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National Handbook of Traffic Control Practices for Lo Volume Rural Roads and Small Cities VOLUME I: Low-Volume Roads

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Dr. Eugene R. Russell, P.E.

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16. Abstract

County and township roads carrying fewer than 400 vehicles per day are classified as low-volume rural roads (LVR) and make up a high percentage of the total rural road mileage in the US. The many miles of these low-volume rural roads present counties and townships with serious concerns, most of which are financial; i.e., how to provide construction and maintenance dollars to improve existing roads or simply maintain them at their current condition; replace or upgrade substandard bridges, and install or maintain necessary traffic signs or pavement markings. In other words, the problem is to provide a reasonably safe roadway system at reasonable cost. A desirable objective is to provide a roadway system in which a prudent driver, even a stranger to the area, will be able to safely travel the roads.

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VOLUME I: Low-Volume Roads

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National Handbook of Traffic Control Practice for Low Volume Rural Roads and Small Cities

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Disclaimer

The contents of this handbook, National Handbook of Traffic Control Practices for Low Volume Rural Roads (NLVR) and the National Handbook of Traffic engineering Practices for Small Cities (NSCH) reflect the views of the Kansas State University Project Director, who is responsible for the contents and facts and accuracy of the data presented in them. The National LVR Handbook has its basis in a state-specific handbook the Director/Author developed for the Kansas DOT; however, all additions, deletions, modifications and /or deviations to better reflect a national Handbook are solely the responsibility of the Project Director. The contents do not necessarily reflect the views or approval of Mack Blackwell Transportation Center, Kansas State University, the Kansas Department of Transportation, nor any local agency in Kansas or their representatives. The handbooks are meant primarily to supplement the Millennium edition of Manual of Traffic Control Devices (MUTCD 2000) and assist in the proper application of MUTCD 2000. Should there be any discrepancy, actual or implied, MUTCD 2000 should be followed.

These Handbooks do not constitute a standard, specification of regulation.

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Volume-I: Traffic Control Practices for Low Volume Rural Roads: National Edition

PREFACE

The purpose of the National Handbook of Traffic Control Practices for Low Volume Rural Roads (NLVR) is to assist local government units throughout the United States (US) in providing safe local roads for the traveling public. It is recognized that funds for construction, maintenance and operation of the local road system are limited and, therefore, the Handbook is aimed at providing a rational balance between maximum safety and minimum cost.

The use of the Handbook by local agencies throughout the US will mean more consistent signing and marking of local roads, thus providing roads which better meet the expectancy of the drivers and are therefore safer. The consistent use of the practices should also decrease the legal liability of local government units in case of lawsuits arising from roadway crashes.

The National LVR Handbook is intended for county (or similar units) and city engineers, county road supervisors, city street superintendents, township boards, and other local officials with low-volume road and street safety responsibilities.

Note: Low-Volume is normally defined as 400 vehicles per day or less.

The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD 2000) provides guidelines for design, installation and use of traffic control devices (signs, signals, and markings) but the guidelines are not substitutes for engineering judgment. It is intended that the NLVR Handbook suggest guidelines for use in conjunction with the MUTCD 2000 for traffic control device installation on low volume rural roads. This NLVR Handbook supplements MUTCD 2000 but is not intended to be a replacement. Every local government unit should have a copy of the latest MUTCD available for reference.

This first national edition (2003) is intended to be in conformance with the Manual On Uniform Traffic Control Devices (MUTCD), Millennium Edition, (as of December 28, 2001) hereafter referred to as MUTCD 2000. The National Handbook should not differ from the MUTCD 2000 and is meant only to supplement it. In that respect, keep in mind that MUTCD 2000 is the standard that must be followed. The National Handbook is not a standard but is intended to provide completely compatible, supplementary material. Its main objective is to assist persons in proper interpretation of the MUTCD 2000 and other topics

that the project director/author believes should enhance low-volume roads safety.

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INTRODUCTION

The Problem

County and township roads carrying fewer than 400 vehicles per day are classified as low-volume rural roads (LVR) and make up a high percentage of the total rural road mileage in the US. The many miles of these low-volume rural roads present counties and townships with serious concerns, most of which are financial; i.e., how to provide construction and maintenance dollars to improve existing roads or simply maintain them at their current condition; replace or upgrade substandard bridges, and install or maintain necessary traffic signs or pavement markings. In other words, the problem is to provide a reasonably safe roadway system at reasonable cost. A desirable objective is to provide a roadway system in which a prudent driver, even a stranger to the area, will be able to safely travel the roads.

Purpose

The main purpose of this National Low-Volume Roads (NLVR) Handbook is to assist local government officials in providing traffic control and guidance for persons driving on LVR. The suggested practices in the Handbook are in accordance, with the Manual on Uniform Traffic Control Devices, Millennium Edition (as of December 28, 2001) (MUTCD 2000) and, in some cases, address more specifically the application of MUTCD 2000 to low-volume rural roads (MUTCD 2000, Part 5). The NLVR also includes background information on the characteristics of low volume rural roads. Through the use of this background information, local governments should be able to better understand the problems of low-volume rural roads and their users, and can therefore, provide a safer roadway.

In order to increase uniformity nationwide, MUTCD 2000 includes guidelines or warrants for most types of traffic control devices. The guidelines outline the decision process to be followed before a traffic control device is installed or removed. MUTCD 2000 states "the decision to use a particular device at a particular location should be made on the basis of an engineering study of the location." This NLVR does not address all situations; however, it has been developed to provide guidance for its users. The need for the placement of traffic control devices as shown in the figures and discussed in the written material has been developed for typical situations as a result of past engineering studies and experience of the Project Director/Author.

Statements made in the NLVR, "if an engineering study indicates", "to be determined by the engineer," or "to be determined by engineering judgment." MUTCD 2000 specifically states that the decision to use a device is based on engineering judgment and engineering studies.

These statements are relevant because MUTCD 2000 specifically indicates that while MUTCD 2000 provides standards for the design and application of traffic control devices, it should not be a substitute for engineering judgment.

The MUTCD 2000 defines an engineering study as: (Sec 1A-13)

"The comprehensive analysis and evaluation of available pertinent information, and the application of appropriate principles, standards, guidance and practice as contained in this *Manual* 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."

The MUTCD 2000 defines engineering judgment as: (Sec 1A-13)

"The evaluation of available pertinent information, and the application of appropriate principles, standards, guidance and practices as contained in this *Manual* 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."

In such instances, reference is made to MUTCD 2000 which states, "Jurisdictions with responsibility for traffic control, that do not have qualified engineers on their staffs, should seek assistance from others such as the state transportation agency, their county, a nearby large city, or a traffic engineering consultant." It is clear that the decision to use traffic control devices rests with the jurisdiction responsible for the roadway. Remember, everyone is responsible for his or her own actions and if it is not clear to a person whether an engineering decision is being made it is recommended that he/she should get assistance. Also, it may be a good idea for county personnel to discuss this matter with the county attorney.

Such safety matters as bridge load limits, roadway surface and cross section, roadway geometry (sharpness of curves and sight distance on vertical curves, etc.) and the removal of roadside obstacles are not addressed in this NLVR Handbook.

Background

Traffic control devices are all signs, signals, markings, and other devices placed on, over, or next to a street or highway by authority of a public body or official having jurisdiction to regulate, warn, or guide traffic.

The need for uniformity in the meaning, design, usage, placement, and maintenance of traffic control devices has been recognized for many years. In response to this need, a manual for uniform traffic control devices for rural highways was first published in 1927. This was followed by a manual for urban streets in 1929. Combined manuals for rural and urban areas were published periodically until 1978 when the Manual on Uniform Traffic Control Devices (MUTCD) was approved and published by the Federal Highway Administration (FHWA) as the National Standard for all highways open to public travel. Subsequent publications of this National Standard were issued in 1988 and 2000. The Millennium edition of the MUTCD (with corrections as of December 28, 2001) MUTCD 2000 is the current manual on which this NLVR Handbook is based. Most States adopt the MUTCD; however, several have a state-specific version, which should be in substantial compliance.

MUTCD 2000 Guidelines or Warrants

In order to increase uniformity nationwide, MUTCD 2000 includes guidelines or warrants for most types of traffic control devices. The guidelines outline a decision process that should be followed before a traffic control device is installed or removed. The decision to use a particular device at a specific location should be made on the basis of an engineering study of the situation or on the basis of engineering judgment. MUTCD 2000 provides guidelines for design and use of traffic control devices (signs, signals, and markings) but the guidelines are not substitutes for engineering judgment. It is intended that the NLVR Handbook suggest guidelines for use in conjunction with MUTCD 2000 for traffic control device installation on low-volume rural roads. Therefore, this Handbook is neither a substitute for engineering judgment nor a legal requirement for installation. However, once a decision to install a traffic control device(s) is made, the device must conform to the MUTCD 2000 and once installed, there is a duty to maintain the device (ITE, Traffic Control Devices Handbook, 2001).

OLD MEANINGS OF "SHALL", "SHOULD" AND "MAY" (MUTCD, 1988 Edition)

The following terms were used consistently throughout the 1988 MUTCD, and were defined as follows: (MUTCD, 1988)

1. SHALL - A mandatory condition. Where certain requirements in the design or application of the device are described with the "shall" stipulation, it is mandatory when an installation is made that these requirements be met.

2. SHOULD - An advisory condition. Where the word "should" is used it is considered to be advisable usage, recommended but not mandatory.

3. MAY - A permissive condition. No requirement for design or application is intended.

NEW FORMAT OF THE MUTCD 2000

The Millennium Edition of the MUTCD (MUTCD 2000) uses a different format. In an attempt to facilitate better understanding of MUTCD 2000 requirements and differentiation between Standards that are mandatory and must be satisfied, Guidances that are recommended and should be followed, but not mandatory and Options that are permissive statements of practice that may be done but carry no requirement or recommendation have been collected and placed under their appropriate heading. For example, all the old "shall" statements were collected and printed under the heading of "Standards"; all the old "should" statements were collected and printed under the heading of "Guidance"; all the old "may" (permissive) statements were collected and printed under the heading of "Options". A new section, under the heading of "support" is intended for informational purposes only, and contains no shall, should or may statements.

The MUTCD 2000 presents the following definitions of standards, guidance, option and support (MUTCD 2000, Introduction, p 1-3):

When used in this handbook, the text headings shall be defined as follows:

1. Standard (the old "shall" statements) – 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. The verb shall is typically used. Standards are sometimes modified by Options.
2. Guidance (the old "should" statements) – 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. 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.

3. Option (the old "may" Statements) – 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.
4. Support (new category not in the previous MUTCD) – 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. The verbs shall, should, and may are not used in Support statements.

To emphasize and differentiate standards from guidance, options and support, standards in the Millennium MUTCD (MUTCD 2000) are printed in bold print.

Standard (MUTCD 2000)

23CFR [Federal Code Governing US Highways] 655.603 also states that traffic control devices on all streets and highways open to public travel in each state shall be in substantial conformance with standards issued or endorsed by the Federal Highway Administrator. [Done via MUTCD 2000 and all updates, amendments, interpretations, etc.]

New MUTCD 2000 section on Low Volume Roads

The MUTCD 2000 now has a section, "Part 5, Traffic Control Devices on Low-Volume Roads." It is important to understand two things: (MUTCD 2000, section 5A.01)

1. It only applies to roads with AADT (Annual Average Daily Traffic) of 400 vehicles or less.
2. The facility must lie outside of built up areas of cities, towns and communities.

Although Part 5 allows some lessening of standards for roadways that are eligible, most other parts of MUTCD 2000 still apply (and must be applied if there is any discrepancy). Also, other sections of MUTCD 2000 can always be applied, i.e., it is not mandatory to follow Part 5 even for low-volume roads. Also, it is not clear to the Project Director, exactly how AADT 400 will be determined.

Compliance dates:

There are many changes in the new MUTCD 2000 due to new standards, etc. However, this does not mean a road authority has to immediately change all their traffic control devices. A phase-in period to conform to new standards has been established.

Use of the Handbook

This NLVR Handbook is intended as a supplement to MUTCD 2000, thereby assisting local government officials in the proper use of traffic control devices. Other information is included that may help local government officials to both increase road safety and reduce liability from lawsuits arising from roadway accidents.
A suggested procedure is presented below:

Suggested Procedure

Outlined below is one suggested procedure, which may be followed in order to make effective use of the Handbook on a unit-wide or a spot-location basis. Steps 2, 3, 5 and 6 will be explained in more detail in later sections.

Steps	Actions
1	READ to understand the NLVR Handbook
2	CLASSIFY roads according to LVR type
3	IDENTIFY area of concern
4	LOCATE section in the NLVR Handbook which addresses the concern
5	PRIORITIZE concerns

6	Develop a PLAN OF ACTION based on priorities
7	TAKE ACTION

It is recommended that counties and other local units of government use some process to evaluate their road system to identify areas of concern. There are many ways to do this, which is best determined by each individual governmental unit. Some examples will be presented in later sections.

PRINCIPLES

More effective use of the NLVR Handbook is possible when the user has an understanding of some principles relating to good operating practices. Included in the basic principles are driver expectancy, positive guidance, and consistency.

Driver Expectancy

Drivers, and people in general, expect things to operate in certain ways. When entering a dark room a person will expect to find an on-off toggle switch for the lights. One also expects the switch will operate up for on and down for off. When it works the other way around, or when there is a rheostat knob, it takes a bit longer to respond to what is actually there. The same situation occurs with drivers. When a driver's expectancy is incorrect, either it takes longer to respond properly or, even worse, the driver may respond poorly or wrongly. (Alexander, G.J. and H. Lunenfeld, 1972) If, for example, a curve sign shows a curve to the right but the road actually curves left, one can imagine the difficulty the driver has in properly negotiating the curve at night - especially a stranger to the area. This may seem to be an extreme example; however, this has been observed rather frequently in the "Winding Road Sign" in which the bottom or beginning curve points in the wrong direction.

What the driver expects on a road is greatly influenced by what was experienced on the previous section of road. Studies have shown that what a driver saw - presence or absence of traffic control devices, road surface type, condition and width, narrow bridges or culverts; etc., (this might be called the "roadway environment") - is what the driver expects for the next 1/2 to 1 mile.

Driver expectancy is affected not only by the very recent experiences but also by those things drivers have learned through past experiences, e.g., advance railroad crossing warning signs are at all railroad grade crossings, stop signs are red, curve warning signs are yellow and diamond shaped, etc.

It follows that the consistent use and placement of traffic control devices can do a great deal toward ensuring that the driver's expectancy is appropriate. This is particularly true for drivers not familiar with the roadway. The unfamiliar driver should be considered when signing a roadway.

Driver expectancies are also affected by the type of road such as an interstate highway, state highway, county or township road. The driver expects to drive each of these with different levels of caution.

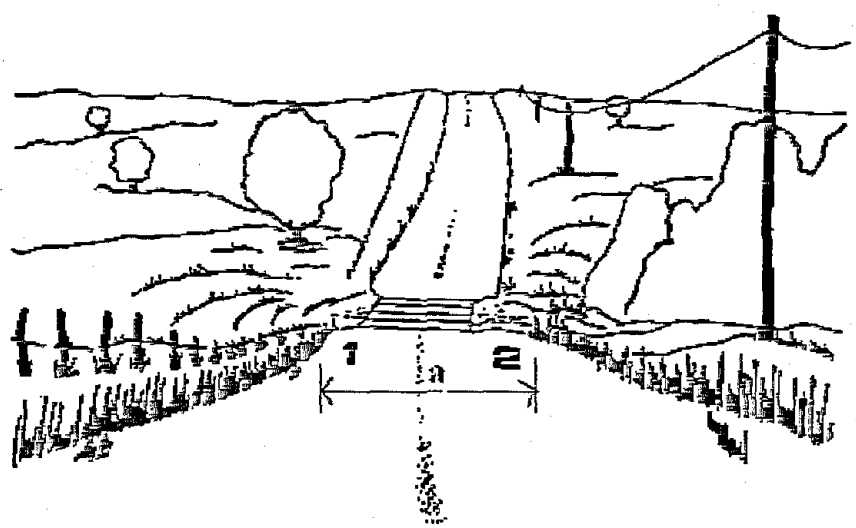
Positive Guidance

Positive guidance is the concept that a driver can be given sufficient information where he needs it and in a form he can best use it to safely avoid a potential hazard. (Alexander, G.J. and H. Lunenfeld, 1973) Positive guidance can be given to the driver through combinations of signs, object markers, safe advisory speed signs, and probably most important of all, the view of the road ahead. If drivers can see the curves far enough ahead to judge their sharpness and adjust to a safe speed, or see the approaching cars on cross roads because the intersections were clear of sight obstructions, or if there were no intersections hidden by the crest of a hill, if all narrow bridges and culverts were visible to drivers from both directions, there would be little need for anything more than an occasional stop or yield sign to assign the right of way at the intersection of LVR roads with higher volume roads. The condition just described might be called "roadway positive guidance." Studies have shown that the edge of the roadway ahead is among the most important guidance information the driver uses. Using the edge of roadway in this manner provides an easy and effective way of providing positive guidance at narrow bridges and culverts or other roadside obstacles.

An Example of Positive Guidance - "Tapering" is a simple technique in which the traveled way (maintained part of the road) is gradually narrowed (tapered) some distance ahead of say, a narrow culvert. If tapering is used, the driver simply follows, as usual, the edge of roadway and thus is guided away from the roadside obstacle. (See Figure 2.) If tapering is not used, the driver may not see the end of the short culvert and if he continues to follow the edge of roadway

(faulty guidance) he may drop a wheel off the end of the culvert. This is illustrated in Figure 1.

The details of the tapering technique are found in Appendix 1.

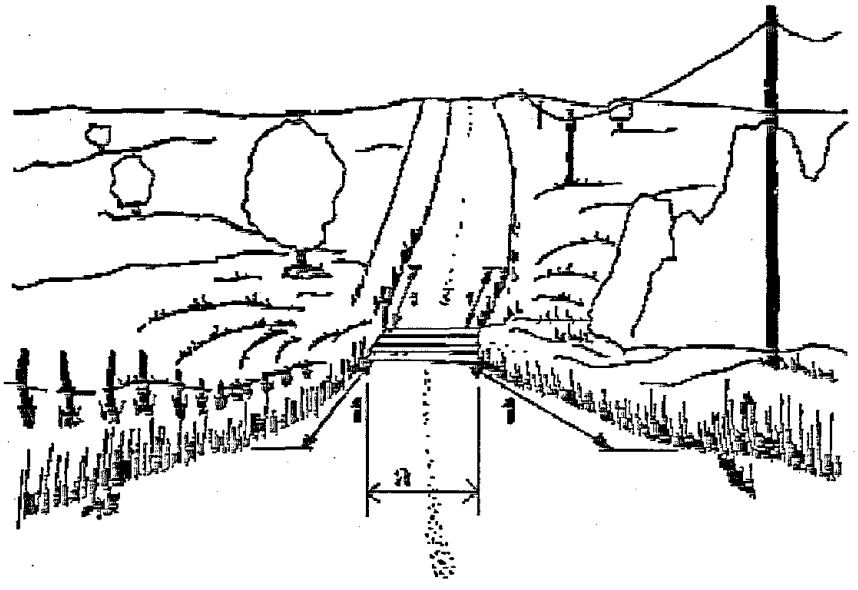


'a' Note: Road is wider than structure

FIGURE 1. Before Tapering Road

1. Roadway wider than culvert or bridge.

2. Roadway edge leads driver into culvert or ditch instead of on roadway.



'a' Note: Road is gradually narrowed to same width as structure
FIGURE 2. After Tapering Road

1. Tapered section - roadway edge leads away from ditch or culvert ends, i.e., roadway width is gradually reduced to width of structure. (See chapter 4 for narrow bridge signing and marking)

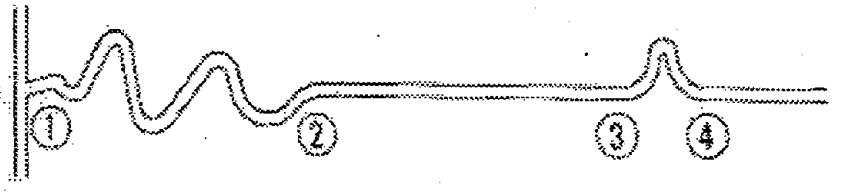
Consistency

Consistency relates to the "sameness" of the nature of the road from one section to another. Inconsistencies are sudden changes in the nature of the road. Inconsistencies violate a driver's expectancy, thus either the road should be made consistent, which is usually impractical, or something should be done to correct the driver's expectancy, i.e. restructure the driver's expectancy. In the case of a hidden curve in a nearly straight roadway, the use of a curve warning sign with, perhaps, an advisory speed plate should correctly restructure the driver's expectancy. After seeing the curve sign, with advisory speed plate the driver expects the curve, knows whether the road curves left or right, and knows the speed at which the curve can be comfortably and safely driven.

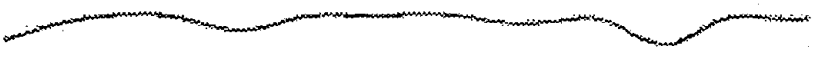
Other examples of inconsistencies are:

- A 2-lane road suddenly narrowing to a 1-lane road.
- A blacktop road changing to a gravel road.
- A bridge narrower than the approaching roadway.
- A blind intersection in an area where most intersections have clear sight distances.

Whether or not a situation is an inconsistency may depend on the direction in which the driver is traveling, and what he/she has experienced in the last half-mile or so.



Plan View



Profile View

FIGURE 3. Plan and Profile Views of a Road

The driver, traveling from 1 to 4 in Figure 3, finds the first part of the road, 1 to 2, very consistent, i.e., there is hardly time to pick up speed before seeing or being on another curve. After passing 2, the road is straight for as much as a mile, and the driver now expects the road to continue - straight - and what is seen confirms this expectancy as visual clues make the road appear to continue straight from 3 to 4 - "just a little dip," thinks the driver. What a surprise to have to suddenly handle three 30 mile-per-hour curves. Obviously, some expectancy restructuring should improve safety and signing is likely the best way to do it. For the driver traveling from 1 to 4, signs should not be needed at 1 or from 1 to 2 since the alignment is consistent. A curve warning sign prior to 3 (probably with an advisory speed plate) should be sufficient to give the driver enough information to handle the situation, i.e., the sign has satisfactorily changed his expectancy so, "what he expects is what he gets" Now, consider the driver traveling from 4 to 1. Likely, the driver will need an advance curve warning sign, with speed plate, placed prior to 4. From 3 to 2, the driver's expectancy builds and more of the same straight road is expected. Prior to 2, an advance "winding road sign" is likely needed for the unfamiliar driver to know what to expect.

Driving the roads is one way to identify inconsistencies. A useful technique for locating inconsistencies, information deficient locations, and expectancy violating situations is the Commentary Driving Procedure, described in a later section (Appendix 10).

LVR A, B, and C Roads* - As noted earlier, a driver's expectancy is influenced by the type of road being traveled and how the driver perceives the road. Traditionally, highways have been classified by administrative jurisdiction such as state, county, or township, by volume and most frequently according to function such as arterials, collectors or local service. It is impossible for a driver to perceive the administrative classification of roads without state, county or township route markers. It is difficult, if not impossible, for the driver to judge the function of the road or its volume without special training. What the driver does observe are the physical roadway characteristics that effect his/her perception of a reasonable or comfortable speed, and degree of vigilance required to drive a road safely, such as, width and type of surface, riding quality, road surface drainage, the presence or absence of traffic control devices, hills, and sharp curves. The LVR road classifications, LVR Type A, LVR Type B, and LVR Type C, are simply guidelines that give us some idea of how drivers perceive a road and how most will probably drive it.

LVR A, B and C Roads describe a classification system that was developed solely for use in the Handbook and does not relate to the state classification

system or other traditional classification systems. It is based solely on presumed driver perception.

LVR Type A B and C Roads, used in this handbook are related to roadway characteristics that drivers readily observe. These characteristics in turn are assumed to influence the way drivers perceive and drive these roads and the drivers' expectancies.

Characteristic*	LVR Road Type		
	LVR A See Figures 4 & 5	LVR B See Figure 6	LVR C Primitive See Figures 7, 8 & 9
Typical Width of Traveled Way and number of visible wheel paths	22' or greater, 3 or 4 visible wheel paths (if gravel)	16'-24', 2 or 3 visible wheel paths	2 or no visible wheel paths
Prudent Operating Speed	40 mph or greater	25-45 mph	40 mph or less
Surface Material	paved or aggregate	aggregate	natural surface may have some aggregate
Riding Quality	No adverse effect	may cause reduction in operating speed	typically poor; may be impassable due to poor weather
Drainage	All-weather road – good surface drainage; water carried to ditches	All-weather road – Some surface ponding; water carried in ditches	Fair-weather road –ditches are narrow or nonexistent; surface ponding likely to affect driveability

The key to the LVR classification is driver perception and expectancy of the road and how it would be driven safely by a driver exercising reasonable care. It is important to understand that the LVR ABC system is based on driver perception, i.e. how the driver perceives the road, which in turn influences how the driver drives the road. However, the perception can be related to some typical physical characteristics.

The typical physical characteristics usually found on each LVR road class are summarized in Table 1. Upon entering a road, many or most of the physical characteristics are almost immediately seen by the driver. After driving a short distance, the width of road, type of surface, and riding quality i.e., the "nature" of the road, will "suggest" an appropriate safe speed to a reasonably prudent driver (a driver exercising reasonable care). Thus Table 1 should provide guidance on how drivers may perceive a particular roadway. It is important to note that drivers' perceptions may change as conditions change. All it takes is a little rain for the effects of a well-drained versus a poorly drained road to become apparent to the driver. After an LVR type C road is graded and/or widened it may be perceived as an LVR type B. Figures 4 through 11 show examples of physical characteristics that LVR types A, Band C roads may have.

TABLE 1. Classification of LVR Roads by Typical Physical Characteristics

*Note: Parameters of characteristics are approximate estimate and may vary due to local conditions.

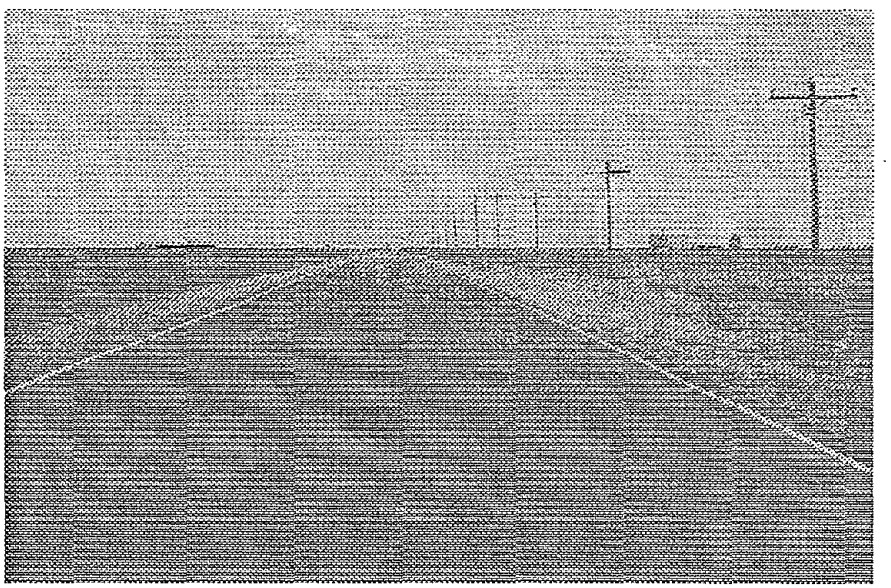


FIGURE 4. LVR Type A Paved Road

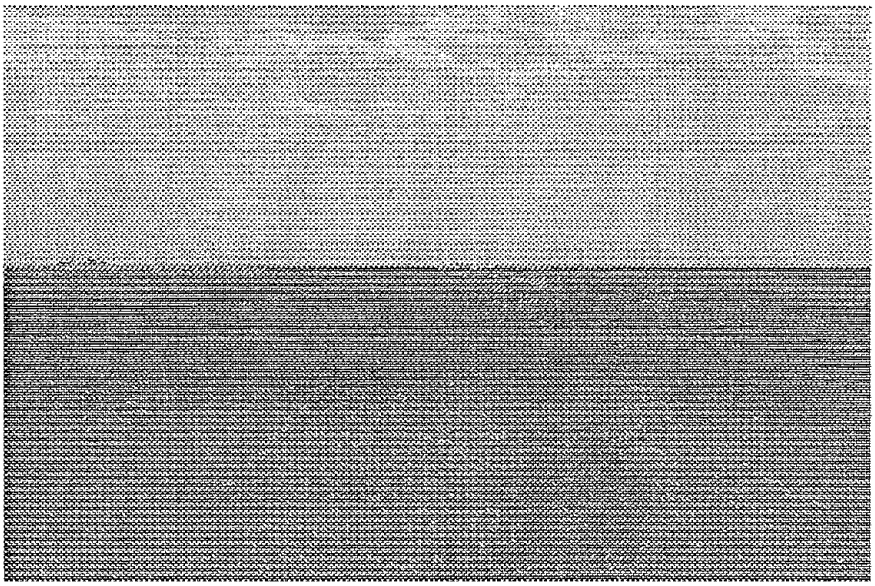


FIGURE 5. LVR Type A Unpaved Road

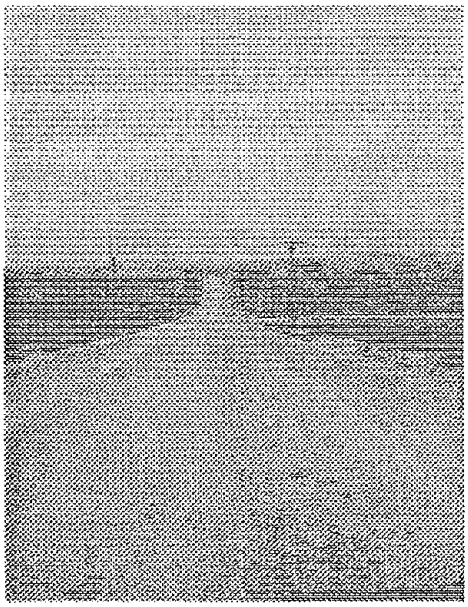


FIGURE 6. LVR Type B Road

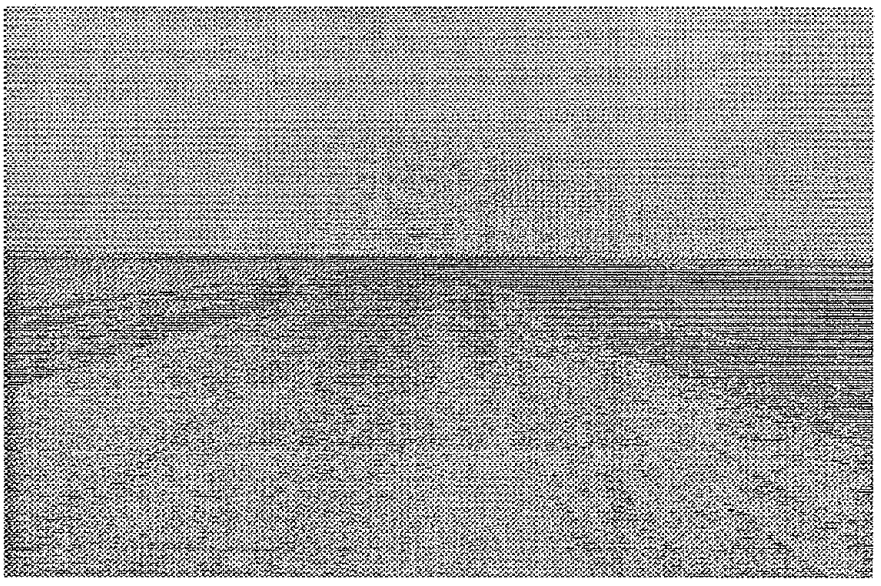


FIGURE 7. LVR Type B Road (Kansas Prairie Soil)

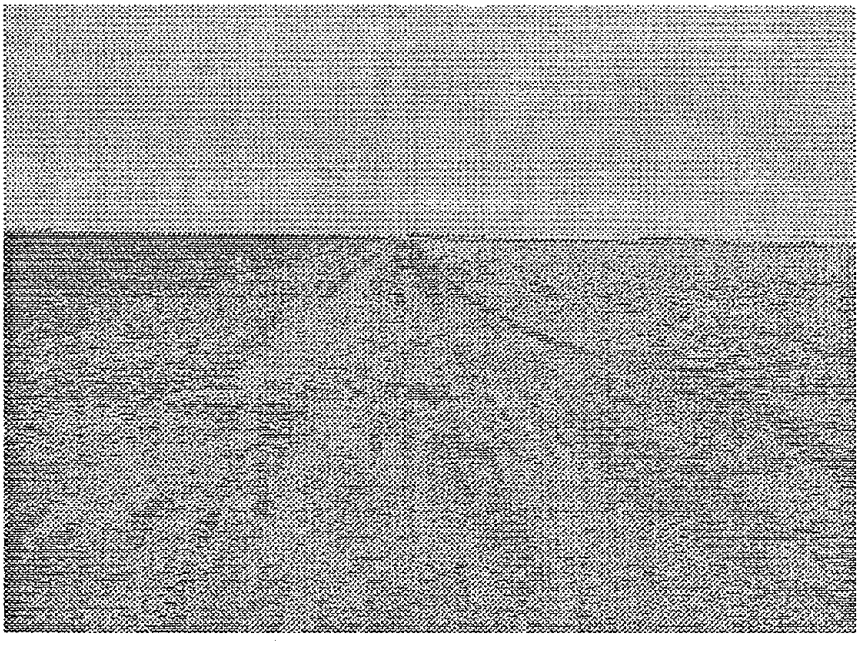


FIGURE 8. LVR Type C Road (Kansas Prairie Soil)

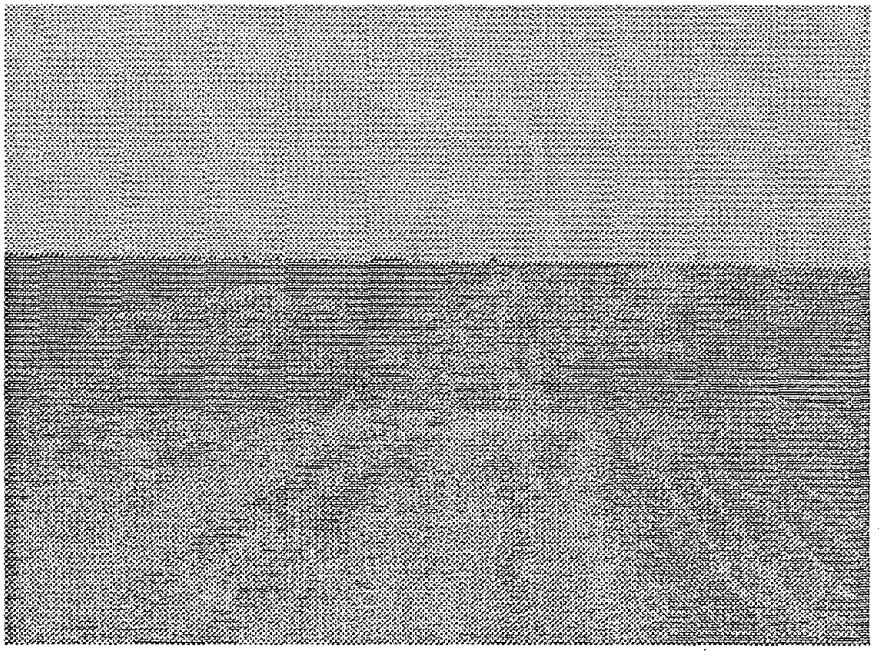


FIGURE 9. Primitive LVR Type C Road (Kansas Prairie Soil)

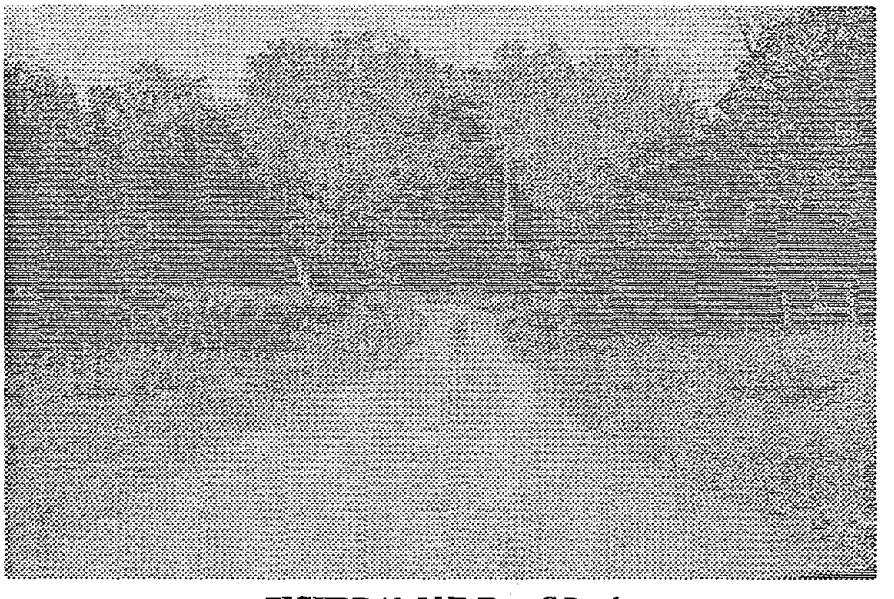
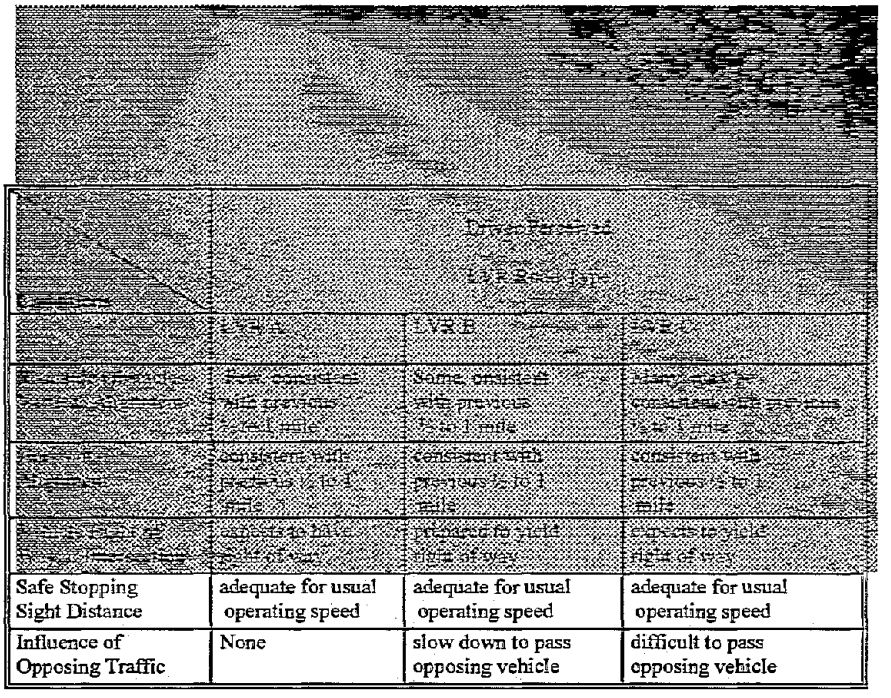


FIGURE 10. LVR Type C Road



Safe Stopping Sight Distance	adequate for usual operating speed	adequate for usual operating speed	adequate for usual operating speed
Influence of Opposing Traffic	None	slow down to pass opposing vehicle	difficult to pass opposing vehicle

FIGURE 11. LVR Type C Road (close up)

Once the driver perceives the roads' characteristics, it is assumed the average, prudent driver will drive the road accordingly. In Table 2 are summarized some of the assumed expectancies related to the LVR classification of rural roads just presented. By knowing what a driver may expect, inconsistencies can be identified and appropriate actions can be taken to lessen or remedy the problem.

TABLE 2. **Some Driver Expectancies by Roadway Type**

Table 3 shows the proper handling of some selected inconsistencies for the three LVR types of roads. Note that just as driver expectancies are different for each type of road (drivers expect a lower level of signing and maintenance on an LVR Type C than on an LVR B or A road), inconsistencies are also different. For example, what may be an inconsistent situation on a LVR A road, often is a consistent situation on a LVR C road and consequently may require little or no positive guidance and minimal signing regarding perception; however, an

engineering study or engineering judgment should always be used to determine the need for signing or not signing relative to driver perception and expectancy.

LVR Road Type / Inconsistency Discussion	Driver Perceived LVR Road Type		
	LVR A	LVR B	LVR C
T or Y Intersection	should be signed	should be signed	should be signed
Railroad Crossing	shall have advance sign and crossbucks	shall have advance sign and crossbucks	Shall have advance sign and crossbucks
Narrow Bridge or Culvert	all shall be signed	all shall have positive guidance -some should be signed	all shall have positive guidance (few should be signed)
Low Water Stream Crossing	should be signed	may be signed	may be signed
Dead End	not applicable	not applicable	not applicable

TABLE 3. Handling of Selected Inconsistencies

Summary:

Classifying the roads as LVR A, B, or C for the purpose of signing provides guidance for local government agencies to treat all roads in a consistent fashion relative to meeting drivers' expectancy. This is important in meeting the objective of providing a reasonably safe roadway system at a reasonable cost.

Traffic Control Devices

MUTCD Definitions:

The MUTCD 2000 defines Traffic control devices as 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. They assist the driver in a number of ways, including warning of potential, assigning vehicular right-of-way at

intersections, providing guidance in navigating the chosen route and informing the driver of regulations such as speed limits, no parking, and weight limits. Information may be given to the driver using a combination of the devices. Standardization of design and usage of traffic control devices helps the driver to quickly understand the information provided so that suitable action can be taken.

Requirements of Traffic Control Devices

The Manual on Uniform Traffic Control Devices (MUTCD 2000) and this NLVR Handbook set forth basic principles and guidelines that govern the design and usage of traffic control devices. It is important that these principles and guidelines be given consideration in the exercise of engineering judgment for the selection and usage of each device.

To be effective, a traffic control device should meet five basic requirements. They are:

1. Fulfill a need;
2. Command attention of drivers;
3. Convey a clear, simple meaning to drivers;
4. Command respect of drivers; and
5. Give adequate time for proper response by drivers.

These requirements are met through properly designing, placing, operating and maintaining traffic control devices. Basic requirements, considerations and device applications are outlined in Table 4 (ITE, Traffic Control Devices Handbook, 2001)

Design of the device refers to size, color, shape, reflectorization and message. The design is important in drawing attention to the device, conveying a clear meaning, and when combined with proper placement, can provide an adequate time for response by the driver. The design of traffic control devices is included in MUTCD 2000. In the design of some devices, minor modification of specified design elements is allowed provided that the essential appearance characteristics are met.

TABLE 4: Traffic Control Device Requirements. (Source: ITE Traffic Control Devices Handbook, 2001)

Basic Requirement	Consideration Employed	Application to Traffic Control Devices
Fulfill a need	Design	Device revisions required after changes in traffic

	Operation	Appropriate device and equipment installed for traffic requirements
	Maintenance	Replacement of defective or illegible devices
	Uniformity	Appropriate standard device and application
Command attention	Design	Size, contrast, color, shape, composition, and illumination
	Placement	Within the viewer's cone of vision
	Maintenance	Legibility of device maintained with advance visibility and retroreflectivity
Convey a clear, simple meaning	Design	Shape, size, color, message simplicity
	Placement	Positioned to address the situation when applicable
	Operation	Consistency between similar situations
	Uniformity	Standard legends for similar situations
Give adequate time for proper response	Design	Legibility and size appropriate for roadway
	Placement	Appropriate legibility and location for adequate response time
	Operation	Placed, maintained, and operated in a uniform and consistent manner
	Uniformity	Facilitation of quicker responses by road users

Based on *MUTCD 2000*, Section 1A.02, p. 1A.1.

Placement of a device should assure:

1. It can be easily seen by a driver so it will command attention and will also provide an adequate time for driver response.
2. It is properly positioned with respect to the situation to aid in conveying the proper meaning.

Maintenance of devices should insure that legibility is retained for good visibility and driver respect, and that devices are removed when no longer needed. Maintenance includes removing weeds, brush, etc., which obstruct the driver's view of the device.

Uniformity or consistency means similar situations should be treated in a similar fashion. The use of a standard device where it is not appropriate may be as bad or even worse than using a nonstandard device. Such misuse may result in disrespect for the device at those locations where the device is needed or the misuse might increase the risk of crashes.

Drivers expect uniformity and, as stated earlier, it is important that the driver's expectancy be met.

References

Alexander G. J and H. Lunenfeld, "Some Factors Affecting Reception and Use of Information by Drivers", Public Roads (June 1972).

Alexander G. J and H. Lunenfeld, Positive Guidance in Traffic Control (Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 1973).

CHAPTER 2

TRAFFIC SIGNS

GENERAL

Signs

Functionally, signs are classified as follows:

REGULATORY signs are notice of traffic laws or regulations and are established by ordinance or resolution of the jurisdictional authority.

WARNING signs call attention to potentially hazardous conditions on or next to a road.

GUIDE signs provide navigation information.

All aspects of signing have been standardized including shape, color, design, size, placement, and reflectivity.

Requirements

Although MUTCD 2000 does not present a legal requirement to install any particular traffic control device, once the decision is made to install a particular device, the design and application of that device must conform to MUTCD 2000.

Or as stated in MUTCD 2000 (Section 1A.09):

Standard (MUTCD 2000)

This Manual describes the application of traffic control devices, but shall not be a legal requirement for their installation.

However, this does not mean or imply that a road jurisdiction can ignore needed traffic control devices. Engineering judgment should be used.

The MUTCD 2000 makes it clear that once the decision to install a particular traffic control device is made, it must conform to MUTCD 2000 or a similar state version. As stated in MUTCD 2000 (in Section 1A.07):

Handbook Note:

In this section, and throughout the rest of this handbook, where a section is headed "standard", "guidance", "option" or "support" followed by a reference to MUTCD 2000, it has been copied from the MUTCD 2000. If the reference is followed by "condensed" it means not all of the MUTCD 2000 section was quoted; if it is followed by "paraphrased" it means that the writer of this handbook attempted to summarize the essence of the section's meaning. It is the intention that the information is the same or consistent with MUTCD 2000, which governs in the case of any discrepancies or question of interpretation.

STANDARDIZATION OF LOCATION (MUTCD 2000, Section 2A.16)

This section contains excerpts from MUTCD 2000 that are considered relevant to the LVR handbook. Sign location really cannot be standardized engineering judgment is usually required. Several examples are presented later in this handbook.

Guidance: (MUTCD 2000, Section 2A.16)

Signs should be located on the right side of the roadway where they are easily recognized and understood by road users. Signs in other locations should be considered only as supplementary to signs in the normal locations, except as otherwise indicated.

Signs should be individually installed on separate posts or mountings except where one sign supplements another or where route or directional signs must be grouped. Signs should be located so that they: (MUTCD 2000, Section 2A.19)

A. Are outside the clear zone unless placed on a breakaway or yielding support;
B. Optimize nighttime visibility;
C. Minimize the effects of mud splatter and debris;
D. Do not obscure each other; and
E. Are not hidden from view.

Standard: (MUTCD 2000, Section 2A.16)

Signs requiring different decisions by the road user shall be spaced sufficiently far apart for the required decisions to be made safely. One of the factors considered when determining the appropriate spacing shall be the posted or 85th percentile speed.

Guidance: (MUTCD 2000, Section 2A.16)

Because regulatory and warning information is more critical to the road user than guidance information, regulatory and warning signing whose location is critical should be displayed rather than guide signing in cases where conflicts occur. Information of a less critical nature should be moved to less critical locations or omitted.

See figures 13 through 17 for proper location of signs.

Mounting Height: (MUTCD 2000, Section 2A.18)

Standard:

Signs installed at the side of the road in rural districts shall be at least 1.5 m (5 ft), measured from the bottom of the sign to the near edge of the pavement. If parking or pedestrian movements should occur, the clearance to the bottom of the sign shall be at least 2.1 m (7 ft).

Option:

The height to the bottom of a secondary sign mounted below another sign may be 0.3 m (1 ft) less than the height specified above.

Where signs are placed 9 m (30 ft) or more from the edge of the traveled way, the height to the bottom of such signs may be 1.5 m (5 ft) above the level of the pavement edge.

A route sign assembly consisting of a route sign and auxiliary signs (see MUTCD 2000, Section 2D.27) may be treated as a single sign for the purposes of this section.

The mounting height may be adjusted when supports are located near the edge of the right-of-way on a steep backslope.

Lateral Offset (MUTCD 2000, Section 2A.19) (See figure 13)

Standard:

The minimum lateral offset from the edge of the shoulder (or if no shoulder exists, from the edge of the pavement) to the near edge of a roadside-mounted sign shall be 1.8 m (6 ft). Roadside-mounted sign supports shall be breakaway, yielding, or shielded with a longitudinal barrier or crash cushion if within the clear zone.

The minimum lateral offset from the edge of the shoulder (or if no shoulder exists, from the edge of the pavement) to the near edge of overhead sign supports (cantilever or sign bridges) shall be 1.8 m (6 ft). Overhead sign supports shall have a barrier or crash cushion to shield them if they are within the clear zone.

Guidance:

All supports should be located as far as practical from the edge of the shoulder. Advantage should be taken to place signs behind existing roadside barriers, on over-crossing structures, or other locations that minimize the exposure of the traffic to sign supports.

Standard:

If signs are placed on existing supports, they shall meet other placement criteria contained in this Manual.

Option:

Lesser lateral offsets may be used on connecting roadways or ramps at interchanges, but not less than 1.8 m (6 ft) from the edge of the traveled way.

In urban areas where lateral offsets are limited, a minimum lateral offset of 0.6 m (2 ft) may be used.

A minimum offset of 0.3 m (1 ft) from the face of the curb may be used in urban areas where sidewalk width is limited or where existing poles are close to the curb.

Option (MUTCD 2000, Section 5A.04):

[Applicable only to low volume roads as defined by the MUTCD 2000] A lateral affect of not less than 0.6m (2 ft) from the roadway edge to the roadway 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.

Orientation (MUTCD 2000, Section 2A.21)

Guidance:

Signs should be vertically mounted at right angels to the direction of, and facing, the traffic that they are intended to serve.

Where mirror reflection from the sign face is encountered to such a degree as to reduce legibility, the sign should be turned slightly away from the road. Signs that are place 9 m (30 ft) or more from the pavement edge should be turned toward the road. On curved alignments, the angle of placement should be determined by the direction of approaching traffic rather than by the roadway edge at the point where the sign is located.

Option:

On grades, sign faces may be tilted forward or back from the vertical position to improve the viewing angle.

Posts and Mountings (MUTCD 2000, Section 2A.22)

Standard:

Sign posts, foundations, and mountings shall be so constructed as to hold signs in a proper and permanent position, and to resist swaying in the wind or displacement by vandalism.

Support: (MUTCD 2000, Section 2A.22)

The latest edition of AASHTO's "Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals" contains additional information regarding posts and mounting.

Maintenance (MUTCD 2000, Section 2A.22)

Guidance:

All traffic signs should be kept properly positioned, clean, and legible, and should have adequate retroreflectivity. Damaged or deteriorated signs should be replaced.

To assure adequate maintenance, a schedule for inspecting (both day and night), cleaning, and replacing signs should be established. Employees of highway agencies, police, and other public agencies whose duties require that they travel o the roadways should be encouraged to report any damaged, deteriorated, or obscured signs at the first opportunity.

Steps should be taken to see that weeds, trees, shrubbery, and construction, maintenance, and utility materials and equipment do not obscure the face of any sign.

A regular schedule of replacement of lighting elements for illuminated signs should be maintained.

Agencies are encouraged to make periodic nighttime inspections of their signing to insure proper performance/visibility.

WARNING SIGNS

General: This section contains excerpts from the MUTCD 2000 that are considered relevant to the LVR Handbook with respect to warning signs.

Function of Warning Signs (MUTCD 2000, Section 2C.01)

Support:

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.

Application of Warning Signs (MUTCD 2000, Section 2C.02)

Standard: (MUTCD 2000, Section 2C.02)

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

Guidance: (MUTCD 2000, Section 2C.02)

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 completely covered when the condition or activity does not exist.

Support: (MUTCD 2000, Section 2C.02)

The application of warning signs can be classified into the categories shown in Table 2C-1 [of MUTCD 2000]. Warning signs specified herein [MUTCD 2000] cover most of the conditions that are likely to be encountered. Special

warning signs for low-volume roads are defined in MUTCD 2000, Section 5A.01.

Design of Warning Signs (MUTCD 2000, Section 2C.03)

Standard: (MUTCD 2000, Section 2C.03)

All warning signs shall be diamond-shaped (square with one diagonal vertical) with a black legend and border on a yellow background unless specifically designated otherwise. Warning signs shall be designed in accordance with the sizes, shapes, colors, and legends contained in the "Standard Highway Signs" book.

Standard: (MUTCD, 2000, Section 2A.05):

Where a word message is applicable, the wording shall be as herein provided. Standardization of these designs does not preclude further improvement by minor changes in the proportion or orientation of symbols, width of borders, or layout of word messages, but all shapes and colors shall be indicated.

The important word in the above standard is "minor." For word signs, only minor changes should be considered. Also, all word messages shall use standard wording and letters as shown in the MUTCD 2000, the "Standard Highway Signs" book and the "Standard Alphabets for Highway Signs and Pavement Marking" (MUTCD 2000, Section 2A.14, Word Messages)

For symbols only those shown in the MUTCD 2000 are allowed. As stated in the MUTCD (MUTCD 2000, Section 2A.13 Symbols)

Standard:

Symbol designs shall in all cases be unmistakably similar to those shown in MUTCD 2000 and the "Standard Highway Signs" book.

Placement of Warning Signs (MUTCD 2000, Section 2C.05)

Standard: (MUTCD 2000, Section 2C.05)

Warning signs shall be installed in accordance with the general requirements for sign placement as described in MUTCD 2000, Sections 2A.16 to 2A.21.

Support: (MUTCD 2000, Section 2C.05)

The total time needed to perceive and complete a reaction to a sign is the sum of the times necessary for Perception, Identification (understanding), Emotion (decision making), and Volition (execution of decision), and is called the PIEV time. The PIEV time can vary from several seconds for general warning signs to 6 seconds or more for warning signs requiring high road user judgment.

Guidance: (MUTCD 2000, Section 2C.05)

Warning signs should be placed so that they provide adequate PIEV time. The distances contained in Table 12 Appendix 5, [MUTCD 2000, Table 2C-4], are for guidance purposes and should be applied with engineering judgment. This table is reproduced in this handbook in Appendix 6. Warning signs should not be placed too far in advance of the condition, such that drivers might tend to forget the warning because of other driving distractions, especially in urban areas.

Minimum spacing between warning signs with different messages should be based on the estimated PIEV time for driver comprehension of and reaction to the second sign. [This is discussed further in this handbook in a following section. In general, on LVR with 55 mph (88km/h) speed limit, they should not be closer than 200 ft (61m).

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

Table 12 in Appendix 5 lists suggested sign placement distances for three conditions. This table is provided as an aid for determining warning sign location.

NLVR Handbook Discussion

It is important to take great care to place signs only where they are needed in order to prevent breeding disrespect for the signs.

If it is feasible, sight obstructions should be removed so that signs become unnecessary. At all times signs shall be visible and kept clear of obstructions such as trees, bushes, and weeds.

The two basic criteria for placement of advance warning signs are the approach speed and the reduced speed required to comply with the sign message! In rural areas, two signs should not be located closer together than 200 feet (61m) along the highway. All signs should be located so as to be viewed by motorists without obstruction for a distance of at least 400 feet (122 m) based upon deceleration from 55 mph (88 km/h) to 30 mph (48 km/h) Table 12 Appendix 5 (Condition C, MUTCD 2000, Table 2C-4)** Placing signs in dips or beyond the crest of hills, and placing informational signs on curves should be avoided.

*See Appendix 5 for advance warning sign placement.

**Vary according to prevailing (operating) speeds if an engineering study so determines (See Appendix 5).

SOME SELECTED WARNING SIGNS

This section will illustrate several warning signs used frequently on low-volume roads. The first series will be Intersection Warning Signs (W2-1 through W2-6).

Guidance: (MUTCD 2000, Section 2C.34)

The intersection sign should illustrate and depict the general configuration of the intersecting roadway, such as cross road, side road, t-intersection, y-intersection or curvilinear alignment.

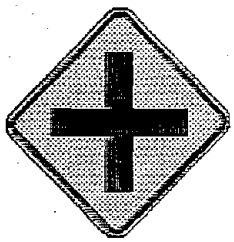
Intersection signs should not be used on approaches controlled by STOP signs, YIELD signs, signals, or where Junction signing (MUTCD 2000, section 2D.13 and 2D.28) or advance route turn assembly signs (MUTCD 2000, section 2D.29) are present.

Where the side roads are not opposite each other, the symbol for the intersection should indicate a slight offset.

Option: (MUTCD 2000, Section 2C.34)

The relative importance of the intersecting roadways may be shown by different widths of lines in the symbol.

An advance street name plaque (MUTCD 2000, section 2C.45) may be installed below an Intersection sign.



W2-1

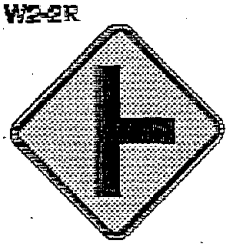
Standard Size
30" x 30"
See MUTCD 2000
Page 2C-29

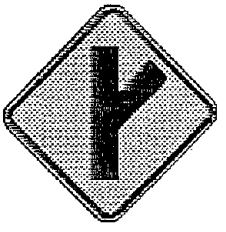
CROSS ROAD Sign (W2-1)
MUTCD 2000, Section 2C.34

The CROSS ROAD sign is intended for use on a through highway to indicate the presence of an obscured crossroad intersection. The relative importance of the intersecting roads may be shown by different widths of the line in the diagram. 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.

EXAMPLE: Figure 15; p. 47

W2-2R



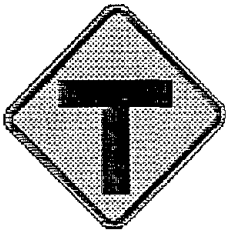


W2-3L

Standard Size
30" x 30"
See MUTCD 2000
Page 2C-29

SIDE ROAD Sign (W2-2, W2-3) (MUTCD 2000, Section 2C.34)

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. The relative importance of the intersecting roads may be shown by different widths of line in the diagram. If the side road occurs in the vicinity of a curve, the symbol may be modified appropriately.

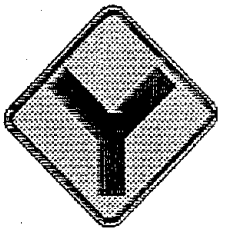


W2-4

Standard Size
30" x 30"
See MUTCD 2000
Page 2C-29

T- SYMBOL SIGN (W2-4) (MUTCD 2000, Section 2C.34)

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. The relative importance of the intersecting roads may be shown by different widths of line in the diagram. It may be desirable to place **two directional LARGE ARROW** sign or chevrons at the head of the T, directly in line with approaching traffic.
EXAMPLE: Figures 16, 17; pp.48, 49



W2-5

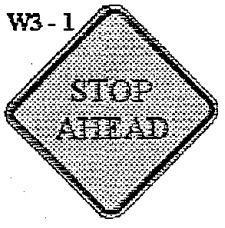
Standard Size
30" x 30"
See MUTCD 2000
Page 2C-29

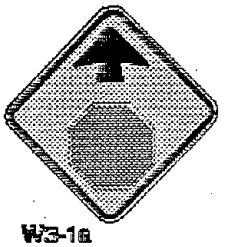
Y- SYMBOL Sign (W2-5) (MUTCD 2000, Section 2C.34)

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. The relative importance of the intersecting roads may be shown by different widths of line in the diagram. It may be desirable to erect a two directional LARGE ARROW sign at the fork of the Y directly in line with approaching traffic.

EXAMPLE: Figure 16; pp. 48

W3 - 1





W3-1a

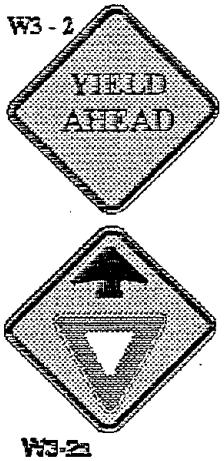
Standard Size
36" x 36"
Minimum Size
30" x 30"
See MUTCD 2000
Page 2C-19

STOP AHEAD Sign (W3-1) (MUTCD 2000, Section 2C.26)

A STOP AHEAD sign is intended for use on an approach to a STOP sign that is not visible for a sufficient distance to permit the driver to bring his vehicle to a stop at the STOP sign. (See MUTCD 2000 Table 2C-4, p.2C-6 for guidance on placement). Obstruction(s) causing the limited visibility may be permanent or intermittent. The STOP AHEAD sign shall be minimum of 30" x 30". In some cases it may be used for emphasis where there is poor observance of the STOP sign.

EXAMPLES: Figure 15, 16; pp.47, 48

YIELD AHEAD Sign (W3-2) (MUTCD 2000, Section 2C.26)



W3-2a
Standard Size
36" x 36"
Minimum Size
30" x 30"
See MUTCD 2000
Page 2C-19

A YIELD AHEAD sign is intended for use on an approach to a YIELD sign that is not visible for a sufficient distance to permit the driver to bring his vehicle to a stop at the YIELD sign (See MUTCD2000 Table 2C-4, p.2C-6 for guidance on placement). Obstruction(s) causing the limited visibility may be permanent or intermittent. The YIELD AHEAD sign shall be a minimum of 30" x 30" in size.

EXAMPLES: Figure 15, 16; pp.47, 48

W1-6R

LARGE ARROW Sign (W1-6, W1-7) (MUTCD 2000, Section 2C.34)

The LARGE ARROW sign shall be a horizontal rectangle with a standard size of 48" x 24", having a large arrow (W1-6) or a double head arrow (W1-7). It shall have a yellow background with symbol in black. A LARGE ARROW sign is intended to be used to give notice of a sharp change in alignment in the direction of travel. It is not to be used where there is no change in the direction of travel (ends of median, center piers, etc.). The LARGE ARROW sign, when used, shall be erected on the outside of a curve or on the far side of an intersection, in line with and at right angles to, approaching traffic. To be effective the LARGE ARROW sign should be visible for at least 500 feet and trial runs by day and night may be desirable to determine final positioning.

W1-7
Standard Size
48" x 24"
See MUTCD 2000
Page 2C-29

TWO DIRECTION LARGE ARROW Sign (MUTCD 2000, Section C.35)

Standard:

The Two-Directional Large Arrow (W1-7) 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 the center piers.

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-Directional Large Arrow sign shall be a horizontal rectangle.
EXAMPLE: Figure 16; p. 48

W1-8
Standard Size
18" x 24"
See MUTCD 2000
Page 2C-9

CHEVRON ALIGNMENT Sign (W1-8) (MUTCD 2000, Section 2C.10)

The Chevron Alignment sign shall be a vertical rectangle with a minimum size of 12" by 18". It shall have a yellow background with chevron symbol in black. The size of sign used should be determined by an engineering study or engineering judgment.

A Chevron Alignment sign may be used as an alternate or supplement to standard delineators and to the Large Arrow sign. The Chevron Alignment sign is intended to be used to give notice of sharp change of alignment with the direction of travel. Chevron Alignment sign is intended to provide additional emphasis and guidance for vehicle operators as to changes in horizontal alignment of the roadway.

Standard:

When used, Chevron Alignment signs, shall be installed used, are erected on the outside of a curve, sharp turn, or on the far side of an intersection, in line with and at approximately a right angle to approaching traffic.

Spacing of the signs should be such that the motorists always have two in view, until the change in alignment eliminates the need for the signs. To be effective, Chevron Alignment signs should be visible for at least 500 feet; trial runs by day and night may be desirable to determine final positioning. *

EXAMPLE: Figure 17; pp. 49

*See Appendix 7 for suggested placement

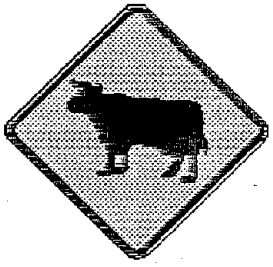
Replacement of Large Arrows at T-intersections

The Chevron alignment sign may be used to replace the two-directional arrow at T-intersections. A series of six chevrons are placed side by side. (Three pointing left, three pointing right as shown in Figure 17, which shows a typical chevron placement at a T-intersection, used in place of the double arrow.

Cattle Crossings

The Advance CATTLE CROSSING sign is intended to alert drivers that cattle may be crossing in the roadway ahead. There is a possibility that the driver may develop a disregard for the sign's meaning when cattle are not seen in the roadway at several Advance CATTLE CROSSING sign locations. The driver's respect for the sign can be increased by placing the Advance CATTLE CROSSING sign only when and where an engineering study or engineering judgment determines it is needed. The recommended practices may also be used for other animal crossing signs.

Description of Traffic Control Devices and Uses



W11-4
Standard Size
30" x 30"
See MUTCD 2000
Page 2C-31

The Advance CATTLE CROSSING sign should be used if the cattle cross at least twice a day most of the year and/ or the stopping sight distance is inadequate.

NLVR Handbook Discussion

If cattle cross less than once a day but more than once a week, the responsible agency should use engineering judgment to decide whether to use permanent signs, temporary signs or no signs at all. The reasons for the decision should be recorded.

For open range country an Advance CATTLE CROSSING sign with a supplementary plate NEXT__MILES may be used.

REGULATORY SIGNS

Intersections

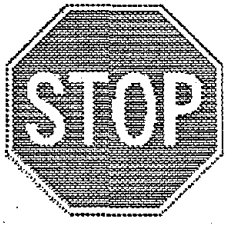
It is desirable for a driver to have an unobstructed view of the intersection and a length of the intersecting road sufficient to permit stopping or slowing the vehicle to avoid collisions. The minimum sight distance considered safe under various conditions is related directly to vehicle speeds and to the distances traveled while the driver sees the situation, reacts and brakes, and should be determined by an engineering study.

Note: See Appendix 6 for further discussion of sight distances at intersections. Those unfamiliar with the principles of the intersection sight distance should read this material before continuing with this section.

Descriptions of Traffic Control Devices and Uses

Given below are some of the MUTCD 2000 warrants for regulatory and warning signs for intersections.

REGULATORY SIGNS



R1-1
Standard Size
30" x 30"
Minimum Size
24" x 24"
See MUTCD 2000
Page 2B-7

STOP Sign (R1-l) MUTCD 2000 Section 2B.04
Application:

Because the STOP sign causes a substantial inconvenience to motorists, it should be used only where warranted. MUTCD 2000 lists specific warrants.

Guidance:

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

A. 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,

B. Street entering a through highway or street.

C. Unsignalized intersection in a signalized area.

D. High speeds, restricted view, or crash records indicate that a need for control by the STOP sign.

E. At Railroad Grade Crossings, under specific conditions (See MUTCD 2000 Part 8 Section 8B.07 and chapter 3 of this handbook)

Standard [Condensed] (MUTCD 2000, Section 2B.05)

- STOP signs shall not be installed at intersections where traffic control signals are installed and operating.
- Portable or part-time STOP signs shall not be used except for emergency and temporary traffic control.

Additional Guidance (MUTCD 2000, Section 2B.05):

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

STOP Sign Placement

The STOP sign shall be installed on the correct side of the traffic lane to which it applies.

When visibility is restricted a Stop Ahead sign shall be installed in advance of the STOP sign.

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

Guidance (MUTCD 2000, Section 2B.06) (condensed)

- Stop lines, when used, should be located at the point where the road user should stop.
- If only one stop sign is installed on an approach, it should not be placed on the far side.
- Where roads intersect at an acute angle, the STOP sign should be set at an angle or shielded so it is out of view of the 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.

MULTIWAY STOP APPLICATIONS (MUTCD 2000, Section 2B.07)

Standard: (MUTCD 2000, Section 2B.04, condensed)

If the number of approach legs controlled by STOP signs at an intersection is 3 or more, the numeral on the supplemental plaque if used, shall correspond. 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.

R1-3

R1-4

Support: (Condensed/paraphrased)

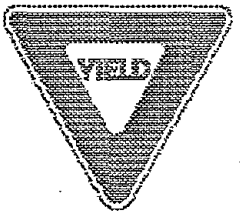
Multiway stop control is used where volume on the intersecting roads is approximately equal if certain traffic conditions exist.

Guidance:

- The decision to install multiway stop control should be based on an engineering study.
- Minimum volumes warrants and other guidance in MUTCD 2000 Section

2B.07 should be considered in the engineering study.

EXAMPLES: Figures 14, 15, 16; pp. 46 - 48



R1-2
Standard Size
36" x 36" x 36"
See MUTCD 2000
Page 2B-7

YIELD Sign (R1-2) MUTCD 2000 Section 2B.08

The YIELD sign assigns right-of-way to traffic on certain approaches to an intersection. Vehicles controlled by a YIELD sign need to slow down or stop, when necessary, to avoid interfering with conflicting traffic.

YIELD Sign Placement (MUTCD 2000, Section 2B.10)
Standard: (condensed/paraphrased)

The YIELD sign shall be installed on the correct side of the traffic lane to which it applies.

When engineering judgment determines that sign visibility is restricted, a Yield Ahead sign shall be installed (See MUTCD 2000, Table 2C-4 for guidance).

The YIELD 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.

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

Guidance (MUTCD 2000, Section 2B.10): (condensed/paraphrased)

YIELD lines, when used, should be located at a point where the road user should yield.

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

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

YIELD Signs may be installed (MUTCD 2000 Section 2B.09):

A. When the ability to see potentially conflicting traffic is sufficient to allow a road user traveling at the posted speed, the 85th percentile speed, or the statutory speed to pass through the intersection or to stop in a safe manner.
B. If controlling a merge-type movement on the entering roadway where acceleration geometry and/or sight distance its not adequate for merging traffic operation.
C. At the second crossroad of a divided highway where the median width is 9 m (30 ft) or greater. A STOP sign may be installed at the entrance to the first roadway and a YIELD sign may be installed at the entrance to the second roadway.
D. At any intersection where a special problem exists and where engineering study indicates the problem to be susceptible to correction by use of the YIELD sign.

See Examples: Figures 14, 16; pp. 46, 48

LOW-VOLUME ROAD INTERSECTION SIGNING CONSIDERATIONS

The following is adapted from the Traffic Control Devices Handbook (TCDH) (ITE 2001). It is recommended that all agencies with responsibility for road safety have a copy (available from Institute of Transportation Engineer's bookstore).

Sight Triangle:

The decision to use a specific traffic control device at an intersection is based upon the driver's ability to see the other legs of the triangle. The sight triangle is used to describe the area, which should be clear of obstacles from a 2-9 ft (2.74 m) height during all seasons of the year (ITE 2001). A sight triangle is shown in Figure 12.

STOP signs, YIELD signs, or no control?

The primary consideration for installing either a STOP or YIELD sign on a low-volume road is intersection sight distance. If the motorist does not have adequate visibility of another vehicle on the intersecting roadway, then some type of intersection control should be considered or the roadside features that restrict the sight distance should be removed. The ITE TCDH recommends the distances shown in figure 12. Note that for roads that carry little traffic, the possibility that two vehicles will arrive at the intersection at the same time is very small. Initially, it is necessary to determine whether enough sight distance exists so that motorists can adequately detect the presence of other vehicles in sufficient time to avoid a collision. If adequate sight distance does exist, then an intersection warning sign could be considered but not required. If the approach traffic volumes are less than 100 ADT, then a YIELD sign could be considered since there is little possibility of two vehicles arriving at the intersection at the same time. As the traffic volumes exceed 100 ADT and begin to approach 400 vehicles, then a STOP sign should be considered. Normally, the STOP or YIELD sign is installed for the vehicles approaching on the lower-volume roadway.

Usually, STOP signs or YIELD signs are used in pairs; however, there may be some locations where this does not apply. When a minor road (Type C) intersects a major road the location may indicate that only one quadrant does not have an adequate sight triangle (See Figure 14). Due care is recommended in the installation of non-paired STOP signs or YIELD signs. Such installations should be considered only if justified and recommended by an engineering study. Engineering judgment is required.

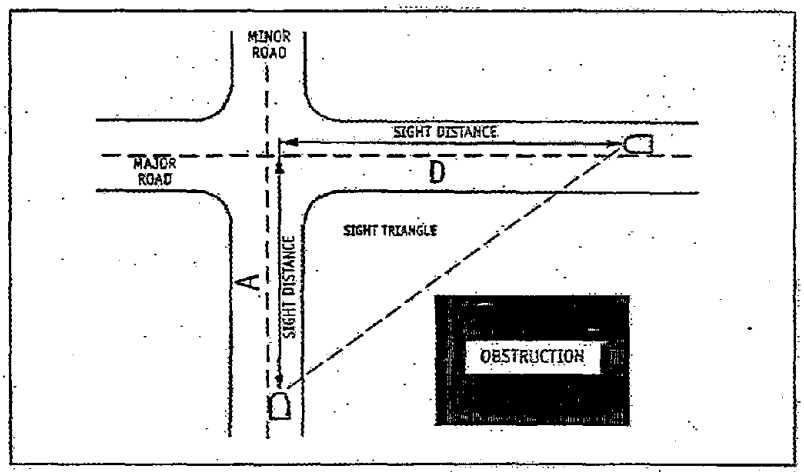
It is very important to also determine if a STOP AHEAD or YIELD AHEAD sign should be used. If adequate sight distance to see the STOP or YIELD sign (as indicated by MUTCD 2000, Table 2C-4, Handbook Table 12) is not available, a STOP AHEAD or YIELD AHEAD should be installed.

T-Intersection Signing:

Because of the widely accepted rule of the road, "yield to the right" at uncontrolled intersections, the minor leg of a T-intersection should be controlled with a STOP or YIELD sign. Otherwise, according to the "yield to the right" rule, a driver on the intersecting leg of a T-intersection with no traffic control would have the right of way no matter how minor the leg, and some courts may rule this way.

Note: Refer to Figures 13, 14, 15, 16 and 17 for some typical examples of intersection signing.

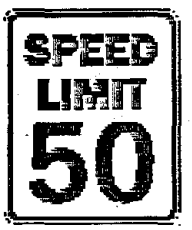
Additional details for determining adequate intersection sight distance can be found in Appendix 6.



		Operating Speed (mph)					
	Distance (ft.)	10	20	30	40	50	60
Stop Control	D	45	90	130	180	220	260
	A	50	50	50	50	50	50
No Control	D	-	125	200	325	475	650
	A	-	125	200	325	475	650

FIGURE 12. Recommended Intersection Sight Triangle and Sight Distances at Various Speeds

SOURCE: "Field Guide for Unpaved Roads," published in March 1997 by the Wyoming Technology Transfer and reproduced in "Traffic Control Devices Handbook, ITE, 2001."



SPEED LIMIT Sign (R2-1) (MUTCD 2000, Section 2B.11)

Two types of Speed Limit signs may be used: one to designate passenger car speeds, including any nighttime information or minimum speed limit that might apply; and the other to show any special speed limits for trucks and other vehicles.

Standard (MUTCD 2000, Section 2B.11)

After an engineering study has been made in accordance with established traffic engineering practices, the speed limit sign shall display the limit established by law, ordinance, regulation or as adopted by the authorized agency. The most common practice is to use the 85th percentile speed. If a public jurisdiction is not familiar with common, appropriate methods to set proper speed limits, the State DOT or a consultant should be contacted.

The speed limit shown shall be in multiples of 5 mph (10 km/h)

Guidance: (MUTCD 2000, Section 2B.11)

When a speed limit is to be posted, it should be the 85th percentile speed of free-flowing traffic, rounded up to the nearest 5 mph (10 km/h) increment.

Standard: (MUTCD 2000, Section 2B.15)

Location of Speed Limit Signs **(MUTCD 2000, Section 2B.15)**

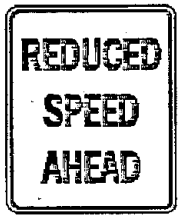
Speed Limit (R2-1) signs, indicating speed limits for which posting is required by law, shall be located at the points of change from one speed limit to another.

At the end of the section to which a speed limit applies, a Speed Limit sign showing the next speed limit shall be installed. Additional Speed Limit signs shall be installed beyond major intersections and at other locations where it is necessary to remind road users of the speed limit that is applicable.

Speed Limit signs indicating the statutory speed limits shall be installed at entrances to the State and at jurisdictional boundaries of metropolitan areas.

At locations where the speed limits changes at a specific point on the roadway for opposite directions of travel, be sure to place speed limit signs applicable to the direction opposite each other to avoid overlapping speed zones.

Reduced Speed Ahead Signs (R2-5 Series) (MUTCD 2000, Section 2B.16)



R2-5a

Standard: (MUTCD 2000, Section 2B.16)

The Reduced Speed Ahead (R2-5 series) signs shall be followed by a Speed Limit (R2-1) sign installed at the beginning of the zone where the speed limit applies. MUTCD Table 2C-4 (Handbook Table 12), condition "C" value should be considered to determine location.

R2-5b

Guidance: (MUTCD 2000, Section 2B.16)

The Reduced Speed Ahead (R2-5 series) signs should be used to inform road users of a reduced speed zone when engineering judgment indicates the need for advance notice to comply with the speed limit posted ahead. Some states use the word "AHEAD" under the numeral.

R2-5c

Option: (MUTCD 2000, Section 2B.16)

The following methods may be used to provide road users with advance notice of a change in the speed limit.

1. Any of the R2-5 series of signs may be displayed.
2. An assembly consisting of the Speed Limit (R2-1) sign with a supplemental legend plaque BEGIN mounted above the R2-1 sign and a supplemental distance plaque, such as 1/6 km or ¼ mi, mounted below the R2-1 sign may be displayed.

SIGN PLACEMENT ILLUSTRATIONS

The Following five pages illustrate recommended sign placements. Engineering judgment should be used in all cases. (Note: For simplicity, metric not included in figures. Refer to MUTCD 2000 for metric values.)

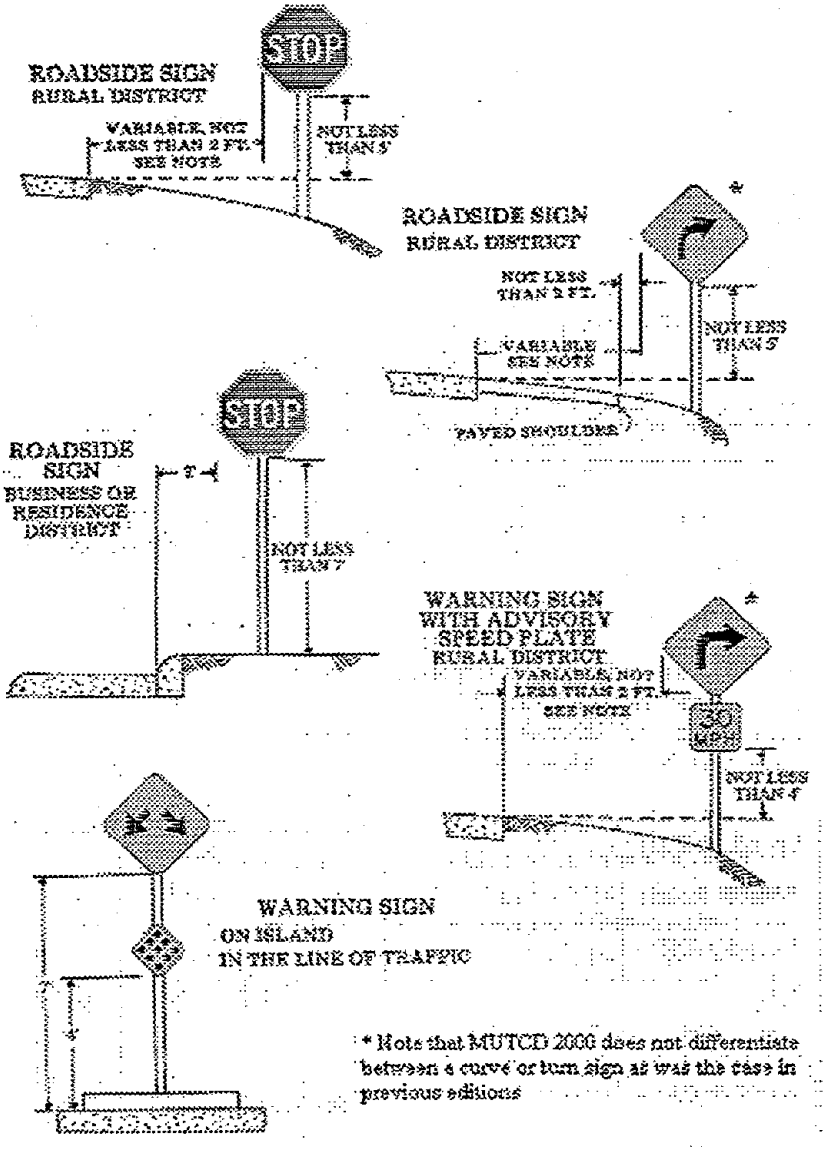


FIGURE 13. Height and Lateral Location of Signs

Note: Recommended lateral placement of signs is 12 ft (3.66 m) from the traveled way; if clearance is not available the minimum should be 2 ft (0.6 m).

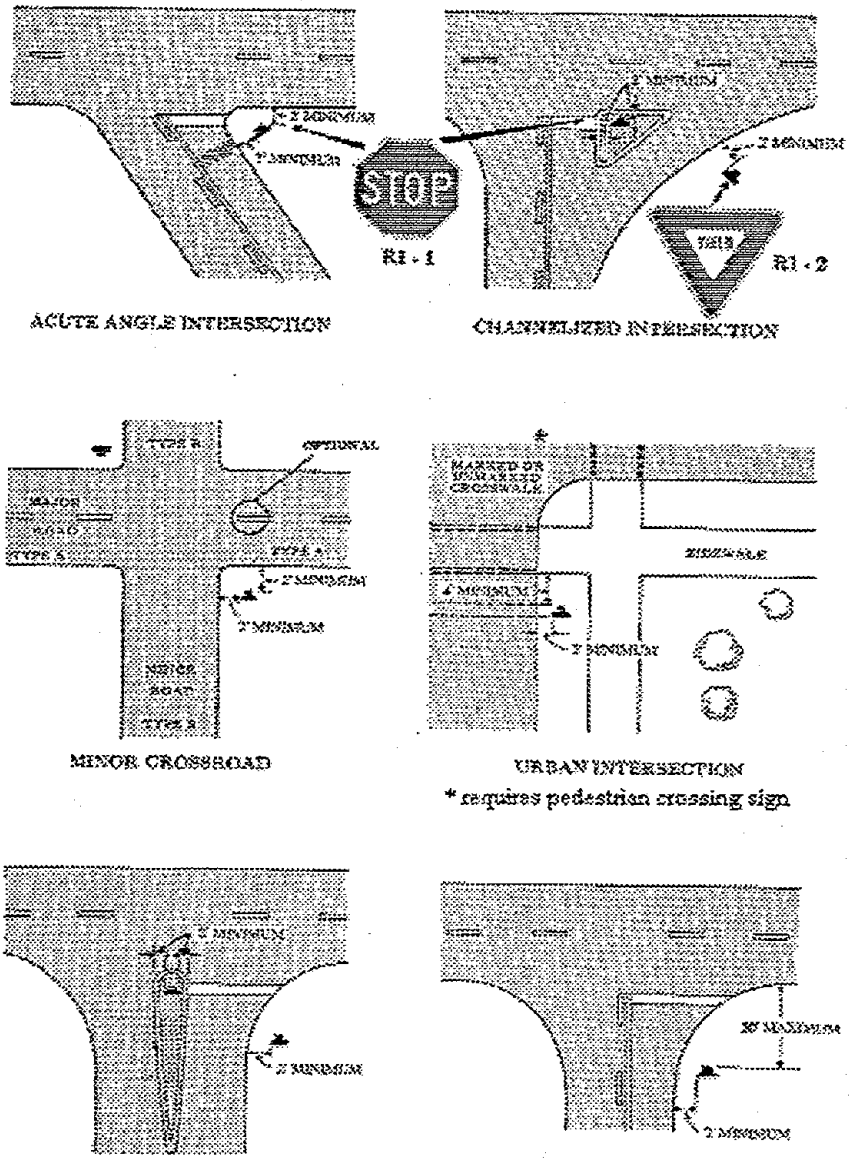


FIGURE 14. Example Locations for STOP and Yield Signs
Note: Recommended lateral placement of signs is 12 ft (3.66 m) from the traveled way; if clearance is not available the minimum should be 2 ft (0.6 m).

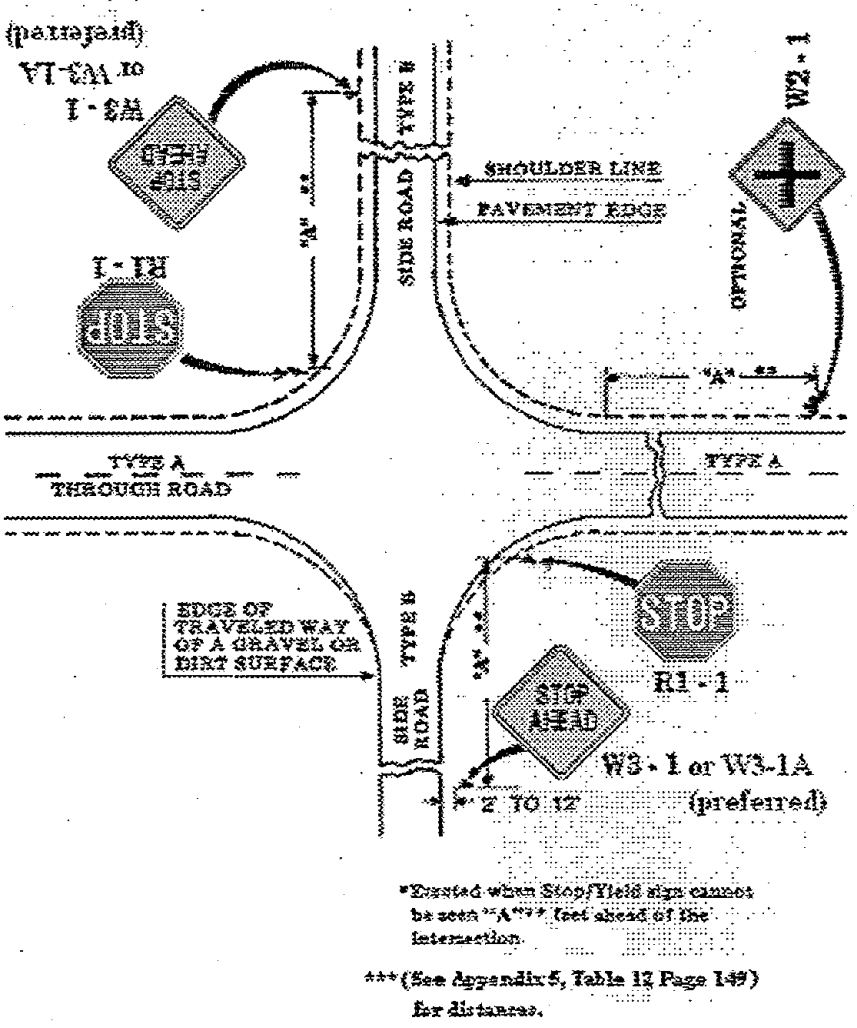


FIGURE 15. Example Location of Signs on a Wide Throated Intersection
Note: Intended for use on Type A and B roads. May be used on Type C roads.

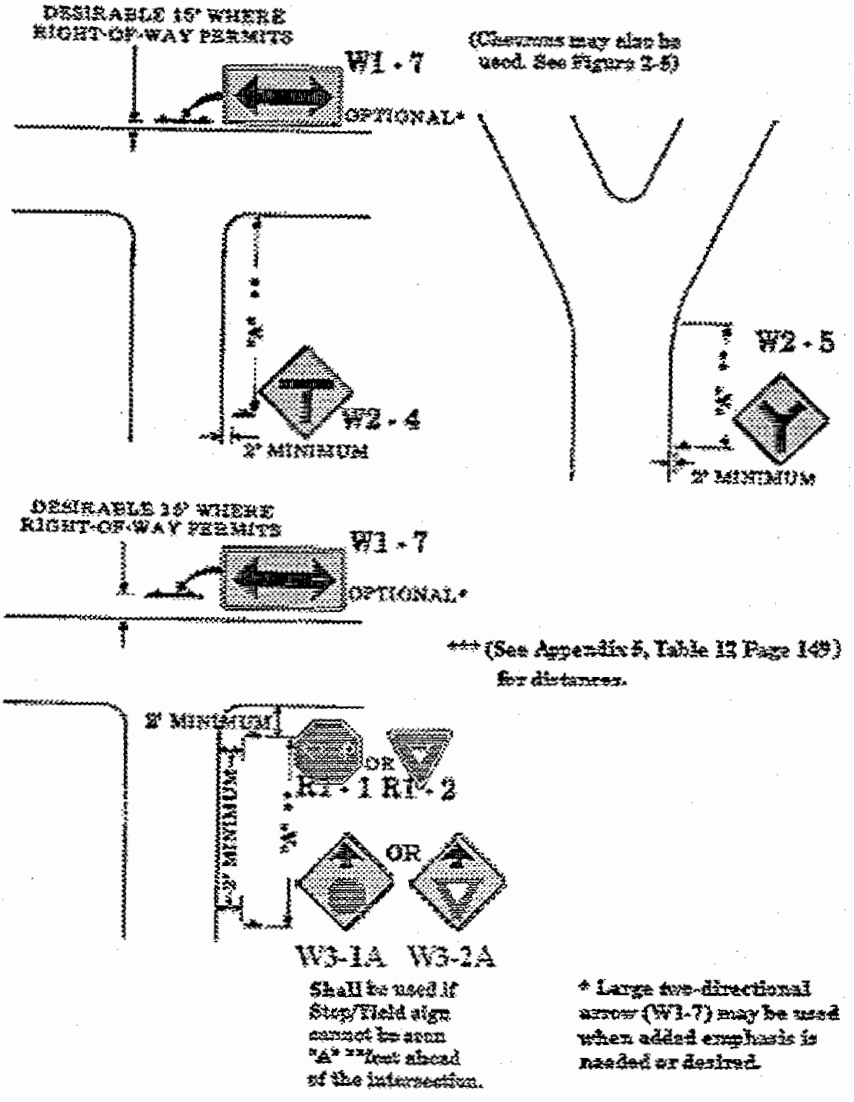
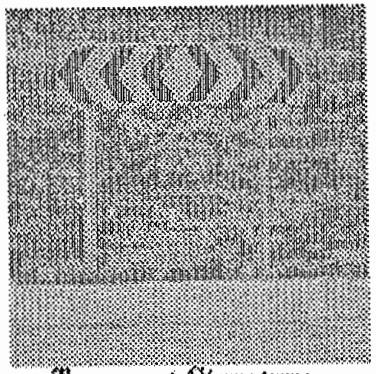
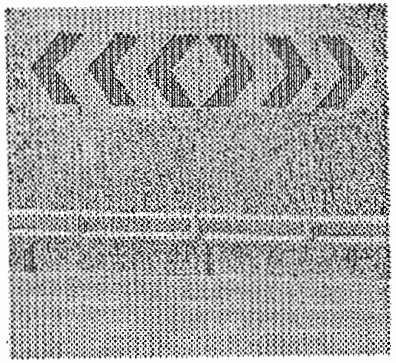


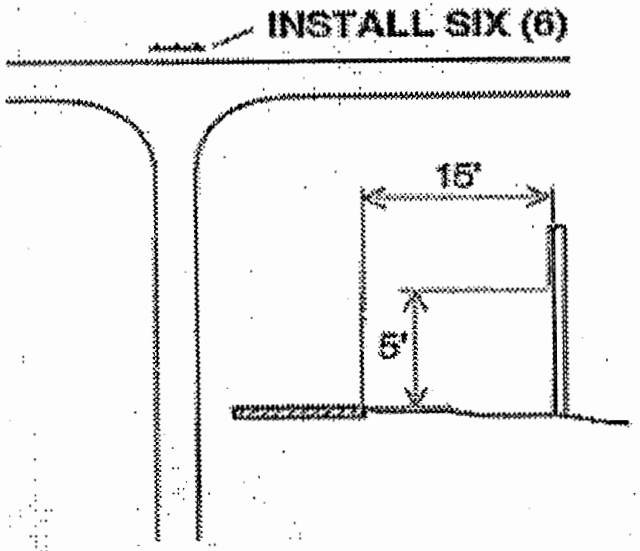
FIGURE 16. Example Location of Signs on T and Y Intersections
Note: Intended for use on Type A and B roads. May be used on Type C roads



Two-post Structure



Three-post Structure



*NOTE:

Standard size: 18"x24" (5.5m x 7.3m)
or larger size signs may be used

FIGURE 17 Example Chevron Installation at T-intersection

HORIZONTAL ALIGNMENT SIGNS: TURNS AND CURVES

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, engineering judgment should take many factors 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 using engineering judgment to determine if the curve is consistent with the previous roadway alignment, and the classification of the road type with regard to driver expectancy. For example, a Type C LVR with consistent curves throughout may need no curve or turn signs. Consistent curve signing is essential.

Horizontal Alignment Signs (W1-1 through W1-5) (MUTCD 2000, Section 2C.06)

Option: (MUTCD 2000, Section 2C.06)

The Horizontal Alignment Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), or Winding Road (W1-5) signs may be used in advance of situations where the horizontal roadway alignment changes. A Large Arrow (W1-6) sign may be used on the outside of the turn or curve (See Page 34).

Guidance: (MUTCD 2000, Section 2C.06)

The application of these signs should conform to Table 5 (MUTCD 2000 Table 2C-5). (Handbook Table 5 below)

Handbook Note:

Curve and turn signs are common on LVR, and their proper application may be important for reducing crash risk by enhancing driver expectancies of curves and turns ahead. This subsection addresses important issues related to signing curves and turns.

Change in MUTCD 2000

Previous editions of the MUTCD clearly specified when a turn (W1-1) or curve (W1-2) sign must be used. If an engineering study, usually by ball banking, (see ADVISORY SAFE SPEED DETERMINATION guidance at the end of this section) indicated an advisory speed of 30 MPH or less, a turn sign would be used; where as, if the advisory speed were greater than 30 MPH a curve sign would be used. The MUTCD 2000 leaves the choice to engineering judgment. (See note 1 under Table 5 below) However, unless there is good reason to do otherwise, (which should be documented) it is recommended that the choice should be based on Table 5.

TABLE 5. Horizontal Alignment Sign Usage (Table 2C-5, MUTCD 2000)

Number of Alignment Changes	Advisory Speed	
	≤ 30 MPH	> 30 MPH
1	Turn (W1-1)[1]	Curve (W1-2)[1]
2[2]	Reverse Turn[3] (W1-3)	Reverse Curve[3] (W1-4)
3 or more[2]	Winding Road[3] (W1-5)	

Notes:

1 Engineering judgment should be used to determine whether the turn or curve should be used.

2 Alignment changes are in opposite directions and are separated by a tangent distance of 180 m (600 ft) or less.

3 A right Reverse turn (W1-3R), Right Reverse Curve (W1-4R), or Right Winding Road (W1-5R) Sign is used if the first change in alignment is to the right; a Left Reverse Turn (W1-3L), Left Reverse Curve (W1-4L), or Left Winding Road (W1-5L) sign is used if the first change in alignment is to the left.

Standard: (MUTCD 2000, Section 2C.06)

When engineering judgment determines the need for a horizontal alignment sign, one of the W1-1 through W1-5 signs shall be used.

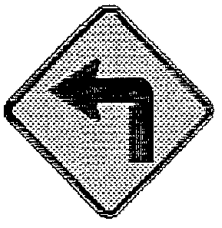
Option: (MUTCD 2000, Section 2C.07)

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

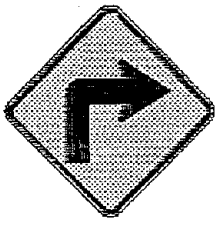
Standard: (MUTCD 2000, Section 2C.06)

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 1200 x 1200 mm (48 x 48 in) for high-speed facilities, and 900 x 900 mm (36 x 36 in) for low-speed facilities (a W1-9 sign is shown on page 55)

Description of Traffic Control Devices and Uses



W1-1 L



W1-1 R

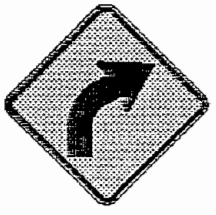
Standard Size
30" x 30"
See MUTCD 2000
Page 2C-9

TURN SIGN (W1-1)

The TURN sign (W1-1R or W1-1L) was intended for use where engineering studies of roadway, geometric, and operating conditions show the advisory speed of a turn to be 30 MPH (48.28 km/h) or less, and this advisory speed is equal to or less than the speed limit established by law or by regulation for that section of highway. **MUTCD 2000 states that engineering judgment should be used to determine whether the Turn sign or Curve sign should be used.** 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 plaque (W13-1).

Except in emergencies or when the condition is temporary, an Advisory Speed plaque shall not be installed until the recommended speed is determined by an engineering study.
EXAMPLE: Figure 20; p.59

W1-2L



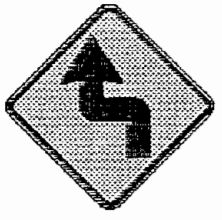
W1-2R

Standard Size
30" x 30"
See MUTCD 2000
Page 2C-9

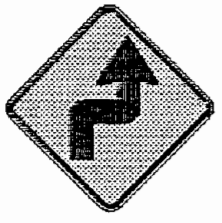
CURVE SIGN (W1-2)

The CURVE sign (W1 -2R or 2L) should be used where engineering judgment determines the need and, usually, conditions are such that the advisory speed is greater than 30 MPH (48.28 km/h) and equal to or less than the speed limit established by law or by regulation for that section of highway. . **MUTCD 2000 states that engineering judgment should be used to determine whether the Turn sign or Curve sign should be used.** Additional protection may be provided by use of the ADVISORY SPEED plaque.

EXAMPLE: Figure 21; p.60



W1-3L



W1-3R

Standard Size
30" x 30"
See MUTCD 2000
Page 2C-9

REVERSE TURN Sign (WI-3)

The REVERSE TURN sign is intended for use to mark two turns or a CURVE and a TURN in opposite directions as defined previously for TURN and CURVE signs that are separated by a tangent of less than 600 feet (182.88 m). If the first turn is to the right, a RIGHT REVERSE TURN sign (WI-3R) shall be used and if the first turn is to the left, a LEFT REVERSE TURN sign (WI-3L) shall be used.

For additional protection the ADVISORY SPEED plate may be used.

Engineering judgment should be used to decide between Reverse Curve and Reverse Turn signs.

REVERSE CURVE Sign (WI-4)

W1-4R

W1-4L

Standard Size
30" x 30"
See MUTCD 2000
Page 2C-9

The REVERSE CURVE sign is intended for use to mark two curves in opposite directions, as defined previously for curve signs that are separated by a tangent of less than 600 feet (182.88 m). If the first curve is to the right, a RIGHT REVERSE CURVE sign (WI-4R) shall be used, and if the first curve is to the left, a LEFT REVERSE CURVE sign (WI-4L) shall be used.

For additional protection the ADVISORY SPEED plate may be used.

Engineering judgment should be used to decide between Reverse Curve and Reverse Turn signs.

WINDING ROAD Sign (WI-5)

W1-5L

W1-5R

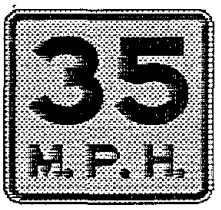
Standard Size
30" x 30"
See MUTCD 2000
Page 2C-9

The WINDING ROAD sign is intended for use where there are three or more turns or curves, as defined previously for TURN and CURVE signs, separated by tangent distances of less than 600 feet (182.88 m). If the first turn or curve is to the right, a RIGHT WINDING ROAD sign (WI-5R) shall be used and if the first curve or turn is to the left, a LEFT WINDING ROAD sign (WI-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 distance plaque (MUTCD 2000, Section 2C.41) indicating a length of roadway over which the winding road condition exists.

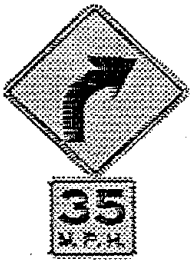


W13-1
Standard Size
24" x 24"
Minimum Size
18" x 18"
See MUTCD 2000
Page 5C-2

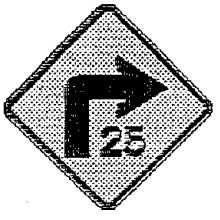
ADVISORY SPEED Plate (W13-1)

The ADVISORY SPEED plate is intended for use to supplement warning signs. It may be used in conjunction with any standard yellow Warning sign to indicate the maximum recommended speed around a curve or through potentially a hazardous location (determined by an engineering study). It shall not be used alone.

EXAMPLES: Figure 20, 21; pp. 59, 60



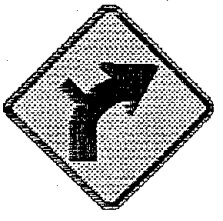
W1-2R with
W13-1



W1-9
Standard Size
30" x 30"
See MUTCD 2000
Page 2C-9

Combination Horizontal Alignment/Advisory Speed Sign (W1-9) (MUTCD 2000, Section 2C.07)

The Turn (W1-1) sign or the curve (W1-2) sign may be combined with the Advisory Speed (W13-1) plaque to create the combined sign (W1-9)



W1-10
Standard Size
30" x 30"
See MUTCD 2000
Page 2C-9

Combination Horizontal Alignment/Intersection Sign (W1-10)

The Turn (W1-1) sign or the curve (W1-2) sign may be combined with the cross road sign (W2-1) or the side road sign (W2-2 or W2-3) sign to create a combined sign (W1-10) that despite the condition where an intersection or side road occurs on a curve or a turn.

Use of Supplemental Plaques (MUTCD 2000, Section 2C.39)

Option:

A supplemental plaque may be displayed with a warning sign when engineering judgment indicates that road users require additional information beyond that contained in the main message of the warning sign. For example, the plaque may indicate distance to some condition.

Standard:

Supplemental plaques shall be used only in combination with Warning or regulatory signs. They shall not be mounted alone or displayed alone. If used, a supplemental plaque shall be installed on the same post(s) as the warning sign.

Design of Supplemental Plaques (MUTCD 2000, Section 2C.40)

A Supplemental plaque shall have the same color legend, border, and background as the warning sign with which it is displayed. Supplemental plaques shall be square or rectangular. A section on advisory safe speed determination can be found at the end of this section.

ADVISORY SAFE SPEED DETERMINATION

The advisory safe speed of a curve can be determined by the use of a ball bank indicator, also known as a slope meter (see Figure 19). For information concerning the mounting of the ball bank indicator, refer to Appendix 4.

The first trial run is made at a speed somewhat below the anticipated maximum safe speed. Subsequent trial runs are conducted with 5 mph speed increments. If a reading of 14 degrees or greater occurs at 20 mph or less then the safe speed is below 20 mph. The curve should be signed for that speed, i.e., 10 or 15 mph, at which a 14 degrees reading occurs. A reading of 12 degrees at a trial speed of 20, 25, and 30 mph indicates that the trial speed, i.e., 20, 25, or 30 mph is the safe speed. A reading of 10 degrees at speeds of 35 mph or greater indicates a safe speed of 35 mph or greater.

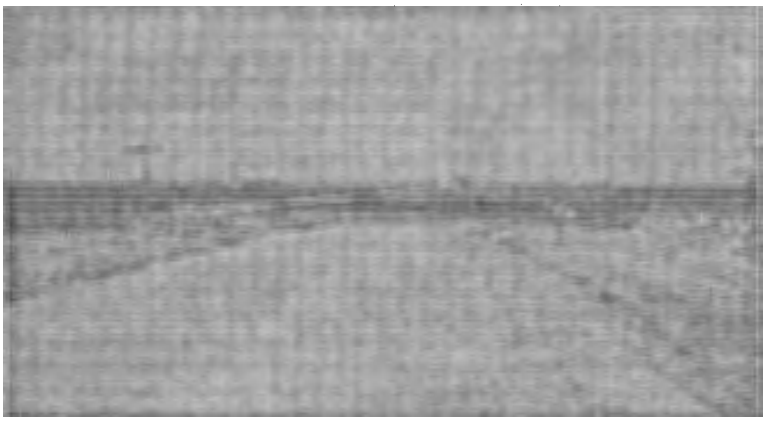


FIGURE 18. A Curve and Its Diagrammatic Sign

Standard:

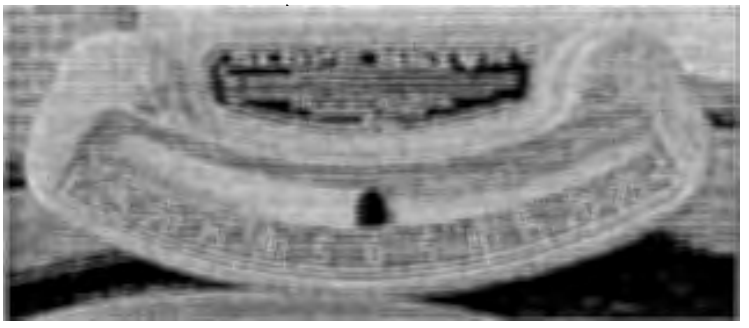


FIGURE 19. Ball Bank Indicator

Table 6 is intended for use in determining signing for Curves and Turns for LVR Type A and LVR Type B roads. It may also be used for signing LVR Type C roads if positive guidance is considered inadequate at specific locations.

TABLE 6. Signing for Curves and Turns*
(Source: Kansas State University; LVR Handbook, 2nd Edition)

Usual Operating Speed	Advisory Speed Based on Ball Bank Indicator								
	60	55	50	45	40	35	30	25	20
60			C	CA	CA	CA	TA	TA	TA
55				C	CA	CA	TA	TA	TA
50					C	CA	TA	TA	TA
45						C	TA	TA	TA
40							T	TA	TA
35								T	TA
30									T
25									
20 or less									

* optional, unofficial guidelines developed by Kansas State University

Key:

C - Curve Sign, Reverse Curve Sign (or winding road sign if applicable)
T - Turn Sign, Reverse Turn Sign (or winding road sign if applicable)
A - Advisory Speed Plate

NOTE: When signing is used refer to Figures 20 and 21 for some typical examples of curve and turn signing.

W1-8

Standard Size
18" x 24"
See MUTCD 2000
Page 2C-9

CHEVRON ALIGNMENT Sign (WI-8)

The CHEVRON ALIGNMENT sign shall be a vertical rectangle with a minimum size of 12" by 18". It shall have a yellow background with chevron symbol in black.

Guidance: (MUTCD 2000, Section 2C.10)

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.

A CHEVRON ALIGNMENT sign may be used to supplement standard delineation treatments and as an alternate or supplement to the LARGE ARROW sign. The CHEVRON ALIGNMENT sign is intended to additional emphasis and guidance for vehicle operators as to changes in horizontal alignment of the roadway.

Guidance (MUTCD 2000, Section 2C.10)

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. (See Appendix 7 for one method of spacing and placement on curves).

W14-3

Standard Size
36" x 48" x 48"
See MUTCD 2000
Page 2C-27

NO PASSING ZONE Sign (W14-3)

The NO PASSING ZONE sign should be used on paved two-lane roads to warn of the beginning of no-passing zones identified either by conventional pavement markings, DO NOT PASS signs, or both. When used, it shall be erected on the left side of the roadway at the beginning of the no-passing zones identified by, pavement markings, DO NOT PASS signs, or both.

Curve warning signs showing a better picture of the actual curve, other than those pictured in the MUTCD 2000 may provide more positive guidance under special conditions. An example of such a case and the recommended sign is

shown in Figure 18. If such a diagrammatic sign is used, it shall conform to the general specifications for sign design found in the MUTCD 2000.

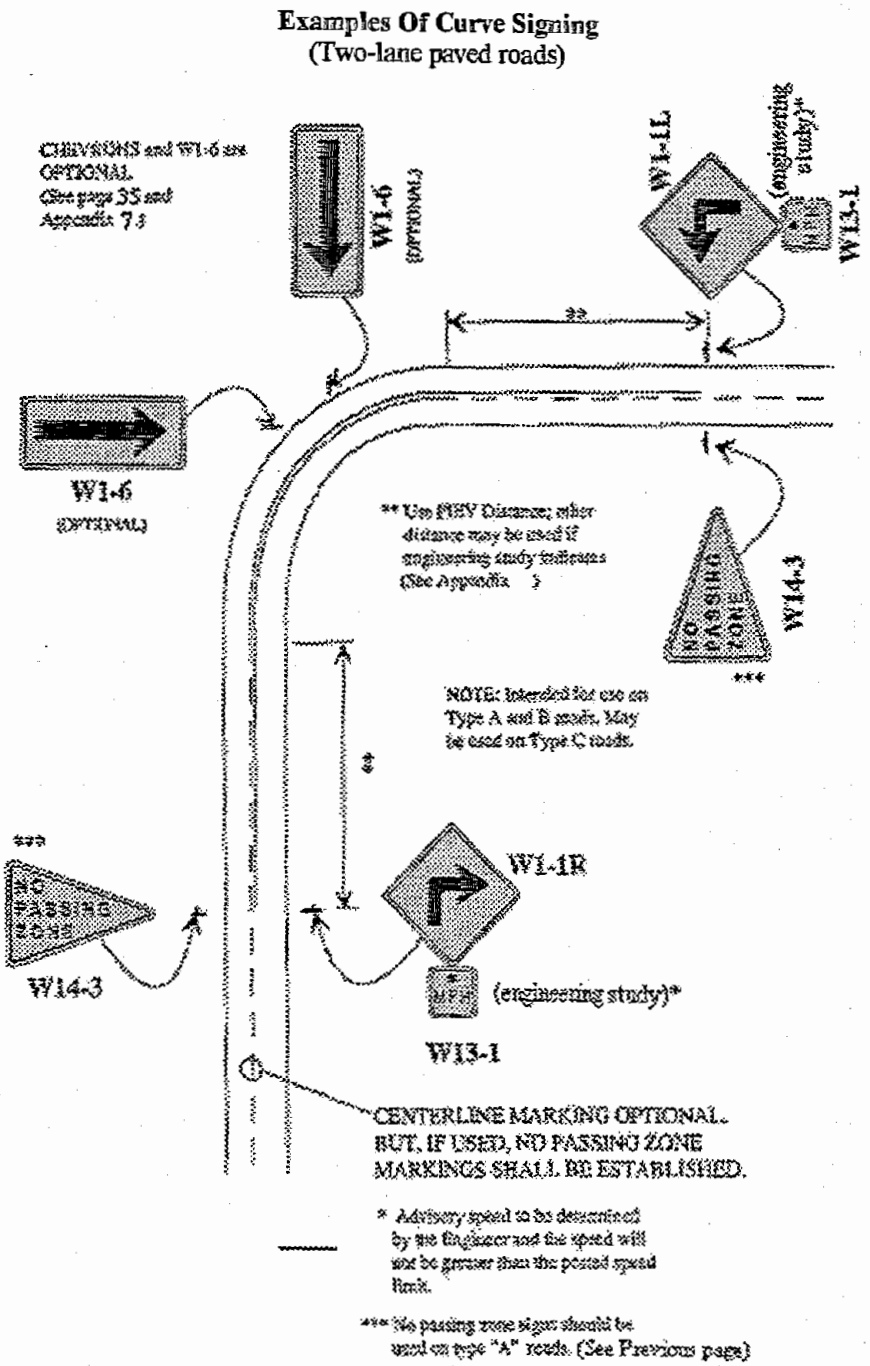


FIGURE 20. Example Signing and Pavement Marking on a Turn With Safe Driving Speed 30 MPH (50 km/hr) or Less

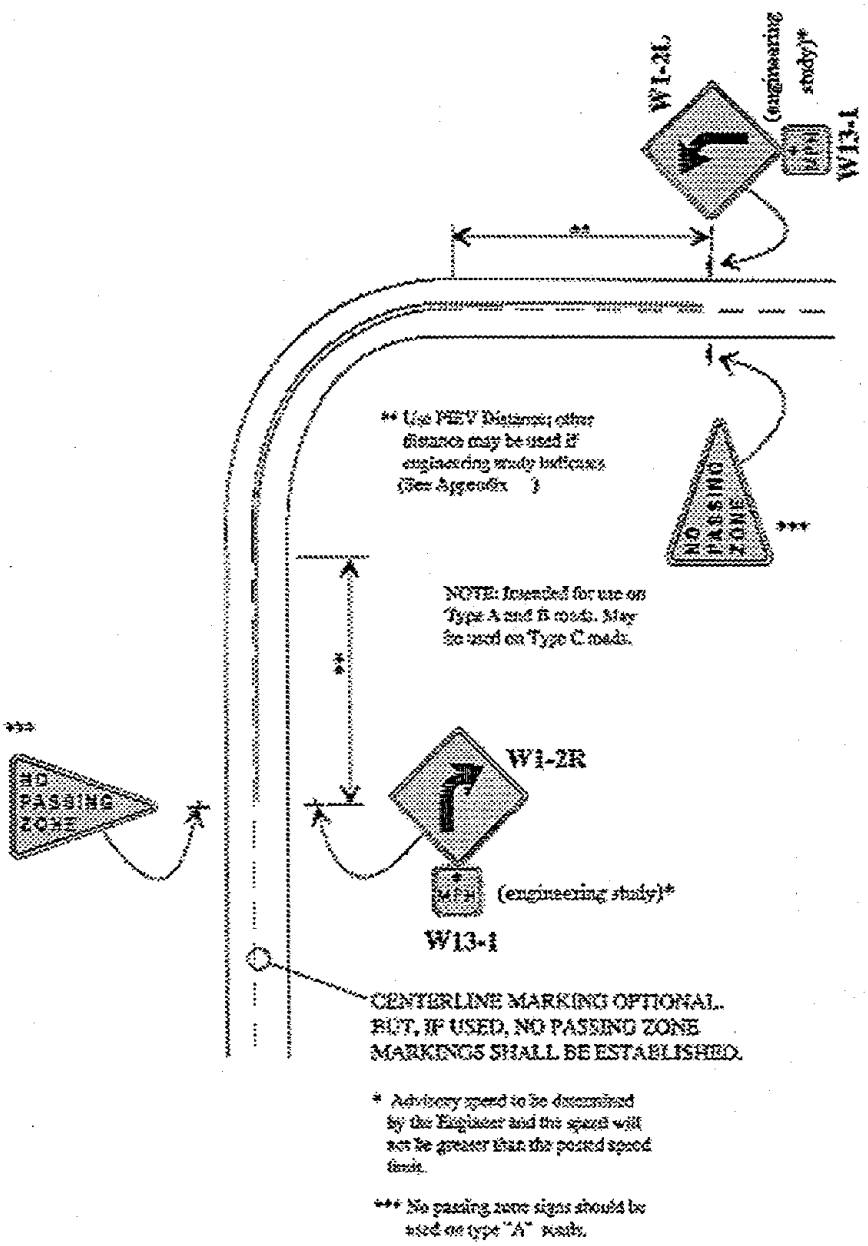


FIGURE 21. Example Signing and Pavement Marking on a Turn With Safe Driving Speed Between 30 MPH (50 km/hr) and 50 MPH (80 km/hr)

CHAPTER 3
HIGHWAY-RAIL INTERSECTION (HRI) SIGNING

(RAILROAD GRADE CROSSINGS)

The railroad grade crossing, although a fairly common occurrence on low-volume rural roads, still provides an inconsistency for the driver and must be marked. The accidents that occur at railroad grade crossings, though infrequent, are generally severe and often result in deaths. The responsibility and authority for administering rail-highway grade crossings programs varies from state to state. For example, in Kansas, the secretary of Transportation is responsible for all grade crossings in the state; the local agencies that have jurisdiction of the roadway on which the crossing exists are responsible for signs and markings on the approaches. In general, the local jurisdiction is most always responsible for signing and marking the approaches. The state DOT should be contacted for details in your state.

Description of Traffic Control Devices and Uses

There are three types of traffic control devices, which provide the driver with information about a railroad grade crossing.

The RAILROAD CROSSING (Crossbuck) signs (R15-1, R15-2) (and the accompanying sign to identify the existence of more than one track) are intended for use at each approach of the crossing itself. The placement and the maintenance of these signs are the responsibility of the railroad company. Missing or damaged crossbucks should be reported to the railroad concerned or to the designated authority in your state.

A new standard has been added to the MUTCD 2000, as follows:

Standard: MUTCD 2000, Section 8B.01. (condensed).

A strip of retro reflective white material not less than 50 mm (2 in) in width shall be used on the back of each blade of each Crossbuck sign for the length of each blade, at all highway-rail grade crossings, except those where Crossbuck signs have been installed back-to-back.

A Strip of retroreflective white material, not less than 50 mm (2in) in width, shall be used on each support at highway-rail grade crossings for the full length of the front and back of the support from the Crossbuck sign or Number of Tracks sign to near ground level.

Two things should be pointed out in regard to the above standard; 1) it is the responsibility of the railroad involved and 2) it has a 10-year phase in period.

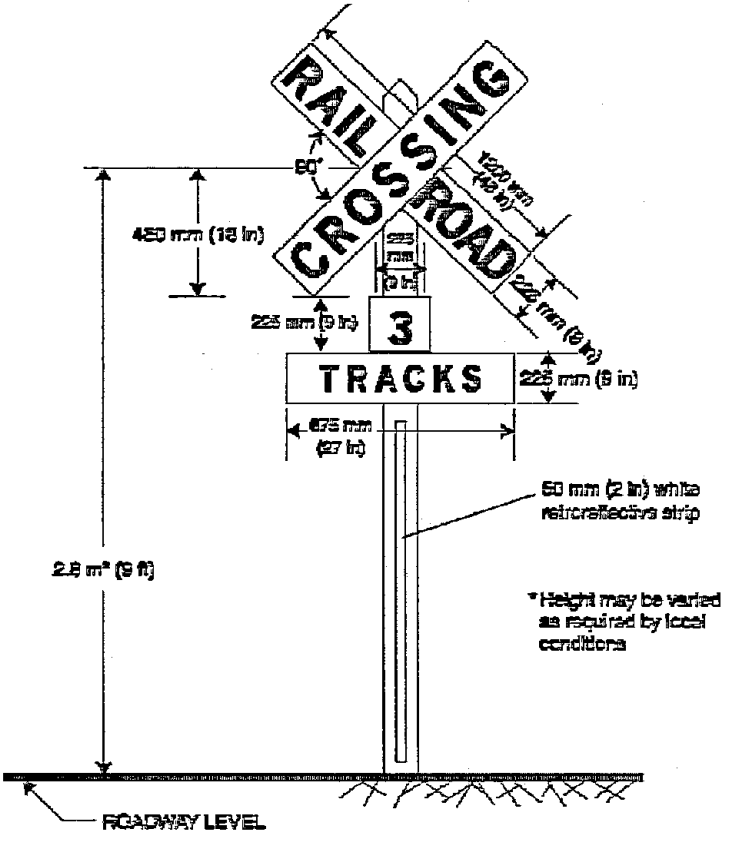
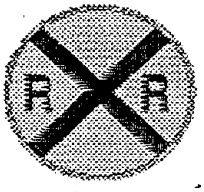


FIGURE 22: Highway-Rail Grade Crossing (Crossbuck) Signs (MUTCD 2000 Figure 8B-1)

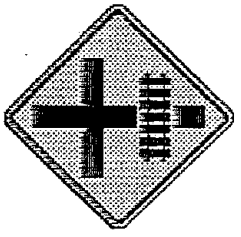
Highway-Rail Grade Crossing Advance Warning Signs (W10 Series) MUTCD 2000, Section 8B.03



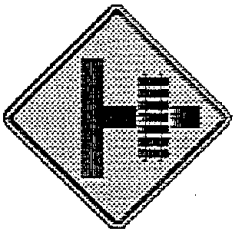
W10-1
Standard Size
36" Diameter
See MUTCD
page 8B-4

RAILROAD ADVANCE Warning Signs (W10-1, 2,3,4)

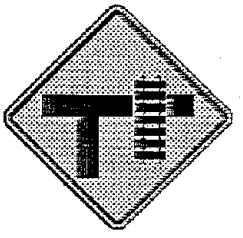
According to the MUTCD 2000, a RAILROAD ADVANCE (W10-1) warning sign shall be used on each roadway in advance of every grade crossing, with very few exceptions. This sign is the responsibility of the local agency that has jurisdiction over the approaching roadway.



W10-2
Standard Size
30" x 30"
See MUTCD 2000
Page 5F-2



W10-3
Standard Size
30" x 30"
See MUTCD 2000
Page 5F-2



W10-4
Standard Size
30" x 30"
See MUTCD 2000
Page 5F-2

Standard: MUTCD 2000, Section 8B.03

A Highway-Rail Grade Crossing Advance Warning (W10-1) Sign shall be used on each highway in advance of every highway-rail grade crossing except in the following circumstances:

A. If the distance between the railroad tracks and the parallel highway, from the edge of the track to the edge of the roadway, is less than 30 m (100 ft), the W10-2, W10-3, or W10-4 signs shall be used on the parallel highway to warn road users making a turn that they will encounter a highway-rail grade crossing soon after making the turn;

B. On low-volume, low-speed highway crossing minor spurs or other tracks that are infrequently used and are flagged by train crews;
C. In business districts where active highway-rail grade crossing traffic control devices are in use; and

D. Where physical conditions do not permit even a partially effective display of the sign.

The W10-2, 3 and 4 signs should be installed on highways that are parallel to railroad. The purpose of these signs is to warn a motorist making a turn that a railroad crossing is ahead. Where there is 100 feet or more between the railroad and the parallel highway, a W 10- 1 sign should be installed in advance of the railroad crossing and the W10-2, 3 or 4 signs on the parallel highway would not be necessary (See Figure 23) and MUTCD 2000, page 8B- 4).

STOP and YIELD Signs at Grade Crossings (RI-I. W3-1) (Handbook Recommendations. See next page for MUTCD 2000, Sec.8B.07 language on this subject)

The use of the STOP and YIELD signs at railroad-highway grade crossings is allowed under certain conditions (see next section for conditions); however, three things should be kept in mind:

1. In Kansas, the decision is the responsibility of the Secretary of Transportation according to state statutes, other states may differ.
2. The decision should be made based on an engineering study.
3. Several research studies have concluded that STOP signs at grade crossings have limited compliance, should be limited to those grade crossings selected after need is established by a detailed traffic engineering study.

   Such crossings should have the following general characteristics:
   - Highway should be secondary in character with low traffic counts.
   - Train traffic should be substantial (at least two-trains per day).
   - Line of sight to an approaching train is restricted by physical features such that approaching traffic is required to reduce speed to 10 mph (16.09 km/h) or less in order to stop safely.
   - At the stop line, there must be sufficient sight distance down the track to afford ample time for a vehicle to cross the track before the arrival of the train.

The engineering study may determine other compelling reasons for the need to install a STOP sign, such as an interim measure until active traffic control signals can be installed. STOP signs shall not be used on primary through highways or at grade crossings with active traffic control devices.

STOP or YIELD Signs at Highway-Rail Grade Crossings (MUTCD 2000, Section 8B.07)

Option: (MUTCD 2000, Section 8B.07)

At the discretion of the State law, STOP (R1-1) or YIELD (R1-2) signs may be used at highway-rail grade crossings that have two or more trains per day and are without automatic traffic control devices.

Support: (MUTCD 2000, Section 8B.07)

Two or more trains per day means an average of two or more trains per day operating over the highway-rail grade crossing for a 12-month period prior to the installation of the STOP or YIELD control sign.

Option: (MUTCD 2000, Section 8B.07)

For other highway-rail grade crossings with passive warning devices, STOP or YIELD signs may be used based on an engineering study

Guidance: (MUTCD 2000, Section 8B.07)

The engineering study should take into consideration such factors as highway and train traffic characteristics (including volume and speed), collision history, and the need for active control devices, and sight distance to the approaching train.

Option: (MUTCD 2000, Section 8B.07)

If a STOP or YIELD sign is installed at a highway-rail grade crossing, it may be installed on the Crossbuck post or on a separate post at a point where the vehicle is to stop, or as near to that point as practical.

Standard: (MUTCD 2000, Section 8B.07)

For all highway-rail grade crossings where STOP or YIELD signs are installed, the placement shall conform to the requirements of Chapter 2B [MUTCD 2000]. Stop Ahead (W3-1a) or Yield Ahead (W3-2a) Advance signs shall also be installed if the criteria for their installation given in Section 2C.26 is met. See Handbook page 48.

Examples Of HRI Signing
(Source: KDOT Maintenance Manual)

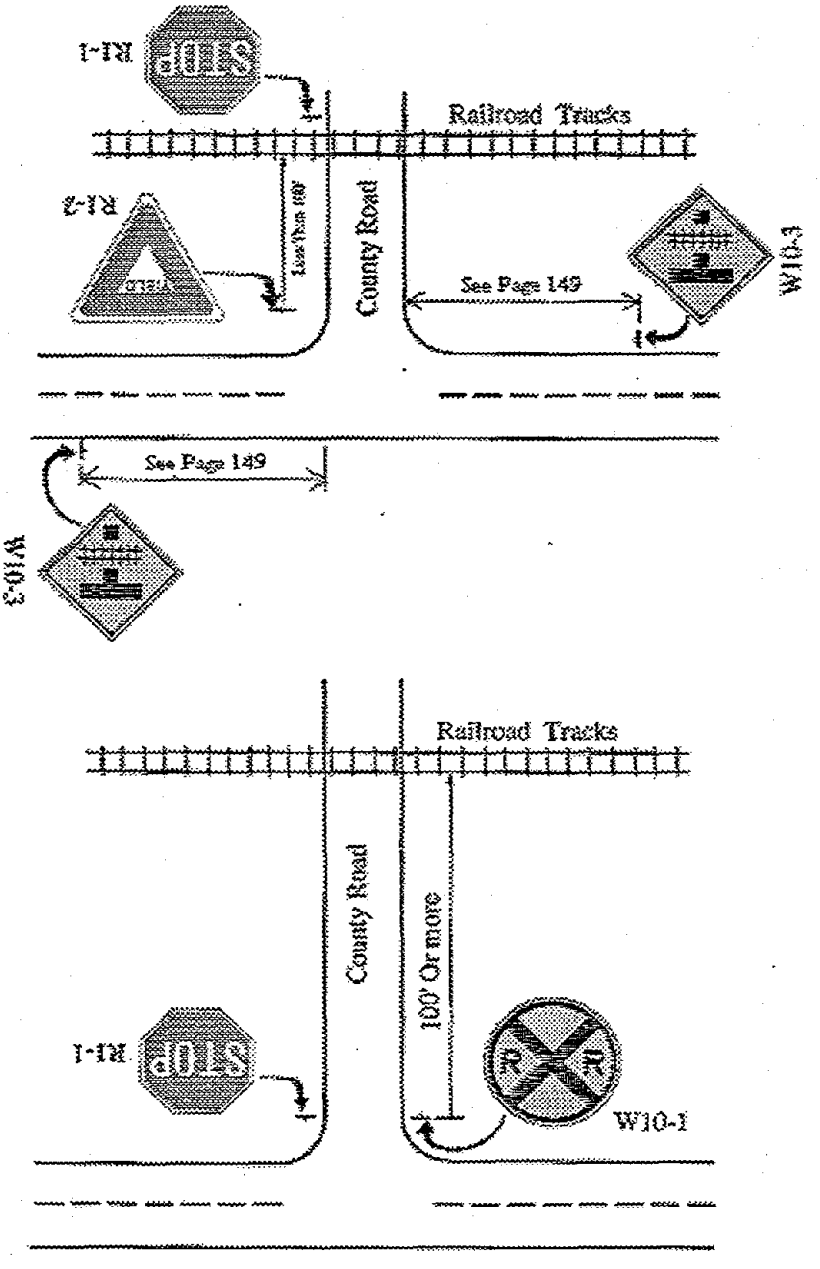


FIGURE 23. Advance Stop Warning for Parallel Railroad Grade Crossing (See Appendix 8 for additional examples)

Pavement Markings at HRI

Summary

Pavement markings in advance of a grade crossing shall consist of an X, the letters RR, a no passing marking (2-lane roads), and certain transverse lines. Identical markings shall be placed in each approach lane on all paved approaches to grade crossings where grade crossing signals or automatic gates are located, and at all other grade crossings where the prevailing speed of highway traffic is 40 mph or greater. When used, a portion of the pavement-marking symbol should be directly opposite the advance warning sign (See figures 24 and 25). If needed, supplemental pavement marking symbol(s) may be placed between the advance warning sign and the crossing. Distances to the advanced warning sign are found in Appendix 5. Check the MUTCD 2000 language that is presented below.

MUTCD 2000 Language

Standard: (MUTCD 2000, Section 8B.16)

All highway-rail grade crossing markings shall be retroreflectorized white. All other markings shall be in accordance with Part 3 [MUTCD 2000].

Pavement markings in advance of a highway-rail grade crossing shall consist of an X, the letters RR, a no-passing markings (two-lane highways), and certain transverse lines as shown in [Figures 8B-2 and 8B-3, MUTCD 2000, pages 8B-13, 8B14]. (See Handbook, next two pages).

Identical markings shall be placed in each approach line on all paved approaches to highway-rail grade crossings where signals or automatic gates are located, and at all other highway-rail grade crossings where the posted or statutory highway speed is 60 km/h (40 mph) or greater.

Pavement markings shall not be required at highway-rail grade crossings where the posted or statutory highway speed is less than 60 km/h (40 mph), or in urban areas, if an engineering study indicates that other installed devices provide suitable warning and control.

Guidance: (MUTCD 2000, Section 8B.16)

When pavement markings are used, a portion of the X symbol should be directly opposite the advance warning sign. The X symbol and letters should be elongated to allow for the low angle at which they will be viewed.

Stop Lines

Guidance: (MUTCD 2000, Section 8B.17)

The stop line should be a transverse line at a right angle to the traveled way at a point where a vehicle is to stop or to as near to that point as possible. The stop line should be placed approximately 2.4 m (8 ft) from the gate (if present), but no closer than 4.6 m (15 ft) from the nearest rail.

No Passing Zone Signs (W14-3) - The "No Passing Zone" sign may be installed at crossings to supplement no passing pavement markings. The sign is to be placed on the left side of the highway at the beginning of the no passing zone. The no passing zone should be 200 ft (60.96 m) preceding the grade crossing.

Advisory Speed Plate (W13-1) - The advisory speed plate may be used when sight or geometric conditions require a speed lower than the posted speed limit. The advisory speed plate should not be erected until the recommended speed has been determined by an engineering study of the specific crossing. The advisory speed plate must be mounted on the same assembly and is normally below the advance warning sign (W-10 series).

Illumination at Grade Crossings- Handbook Discussion`

At grade crossings where railroad operations are conducted at night, particularly where train speeds are low, where crossings are blocked for long periods, or crash history indicates that motorists experience difficulty in seeing trains or control devices during the hours of darkness, illumination at and adjacent to the crossing may be installed to supplement other traffic control devices where an engineering analysis determines that better visibility of the train is needed. Regardless of the presence of other control devices, illumination will aid the motorist in observing the presence of railroad cars on a crossing where the gradient of the vehicular approaches is such that the headlights of an oncoming vehicle shine under or over the cars.

Recommended types and locations of luminaries for grade crossing illumination are contained in the American National Standard Practice for Roadway Lighting, RP8*. In any event, luminaries shall be so located and light there from so directed to adequately illuminate the side of the train but care must be taken as to not interfere with aspects of the railroad signal system and not interfere with the field of view of members of the locomotive crew. An engineering study should determine the proper placement. (See also, MUTCD 2000, page 8C-1, section 8C.01)

*Available from the Illuminating Engineering Society, New York, N.Y. 10017

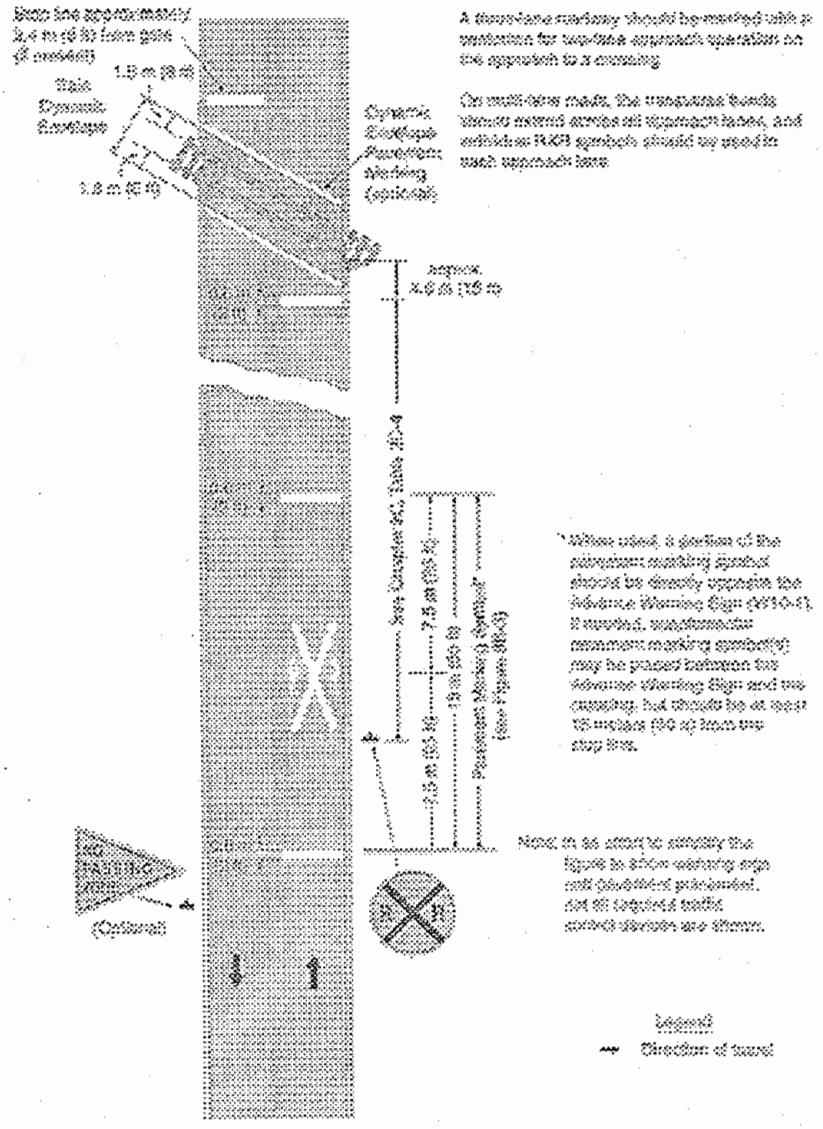


FIGURE 24. Example Placement of Warning Signs and Pavement Markings at Railroad-Highway Grade Crossings [Source: MUTCD 2000, Figure 8B-2, page 8B-13] (See next page for alternative (narrow) pavement markings)

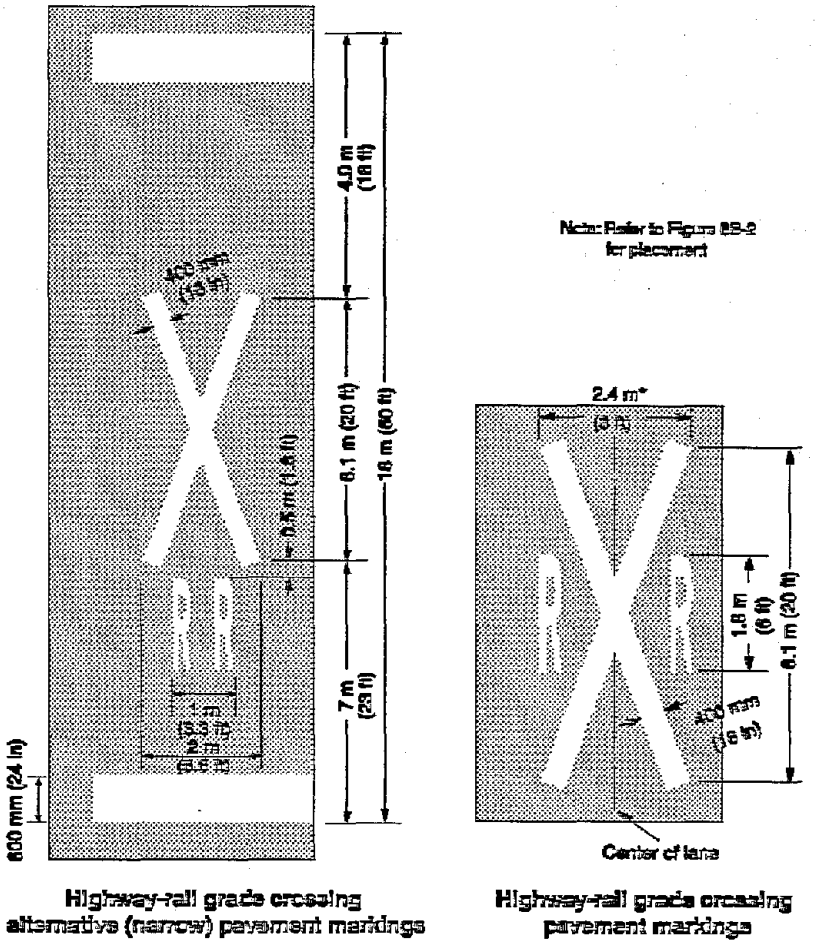
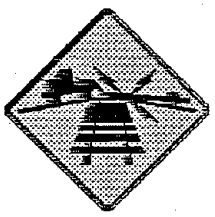


FIGURE 25. Typical Highway-Rail Grade Crossing Pavement Markings.

Low Ground Clearance Highway-Rail Grade Crossing Sign (W10-5)



W10-5

Guidance: (MUTCD 2000, Section 8B.14)

If the highway profile conditions are sufficiently abrupt to create a hang- up situation for long wheelbase vehicles or for trailers with low ground clearance, the Low Ground Clearance Highway-Rail Grade Crossing (W10-5) sign should be installed in advance of the highway-rail grade crossing.

Standard: (MUTCD 2000, Section 8B.14)

New warning signs such as this that might not be readily recognizable by the public shall be accompanied by an educational plaque, LOW GROUND CLEARANCE which is to remain in place for at least 3 years after its initial installation (see Chapter 2A).

Guidance: (MUTCD 2000, Section 8B.14)

Auxiliary signs such as AHEAD, NEXT CROSSING, or USE NEXT CROSSING (with appropriate arrows) should be placed at the nearest intersecting highway where a vehicle can detour or at a point on the highway wide enough to permit a U-turn.

If engineering judgment of roadway geometric and operating conditions confirms that vehicle speeds across the railroad tracks should be below the posted speed limit, a W13-1 advisory speed plaque should be posted.

Option: (MUTCD 2000, Section 8B.14)

If the highway-rail grade crossing is rough, word message signs such as BUMP, DIP, or ROUGH CROSSING may be installed. A W13-1 advisory speed plaque may be installed below the word message sign in advance of rough crossings.

Support: (MUTCD 2000, Section 8B.14)

Information on railroad ground clearance requirements is also available in the "American Railway Engineering and Maintenance-of-Way Association's Engineering Manual", or the American Association of State Highway and Transportation Officials' "Policy on Geometric Design of highways and Streets" (see Section 1A.11)

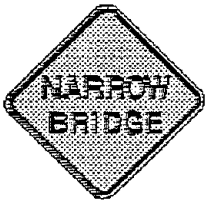
CHAPTER 4

NARROW BRIDGES, CULVERTS AND ROADSIDE OBSTACLES

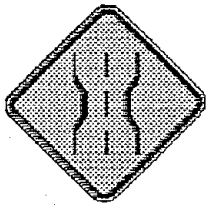
General:

Bridges and culverts that are narrower than the approach roadway and narrow roadways with obstacles adjacent to the shoulder violate the driver's expectancy and are, therefore, considered to be inconsistencies. As such, positive guidance should be provided so that the driver has sufficient information to safely negotiate the narrow bridge, culvert or adjacent obstacle. This section covers several different, but related, problems - narrow bridges and culverts, one-lane bridges and culverts, and roadside obstacles.

Description of Traffic Control Devices and Uses



W5-2



W5-2a

Standard Size
30" x 30"
See MUTCD 2000
Page 2C-17

NARROW BRIDGE Sign (W5-2) (W5-2a) (MUTCD 2000, Section 2C.14 and 5C.05)

Guidance:

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

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

Option:

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

The Narrow Bridge (W5-2a) symbol sign may be used as an alternate to the word message NARROW BRIDGE sign.

EXAMPLES: Figure 27, 28; pp. 79, 80

W5-3
Standard Size
36" x 36"
Minimum Size
30" x 30"
See MUTCD 2000
Page 5C-3

ONE-LANE BRIDGE Sign (W5-3)

Guidance: (MUTCD 2000, Section 2C.15)

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

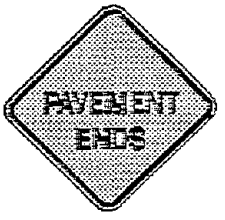
A. Having a clear roadway width of less than 4.9 m (16 ft), or

B. Having a clear roadway width of less than 5.5 m (18 ft) when commercial vehicles constitute a high proportion of the traffic, or

C. Having a clear roadway width of 5.5 m (18 ft) or less, where the sight distance is limited on the approach to the structure.

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

EXAMPLES: Figure 27, 28; pp. 79, 80



W8-3
Standard Size
36" x 36"
See MUTCD 2000
Page 2C-19

PAVEMENT ENDS Sign (W8-3)

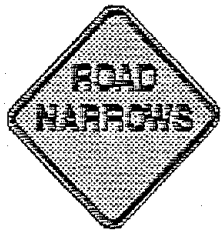
Guidance: (MUTCD 2000, Section 2C.23)

A PAVEMENT ENDS (W8-3) word message sign should be used where a paved surface changes to either a gravel treated surface or an earth road surface.

Option: (MUTCD 2000, Section 2C.23)

An Advisory Speed plaque (see Section 2C.42) may be used when the change in roadway condition requires a reduced speed.

ROAD NARROWS Sign (W5-1)



W5-1
Standard Size
36" x 36"
See MUTCD 2000
Page 2C-17

Guidance: (MUTCD 2000, Section 2C.13)

A ROAD NARROWS (W5-1) sign should be used in advance of a transition on two-lane roads where the pavement width is reduced abruptly to a width such that vehicles might not be able to pass without reducing speed.

Option: (MUTCD 2000, Section 2C.13)

Additional emphasis may be provided by the use of object markers and delineators (see Chapters 3C and 3D). The Advisory Speed (W13-1) plaque (see Section 2C.42) may be used to indicate the recommended speed.

Handbook Discussion

Since the driver's expectancy changes with the physical characteristics of the roadway, the degree of positive guidance required also changes. The following guidelines are intended for use at or near a narrow or one-lane bridge or culvert. These guidelines are divided according to the type of road on which they are to be used. Engineering judgment should be used.

LVR Type A: (See Figures 26 through 30)

1. A NARROW BRIDGE sign or a ONE-LANE BRIDGE sign should be used on each approach.

2. Type 3 object markers (see Figures 27 and 28) shall be used on each approach.
3. The approaches to the structures should be tapered (see page 140 Appendix 1)
4. Guardrail may be used.
5. Delineators may be used.
6. Pavement markings may be used.

LVR Type B and LVR Type C:

1. A NARROW BRIDGE sign or a ONE-LANE BRIDGE sign may be used.

2. Type 3 object markers shall be used on each approach, UNLESS the approaches to the structure are tapered such that the structure is no longer narrower than the roadway (see page 140 and Appendix 1). If tapering is used, Type 3 object markers may be used to warn of additional objects (e.g. concrete bridge rails)*.

In addition to the signs, which designate narrow bridges or culverts, or one-lane bridges or culverts, the existence of the structures and/or adjacent obstacles can be shown through the use of object markers (see Figures 26 - 30) or other means of positive guidance. Since it is generally believed that the driver gets the most information from the physical characteristics of a roadway, there is a greater potential for providing the driver with positive guidance by modifying the physical characteristics to lead the driver safely through the area. This is the principle involved in the practice of tapering the approach of a roadway so that it gradually narrows to the width of the structure (See Appendix 1).

OBJECT MARKERS (from MUTCD, page 3C-1)

Object Marker Design and Placement Height Support (MUTCD, Section 3C.01)

Object markers are used to mark obstructions within or adjacent to the roadway.

Standard: (MUTCD 2000, Section 3C.01)

When used, object markers shall consist of an arrangement of one or more of the following types:

Type 1—either a marker consisting of nine yellow retroreflectors, each with a minimum diameter of 75 mm (3 in), mounted symmetrically on a yellow or black diamond panel 450 mm (18 in) 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 75 mm (3 in), arranged either horizontally or vertically on a white panel; or on an all-yellow retroreflective panel, measuring at least 150 x 300 mm (6 x 12 in).

Type 3—a striped marker, 300 x 900 mm (12 x 36 in), 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 75 mm (3 in).

Placement

Guidance: (MUTCD 2000, Section 3C.01)

When used for marking objects in the roadway or objects that are 2.4 m (8 ft) or less from the shoulder or curb, the mounting height to the bottom of the object marker should be at least 1.2 m (4 ft) above the surface of the nearest traffic lane.

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

Option: (MUTCD 2000, Section 3C.01)

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.

Markings for Objects in the Roadway (MUTCD 2000, Section 3C.02)

Standard: (MUTCD 2000, Section 3C.02)

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 3B.10).

Option: (MUTCD 2000, Section 3C.02)

To provide additional emphasis, large surfaces such as bridge piers may be painted with diagonal stripes, 300 mm (12 in) or greater in width, similar in design to the Type 3 object marker.

Standard: (MUTCD 2000, Section 3C.02)

The alternating black and retroreflective yellow stripes (OM-3L, OM-3R) shall be sloped down at an angle of 45 degrees toward the side on which traffic is to pass the obstruction. If traffic can pass to either side of the obstruction, the alternating black and retroreflective yellow stripes (OM-3C) shall form chevrons that point upwards.

Option: (MUTCD 2000, Section 3C.02)

Appropriate signs (see MUTCD 2000, Sections, 2B.28 and 2C.18, MUTCD 2000) directing traffic to one or both sides of the obstruction may be used instead of the object marker.

Markings for Objects Adjacent to the Roadway

Support: (MUTCD 2000, Section 3C.03)

Objects not actually in the roadway may be 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 may not be a physical object involved, but other roadside conditions such as narrow shoulder drop-offs, gores, small islands and abrupt changes in the roadway alignment may make it undesirable for a driver to leave the roadway and therefore would create a need for a marker. Note: Type 2 or 3 may be used for such purpose.

End of Roadway Markers:

Support: (MUTCD 2000, Section 3C.04)

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.

Standard: (MUTCD 2000, Section 3C.04)

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

Option: (MUTCD 2000, Section 3C.04)

The end-of-roadway marker may be used in instances where there are no alternate vehicular paths.

Where conditions warrant, more than one marker, or a larger marker with or without a Type III barricade (see Section 3F.01), may be used at the end of the roadway.

Standard: (MUTCD 2000, Section 3C.04)

The minimum mounting height of an end-of-the-roadway marker shall be 1.2 m (4 ft).

Guidance: (MUTCD 2000, Section 3C.04)

Appropriate advance warning signs (see MUTCD 2000, Chapter 2C) should be used.

See Figure 26 on the next page for Typical Object Markers and Typical End of Road Markers.

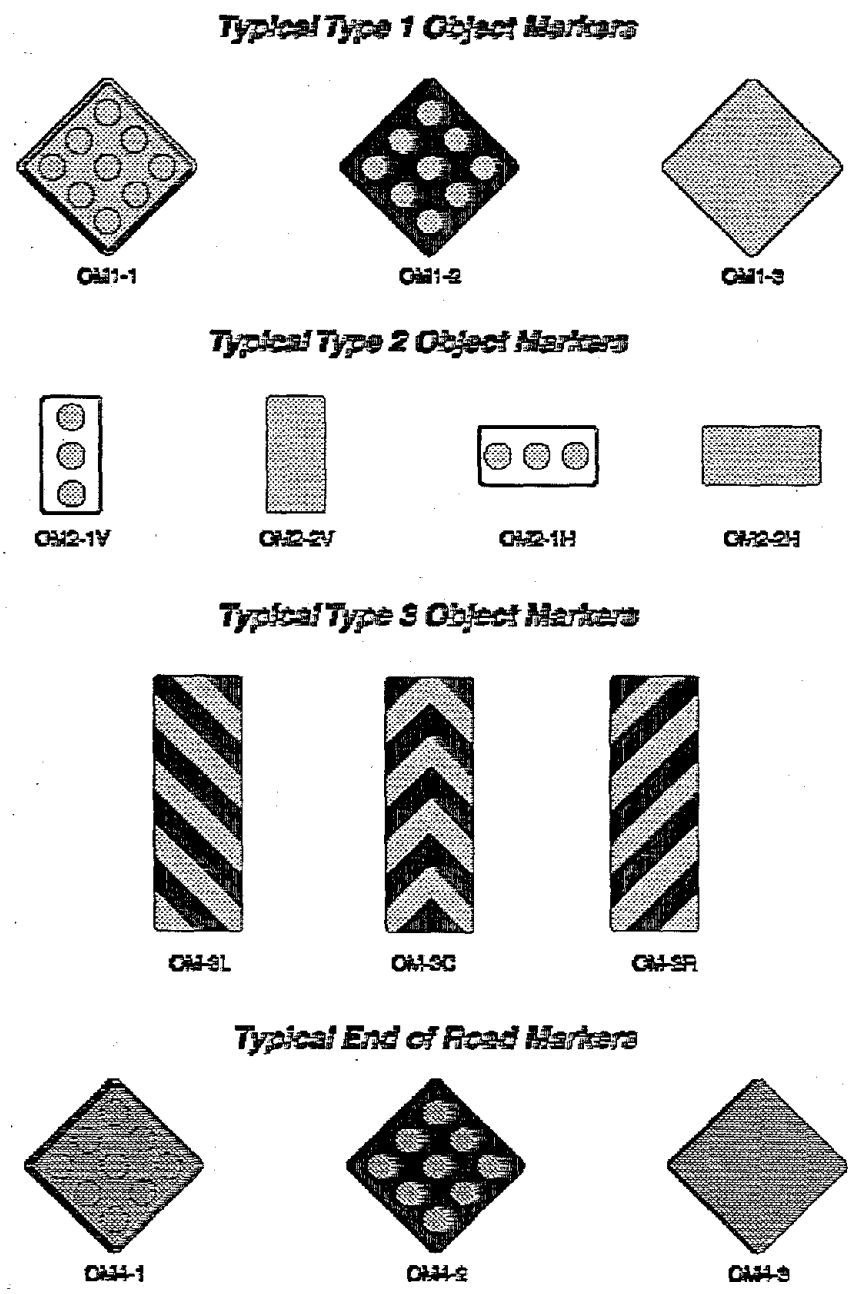


FIGURE 26. Example Type 1, Type 2 and Type 3 Object Markers (From MUTCD 2000, page 3C-2)

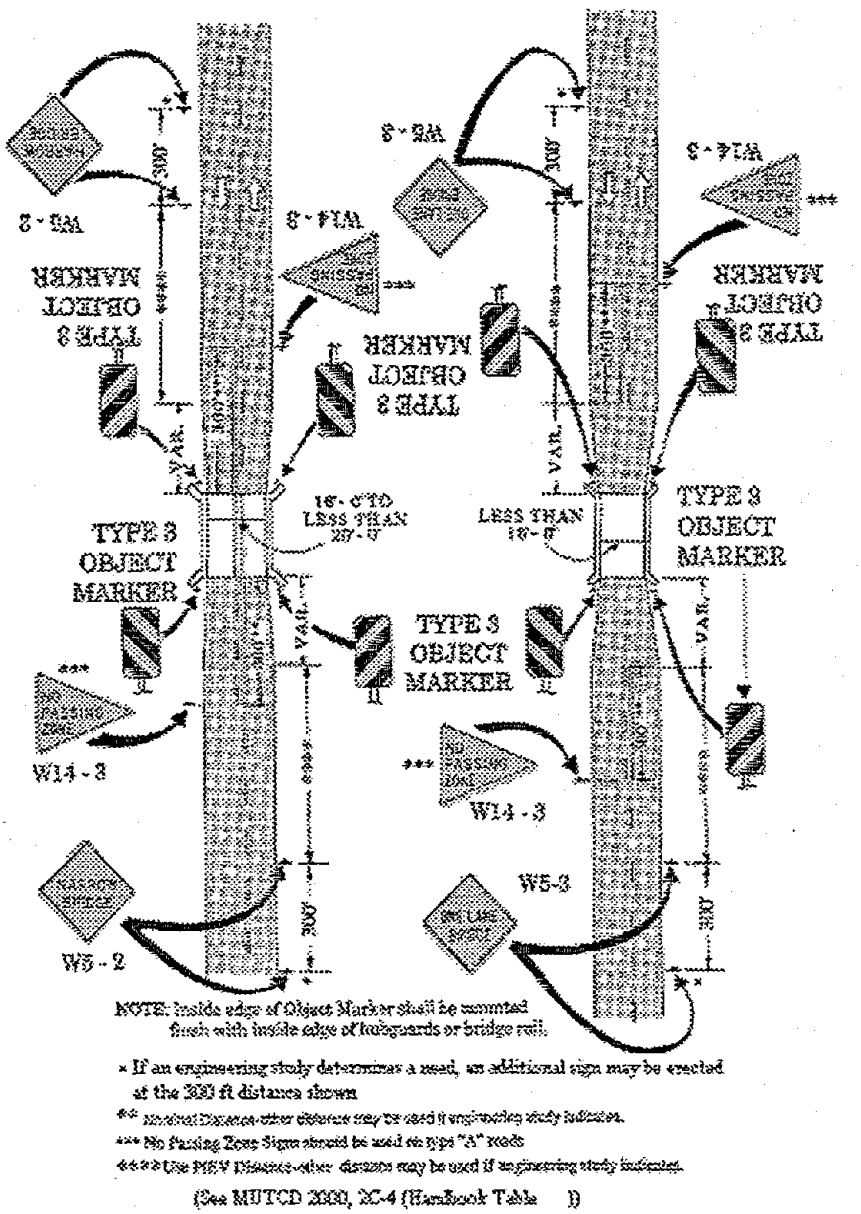


FIGURE 27. Example Signing and Marking for a Narrow Structure and a One-Lane Structure. **Alternate A: Type 3 Object Markers on all four corners.** (See Figure 4-3 for Alternate B for use of Type 3 Object Markers, Double Faced, positioned on the right side of each approach.)

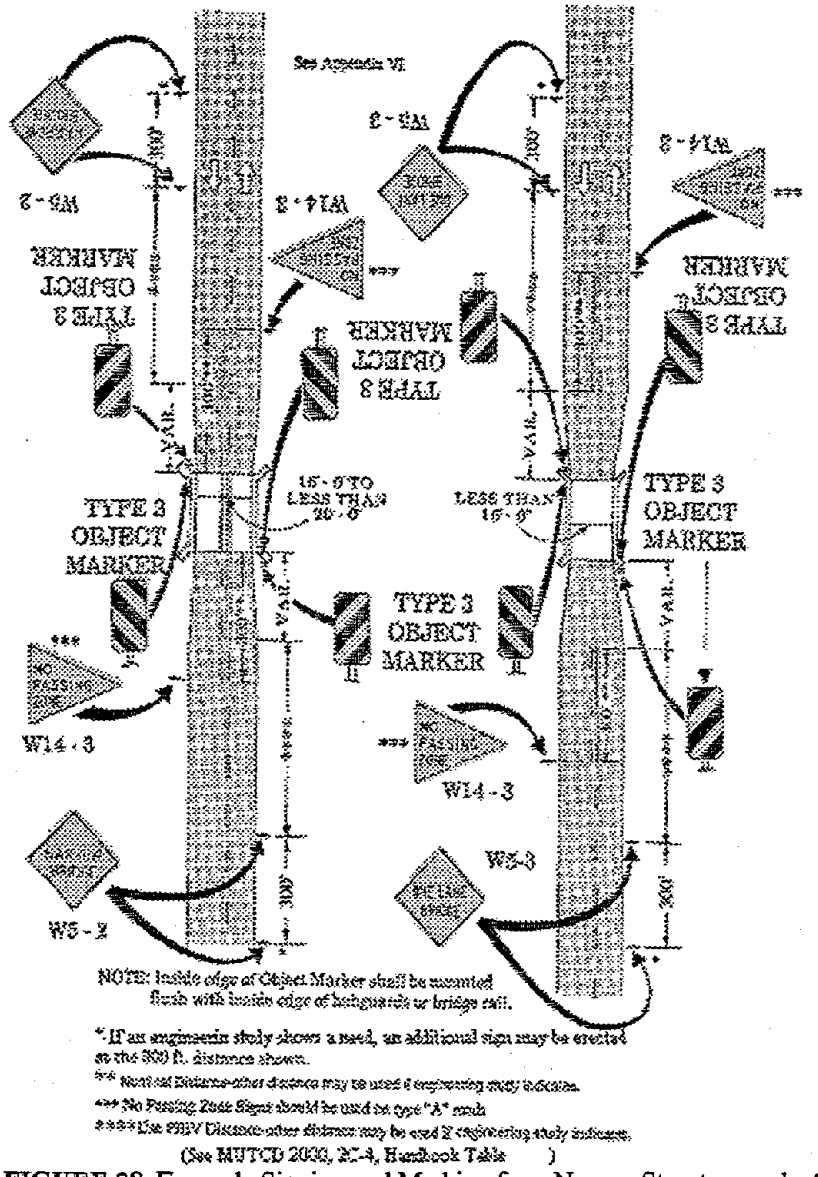


FIGURE 28. Example Signing and Marking for a Narrow Structure and a One-Lane Structure. **Alternate B: Type 3 Object Markers on both sides of single post positioned on right side of each approach.** Note that this "staggering" allows farmers better opportunity to move large equipment across without

hitting the markers. (See Figure 4-2 for Alternate A for use of Type 3 Object Markers on all four corners.)

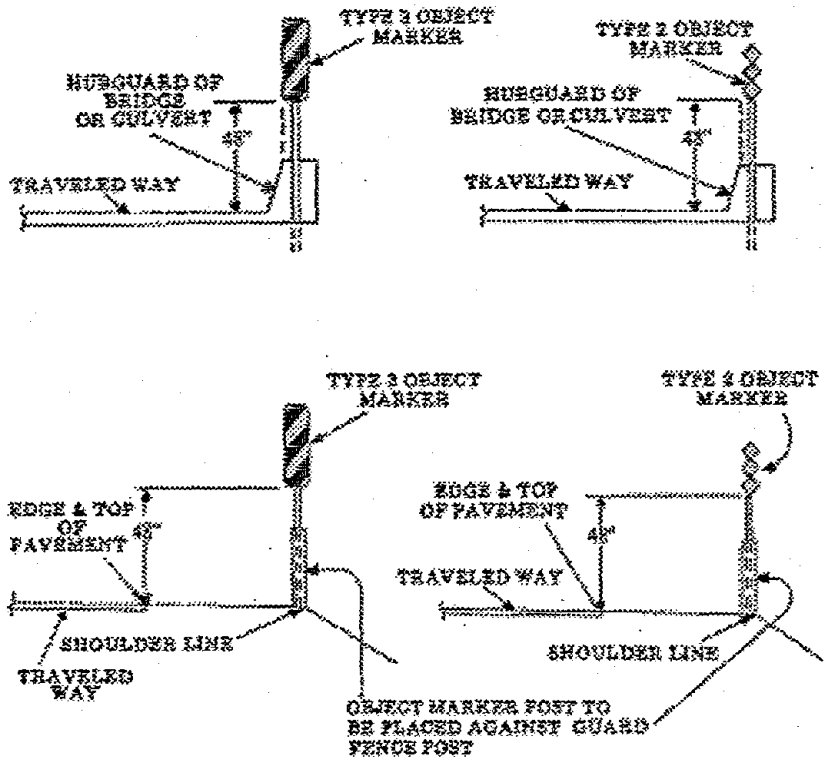


FIGURE 29. Example Mounting of Object Marker

Marking Narrow Structures-Handbook Discussion

For certain narrow structures that may be used by equipment wider than the structure, the mounting height of the object markers may be adjusted to a lower height according to need, based on engineering judgment.

If the mounting height of the object markers is lower than normal height, the maintenance of the object markers may require the removal of

vegetation, debris or other obstruction to maintain good visibility of the object marker.

The local authority installing the traffic control devices should retain permanent documentation of the locations and justification for erecting lower object markers.

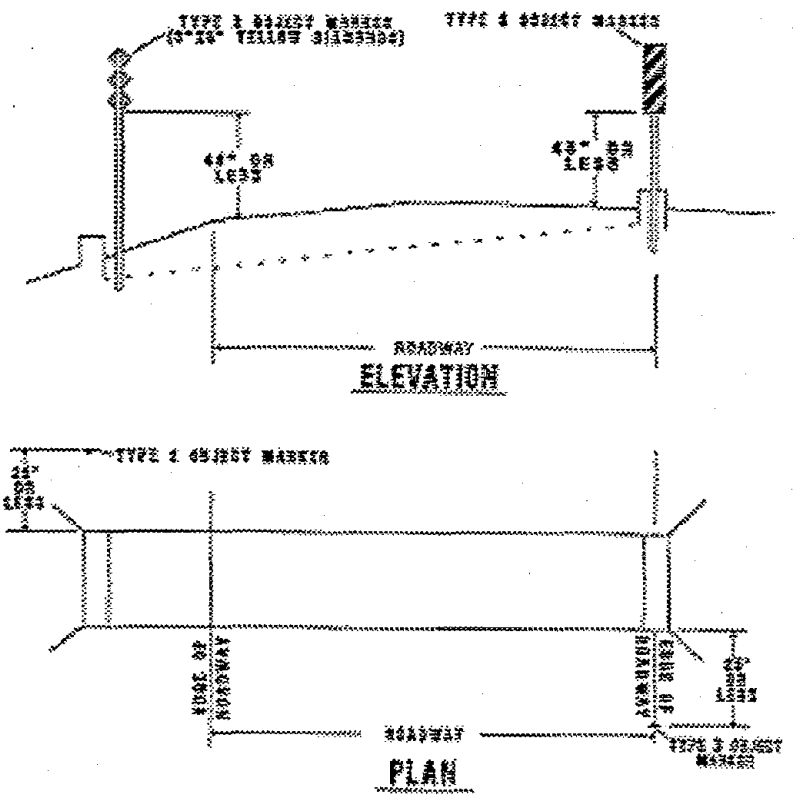
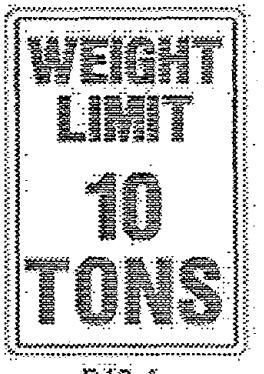
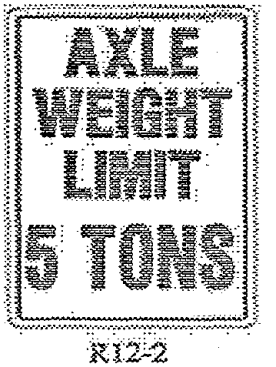


FIGURE 30. Example Mounting of Object Marker on Narrow Bridge Which is Used by Wide Farm Equipment

WEIGHT LIMIT SIGNS (R12-1 to R12-5)

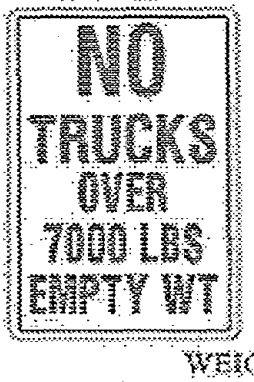


R12-1
Standard Size
24" x 30"

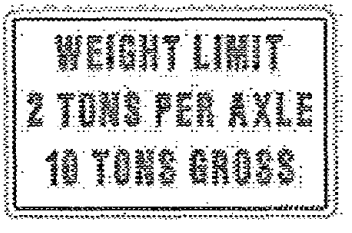


R12-2
Standard Size
24" x 30

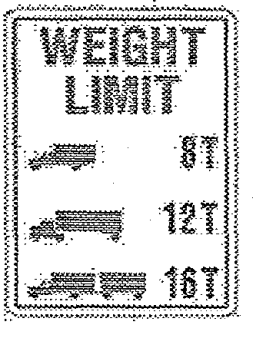
R12-3
Standard Size
24"x36"



R12-4
Standard Size
30" x24"



R12-5
Standard Size
24" x 36"



WEIGHT LIMIT Signs (R12-1 to 5)

Due to seasonal weakening of the road surface, obsolescence of bridges or pavements, or other impairment of roadways, it is often necessary to limit the load permitted on a roadway.

Standard: (MUTCD 2000, Section 2B.43)

If used, the Weight Limit sign shall be located in advance of the applicable section of highway or structure.

Guidance: (MUCTD 2000, Section 2B.43)

If used, the weight limit sign with an advisory distance ahead legend should be placed at approach road intersections or other points where prohibited vehicles can detour or turn around.

Option: (MUTCD 2000, Section 2B.43)

The Weight Limit sign (R12-1) carrying the legend WEIGHT LIMIT (X) TONS, may be used to indicate restrictions pertaining to total vehicle weight restrictions including load.

Where the restriction applies to axle weight rather than gross load, the legend may be AXLE WEIGHT LIMIT (X) TONS (R12-2).

To restrict trucks of certain sizes by reference to empty weight in residential districts, the legend may be NO TRUCKS OVER (XX) TONS (or XX Kg) EMPTY WEIGHT (R12-3).

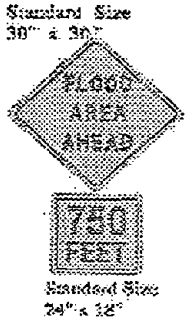
In areas where multiple regulations of the type described above are applicable, a sign combining the necessary messages on a single panel may be used, such as WEIGHT LIMIT (X) TONS PER AXLE, (XX) TONS GROSS (R12-4).

Posting of specific load limits may be accomplished by use of the Weight Limit symbol sign (R12-5). A sign containing the legend WEIGHT LIMIT on the top two lines, and showing three different truck symbols And their respective weight limits for which restrictions apply may be used, with the weight limits shown to the right of each symbol as (XX) T. A bottom line of legend stating GROSS WT may be included if needed for enforcement purposes.

Low water stream crossings, (LWSC's or fords), are rarely encountered by the driver; therefore, they can be considered inconsistencies and should be well marked. Engineering judgment should be used. Some states may have state-specific laws or policies that relate to low-water crossings. Your state DOT should be consulted.

These signs are not specifically shown in MUTCD 2000. However, when used they shall conform to criteria in sections 2C.02 and 2C.03 of MUTCD 2000, which covers the application and design of warning signs.

The FLOOD AREA AHEAD sign shall consist of black letters and border on a yellow background. It shall conform to MUTCD 2000 standards for warning signs as covered in MUTCD 2000, Sections 2C.02 and 2C.03, MUTCD 2000.



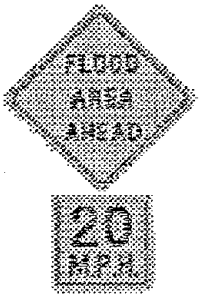
The IMPASSABLE DURING HIGH WATER sign shall consist of black letters and borders on a yellow background. It shall conform to MUTCD standards for warning signs. (MUTCD 2000, Sections 2C.02 and 2C.03)

The DO NOT ENTER WHEN FLOODED sign shall consist of black letters and border on a white background. It shall conform to MUTCD standards for regulatory signs. (MUTCD 2000, Sections 2B.01, 2B.02 and 2B.03)

LOW WATER STREAM CROSSINGS

Since it is a regulatory sign it requires a resolution or ordinance to be passed before it is installed.

A supplemental DISTANCE ADVISORY plate should be used if the location of an LWSC is not apparent from a point in advance of the crossing at least as great as the distances shows in MUTCD 2000, Table 2C-4. The plate would normally display the legend "XX FEET" based on engineering judgment, and would be placed directly beneath and on the same post as the FLOOD AREA AHEAD sign (See Figure 32). The plate shall consist of black letters and border on a yellow background. It shall not be used alone.



An **ADVISORY SPEED** plate may be used if an engineering study or engineering judgment determines that the maximum recommended speed at an LWSC is less than the usual operating speed. If used, the plate shall be placed directly beneath and on the same post as the FLOOD AREA AHEAD sign unless a supplemental DISTANCE ADVISORY plate is used i.e., the two plates should not be used together (See Figure 32).

Handbook Discussion

Experience reported by persons having responsibility for road systems including LWSCs indicates some concern with liability problems growing out of their use (Carstens and Woo, 1981). However, a majority of officials having this experience report that they are satisfied with LWSCs and the road users seem to accept them.

This experience suggests that a risk analysis generally will show that the potential for crashes and liability will be reduced, rather than increased, when a LWSC is substituted for a bridge that is structurally deficient or functionally obsolete. An engineering study or engineering judgment should be used to

determine that adequate warning of the presence of a LWSC be given to minimize the risk of crashes.

One of the conclusions from the research is that the risk of crashes and liability would be further reduced if motorists were discouraged from crossing a LWSC while it is flooded (Carstens and Woo, 1981). The findings from an evaluation of alternative signing patterns support this conclusion by suggesting the use of a regulatory sign with the message DO NOT ENTER WHEN FLOODED. The intent of this sign is to prohibit passage across the LWSC if the roadway is covered with water.

At LWSCs, debris or mud may remain on the roadway after floodwaters have receded and erosion of the roadway may have occurred. Thus, it is important that road segments with LWSCs be checked following heavy rains so that any required maintenance may be performed promptly or that the road can be closed if necessary.

On LVR Type A and LVR Type B roads, the three signs FLOOD AREA AHEAD, IMPASSABLE DURING HIGH WATER and DO NOT ENTER WHEN FLOODED, should be used (see Figure 32).

On LVR Type C roads, the FLOOD AREA AHEAD sign should be used. The IMPASSABLE DURING HIGH WATER and/or DO NOT ENTER WHEN FLOODED signs may be used in addition.

For LVR Type A, LVR Type B, and LVR Type C roads, if only one sign is used, it should be the FLOOD AREA AHEAD sign. If ,more than one sign is used, the first sign should be the FLOOD AREA AHEAD sign.

The placement of the sign(s) may vary depending on the usual operating speed and the terrain. It is important not to overload the driver too much information or too many tasks to perform, such as a steep grade to negotiate with the FLOOD AREA AHEAD sign on the steep grade. In a case such as this it is best to warn of the steep grade and also warn of the LWSC before the grade. Distances longer or shorter than those shown in Figure 32 may be used if an engineering study or engineering judgment so indicates.

Reference

1. R. L. Carstens and R. Yun-Hao Woo, Liability and Traffic Control Considerations for Low Water Stream Crossings (Ames, Iowa: Engineering Research Institute, Iowa State University, April 1981).

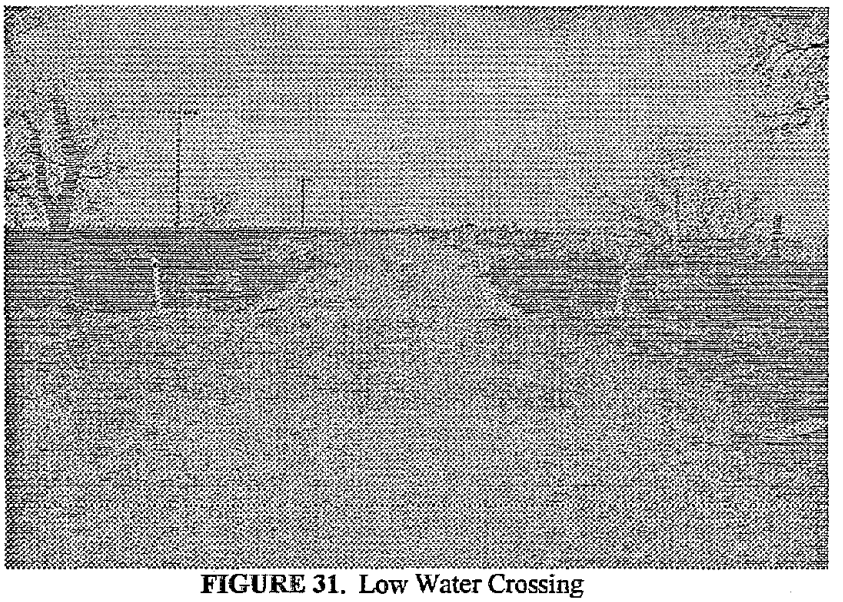
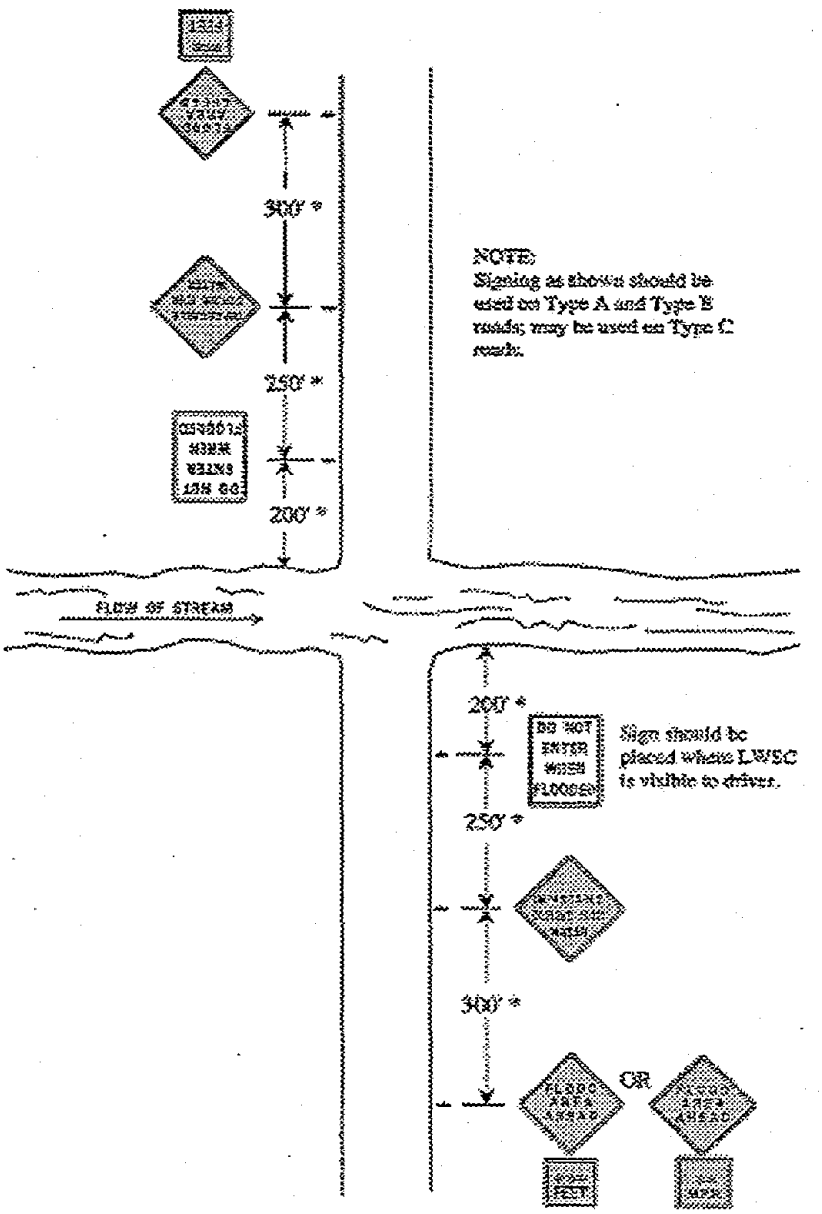


FIGURE 31. Low Water Crossing



*distance may vary according to an engineering study or engineering judgment

FIGURE 32. Example Signing of Low Water Stream Crossing

CHAPTER 5

SIGN INSTALLATION AND SIGN SUPPORT SYSTEMS

Introduction

Most of the material on the sign installation in this chapter is reproduced with minor editing, from the USDOT, FHWA, Maintenance of Small Traffic Signs; A guide for Street and Highway Maintenance Personnel, FHWA-RT-90-002, Washington, DC, 1990

General Location Guidelines

All locations for signs should be carefully checked before installing the sign to assure that there is no sight obstruction between the sign's location and the motorist's point of observation.

Some of the common problem placements to be avoided are:

- Beyond the crest of a hill;
- Where there are dips in the roadway;
- 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;
- Where signs are too close to trees or other foliage that could cover the sign face, or could grow and cover the sign face. Remember, it doesn't take long or cost much to cut brush out of the way.

If a roadway design does not permit adequate placement of the required signs, then it may be worthwhile to consider a revision in the geometric design of the roadway. A bad geometric design cannot be corrected by signing.

The longitudinal location of signs along the highway depends on the type of sign used, the nature of the message, and the desired motorist response.

As a general rule of thumb,

Warning signs are normally placed in advance of the condition to which they call attention. Regulatory signs are placed where their mandate or prohibition applies or begins.

Guide signs are placed at varying locations to inform drivers of their route

of travel, destinations, and points of interest.

Although signs with different purposes should not be located closer together than 61 meters (200 feet) if it can be avoided, signs at intersections and in urban areas cannot always meet the requirements.

Signs should be placed so as to be compatible with other signs in the area and with other roadway features in the area. For example, speed limit signs should not be placed just before an intersection, school zones, or a problem curve, which is posted with a lower speed. Before placing warning signs, Table 2C-4 in MUTCD 2000 - "A Guide for Advance Warning Sign Placement Distance" should be used to determine minimum warning sign placement distances. (Handbook Table 12)

Lateral Clearance for roadside signs is the distance from the edge of the roadway (edge of pavement) to the nearest edge of the sign.

All signs, regardless of size, constitute a potential hazard for the motorist. Therefore, signs are normally located as far from the roadway as practical.

The MUTCD 2000 states ***"normally, signs should not be closer than 1.8 meters (6 feet) from the edge of the shoulder or, if no shoulder, 3.6 meters (12 feet) from the edge of the traveled way".*** **On most local roads and streets, particularly in rural areas, these distances are unrealistic, impractical and/or undesirable. On rural, low-volume roads with no shoulder and narrow right-of-way, these distances would put signs in the bushes or weeds and not meet the "prime directive" of having signs easily seen by drivers, "visibility of utmost importance. "**

As a general rule, the following guidelines should be followed:

- Get as close as possible to the 1.8 meter (6 feet) distance from the edge of shoulder.

- All signs should be at least 0.6 meters (2 feet) outside the shoulder or, if none, 0.6 meters (2 feet) outside the traveled way. Otherwise, trucks or other large vehicles using the shoulder may hit the sign.

- Signs should be located at least 0.6 meters (2 feet) behind the curb when curb sections are used. This will help insure the trucks and other large vehicles pulling up next to the curb will not hit the sign.

- In urban areas, 0.3 meters (1 foot) behind the curb is permissible where sidewalk width is limited or where existing poles are close to the curb.

Fundamentals of Sign Location

It is of the greatest importance that the placement of a traffic sign ensures that:

1. It can be easily seen by a driver and will command respect.
2. It is properly positioned to convey the proper meaning with respect to the situation.

MUTCD sets guidelines on sign placement. However, these are meant to be used with engineering judgment. Sign positioning, as defined in the manual, is associated with an assumed set of conditions portraying a typical situation.

Since no two roadways are exactly alike, it follows that these basic standards are intended only as a guide. The guidelines provided in the MUTCD should be tempered by the existing conditions to assure that the sign will be seen by the drivers, and that the drivers will have adequate response time.

Jurisdictions with responsibility for traffic control should have qualified traffic engineering expertise on their staff or should seek assistance from their state Department of Transportation, county, nearby large city, traffic consultant or Local Technical Assistance Program (Technology Transfer Center).

Installing New Post and Sign

The proper steps in installing a new post and sign in a rural setting are:

- Use a cap to protect the driver--these caps are available in a variety of sizes and shapes for the various sizes and shapes of the posts,
- Measure and mark the post 1.5 meters (5 feet) from the bottom of the sign. Then drive the post to that mark. Bolt the sign to the post.
- For a wooden post, attach the sign first, then measure and mark 1.5 meters (5 feet) from the bottom of the sign.
- Measure the remaining length of the post, and dig a hole that deep. It is important to tamp soil in around the pole for stability.

SAFE SIGN SUPPORT SYSTEMS

Wood Post

Wood posts are the most common sign support. Posts of the proper size and installation will break off when hit by a vehicle. They should be southern yellow pine, grade 2 or equivalent, and pressure treated.

Small supports. Cross section is 10,000 sq. mm (16 sq. inches). Posts should be buried in firm ground to a minimum recommended depth of 90cm (3 feet). You may need to bury the post deeper to reduce vandalism. Do not encase post in concrete. One or two posts* may be used. (*One post at each end of sign; not a single post made of two rails bolted together.)

Large supports should be drilled. A 150mm x 200mm (6" x 8") wood post can be used if the cross section is weakened by drilling two 75mm (3-inch) holes drilled perpendicular to roadway. A 100mm x 100mm (4" x 4") is the largest un-drilled wood post recommended to act as a breakaway support.

Sign panels. Sign panels should be bolted to the post with oversized washers. This will prevent the panel from separating from the post on impact and then penetrating a windshield. Set the bottom of the sign panel a minimum 1.5 meters (5 feet) above the roadway. This will limit the chance of the sign and post rotating and hitting the car's windshield.

Perforated Square Steel Tube (PSST)

Another signpost is the perforated 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 0.9 meters (3 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 signpost put back in place.

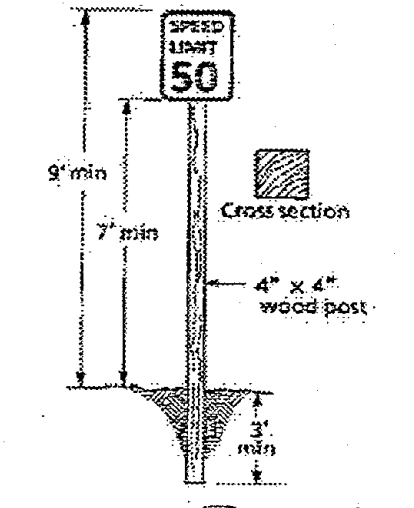
Maximum post size (to be considered breakaway)

Max. Sign size	Post Size

750mm x 750mm (30" x 30")	57mm x 57mm x 2.67mm (2.25 " x 2.25 " x 0. 105 ")

Sign panels. Attach the sign panels tightly to the post and use oversized washers to keep the sign from breaking loose from the post when a vehicle hits it. Sign panels should be mounted a minimum of 1.5 or 2.1 meters (5 ft or 7 ft) above the roadway, as appropriate for rural or urban, respectively.

There are many other products available commercially for sign supports. Use depends on local requirements and costs. Below are four of the most common types of small sign supports.



Maximum Post Sizes

Max. Sign Panel	Post Size
18"×24"	4"×4" nom.
30"×30"	4"×6" nom. (2" holes)
36"×48"	6"×6" nom. (2" holes)

FIGURE 33. Example Wood Post

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. In order to more easily extract damaged posts, drive the posts no deeper than 1.1m (3.5 ft.)

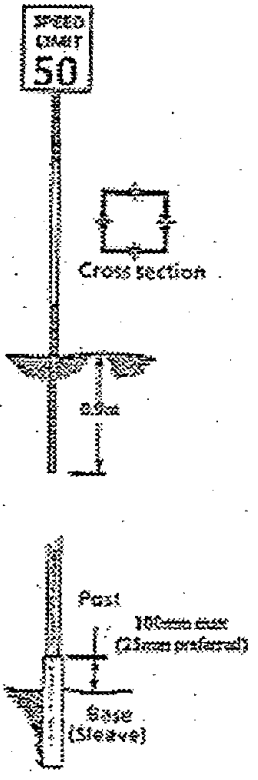


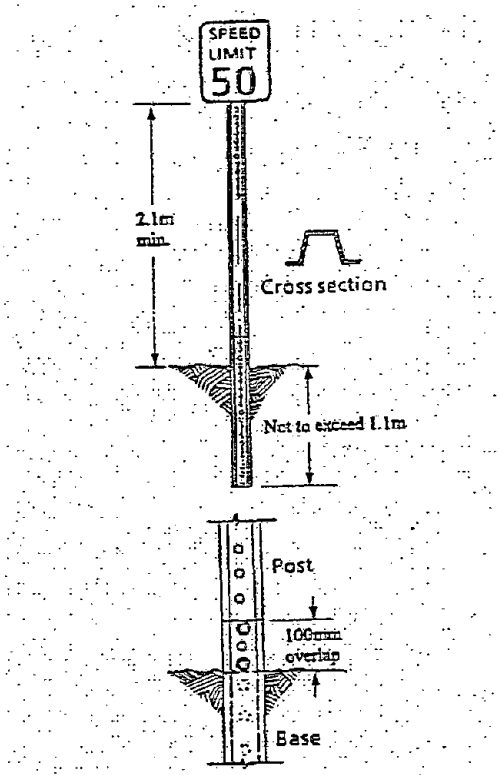
FIGURE 34. Example Perforated Square Steel Tube Design

Breakaway devices. Commercial splices can be purchased to install at ground level (see figure 35, lower drawing). They allow the post to break off on impact. These devices improve safety when the post is hit, will make repair easier, and will make it possible to use a U-channel post when it has to be placed in a concrete area.

An alternate installation is to set a stub post in concrete with a 100mm (4-inch) length available to bolt to the sign post as a base connection.

Sign panels. Sign panels should be securely bolted to the post with oversized washers. This will prevent the panel from separating from the post on impact and then penetrating a windshield. Set the bottom of the sign panel a minimum

of 1.5 or 2.1 meters (5 or 7 feet) above the roadway, as appropriate for rural or urban, respectively. This limits the chance of the sign hitting a car's windshield.



Maximum post size

Max. Size Panel	Post Size
450mm x 600mm (18" x 24")	2 lb/ft (14.5 kg/m)
750mm x 750mm (30" x 30")	3 lb/ft (21.7 kg/m)
900mm x 1200mm (36" x 48")	2@2lb/ft (14.5 kg/m)

FIGURE 35. Example U channel

Steel Pipe Post

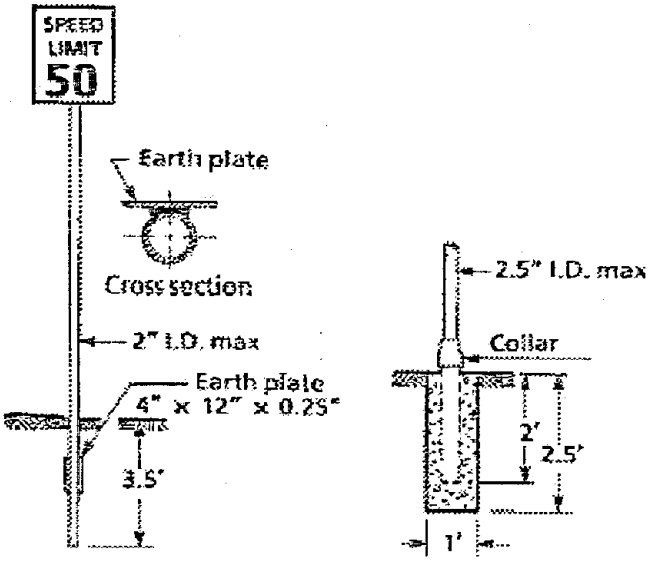
Steel pipe posts are used less frequently than wood or U-channel posts, but are often used in cities to support small signs. Standard steel pipe, schedule 40, galvanized, should be used.

Post support. Steel pipe posts can be driven directly into the ground to a depth of at least 1.1 meter (3.5 feet). A steel plate (earth plate) measuring 102mm x

305mm x 6.4mm (4" x 12" x 0.25") should be welded or bolted to the pipe (see figure 36) to keep the sign from rotating in the wind and to help in driving the post.

Breakaway devices. A collar assembly (see example in the lower drawing) is recommended if the sign is likely to be hit. A collar assembly consists of a concrete footing (usually 0.76m (2.5') deep x 0.3m (1') diameter), a 0.6m (2foot) pipe base (usually one pipe size larger than the post), and a pipe reduction 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.

Sign panels. Sign panels should be securely attached to the pipe post using pipe clamps. This prevents the sign panel from rotating or slipping loose from the post if it is hit. Tight fasteners will limit the danger of a sign penetrating a windshield when a vehicle hits. Sign panels should be mounted a minimum of 2.1 meters (7 feet) above the roadway.



Maximum Post Size

Max. Sign Panel	Pipe Size
30"×30"	2.0 in. I.D.
36"×48"	2.5 in. I.D.

FIGURE 36: Example of steel pipe

Reference

USDOT, FHWA, Maintenance of Small Traffic Signs; A guide for Street and Highway Maintenance Personnel, FHWA-RT-90-002, Washington, DC, 1990

CHAPTER 6
TEMPORARY TRAFFIC CONTROL

CONSTRUCTION AND MAINTENANCE

General:

The special condition of construction and/or maintenance zones causes an inconsistency for the driver and therefore, some type of advance notice should be provided.

As stated in MUTCD 2000

Standard: (MUTCD 2000, Section 6B.01)

The control of road users through a temporary traffic control zone shall be an essential part of highway construction, utility work maintenance operations, and incident management.

Handbook Discussion:

For minor construction on low-volume rural roads, the simple notice may be adequate –e.g., one sign on either side of the work zone, as long as it lets the driver know what to expect. Engineering judgment should be used. If there is any doubt regarding the adequacy of the temporary traffic control, local agencies should seek assistance from the State, a County or consultant knowledgeable (for example, trained and/or certified) in proper, temporary traffic control practices). In all cases, applicable sections of the MUTCD 2000,particularly Part 6 or Part 5, should be followed.

The MUTCD 2000 gives a thorough guide for the use of traffic control devices at construction and maintenance zones. The current term for these devices is, "Temporary Traffic Control" and it is Part 6 of MUTCD 2000. For maintenance and minor construction on LVR, there may not be a need for the sequence of construction approach warning signs prescribed for major operations. Engineering judgment must be used in all cases.

LVR Temporary Traffic Control

As stated in MUTCD 2000, Part 5, Traffic Control Devices for Low-Volume Roads (TCD/LVR) (defined by MUTCD 2000 as roads with AADT 400 vehicles or less).

Option: (MUTCD 2000, Section 5G.02)

Maintenance activities may not require extensive temporary traffic control if the traffic volumes and speeds are low. The traffic operations shown in [MUTCD 2000] Figures 6H-1, 6H-11, 6H-13, 6H-15 and 6H-16 of Part 6 are among those that may be most applicable on low-volume roads. Also MUTCD 2000, Chapter 5, TCD/LVR has some key guidance that should be considered:

Guidance: (MUTCD 2000, Section 5G.02)

The safety of road users, including pedestrians and bicyclists, as well as personnel in work zones, should be an integral and high priority element of every project in the planning, design, maintenance, and construction phases. Part 6 should be reviewed for additional criteria, specific details, and more complex temporary traffic control zone requirements. The following principles should be applied to temporary traffic control zones:

A. Traffic movement should be disrupted as little as possible.
B. Road users should be guided in a clear and positive manner while approaching and within construction, maintenance, and utility work areas.
C. Routine inspection and maintenance of traffic control elements should be performed both day and night.
D. Both the contracting agency and the contractor should assign at least one person on each project to have day-to-day responsibility for assuring that the traffic control elements are operating effectively and any needed operational changes are brought to the attention of their supervisors.

Traffic control in temporary traffic control zones should be designed on the assumption that road users will only reduce their speeds if they clearly perceive a need to do so, and then only in small increments of speed. Temporary traffic control zones should not present a surprise to the road user. Frequent and/or abrupt changes in geometrics and other features should be avoided. Transitions should be well delineated and long enough to accommodate driving conditions at the speeds vehicles are realistically expected to travel.

A Traffic Control Plan (see Section 6C.01) should be used for a temporary traffic control zone on a low-volume road to specify particular traffic control devices and features, or to reference typical drawings such as those contained in Part 6.

Support: (MUTCD 2000, Section 5G.02)

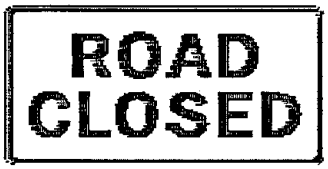
Applications of speed reduction countermeasures and enforcement can be effective in reducing traffic speeds in temporary traffic control zones.

Handbook Discussion

The alternatives presented here should provide sufficient guidance for the case of maintenance or minor construction on low-volume roads. In some cases, to speed up construction, it may be better to close the road to through traffic during maintenance or construction. (See MUTCD 2000, Figure 6H-13, page 6H-31)

For more extensive construction or maintenance, follow the guidelines as set for by MUTCD 2000, Part 6. It should be noted that such construction and maintenance, regardless of whether it is being done by public or private agencies, if it is being done on a public roadway, the guidelines should be followed.

ROAD (STREET) CLOSED Sign (R11-2)



R11-2
48" x 30"
See MUTCD 2000
Page 5B-2

The ROAD (STREET) CLOSED sign shall have a standard, and minimum, size of 48" x 30" (1200 x 750 mm).

The ROAD (STREET) CLOSED sign should be used when the roadway is closed to all road users except contractors' equipment or officially authorized vehicles. The R11-2 sign should be accompanied by appropriate warning and detour signing.

Guidance: (MUTCD 2000, Section 6F.08)

The ROAD (STREET) CLOSED sign should be installed at or near the center of the roadway on or above a Type III barricade that closes the roadway (See [MUTCD 2000] Section 6F.60).

Standard: (MUTCD 2000, Section 6F.08)

The ROAD (STREET) CLOSED sign shall not be used where road user flow is maintained or where the actual closure is some distance beyond the sign.

Local Traffic Only Signs (R11-3a, R11-4)

Guidance: (MUTCD 2000, Section 6F.09)

The local Traffic Only Signs should be used where road user flow detours to avoid a closure some distance beyond the sign, but where the local road users can use the roadway to the point of closure. These signs should be accompanied by appropriate warning and detour signing.

In rural applications, the Local Traffic Only sign should have the legend ROAD CLOSED XX KM (MILES) AHEAD LOCAL TRAFFIC ONLY(R11-3a).

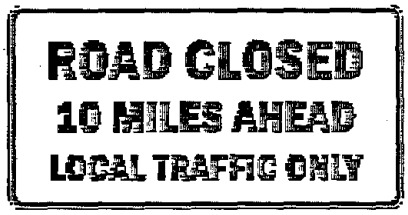
Option: (MUTCD 2000, Section 6F.09)

In urban areas, the legend ROAD (STREET) CLOSED TO THRU TRAFFIC (R11-4) or ROAD CLOSED, LOCAL TRAFFIC ONLY may be used. Where the sign faces through traffic, it shall be preceded by an advance ROAD CLOSED warning sign (MUTCD sec. 6B-17) with the secondary legend AHEAD and, if applicable, an Advance DETOUR warning sign (MUTCD sec. 6B-16).

Position of Advance Warning Signs

Guidance: (MUTCD 2000 Section 6F.16)

Where the highway conditions permit, warning signs should be placed in advance of the temporary traffic control zone at varying distances depending on roadway type, condition and posted speed. Handbook Table 7 (MUTCD 2000, Table 6C-1) contains information regarding the spacing of advance warning signs. Where a series of two or more advance warning signs is used, the closest sign to the temporary traffic control zone should be placed approximately 30 m (100 ft) for low-speed urban streets to 300 m (1000 ft) or more for expressways and freeways.



R11-5a
60" x 30"
See MUTCD 2000
Page 2B-56

R11-4
60" x 30"
See MUTCD 2000
Page 2B-56

Advance Warning Area (MUTCD 2000, Section 6C.04)
Guidance (partial):

On the urban streets, the effective placement of the first warning sign in the feet should range from 4 times the speed limit to 8 times the speed limit in MPH, with the high end of the range being used when speeds are relatively high.

Since rural highways are normally characterized by higher speeds, the effective placement of the first warning sign in feet should be substantially longer – from 8 to 12 times the speed limit in MPH. Since two or more advance warning signs are normally used for these conditions, the advance warning area should extend 1500 ft or more for open highway conditions

TABLE 7. Suggested Advance Warning Sign Placement
Source: MUTCD 2000, Table 6C-1

Road Type	Distance Between Signs**		
	A	B	C
Urban (low speed)*	30 (100)	30 (100)	30 (100)
Urban (high speed)*	100 (320)	100 (300)	100 (320)
Rural	150 (500)	150 (500)	150 (500)
Expressway / Freeway	350 (1,000)	450 (1,500)	800 (2,640)

* Speed category to be determined by highway agency

** Distances are shown in meters (feet). The column headings A, B, and C are the dimensions shown in Figures 6H-1 through 6H-45.# The A dimension is the distance from the transition or point of restriction to the first sign. The B dimension is the distance between the first and second signs. The C dimension is the distance between the second and third signs. (The third sign is the first one in a three-sign series encountered by a driver approaching a temporary traffic control zone.)

(See Figures 37 and 38)

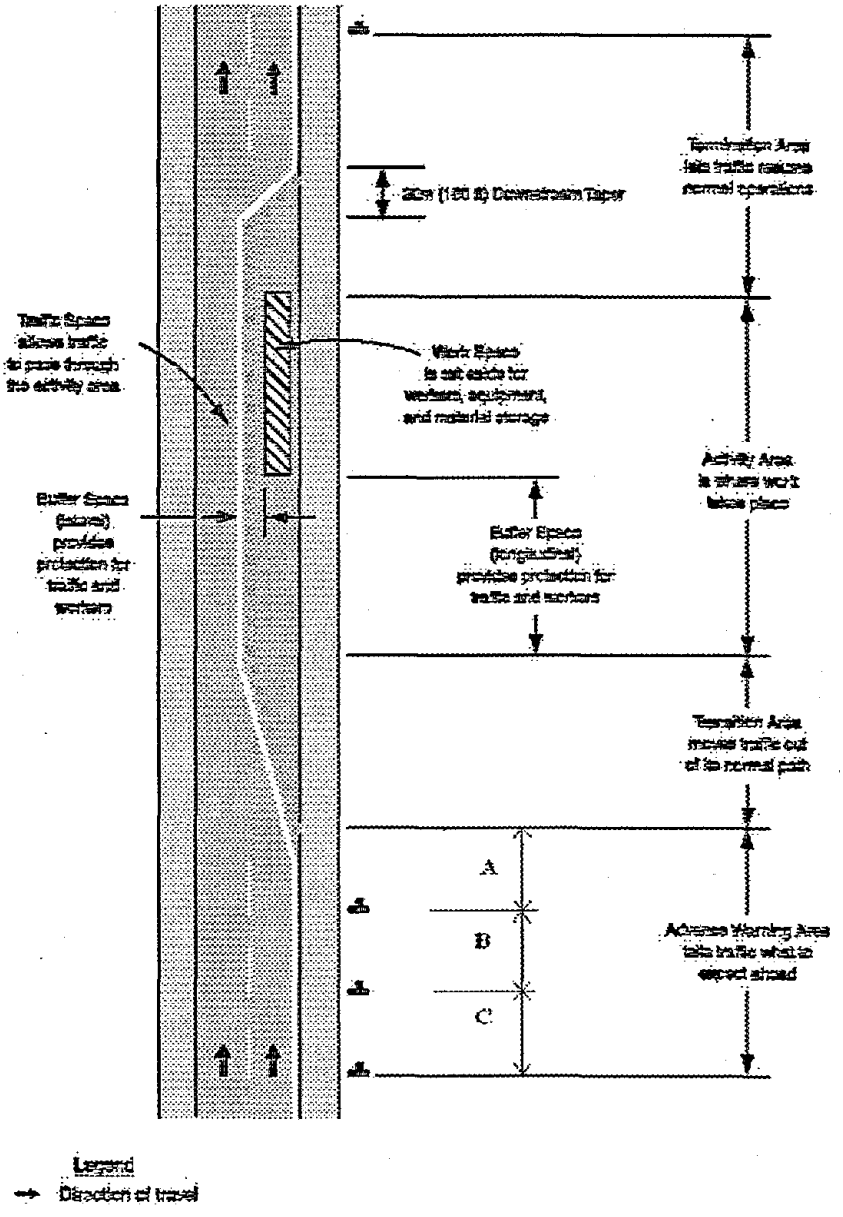


FIGURE 37. Component Parts Of a Temporary Traffic Control Zone
Source: MUTCD 2000 Figure 6C-1

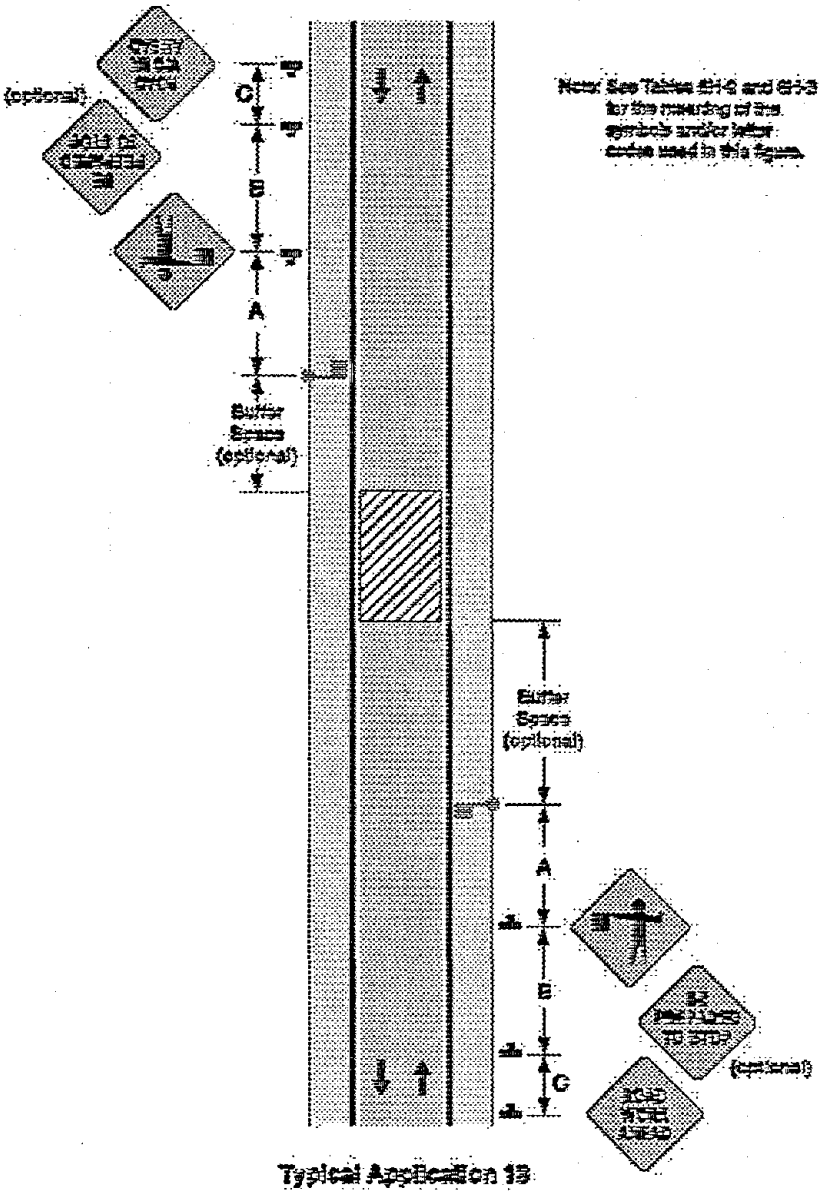


FIGURE 38. Temporary Road Closure
Source: MUTCD 2000 Figure 6H-13

Detour Signs and Markers

General Discussion:

The DETOUR ARROW sign (M4-10) is used at a point where a detour roadway or route has been established due to the closure of a street or highway to through traffic. It should normally be mounted just below the ROAD CLOSED sign or the LOCAL TRAFFIC ONLY sign.

The DETOUR Arrow sign uses a horizontal arrow pointed to the right or left as required at each location.

Each detour shall be adequately marked with standard temporary route markers and destination signs as a responsibility of the highway agency. The Detour marker (M4-8) mounted at the top of a route marker assembly is to be used to mark a temporary route that branches from a regular numbered route; bypasses a section of a route that is closed or blocked by construction, major maintenance, roadway damage or traffic emergency; and rejoins the regularly numbered route beyond that section.

The DETOUR sign (M4-9) is to be used for unnumbered routes; for use in emergency situations; for periods of short durations; or where, over relatively short distances, it is not necessary to show route markers to guide traffic along the detour and back to its desired route. A STREET NAME sign may be placed above or incorporated in the DETOUR sign (M4-9) to indicate the name of the roadway for which the detour was established.

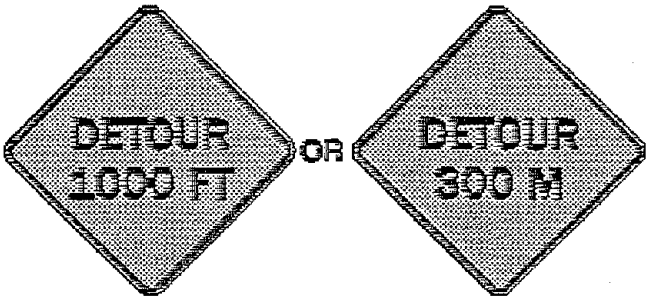
M4-8a
24 x 18 in

M4-8b
24 x 12 in

M4-9
30 x 24 in

M4-10
48 x 18 in

The END DETOUR sign (M4-8a and M4-8b) may be used to advise the motorist that the detour has ended. The END DETOUR sign may be used on either numbered highways or unnumbered roadways. If used on a numbered highway, it should be erected above a route marker located near the end of the detour.



W20-2
1200 x 1200 mm
(48 x 48 in)

DETOUR Sign (W20-2)

Standard: (MUTCD 2000, Section 6F.18)

The DETOUR Sign (W20-2) shall have the legend DETOUR, XX m (ft), XX Km (Miles), or AHEAD. It should be used in advance of a road user detour over a different roadway or route.

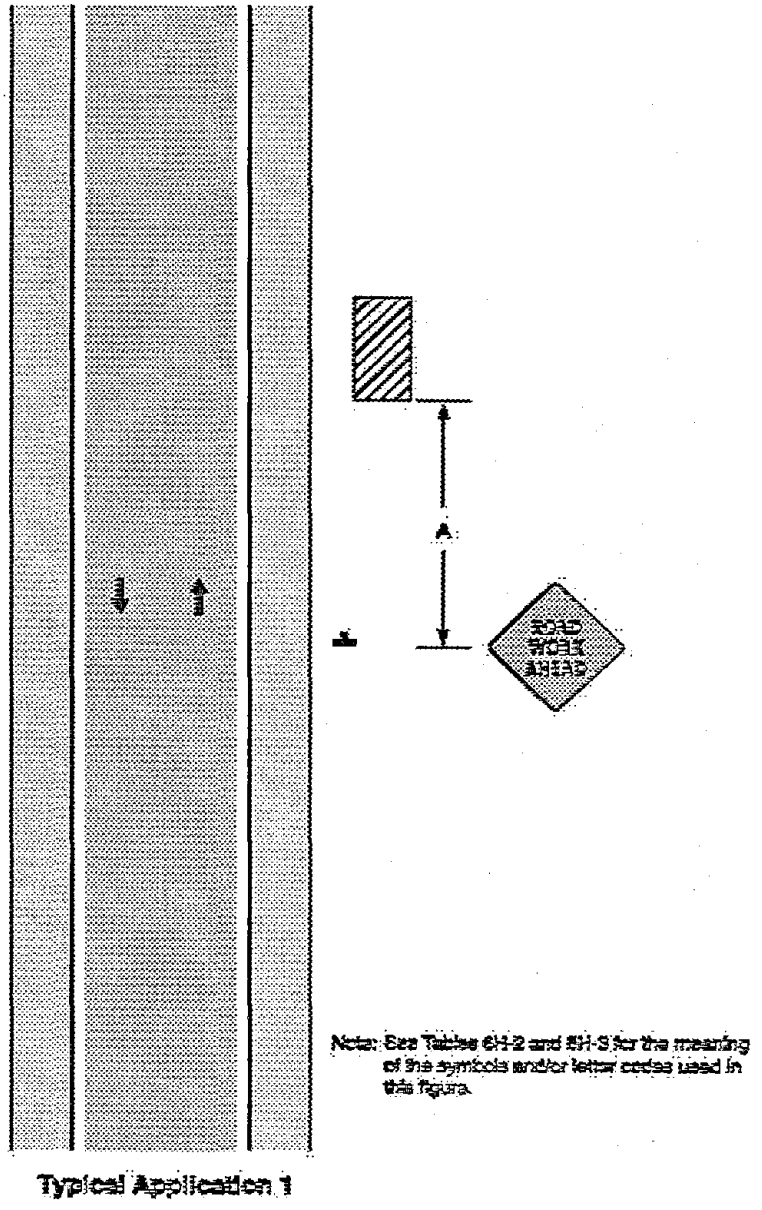


FIGURE 39. Work Beyond the Shoulder
Source: MUTCD 2000, Figure 6H-1

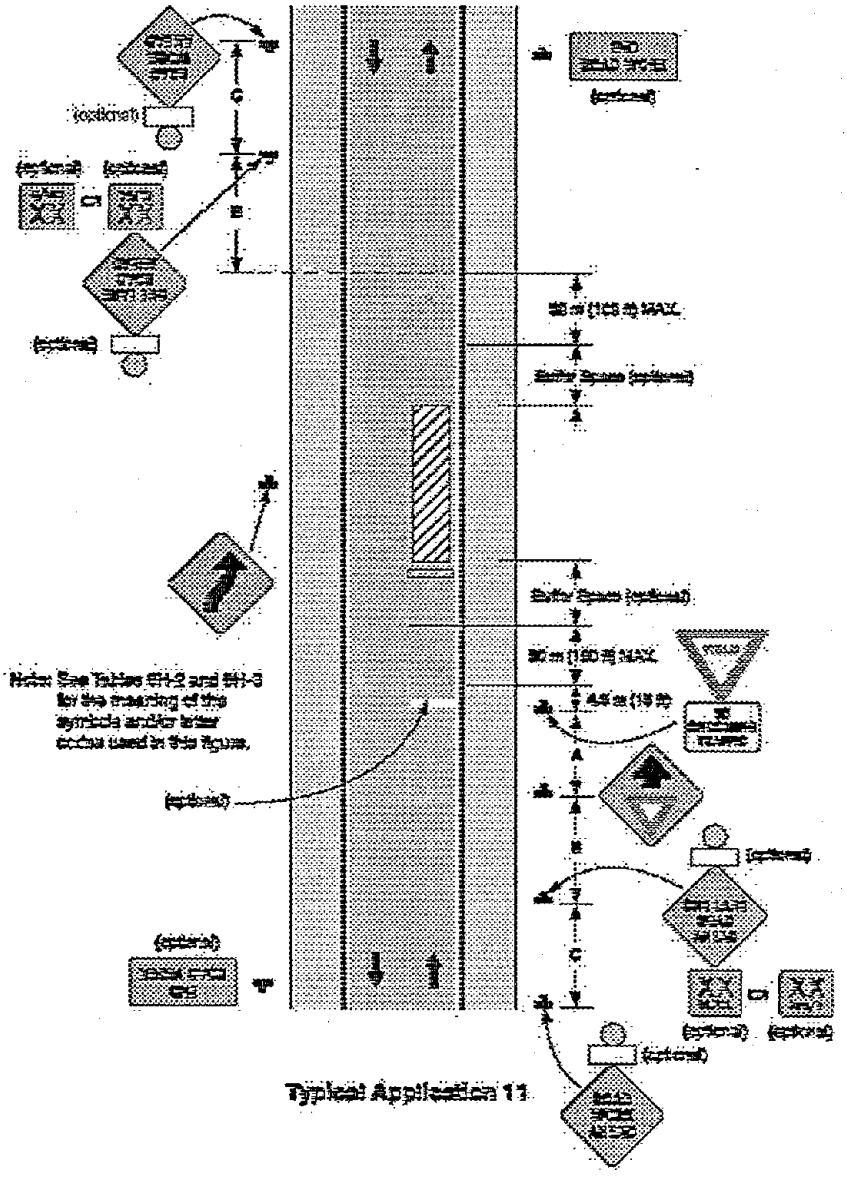
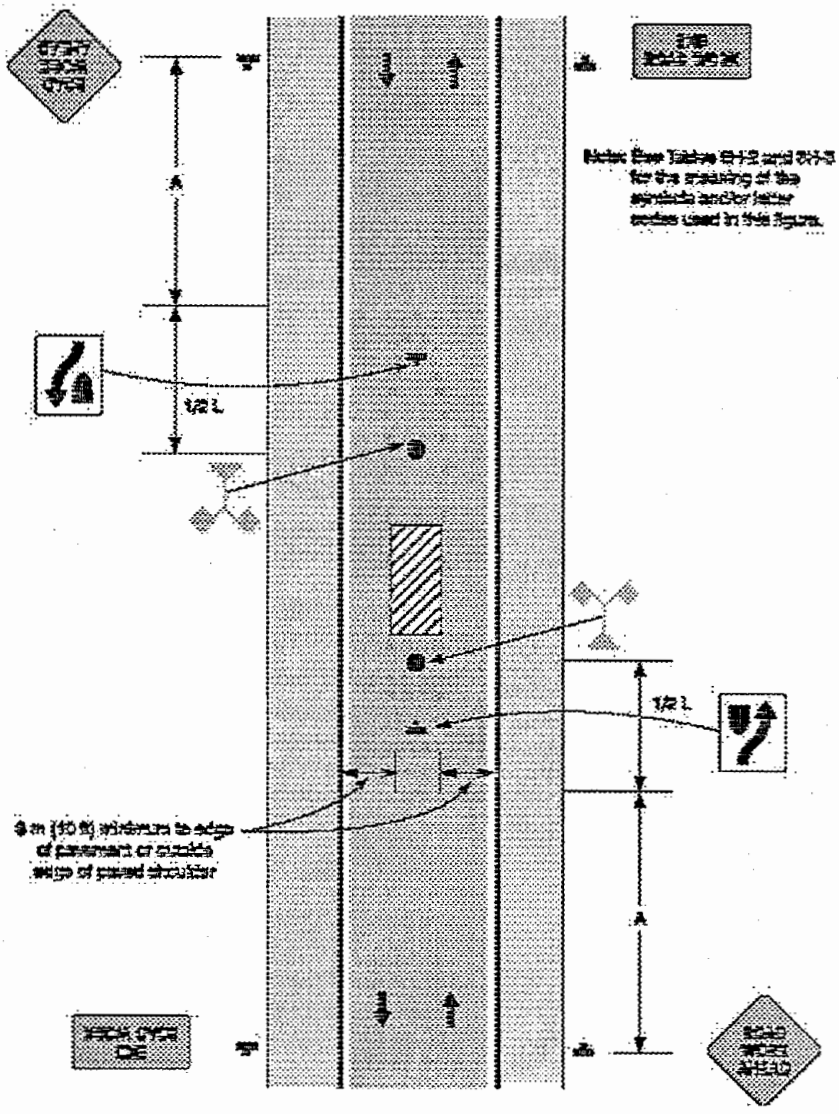


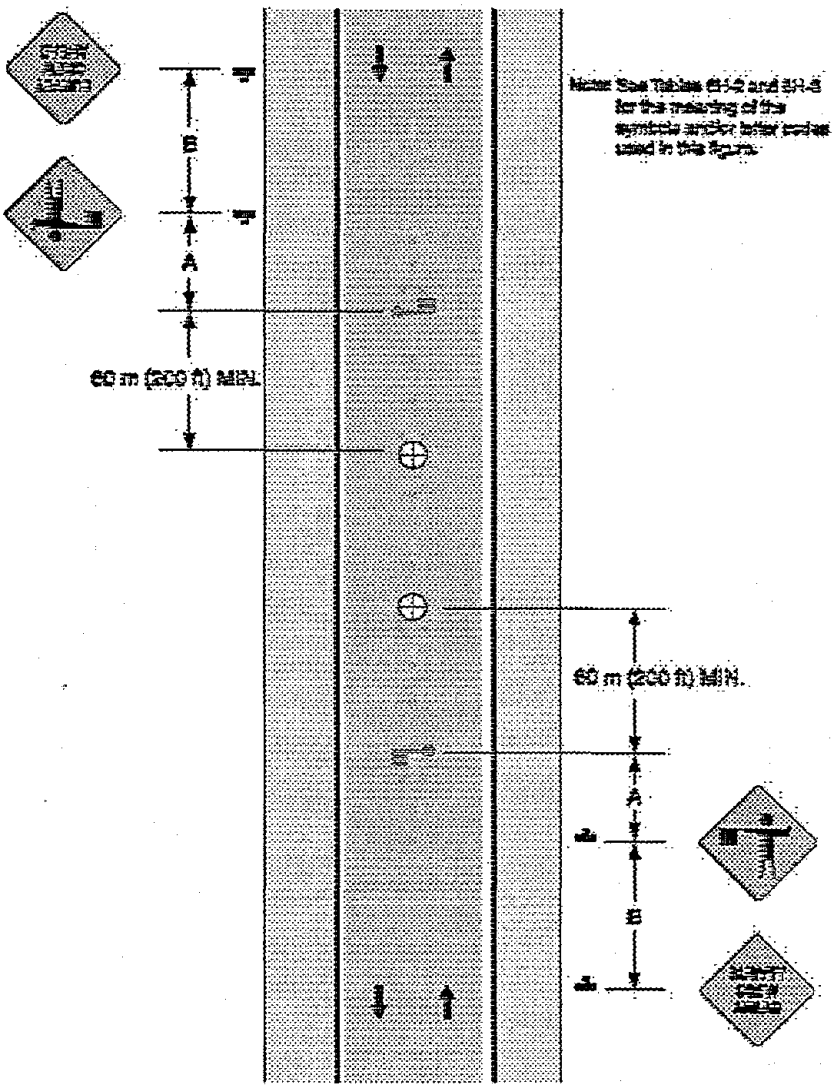
FIGURE 40. **Lane closure on Low-Volume Two-Lane Road (TA-11)**

Source: MUTCD 2000, Figure 6H-11



Typical Application 15

FIGURE 41. Work in center of Low-Volume Road (TA-15)
Source: MUTCD 2000, Figure 6H-15



Typical Application 18

FIGURE 42. **Surveying Along Centerline of Low-Volume Road (TA-16)**

Source: MUTCD 2000, Figure 6H-16

CHAPTER 7
SELF ASSESSMENT-DETERMINING POTENTIAL PROBLEMS/RISKS

General

There are several strategies or methods that personnel responsible for public safety on the local roadways-county's or city engineers, road supervisors, etc- can implement to insure that road signs and markings are properly installed and maintained, a few will be presented below. The commentary driving method, developed and promoted by Kansas State University (KSU) is very efficient and cost effective. The author believes it is the most cost effective method. (Nothing in this LVR handbook is intended to imply that any one of the methods is *the* one method that must be used. What is important is that every jurisdiction has some method that works for them.

Public jurisdictions have a duty to sign and /or mark certain specific operating conditions, to install devices that conform to the MUTCD, and to maintain these devices. Local agencies should have a policy, which includes some systematic means to insure compliance with the above. Four are discussed below, but are not the only methods that could be used, and they may not necessarily be the best for a given local government.

Discussed here will be:

1. General Inspection Guidelines,
2. A sign management system,
3. Road Safety Audits, and
4. Commentary Driving.

The extent of the system, and whether formal or informal, depends upon the particular needs of each jurisdiction.

General Inspection Guidelines

The following sign inspection guidelines from the ITE Traffic Control Devices Handbook (TCDH) may be beneficial (ITE, 2001).

A traffic control device must be periodically reviewed in the field either as a maintenance requirement or to determine whether the device is fulfilling its purpose. Inspection of traffic control devices can be triggered for a number of reasons:

- Periodic maintenance inspection
- Investigation of a citizen complaint
- Safety study or investigation of crashes
- Determination of retro reflectivity
- Operational evaluation of recently completed projects.

Each visit to a location should review the effectiveness of all traffic control devices even though the trip to the site may have been initiated for only one device or one particular reason.

It is important for tort liability purposes to document that the traffic control devices were reviewed in the field by the agency personnel to supply evidence that the device were in place at that time and in satisfactory operational condition. The documentation, at a minimum, should indicate date, time, name of inspector, location, any observations and recommendations for traffic control device improvements or replacement. If improvements or replacements are recommended, there should be some follow-up assurance that the work was accomplished. It is important that highway signs have proper retroreflectivity. This is important for the safety of the motoring public at night. It may become more important in the future as retroreflectivity standards or guidelines are developed by the FHWA. Chapter 8 presents the principles of retroreflection and suggested policy for checking night visibility of highway signs.

Sign Management System

As stated in the ITE, Traffic Control Devices Handbook (TCDH) (ITE, 2001): The need for a detailed management system will vary with the miles of roadway under jurisdiction, the number of traffic control devices installed and the capabilities of the agency. However, an agency should know the number and location of traffic control devices in its system, maintain them in good operating condition for the public and be responsive to any public concerns relative to the devices.

Most local jurisdictions use some form or portion of a management system although it may not be formalized. Details may be found in the ITE, TCDH, a viable system needs to be tailored to the local agencies specific needs. Thus, only a list of suggested activities is presented here. As listed in the TCDH, activities associated with a sign management system may include (ITE 2001).

A. Need:
    1. Inventory of traffic control devices
    2. Feedback – complaints, inspection, surveillance
    3. MUTCD applications
    4. Safety/liability concerns
    5. Traffic control device programs- signing, markings, traffic signals, railroad grade crossings, school zones, temporary traffic control

B. New Traffic Control Devices:
    1. Traffic control device evaluations
    2. Traffic control on newly completed projects
    3. Devices resulting from change in standards or policies

C. Maintenance activities:
    1. Routine maintenance–cleaning, repair of deterioration, vegetation control, post repair, device replacement, relamping, removal, operational review, contract maintenance.
    2. Emergency maintenance–damage due to vehicle collisions, outages, missing devices.
    3. Vandalism-graffiti removal/cleaning, replacement
D. Infrastructure:
    1. Personnel – organization, job descriptions, productivity, service levels
    2. Equipment- utilization, special equipment, rental versus ownership
    3. Budget- personnel, equipment, materials, contracts
    4. Materials- bulk purchase, specifications, contract services
    5. Facilities- fabrication shops, bulk storage, inventory storage
    6. Signal maintenance shops- repair, testing, inventory
E. Management Control:
    1. Organization and supervision
    2. Agency policies
    3. Material control and accounting
    4. Technical Expertise and control

Road Safety Audits (ITE 2001)

In the late 1990's, FHWA was strongly promoting Road Safety Audits (RSA) to improve roadway safety. RSA is a technique initiated in England and used heavily in Australia, New Zealand and a few other countries. Several U.S states have conducted pilot projects. Kansas DOT performs a form of RSA on existing state rural roads on a county-by-county basis. Overall, it consists of driving all the roads, noting potential problems and writing a report.

In recent years, RSA is being adapted for different situations and can take many forms. As originally developed, it is defined as the formal explanation of an existing or future road project or any other project which interacts with road users, in which an independent qualified examiner reports on the project's accident potential and safety performance.

The essential elements of the above definition are that:

- It is a formal process
- It is an independent process
- It is carried out by a team or individual with appropriate experience and training
- It is restricted to road safety issues
- The outcome is a report that identifies road safety deficiencies and, if appropriate, makes recommendations aimed at removing or reducing deficiencies.

- The report must be formally addressed by the appropriate road decision makers

The ITE TCDH suggests an RSA for Traffic Control Devices would take the following form (ITE 2001)

TABLE 8. Suggested Road Safety Audit Questions for Traffic Control Devices (Source: ITE 2001)

1. Are road users using the roadway facilities as intended?
2. Are 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 and 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 the 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. Are 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 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 conforming 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?
24. Is the intersection treatment reasonable for the bicycle volume? Are the 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?

* These may not apply to most LVR

An RSA can be performed on existing highways although it is more correctly called a Road Safety Audit Review (RSAR). An RSAR may be performed by a team or by an individual; the team or individual should have experience and/or expertise in signing and marking of LVR.

Commentary Driving Procedure

The information that a driver receives from the road must be correct, pertinent, concise and presented in such a way that it is readily understood and usable to the driver. In many cases, however, this information is not consistent with what he expects to receive or should receive. If the driver's expectancy of the roadway environment is violated, a potentially hazardous situation exists. A person whose expectancy is violated may react wrong, react more slowly, or not react at all. The Commentary Driving Procedure was developed by R. S. Hostetter et al. (1985) and is highly useful in doing safety evaluations of Low Volume Rural (LVR) Roads, quickly and cheaply. Commentary Driving is a procedure in which at the beginning of a section or road to be evaluated for potentially hazardous locations, the driver (evaluator) states his "expectancies" of the road and as he proceeds along the road he "comments" on locations/conditions which violate his expectancy.

It must be emphasized that Commentary does *not,* by itself, constitute a complete evaluation procedure. It is only meant to flag *possible* deficient locations that need further engineering study. After doing the "commentary" on a section of the road, the evaluator returns (at a later date) and does a more detailed study of problem locations identified in the "commentary." Note that the problem locations those which violate a driver's expectancy, are also locations with information deficiencies.

Missing information
Incomplete information
Inappropriate message
Misleading/confusing information
Inappropriate location
Obstruction by weeds, brush, etc
Inconsistent information

Commentary Driving, and all methods of analyzing LVR should be greatly aided by the use of Information Deficiency Evaluation Checklists. The checklists have been developed for nine typical situations and "other". These are presented in the Appendix 10.

1. Stop-controlled intersection
2. Narrow/one-lane bridge
3. Horizontal curve
4. Tangential intersection

5. Intersection which requires a turn
6. Railroad-highway grade crossing
7. Uncontrolled Y-intersection
8. Low water stream crossing
9. Height/weight limit restrictions
10. Other

Since Commentary Driving may not be as well known as several other methods that a local agency may use, and since it is more difficult to find in readily available references, details are presented in the Appendix 9.

References:

Institute of Transportation Engineers, Traffic Control Devices Handbook 2001, Editor: James L. Pline, Publication No. IR-112 (ITE 2001).

CHAPTER 8
PRINCIPLES OF RETROREFLECTION

Introduction

MUTCD 2000 contains no requirement for sign sheeting retroreflectivity values. However, the U.S. Congress recently passed a law mandating the Federal Highway Administration (FHWA) to develop standards for minimum highway sign retroreflectivity. The 1993 Highway Appropriations Act contained the following language; "The Secretary of Transportation shall revise the MUTCD to include a standard for a minimum level of retroreflectivity that must be maintained for the traffic signs and pavement markings which apply to all roads open to public travel".

The concept of minimum standards of sign retroreflectivity is very controversial. There has been considerable research on what form the standards should take and several committees, organizations, etc., that have attempted to evaluate the research and/or lobby for or against the recommended values.

It is not the intent here to argue for or against these standards or to attempt to speculate on what form they will take. However, unless the U.S. Congress repeals the law, which is unlikely, some form of standards will eventually be published in some form supplement or addendum to MUTCD 2000. Therefore, it behooves persons with responsibility for road and street safety, e.g., installing and maintaining traffic signs, to have some basic understanding of retroreflectivity. It is not well understood, even by Traffic Engineering Professionals. Thus, the objective of this section is to present basic definitions and key principles of retroreflectivity that should give the reader a good (or better) understanding of retroreflectivity.

This section will cover:

1. What retroreflectivity is,
2. Basic definitions,
3. Sheeting types,
4. Critical angles for
   a. placement
   b. measurement
   c. brightness (luminance),
5. Results of a Cost Effectiveness Study, and
6. Miscellaneous Information.

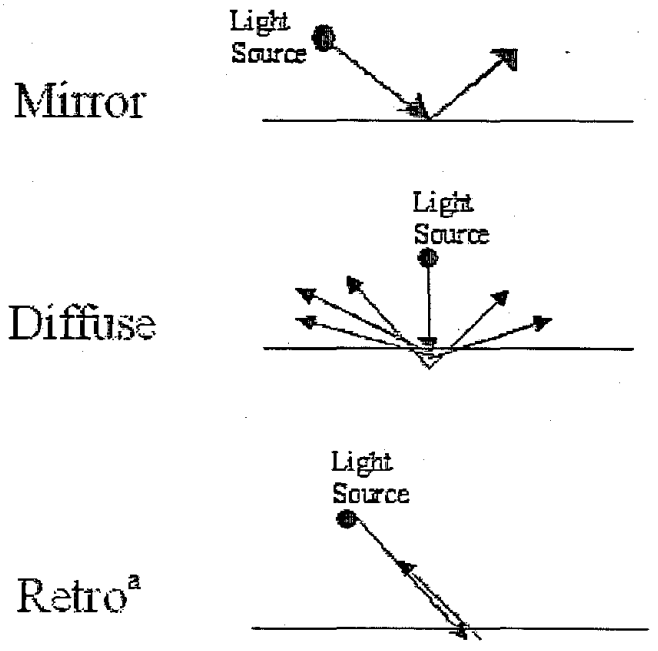
Retroreflectivity – What it is.

There are three types of reflection.

1. Mirror,

2. Diffuse and
3. Retro.

These are illustrated in figure 43.



[a]In highway signing "Retro-" is the important one.

FIGURE 43. Three types of reflection

Unless we are in total darkness, where we see nothing, everything we see is reflecting some light, otherwise we would not be able to see it. Generally, this is diffuse reflection. Light rays that strike a surface are diffused or scattered in all directions. We all are familiar with mirrors, and mirror reflection. A light ray striking a mirror is reflected from the mirror at the same angle as it strikes the mirror. A surface that retroreflects, sends most rays of light that strike it back toward the direction it came from. Retroreflection means that light is reflected back toward the light source.

In regard to highway signs, it is the principle of retroreflection that makes road and street signs visible to the motorist at night when light from their vehicles' headlights strikes the sign sheeting and is retro-reflected back toward the light source, i.e., the vehicle headlights. The result of this is that the sign appears to be "lit up", i.e., have some degree of "brightness". The name for this

brightness is luminance. How much is retroreflected – it is never 100% and how bright the sign appears to a driver, depends upon the sign sheeting and some key principles discussed below.

The following section contains definitions that are important to understanding the basic principles of retroreflection. These terms are directly applicable to this discussion and will be used below to explain key principles of retroreflection.

Basic Definitions

Retroreflection Definitions

Retroreflection – reflection in which radiation is returned in directions close to the direction from which it came, this property being maintained over wide variations of the direction of the incident radiation (i.e., light hitting the sign).

Retroreflector – a surface or device from which, when directionally irradiated, (e.g., by headlights) relatively large portion of the reflected radiation is retroreflected.

Retroreflective Material – a material that has a thin continuous layer of small retroreflective elements on a very near its exposed surfaced.

Retroreflective Sheeting – a retroreflective material preassembled as a thin film ready for use.

Photometric Definitions

The Photometric terms defined below are used to specify the performance of retroreflective materials.

Luminous Flux, F, the rate of flow of light from a source. The unit of this is the lumen (lm).

Luminous Intensity, I, the concentration or density of luminous flux per unit solid angle in a given direction. The unit of luminous intensity is the candela (cd.), formerly the candle, and luminous intensity is often referred to as candle-power.

Luminance, L, the light emitted per unit area of the surface. The luminance in a given direction of a surface emitting light is the luminous intensity, I,

measured in that direction divided by the area of this surface projected perpendicular to the direction considered. The unit of luminance is the foot-lambert, the luminance of a surface emitting a flux of one lumen per square foot.

Illumination, E, at any point of a surface receiving light is the density of the luminous flux at that point, or the flux divided by the area of the surface, when the latter is uniformly illuminated. The unit is the lumen per square foot (lm/ft^2), the illumination of a surface normal to the direction of the light one foot from a source of one candle-power. This unit was formerly called the foot-candle.

Specific Intensity, SI, is the ratio of luminous intensity of a surface to the normal illuminance. The units are candelas per foot candle (cd/fc).

Specific Intensity per Unit Area, SIA, is the ratio of the luminous intensity of the surface to the normal illuminance and to the area of the retroreflective surface. Its units are candelas per foot candle per square foot (cd/fc/sq.ft., English System) or candelas per lux per meter square ($cd/lux/m^2$, metric system)

Coefficient of Retroreflectivity, R_A, is the common term for SIA. It can be defined in more common terms as, the mount of luminance (light) measured as candelas that comes out from a retroreflective material per amount of light coming into the material from a light source, e.g., vehicle headlights for a specified geometrical system (as described in the next section). Since the term is interchangeable with SIA, the units are the same, candelas per footcandle per square foot ($cd/fc/ft^2$) or, in metric, candelas per lux per square meter ($cd/lx/m^2$).

Geometrical System

The geometrical coordinate system used to describe retroreflection was developed and standardized by the Subcommittee on Retroreflection of Committee 2.3 on Materials of the International Commission on Illumination (Commission International de l'Eclairage, CIE).

Reference Center, a point on or near a retroreflector which is designated to be the center of the device for the purpose of specifying its performance.

Reference Axis, a designated line segment from the reference center which is used to describe the angular position of the retroreflector (i.e. a line perpendicular to a sign face).

Illumination Axis, a line segment from the reference center to the light source [e.g., headlights].

Observation Axis, a line segment from the reference center to the receptor [e.g. viewers' eyes].

Observation Angle, α, the angle between the illumination axis and the observation axis. The observation angle is always positive and in the context of retroreflection is restricted to small acute angles.

Entrance Angle, β, the angle from the illumination axis to the reference axis.

Quick Reference Summary

For those not familiar with retroreflectivity, it can be difficult to keep the above terms straight. It may be helpful to remember:

1. Highway signs are commonly said to be "reflectorized" but the correct term is *retroreflective*.
2. They are retroreflective because they reflect the light toward the light source within a wide range of angles.
3. *Illuminance* is the light that hits the sign, e.g., from a vehicle headlight; *luminance* is the light reflected from the sign, which gives the sign the appearance of being "lit up", i.e., *luminance*.
4. The coefficient of reflectivity, R_A (common term) or specific intensity per unit area, SIA, is a measure of *how much* of the light that hits the sign (illuminance) is retroreflected (luminance) toward the source (headlights).
5. The luminance of a sign is dependent upon:
   a. R_A – which depends on the material and the two angles in b. and c. below.
   b. The angle which the illuminance hits the sign (*entrance angle*).
   c. The angle between the viewer's eye and the light source (*observation angle*) (effect of angularity explained in the next section), and
   d. The amount of illumination hitting the sign which varies according to type of headlights, headlight arm, angle from headlight to sign and other environmental factors.

Summary of Key Points

In regard to the above definitions, the key points in regard to sign brightness at night – called luminance – depends upon the sign sheeting SIA (Specific Intensity per unit area which varies according to type of sign sheeting), the

amount of light striking the sign surface from a vehicle's headlights – called illuminance, and some critical angles formed by the relative positions and orientation of a vehicle, its headlights and a sign.

Figure 44 below illustrates a geometrical system that shows the most critical elements and angles of a retroreflection system (i.e., driver, vehicle headlights and sign face). First, the reference axis is a line projection perpendicular to the sign face from which the entrance angle, β, and observation angle, α, are measured. The angle between the illumination axis, i.e., a light ray (illuminance) from the light source (headlight) to the sign and a line from the sign (representing the reflected light or luminance) to a driver's eye (receptor) is called the observation angle, α.

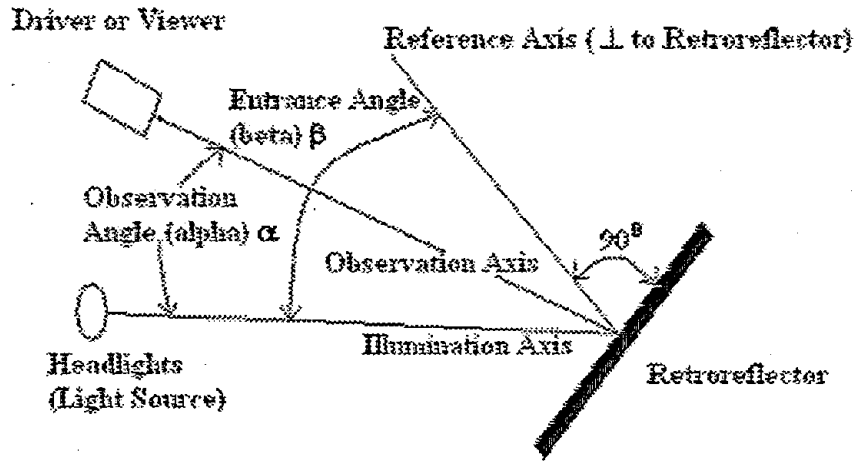


FIGURE 44: Schematic of Retroreflective Geometrical System

It is very important to understand that the brightness (luminance) of a sign at night is very sensitive to the observation angle, α. The angle between the line representing a light ray hitting the sign and the perpendicular projection from the sign surface (reference axis) is called the entrance angles, β. Up to about 30°, the brightness (luminance) of a sign is relatively insensitive to changes in β for most sign sheeting material, however, if a sign has poor placement or enough twist to exceed this value, it may have little or no luminance.

Figure 45 below is a schematic diagram showing the key angles α and β in relation to a vehicle.

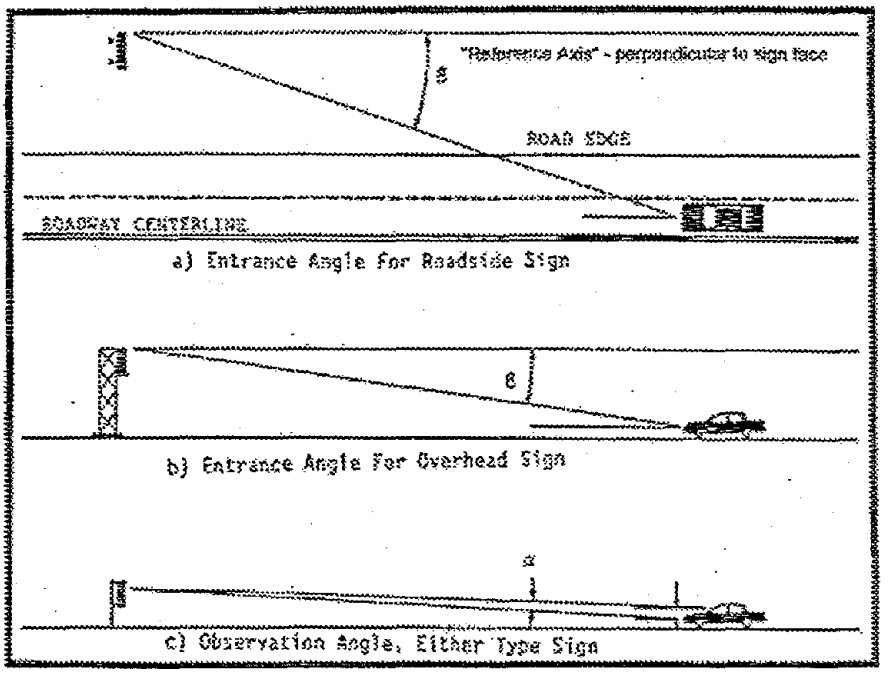


FIGURE 45: Entrance and observation angles in retroreflectivity measurement.

Entrance angle, β, is a function of:

- Sign offset
- Distance of vehicle to sign
- Travel lane of the vehicle
- Curvature of the road
- Twist of sign on post

Observation angle, α, varies with:

- Distance of vehicle to sign
- Separation of headlights and driver's eyes

It is very important to understand that α, is the most important variable in determining the brightness of a sign (its luminance) for a specified sheeting type and given value of illuminance.

As illustrated in figure 45, how bright a sign appears to an approaching driver (within an allowable β value) varies as α varies, and α varies with distance as a vehicle approaches a sign, i.e., it will be very small when a vehicle is far away and increases as the vehicle approaches the sign. It will also vary if

a vehicle changes lanes or position in a lane. It is important to understand that α is not a constant value and sign brightness (luminance) changes when α changes.

Even though sign brightness is more sensitive to α than β, β cannot be ignored. If β is very large, e.g. greater than 20^0 to 30^0 luminance may be substantially decreased (the actual limiting value of β varies with sheeting type). Beta (β) is best controlled by proper sign placement. Improper placement, e.g. signs to far off the road, too high, bent or twisted, can result in large values of β and also a decrease in the amount of light from the headlights (illuminance) hitting the sign face and, therefore, the sign brightness (luminance).

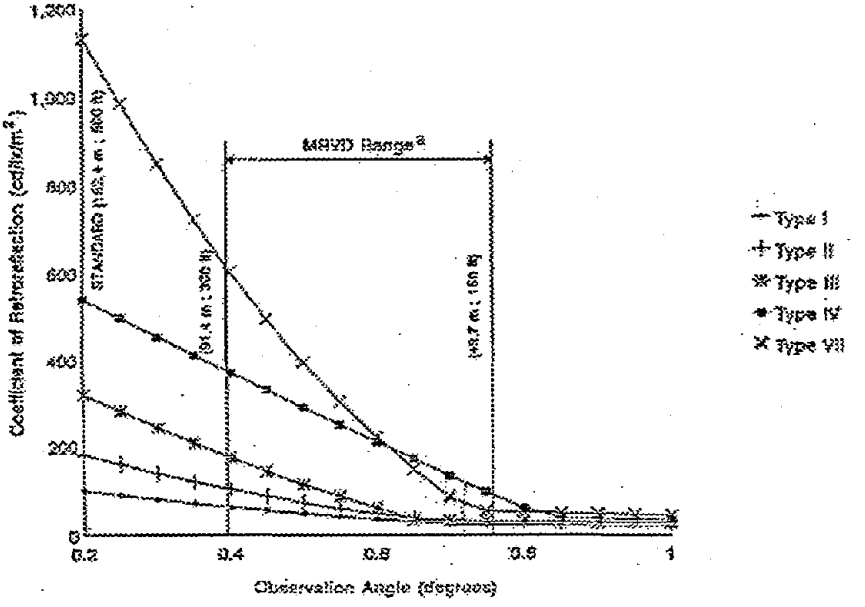


FIGURE 46. Relationship between coefficient of retroreflection observation angle with constant entrance angle.
(Note: Angle typically increases as a vehicle nears a sign)
[a]Range in which sign needs to be visible to a driver in order to have time to react properly.

Sign Sheeting Types

The two major categories of sign sheeting are enclosed lens, encapsulated lens, and prismatic. Engineering grade sheeting is an example of enclosed lens sheeting. One of the widely used encapsulated lens sign sheeting is generally called high intensity or high performance sheeting. Newer, brighter sheeting, such as Diamond Grade™, are prismatic types.

Enclosed and encapsulated lens sheeting use glass beads to retroreflect entering light rays. The prismatic type sheetings use other types of reflectors. In general, the enclosed lens types (Engineering Grades) have the least brightness and the prismatic types have the greatest brightness for any given value of illuminance that strikes the material. See Table 9 for typical SIA values of new sheeting by the most common ASTM types.

TABLE 9. Minimum SIA Values[a] for ASTM Types II, III and Diamond Grade™ retro-reflective sheeting.

Sheeting Type and Common Names	White	Green	Blue
Type II (enclosed lens sheeting; engineering grade)	70	9	4
Type II-A (enclosed lens sheeting; super-engineering grade)	140	30	10
Type III-A (encapsulated-lens sheeting, high-intensity or high-performance)[b]	250	45	20
Type III-B (prismatic or cube corner; high-intensity or high-performance)[b]	250	45	20
Type III-C (cube-corner; high-intensity or high-performance) [b]	250	35	20
Diamond Grade	800	75	43

[a]Table values are from FP-85 except for Diamond Grade which is from the manufacturers.

[b]No differentiation is made between the terms "high-intensity" and "high-performance." (Type III-A, high-intensity, supplied by 3M Company, has been the most commonly used high-performance sheeting, but in recent years other manufacturers are producing similar sign sheeting.)

Sign Brightness Measures

The ability of sign sheeting to retroreflect light is measured by specific intensity per unit area, SIA or R_A. Referring back to the definitions, it can be seen that SIA (R_A) is defined as the ratio of the luminous intensity of the surface [the sign brightness viewed from a given direction] to the normal illuminance [light hitting the sign normal or perpendicular to the surface] and to the area of the surface. SIA/ R_A has been standardized for a specific [light] entrance angle and a specific [viewer] observation angle - $\alpha = 0.2$ degrees and $\beta = -4.0$ degrees. The unit of measurement for SIA/ R_A is candelas (returned light or luminance) per one-foot candle (of headlight illuminance striking the sign) per square foot of sign sheeting (cd/fc/ft^2). In the metric system the measure is candelas per lux

per square meter. Instruments that measure sign sheeting record the SIA/ R_A value only at these standard angles, i.e., $\alpha = 0.2^0$ and $\beta = -4.0^0$. Manufacturers report the SIA/ R_A values of new sheeting at these standard angles. Sheeting purchase specifications for SIA are given at these standard angles. When an instrument to measure SIA/ R_A, a retroreflectometer, is used, it records the value at the standard angles, only. For these standard angles, $\alpha = 0.2$, $\beta = -4.0$, the luminance of a sign can be calculated by multiplying the footcandles hitting the sign sheeting (measured at the sign surface) times the standard SIA/ R_A value times the area of the sheeting. The luminance of all sheeting varies as these angles change and generally decreases as α increases as figure 8-4 illustrates. From a long distance, say 1,000 or 2,000 feet, luminance is low because illuminance hitting the sign from the vehicle's headlights is low (it varies inversely with the square of the distance). As the vehicle moves closer, illuminance hitting the sign increases and the observation angle is small – near the standard 0.2^0. As the vehicle nears the sign, at some point the observation angle, α, increases to where the luminance decreases rapidly, even though illuminance form the headlights may be increasing.

Note that to calculate what a sign's luminance value would be at any other angles than $\alpha = 0.2°$ and $\beta = -4.0°$, an R_A value for those angles must be used. R_A values at these angles are not readily available, as they can only be determined by sophisticated, expensive laboratory equipment. However, there are computer programs available that can make these sorts of calculations.

Life Cycle Costs

High performance or high intensity sheeting has a higher first cost than engineering grade sheeting. Apparently this is the main reason some local jurisdictions are reluctant to use it.

A study done at Kansas State University (KSU) for the Kansas Department of Transportation (KDOT) used KDOT cost figures and data on service life and calculated life cycle costs for engineering grade sheeting and high intensity sheeting. The results are shown below in Table 10.

TABLE 10. Life Cycle Costs for Engineering grade and High performance Sheeting from a KDOT Study

	Equivalent Uniform Annual Cost, ($)[a]		Average Annual Cost, ($)	
	Engineering Grade	High-Performance	Engineering Grade	High-Performance
Overhead Guide Sign (New)	243.40	206.28	163.35	162.50
Overhead Guide Signs(Refurbishing)	178.80	152.20	120.00	120.00
Roadside Signs (New)	6.95	4.79	4.66	3.77

[a]Equivalent Uniform Annual Cost method is the preferred method for highway life-cycle cost studies and is more accurate than other methods.

Checking Retroreflectivity

The use of a "Retroreflectometer" may some day become a requirement to verify the retroreflective condition of all traffic control devices within the jurisdiction of the agency. However, an expensive and time-consuming retroreflectometere may not be necessary if adequate sign inspection is documented. Also, a high retroreflector reading does not ensure that a sign has adequate night visibility to an approaching driver.

The agency should establish a written policy regarding the maintenance and inspection of all traffic control devices. A written traffic control device inspection program shows intent and when used properly, should provide the agency with good tort liability protection. As part of that policy would be a section regarding sign retroreflectivity. The policy would include but is not limited to the following:

1. Review each traffic control device bi-annually regarding retroreflectivity.
2. A check list of times to be reviewed should be part of the policy.
3. The inspection would be conducted at night and the agency should train personnel in the proper methods to complete this type of inspection.
4. Any signage not meeting the guidelines set forth in the written check list would be scheduled for replacement.
5. Records are to be kept as long as the sign remains at that location.

The basic theory is that it is more important that the signage perform correctly under actual field conditions than it is to meet specific retroreflective numbers. As explained in previous sections, the standard R_A (SIA) numbers ($\alpha = 0.2^0$ and $\beta = -4.0^0$) do *not* insure that a sign appears bright (has good luminance) to an approaching driver. Poor placement can negate a high R_A (SIA) value. After all, it is the driver that ultimately makes the observation of the traffic control device.

Other Potential Implementation Methods

It is likely that there may be multiple options to determine and maintain adequate nighttime visibility of signs. This concept may allow local agencies to implement the method(s) most suitable to them. Some of the possible methods available are:

- Nighttime sign inspection by trained observers,

- Expected service life,
- Inspection panels,
- Measured retroreflectivity values,
- Control signs, or
- Other methods.

Note: It may be advantageous for local governments to have a sign inventory system. Sign Management Systems are discussed in the next chapter.

CHAPTER 9

INVENTORY SYSTEMS FOR TRAFFIC CONTROL DEVICES

The material in this chapter is reproduced with permission from the "Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties", Iowa DOT, Ames, IA 2001

An inventory of signs and markings is a critical element for effective governmental transportation management practices. The investment in signs and markings is significant when considering all the assets of a government agency. The ideal inventory system would track signs and markings from initial installation, through inspections and maintenance, and until removal from the system.

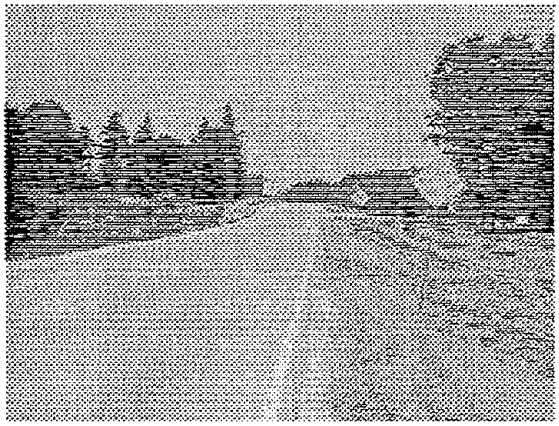


FIGURE 47. Rural highway with signs and pavement markings

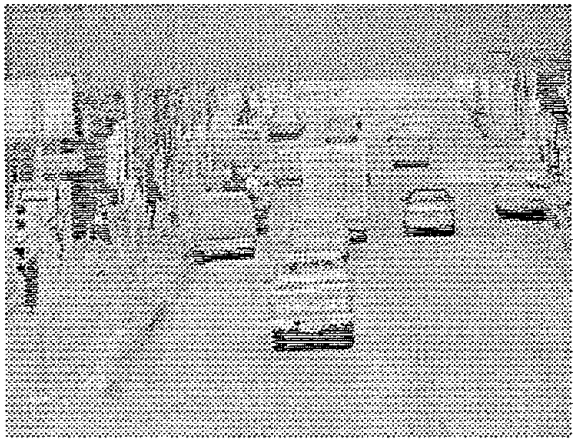


FIGURE 48. Urban Street with signs and pavement markings

A traffic control device inventory can be a valuable asset in tort liability cases. This inventory can provide documentation of the condition of specific signs and markings in place for any given period. In addition, pertinent inspection and maintenance activities would be noted in the inventory and available for use by the agency.

An inventory system can be used for many activities. It can identify signs for replacement based on criteria such as age or condition. Recording and evaluating maintenance and replacement history can help an agency to identify high-vandalism areas or sign locations with visibility or operational deficiencies. In addition, planning and budgeting for sign replacement or expansion of new development areas is much easier to accomplish with inventory records identifying existing signs and required maintenance activities. A sign inventory can be used to manage personnel and maximize production by combining work orders and scheduling routine maintenance activities. The system can track responses to requests and complaints, resulting in an improved level of service to the public.

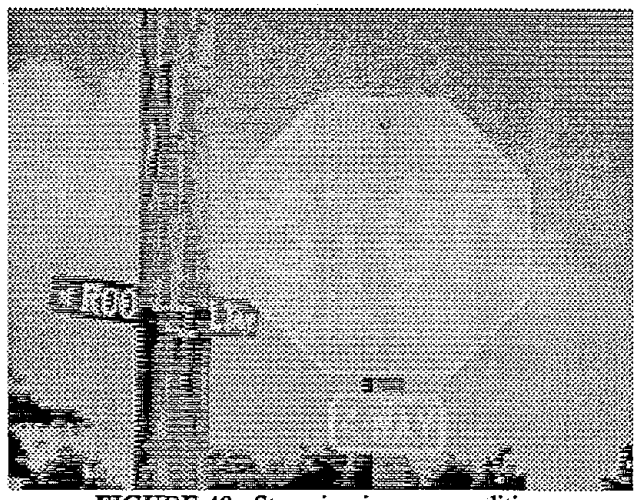


FIGURE 49. Stop sign in poor condition
NOTE: Street sign is improperly placed

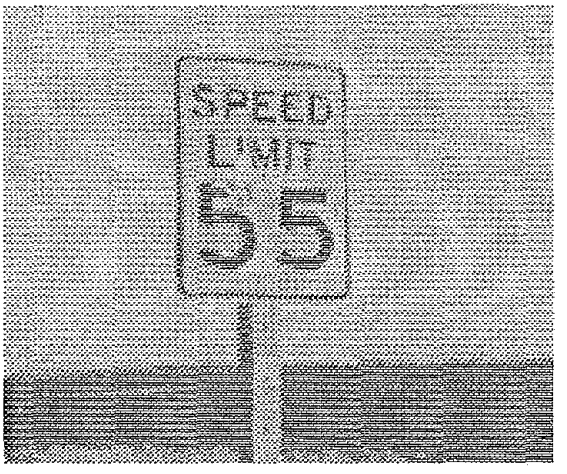


FIGURE 50. Vandalized Speed Limit sign

FIGURE 51. Vandalized sign

A critical element of a successfully operating inventory is the involvement of all staff whose job requires an interest in traffic control devices. In a large county, this staff may include engineers, transportation planners, accountants, office managers, enforcement officers, administrators, and most important, installation and maintenance staff. In smaller counties it may be only two or three employees; however, this involvement is particularly important for the staff responsible for collecting the original data, maintaining traffic control

devices, and keeping an inventory system current. An efficient inventory system results from involvement of all interested parties.

Choosing a System

Inventory systems range from very basic to quite sophisticated depending on the resources available to and the needs of an agency. A very basic inventory system might consist of manual records, such as paper files of activities or a card system, to maintain the system and keep it current.

Many transportation agencies use an automated or computerized system. Each agency should consider several factors before making a selection between one of the many computer programs available:

- agency requirements
- computer capabilities
- availability of trained staff to support the system and keep it current
- improved accuracy and production with use of laptop computers for field operations

When selecting an inventory system, the following issues should be addressed:

- Does the system match the selected data elements? Are all data elements recorded?
- Is there an understanding of the basic features of a software program as compared to data elements?
- Do the hardware and software requirements of computer programs match the existing computer system?
- Have user support and references been reviewed?
- What does the initial cost include?
- Are there maintenance costs with the program?

Software that provides basic inventory features has been developed and is available at minimal cost to local agencies. These programs can be effectively used as a low-cost supplement to a sign management system.

Developing the System

Development of the system should involve key personnel, including management representatives, office staff, work crew supervisors, sign workers, and other affected offices within the agency. The development of an inventory system should also include all critical tasks: selecting and purchasing software, collecting initial data, daily operations, and reporting procedures, along with ancillary tasks such as enforcement and risk management.

Choosing a Reference System

Several reference systems can be considered to locate traffic control devices for the inventory. The chosen reference system should be compatible with other

systems within the agency and use the same reference points. The most common references used are shown in the following list:

- route/milepost/distance
- route/mile point/distance
- link/node/distance
- route/intersection/direction/distance
- global positioning systems, which may offer additional location options for the future
- linear referencing systems

Each of these reference methods has particular advantages to consider, but the most important factors are compatibility with other agency systems, staff buy-in, and ease of use.

Determining Elements of the Inventory

Inventory data elements are selected to provide most appropriate information to meet agency needs. These elements can be divided into three categories: core, critical, and desirable.

Core Elements. Core data elements reveal location, description, condition, and inspection and maintenance history. Core elements are essential to an inventory. These elements identify replacements, provide documentation in tort liability, and furnish benefits in management and budgeting.

Core elements typically include the following:

- location
- position
- sign code (*MUTCD* designation)
- sign condition
- maintenance activities
- installation, inspection, and maintenance dates

Critical Elements. Critical data elements provide more information about devices. These elements are valuable in keeping proper inventories in stock and can provide additional information that supports the agency in tort liability issues. With data from the following critical element list, an agency can document that traffic control devices comply with established standards and guidelines.

Critical elements normally include the following:

- dimensions
- sheeting type
- sign blank type

- post/support type and condition
- sign orientation
- posted speed limit at the time activities were conducted

Desirable Elements. Desirable data elements can provide additional information about sign installation that can help with maintenance and replacement activities.

Desirable elements include the following:

- offset
- height
- retroreflectivity (documentation will be more important when minimum standards are adopted nationally)
- inspector name
- sign identification number, if different from *MUTCD*
- images of the sign
- comments
- other reference numbers

Collecting the Data

The most formidable task after selecting an inventory management system, whether manual or computerized, is the collection of initial data. In addition to a significant investment in staff time, collection costs can range from $2 to $5 per sign. To reduce initial cost and staff time, phased data collection can be considered. A systematic approach should be developed that completes the task within a reasonable time, i.e., four years or less. Data may be collected by area or sign type. Regular agency staff, temporary employees, or consultants can be used to collect this data, but all should be properly trained. It is very important that initial information be accurate.

When the initial data collection effort is organized, the following recommendations should be considered and/or followed:

- Select a standard approach that matches other databases within the agency, if possible.
- Decide whether to use route names or route numbers for location.
- What signs should be included? All or one specific type, such as regulatory signs?
- How do we determine whose sign is it?
- Train personnel to collect and enter data.
- Determine the area to be inventoried (do only a section each year until the initial data collection is completed.)
- Decide whether to use manual data collection, laptop computers, or photo/video logging to gather initial data.

Maintaining the Inventory

After an inventory system has been adopted and initial data collection activities are completed, the next critical task is keeping the system current. If the inventory is not up to date, much of the value and the investment in resources will be lost in a relatively short time.

A work order process is a common method of keeping inventories current. With this procedure, work orders are completed at the time any activity is finished. Usually, the field crews that perform the work are best qualified to record the data. Pen-based computers have been used successfully for this purpose in some agencies. It is important to enter this information into the database on a regular schedule, daily if possible.
Documentation of important daily activities should be a key factor in software selection.

Inventories of traffic control devices can be a very valuable asset for any transportation agency. However, development and establishment can involve a significant investment in staff time and funding. Continued maintenance of the system is mandatory for efficient and effective operation.

Please refer to the following sources for more in-depth information:
Institute of Transportation Engineers, *Traffic Signing Handbook*

Institute of Transportation Engineers, *The Traffic Safety Toolbox: A Primer on Traffic Safety.*

The Center for Transportation Research and Education, a center of Iowa State University

CHAPTER - 10
MODERN ROUNDABOUTS

The modern roundabout is the safest, most efficient form of intersection traffic control available today. In this section, the term modern roundabout is used to stress that these modern traffic control devices (TCDs) are distinctly different from the big, high speed, generally confusing, circular intersections built in the early 1900's. Some of these circular intersections, sometimes called rotaries, still exist in the eastern USA. But they are not modern roundabouts. The first modern roundabout was built in the USA in 1990. Keep in mind anything built prior to that is probably not a modern roundabout and most likely won't have the characteristics that make them safe and efficient.

There is no doubt that modern roundabouts are much safer than all other forms of intersection traffic control. This is a proven fact based on both USA studies and worldwide studies. A USA study of intersections where modern roundabouts replaced stop signs and traffic signals showed the roundabouts reduced all crashes by about 40% and injury crashes by about 80%. Also, fatal crashes can be expected to be reduced by 90%.

In regard to efficiency, modern roundabouts require less stopping and they reduce delay to motorists. Studies of several roundabouts in Kansas by KSU have shown that in regard to total stopping and delay they are comparable to two-way stop controlled intersection, and have significantly less stopping and delay (up to 80%) than four-way stop control and traffic signals.

In spite of the proven safety record and operational efficiency, there is often unwarranted opposition by some persons. Usually the opposition is due to lack of understanding of exactly what a modern roundabout is and/or confusing them with the big, old traffic circles from years past or small traffic circles that may be used for speed control at residential intersections. Thus, it is important that people understand what a modern roundabout is and what it isn't. The following definitions from the Federal Highway Administration (FHWA) Roundabout Guide are a good start (FHWA, 1999).

A roundabout is a type of circular intersection, but not all circular intersections can be classified as roundabouts. In fact, there are at least three distinct types of circular intersections:

- *Rotaries* are old-style circular intersections common to the United States prior to the 1960's. Rotaries are characterized by a large diameter, often in excess of 100 m (300 ft). This large diameter typically results in travel speeds within the circulatory roadway that exceed 50 km/h (30 mph). They typically provide little or no horizontal deflection of the paths of through traffic and may even operate according to the traditional "yield-to-the-right" rule, i.e., circulating traffic yields to entering traffic.

- [Small] *Neighborhood traffic circles* are typically built at the intersections of local streets for reasons of traffic calming and/or aesthetics. The intersection approaches may be uncontrolled or stop-controlled. They do not typically include raised channelization to guide the approaching driver onto the circulatory roadway. At some traffic circles, left-turning movements are allowed to occur to the left of (clockwise around) the central island, potentially conflicting with other circulating traffic.

- *Roundabouts* are circular intersections with specific design and traffic control features. These features include yield control of all entering traffic, channelized approaches, (i.e., raised splitter islands) and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less than 50 km/h (30 mph). Thus, roundabouts are a subset of a wide range of circular intersection forms.

FIGURE 52. Key features of a roundabout

Key features in the figure above are described below (Source FHWA, 1999).

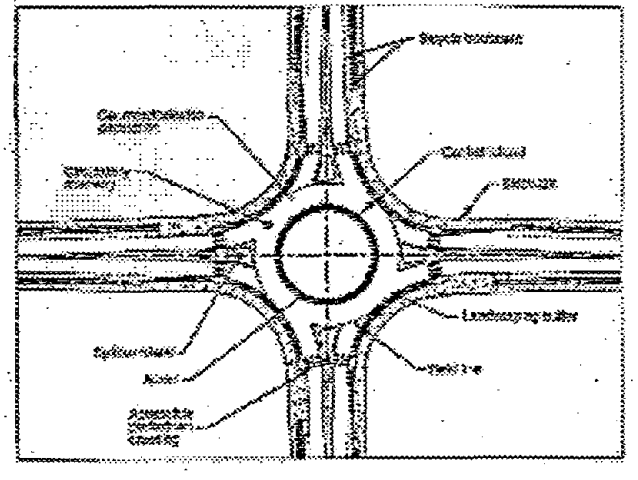
Central island — The *central island* is the raised area in the center of a roundabout around which traffic circulate.

Splitter island — A *splitter island* is a raised or painted area on an approach used to separate entering from exiting traffic, deflect and slow entering traffic, and provide storage space for pedestrians crossing the road in two stages.

Circulatory roadway — The *circulatory roadway* is the curved path used by vehicles to travel in a counter-clockwise fashion around the central island.

Apron — If required on smaller roundabouts to accommodate the wheel tracking of large vehicles, an *apron* is the mountable portion of the central island adjacent to the circulatory roadway.

Yield line — A *yield line* is a pavement marking used to mark the point of entry for an approach into the circulatory roadway and is generally marked along the inscribed circle. Entering vehicles must yield to any circulating traffic coming from the left before crossing this line into the circulatory roadway.



Accessible pedestrian crossings

Accessible pedestrian crossings should be provided at all roundabouts. The crossing location is set back from the yield line, and the splitter island is cut to allow pedestrians, wheelchairs, strollers, and bicycles to pass through.

Bicycle treatments

Bicycle treatments at roundabouts provide bicyclists the option of traveling through the roundabout either as a vehicle or as a pedestrian, depending on the bicyclist's level of comfort.

Landscaping buffer

Landscaping buffers are provided at most roundabouts to separate vehicular and pedestrian traffic and to encourage pedestrians to cross only at the designated crossing locations. Landscaping buffers can also significantly improve the aesthetics of the intersection.

Inscribed circle diameter

The *inscribed circle diameter* is the basic parameter used to define the size of a roundabout. It is measured between the outer edges of the circulatory roadway.

The Following roundabout dimensions are illustrated in the Figure 53

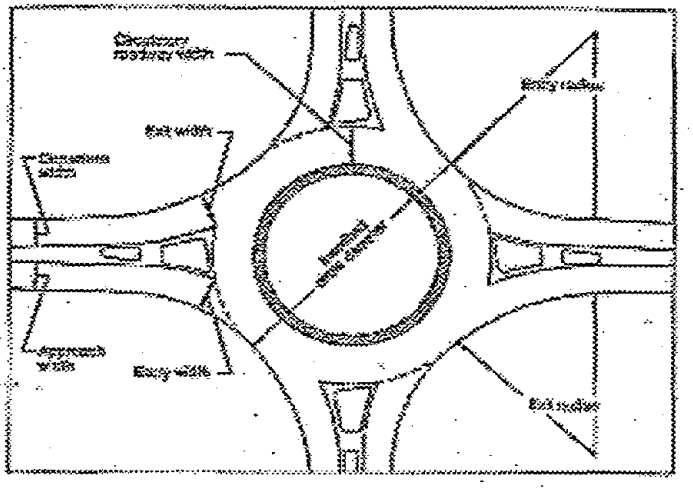


FIGURE 53. Roundabout Dimension Locations

Circulatory roadway width

The *circulatory roadway width* defines the roadway width for vehicle circulation around the central island. It is measured as the width between the outer edge of this roadway and the central island. It does not include the width of any mountable apron, which is defined to be part of the central island.

Approach width

The *approach width* is the width of the roadway used by approaching traffic upstream of any changes in width associated with the roundabout. The approach width is typically no more than half of the total width of the roadway.

Departure width

The *departure width* is the width of the roadway used by departing traffic downstream of any chances in width associated with the roundabout. The departure width is typically less than or equal to half of the total width of the roadway.

Entry width

The *entry width* defines the width of the entry where it meets the inscribed circle. It is measured perpendicularly from the right edge of the entry to the intersection point of the left edge line and the inscribed circle.

Exit width

The *exit width* defines the width of the exit where it meets the inscribed circle. It is measured perpendicularly from the right edge of the exit to the intersection point of the left edge line and the inscribed circle.

Entry radius

The *entry radius* is the minimum radius of curvature of the outside curb at the entry.

Exit radius

The *exit radius* is the minimum radius of curvature of the outside curb at the exit.

A modern roundabout has yield control on all entries. Vehicles in the circle - on the one-way circulating roadway - have the right of way. It is no different than a driver entering a through one-way roadway with traffic traveling left to right from a street with a yield sign at the intersection. The driver looks to the left and enters the roadway immediately if there is a sufficient gap; or if there is not a sufficient gap yields until there is one. The only difference in entering a

modern roundabout compared to a one-way roadway is that the one-way roadway being entered is curved.

Summary

In summary, compared to other forms of intersection traffic control, modern roundabouts - different than older traffic circles or rotaries built prior to 1990 - are safer, require less delay or stopping and have lower life cycle costs. The costs associated with constructing and operating a modern roundabout are considerably less than the costs of a traffic signal. In short, use of modern roundabouts for intersection traffic control can save lives and money while cutting air pollution, and motorists' frustration by reducing stopping, de.

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