broken safety pipes from prior impacts can severely affect performance during the next impact. Bent or broken safety pipes should be repaired or replaced.
2. Check to ensure that the safety pipes are installed in the proper direction. Safety pipes on culverts passing beneath the main road should be placed on 30-inch (0.75 m) centers and run from top to bottom of the culvert. Parallel culverts should have the safety pipes on 2-foot (0.6 m) centers and run from side to side.
3. Check that the bolts are 16 mm and fastened securely.
4. Check that grate assemblies are correctly fastened and do not extend more than 4 inches (100 mm) above the surrounding terrain.
5. Check if the headwall is flush with embankment slope. Is redesign or barrier installation necessary?
6. Clean drainage pipe with water jet or other appropriate method.
7. Look for cracks, disintegration of concrete, and broken wing walls. Report deterioration to the Maintenance Engineer.
8. Culverts under high fills, especially in the first few years after construction, should be checked for settlement that may cause cracks or cause construction joints to open.

B. Pipe Apron

1. Check the apron guard to determine if it requires cleaning. If there is debris on the guard, it should be cleaned.
2. Look for damage on the pipe apron. If the pipe apron is damaged, repair to a like-new condition. If replacement of the pipe apron is required, contact the resident maintenance engineer to determine what pipe apron should be used.
3. Look for damage on the apron guard. If the apron guard is damaged, repair to a like-new condition. Replace apron guard if damage is too extensive to repair.

4. Check to see if there is erosion at the outlet. If so, place broken concrete or stone at the outlet to prevent erosion problems. The stone placed shall not project up more than four inches (100 mm) above the ground to avoid snagging vehicles.

C. Intake

Intakes are used to collect water so that it can be carried away from the roadway. They are located in medians of divided roadways and sometimes in roadside ditches. Intakes should be designed and located to present a minimal obstacle to motorist who stray or deviate from the roadway.

1. Check the intake structure to determine if it needs cleaning. If there is debris in the intake structure, it should be removed.
2. Does this particular intake accumulate more debris than others in the area? If it does, determine the cause and take appropriate measures.
3. Is there erosion around the intake that would cause water to pond or cause a vehicle to snag in the intake? If soil has eroded, it should be replaced and recompacted.

D. Grate

1. Check the grate to see if it has broken or deformed bars. If it does, repair or replace the grate.
2. Make sure that the grate is anchored to the foundation. If it is not, correct the situation.
3. Modify grates so that they are flush with the surrounding terrain, and not too steep.
4. Check grates to make sure they are structurally adequate and that the bars are running in the correct direction.

E. Ditches

The primary function of a roadside ditch is to collect and convey surface water along the highway right-of-way until it can be drained away from the roadbed. Ditches vary in width depending on the amount of water they need to carry.

1. Determine if the ditch requires cleaning. Remove all silt from the ditch when it interferes with normal functioning. The silt needs to be removed when water ponds in the ditch, water is diverted onto private property, or when water is diverted onto the shoulder or surface.
2. Has the ditch deteriorated due to erosion? Repair the ditches when it appears that the roadway, structures, or adjoining property may be damaged by continued erosion.
3. Has-the ditch deteriorated due to slides? Repair the ditch when it appears that the roadway, structures, or adjoining property may be damaged by continued slides.
4. Has the ditch deteriorated due to cave-ins? Repair the ditch when it appears that the roadway, structures, or adjoining property may be damaged by continued cave-ins.
5. Does the ditch meet the original standards that it was built to? If not, work should be scheduled to regrade the ditch.

F. Shielding Concerns

1. Is a barrier needed?
2. Does an existing barrier adequately shield the drainage structure?
3. Is the barrier installed correctly with approved terminals?
4. If the barrier has been impacted, is it still serviceable or is maintenance required?

5. Are appropriate obstacle markers and delineators in place?

G. Other Considerations

1. Grade roadside beyond the shoulder where possible to remove pockets and smooth out the recovery area.
2. Regrade gore areas where roadsides diverge, such as at "Y" intersections, to provide a safe recovery space.
3. Reshape slopes next to structures to provide flatter recovery areas.
4. Remove or relocate culvert headwalls.
5. Grates at an angle are much safer for bicyclists or anything with narrow wheels than parallel grates. Check with your supervisor to see if you can replace parallel grates with angle grates.
6. Sometimes large stones are dumped in a washout as a quick fix until a full repair can be made. Never leave large or loose stones on the edge of the roadway. Level the stones and mark the area with warning devices such as vertical panels.

Summary Of Drainage Features

1. As a general rule barrier curbs should not be installed on roadways with design speeds greater than 40 mph (65 km/h).
2. Both vertical and sloping curbs increase the probability of vehicle rollover and loss of control on high speed facilitates.
3. If curbs are used with a guardrail, the face of the guardrail should be flush with the curb face.
4. Drop inlet grates at locations with pedestrian activity must be designed to safely accommodate both pedestrian and bicycle traffic.
5. Proper hydraulic design is also a safety concern. Roadway flooding and improper removal of surface water can result in crashes as well as roadbed damage.
6. The flatter the embankment slopes, the safer the roadside. Parallel embankments should be as flat as possible, but not steeper than 3:1. Cross slopes should be preferably 10:1, but generally not less than 6:1. Cross slopes in urban areas and in low speed areas (less than 40 mph (65 km/h)) may be steeper than 6:1.
7. Headwalls of the drainage structure should match the slope of the embankment.
8. Culverts passing beneath the main roadway, cross drainage structures, should not be installed on slopes steeper than 3:1. Cross drainage structures consisting of one 36-inch (0.9 m) pipe or multiple round pipes of 30 inches (750 mm) or less do not need grates or safety pipes.
9. Cross drainage structures larger than above should have grates or safety pipes installed. Safety pipes should be installed on 30-inch (750 mm) centers and run from top to bottom of the culvert. .
10. Culverts for passing water parallel to the main roadway should generally not be installed on slopes steeper than 6:1. Parallel structures consisting of a single pipe 24 inches (0.6 m) or less in diameter do not require a grate.
11. Parallel structures consisting of multiple pipes or a single pipe greater than 24 inches (0.6 m) require a grate or safety pipes. Safety pipes for parallel grates should be placed on 24-inch (0.6 m) centers and run from side to side.

12. Preferred ditch sections must be used with parallel grates.
13. The best solution is to eliminate the drainage structures by installing a drainage sewer and covering it to achieve a flat roadside. This option should be considered for medians, roadways with closely spaced driveways, and locations with high accident potential.
14. Consideration should be given to moving the structures further away from the main roadway.
15. Drainage structures should not extend more than 4 inches (100 mm) above the surrounding terrain. This includes headwalls, wingwalls, grates, and the end of the culvert pipe.
16. Commercial products are available to extend the existing drainage pipe and achieve a safety slope end section.
17. If insufficient room exists to provide the desired slope, then a sloped drop box can often be constructed.
18. If everything to provide a safe and hydraulically efficient drainage structure fails, then shielding should be installed.

For additional information important information about drainage features, please refer to: "2002 Roadside Design Guide", American Association of State Highway and Transportations Officials (AASHTO), Washington, DC, 2002

Chapter 22: Roadside Barriers

Single-vehicle, run-off-road crashes account for approximately thirty percent of highway fatalities. These fatalities result from vehicles colliding with a fixed object such as trees, utility poles, unshielded bridge rail ends, or steep sideslopes.

Strategies to help reduce run-off-road crash problems include:

A. Keep vehicles from encroaching on the roadside

- Install shoulder rumble strips;
- Provide enhanced shoulder or in-lane delineation and marking for sharp curves;
- Provide improved highway geometry for horizontal curves;
- Provide enhanced pavement markings;
- Provide skid-resistant pavement surfaces; and
- Eliminate shoulder drop-offs.

B. Minimize the likelihood of crashing into an object or overturning if the vehicle travels off the shoulders

- Design safer slopes and ditches to prevent rollovers;
- Remove/relocate objects in hazardous locations; and
- Delineate trees or utility poles with retroreflective tape.

C. Reduce the severity of the crash

- Reduce crash severity by making roadside hardware crashworthy or traversable and shielding fixed-object hazards with barriers.

What Is The Purpose Of Roadside Barriers?[1]

A roadside barrier is a longitudinal barrier used to shield motorists from natural or man-made obstacles located along either side of a traveled way. It may also be used to protect pedestrians and cyclists from vehicular traffic under special conditions.

The primary purpose of all roadside barriers is to prevent a vehicle from leaving the traveled way and striking a fixed object or terrain feature that is less forgiving than striking the barrier itself. This purpose is accomplished by using a barrier system to contain and redirect the impacting vehicle.

Your first action should always be to remove hazards, as barriers themselves can be hazards to drivers. About thirty percent of crashes involving a barrier result in injuries or fatalities, which is why you should install barriers only when they pose a lesser risk for drivers than colliding with

[1] Source: 2002 AASHTO Roadside Design Guide

other roadside hazards. Remember that the barrier will probably be hit more often because it will be closer to the road than the object it shields.

A primary factor in your deliberation should be cost-effectiveness. If the barrier costs (installation, maintenance, and cost of crashes with the rail) are higher than the benefits (reduced crash severity), a barrier is probably not the best solution.

Also, once you install a barrier, you are responsible for maintaining it. If your agency cannot commit to regular barrier inspection and prompt repair of damage from crashes or corrosion, then consider other remedies.

This Chapter will help you decide whether barriers will improve safety on your agency's roads.

Typical Classification Of Barriers

Barriers are typically classified by their primary function as follows:

A. Roadside Barriers: Longitudinal barriers that shield motorists from dangerous conditions along the roadside and reduce the severity of run-off-road crashes. When designed, installed, and maintained properly, they function by containing and redirecting errant vehicles.

B. Median Barriers: Longitudinal barriers that primarily function to prevent an errant vehicle from crossing the highway median.

C. Bridge Railing: Longitudinal barriers whose primary function is to prevent an errant vehicle from going over the side of a bridge structure.

D. Crash Cushion: An impact attenuator device that prevents an errant vehicle from impacting fixed object hazards by gradually decelerating the vehicle to a safe stop or redirecting the vehicle away from the hazard.

The content of this Chapter is based on the 2002 AASHTO Roadside Design Guide and will only focus on the roadside and median barriers.

Warrants For Roadside Barriers

Barrier warrants are based on the premise that a traffic barrier should be installed only if it reduces the severity of potential crashes. It is important to note that the probability and frequency of run-off-road crashes are not directly related to the severity of potential crashes.

The 2002 AASHTO Design Guide gives warrants for barrier installation. If the consequences of a vehicle striking a fixed object or running off the road are more serious than hitting a traffic barrier, the barrier is considered warranted.

Thus, warrants may also be established by using a cost- benefit analysis whereby factors such as design speed and traffic volume can be evaluated in relation to barrier need. Costs associated with the barrier (installation cost, maintenance costs and crash costs) are compared to similar costs associated with the unshielded hazard. This procedure is typically used to evaluate three options:

1. Remove or reduce the hazard so that it no longer requires shielding.
2. Install an appropriate barrier.
3. Leave the hazard unshielded.

The third option would normally be cost-effective only on low volume and/or low speed facilities or where engineering studies show the probability of crash is low.

Highway hazards that warrant shielding by a roadside barrier can be placed in one of two basic categories: embankments or roadside obstacles. Pedestrians and other bystanders may also warrant protection from vehicular traffic. Specific highway features contained in each of these categories are discussed in the following sections.

A. Embankments

Embankment height and side slope are the basic factors considered in determining barrier need as shown in Figure 22-1. These criteria are based on studies of the relative severity of encroachments on embankments versus impacts with roadside barriers. Embankments with slope and height combinations on or below the curve do not warrant shielding unless they contain obstacles within the clear zone that present a serious hazard to errant motorists. Figure 22-1, however, accounts for neither the probability of an encroachment occurring nor the relative costs of installing a traffic barrier versus leaving the slope unshielded.

A rounded slope reduces the chances of an errant vehicle becoming airborne, thus reducing the hazard of an encroachment by affording the driver more control over the vehicle. Optimum rounding is arbitrarily defined as the minimum radius that a standard size automobile can negotiate without losing tire contact.

B. Roadside Obstacles

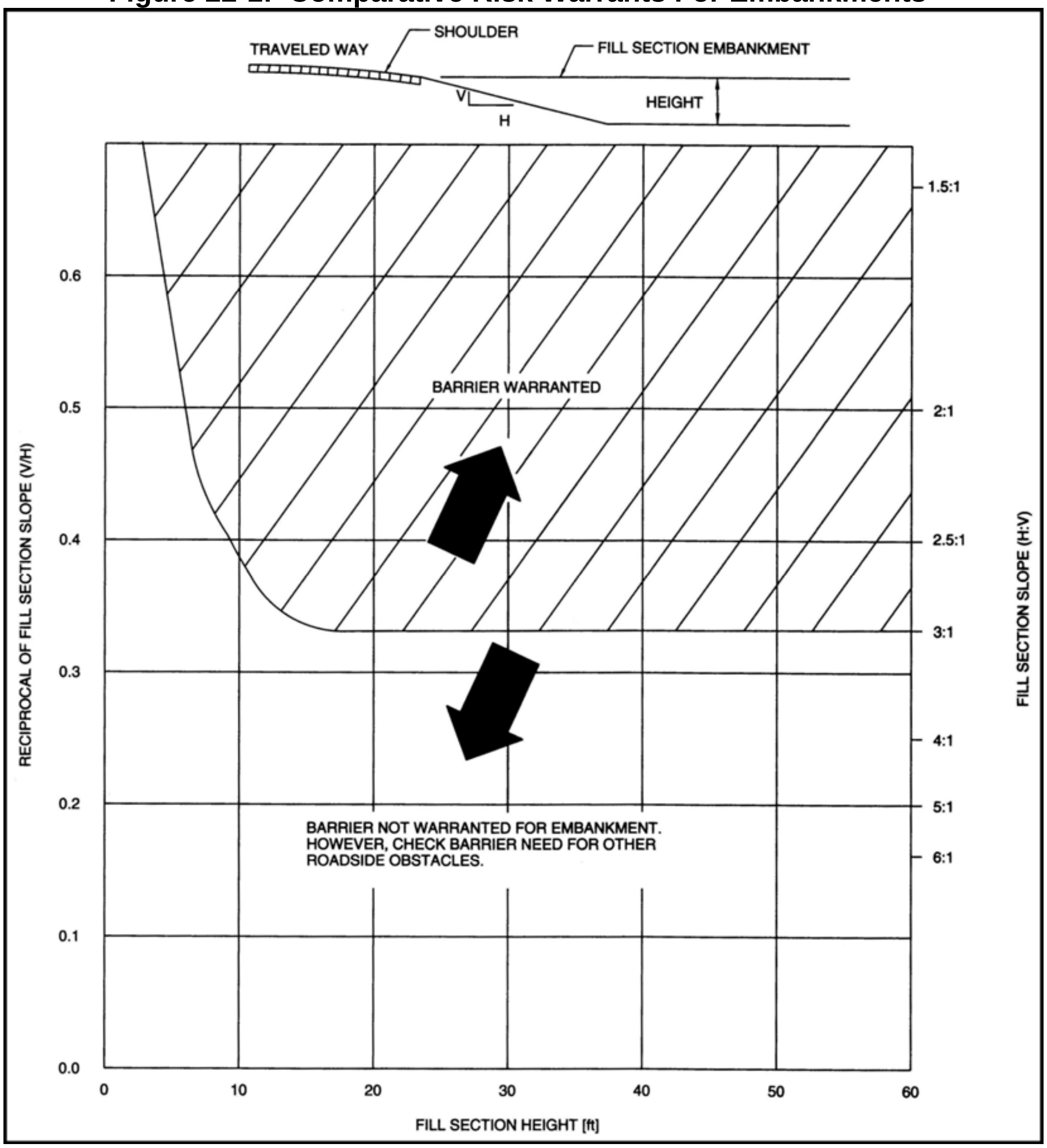
Roadside obstacles may be nontraversable hazards or fixed objects and may be either man-made (such as culvert inlets) or natural (such as trees). Together, these highway hazards account for over thirty percent of all highway fatalities each year. Barrier warrants for roadside obstacles are a function of the obstacle itself and the likelihood that it will be hit. However, a barrier should be installed only if it is clear that the result of a vehicle striking the barrier will be less severe than the accident resulting from hitting the unshielded object.

Nontraversable and fixed object hazards which normally warrant shielding are listed in Table 22-1. While roadside obstacles immediately adjacent to the traveled way are usually removed, relocated, modified (to be less hazardous) or shielded, the optimal solution becomes less evident as the distance between the hazard and the roadway increases. The clear zone table contained in Chapter 20: is intended as a guide to aid the designer in determining if the hazard constitutes a significant-enough threat to an errant motorist to warrant action.

C. Bystanders, Pedestrians, and Cyclists

Bystanders, pedestrians, and cyclists are another area of concern to highway engineers. The most desirable solution to this problem is to separate them from vehicular traffic. Since this solution is not always practical, alternate means of protecting them is sometimes necessary. On low speed streets, a barrier curb will usually suffice to separate pedestrians and cyclists from vehicular traffic. However, at speeds over 40 mph (65 km/h) a vehicle may mount the curb from relatively flat approach angles. Hence, when sidewalks or bicycle paths are adjacent to the traveled way of high speed facilities, consideration may be given to installing a barrier to shield pedestrians, cyclists, businesses, and/or residences which are near the right-of-way, particularly at locations having a history of run-off-road crashes.

Figure 22-1: Comparative Risk Warrants For Embankments[2]



[2] Source: 2002 AASHTO Roadside Design Guide

Table 22-1: Barrier Warrants For Nontraversable And Fixed Object Hazards[3]

Obstacles	Mitigating Measure
Bridge piers, abutments and railing ends	Shielding generally required
Boulders	A judgment decision based on nature of hazard and likelihood of impact
Culverts, pipes, headwalls	A judgment decision based on size, shape, and location of hazard
Cut slopes (smooth)	Shielding not generally required
Cut slopes (rough)	A judgment decision based on likelihood of impact
Ditches (parallel)	Refer to Chapter 20
Ditches (perpendicular)	Shielding generally required if likelihood of head-on impact is high
Embankment	A judgment decision based on fill height and slope (See Figure 22-1)
Retaining wall	A judgment decision based on relative smoothness of wall and anticipated maximum angle of impact
Sign/luminaire supports*	Shielding generally required for non-breakaway supports
Traffic signal supports**	Isolated traffic signals within a clear zone on high-speed rural facilities may warrant shielding
Trees	A judgment decision based on site specific circumstances
Utility poles	Shielding may be warranted on a case-by-case basis
Permanent bodies of water	A judgment decision based on location and depth of water and likelihood of encroachment
Notes: Shielding a non-traversable or fixed object hazard is usually warranted only when the hazard is within the clear zone and cannot practically or economically be removed, relocated, or made breakaway, and it is determined that the barrier is a lesser hazard than the unshielded condition. Marginal situations, with respect to placement or omission of a barrier, will usually be decided by accident experience, either at the site or at a comparable site. * Where feasible, all sign and luminaire supports should be a breakaway design regardless of their distance from the roadway if there is a reasonable likelihood of their being hit by an errant motorist. ** In practice, relatively few traffic signal supports, including flashing light signals and gates used at railroad crossing, are shielded. If shielding is deemed necessary, however, crash cushions are sometimes used in lieu of a longitudinal barrier installation.	

Functions Of Roadside Barrier Elements

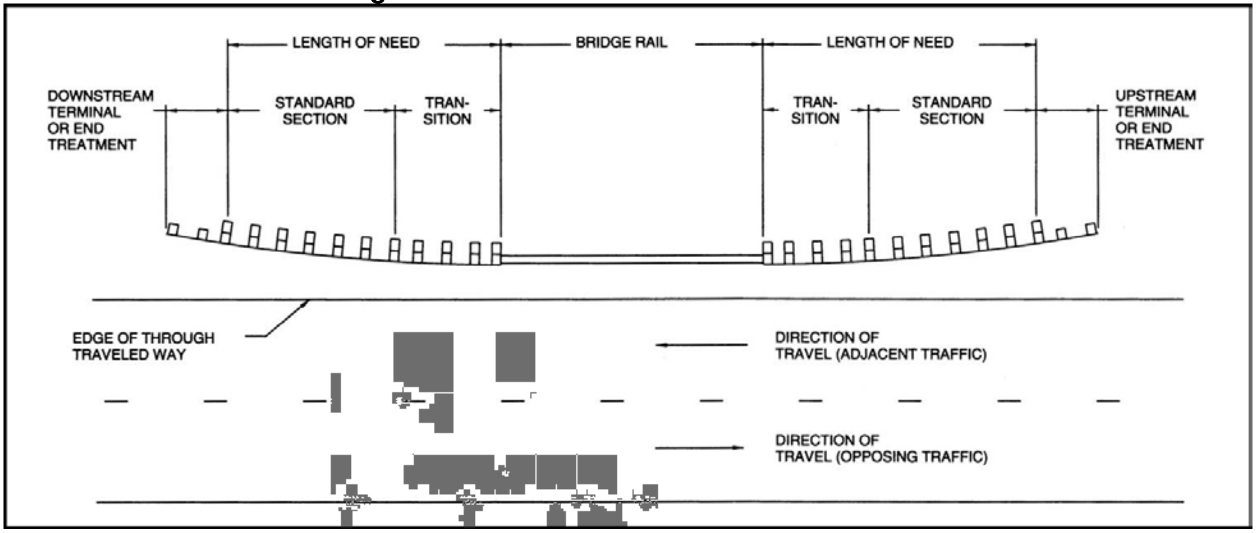
Figure 22-2 below shows the various roadside barrier elements. Functions of the various roadside barrier elements are as follows:

- End treatment – design modification to the end of a longitudinal barrier intended to safely accommodate end impacts and to develop the structural capacity of the barrier.
- Length of need (LON) – total length of the barrier needed to shield the area of concern.
- Standard section – section of barrier having standard design features.
- Transition – section of barrier between two different barriers or between a barrier and a bridge rail or a rigid object such as a bridge pier, designed to provide a gradual change in stiffness to prevent vehicle pocketing or snagging.

For designs of the various elements of longitudinal barriers, refer to 2002 AASHTO Roadside Design Guide.

[3] Source: 2002 AASHTO Roadside Design Guide

Figure 22-2: Roadside Barrier Elements[4]



Categories Of The Roadside Barriers

Roadside barriers are usually categorized as flexible, semi-rigid, or rigid, depending on their deflection characteristics upon impact. Flexible systems are generally more forgiving than the other categories, since much of the impact is dissipated by the deflection of the barrier and lower impact forces are imposed upon the vehicle. Some of the most widely used roadside barriers used in Oregon will be discussed in the following sections.

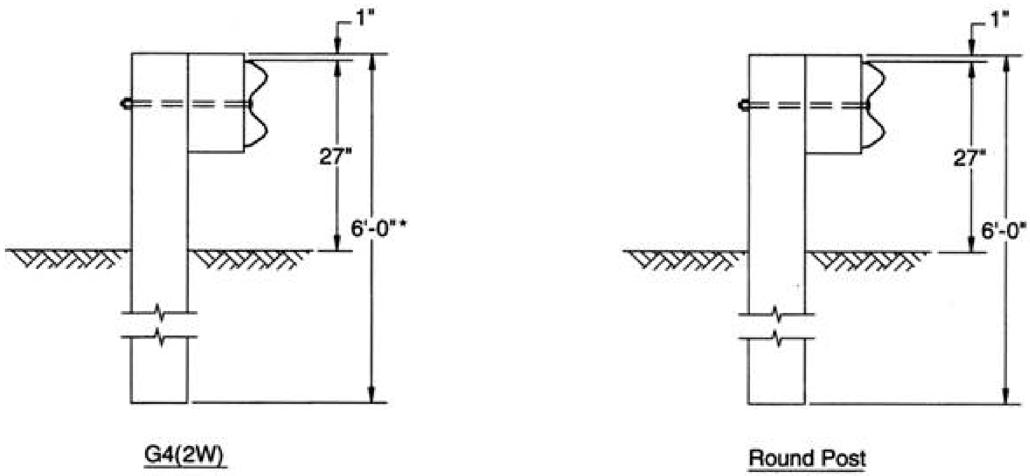
A. Semi-Rigid Systems

1. Blocked-Out W-Beam (Strong Post)

Strong-post W-beam is the most common barrier system in use today. It is characterized by wood or steel posts and a W-beam rail element that is blocked out from the posts. The blockage minimizes vehicle snagging and reduces the likelihood of a vehicle vaulting over the barrier by maintaining rail height during the initial stages of post deflection. Several acceptable post designs are in use, the most common being 6” x 8” (150 to 0.2 m) wood posts, as shown in Figure 22-3 and Figure 22-4. This system is set 27” (690 mm) to the top of rail and have a 6’3” (1.9 m) post spacing. Block-outs are typically of the same material and cross-section as the posts. The maximum deflection observed with this system was approximately 3 feet (0.90 m). For barrier installation and details refer to ODOT Standard Drawings, numbers RD400 to RD460. Typical elements of the W-beam on Blocked-out Wood Posts are shown in Figure 22-5.

[4] Source: 2002 AASHTO Roadside Design Guide

Figure 22-3: W-Beam On Blocked-Out Wood Posts (Semi-Rigid)[5]



AASHTO Designation varies with post type as noted below:

Post Type:	G4(2W)–6 in. x 8 in. wood**
	Round Post–7-in. diameter wood
Post Spacing:	6 ft-3 in.
Maximum Dynamic Deflection:	approximately 3 ft

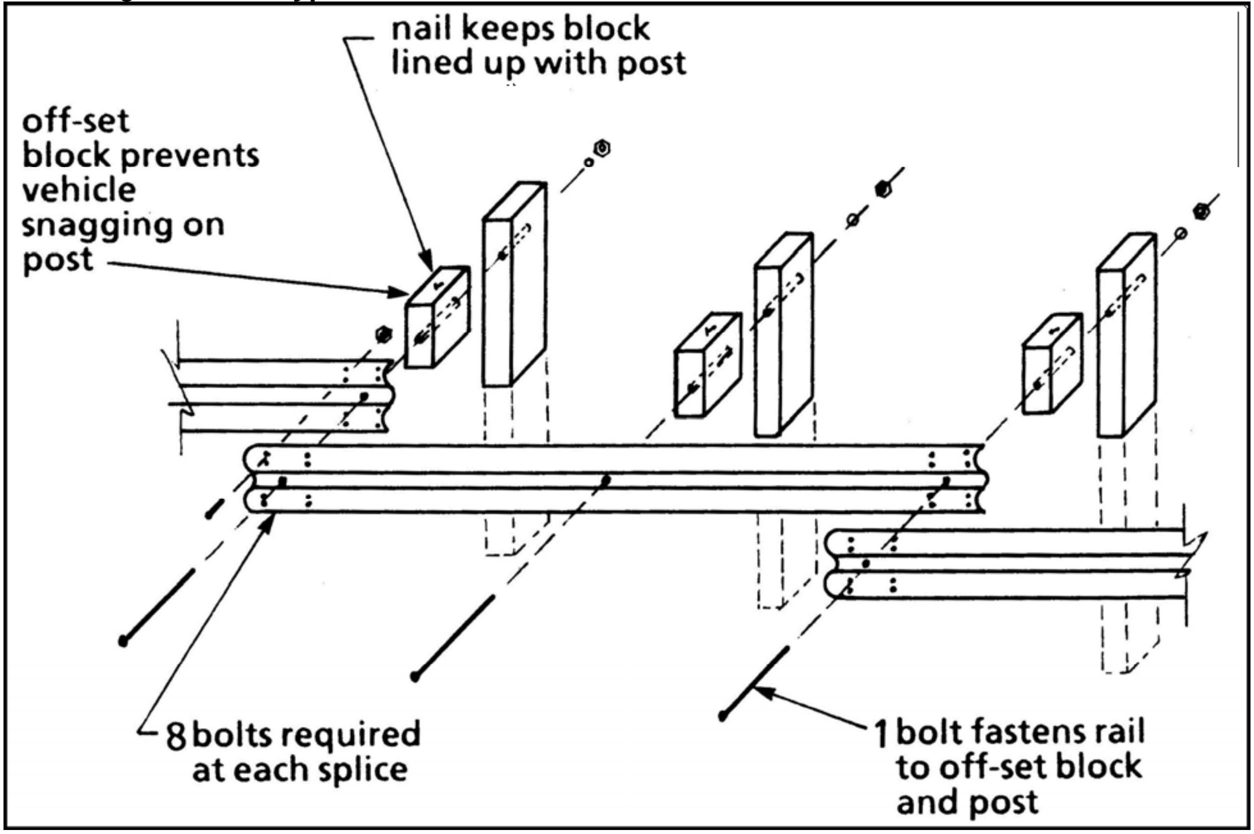
* 5 ft-4 in. posts are also acceptable

** 8 in. x 8 in. wood posts are also acceptable

Figure 22-4: W-Beam On Blocked-Out Wood Posts (Semi-Rigid Barrier)

[5] Source: 2002 AASHTO Roadside Design Guide

Figure 22-5: Typical Elements Of The W-Beam On Blocked-Out Wood Posts[6]



Typical elements of the W-beam barrier on blocked-out wood posts:

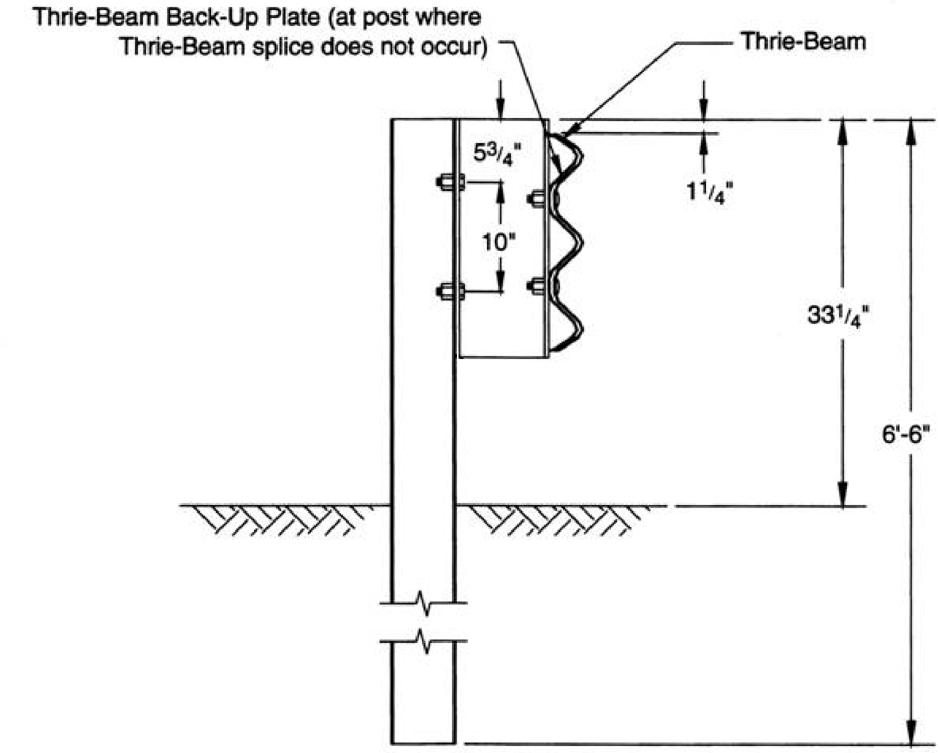
- 12'-6" galvanized steel W-beam rail sections.
- Eight 5/8" x 1-1/4" galvanized button head (carriage) bolts with recess nuts for each splice in the rail.
- One 5/8" x 18" long galvanized button head (carriage) bolt with washer and recess nut for fastening rail to wooden post with offset wooden block.
- One 6" x 8" x 1'-2" treated wood offset block to space the rail from the post.
- 6" x 8" x 6'-0" treated wood posts.
- One 10d galvanized nail to keep offset block lined up to post.

2. Blocked-Out Thrie-Beam (Strong Post)

This system is a stronger version of the blocked-out W-beam rail. Like the common W-beam designs, block-outs are 6" x 8" wood blocks and have a 6'3" (1.9 m) post spacing. This barrier has been successfully crash-tested with a top railing height of 32" (810 mm). The maximum deflection observed with this system was 1.0 to 3.0 feet (0.3 to 0.9 m). For blocked-out thrie-beam installation design details, refer to ODOT Standard Drawing number RD410. The blocked-out thrie-beam (strong post) barrier is shown in Figure 22-6 and Figure 22-7.

[6] Source: W-Beam Barrier Repair and Maintenance, USDOT, FHWA

Figure 22-6: Blocked Out Thrie Beam On Strong Posts (Semi-Rigid)[7]



AASHTO Designation:	**G 9**
Post Type:	W6 x 9 steel or 6 in. x 8 in. wood*
Post Spacing:	6 ft-3 in.
Beam Type:	12 gage thrie-beam
Maximum Dynamic Deflection:	Approximately 24 in.

Figure 22-7: Blocked Out Thrie Beam On Strong Posts (Semi-Rigid)[8]

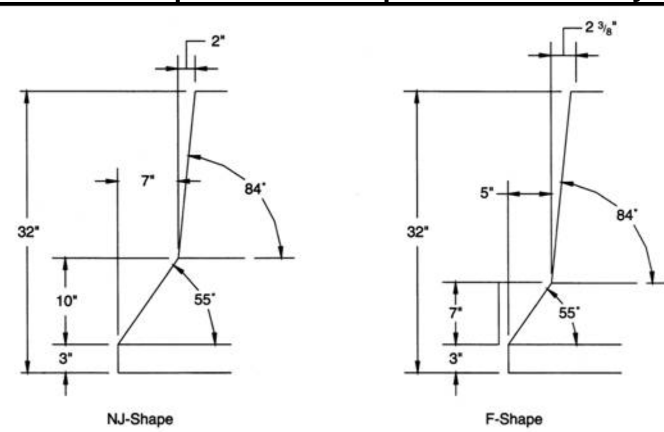
[7] Source: 2002 AASHTO Roadside Design Guide
[8] Source: Trinity Highway Project

B. Rigid Systems

1. Concrete Safety Shape (New Jersey Barrier)

The concrete safety shape roadside barrier is a rigid system having a sloped front face and a vertical back face. Except for the back face, the design details and performance of this barrier are identical to the concrete median barrier (CMB). The barrier height for the basic design is 32” (810 mm). This includes provision for a 3” (75mm) future pavement overlay, reducing the height to 29” (735mm). When overlay depths are expected to exceed 3” (75mm), the height of the concrete barrier must be adjusted. To counteract the overturning moment of trucks with higher centers of gravity or unrestrained loads, walls even higher than 42” (1070 mm) are recommended. The F-Shape Concrete Barrier is by far the most common rigid traffic barrier used in Oregon. Its popularity is based on its relatively low cost, an essentially effective performance, and its maintenance-free characteristics. For F-Shape Concrete Barriers installation and details refer to ODOT Standard Drawings, numbers RD500 to RD580. F-Shape and New Jersey Concrete Barriers are shown in Figure 22-8.

Figure 22-8: F-Shape And NJ-Shape Concrete Safety Barriers[9]



AASHTO Designation:	**SGM11a**	**SGM10a**
Nominal Barrier Height:	32 in.	32 in.
Maximum Dynamic Deflection*:	0	0

Remarks: The concrete safety shapes are the only operational rigid barriers. The lower sloped face redirects vehicles without damage under low-impact conditions. During moderate to severe impacts, some energy is dissipated when the vehicle is lifted off the pavement. The loss of tire contact with the pavement also aids redirection.

The details of the shape are critical. The distance from the pavement to the break between the upper and lower slopes should be kept at 13 in. or below. Barrier performance under moderate to severe impact conditions is not significantly affected by overlays on the lower sloped face. The overall height of the barrier, however, needs to be maintained at a minimum of 29 in.

Selection Criteria For Roadside Barriers

Once it has been decided that a roadside barrier is warranted, a specific barrier type must be selected. Although this selection process is complicated by a number of variables and the lack of objective criteria, there are some general guidelines that can be followed. The most desirable

[9] Source: 2002 AASHTO Roadside Design Guide

system is usually one that offers the required degree of shielding at the lowest cost. Table 22-2 summarizes the factors that should be considered before making a final selection.

Table 22-2: Selection Criteria For Roadside Barriers

Criteria	Comments
1. Performance Capability	Barrier must be structurally able to contain and redirect design vehicle.
2. Deflection	Expected deflection of barrier should not exceed available room to deflect.
3. Site Conditions	Slope approaching the barrier and distance from traveled way may preclude use of some barrier types.
4. Compatibility	Barrier must be compatible with planned end anchor and capable of transitioning to other barrier systems (such as bridge railing).
5. Cost	Standard barrier systems are relatively consistent in cost, but high-performance railings can cost significantly more.
6. Maintenance	
A. Routine	Few systems require a significant amount of routine maintenance.
B. Collision	Generally, flexible or semi-rigid systems require significantly more maintenance after a collision than rigid or high performance railings.
C. Materials Storage	The fewer different systems used, the fewer inventory items/storage space required.
D. Simplicity	Simpler designs, besides costing less, are more likely to be reconstructed properly by field personnel.
7. Aesthetics	Occasionally, barrier aesthetics is an important consideration in its selection.
8. Field Experience	The performance and maintenance requirements of existing systems should be monitored to identify problems that could be lessened or eliminated by using a different barrier type.

Placement And Installation Considerations

A. Proximity to Obstacle

The distance from the barrier to the obstacle being protected must be greater than the maximum deflection of the barrier system or there is a chance that the vehicle will still hit the obstacle. See Figure 22-9.

If the desirable distance cannot be provided, the barrier system must be stiffened in the area of the fixed obstacle to lessen the possible deflection. Methods used to stiffen rails include:

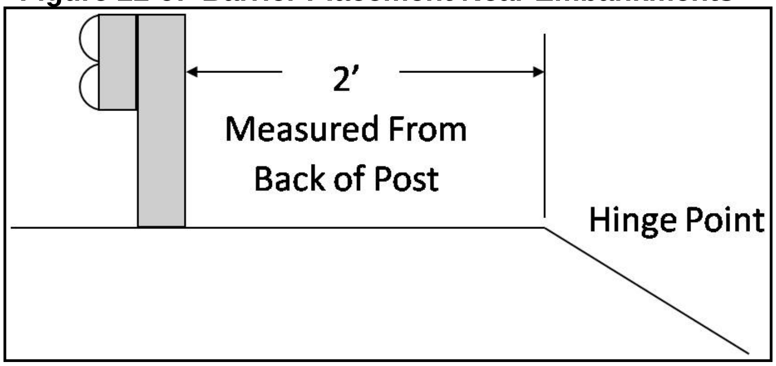
- Increasing the number of support posts (common practice is to use half the normal spacing).
- Provide stiffer rail section by using thicker 10 to 12 gage rail panels.

B. Lateral Placement

Roadside barriers should be placed as far back from the traveled way as practicable, thereby providing recovery space in front of them. This recovery space should be kept flat and free of objects. The entire area in front of the barrier should be graded to a slope of 10:1 or flatter.

Curbs may cause a vehicle to vault, depending upon the shape of the curb, the vehicle's speed, and the angle of the impact. To prevent this, curbs should be either placed flush with or behind the face of the barrier, or ten or more feet in front of the barrier.

Figure 22-9: Barrier Placement Near Embankments[10]



If the barrier posts are placed too close to the hinge point on the shoulder, the posts may be pushed back when the rail is struck. It is recommended that the back of the post be at least two feet (0.6 m) in front of the edge of the top of the embankment, as illustrated in Figure 22-9.

It is also generally desirable that there be uniform clearance between traffic and roadside features such as bridge railings, parapets, retaining walls, and roadside barriers, particularly in urban areas where there is a preponderance of these elements. The distance from the edge of the traveled way, beyond which a roadside object will not be perceived as hazardous and result in a motorist's reducing speed or changing vehicle position on the roadway, is called the shy line offset. This distance varies for different design speeds as indicated in Table 22-3. If possible, a roadside barrier should be placed beyond the shy line offset, particularly for relatively short, isolated installations. For long, continuous runs of railings this offset distance is not so critical, especially if the barrier is first introduced beyond the shy line and gradually transitioned nearer the roadway.

Table 22-3: Suggested Shy Line Offset (LS) Values[11]

Design Speed		Shy Line Offset LS	
(mph)	(km/h)	(feet)	(meter)
80	130	12.1	3.7
70	110	9.2	2.8
60	100	7.9	2.4
50	80	6.6	2
40	65	4.6	1.4
30	50	3.6	1.1

C. Flare Rate

A roadside barrier is considered flared when it is not parallel to the edge of the traveled way. Flare is normally used to locate the barrier terminal farther from the roadway, to minimize a driver's reaction to an obstacle near the road by gradually introducing a parallel barrier

[10] Source: 2002 AASHTO Roadside Design Guide
[11] Source: 2002 AASHTO Roadside Design Guide

installation, to transition a roadside barrier to an obstacle nearer the roadway such as a bridge parapet or railing, or to reduce the total length of rail needed.

As shown in Table 22-4, the maximum recommended flare rates are a function of highway design speed and barrier type. Flatter flare rates may be used and often are, particularly where extensive grading would be required to ensure a flat approach to the barrier from the traveled way. This is often the case on existing facilities having relatively steep embankment slopes.

Table 22-4: Suggested Flare Rates For Barrier Design[12]

Design Speed		Flare Rate for Barrier inside Shy Line	Flare Rate for Barrier beyond Shy Line	
mph	km/h			
70	110	30:1	20:1*	15:1**
60	100	26:1	17:1*	13:1**
50	80	21:1	14:1*	11:1**
40	60	16:1	10:1*	8:1**
30	50	13:1	8:1*	7:1**

* Suggested maximum flare rate for rigid barrier systems
** Suggested maximum flare rate for semi-rigid systems

D. Height

Barriers must be installed at the proper height. A low barrier will allow the vehicle to ride up over it and a high barrier my trap the vehicle wheel on the post. This type of snagging can be avoided through the addition of a "rub rail" below the normal rail. As mentioned earlier, the area in front of the barrier should be flat—preferably with a slope of 10:1 or flatter.

E. Support Posts, Block-Outs, and Connecting Hardware

Design specifications must be followed closely in the installation and maintenance of barriers and other barriers. Seemingly minor changes in the field can result in a total failure of the barrier to provide the intended action. Recommended guidelines for installation and maintenance are:

- Use bolts with the specified size and hardness.
- Use washers when, and only when, they are called for in design specifications.
- Make sure connections are tight (if they rattle, they are too loose).
- Use block-outs when they are called for in design.
- Attach block-outs securely so that they stay in proper alignment. A single 10d nail can prevent rotation of a wood block-out.

F. Splices

The connections between sections of barriers can result in weak areas. For rail systems, such as W-beams, it is necessary to keep the full strength of the beam section throughout its entire length. Guidelines are:

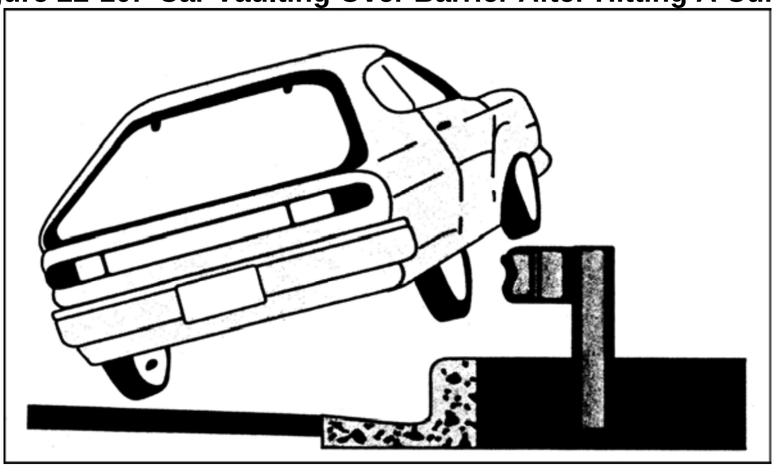
[12] Source: 2002 AASHTO Roadside Design Guide

- Splices in a metal beam barrier should be at least as strong as the beam itself.
- All bolts called for in the design must be put in place.
- Lapped splices should be constructed so that the outer rail overlaps in the downstream direction (to avoid snagging).
- Splices in precasted sections of concrete barriers should be smooth (to avoid snagging).
- Field-cut holes are to be avoided.

G. Barrier and Curb

When a vehicle hits a curb, it will usually bounce upward. Even at moderate speeds, the bounce can be high enough to vault the vehicle over the barrier. If possible, don't use curbs with barriers. Figure 22-10 illustrates a vehicle colliding with a curb. Because the barrier is located behind the curb, the vehicle can bounce high enough to vault the barrier. The vehicle vaulted the barrier because it struck the curb first and became airborne before reaching the barrier.

Figure 22-10: Car Vaulting Over Barrier After Hitting A Curb[13]



H. Length of Barrier Needed

The length of a roadside barrier needed to protect a given hazard depends on the size and shape of the hazard and its distance from the travel lane. The following general guidelines apply:

- Extend the beginning far enough upstream to prevent vehicle from getting in behind the barrier and hitting the hazardous object.
- Avoid short gaps between adjacent barrier sections by joining the two barriers (gaps of less than 200 feet (61 m) should be closed). Figure 22-11 shows short gaps between adjacent barrier sections.
- Extend the barrier far enough downstream to fully protect the hazard.
- If opposing traffic can be expected to cross over and hit the hazardous object, extend the downstream end far enough to shield the object from this opposing traffic.
- Extend the barrier to close short gaps that can occur between the upstream end of the barrier and solid features such as a structure, cut slope, or rock face.

[13] Source: Road Safety Fundamentals, USDOT, FHWA

- Use a Type 3 Object Marker to mark roadside barriers and end treatments, as shown in Figure 22-12.

Additional information pertaining to the design length of the roadside barriers and barrier end treatments are found in the 2002 AASHTO Roadside Design Guide.

Figure 22-11: Short Gaps Between Adjacent Barrier Sections

Figure 22-12: Roadside Barrier And End Treatment Marked With Type 3 Object Marker

What Are The Various Types Of Barrier End Treatments?

The end of a barrier can be extremely hazardous. Impact with the untreated end of a metal beam type system may result in the beam penetrating the passenger compartment or stopping the vehicle abruptly. Impact with the untreated end of a concrete barrier will result in intolerable impact forces. A crashworthy end treatment for a barrier is essential if the barrier is terminated where it is vulnerable to high speed, head-on impacts.
Typical barrier end treatments used in Oregon are listed below.

- Anchored in backslope
- Three-strand cable terminal
- Slotted Rail Terminal (SRT-350)
- Flared Energy-Absorbing Terminal (FLEAT)
- Extruder terminal (ET-PLUS)
- Sequential Kinking Terminal (SKT-350)
- Sloped concrete end treatment
- Crash cushions

Some of the above barrier end treatments are shown in Figure 22-13. Figure 22-14 shows the results of the crash of a truck into a barrier where the rail was ruptured and penetrated the passenger compartment. For additional information about the barrier end treatments refer to Chapter 8 of the 2002 AASHTO Roadside Design Guide.

Figure 22-13: Types Of Barrier End Treatments[14]

Extruder Terminal (ET-PLUS)

Slotted Rail (SRT-350)

Sequential Kinking Terminal (SKT-350)

Flared Energy Absorbing Terminal (FLEAT)

[14] Source: Trinity Highway Products

Figure 22-14: Barrier End Crash With Beam Penetrating Passenger Compartment

Roles Of Maintenance Personnel For Roadside Barrier Inspections

Although maintenance personnel are not generally responsible for establishing barrier need and placement, they should be aware of standards of practice and, when appropriate, alert proper officials of substandard conditions. The critical areas of concern include:

1. Length of barrier and terminal in relation to the problem;
2. Lateral distance between barrier & rigid objects;
3. Sloping terrain between barrier and roadway; and
4. Abrupt vertical geometric figures such as curbs and sidewalks between the barrier and the roadway.

Roadside Barriers Maintenance Policies

There are three alternatives to consider when significant sections of barrier (greater than 100 feet or 30 m) are damaged. The alternatives are to upgrade or remove the existing run of barrier. In deciding which alternative is appropriate, there are several factors to consider:

A. Removal:

This option requires a determination if the barrier is still needed. Roadside barriers installed some time ago may be unnecessary because of changed site conditions or by present warrants (See the 2002 AASHTO Roadside Design Guide for current warrants). Since roadside barriers are fixed objects themselves, it may be more beneficial (i.e., increase safety and reduce maintenance) to remove the barrier rather than to restore it. Factors influencing the removal decision include traffic volumes, cost-effectiveness, crash experience, continued maintenance costs, and the condition and type of existing barrier. Occasionally, the barrier requires that steep fill slopes be flattened. At a minimum, the slopes should be flattened to at least 1:4 on freeways and 1:3 on non-freeways. The slopes of 1:3 to 1:4 are considered traversable but non-recoverable on a fill slope.

B. Upgrading:

This option is viable when the existing barrier is substandard by current standards and the cost to upgrade to current standards is nominal compared to replacement in kind. Because of the more severe crash conditions caused by barrier terminals (upstream end), substandard terminals should always be evaluated for possible upgrading.

C. Repair:

This option involves assessing how quickly repairs need to be made based on the extent of damage, which can be categorized into three levels:

1. Damage is so severe that the barrier no longer functions and may itself be an increased hazard to motorists.
2. Damage is obvious but the barrier may still perform satisfactorily for most traffic conditions.
3. Damage is minor, and the barrier will continue to function adequately.

Out Of Date Installations

Out of date installations are normally left in place until the roadway is reconstructed, or until they are damaged in a crash. When damaged in a crash, the decision of whether to replace it as originally constructed or to upgrade it to current standards needs to be made. The following rules of thumb are used by some agencies.

- If 25 percent (one corner) of a barrier transition or connection to a bridge is damaged beyond repair, then all four corners should be upgraded to current standards. It is possible that the current approach barrier will not attach to the older bridge rail. If this situation is encountered then a more extensive retrofit may be necessary.
- If 50 percent of an installation is damaged beyond repair, then the entire barrier should be replaced with a barrier meeting current standards. This applies to long runs of barrier as well as short runs.
- When an upgrade is made, notify the appropriate office within the agency to enable update of any record systems.

Deciding What Needs To Be Done After The Barrier Has Been Damaged

Define the extent (or severity) of damage.

1. Barrier damage is so bad that it no longer functions and may itself be a hazard to motorists.
    a. The rail beam is pulled completely apart.
    b. Three or more posts are broken off or are no longer attached to the rail.
    c. Rail beam is bent or pushed more than 18 inches (450 mm) out of line.
2. Barrier is obviously damaged but may still work for most traffic conditions.
    a. Even though badly bent or crushed, rail beam is not separated anywhere.
    b. Two or fewer posts are broken off or separated from the rail beam.
    c. Rail beam is bent or pushed out of line less than 12 inches (0.3 m).
3. Barrier damage is minor. It will continue to work.
    a. Rail beam may be crushed or flattened but it is not cut.
    b. No posts are broken off or separated from rail beam.
    c. Rail beam is bent or pushed out of line less than six inches.

Deciding What To Do About The Damage

1. When the barrier damage is so bad that it no longer functions and may itself be a hazard to motorists:
    a. Clear any debris from the traffic lanes and shoulder;
    b. Put out temporary warning devices such as vertical panels or small barricades to warn traffic away if it cannot be fixed immediately; and
    c. Figure out what materials and equipment are needed to fix it, and get the repair job started as soon as possible.
2. When the barrier is obviously damaged but may still work for most traffic conditions:
    a. Make a good inspection of the damage to be certain it will be acceptable for a while;
    b. Make a damage inspection report and repair request for parts and equipment;
    c. Schedule the repair along with other scheduled work; and
    d. Check the damage site frequently to see if it has been hit again or damaged worse than first thought. Such damage may make it important to repair the damage more quickly.
3. When the barrier damage is minor and the barrier will continue to work:
    a. Decide if the damage is bad enough to be worth fixing at all;
    b. Decide how much is to be repaired, if any repair is to be made to the minor damage; and
    c. Report what is to be done for any repair thought to be needed, and schedule the repair when convenient to the work schedule.

Placing Temporary Warnings And Markers

Is the barrier still functional? Is the damage minor or will the barrier still work for most traffic conditions?

Yes	Then temporary warning devices should not be needed.
No	If the barrier can no longer function and may itself be a hazard to motorists, then place temporary warnings and markers until repairs are made.

Further checks when placing temporary warnings and markers:

Is the shoulder narrow or the barrier within 6 feet (1.83 m) of the outside edge of the traveled lane?

Yes	Then vertical panels or some other small delineation device is suggested if there is room for traffic to pass by. Space may be limited such that attaching reflectors to the rail may be all that can be done to mark the area.
No	Then safety barrels, Type II barricades, or vertical panels may be used to mark the danger and warn drivers away from it.

Will traffic be exposed to the damage area overnight or during hours of darkness?

Yes	Then consider using flashers on the warning devices and markers.
No	Then flashers are not needed on the warning devices and markers.

Some Tips To Increase Safety

- W-beam rail sections must not be badly bent out of shape.
- Bolts must be the right size and be tight.
- Wooden posts must not be loose, broken, or rotted.
- Steel posts must not be bent or pushed off line so badly that a vehicle hitting the rail will slide off the road.
- Rail sections must be blocked out away from the posts.
- Surface under the rail needs to be free of holes and eroded ruts that a wheel can drop into.
- General line of the barrier should be a smooth path.
- Barrier needs to be at the correct height from the ground.

MAINTENANCE CHECKLIST AFTER REPAIR IS COMPLETED

________ Have all the bolts been checked to see that each one is tightened snug?

________ Was a block-out used on each post?

________ Was a nail driven in each wood block-out to toe-nail the block to the wood post?

________ Does each steel post in between the splices have a back-up plate behind the rail beam?

________ If hazard markers or delineators or reflectors were installed, are they located properly on the barrier?

________ Was the barrier height checked to make sure it did not shift up or down out of tolerance during the final assembly?

Date repair completed: ___________________________

Repair completion inspected by:
____(signed)

For additional important information about roadside barriers, please refer to:

- " W-Beam Guardrail Repair, A Guide For Highway And Street Maintenance Personnel", U.S.DOT, FHWA, Number 2008, which is available at: http://safety.fhwa.dot.gov/local_rural/training/fhwasa08002/
- "2002 Roadside Design Guide," American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C.

Chapter 23: Road Surface, Shoulder, And Pavement Management

Good road surfaces should:

- Provide a durable travel surface that will withstand repeated wheel loads without undue deformation.
- Provide for the drainage of water from the pavement surface and prevent water from entering the base courses below the pavement surface.
- Provide a skid resistant surface.

Factors Affecting Pavement Performance

Pavements have a finite life and wear out for several reasons, including:

A. Design Considerations – Many pavement failures are associated with the use of the wrong design or mix, or not considering drainage.
B. Extreme Climates – Changes in temperature, moisture, freezing, and thawing all cause pavements to wear out.
C. Traffic Loads – Trucks are particularly damaging; the heavier they are the more damage they cause. Also, increased tire pressures and slow speeds accelerate damage in pavement surfaces. In some instances, automobiles with studded tires can cause severe pavement surface problems.
D. Construction quality – Variability in the quality or thickness of the materials or construction practices can lead to early failure.

Table 23-1 summarizes the most important causes of pavement failures.

Table 23-1: Important Factors Affecting Pavement Performance[1]

Category	Factor
Design	• Inadequate thickness • Use of inappropriate mix • Drainage problems
Traffic	• Heavy loads • High tire pressures • Studded tires • Slow moving (static) loads
Extreme Climate	• Freeze-thaw cycles • Moisture • Aging
Construction Quality	• Variable materials • Variable thickness • Poor compaction

[1] Source: Asphalt Pavement Design Guide, APAO, Salem, OR, 2003

Drainage-Related Factors Affecting Pavement Performance

Surface drainage is essential to avoiding hydroplaning of vehicles and ensuring that water will not soak into and weaken the base and subbase. In hydroplaning, vehicle tires ride on a thin film of water rather than in direct contact with the roadway. In this situation, the tire/pavement friction needed for steering and braking control are lost.

Four factors determine how well water will drain from the pavement surface:

1. The cross slope of the pavement.
2. The roughness of the pavement surface.
3. The number of wheel ruts, depressions, and potholes that can trap water or slow its movement to the edge of the pavement.
4. The build up of material along the edge of the pavement.

Sections of pavement with poor drainage properties can be identified by observing which areas remain wet after a rain. Typical problem sections include:

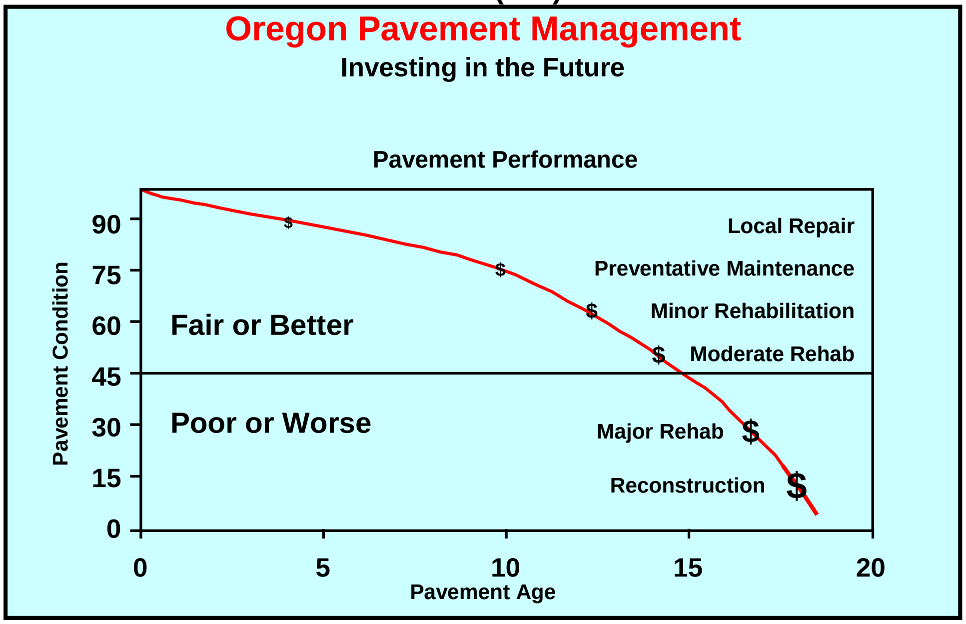
- Low, depressed sections in a wavy pavement.
- Inner edges of horizontal curves where superelevation produces a low spot.
- Wheel ruts in the lane where water can be trapped.
- Underpasses that collect water.
- Curbed sections of roadway where the drainage grates provided are not large enough to remove all the water.
- Potholes in deteriorated pavement surfaces.
- Water standing along the edge of the pavement.

Areas of poor drainage should be looked at to see if reconstruction is needed, improved side drainage can solve the problem, or one of the better-draining surface treatments should be applied.

What Is The Pavement Management System?

The Pavement Management System (PMS) is a set of tools or methods that can assist decision makers in finding cost-effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition. It provides the information necessary to make these decisions. The PMS consists of two basic components: A comprehensive database, which contains current and historical information on pavement condition, pavement structure, and traffic; and a set of tools that allows agencies to determine existing and future pavement conditions, predict financial needs, and identify and prioritize pavement preservation projects.

Figure 23-1: Pavement Condition Index (PCI) As A Function Of Pavement Age[2]



The Pavement Condition Index (PCI) is used by pavement managers to track pavement distress over time. The higher the number, the lower the amount of distress present. Pavements are maintained and/or rehabilitated when the PCI drops to a level of 40-60. Figure 23-1 shows the PCI as a function of pavement age. For questions regarding the Pavement Management System, contact:

Mr. John Coplantz,
Pavement Management Engineer, ODOT Construction Section
Tel.: (503) 986-3119
Email: john.s.coplantz@odot.state.or.us

Role Of Maintenance Personnel For Pavement Inspections

Early detection and repair of minor defects is, without doubt, the most important work done by the maintenance crew. Cracks and other surface breaks in their first stages are almost unnoticeable, and they may develop into serious defects if not repaired early. For this reason, qualified inspectors should make frequent, close inspections of the pavement. Indeed, this measure is necessary for effective use of maintenance money.

An inspection made from a moving vehicle, even one barely moving, is usually not close enough to detect areas where distress may begin. Cracks or other surface defects are often so small that only a person on foot can spot them. There are other small signs, such as mud or water on the pavement or shoulder that may signal future trouble. It is best to walk the pavement for close inspection or, at a minimum, inspect selected stretches of roadway.

[2] Source: Oregon Department of Transportation Construction Section, Pavement Management System

Upon detection of the warning signs, make the required investigation to determine the cause of the distress and make the proper repair.

As was mentioned before, good drainage is absolutely essential for satisfactory pavement performance and long–term, trouble-free service. The accumulation of excess water in the base or subgrade under a pavement surface may cause surface damage such as alligator cracking and upheaval. Moisture problems will not go away by filling cracks or placing skin patches. The source of the problem must be identified and eliminated.

One form of preventative maintenance is the seasonal inspection and cleaning of drainage systems. Properly working drains can eliminate some of the major causes of pavement damage. Each inspection should include all surface drainage structures, ditches and channels. Immediately clean out any clogged part of the system.

Examine subsurface drains to make sure they are working properly. The abnormal appearance of water on the pavement surface may indicate improperly located, incorrectly designed, or clogged subsurface drains. All drain outlets should be well marked on the ground and on maintenance maps so that they will not be overlooked on inspection trips.

When Is It Necessary To Repair The Road Surface?

Make repairs as soon as possible after their need is discovered. The true cause(s) of the pavement distress must first be determined. Repairs can then be made to correct the cause of the distress and prevent or retard its reoccurrence. This is particularly important when the defect makes driving hazardous.

Weather conditions often make temporary repairs necessary to prevent further damage until more permanent repairs can be made. Selecting the best time to make repairs involves the careful balancing of several factors, and requires both experience and judgment. Be careful not to allow temporary repairs to become permanent repairs. The problem is time—be sure to take the time to do a permanent repair. Time and money spent for such repairs are good investments because the same repairs are not made repeatedly.

Table 23-2 shows the generally suggested optimum timing for the various maintenance treatments.

Table 23-2: Optimum Timing For The Various Maintenance Treatments[3]

Maintenance Treatments	Pavement Age (Years)
Fog Seals	1-2
Emulsion Seal Coats	1-3
Chip Seals	4-7
Slurry Seals	4-7
Thin Overlays (<25 mm)	8-12
Thick Overlays (100 mm)	10-18

[3] Source: Asphalt Pavement Association of Oregon (APAO), Asphalt Pavement Design Guide

What Are Corrective And Preventative Maintenance?

A. Preventative Maintenance – Used to preserve the pavement in good condition and can include the following treatments:

- Crack sealants
- Fog seals
- Chip seals
- Slurry seals and microsurfacing
- Thin hot-mix overlays

B. Corrective Maintenance or Rehabilitation – Used when the pavement provides lower service in terms of:

- Load-carrying capability (excessive deflection)
- Waterproofing (cracks)
- Surface deformation (rutting)
- Surface fiction (too slick)
- Ride quality (bumps)

Each of the preventative and corrective maintenance treatments are discussed in the next section.

What Are The Corrective And Preventative Maintenance Treatments?

Based on the Asphalt Pavement Design Guide published by the Asphalt Pavement Association of Oregon (APAO), several maintenance treatments are available to agencies for preventative or corrective maintenance. They include the following.

A. Crack Sealants – The materials, which usually consist of a modified asphalt, are applied to cracked pavements to prevent water from entering the cracks. Most of these materials have an effective life of only one to two years. Furthermore, if crack sealants are applied too thickly on the surface adjacent to the crack, they have a tendency to bleed through subsequent overlays. It is important to clean the cracks prior to applying the sealant.

B. Fog (Flush) Seals – This is a light application of an asphalt emulsion (usually a CSS-1) without aggregate cover to restore the durability of the asphalt mix. It can be very effective, but if applied in excess it can produce a slippery pavement.

C. Asphalt Emulsion Seal Coats – An asphalt emulsion seal coat consists of a mixture of asphalt emulsion and inert fillers. The mixture is approximately 80 to 85 percent emulsion and 20 to 15 percent filler, depending on the manufacturer. Most emulsion seal coats are machine applied either by spraying or with a squeegee.

D. Chip Seals – A chip seal is an application of asphalt followed with an aggregate cover. This type of maintenance technique can consist of single or multiple layers ranging in thickness from 3/8 to 1.0 inch (9.5 to 25 mm). A typical chip seal used in Oregon consists of an application of a rapid-setting emulsion, followed by an application of 3/8 to 1.0 inch (9.5 to 25 mm) aggregate.

E. Slurry Seals – This treatment is a mixture of well-graded sand size aggregate, mineral filler, and asphalt emulsion. A single course is usually applied in thickness of 1/8 to 3/8 inches (3 to 9 mm). Slurry seals are normally used in areas where the primary pavement distress is excessive oxidation and hardening of the existing asphalt pavement. They are used for sealing minor surface cracks and voids, retarding surface raveling, and, in some cases, for improving surface friction characteristics.
F. Microsurfacings – This is a polymer-modified slurry seal system developed originally in Europe. Its most common uses are rut filling, minor leveling, and restoration of skid-resistant surfaces.

G. Thin Hot Mix Overlays – Both open-graded and dense-graded mixes have been used in thicknesses of 1.0 to 1.5 inches (25 to 37.5 mm). These materials make use of aggregates with a top size of 3/8 to 1/2 inch (9.5 to 12.5 mm). The expected life of thin hot mix overlays is normally 8 to 12 years, depending on the condition of the pavement it is placed on, traffic, and climate. This maintenance treatment works best for improving ride quality and is the only treatment that adds to the structural strength of the pavement.

H. Overlays – Conventional dense- or open-graded mixes are normally used on highways to rehabilitate asphalt concrete pavements. The recommended overlay thickness should be determined by a consultant to ensure it will accommodate the anticipated traffic.

I. Mill and Fill – This is another common rehabilitation technique for repairing distressed asphalt pavements. It typically consists of milling the existing pavement to depths of 2 inches (50 mm) to remove the distressed surface layer and filling the cavity with a dense-graded mix. Open-graded mixes have also been used, but drainage channels are required to remove the water, which will accumulate in the trenched areas. If only a mill and fill is used, the procedure does not necessarily strengthen the pavement. Strengthening is achieved when the mill and fill operation also receives an overlay.

Details of the above maintenance treatments can be found in the publications of the Asphalt Institute (MS-16, MS-17, MS-19).

What Are The Expectations From Paving Inspectors?

Lay out quality and workmanship expectations at pre-paving meeting (this might take place on site prior to start-up or at an office). Ask the contractor what concerns and issues he or she might have with the paving and specifications, and resolve these concerns and issues before the start of paving.

Point out problems and concerns to the contractor while they are occurring, not after the fact.

Evaluate test results of compaction and mix quality control (QC) in "real time" so adjustments can be made rather than after the fact when nothing can be corrected.

Work with the contractor to resolve problems (your job is to help him or her be successful building a quality project; it is not to try to catch him or her doing something out of specification.

Above all apply good common sense and recognize that specifications often have gray areas that need interpretation and do not fit every situation.

What Are Important Items To Check And Pay Attention To During Pavement Construction?

A. Surface Preparation

- Surfaces should be clean (for overlays).
- If paving on rock, the surface should be uniform and sound. If in doubt do a proof roll with a loaded truck to check for soft and weak areas.
- When applying tack, the shot should be uniform and thin. Breaking of tack is not critical.

B. Paving

- Delivery should be as continuous as possible minimizing delays between trucks.
- Do not allow trucks to clean material from the tail gate and leave it on the grade as this material will cool rapidly and result in a bump and a weak spot.
- Check mat texture for uniformity; do not accept or tolerate segregation.
- Longitudinal joints should be straight, even, and tight. Raking of joints should be minimized to avoid segregation and broadcasting of "bones" onto the mat.
- Longitudinal joint should be "pinched" from the hot side lapping onto the cold mat, not the other way around.

C. Compaction

- Does the equipment meet specification (minimum size and weight, correct type, etc.)?
- Is the mix being delivered and compacted at the proper temperature (compaction temperature range comes from the mix design; generally for PG64 grade binders the "ideal" compaction temperature will be 285-295 degrees F and for PG70 grade binders 295-305 degrees F)?
- Is the roller pattern providing adequate compactive effort (normally should get 4 to 6 coverage prior to the mix cooling to below 220 degrees F and 6 to 8 total coverage prior to cooling to below 160-170 degrees F)?
- Rollers should turn as they reverse direction and avoid parking on a hot mat.
- Achieve specification density if applicable (be aware that nuclear gauges are a tool to estimate bulk density and are susceptible to significant variation).
- Monitor the roller pattern for consistency.

Pavement Factors Affecting Safety Of The Motorist

A. Skid Resistance

From a safety viewpoint, the pavement characteristic of most interest is skid resistance. It is particularly critical under wet weather conditions. Typically, half of the friction (resistance to skidding) of a dry pavement is lost when the pavement becomes wet.

Skid resistance in a pavement is a function of the "grittiness" of the surface texture. A slick or "oily" pavement offers little skid resistance; a surface composed of angular aggregate which "bites" into the tire produces a high friction coefficient—a high "coefficient" means that the pavement will better resist sliding by the tire.

Means to increase the skid resistance of the bituminous pavements and overlays include:

1. Chip Seals – Chip seals generally produce a fairly coarse surface and increase surface drainage.
2. Open-Graded Mix – An open-graded mix is one that contains a small percentage of aggregate particles in the small range. This results in more air voids because there are not enough small particles to fill in the voids between the larger particles. It produces the surface that allows surface water to flow around the large particles in the pavement, and then run out to the side of the pavement on a smooth waterproof layer. This reduces the potential for hydroplaning action.

B. Pavement Edge Drop-off

Pavement edge drop-off is the vertical differential between adjacent lanes or between pavement edge and the shoulder. Drop-offs may develop during highway work such as resurfacing or shoulder repair work or through deterioration of shoulders caused by rutting or erosion. When not properly addressed, drop-offs may lead to loss of control, with an increased potential for a serious crash. Vertical drop-offs of more than 2 inches (50 mm) are dangerous to motorists and must be avoided. Regular inspection of shoulder conditions should be undertaken as part of the overall maintenance program to identify pavement drop-offs. These areas should be repaired as soon as possible. There are several ways to reduce the effects of pavement edge drop-offs. Install a paved or stabilized shoulder where traffic continually wears away gravel or grass shoulders. In curves, safety widening can prevent the drop-off caused by the back wheels of trucks that wear down unpaved shoulders. Building the pavement edge with a one-on-one slope reduces the steering angle needed to return the vehicle to the pavement. For more information on safety edges, refer to http://safety.fhwa.dot.gov/media/safetyedge.htm.

C. Pavement Roughness

Bumpy surfaces cause the vehicle's wheels to bounce. The driver cannot steer or brake while the tire is not in contact with the pavement. This is particularly dangerous on horizontal curves, as the vehicle tends toward the outside of the curve anyway. A bumpy pavement surface may be caused by "shoving" of the surface material (usually by heavy trucks), or by failure of the base, subbase, or subgrade. Repairs generally involve the removal and replacement of bad pavement, base, and subbase material.

D. Shoulder Joint

Separation at the joint between the travel lane and the paved shoulder can cause a driver to lose steering control if the two surfaces do not remain at the same height – i.e., the shoulder is either higher or lower than the travel lane. Separated shoulder joints also allow water to enter the subgrade, and this may lead to ruts and potholes. This problem is easily identified by visual inspection, and the gaps should be filled with suitable sealing material.

E. Edge Raveling

Raveled or uneven pavement edges can cause steering problems. Also, drivers shy away from such edges; this reduces the effective width of the travel lane. A paved shoulder may be the solution in this situation also.

F. Uneven Lane Surface

Pavements which contain many patched sections or that have settled or heaved to produce a “roller coaster” effect create a very undesirable driving surface. Care should be taken to blend in patches and/or overlays with the existing pavement to provide smooth edge transitions and reduce changes in color and texture. These color and texture changes can be misleading, especially at night. Drivers may try to dodge around them, thinking they are potholes, puddles, or other rough spots.

Pavement Failure (Distress) Identification

The key to proper maintenance of asphalt pavements is to understand the causes of failures and the action(s) needed for correction before any repair work is done. To make the most of maintenance budgets, proven methods must be used to correct failures and to prevent their recurrence.

The following section provides basic information on the most common types of pavement failures, including their probable causes and the measures recommended for their correction. This section is based on the information and photographs from the Asphalt Pavement Design Guide, published by the Asphalt Pavement Association of Oregon (APAO), the Distress Survey Manual, published by the Oregon Department of Transportation, and Pavement Interactive, developed by the University of Washington.

A. Channels or Rutting

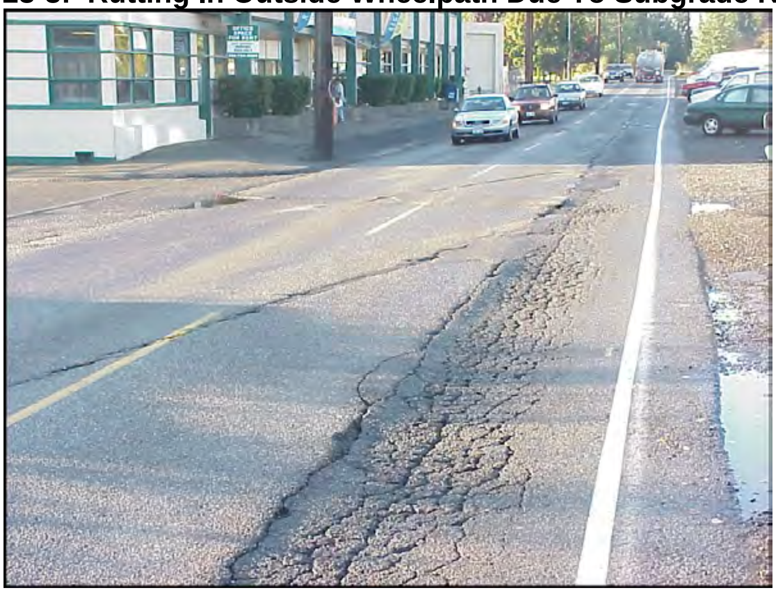
Channels are caused by heavy loads and high tire pressure, studded tire wear, subgrade settlement caused by saturation, poor construction methods such as compaction of hot-mix asphalt (HMA) layer during construction, or asphalt mixtures of inadequate strength. Ruts are particularly evident after rain when they are filled with water and can cause hydroplaning.

Where the depression is 1 inch (25 mm) or less and the surface is cracked but still largely intact, the area can be skin patched. Where the depression is more than 1 inch (25 mm) and the surface is cracked but still largely intact, an asphalt concrete overlay is recommended.

Where the surface is badly cracked and loose (regardless of the amount of depression), remove the old surface. If the area shows signs of mud being pumped to the surface, remove all wet material, replace base material, compact, prime, and build up with asphalt concrete. Figure 23-2 and Figure 23-3 illustrate channels or rutting.

Figure 23-2: Channels Or Rutting Caused By Mix Design Or Mix Production Problem[4]

Figure 23-3: Rutting In Outside Wheelpath Due To Subgrade Rutting[5]



B. Fatigue (Alligator) Cracking

This is a series of interconnected cracks caused by failure of the HMA surface or stabilized base under repeated traffic loading. In thin pavements, cracking initiates at the bottom of the HMA layer, where the tensile stress is the highest, and then propagates to the surface as one or more longitudinal cracks. In thick pavements, the cracks most likely initiate from the top in areas of high localized tensile stresses resulting from tire-pavement interaction and asphalt binder aging. After repeated loading, the longitudinal cracks connect, forming many-sided, sharp-angled pieces that develop into a pattern resembling the back of an alligator or crocodile.

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[4] Source: http://pavementinteractive.org, developed by the University of Washington

[5] Source: http://pavementinteractive.org, developed by the University of Washington

Fatigue cracking is a structural failure and allows moisture infiltration, roughness, and further deterioration to a pothole.

Fatigue cracking is caused by:

- Decrease in pavement load supporting characteristics
    - Loss of base, subbase, or subgrade support (e.g. poor drainage or spring thaw results in a less stiff base)
    - Stripping on the bottom of the HMA layer (the stripped portion contributes little to pavement strength so the effective HMA thickness decreases)
- Increase in loading (e.g. more or heavier loads than anticipated in design)
- Inadequate structural design
- Poor construction (e.g. inadequate compaction)

A fatigue-cracked pavement should be investigated to determine the root cause of failure. Any investigation should involve digging a pit or coring the pavement to determine the pavement's structural makeup, as well as to determining whether or not subsurface moisture is a contributing factor. Once the characteristic alligator pattern is apparent, repair by crack sealing is generally ineffective. Fatigue crack repair includes skin patching, which should be applied only when weather permits. This is often a temporary measure and should not be considered a permanent correction to a major problem. Alligator cracking generally requires removal of the cracked pavement and an asphalt patch of at least 4 inches (100 mm) in depth.

Where distortion (rutting) is 1 inch (25 mm) or less and the existing surface is intact, a skin patch should be applied. Where distortion is more than 1 inch (25 mm) and the existing surface is intact, a tack coat should be applied, followed by an asphalt concrete overlay.

Where the existing surface is badly cracked and loose (regardless of amount of distortion), remove the old surface, tack the area, and repair using asphalt concrete. Sound judgment should be used to determine when the existing surface is considered firm and should remain in place or when it is considered loose and should be removed before placing the asphalt concrete overlay.

There are several causes of this type of distress. Often, poor drainage resulting in a wet base and/or subgrade is responsible. If the pavement is properly drained, then water is getting to the base and/or subgrade from cracks or holes in the surface or from moisture coming up through the subgrade. This distress should be repaired as follows:

- Cut out pavement and wet material.
- If the base or surface is wet from underneath, install necessary underdrains to prevent future saturation.

Figure 23-4 and Figure 23-5 illustrate fatigue (alligator) cracking.

Figure 23-4: Fatigue (Alligator) Cracking Resulting From Frost Action[6]

Figure 23-5: Fatigue (Alligator) Cracking Due To Lack of Edge Support on the Right Pavement Edge[7]

C. Longitudinal Cracking

These are cracks parallel to the pavement's centerline or laydown direction that allow moisture infiltration, roughness, and possible structural failure. Longitudinal cracking is caused by poor joint construction or location. Joints are generally the least dense areas of pavement and should therefore be constructed outside of the wheelpath so that they are infrequently loaded.

If the cracking is less than 1/4 inch (6 mm) in width, no maintenance is required. Otherwise, a crack should be filled with an emulsified asphalt or a joint seal material. Figure 23-6 and Figure 23-7 illustrate longitudinal cracking.

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[6] Source: http://pavementinteractive.org, developed by the University of Washington
[7] Source: http://pavementinteractive.org, developed by the University of Washington

Figure 23-6: Longitudinal Cracking Appearing As The Onset Of Fatigue Cracking[8]

Figure 23-7: Longitudinal Cracking From Poor Longitudinal Joint Construction[9]

[8] Source: http://pavementinteractive.org, developed by the University of Washington
[9] Source: http://pavementinteractive.org, developed by the University of Washington

D. Reflection Cracking

Reflection cracking is caused by vertical and horizontal movements in the pavement beneath overlays that result from expansion and contraction with temperature or moisture changes. Reflection cracking is very apparent where HMA has been placed over Portland cement concrete pavement or where old alligator cracks have propagated up through an overlay or patch.

If reflection cracks are less than 1/4 inch (6 mm) in width, no maintenance is required. Larger cracks should be routed, cleaned, filled with a joint seal material or emulsified asphalt, and covered with sand. Figure 23-8 through Figure 23-10 illustrate reflection cracking.

Figure 23-8: Reflection Cracking On An Arterial[10]

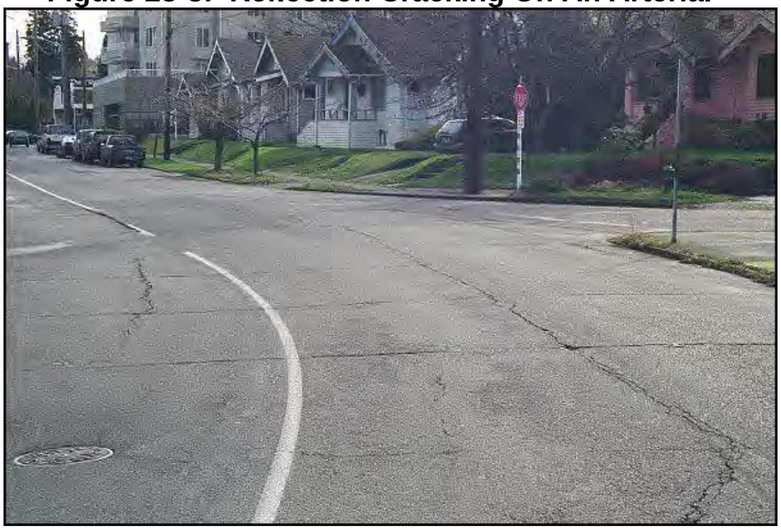

Figure 23-9: Reflection Cracking On An Arterial[11]

[10] Source: http://pavementinteractive.org, developed by the University of Washington
[11] Source: http://pavementinteractive.org, developed by the University of Washington

Figure 23-10: Reflection Cracking Up Close[12]

E. Transverse Cracking

A transverse crack follows a course approximately at right angles to the pavement center line, usually extending across the full pavement width. Transverse cracks are often the result of reflection cracking; however, they are also the result of stresses induced by low-temperature contraction of the pavement, especially as the asphalt ages and becomes more brittle. Repair procedures for transverse cracking are similar to those for reflection cracking. Figure 23-11 illustrates transverse cracking.

Figure 23-11: Small Transverse Crack In The Rocky Mountains In Colorado[13]

[12] Source: http://pavementinteractive.org, developed by the University of Washington

[13] Source: http://pavementinteractive.org, developed by the University of Washington

F. Block Cracking

Block cracks are interconnected cracks that divide the pavement up into rectangular pieces. Blocks range in size from approximately 1 foot^2 (100 mm^2) to 100 foot^2 (9 m^2). Block cracking normally occurs over a large portion of pavement area but sometimes will occur only in non-traffic areas.

Block cracking is caused by the inability of an asphalt binder to expand and contract with temperature cycles because of aging or a poor choice asphalt binder mix design.

For cracking less than 1/2 inch (12.5 mm) in width, use a crack seal to prevent the entry of moisture into the subgrade through the cracks. For cracking more than 1/2 inch (12.5 mm) in width, remove and replace the cracked pavement layer with an overlay.

Figure 23-12 and Figure 23-13 illustrate block cracking.

Figure 23-12: Block Cracking In A Residential Driveway[14]

[14] Source: http://pavementinteractive.org, developed by the University of Washington

Figure 23-13: Block Cracking On A Low Volume Pavement[15]

G. Slippage Cracking

Slippage cracks are crescent-shaped cracks that usually point in the direction of traffic movement. They result from insufficient bonds between the surface and underlying courses. This insufficiency is caused by dust, oil, water, or a lack of tack coat between the two courses, as well as braking or turning wheels that cause the pavement to slide and deform.

To repair slippage cracks, neatly remove the unbounded section of the surface and thoroughly clean the underlying surface with a high quality asphalt concrete. During inclement weather, keep the exposed area filled with cold mix material if it is likely to be a traffic hazard.

Figure 23-14 illustrates slippage cracking.

[15] Source: http://pavementinteractive.org, developed by the University of Washington

Figure 23-14: Slippage Cracking At An Intersection Where Vehicles Start[16]

H. Bleeding or Flushing

This distress occurs when there is a film of excess asphalt binder on the pavement surface that creates a glass-like, reflective surface that can become quite sticky. Contributing factors include insufficient coarse stone, excessive rolling during placement, stripping of the asphalt from the aggregate, and low air voids.

Minor bleeding can often be corrected by applying coarse sand or stone screenings to blot up excess asphalt. Major bleeding can be corrected by cutting off excess asphalt with a motor grader or removing it with a "heater planer." If the resulting surface is excessively rough, resurfacing may be necessary. Figure 23-15 illustrates bleeding or flushing.

[16] Source: http://pavementinteractive.org, developed by the University of Washington

Figure 23-15: Bleeding As A Result Of Overasphalting[17]

I. Raveling

Raveling is the progressive disintegration of an HMA layer from the surface downward as a result of the dislodgement of aggregate particles. Possible causes of raveling include:

- A dust coating on the aggregate particles that forces the asphalt binder to bond with the dust rather than the aggregate;
- Aggregate segregation—fine particles are missing from the aggregate mix, so the asphalt binder is only able to bind the remaining coarse particles at their relatively few contact points;
- Inadequate compaction during construction; and/or
- Excessive heating during mixing.

When a small percentage of the pavement is raveling, it can be repaired with a skin patch (this includes edge raveling). When a large percentage of the pavement shows raveling, the pavement should be surface-treated or resurfaced. Figure 23-16 illustrates raveling.

[17] Source: http://pavementinteractive.org, developed by the University of Washington

Figure 23-16: Raveling Due To Low Density[18]

J. Corrugation and Shoving

Corrugations and shoving are caused by instability in the asphalt layers, which are the result of a mixture that is too rich in asphalt, has too high of a proportion of fine aggregate, has coarse or fine aggregate that is too rounded or too smooth-textured, or has asphalt cement that is too soft for the traffic conditions. This type of distress frequently occurs at grade intersections as a result of braking forces imposed by stopping vehicles.

To repair corrugations in an aggregate base overlain with a thin surface treatment, scarify the pavement, add aggregate as needed, mix well, recompact, prime, and then resurface. Where the surface has 2 inches (50 mm) or more of asphalt plant mix, corrugations can be removed with a "heater planer" or by cold planing. After removal of corrugations, cover with a new surface treatment or new asphalt overlay. To repair shoved areas, remove surface and base as necessary and replace with a more stable material to prevent recurrence. Figure 23-17 and Figure 23-18 illustrate corrugation and shoving, respectively.

[18] Source: http://pavementinteractive.org, developed by the University of Washington

Figure 23-17: Corrugations On A Steep City Street[19]

Figure 23-18: Shoving At A Busy Intersection

K. Potholes

Potholes are small, bowl-shaped depressions in the pavement surface that penetrate all the way through the HMA layer down to the base course. They generally have sharp edges and vertical sides near the top of the hole. Potholes are most likely to occur on roads with thin HMA surfaces of 1 to 2 inches (25 to 50 mm) and seldom occur on roads with 4-inch (100 mm) or deeper surfaces. Generally, potholes are the end result of fatigue cracking. As alligator cracking becomes severe, the interconnected cracks create small chunks of pavement, which can be dislodged as vehicles drive over them. The remaining hole after the pavement chunk is dislodged is called a pothole.

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[19] Source: http://pavementinteractive.org, developed by the University of Washington

Potholes occur most frequently during the winter months when it is difficult to make the most desirable repairs. Consequently, it is often necessary to repair potholes in ways that are less than permanent. General patching should not be done during inclement weather except to correct hazardous conditions. Sound judgment must be exercised when making repairs during poor weather conditions.

Potholes are caused by water penetrating the surface and causing the base and/or subgrade to become wet and unstable. They also may be caused by a surface that is too thin or that lacks sufficient asphalt cement, lacks sufficient base, has high shoulders, has clogged ditches, or has edge drains. Figure 23-19 and Figure 23-20 illustrate potholes.

To repair potholes in asphalt concrete surface, take the following actions:

- Clean out the hole
- Remove any wet base
- Square up the pothole with neat lines perpendicular & parallel to the centerline
- Prime the pothole
- Fill the pothole with asphalt concrete

Figure 23-19: Pothole As A Result Of Fatigue Cracking[20]

[20] Source: http://pavementinteractive.org, developed by the University of Washington

Figure 23-20: Pothole On A Residential Road After Heavy Rains[21]

L. Hot Mix Asphalt (HMA) Patching

Patches are a common method of treating an area of localized distress. Patches can be either full- or partial-depth.

Full-depth patches are necessary where the entire depth of the pavement is distressed. Often times, the underlying base, subbase, or subgrade material is the distressed root cause and will also need repair. Partial-depth patches are used for pavement distresses like raveling, rutting, delamination, and cracking where the depth of the crack does not extend through the entire pavement depth.

Patching material can be any HMA or cold mix asphalt material as well as certain types of slurries. Typically, some form of HMA is used for permanent patches while cold mix is often used for temporary emergency repairs. The procedure for patching is as follows:

1. Remove all water and debris from the pothole.
2. Square up the pothole sides so they are vertical and have intact pavement on all sides.
3. Place the patching material into the hole, making sure that it mounds in the center and tapers down to the edges so that it meets flush with the surrounding pavement edges.
4. Compact the patching material starting in the center and working out toward the edges, using a vibratory plate compactor or single-drum vibratory roller.
5. Check the compacted patching material for a slight crown so that subsequent traffic loading will compact it down to the surrounding pavement height.

Figure 23-21 and Figure 23-22 illustrate hot mix asphalt (HMA) patching.

[21] Source: http://pavementinteractive.org, developed by the University of Washington

Figure 23-21: Hot Mix Asphalt (HMA) Patching: Full-Depth Patch[22]

Figure 23-22: Hot Mix Asphalt (HMA) Patching: Partial-Depth Patch[23]

Shoulders

Shoulders are an important part of highway safety. They must be properly constructed and maintained, or problems will occur. Shoulders serve several functions, including:

- Providing a refuge area for stopped and disabled vehicles.
- Providing an "escape route" which may be used to avoid a collision with another vehicle.
- Protecting the edge of the travel lane from erosion.
- Providing a recovery area when a driver strays off the travel surface.
- An increase in the effective width of the adjacent lane (drivers will feel comfortable driving at a greater distance from the center line).

[22] Source: http://pavementinteractive.org, developed by the University of Washington
[23] Source: http://pavementinteractive.org, developed by the University of Washington

Functional Requirements Of Shoulders

Unpaved shoulders are stabilized by grading and compacting well-drained materials treatment. A good stabilized shoulder can protect the edge of the travel lane, however. If well maintained, edge drop-offs and edge raveling can be prevented.

The stabilized shoulder should extend at least two to four feet outward from the pavement edge to provide for occasional wheel loads. Sod shoulders should be mowed so drivers will know that they can be used in an emergency. Gravel shoulders should be compacted so that loose gravel will not be thrown into the travel lane.

Factors Affecting Performance Of Shoulders

A. Shoulder Width

Even the 2-foot (0.6 m) paved shoulder increases the effective lane width and greatly reduces the potential loss-of-control problems associated with edge drop-offs. Shoulders 2 to 6 feet (0.6 m to 1.8 m) wide increase traffic capacity and provide structural protection of the pavement. An 8-foot (2.4 m) paved shoulder provides room for a passenger car to come to a stop completely off the travel lane. A minimum width of ten feet is needed if a shoulder is to be used as an auxiliary traffic-carrying lane.

B. Cross Slope

The shoulder cross slope should be steep enough to remove water from the pavement quickly (¼ inch per foot for paved to a maximum of 1 inch per foot for turf shoulder). However, steering control may be difficult to maintain if the cross slope is too steep. The difference in cross slope between the shoulder and the adjacent pavement should not exceed 8%.

C. Pavement/Shoulder Joint

Poor pavement/shoulder joints lead to severe maintenance problems. Separation of the joint allows water to get beneath both the pavement and the shoulder, thereby reducing their strengths. When this happens, vegetation often grows in the widening crack, further aggravating the problem. Shoulder settlement and pavement edge raveling may follow; edge lines will be difficult to maintain.

D. Out Edge of Shoulder

Breakdown of the outer edge of the shoulder often moves toward the travel lane. Soil can be eroded away from the edge of the shoulder by running water (after a rain storm), which will severely weaken the shoulder. On the other hand, if soil builds up at the shoulder edge, a dike can be formed that will prevent water from draining away.

E. Surface Condition

A shoulder with cracks, depressions and uneven settlement is not very useful. Drivers will shy away from such shoulders—they may fear possible loss of control, or just dislike running over rough areas. Hence, a bad shoulder surface can defeat all the shoulder functions that involve voluntary traffic movements.

F. Pavement/Shoulder Contrast

Visual contrast between the travel lane and shoulder delineates the edge of the lane and emphasizes the fact that the shoulder has a special purpose. Contrast can be achieved by color and/or textural differences between the two surfaces. A texture change that causes tire noise is useful in alerting drivers who accidentally stray from the travel lane.

Maintenance Of Pavements And Shoulders

Many of the problems discussed in this Chapter can be identified and corrected during routine maintenance operations. Field personnel can provide important information on conditions that need correction and improvement. Areas of poor surface condition, inadequate drainage, and hazardous edge conditions can be spotted during travel to and from maintenance sites.

Sections of pavement containing edge drop-offs, edge raveling, roadside wheel ruts, and/or separated shoulder joints should be scheduled for maintenance as soon as possible. These inevitably lead to more severe pavement problems, and if such pavements are left unattended, eventual repair costs will be high. Shoulders on curves deserve special attention because vehicles frequently use shoulders in this situation.

For a self-directed learning tool regarding pavement types, materials, design considerations, mix design, structural design, construction, quality assurance, specifications, evaluation, maintenance, rehabilitation, and pavement management, please refer to the Pavement Interactive Website at http://pavementinteractive.org. For the most current information and technical assistance on road surfaces, please contact:

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