TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA/TX-94/1273-2F	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle TEXAS HIGHWAY-RAIL INTERSECTION FIELD REFERENCE GUIDE		5. Report Date November 1993 Revised: May 1994 6. Performing Organization Code
7. Author (s) Richard T. Bartoskewitz, Daniel B. Fambro, and Hoy A. Richards		8. Performing Organization Report No. Research Report 1273-2F
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135		10. Work Unit No. (TRAIS) 11. Contract or Grant No. Study No. 0-1273
12. Sponsoring Agency Name and Address Texas Department of Transportation Office of Research and Technology Transfer P.O. Box 5080 Austin, Texas 78763-5080		13. Type of Report and Period Covered Final: September 1991-November 1993 14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. Research Study Title: Methods to Enhance Safety of Passive Warning Devices at Railroad-Highway Grade Crossings.

16. Abstract

The design, construction, operation, and maintenance of highway-rail intersections present unique challenges to both highway and railroad engineers. The railroad grade crossing represents the physical intersection of two distinctly different modes of transportation, each of which varies considerably in terms of their equipment, travelled ways, and methods of control and operation.

Safety at highway-rail intersections has been a national priority for over two decades. Substantial reductions in crashes, injuries, and fatalities have been realized as a result of grade crossing improvement programs. Grade crossing safety has reached a point where further safety improvements will likely require the development of new approaches and innovative technologies. Proper design and construction of new grade crossings ensures safe and efficient operation. Proper maintenance of existing crossings helps to achieve continued safety and efficiency.

The field guide has been developed to assist agencies responsible for the design, construction, operation, and maintenance of highway-rail intersections in the performance of these responsibilities. It is a reference source for city, county, and state personnel that must address these issues as part of their official duties. Railroad personnel will find the reference guide helpful in obtaining a basic understanding of highway and traffic engineering concerns with regard to highway-rail intersections. The guide includes information on problem identification and engineering studies, improvement alternatives, special programs and activities, and key reference documents.

17. Key Words	18. Distribution Statement
Railroad Grade Crossing, Highway Safety, Highway Design, Traffic Control Devices, Maintenance and Construction, Work Zone.	No Restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	164	

Form DOT F 1700.7 (8-72)

TEXAS HIGHWAY-RAIL INTERSECTION FIELD REFERENCE GUIDE

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Research Report 1273-2F
Research Study Number 0-1273
Study Title: Methods to Enhance Safety of
Passive Warning Devices at Railroad-Highway Grade Crossings

Sponsored by the
Texas Department of Transportation
In Cooperation with
U.S. Department of Transportation
Federal Highway Administration

November 1993
Revised: May 1994

TEXAS TRANSPORTATION INSTITUTE
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IMPLEMENTATION STATEMENT

The objective of this study is to develop enhanced passive warning systems for use at railroad-highway grade crossings in Texas. In addition to new or enhanced passive signing, these safety improvements would include resources to assist engineering staff and field personnel in the design, construction, operation, and maintenance of railroad-highway grade crossings.

This document assimilates practices and procedures for addressing issues of railroad-highway grade crossing safety. It presents criteria for the selection of engineering study methodologies appropriate for specific safety concerns, and includes procedures for diagnostic studies and sight distance evaluations. Safety improvement alternatives, including grade crossing removal, the use of active and passive traffic control devices, and improvements to the physical environment of the highway-railroad grade crossing, are described. The guide includes guidelines for performing construction and maintenance activities at or near grade crossings. Finally, this document serves as a reference source of information on several programs intended to improve safety at highway-railroad grade crossings.

The information contained within the Field Reference Guide will be of immediate interest to all personnel who work with highway-railroad grade crossings on a daily basis.

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation, and is not intended for construction, bidding, or permit purposes. The engineer in charge of the research project was Dr. Daniel B. Fambro, P.E. No. 47535 (Texas).

ACKNOWLEDGMENT

This field reference guide was developed as part of a study entitled "Methods to Enhance Safety of Passive Warning Devices at Railroad-Highway Grade Crossings" by the Texas Transportation Institute and sponsored by the Texas Department of Transportation in cooperation with the United States Department of Transportation, Federal Highway Administration. Dr. Daniel B. Fambro, P.E. No. 47535 (Texas) of the Texas Transportation Institute served as the research supervisor, and Mr. Ken Willis (retired) and Mr. Darin Kosmak of the Texas Department of Transportation served as technical coordinators.

The authors acknowledge Mr. Luis Ybanez and Mr. Wesley Pair of the Texas Department of Transportation, who provided advice and comments regarding the study. The authors also acknowledge Mr. Byron Blaschke and Mr. Frank Holzmann of the Texas Department of Transportation for their support of this research.

Several members of the Texas Transportation Institute staff provided valuable assistance in preparing the manuscript. Mr. Srinivas Sangineni, Mr. Casey Sledge, and Mr. Kelly Parma aided the preparation of figures and tables for the report. Ms. Kelly Klaver and Ms. Jennifer Schueler are acknowledged for their review and comments.

Finally, special thanks are extended to Mr. Ray Stoker, Jr., former chair of the Texas Transportation Commission. Mr. Stoker is an ardent supporter of highway-rail safety in the State of Texas, and his dedication to this cause was the driving force behind the research.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Highway-railroad grade crossings are the physical intersection of two distinct transportation modes, which differ in terms of their traveled ways and their operating characteristics. Grade crossings present special challenges to those agencies and individuals that are charged with their design, construction, operation, and maintenance.

Despite significant improvements in safety at highway-rail intersections over recent years, grade crossing safety remains a constant challenge to state and local transportation authorities and to the railroad companies. New residential, commercial, and industrial developments necessitate new points of access across existing railroad lines. Furthermore, the anticipated introduction of high-speed train service within new or existing railroad corridors emphasizes the importance of effective procedures and safety practices.

An understanding of the two basic components of the highway-rail intersection, the highway and the railroad, is essential. The needs of all highway users, including drivers, pedestrians, bicyclists, and motorcyclists, must be addressed. Design and construction of the roadway and the grade crossing environment impact the safety and efficiency of traffic operations at the highway-rail intersection. The performance characteristics of highway vehicles are important considerations as well.

No grade crossing safety initiative can achieve its maximum safety potential if decisions are not based upon good, sound data. Engineering studies provide the data essential to the identification of safety and operational deficiencies, and to the evaluation and selection of improvement alternatives. Diagnostic evaluations and sight distance studies are but two of the techniques that have been identified; others may be appropriate to address specific types of problems.

The engineer is presented a wide range of improvement alternatives from which to choose. These range from removal or elimination of the grade crossing altogether to simple modifications or site improvements designed to improve the ability of drivers to negotiate the crossing safely. Installation of passive or active traffic control is frequently considered.

Improved highway-rail safety is best achieved by a team effort. Cooperation between local, state, and federal authorities improves the so-called "Three Es" of highway-rail safety: engineering, enforcement, and education. The Texas Department of Transportation, Texas Department of Public Safety, Railroad Commission of Texas, Federal Railroad Administration, Federal Highway Administration, and Operation Lifesaver offer resources to save lives at railroad-highway grade crossings statewide.

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1.0 INTRODUCTION

1.1 BACKGROUND

Highway-rail intersections present special challenges to both highway and railroad engineers. The 1986 *Railroad-Highway Grade Crossing Handbook* describes the unique nature of the problem by stating, "The railroad-highway grade crossing...constitutes the intersection of two transportation modes, which differ both in the physical characteristics of their traveled ways and in their operations" (1).

Safety issues associated with highway-rail intersections have been a national priority for over twenty years. Since the passage of the Highway Safety Act and the Federal Railroad Safety Act in 1970, federal expenditures for safety improvements at highway-railroad intersections have approached $2.3 billion. Over 25,000 improvement projects have been funded nationwide, and the Federal Highway Administration estimates that 6,400 lives have been saved as a result.

Considering these numbers, and the fact that accidents at highway-rail intersections constitute a small percentage of the total accidents which occur on the nation's public highways annually, it may seem that the problem has been solved. Yet in 1992, the Federal Railroad Administration reports 579 fatalities and 1,975 injuries occurred in collisions between highway vehicles and rail equipment (2). Texas leads the nation in crashes at highway-rail intersections. There were 59 fatalities and 196 injuries in 486 crashes at public and private highway-rail intersections in Texas in 1992. In these 486 crashes, Operation Lifesaver observed the following trends:

- 66 percent occurred in clear weather;
- 61 percent involved train speeds less than 29 mph;
- 60 percent involved automobiles;
- 54 percent occurred during daylight hours;
- 52 percent occurred at intersections with active warning signals;
- 52 percent occurred when the driver's view was unobstructed; and
- 25 percent involved vehicles running into trains.

Texas also leads the nation in the number of highway-rail intersections, with over 12,600. In addition, there are nearly 7,000 private highway-rail intersections in the state.

Further reductions in the number of accidents, injuries, and fatalities will likely require the development of new approaches and innovative technologies. Maintaining the current level of safety will require continued dedication of resources. This commitment will ensure that new grade crossings are properly constructed from the standpoint of safety and efficient operation, and that maintenance of existing grade crossings is adequate as well.

1.2 PURPOSE

The field reference guide has been developed to assist agencies responsible for the design, construction, operation, and maintenance of highway-rail intersections in the performance of these responsibilities. The purpose of the guide is to serve as a reference source for city, county, and state personnel that must deal with grade crossing safety issues as part of their official duties. Although all involved in grade crossing safety activities will find the information contained herein useful, the guide is directed toward field personnel who are involved in these activities on a day-to-day basis.

1.3 SCOPE

The field reference guide addresses issues critical to the safe and efficient operation of the highway-rail intersection. The following topics are emphasized:

- Definition and description of the highway-rail intersection,
- Problem identification and engineering studies,
- Safety improvement options,
- Special highway-rail programs, and
- Coordination contacts.

1.4 DEVELOPMENT OF THE FIELD REFERENCE GUIDE

Several publications and documents provided source material for the field reference guide. The following publications were used extensively in the development of this guide:

- 1980 *Texas Manual on Uniform Traffic Control Devices* (with revisions) (3)
- *Railroad-Highway Grade Crossing Handbook*, Second edition (1)
- FHWA's *Traffic Control Devices Handbook* (4)
- AASHTO's *A Policy on Geometric Design of Highways and Streets*, 1990 (5).

These references, and other publications cited in Section 7.0, contain valuable information on the planning, design, operation, and maintenance of highway-rail intersections. They are an excellent source of additional information for those involved in highway-rail safety.

2.0 THE HIGHWAY-RAIL INTERSECTION

2.1 DEFINITION OF THE HIGHWAY-RAIL INTERSECTION

A highway-railroad at-grade crossing is the physical intersection of a roadway, street or highway with one or more railroad tracks. An at-grade crossing differs from a highway-railroad grade-separated crossing in that highway users and railroad equipment share space at the crossing. In the case of a grade separation, an underpass or overpass separates the highway and railroad track.

From an engineering perspective, the highway-railroad at-grade crossing may be considered as a special type of highway intersection. The three principal elements in the design of any highway intersection are present at the grade crossing: the driver, the vehicle, and the physical intersection. These elements must be considered in the performance of any design, construction, modification, or maintenance activities which affect the highway-railroad grade crossing and its surroundings.

For consistency, the field reference guide adopts the term *highway* in referring to all public roadways, including county roads, city streets, and highways. The term *highway-rail intersection* is adopted in recognition of the fact that grade crossings are a special case of a highway intersection.

2.2 COMPONENTS OF THE HIGHWAY-RAIL INTERSECTION

The Highway Component

The Highway Component of a highway-rail intersection consists of six factors:

- Drivers,
- Traffic control devices,
- Vehicles,
- Roadway,
- Pedestrians, and
- Bicyclists and motorcyclists.

Driver. The driver is responsible for obeying all traffic control devices, traffic regulations, and rules of the road. Legally, responsibility for avoiding a collision with a train is assigned to the driver. An awareness of the driver's capabilities, limitations, needs, and obligations is essential to the proper design, construction, and maintenance of crossing installations and improvements. With such information, the engineer can assist drivers in fulfilling their obligations in the interest of safety.

The Uniform Vehicle Code (UVC) describes actions required of the driver (6). Three situations encountered at highway-rail intersections are addressed: approach speed, passing, and stopping. The requirements of Section 11-701 of the UVC, entitled "Obedience to Signal Indicating Approach of Train," are as follows:

(a) Whenever any person driving a vehicle approaches a railroad grade crossing under any of the circumstances stated in this section, the driver of such vehicle shall stop within 50 feet but not less than 15 feet from the nearest rail of such railroad, and shall not proceed until he can do so safely. The foregoing requirements shall apply when:

(1) A clearly visible electric or mechanical signal device gives warning of the immediate approach of a railroad train;

(2) A crossing gate is lowered or when a human flagman gives or continues to give a signal of the approach or passage of a railroad train;

(3) A railroad train approaching within approximately 1,500 feet of the highway crossing emits a signal audible from such distance and such railroad train, by reason of its speed or nearness to such crossing, is an immediate hazard;

(4) An approaching railroad train is plainly visible and is in hazardous proximity to such crossing.

(b) No person shall drive any vehicle through, around or under any crossing gate or barrier at a railroad crossing while such gate or barrier is closed or is being opened or closed.

The Texas Motor Vehicle Commission Code states these legal requirements (7). To summarize, the Code mandates that the driver yield right-of-way to any train occupying or about to occupy the crossing.

Drivers generally have two critical information requirements when they approach a highway-rail intersection. First, inform them that they are approaching a crossing. Next, they must be alerted to the fact that a train is occupying, or is about to occupy, the crossing. These two basic needs can be fulfilled through proper engineering of the highway approach and its immediate surroundings, and by appropriate application of traffic control devices.

Three information handling zones exist at highway-rail intersections: approach zone, non-recovery zone, and hazard zone. Specific points on the highway at which the driver, assuming ideal conditions, executes certain decisions define these zones.

Approach zone. The first zone which the driver encounters is the approach zone. Here, the driver begins to formulate a course of action to avoid a collision. The driver should begin to search for trains, recognize and identify potential hazards, and decide upon a safe course of action. The driver must become aware that a crossing is ahead. An assumption is made that the driver has no prior experience with the crossing, and therefore has no specific knowledge of its location or layout. An advance warning sign located at a sufficient distance from the crossing most often provides this information. This allows the driver ample time to slow down or execute other avoidance maneuvers deemed necessary. The approach zone begins at a distance from the crossing equivalent to the decision sight distance, which is a function of either the posted speed limit or the approach speed.

Non-recovery zone. The non-recovery zone immediately follows the approach zone, and begins at a distance from the crossing equivalent to the stopping sight distance. The posted speed or approach speed determines stopping sight distance, with consideration also given to the prevailing highway pavement conditions. At the onset of the non-recovery zone, the driver must make a decision to stop if a train is occupying or is about to occupy the crossing. If the decision to stop or to go is delayed beyond this point, the driver may be unable to bring the vehicle to a stop within the distance available, which increases the potential for a collision.

Hazard zone. The last information handling zone at the highway-rail intersection is the hazard zone, which is the portion of the highway where a collision between a moving or stopped motor vehicle and a moving or stopped train can occur. The driver's task when driving through the hazard zone is to safely negotiate the crossing. If the driver must stop the vehicle because a train is approaching or occupying the crossing, it is desirable to stop the vehicle short of the hazard zone. A distance of 15 feet in either direction from the nearest and farthest rail along the highway centerline defines this last information zone.

Traffic control devices. Traffic control devices satisfy drivers' information needs at highway-rail intersections. These traffic control devices are either warning devices or regulatory devices. The function of a warning device, as defined by the *1980 Texas Manual on Uniform Traffic Control Devices for Streets and Highways* (TMUTCD), is "to warn traffic of existing or potentially hazardous conditions on or adjacent to a highway or street" (3). Such devices inform drivers to exercise caution in negotiating a given section of roadway, and alert them that a speed reduction, steering maneuver, stop, or other action may be necessary to avoid the potentially hazardous condition. The most common warning sign employed at highway-rail intersections is the circular W10-1 Railroad Advance Warning Sign. The 1980 TMUTCD states that "regulatory signs inform highway users of traffic laws or regulations and indicate the applicability of legal requirements that would not otherwise be apparent" (3). Crossbuck signs and flashing light signals are common regulatory devices used at highway-rail intersections.

Passive devices. Passive devices serve two basic functions. First, they inform the motorist of the location of the crossing. Second, passive devices require that the driver operate the vehicle in a manner that allows it to be stopped safely if a train is approaching or occupying the crossing. The driver assumes the burden of responsibility to determine whether or not it is safe to cross.

When the driver encounters a passive control device, a number of actions may be considered "appropriate" responses, depending upon the roadway, traffic, and environmental conditions present. As a minimum, the driver should look and listen for trains and be prepared to slow or stop the vehicle. Where sight obstructions, weather, other traffic, etc. limit the visibility of the crossing and the tracks, the most appropriate response is to reduce vehicle speed to provide more time to search for a train. If a train is present at or near the crossing, the only acceptable driver response is for the driver to yield the right-of-way to the train.

Active devices. Active devices assist the driver in making the decision to stop clear of the crossing or to proceed through the crossing without stopping. As with passive devices, the function of an active device is two-fold. First, it locates the crossing. In addition, active devices inform the driver of the presence or absence of a train.

Active control devices demand less of the driver than do passive devices. Active devices provide more specific information to the driver about the presence of a train. A passive device informs the driver of the potential presence of a train. It then becomes the driver's responsibility to determine whether or not a train is present. On the other hand, active devices, by design, convey either "yes, a train is approaching or occupying the crossing" or the message "no, a train is not approaching or occupying the crossing." If the device is not activated, the driver is allowed to proceed with caution but without stopping. If the device is activated, the driver must stop the vehicle safely and ascertain whether or not it is safe to continue. If it is deemed safe to continue, the driver may do so. Otherwise, the crossing must not be entered until the train has passed and it is safe to proceed.

Vehicle. The vehicle is an integral part of the highway system. There are two issues to consider with regard to the vehicle: design and performance characteristics, and cargo.

On today's highways, a wide array of vehicles can be found, ranging from bicycles and motorcycles to automobiles and tractor-trailer trucks. Each type has different capabilities and limitations that impact safety and operations at highway-rail intersections. The important aspects to consider include: vehicle dimensions of length and width, braking performance, acceleration performance, and concerns associated with certain special vehicle classes.

Vehicle length. Vehicle length is a consideration in the determination of minimum quadrant sight distance requirements for the highway approach to the grade crossing. Vehicle length determines, to some extent, the amount of time a vehicle is exposed or at risk as it negotiates the crossing. For example, a tractor-trailer truck occupies the crossing longer than a passenger car does due to its considerably greater length. Given a design vehicle length and the available sight distance for a specified crossing, the safe approach speed can be calculated.

In the calculation of minimum required track sight distance from a stopped vehicle, vehicle length takes on even greater importance. A vehicle accelerating from a stop occupies the crossing for a greater length of time than does a vehicle that negotiates the crossing without stopping. A truck stopped at a crossing must perform three operations in order to safely clear the crossing: start-up when the clutch is being engaged, acceleration from the point of full clutch engagement, and continued travel until the crossing is cleared. The sight distance calculations presented in the AASHTO Green Book for a stopped vehicle assume vehicle acceleration in first gear of 1.47 ft/sec^2. Furthermore, exposure to the risk of a collision with a train is directly proportional to the vehicle length. These two factors necessitate track sight distances adequate to clear a stopped vehicle prior to the arrival of a train that is just out of the driver's view as the driver begins to cross the tracks. Therefore, design vehicle lengths should be carefully chosen with proper consideration given to the types of vehicles likely to use a given crossing. More specifically, the longest vehicle length that is anticipated should be considered.

Design lengths for various classes of vehicles are specified by the American Association of State Highway and Transportation Officials (AASHTO) in *A Policy on Geometric Design of Highways and Streets*, also commonly referred to as the "Green Book" (5). The Green Book assumes a vehicle length of 65 feet (WB-60) in calculating sight distance requirements for at-grade highway-rail intersections. For design purposes, it is usual practice to provide a "worst case" design. Such a design specifies values for design variables that typify the conditions most conducive to a collision. The advantage of such designs is that they afford an extra margin of safety under most operating conditions. With this in mind, the design vehicle length selected for design purposes should at a minimum equal, and desirably exceed, 55 feet (WB-50). This length is substantially longer than that typical of passenger cars and many other classes of vehicles, thereby providing them with an additional factor of safety.

Vehicle width. Vehicle width may be a consideration in the selection of the width of lanes and total pavement width at a highway-rail intersection. Typical vehicle widths, as specified by AASHTO, range from 7 feet for passenger cars to 8.5 feet for buses and combination trucks.

The proper design of crossings considers underclearance and wheelbase. Many accidents have resulted from long trucks with low clearances becoming stuck or "high-centered" on the crossing. The grades of the crossing and its approaches should be adequate to avoid this problem. The AASHTO Green Book specifies wheelbase measurements for the various design vehicle types; however, it does not specify the underclearance dimension.

Braking performance. Braking performance is especially important at crossings that experience high truck volumes. Trucks typically require greater distance to brake to a stop from a given speed than do smaller highway vehicles due to their greater size and weight. Thus, available sight distances dictate slower operating speeds to compensate for truck braking in these situations.

Acceleration performance. The ability of a vehicle, especially a heavy vehicle, to accelerate through the highway-rail intersection from a moving or a stopped condition should be considered. The driver of a vehicle approaching an unsignalized (passive) crossing scans the tracks for approaching trains. If a train is approaching, the driver judges the train's speed and distance from the crossing relative to the speed and distance from the crossing of his or her own vehicle. The driver may decide that it is possible to accelerate to a higher speed in order to clear the crossing prior to the train's arrival.

Acceleration is important for vehicles which must stop before proceeding through the intersection. The mandatory stop requirement may be imposed by either a traffic control device, such as a stop sign, or by laws regulating specific types of motor vehicles, such as school buses and hazardous materials haulers. When proceeding from a stop, the vehicle operator must shift into first gear and accelerate through the crossing to clear the tracks. This process takes considerably more time than would be required for the vehicle to traverse the same crossing without stopping. While the vehicle is traversing the tracks, it is exposed to the potential of being struck by a train. The driver must look both ways down the tracks and determine if the clearance time is adequate. The critical design parameter for track sight distance, therefore, is the amount of time that the vehicle occupies the crossing, which in turn is in part a function of acceleration performance.

Special vehicles. Collisions at highway-rail intersections involving certain special vehicles pose risks of substantially greater fatalities and injuries than most other motor vehicle-train crashes. These special vehicles include: hazardous materials carriers, intercity passenger buses, transit buses, and school buses. Law requires many special vehicles to come to a complete stop before proceeding through the crossing.

The mandatory stop requirement poses two safety issues.

- *Sight distance.* Sight distance along the tracks in both directions (track sight distance) must be adequate to allow the vehicle to safely clear the crossing following the mandatory stop.

- *Driver inattention.* Crash experience indicates that these vehicles are frequently involved in rear-end type collisions at highway-rail intersections. These collisions do not typically involve railroad equipment. In most cases, inattention on the part of following drivers, who do not recognize and properly respond to the stopped vehicle, causes the accidents.

Roadway. Roadway characteristics relevant to the design and construction of safe highway-rail intersections include: location and type of road, traffic volume, roadway geometry, crossing surface condition, adjacent highway-highway intersections, and illumination.

Location and type of road. Several features distinguish urban and rural highway-rail intersections. Urban grade crossing locations typically experience higher traffic volumes than rural locations. Limited sight distance due to buildings and other permanent structures is a common problem in urbanized areas. Controlled intersections, driveways, business establishments, advertisements, signs, billboards, and parking are encountered in urban areas and may influence safety and traffic operation near and at the crossing.

Rural crossing locations present special challenges as well. Approach speeds are typically higher in rural areas than in urban settings. Sight distance restrictions may exist due to trees, brush, crops, or other vegetation. The highway agency is assigned responsibility for removal or control of trees and vegetation within highway rights-of-way. Likewise, the railroad company is responsible for clearing vegetation along railroad tracks which may restrict sight distance. Unfortunately, it is often very difficult, if not impossible, to take any action with regard to sight obstructions located on adjacent farms or other private property.

Traffic volume. The effect of traffic volume upon accident experience at highway-rail intersections has been demonstrated by several studies. In general, accident experience is likely to increase as the traffic volume at a given location increases, if all other factors remain constant. This tendency is referred to as accident exposure. Simply stated, as more and more drivers travel through a given crossing, there are more opportunities for an accident between a train and a motor vehicle to occur.

Roadway geometry. Geometric design features that may influence safety at highway-rail intersections include number of lanes of travel, pavement width, horizontal roadway alignment, vertical roadway alignment, angle of intersection, and crossing elevation.

- *Lane width.* Reduced lane widths at a crossing may contribute to increased train-involved and non-train involved accident experience. Rear-end collisions between highway vehicles are a particular problem due to mandatory stop requirements imposed upon certain classes of vehicles, such as school buses and hazardous materials haulers. Multi-lane highways allow vehicles that do not have to stop to safely maneuver around those for which a stop is a requirement. Lane width and number of lanes also affect the visibility of signs and signals used to warn motorists of the crossing and/or the presence of a train. Traffic control device selection and placement can help resolve this problem.

- *Roadway alignment.* Horizontal and vertical roadway alignment affect sight distance and approach speeds at highway-rail intersections. Approach grades can act to either raise or lower speeds in advance of the crossing. Downgrades of significant magnitude lengthen stopping distances, particularly for heavy vehicles. If the crossing is located just beyond the crest of a hill, this may impair visibility of the crossing. Likewise, curves or bends in the roadway can limit the driver's view of the crossing or of traffic control devices at the crossing.

- *Angle of intersection.* The angle of the intersection between the railroad track and the centerline of the highway is sometimes a factor in the safety of the highway-rail intersection. Drivers are expected to look both ways for trains as they approach a crossing. In the absence of significant sight obstructions, simple eye movement usually accomplishes the scan of the railroad track. Restricted sight distance requires overt action on the part of the driver to fulfill this driving task. Drivers must turn their head to look down the track.

  At a perpendicular crossing, one at which the angle of intersection is approximately 90 degrees, the necessary head movement is typically no more than a slight turning of the head from side to side; however, if the angle of intersection is rather small, 30 degrees for instance, drivers must turn and look back over their shoulders to see the tracks. The head movement for an acute angle crossing requires considerably more effort of the driver, and can impair the driver's ability to concentrate on other events or objects within the highway environment.

- *Crossing elevation.* Crossing elevation is a factor in many accidents at highway-rail intersections. A vehicle starting from a stopped position cannot accelerate quickly through the crossing. Although this problem is observed for virtually all classes of vehicles, it can be particularly troublesome for large or lengthy vehicles, especially school buses and large trucks that must comply with mandatory stop requirements. It is not uncommon for a long vehicle, such as a low-boy tractor-trailer combination, to become trapped or "hung" on a hump crossing due to the inadequate underclearance.

Crossing surface condition. A smooth crossing improves safety and efficient traffic operation at highway-rail intersections. Providing a smooth crossing is complicated by the fact that the highway is actually a flexible material supported by a rigid subgrade; whereas, the railroad track is a flexible "platform." Besides causing gradual damage to a vehicle's suspension and alignment, a rough crossing may distract the driver's attention from other important driving tasks (e.g., looking for trains). The driver may also be compelled to decrease the vehicle's speed to minimize discomfort. Reducing speed can create a potential for rear-end accidents and also limits highway capacity. A smooth crossing provides greater driver comfort, does not distract the driver from other driving tasks, and allows the driver to maintain an even speed profile through the crossing.

Adjacent highway-highway intersections. Highways and railroad tracks often parallel one another. Roadways which intersect the railroad track will also encounter a highway-highway intersection in close proximity to the railroad track. Parallel highways and railroad tracks present a number of safety issues which should be considered in the design of the crossing.

The presence of a highway intersection near the rail intersection places additional demands upon the driver's attention. The driver must be cognizant of potential conflicts due to other highway vehicles, as well as those presented by trains. It is likely that most drivers will attend primarily to the intersecting highway rather than the railroad track they are crossing. The most probable explanation is driver experience. Most drivers rarely encounter trains at highway-rail intersections; on the other hand, drivers frequently encounter opposing highway traffic at highway intersections. Therefore, their likely response is to perceive the highway intersection as presenting the greatest potential risk. The railroad intersection may not be perceived as presenting a high risk of an accident.

The actual separation distance between the railroad track and the highway intersection is important. This length of highway acts as a storage area for queued vehicles waiting to cross or turn onto the parallel roadway. If the parallel roadway experiences high traffic volumes, and the intersection is stop-controlled or signalized, substantial queues may develop which can extend back beyond the crossing. A queued vehicle which pulls onto the crossing and stops can become trapped by the other vehicles to its front and rear. Therefore, the critical separation distance can be expressed as a function of the expected maximum queue length at the highway intersection.

The separation distance between the railroad track and the parallel highway is also important when a long vehicle, such as a tractor-trailer combination or school bus, pulls through the crossing and then stops as it prepares to enter or cross the parallel highway. If the separation distance is not adequate, the rear of the vehicle may overhang the crossing, leaving the vehicle at risk of being struck by a train.

Illumination. Illumination can aid in reducing nighttime accident experience at highway-rail intersections. Many possible solutions have been investigated to improve nighttime visibility of trains, including railcar reflectorization; however, overhead illumination of the crossing appears to be the desirable solution to the problem, particularly in rural areas and at passive crossings. The feasibility of this alternative depends upon the availability and reliability of commercial power sources.

Pedestrians. In most instances, a pedestrian within the railroad right-of-way is, technically, a trespasser. Railroad tracks and the immediately surrounding property are private property and are not open to the traveling public. Nevertheless, there are instances where railroad intersections must accommodate pedestrian movements. These situations may occur at a highway-rail intersection, or at a pedestrian crossing where a sidewalk intersects the tracks.

The safety of pedestrians crossing railroads is the most difficult to control because of the relative ease with which pedestrians can go under or around lowered gates. Pedestrians typically seek the shortest path and, therefore, may not always cross the tracks at the highway or designated pedestrian crossing. Several countermeasures are listed for enhancing pedestrian safety at railroad crossings. These strategies include:

- Enclosing the railroad by fencing or other means,
- Providing a grade-separated pedestrian walkway,
- Employing signs to warn or direct pedestrians,
- Educating the public about pedestrian safety around railroad tracks, and
- Increasing surveillance and enforcement to reduce trespassing.

Bicyclists / Motorcyclists. Although motorcycles and bicycles typically travel at different speeds, these vehicles can experience similar problems at crossings. Depending on the angle and type of crossing, a cyclist may lose control of the vehicle if the wheel becomes trapped in the flangeway. The surface materials and the flangeway width and depth must be evaluated. The more the crossing deviates from the ideal 90 degree crossing angle, the greater the potential for a cycle wheel to be trapped in the flangeway. If the crossing angle is less than 45 degrees, consideration should be given to widening the bikeway to allow sufficient width to cross the tracks at a safer angle. Other than smooth surface treatments, there are no special controls for these vehicles; however, if a bicycle trail crosses tracks at-grade, suitable markings and signs should warn the bicyclist of this condition.

The Railroad Component.

The Railroad Component of a highway-rail intersection consists of the train and the track.

The Train. For the purposes of highway-rail intersection safety, any rail operation over a highway is of concern. The design of traffic control systems at highway-rail intersections must allow for wide variations in train length, train speed, and train occurrence.

Long trains (e.g., unit coal or grain trains) directly affect the operation of highway traffic and indirectly affect safety. Because of their length, unit trains take longer to pass over a crossing and, in effect, close the crossing to highway traffic for a longer period of time. Some communities have passed ordinances restricting train speed to improve safety. This practice directly reduces the level of service for highway traffic. Because of the longer period of time during which the crossing is closed to highway traffic, a motorist may take risks by trying to beat the train through the crossing, often resulting in collisions.

Trains other than unit trains often consist of a variety of cars and freight. Trains often must stop to pick up or set out cars. Unfortunately, some of these pick-up and set-out points are located in the central portion of communities. This situation results in trains making the switching movement while moving slowly over the crossing, or even standing on the crossing. A freight train stopped on all of its crossings can physically separate an entire community. Railroads have operating procedures designed to prevent extensive blockage of crossings and many communities have passed regulations prohibiting the blockage of crossings for certain lengths of time.

Locomotives are equipped with various safety devices. Virtually all are equipped with headlights and air-powered horns. Many are also equipped with beacons, strobe lights, ditch lights, or sequentially flashing lights. Air-powered horns are used to sound a warning of a train's approach. The locomotive engineer sounds the horn in advance of a crossing in a sequence of two long blasts, followed by a short blast, then followed by one long blast. A whistle post located at trackside indicates the point of initiation for the whistle. Some local agencies have passed ordinances prohibiting the sounding of the whistle in certain areas. Whistle-ban ordinances are not generally recommended because the train whistle provides warning to a motorist or pedestrian that a train is approaching. Even at crossings with active traffic control systems, the whistle provides a redundant indication.

Illumination of railroad freight equipment is not typical. The installation of reflectorized markers has been and is currently being studied; however, the rapid accumulation of dirt necessitates frequent cleaning of the reflectors and represents more than half of the total cost of reflectorization. Degradation of reflective intensity results in the reflector providing little to no improvement in visibility of freight cars at crossings.

Primarily because of their enormous weight, trains are slow to accelerate and decelerate. A train's acceleration capability is a function of the number of locomotives, the horsepower rating of each locomotive, the number and weight of the cars, and the presence of grades. Braking distances are dependent upon number and horsepower rating(s) of the locomotives, the number and weight of the cars, the adhesion of wheels on rails, train speed, and grade. The braking distance of a train is difficult to state exactly; however, in most cases a train traveling at 50 miles per hour will require up to a mile or more to reach a complete stop.

The Track. Railroad track in the United States is classified into six categories based upon maximum permissible operating speed. The Federal Railroad Administration's track safety standards set maximum train speeds for each class of track as indicated in Table 2-1.

Table 2-1. Maximum Train Speeds as a Function of Track Class

Track Class	Maximum Passenger Speeds (mph)	Maximum Freight Speeds (mph)
6	110	110
5	90	80
4	80	60
3	60	40
2	30	25
1	15	10
Excepted	None Allowed	10

Source: Reference (4)

Railroad track gauge has been standardized in the United States since the late-1800s. The standard track gauge is 4 feet 8.5 inches. The number and width of tracks are important considerations in determining sight distance requirements for highway-rail intersections.

As with highways, railroad track is classified into several categories depending upon function in terms of rail traffic flow. Main tracks handle through train movements between and through stations and terminals. Branch line trackage typically carries freight from its origin to the main line. Passing tracks, or sidings, are used for meeting and passing trains. Side tracks and industrial tracks are used for the loading, unloading, and storage of railcars.

For the purposes of highway-rail safety programs, "main" tracks are considered to be those that carry through train movements, as opposed to switching or terminal movements. Thus, branch lines are considered to have a main track. Accident statistics indicate that a majority of highway-rail intersection collisions occur at main track crossings. This observation can be attributed to the fact that there are more main track intersections with highways than there are side track (or switching track) intersections. Also, main tracks typically experience higher train volumes.

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3.0 ENGINEERING STUDIES

3.1 INTRODUCTION

Engineering studies should be conducted regularly of all highway-rail intersections within the state as part of a deliberate program. An engineering study consists of a review of site characteristics, the existing traffic control system, and highway and railroad operational characteristics. Based on a review of these conditions, an assessment of existing and potential hazards can be made. If the review identifies safety deficiencies, countermeasures can be recommended. The purpose of these studies is to review the crossing and its environment, identify the nature of any problems, and recommend alternative improvements.

A common practice in many states is to conduct engineering studies of highway-rail intersections identified as candidates for improvement by the priority schedule. This practice is an effective technique for identifying problems and recommending specific improvements at crossings which present the greatest hazard relative to all crossings considered. Unfortunately, this process fails to address safety at the remaining crossings, those that are not ranked highly by the prioritization process.

Adoption of a program of highway-rail intersection inspection is recommended. Engineering studies involving site visits, field surveys, or any of the techniques described within this section can be useful tools in recognizing unusual conditions that may degrade safety. These procedures can also be applied to develop interim improvement measures, which are intended to improve safety until such time as more extensive improvements (e.g., installation of active traffic control devices or grade separation) are justified by the priority schedule. It is recognized that such efforts are constrained by the availability of funding and by labor requirements. A possible inspection program may involve engineering studies conducted of all highway-rail intersections within the state by a one- or two-person crew on a three- to five-year interval.

3.2 DIAGNOSTIC EVALUATION

A particular type of engineering study which has been adopted by the Federal Highway Administration in its *Highway Safety Engineering Studies Procedural Guide* (8) and by many states is the diagnostic evaluation procedure. This term describes a simple survey procedure, utilizing experienced individuals from various agencies and disciplines. The procedure involves the diagnostic team's evaluation of the crossing as to its deficiencies, and judgmental consensus as to the recommended improvements.

Study Team Selection and Composition

The primary factors to be considered in the assignment of people to the diagnostic team are that the team is interdisciplinary in nature and that it is representative of all groups having responsibility for the safe operation of grade crossings.

In order that each of the factors relating to the operational and physical characteristics of the crossing may be properly identified, individual team members should be selected on the basis of their specific expertise and experience. The overall structure of the team should be built upon three complimentary attributes: local responsibility, administrative responsibility, and advisory ability. The diagnostic team should have experience in the following areas:

- *Traffic operations.* Includes both highway and railroad traffic operations; knowledge of highway safety, vehicular and train volume, peak period characteristics, operating speeds, types of vehicles, and train class and length.

- *Signals.* Includes both highway and railroad signals; knowledge of grade crossing active traffic control signal systems, interconnection with adjacent signalized highway intersections, traffic control devices for vehicle operations, traffic control devices for highway-rail intersections, and highway signs and pavement markings.

- *Administration.* It is important to recognize that many of the problems relating to grade crossing safety involve the apportionment of administrative and financial responsibility. This importance should be reflected in the membership of the diagnostic team. Members of the team representing the administration area should be carefully selected from policy making echelons of both highway department and railroad company management. The primary responsibility of these representatives is to advise the team of specific policy and administrative rules applicable to any decision to modify or upgrade grade crossing traffic control devices.

To ensure appropriate representation on the diagnostic team, it is suggested that a team be composed of members chosen from the following:

- Traffic engineer with safety experience (desirable on all teams),
- Railroad signal engineer (desirable when active devices are involved),
- Railroad administrative official,
- Highway or street administrative official,
- Human factors engineer,
- Law enforcement officer, and
- Regulatory agency official (where applicable).

Data Requirements

The collection of physical data to support and supplement the diagnostic study of highway-rail intersections may be classified into two categories: operational characteristics and site characteristics. Operational characteristics include: train and vehicle speed; volume; type and distribution, including passenger trains and buses; accident records; signalization and signing; and adjacent roadway and railroad vehicle and train operations. Site characteristics include: road and track geometries; location of buildings, trees, and other structures near the crossing; location of adjacent streets, roadways, and railroads; topography of the immediate area; and population density.

Diagnostic Evaluation Procedures

The diagnostic team should study each crossing with a group review of all available data and a group inspection of the crossing and its surrounding area. The objective is to determine the conditions at the grade crossing which affect safety and traffic operations. Appendix A presents a sample diagnostic evaluation, including the study procedure and questions to be answered by each member of the diagnostic team.

Implementation of Study Results

When the diagnostic study of a crossing has been completed, the results and recommendations should be documented. Implementation of these recommendations should follow as soon as possible. The implementing step of the improvement process may require any of the following:

- *Site improvements.* Removal of obstructions in the sight triangle, highway realignment, improved cross section, drainage, or illumination of the crossing.
- *Crossing surfaces.* Rehabilitation of the highway structure, the track structure, or both; or installation of drainage and subgrade filter fabric.
- *Traffic control devices.* Installation of passive or active control devices, or upgrading of the existing control system.

TxDOT Diagnostic Team Procedures

The composition of the diagnostic inspection team and the diagnostic inspection procedures observed by TxDOT differ somewhat from those described in the *Highway Safety Engineering Studies Procedural Guide*. This section briefly describes the diagnostic inspection procedure as it is applied in the state of Texas.

A minimum of three entities comprise a diagnostic inspection team for a public highway-rail intersection on the state highway system: a representative of the TxDOT Traffic Operations Division Railroad Section; a representative of the local TxDOT District Office; and a representative of the railroad company. For off-system locations, a fourth member representing the city or county authority responsible for maintaining the roadway approaches to the highway-rail intersection joins the team. If the roadway is used by school buses, a representative of the school district is included at both on- and off-system projects.

For a typical inspection, the diagnostic team assembles in the field at the project location. The continued need for the crossing and the potential for crossing closure and/or consolidation are the first options considered by the team. If the crossing is not a candidate for closure, then the diagnostic team discusses safety enhancements that may be appropriate:

- Active warning devices, in most cases train-activated flashing light signals, bells, and gates,
- Advance warning signs and pavement markings,
- Active advance warning flashers, especially if sight distance is a factor on the crossing approach,
- Interconnection or preemption with traffic signals,
- Other appropriate safety-enhancing features (i.e., recommend improvements to roadway approaches and/or crossing surface, trim trees and vegetation, etc.), and
- Necessary adjustments to existing drainage facilities and/or utilities.

The team determines which enhancements or combinations of enhancements comprise the best solution for the safety problems at the location. In accordance with MUTCD guidelines, the installation of stop signs on an interim basis until the signal devices are placed in service is recommended.

The diagnostic team prepares the initial project plan sheets when it reaches a consensus on what type of safety enhancements should be implemented. The project plan sheets are rough sketches of the crossing and the immediate surrounding area. The plan sheets indicate placement locations and distances of signals, signal cabinets, signs, and other enhancements, including adjustments to existing drainage facilities and utilities. General note sheets are completed in the field also. These documents describe the type of track circuitry for train activation of the warning devices and address the treatment of any parallel roadways. Preliminary fill material quantities and drainage are also calculated in the field and shown on the general note sheets.

3.3 SIGHT DISTANCE STUDY

At many highway-rail intersections, it may be necessary to conduct a sight distance study to determine if the three types of sight distance (e.g., approach, quadrant, and track sight distance) are provided, and if they are not, what if anything can be done to alleviate the situation. Numerous methods of measuring sight distance are practiced. This section presents a simple, low-cost procedure for estimating sight distances on the approach to and at highway-rail intersections.

The pacing method is one simple method that is used for obtaining rough estimates of available sight distances at highway-rail intersections. The required data can be easily collected by a two- or three-person team, and no special equipment is required. Depending upon the complexity of the crossings and their distance from one another, a team of three data collectors can obtain measurements at up to four crossings in approximately one hour. Thus, this method is especially suited to situations where precise measurements are not crucial and a large number of sites must be investigated in a relatively short amount of time.

Sight Distance Study Procedure

A low-cost procedure for conducting sight distance studies is presented in Appendix B.

3.4 OTHER ENGINEERING STUDIES

A variety of possible safety deficiencies contribute to collisions involving trains and highway vehicles. In order to correct these deficiencies, it is essential that accurate and descriptive data be available as a basis for developing, evaluating and selecting, and implementing safety improvement options. In addition to the diagnostic study procedure described in Section 3.2, several other types of engineering studies may be appropriate when evaluating safety of highway-rail intersections:

- Highway lighting study,
- Roadway inventory study,
- Spot speed study,
- Traffic conflict study,
- Traffic control device study,
- Traffic volume study,
- Skid resistance study, and
- Weather-related study.

Descriptions of these techniques, including personnel and equipment requirements, and study procedures, are provided in the Federal Highway Administration's *Highway Safety Engineering Studies: Procedural Guide* (8).

Table 3-1 can be used to determine the type of study appropriate for various potential accident causes. It should be recognized that it may be appropriate to consider causes and/or study methods other than those listed here.

3.5 SPECIAL STUDIES

Certain highways and railroad lines are used by vehicles or trains which either exhibit special operating requirements, haul hazardous or dangerous cargoes, or carry large numbers of passengers. These highway and rail routes warrant special consideration, as collisions involving special vehicles pose the threat of substantial loss of life, property damage, and environmental harm. Tables 3-2 and 3-3 list these special vehicle concerns and their respective data requirements.

Table 3-1. Possible Accident Causes, Data Requirements, and Engineering Study Procedures

Possible Accident Causes	Data Requirements	Engineering Study Procedures
Restricted sight distance	Roadway inventory Speed characteristics Sight distance characteristics Railroad data	Roadway Inventory Study Weather-related Study Highway Lighting Study
Poor visibility	Roadway inventory Fog data Lighting data	Roadway Inventory Study Weather-related Study Highway Lighting Study
Excessive approach speeds	Speed characteristics	Spot Speed Study
Improper traffic signal preemption timing	Roadway inventory	Roadway Inventory Study Volume Study Diagnostic Evaluation
Inadequate pavement markings	Roadway inventory	Roadway Inventory Study Diagnostic Evaluation Traffic Control Device Study
Slippery surface	Skid resistance characteristics Conflicts related to slippery surfaces	Skid Resistance Study Weather-related Study
Improper preemption timing of railroad signals or gates	Speed data Sight distance characteristics Roadway inventory Railroad data	Spot Speed Study Sight Distance Study Roadway Inventory Study Diagnostic Evaluation
Rough crossing surface	Roadway inventory Traffic conflicts	Roadway Inventory Study Traffic Conflict Study
Sharp crossing angle	Roadway inventory Speed data Sight distance characteristics Railroad data	Roadway Inventory Study Spot Speed Study Sight Distance Study Diagnostic Evaluation

Source: Reference (8)

Table 3-2. Special Highway Operations and Related Data Requirements

Special Highway Operation	Data Requirements
Tractor-trailer Combination • "Low-boy truck" • Long wheelbase • Low trailer clearance	truck volume approach sight distance quadrant sight distance track sight distance number of tracks maximum train speed number of highway lanes highway speed limit / approach speed highway approach grade / "hump" crossing proximity to adjacent intersection
Hazardous Materials Hauler • Tanker truck • Explosive/flammable cargo • Radioactive cargo	truck volume approach sight distance track sight distance number of tracks maximum train speed passenger train operation number of highway lanes highway speed limit / approach speed proximity to adjacent intersection
Buses • School bus • Private/commercial bus	bus volume approach sight distance track sight distance number of tracks maximum train speed number of highway lanes highway speed limit / approach speed proximity to adjacent intersection

Table 3-3. Special Rail Operations and Related Data Requirements

Special Rail Operation	Data Requirements
Passenger Service • AMTRAK routes • Commuter rail passenger service • Light rail transit service • Private passenger service • Tourist/special excursion services • High speed service	traffic volume highway approach speed approach sight distance quadrant sight distance track sight distance maximum train speed traffic control devices • advance warning signs/devices • passive warning signs/devices • train-activated warning devices
Hazardous Materials Shipments • Chemicals • Explosives • Nuclear waste	traffic volume highway approach speed approach sight distance quadrant sight distance track sight distance traffic control devices • advance warning signs/devices • passive warning signs/devices • train-activated warning devices

4.0 SAFETY IMPROVEMENT ALTERNATIVES

4.1 HIGHWAY-RAIL INTERSECTION ELIMINATION

The first alternative to investigate for improvement of a highway-rail intersection is removal or elimination. Closure or consolidation, highway relocation, railroad relocation, and grade separation are options for crossing elimination. Issues associated with abandoned or inactive grade crossings demand consideration.

Texas MUTCD Provisions

Any highway grade crossing for which there is not a demonstrated need should be closed. Where a railroad track has been abandoned or its use discontinued, all related traffic control devices shall be removed, and the tracks should be removed or covered.

General Considerations

Several factors may influence the decision to eliminate a highway-rail intersection, as summarized below.

- Each railroad company operating over a candidate crossing should indicate their intent for future utilization of that section of track. If track abandonment is anticipated, roadway closure or any crossing improvements should be held in abeyance pending resolution of the track abandonment proposal.

- A roadway closure should not exert a negative impact on the local transportation system. Alternative public crossings should be within a reasonable travel time and distance. The alternate crossings and connecting roadways should have sufficient capacity to accommodate the diverted traffic safely and efficiently.

- Avoid closing roadway crossings that serve as a direct route for vital traffic such as ambulances, fire trucks, or other emergency vehicles.

- Consider the economic impact to existing or planned businesses located nearby.

- Carefully evaluate the accident experience or hazard potential for the crossing under study. Items to review include: number and severity of accidents, type and number of trains, train speed range, and time periods that trains block the crossing.

Crossing Closure and Consolidation

Closure of highway-rail intersections is normally accomplished by closing the highway. Many of the characteristics of the community influence the number of crossings needed to carry highway traffic over a railroad. A study of highway traffic flow should be conducted to determine origin and destination points and needed highway capacity. Highway operation over several crossings may be consolidated to move over a nearby crossing with flashing lights and gates, or via a nearby grade separation. Alternative routes should be within reasonable travel time and distance from a closed crossing. The alternate routes should have sufficient capacity to accommodate the diverted traffic safely and efficiently.

Negative community attitudes, funding problems, or a lack of forceful state laws authorizing closure are common obstacles to crossing closure. Legislation that authorizes a state agency to close crossings facilitates the implementation of closures. Often, a state agency can accomplish closure where local efforts fail due to citizen biases and fear of losing access across the railroad. Local opposition may sometimes be overcome through emphasis on the benefits resulting from closure, such as improved traffic flow and safety as traffic is redirected to grade separations or crossings with active traffic control devices. Railroads often support closure, not only because of safety concerns, but also because closure eliminates maintenance costs associated with the crossings.

Crossing consolidation is an effective technique for using limited funds to improve safety at multiple railroad crossings. This method improves several crossings in a community or within a rail corridor while other crossings are permanently closed. In effect, traffic that formerly used two or more crossings is now combined or "consolidated" at the remaining crossings. Typically, the traffic control devices at remaining crossings are upgraded to include flashing light signals and gates. A study of traffic flow in the area should be conducted beforehand to assure continued access across the railroad. Installation of more sophisticated traffic control systems at the remaining crossings, and perhaps the construction of a grade separation at one of the remaining crossings, may improve traffic flow in some instances.

Access over the railroad by emergency vehicles, ambulances, fire trucks, and police must be considered in deciding whether or not to close a crossing. Crossings frequently utilized by emergency vehicles should not be closed. These crossings should be candidates for grade separation or the installation of active traffic control devices.

Criteria for identifying candidate crossings for closure must relate directly to existing operational and geometric characteristics. Specific criteria are difficult to establish. The number of vehicles using the crossing and the accessibility of alternate crossings are significant criteria in determining whether the elimination of a particular crossing is practical. Existing criteria and values differ among agencies. The *Traffic Control Devices Handbook* (4) suggests the criteria in Table 4-1. It is important to avoid using these criteria without objective engineering and economic assessment of the positive and negative impacts of the closure.

Table 4-1. Criteria for Crossing Closure

<table>
<tr><th>Type of Rail Line</th><th>Highway Volume Criteria</th><th>Train Volume Criteria</th><th>Alternate Crossing Criteria</th></tr>
<tr><td>Branch line</td><td rowspan="2">< 2,000 ADT</td><td>> 2 trains/day</td><td rowspan="2">Alternate crossing within 0.25 mile with less than 5,000 ADT if two-lane, or less than 15,000 ADT if four-lane</td></tr>
<tr><td>Spur track</td><td>> 15 trains/day</td></tr>
<tr><td>Main line</td><td colspan="3">More than five crossings within a one-mile segment.</td></tr>
</table>

Source: (4)

When a crossing is permanently closed to highway traffic, the crossing surface, pavement markings, and all traffic control devices both at the crossing and approaching the crossing should be removed. Generally, the railroad is responsible for removing the crossing surface and traffic control devices located at the crossing. The highway authority is responsible for removing traffic control devices in advance of and approaching the crossing. Nearby highway traffic signals interconnected with crossing signals located at the closed crossing should have their phasing and timing readjusted.

The highway authority is also responsible to alert motorists to the closed roadway. A Type III barricade conforming to the design criteria of Section 6C-8 of the Texas MUTCD may be erected, except the colors of the stripes shall be reflectorized white and reflectorized red. Warning and regulatory signing may also be an appropriate means of alerting motorists to the closed roadway; these may include the Road Closed (R11-2) sign, the Local Traffic Only (R11-3) sign, or the Road Closed To Thru Traffic (R11-4) sign, plus appropriate advance warning signs applicable to the specific crossing. When the street leading to the crossing is also closed, a T-intersection sign (W2-4) may be used to direct traffic onto existing parallel roadways to access the next crossing.

Consideration should also be given to advising motorists of alternate routes across the railroad. If trucks use the closed crossing, they should be given advance information of the closure at points where they can conveniently alter their route.

Relocation and Consolidation

A second option is relocation of either the highway or the railroad track, or consolidation of two or more railroad lines into a single route. Planning for such projects is complex and often controversial. Long-range plans for relocation and consolidation of railroads in urbanized areas should be reviewed prior to making any decisions relating to crossing improvement by either grade separation or traffic control systems. Urbanized area transportation plans and railroad studies for mergers and consolidation are two sources of information. Relocation and consolidation are also some of the most expensive options available, necessitating careful study to ensure the expenses involved are reasonably justified.

Railroad relocation to the outer limits of the community may be a viable alternative for alleviating operational, safety, and environmental concerns while retaining the economic benefits of railroad service to the community. Relocation generally involves the complete rebuilding of railroad facilities, including acquisition of new right-of-way and construction of track, drainage structures, signals and communications, crossings and separations, station facilities, and utilities.

Benefits of railroad relocation extend beyond those associated with crossing safety and operations; improved environmental quality resulting from decreased noise and air pollution, improved land use and appearance, and improvements in the railroad's operational efficiency may also be realized. Obstructions to emergency vehicles and safer routes for hazardous materials movement are also possible benefits.

Many factors exist in planning for railroad relocation. The new route should provide good alignment, minimum grades, and adequate drainage. Sufficient right-of-way should be available to provide the necessary horizontal clearances, additional rail facilities as service grows, and a buffer for abating noise and vibrations. The number of new highway-rail intersections should be minimal.

Zoning the property adjacent to the railroad as light and heavy industrial further isolates the railroad corridor from residential and commercial activity. Businesses and industry desiring rail service can locate in this area.

Highway relocations are implemented to provide improved traffic flow around communities and other developed areas. Planning for highway relocations should consider routes that would eliminate highway-rail intersections by avoiding the need for access over railroad tracks or by providing grade separations.

Grade Separation

If crossing closure, relocation, or consolidation are not options, the optimum improvement is separation of the railroad and highway grades. Although this alternative requires a large expenditure of funds, the benefits that may result include reduced highway congestion and motorist delay, and improved safety. The grade separation alternative should be considered specifically in the design of new highway routes and in improvements to railroad facilities. Railroad routes used for high speed railroad passenger service should have no at-grade intersections.

No federal criteria for grade separations exist. Specific criteria provide a means to justify the expenditure of funds for separating grades at some crossings while not separating grades at others. Obviously, the decision-making process should consider costs and benefits; however, some are difficult to quantify. Thus, engineering judgment plays a major role in selecting the grade separation alternative.

Consideration of grade separations as an alternative for heavily-traveled crossings is recommended. Costs and benefits should be carefully weighed, however, as grade separations are expensive to construct and maintain. In some cases, it may be feasible to separate grades at one crossing in a community and close most of the remaining crossings.

Abandoned Highway-Rail Intersections

Federal safety regulations and state laws require buses carrying passengers and trucks transporting hazardous materials to stop at most highway-rail intersections. The practice of leaving traffic control devices in place at abandoned crossings tends to reduce the credibility of similar devices at crossings currently in use.

Records of rail line abandonment hearings conducted by the Interstate Commerce Commission (ICC) identify locations where abandoned crossings may exist. Before proceeding with physical removal, however, confirmation of the abandonment should be sought from the former owner (if the former owner is still in business) and/or the state railroad regulatory agency. Even though a rail line has been identified as abandoned, it is possible that another railroad company or a subsidiary of the original owner may now be serving the line.

Where it has been determined that a railroad track has been abandoned, all related traffic control devices (including pavement markings) should be removed, the track should be removed, and the roadway surface restored to the appearance of a continuous section.

Occasionally, rail lines may exist that are not being used by the railroads, but which have not been ruled officially abandoned by ICC action. It may be possible to close the unused crossings on these lines by paving over the tracks and removing the warning devices until such time as rail service might resume. Such an action would require an agreement between the appropriate highway agency and the railroad. Governmental authorities should solicit help in identifying unused crossings. Sources of help include the railroads, state and local police agencies, commercial bus companies, school bus operators, hazardous materials carriers, and local public officials.

4.2 PASSIVE TRAFFIC CONTROL DEVICES

Introduction

Passive traffic control devices for highway-rail intersections consist of regulatory, warning, and guidance signs, and supplemental pavement markings. Passive devices provide static messages of warning, guidance, and in some instances, mandatory action. While signs and markings are passive devices, they are also used with and to supplement active devices.

Federal law requires that as a minimum, signs shall be provided at all crossings. The railroad company usually installs and maintains the railroad crossbuck sign and other supplemental signs attached to the crossbuck mast (except for the Railroad Signal Malfunction

Sign). The agency responsible for maintenance of the roadway is normally responsible for advance warning signs and pavement markings.

In the sections that follow, italicized print signifies a specific requirement as stated in the 1980 *Texas Manual on Uniform Traffic Control Devices* (3).

Railroad Crossing (Crossbuck) Sign

The railroad crossing sign, commonly identified as the "crossbuck" sign, as a minimum shall be white reflectorized sheeting or equal, with the words RAILROAD CROSSING in black lettering. As a minimum, one crossbuck sign shall be used on each roadway approach to every grade crossing, alone or in combination with other traffic control devices.

Where physically feasible and visible to approaching traffic the crossbuck sign shall be installed on the right hand side of the roadway pavement or shoulder in accordance with the criteria in sections 2A-21 through 2A-27 and figures 2-1 and 2-1 (pages 2A-9 and 2A-10) and should be located with respect to the nearest track in accordance with signal locations in figure 8-7, (page 8C-6). The normal lateral clearances (sec. 2A-24), 6 feet from the edge of the highway shoulder or 12 feet from the edge of the traveled way in rural areas and 2 feet from the face of the curb in urban areas will usually be attainable. Where unusual conditions demand, variations determined by good judgment should provide the best possible combination of view and safety clearances attainable, occasionally utilizing a location on the left-hand side of the roadway.

Appropriate details of R15-1 and R15-2 are available in the Standard Highway Sign Designs publication. Figure 4-1 depicts the standard crossbuck sign for use at highway-rail intersections.

Supplemental Number of Tracks Sign

If there are two or more tracks between the signs, the number of tracks shall be indicated on an auxiliary sign of inverted T shape mounted below the crossbuck and at the heights indicated in figure 8-1 except that use of this auxiliary sign is optional at crossings with automatic gates. Figure 4-1 shows the supplemental Number of Tracks sign for use with the standard crossbuck sign at highway-rail intersections.

Railroad Advance Warning Signs

A Railroad Advance Warning (W10-1) sign shall be used on each roadway in advance of every grade crossing except:

1. *On low-volume, low-speed roadways crossing minor spurs or other tracks that are infrequently used and which are flagged by train crews.*

2. *In the business districts of urban areas where active grade crossing traffic control devices are in use.*

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

Placement of the sign shall be in accordance with Section 2C-3 and Sections 2A-21 to 2A-27, normally 750 feet or more in advance of the crossing in rural areas and 250 feet in advance of the crossing in urban areas, except that in a residential or business district where low speeds are prevalent, the signs may be placed a minimum distance of 100 feet from the crossing. On divided highways and one way roads, it is desirable to erect an additional sign on the left side of the roadway.

The W10-2, 3, and 4 signs may be installed on highways that are parallel to railroads. 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 W10-1 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. Figure 4-2 illustrates railroad advance warning signs W10-1 through W10-4.

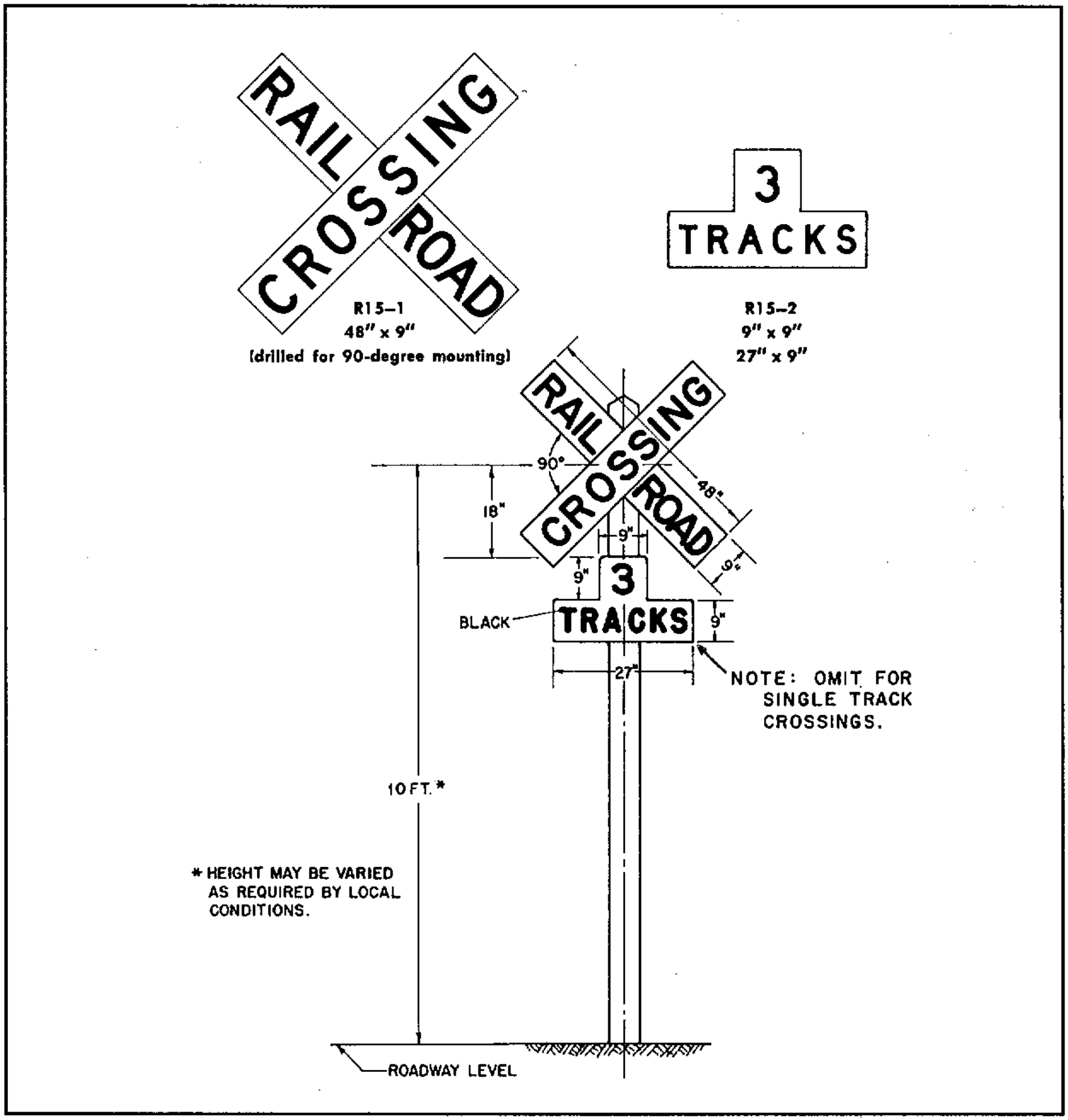


Figure 4-1. Standard Railroad-Highway Crossbuck Sign and Supplemental Number of Tracks Sign (3)

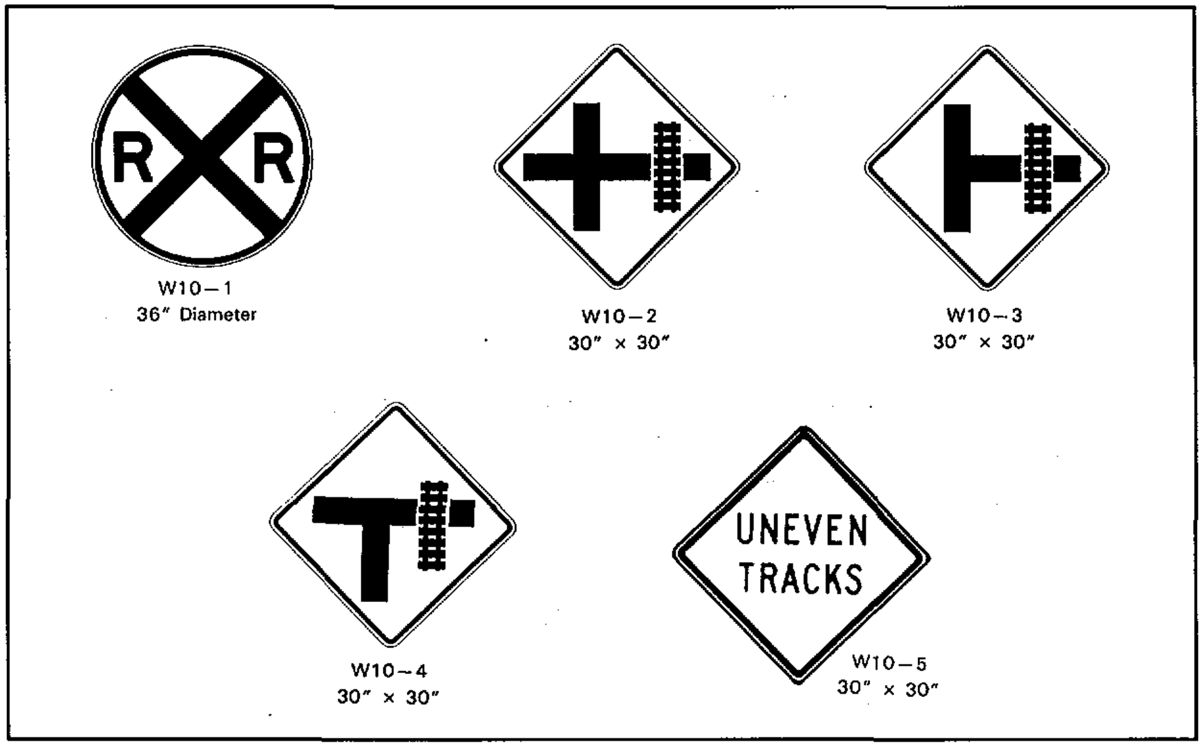


Figure 4-2. Railroad Advance Warning Signs (3)

Uneven Tracks Warning Sign

The UNEVEN TRACKS sign is intended to be used to warn of a railroad crossing which is so uneven or rough as to be a hazard to vehicles crossing the tracks at the normal speed on the approach roadway. Additional protection may be provided by use of the W13-1 ADVISORY SPEED sign. The W10-5 sign when used should be erected 100 feet beyond the W10-1 RAILROAD ADVANCE WARNING sign, subject to adjustment to local conditions.

Advisory Speed Plate

The advisory speed plate is intended for use to supplement warning signs. The standard size of the Advisory Speed plate shall be 18 x 18 inches. Advisory Speed plates used with 36-inch and larger warning signs shall be 24 x 24 inches.

The plate shall carry the message (35) MPH in black on a yellow background except for construction and maintenance signs (sec. 6B-34). The speed shown shall be a multiple of 5 miles per hour. The plate may be used in conjunction with any standard yellow warning sign to indicate the maximum recommended speed around a curve or through a hazardous location. It shall not be used in conjunction with any sign other than a warning sign, nor shall it be used alone. When used, it shall be mounted on the same assembly and normally below the standard warning sign (fig. 2-1, page 2A-9).

Except in emergencies, or at construction or maintenance sites, where the situation calling for an advisory speed is temporary, an Advisory Speed plate shall not be erected until the recommended speed has been determined by accepted traffic engineering procedures. Because changes in surface characteristics, sight distance, etc., may alter the recommended speed, each location should be periodically checked and the speed plate corrected if necessary.

STOP and YIELD Signs at Grade Crossings

One of the more controversial issues in highway-rail safety is the use of stop and yield control at highway-rail intersections. Recent legislation has made it easier to install Stop and Yield signs. Nevertheless, the responsible authority should ensure that such installations are justified and that they conform to all applicable standards. As with any new installation of a traffic control device, the decision to install Stop or Yield signs at a highway-rail intersection should be made on the basis of an engineering study of the crossing.

Texas MUTCD Provisions. *The use of the STOP sign at railroad-highway grade crossings shall be limited to those grade crossings selected after need is established by a detailed traffic engineering study. Such crossings should have the following characteristics:*

1. *Highway should be secondary in character with low traffic counts;*

2. *Train traffic should be substantial;*

3. *Line of sight to an approaching train is restricted by physical features such that approaching traffic is required to reduce speed to 10 mph or less in order to stop safely; and*

4. *At the stop bar, 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, however, this should only be an interim measure until active traffic control devices can be installed. STOP signs shall not be used on primary through highways or at grade crossings with active traffic control devices.

Whenever a STOP sign is installed at a grade crossing, a Stop Ahead sign shall be installed in advance of the STOP sign.

1988 National MUTCD Revision. Section 1077 of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) required revision of the National Manual on Uniform Traffic Control Devices to grant states and local governments the discretionary authority to install STOP or YIELD signs at any highway-rail grade crossing without automatic traffic control devices with two or more trains per day (9). The revised Section 8B-9 of the National MUTCD states:

STOP or YIELD signs may be used at highway-rail grade crossings, at the discretion of the responsible State or Local jurisdiction, for crossings that have two or more trains per day and are without automatic traffic control devices.

For other crossings with passive protection, STOP or YIELD signs may be used after need is established by a traffic engineering study. The study should take into consideration such factors as: volume and character of highway and train traffic, adequacy of stopping sight distance, crossing accident history, and need for active control devices.

For all highway-rail grade crossings where STOP or YIELD signs are installed, the placement shall conform to the requirements of MUTCD Section 2B-9 Location of Stop Sign and Yield Sign. STOP AHEAD or YIELD AHEAD Advance Warning signs shall also be installed.

Recommended Guidance. In a cooperative effort, the Federal Highway Administration (FHWA) and the Federal Railroad Administration (FRA) have developed the following "Considerations to Apply in Assessing the Need for STOP or YIELD Signs at Highway-Railroad Grade Crossings" (9).

The FHWA and FRA recommend that the following general factors be considered when reviewing a crossing for possible STOP or YIELD sign installation:

- Volume, type and speed of highway traffic,
- Frequency, type and speed of trains,
- Number of tracks,
- Intersection angles,
- Adequacy of stopping sight distances,
- Need for automated warning devices, and
- Crossing accident history.

The FHWA and FRA recommend that the following specific factors be applied in determining first priority with respect to new STOP sign installations.

It is recommended that the following considerations be met in every case before a STOP sign is installed:

- Local and/or State police and judicial officials will commit to a program of enforcement no less vigorous than would apply at a highway intersection equipped with STOP signs.

- Installation of a STOP sign would not occasion a more dangerous situation (taking into consideration both the likelihood and severity of highway-rail collisions and other highway traffic risks) than would exist with a YIELD sign.

Any one of the following conditions indicates that use of STOP signs would tend to reduce risk of a collision. It is recommended that the following considerations be weighed against the opposing factors outlined next:

- Maximum train speeds equal or exceed 30 mph (a factor highly correlated with highway-rail accident severity).
- Highway traffic mix include buses, hazardous materials carriers and/or large (trash or earth moving) equipment.
- Train movements are 10 or more per day, 5 or more days per week.
- The rail line is used by passenger trains.
- The rail line is regularly used to transport a significant quantity of hazardous material.
- The highway crosses two or more tracks, particularly where both tracks are main tracks or one track is a passing siding that is frequently used. (Note: If Federal-aid funds are used in a highway-rail grade crossing improvement project with multiple main line tracks, gates and flashing lights are required.)
- The angle of approach to the crossing is skewed.
- The line of sight from an approaching highway vehicle to an approaching train is restricted such that approaching traffic is required to substantially reduce speed.

Opposing factors to be weighed in opposition to Stop signs include:

- The highway is other than secondary in character. Recommended maximum of 400 ADT in rural areas, and 1,500 ADT in urban areas. (If any of the positive indications apply to a crossing with traffic counts in excess of these levels, strong consideration should be given to installation of automated warning devices.)
- The roadway is a steep ascending grade to or through the crossing, sight distance in both directions is unrestricted in relation to maximum closing speed, and the crossing is used by heavy vehicles. (Note: A crossing where there is insufficient time for any vehicle, proceeding from a complete stop, to safely traverse the crossing within the time allowed by maximum train speed, is an inherently unsafe crossing that should be closed.)

Application. Figure 4-3 depicts the typical application of a Stop sign at a highway-rail intersection. When using Figure 4-3, Table 4-2 should be consulted to determine the appropriate placement distance of the Stop Ahead warning sign. Table 4-2 suggests minimum warning sign placement distances as a function of the posted or 85th-percentile speed (whichever is greater).

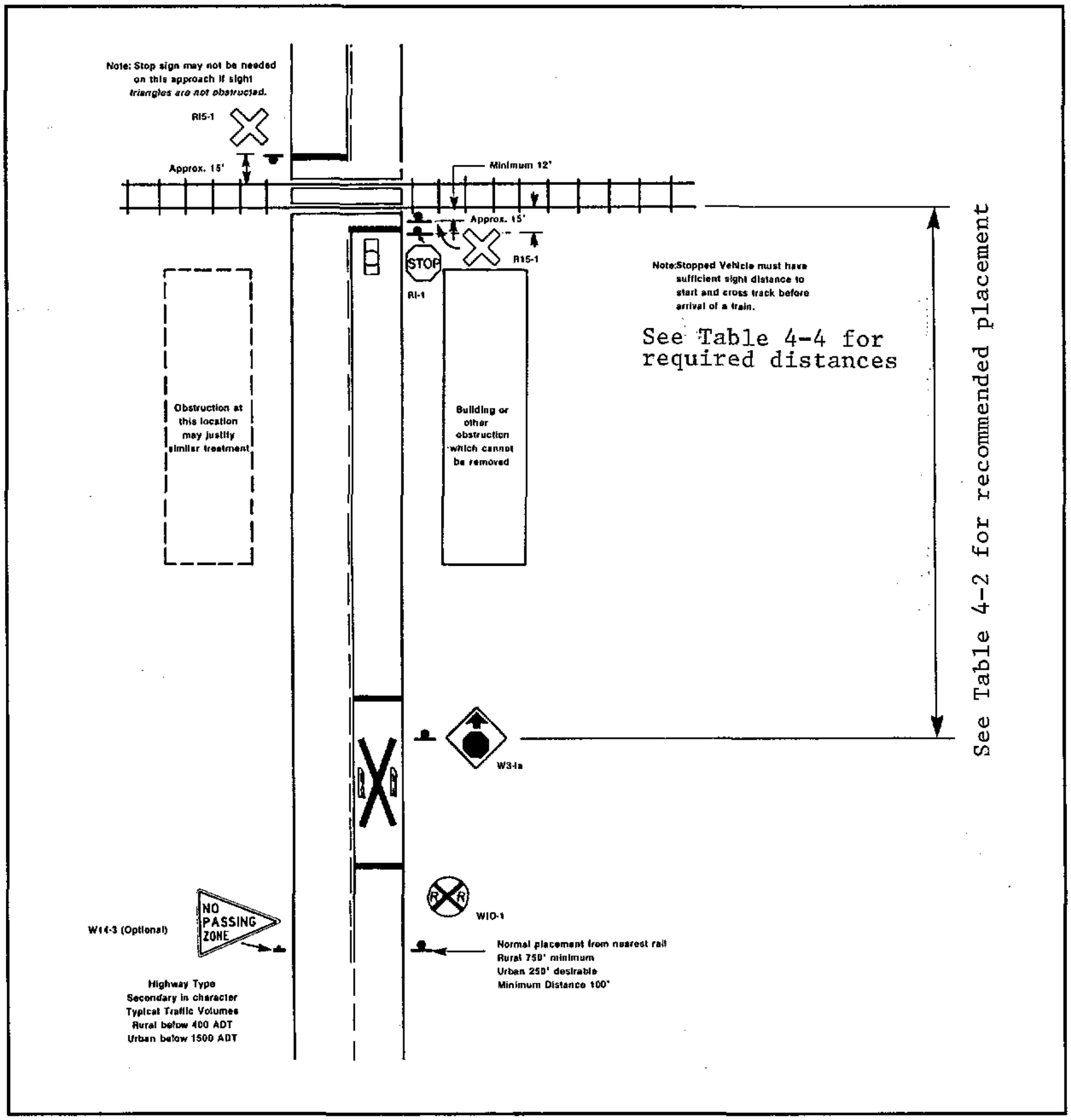


Figure 4-3. Typical Application of a STOP Sign at a Highway-Rail Intersection (4)

The distances shown in Table 4-2 apply to situations in which the driver may be required to come to a complete stop, such as at a signalized intersection, stop- or yield-controlled intersection, or crossroad.

Table 4-2. Suggested Minimum Warning Sign Placement Distance (Ft) -- STOP Condition[1]

Posted or 85th-Percentile Speed (mph) (Use Higher Speed)	Placement Distance (feet)[2]
20	([3])
25	([3])
30	100
35	150
40	225
45	300
50	375
55	450
60	550

[1]Distances shown are for level roadways. Corrections should be made for grades. Distances based on 36-inch signs. If 48-inch signs are used, the legibility distance may be increased to 200 feet. This would permit reduction of the placement distance by 75 feet.
[2]Distance provides for 3-second PIEV, 125-foot sign legibility distance, and braking distance.
[3]No suggested minimum distance provided. At these speeds, sign location depends on the physical conditions present at the site.
Source: (4)

Exempt Crossing Signs

When authorized by law or regulation a supplemental sign (R15-3) bearing the word EXEMPT may be used below the Crossbuck and Track signs at the crossing, and supplemental sign (W10-1a) may be used below the Railroad Advance Warning sign. These supplemental signs are to inform drivers of vehicles carrying passengers for hire, school buses carrying children, or vehicles carrying flammable or hazardous materials that a stop is not required at certain designated grade crossings, except when a train, locomotive, or other railroad equipment is approaching or occupying the crossing or the driver's view of the sign is blocked.

Do Not Stop on Tracks Sign

Whenever an engineering study determines that the potential for vehicles stopping on the tracks is high, a DO NOT STOP ON TRACKS sign should be used. The sign should normally be placed on the far right side of the grade crossing. On multilane roads and one-way roadways a second sign should be placed on the far left side of the grade crossing.

Pavement Markings

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.*

The markings shall also be placed at crossings where engineering studies indicate there is a significant potential conflict between vehicles and trains. At minor crossings or in urban areas, these markings may be omitted if engineering study indicates that other devices installed provide suitable control.

The design of railroad crossing pavement markings shall be essentially as illustrated in figure 8-2. The symbols and letters are elongated to allow for the low angle at which they are viewed. All markings shall be reflectorized white except for the no-passing markings which shall be reflectorized yellow.

Figure 4-4 illustrates typical pavement markings at highway-rail intersections. Appendix D provides additional figures illustrating highway-rail intersection signing and pavement markings.

No Passing Zone Sign

The NO PASSING ZONE Sign (W14-3) may be installed at crossings to supplement no passing pavement markings. This sign consists of black letters and border on a yellow background, and is in the shape of a pennant with dimensions of 36 x 48 x 48 inches. The sign is placed at the beginning of the no passing zone, typically 10 feet prior to the first transverse pavement marking on the highway approach.

Sign Placement

Figures 4-5 through 4-7 illustrate typical arrangements of the Crossbuck, Stop, and Railroad Advance Warning signs for various intersection configurations. Figure 4-5 depicts the typical sign placement for a highway-rail intersection with a parallel roadway located 100 feet or more from the crossing. Figure 4-6 illustrates sign placement when the parallel roadway is within 100 feet of the crossing and traffic on the intersecting roadway is required to stop at the highway intersection. Figure 4-7 illustrates sign placement for the situation in which a parallel roadway is located within 100 feet of the crossing and traffic on the parallel roadway must stop. When using figures 4-6 and 4-7, refer to Table 4-2 for the placement distance of the W10-2 Advance Warning sign. Appendix D includes additional figures illustrating highway-rail intersection signing and pavement markings.

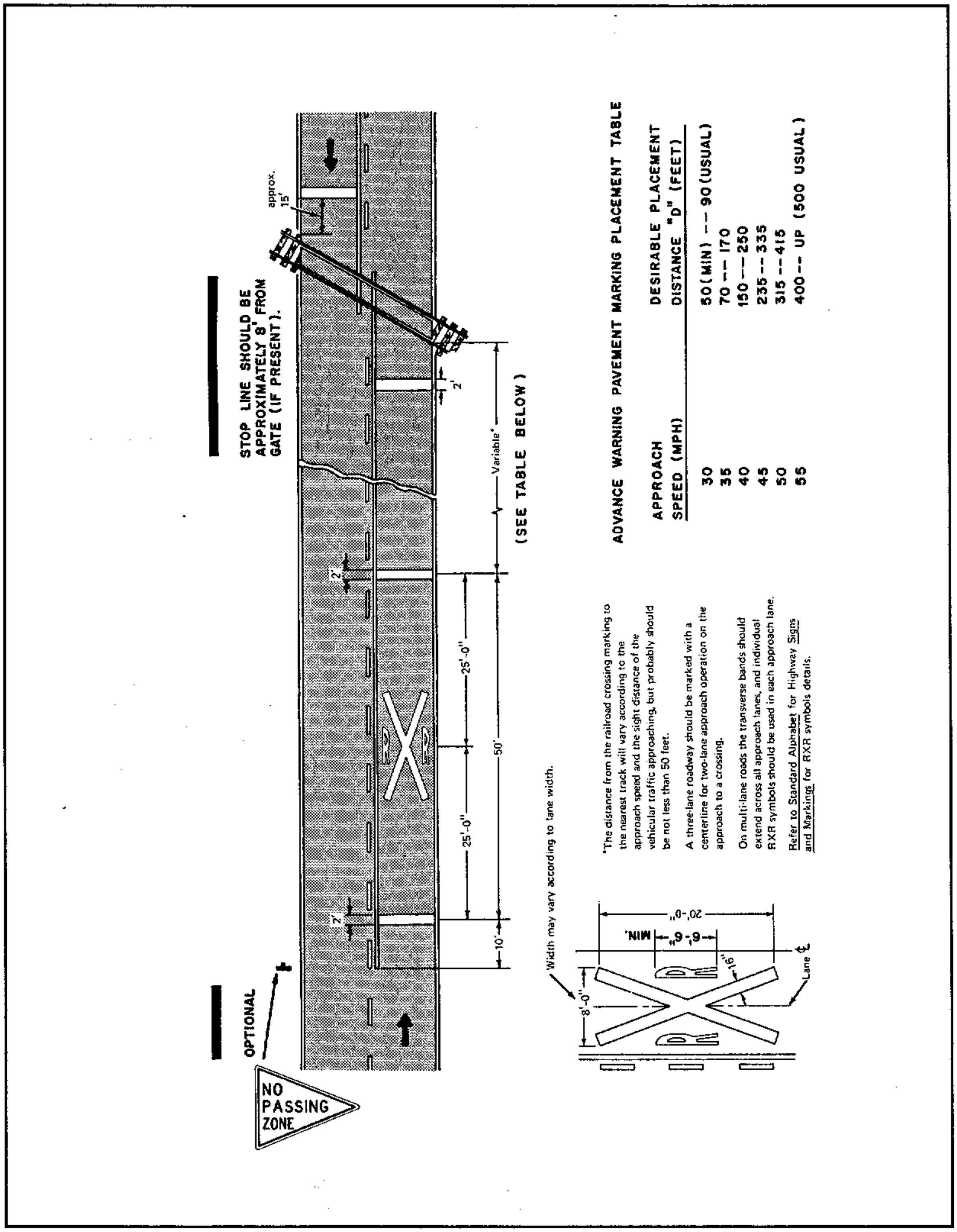


Figure 4-4. Typical Pavement Markings at Highway-Rail Intersections (3)

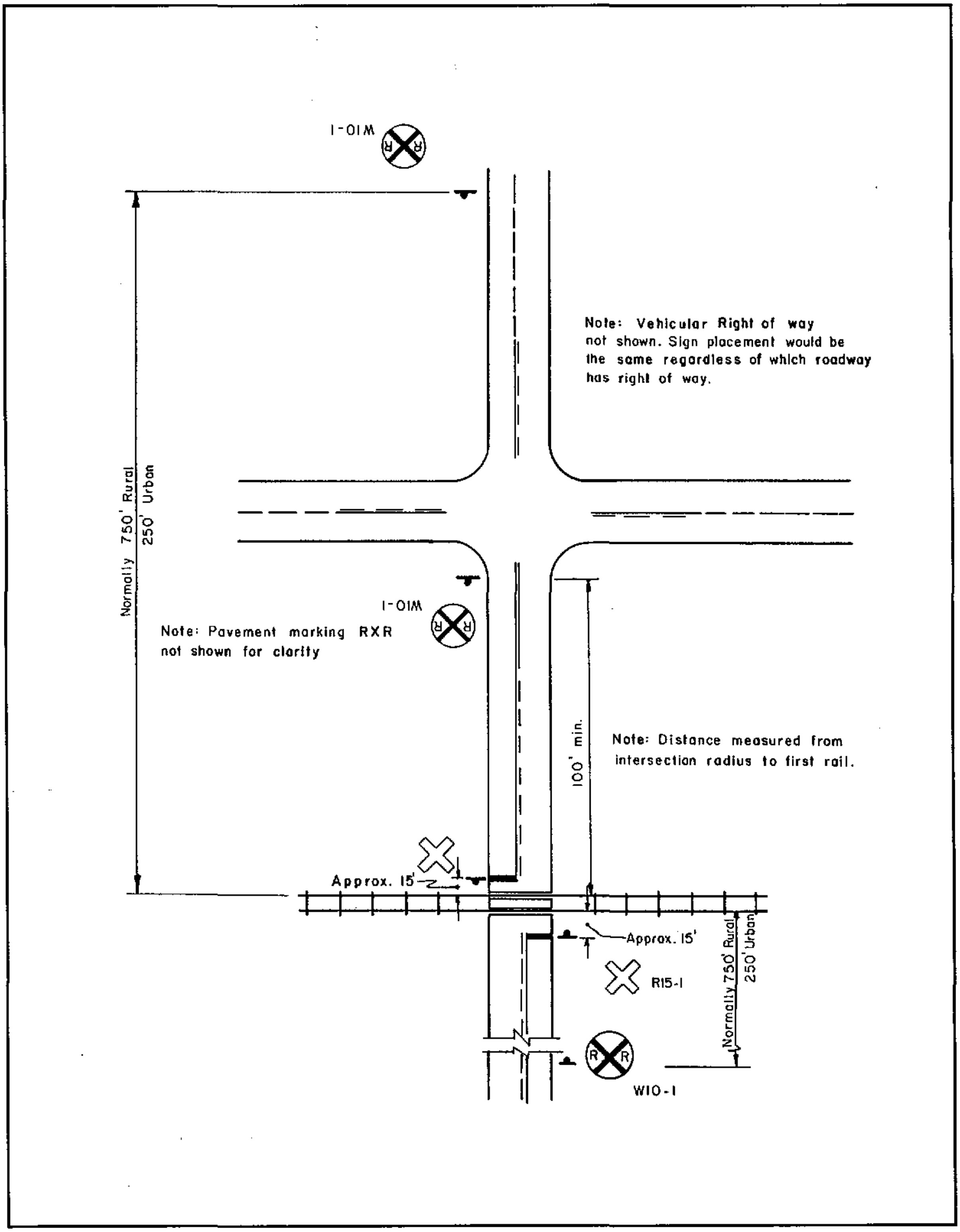


Figure 4-5. Typical Sign Placement Where Parallel Road Is Over 100 Feet From Crossing (4)

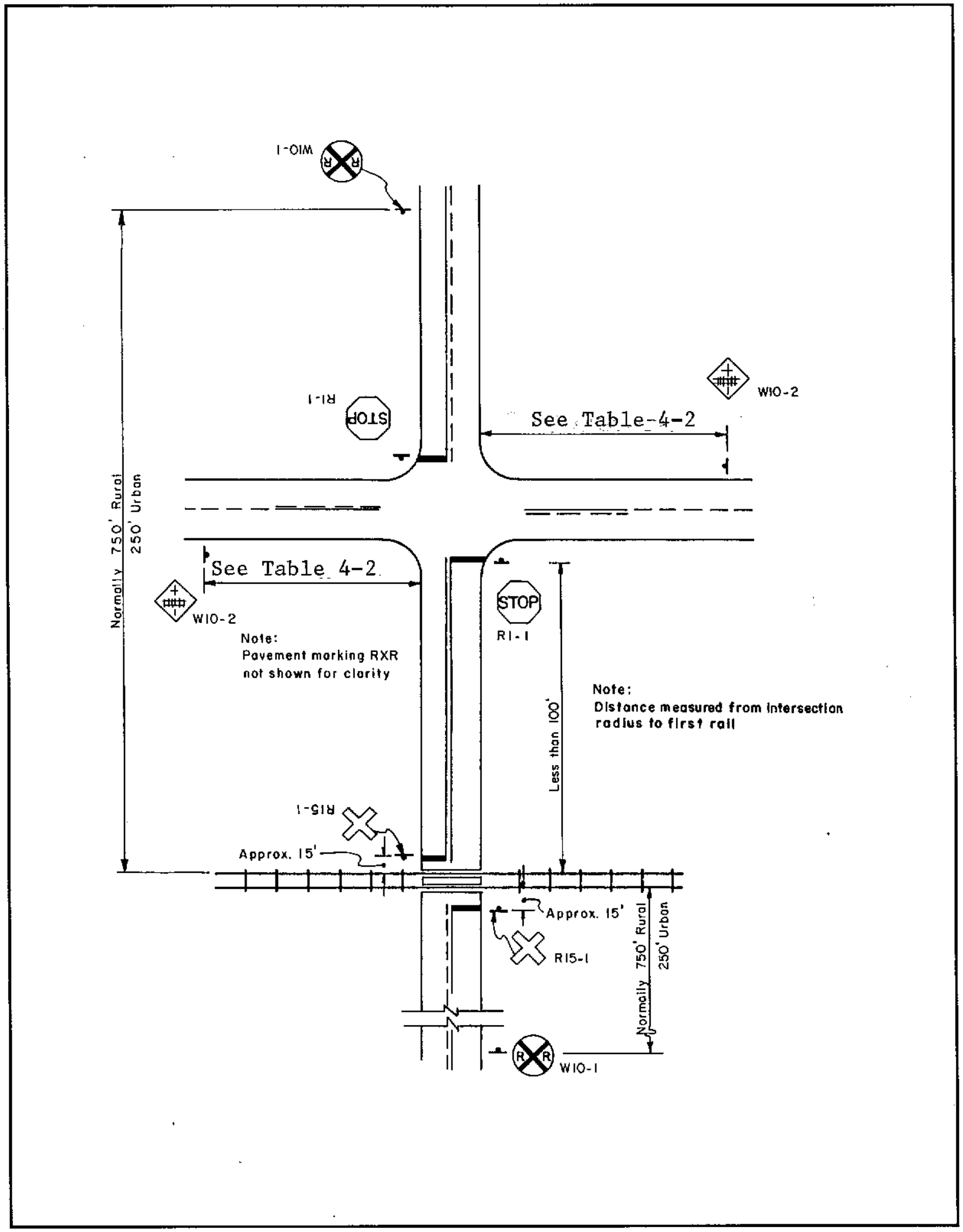


Figure 4-6. Typical Sign Placement Where Parallel Road Is Within 100 Feet of Crossing and Intersecting Road Traffic Must Stop (4)

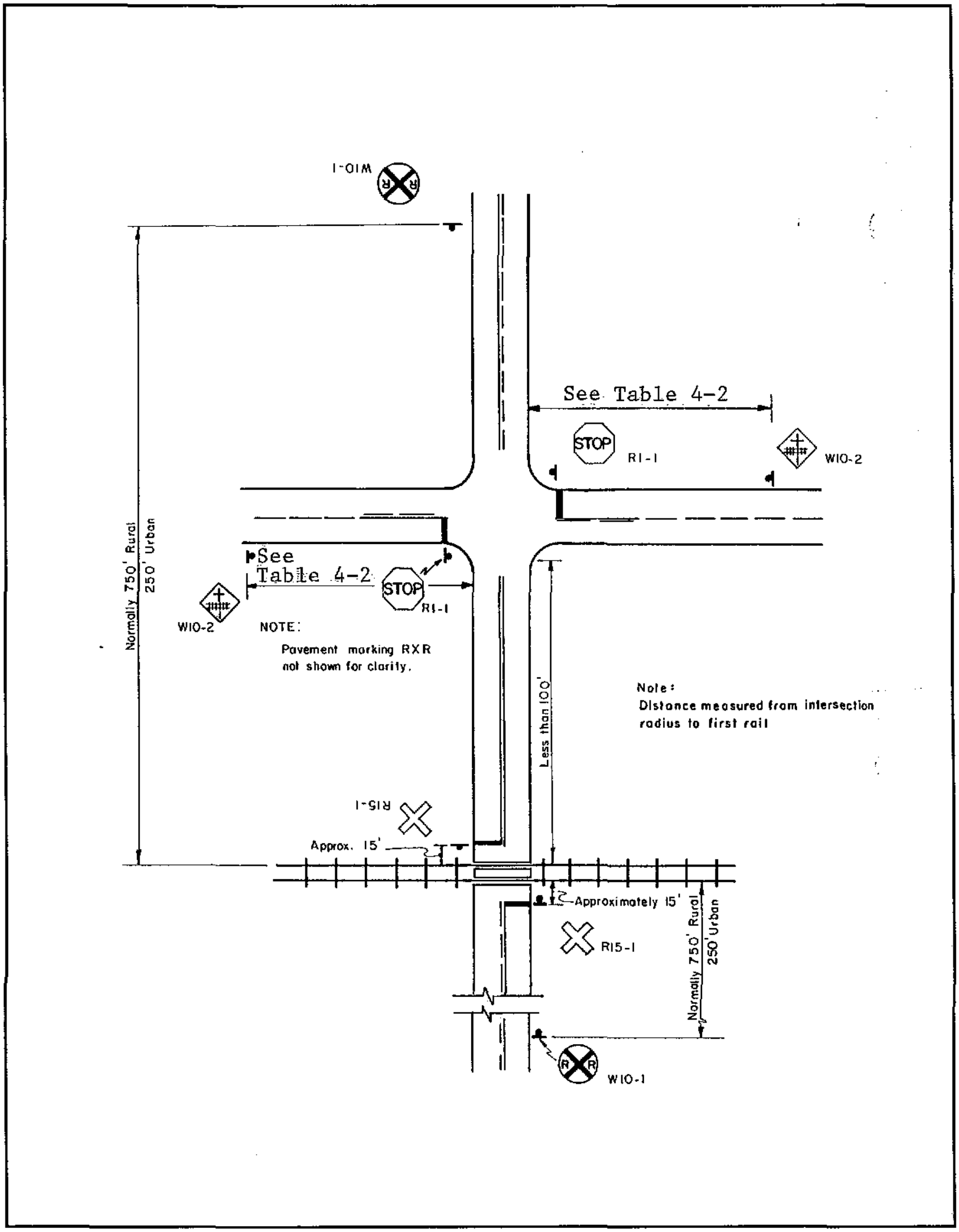


Figure 4-7. Typical Sign Placement Where Parallel Road Is Within 100 Feet of Crossing and Parallel Road Traffic Must Stop (4)

4.3 ACTIVE TRAFFIC CONTROL DEVICES

Introduction

Active traffic control systems inform motorists and pedestrians of the approach or presence of trains, locomotives, or railroad cars on grade crossings. Passage of a train over a detection circuit in the track activates these systems, except in a few situations where manual control or manual operation exists. Active control devices are supplemented with the same signs and pavement markings that are used for passive control. Active traffic control devices include flashing light signals, both post-mounted and cantilevered; bells; automatic gates; active advance warning devices; and highway traffic signals.

Flashing Light Signals

Flashing light signals constitute the minimum level of active control currently being installed at railroad-highway grade crossings. This control device consists of two alternately flashing red light units mounted 30 inches apart on a horizontal crossarm. Flashing light signals are generally post-mounted, but where improved visibility is required, cantilevered flashing light signals are used.

Texas MUTCD Provisions. The Texas MUTCD makes the following provisions for post-mounted flashing light signals used at highway-rail intersections.

When indicating the approach or presence of a train, the flashing light signal, illustrated in figure 8-3, shall display toward approaching highway traffic the aspect of two red lights in a horizontal line flashing alternately. As shown in figure 8-3, the typical flashing light signal assembly on a side of the roadway location includes a standard crossbuck sign and, where there is more than one track, an auxiliary "number of tracks" sign, all of which indicate to vehicle operators and pedestrians at all times the location of a grade crossing. A bell may be included in the assembly and operated in conjunction with the flashing lights. Bells are a particularly suitable warning for pedestrians and bicyclists.

The flashing light signals should normally be placed to the right of approaching highway traffic on all roadway approaches to a crossing. They should be located laterally with respect to the highway in conformance with figure 8-6, (page 8C-5) except where such location would compromise signal display effectiveness. As stated in section 8A-3, if it is practical, equipment housings (controller cabinets) should have a lateral clearance of 30 feet from the roadway and adequate clearance from the tracks. Where conditions warrant, escape areas, attenuators, or guardrails should be provided.

Additional pairs of lights may be mounted on the same supporting post and directed toward vehicular traffic approaching the crossing from other than the principal highway route. Such may well be the case where there are approaching routes on roadways closely adjacent to and parallel to the railroad. At crossings of a highway with traffic in both directions, back-to-back pairs of lights shall be placed on each side of the tracks. On one way streets and divided highways, signals shall be placed on the approach side of the crossing normally on both sides *of the roadway and may be equipped with back lights. Typical location plans for signals are shown in figure 8-7, (page 8C-6).*

The Texas MUTCD includes the following provisions for the use of cantilever-supported flashing light signals at highway-rail intersections.

Where required for better visibility to approaching traffic, particularly on multi-lane approaches, cantilevered flashing light signals are used in the manner shown in figure 8-4. In addition to the flashing lights cantilevered over the roadways, flashing lights should usually be placed on the supporting post.

Although cantilever signals are more commonly used on multi-lane highways, they are also suitable for other locations where additional emphasis is needed. These locations may include high speed rural highways, high volume two-lane highways, or specific locations where there are distractions. If one pair of cantilever flashing lights would be visible to drivers in all approaching lanes, except the right lane which has a view of the post mounted signals, other flashing lights are not required on the cantilever arm. A pair of lights overhead for each approaching lane is not required, inasmuch as the warning aspect is at all times identical for all.

Breakaway or frangible bases ***shall not be used*** *for cantilever signal supports. Where conditions warrant, escape area, attenuators, or properly designed guardrails should be provided.*

General Considerations. Figure 4-8 depicts a typical post-mounted flashing light signal installation. Figure 4-9 illustrates a typical cantilever-supported flashing light signal installation.

Flashing light signals consist of two light units that flash alternately at a rate of 45 to 65 times per minute. The main components of a flashing light unit are the hood, background, roundel, lamp, lampholder, reflector, and housing. The background is 20 or 24 inches in diameter and is painted a nonreflecting black to provide a contrast for the red light. The hood is also painted black.

Flashing light units are available in two roundel (lens) sizes, 8-3/8 inch and 12 inch diameter. The latter may provide somewhat better visibility, and are used exclusively on all new installations and upgrades. The roundel is red and comes in a variety of designs that direct the light toward the motorist. The spreadlight roundel distributes light through the entire angle, one-half the angle being on each side of the beam axis. A deflecting roundel directs a portion of the light from the beam to one side of the axis in the direction indicated on the lens. The design of a roundel having both spreadlight and deflecting features provides deflection at a right angle to the spread. An example is the 30 degree horizontal deflection and 15 degree vertical spread. A roundel using a 20 degree spread and 32 degree downward deflection can be used on cantilevers. Back light units may use a 70 degree horizontal spread.

The lamp consists of a low wattage bulb used to ensure operation on standby battery power should commercial power fail. The wattage most commonly used is 18 or 25 watts. The reflector, or mirror, mounted behind the lamp, directs the light back through the roundel.

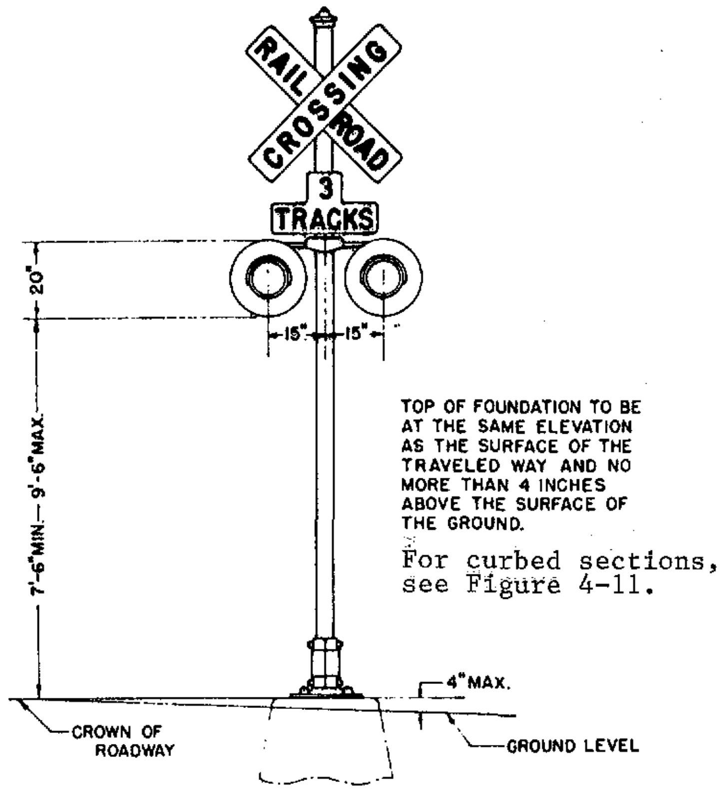
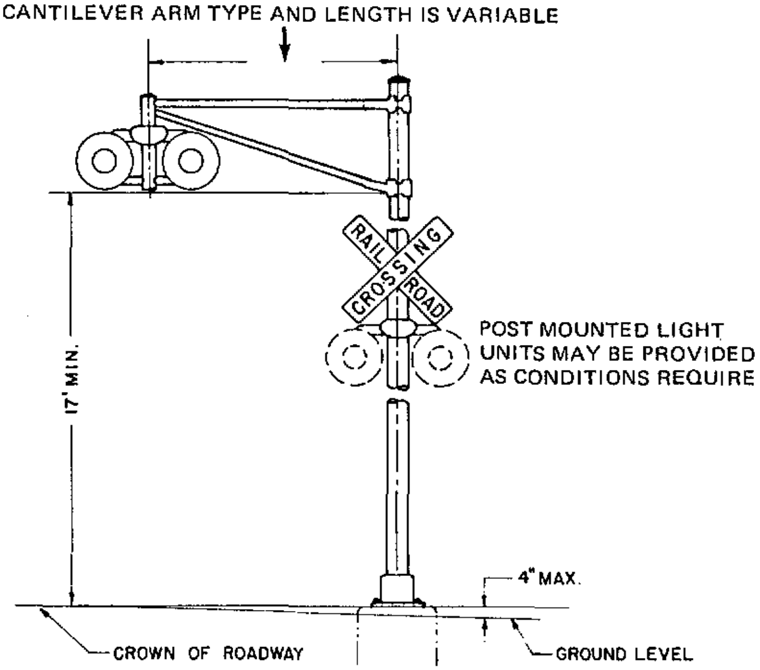


Figure 4-8. Typical Post-Mounted Flashing Light Signal (3)



TOP OF FOUNDATION TO BE AT THE SAME ELEVATION AS THE SURFACE OF THE TRAVELED WAY AND NO MORE THAN 4 INCHES ABOVE THE SURFACE OF THE GROUND.

For curbed sections, see Figure 4-11.

Figure 4-9. Typical Cantilever-Supported Flashing Light Signal (3)

Proper alignment of the light is essential. Because of low wattage and narrow beams, the lamp must be precisely aligned to direct the narrow intense beam toward the approaching motorist. The flashing light unit on the right hand side of the highway is usually aligned to cover a distance approximately 50 feet up to a maximum of 1000 feet out from the crossing. The light units mounted on the back of the signals on the opposing approach, and thus on the left, are usually aligned to cover the near approach to the crossing, out to a distance about 50 feet from the crossing.

The MUTCD requires mounting of two sets of flashing lights on each supporting post, back-to-back, such that two sets of flashing lights face the motorist - one set on the right or near side of the crossing, and one set on the left or far side of the crossing. Back-to-back light units may not be required on one-way highways. A crossbuck is always used in conjunction with the flashing light signal, usually mounted on the same post above the light units.

Some considerations for evaluating the need for installation of flashing light signals, as spelled out in the AASHTO Green Book (5), include: the type of highway, volume of vehicular traffic, volume of railroad traffic, maximum speed of the railroad trains, permissible speed of vehicular traffic, the volume of pedestrian traffic, accident record, sight distance, and the geometry of the crossing.

Flashing light signals are generally post-mounted, but where improved visibility to approaching traffic is required, cantilevered flashing light signals are used. Cantilevered flashing light signals may be appropriate when any of the following conditions exists:

- Multilane highways,
- Highways with paved shoulders or a parking lane that would require a post-mounted light to be located more than 10 feet from the edge of the travel lane,
- Roadside foliage obstructing the view of post-mounted flashing light signals,
- Line of roadside obstacles such as utility poles,
- Distracting backgrounds such as an excessive number of neon signs, and
- Horizontal or vertical curves where extension of flashing lights over the traffic lanes will provide sufficient visibility for the required stopping sight distance.

A typical installation consists of one pair of cantilevered lights on each highway approach supplemented with a pair of lights mounted on the supporting mast. Two or more pairs of cantilevered flashing lights may be desirable for multi-lane approaches.

Cantilevers are available with fixed, rotatable, or walkout supports. The primary disadvantage of the fixed support is that maintenance of the light unit is usually performed from equipment in the traffic lane, thereby blocking highway traffic. Rotatable cantilevers can be turned to the side of the highway for maintenance, but not for aligning the flashing lights.

Walkout cantilevers allow for easier maintenance. Standard cantilevers for mounting flashing lights are made with arm lengths up to 40 feet. Where cantilever arm length in excess of 35 feet is required, a bridge structure is preferred.

Automatic Gate

All new signal installations at highway-rail intersections include automatic gate devices. The automatic gate functions to deter drivers from entering the crossing when a train is approaching.

Texas MUTCD Provisions. *An automatic gate is a traffic control device used as an adjunct to flashing lights. The device consists of a drive mechanism and a fully reflectorized red and white striped gate arm with lights, and which in the down position extends across the approaching lanes of highway traffic about 4 feet above the top of the pavement. The flashing light signal may be supported on the same post with the gate mechanism or separately mounted. A schematic view of the gate arm in the down position is shown in figure 8-5. This view does not show any of the several mechanisms used to raise and lower the arm.*

In its normal upright position, when no train is approaching or occupying the crossing, the gate arm should be either vertical or nearly so (fig. 8-6). Typical minimum clearance is 2 feet from face of vertical curb to closest part of signal or gate arm in its upright position for a distance of 17 feet above the crown of the roadway. Where there is no curb, a minimum horizontal clearance of 2 feet from edge of a paved or surfaced shoulder shall be provided with a minimum clearance of 6 feet from the edge of the traveled roadway. Where gates are located in the median, additional width may be required to provide the minimum clearance for the counterweight supports. Where conditions warrant, escape routes, attenuators, or guardrails should be provided.

In a normal sequence of operation the flashing light signals and the lights on the gate arm in its normal upright position are activated immediately upon detection of the approach of a train. The gate arm shall start its downward motion not less than 3 seconds after the signal lights start to operate, shall reach its horizontal position before the arrival of any train, and shall remain in that position as long as the train occupies the crossing. When the train clears the crossing, and no other train is approaching, the gate arm shall ascend to its upright position normally in not more than 12 seconds, following which the flashing lights and the lights on the gate arm shall cease operation. In the design of individual installations, consideration should be given to timing the operation of the gate arm to accommodate slow moving trucks. Timing the operation of the gate arm shall be coordinated with the preemption sequence of adjacent traffic control signals.

Typical location plans for automatic gates are shown in figure 8-7. Component details are described in section 8C-7.

General Considerations. Figures 4-10 and 4-11 depict schematic views of an automatic gate and typical clearances for flashing light signals and automatic gates. Figure 4-12 illustrates a typical location plan for flashing light signals and automatic gates.

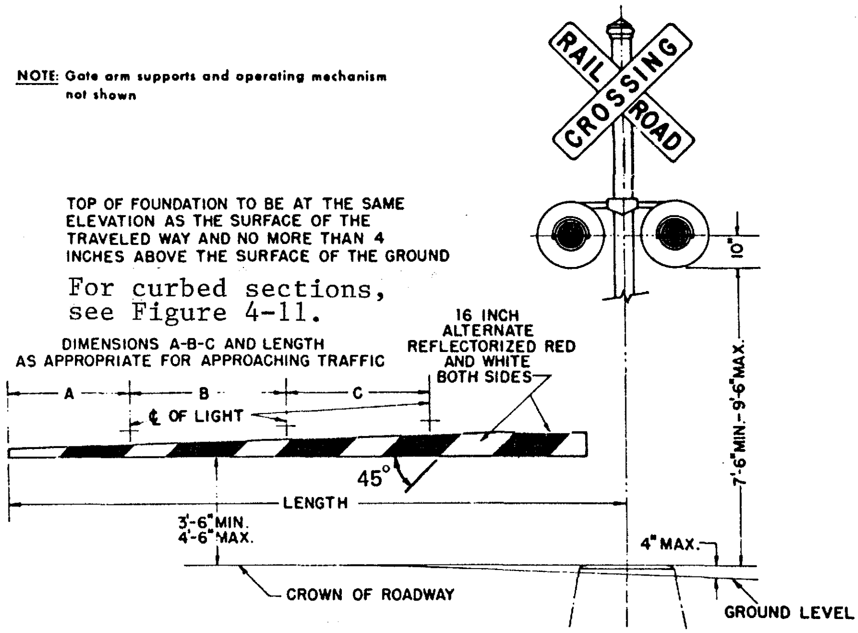


Figure 4-10. Schematic View of an Automatic Gate (3)

Typical minimum clearance is 2 feet from face of vertical curb to closest part of signal or gate arm in its upright position for a distance of 17 feet above the crown of the roadway.

Where there is no curb, a minimum horizontal clearance of 2 feet from edge of a paved or surfaced shoulder shall be provided with a minimum clearance of 6 feet from the edge of the traveled roadway where there is no curb or shoulder, the minimum horizontal clearance shall be 6 feet from the edge of the roadway.

Where gates are located in the median, additional width may be required to provide the minimum clearance for the counterweight supports.

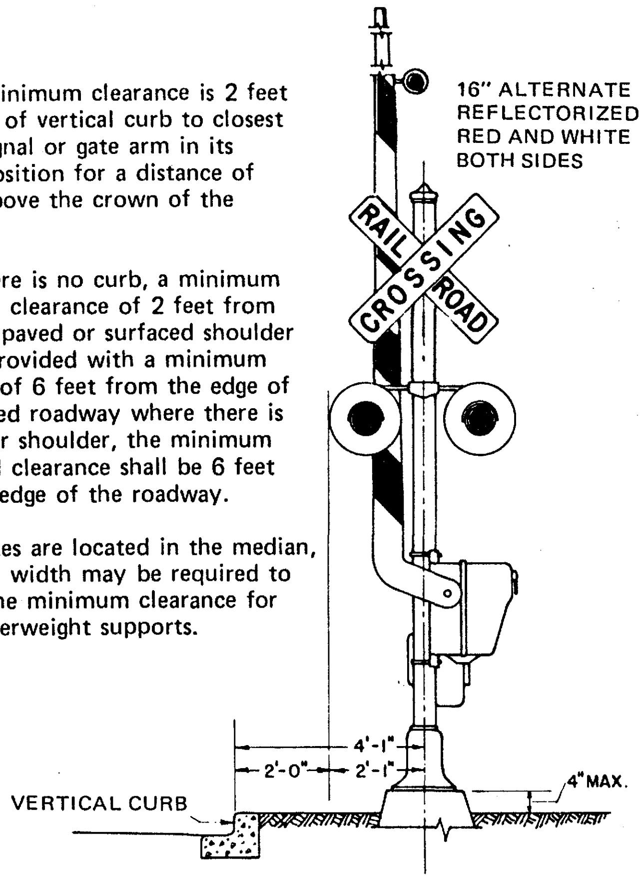


Figure 4-11. Typical Clearances for Flashing Light Signals and Automatic Gates (3)

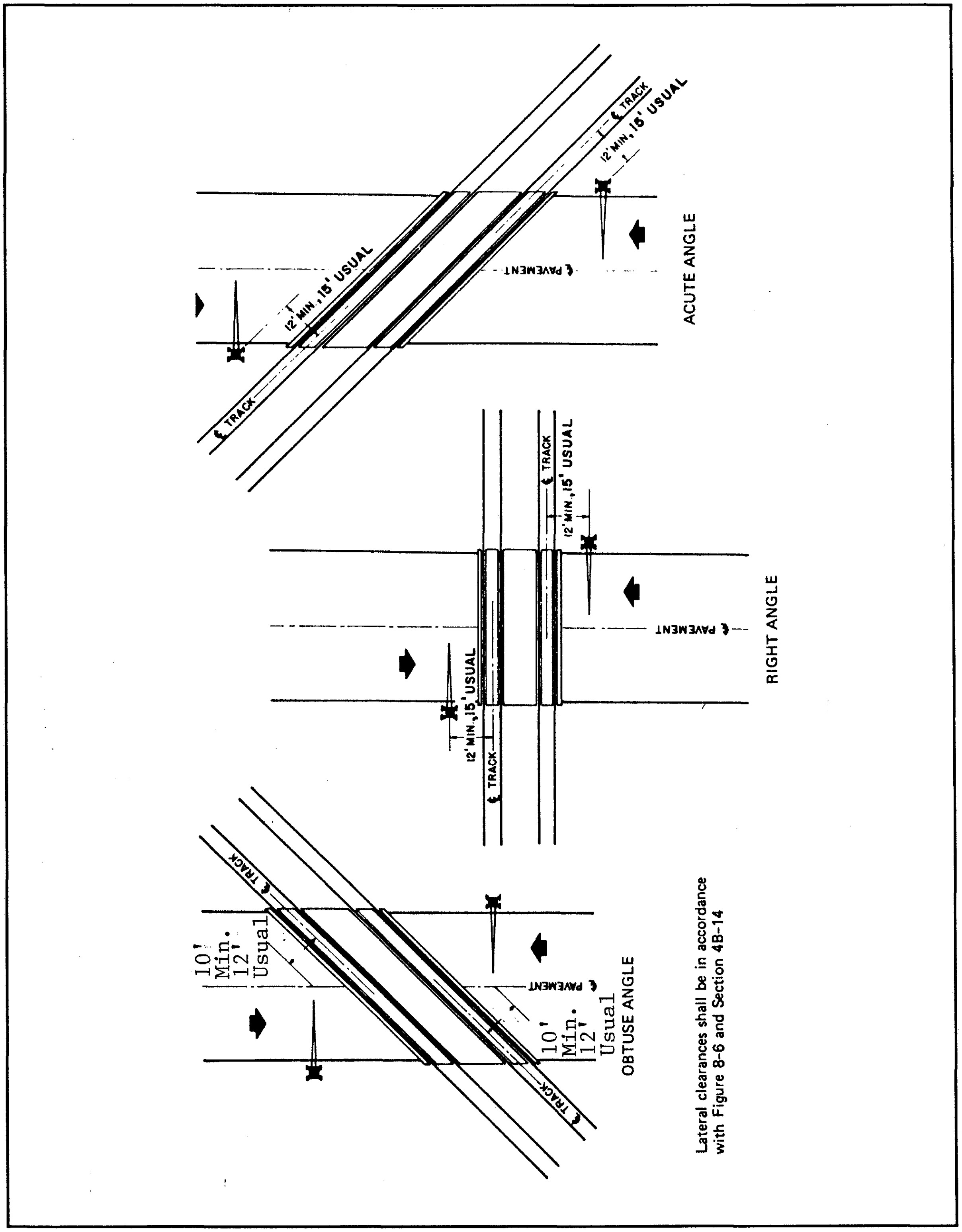


Figure 4-12. Typical Location Plan for Flashing Light Signals and Automatic Gates (3)

An automatic gate serves as a barrier across the highway when a train is approaching or occupying the crossing. The gate is reflectorized with 16-inch diagonal red and white stripes. To enhance visibility during darkness, three red lights are placed on the gate arm. The light nearest to the tip burns steadily while the other two flash alternately. The gate is combined with a standard flashing light signal that provides additional warning before the arm starts to descend, while the gate arm is across the highway, and until the gate arm ascends to clearance. The gate mechanism is either supported on the same post with the flashing light signal or separately mounted on a pedestal adjacent to the flashing light signal post.

In a normal sequence of operation, the flashing light signals and the lights on the gate arm in its normal upright position are activated immediately upon detection of the approach of a train. The gate arm starts its downward motion not less than three seconds after the signal lights begin to operate, reaches its horizontal position before the arrival of the train, and remains in that position as long as the train occupies the crossing. When the train clears the crossing and no other train is approaching, the gate arm ascends to its upright position normally in not more than 12 seconds, following which the flashing lights and the lights on the gate arm cease operation. In the design of individual installations, consideration should be given to timing the operation of the gate arm to accommodate slow moving trucks.

In determining the need for automatic gates, consider the following factors:

- Multiple main line railroad tracks,
- Multiple tracks where a train on or near the crossing can obscure the movement of another train approaching the crossing,
- High speed train operation combined with restricted sight distance,
- A combination of high speed and moderately high volume highway and railroad traffic,
- Presence of school buses, transit buses, or farm vehicles in the traffic stream,
- Presence of trucks carrying hazardous materials, particularly when the view down the track from a stopped vehicle is obstructed,
- Continuance of accidents after flashing light signals have been installed, and
- Presence of passenger trains.

On two-way streets, the gates should cover enough of the approach highway to physically block the motorist from driving around the gate without going into the opposing traffic lane. On multi-lane divided highways, an opening of approximately six feet may be provided for emergency vehicles.

Gates may be aluminum, fiberglass, or wood. Fiberglass or aluminum gates may be designed with a breakaway feature so that the gate disengages from the mechanism when struck. The feasible gate length is 40 feet. When conditions require a longer gate, it may be necessary to place gate assemblies in the median. In these cases, crash cushions or other safety barriers may be desirable. Under no circumstances should signals or gate assemblies be placed in an unprotected painted median.

When no train is approaching or occupying the crossing, the gate arm remains in a vertical position and the minimum clearance from the vertical face of the curb to the nearest part of the gate arm or signal is two feet for a distance of 17 feet above the highway. Where there is no curb, a minimum horizontal clearance of two feet from the edge of a paved or surfaced shoulder is required, with a minimum clearance of six feet from the edge of the traveled highway. Where there is no curb or shoulder, the minimum horizontal clearance from the traveled way is six feet. Where flashing lights or gates exist in the median, additional width may be required to provide the minimum clearance for the counterweight support.

The lateral location of flashing light and gate assemblies must also provide adequate clearances from the track as well as space for construction of the foundations. The area for the foundation and excavation must be analyzed to determine the effects upon sidewalks, utility facilities, and drainage. The minimum clearance between the center of the flashing light assembly and the center of the tracks is 12 feet, although some railroads prefer a 15 foot minimum clearance.

If it is necessary to locate the supporting post in a potentially hazardous position to ensure adequate visibility, some type of safety barrier should be considered.

Warning Bell

The crossing bell is an audible warning signal used to supplement other active warning devices. The bell's effectiveness as a warning to motorists is limited because today's motor vehicles are well-insulated from outside noise. Its present day value is to warn pedestrians and bicyclists. Bells also warn passengers at commuter stations that a train is arriving.

When used, the bell is usually mounted on top of the supporting mast of one of the flashing light signals. The bell is positioned so that the gong is parallel to the sidewalk or street.

The bell may interact with the flashing light in various ways. The most common application is for the bell to sound whenever the flashing light signals are operating. The bell circuitry may be designed so that the bell stops ringing when the lead end of the train reaches the crossing. When gates are used, the bell may be silenced when the gate arms descend to within 10 degrees of the horizontal position. Silencing the bell when the train reaches the crossing or when the gates are down may be desired to accommodate residents of suburban areas.

Train Detection

The design and installation of train detection circuits is performed by railroad signal engineers; however, it is important that highway traffic engineers understand the basic underlying principles of train detection in order to effectively provide for the control of highway traffic at the crossing.

Texas MUTCD Provisions. *To serve their purpose of advising motorists and pedestrians of the approach or presence of trains, locomotives, or railroad cars on grade crossings, the devices employed in active traffic control systems shall be actuated by some form of train detection. Generally, the method is automatic, requiring no personnel to operate it, although a small number of such installations are still operated under manual control. The automatic method currently uses the railroad circuit (a control circuit which includes all train movement detection and logic components which are physically and/or electrically integrated with track structures or associated manual control).*

Railroad circuits insofar as practical shall be designed on the fail-safe principle, which uses closed circuits.

On tracks where train operate at speeds of 20 mph or higher, circuits controlling automatic flashing light signals shall provide for a minimum operation of 20 seconds before arrival of any train on such track. On other tracks used for switching and assembling trains a means shall be provided to warn approaching highway traffic. For automatic gate operation, circuits shall provide for the operating sequence described in section 8C-4.

Where the speeds of different trains on a given track vary considerably under normal operation, special devices or circuits should be installed to provide reasonably uniform notice in advance of all train movements over the crossing. Special control features should be used to eliminate the effects of station stops and switching operations within approach control circuits.

General Provisions. Generally, train detection methods are automatic, requiring no personnel to operate them. The automatic method uses the railroad circuit. This electrical circuit uses the rails as conductors in such a way that the presence of a solid electrical path, as provided by the wheels and axles of a locomotive or railroad car, shunts the circuit and activates the device. The system is also designed to be "fail-safe"; that is, any shunt of the circuit, whether by railroad equipment, vandalism, or "open circuit," such as a broken rail or track connection, activates the crossing signals.

Power supply. Crossing signals are normally dark unless a train is approaching or occupying the crossing. There is no indication to the highway user when power has failed. Crossing control systems also operate on standby battery should commercial power be terminated for any reason. Storage battery standby power is provided to span periods of commercial power failure. The standby assures normal operation of the crossing signals during a commercial power outage, typically providing normal operation for 24 to 48 hours after the loss of commercial power. In some instances, solar panels have been used as an alternative power source for active control devices.

Warning time. On tracks where trains operate at speeds of 20 mph or higher, the circuits controlling automatic flashing light signals shall provide for a minimum operation of 20 seconds before the arrival of any train. The warning time should be of sufficient length to ensure clearance of a vehicle that might have stopped at the crossing and then proceeded to cross just before the flashing light began operation. Factors that can affect the warning time include the width of the crossing, length and acceleration capabilities of vehicles that use the crossing, highway grades, and the condition of the crossing surface.

Care should be taken that the warning time is not excessive. If the motorist cannot see the train approaching (due to sight obstructions or track curvature), excessive warning time may cause a motorist to attempt to cross the tracks despite the operation of the flashing light signals.

Excessive warning time has been determined to be a contributing factor in some accidents. Motorists may stop at an activated flashing light signal and, seeing no train approaching or seeing a distant train moving very slowly, ignore the warning of the signals and cross the tracks. An accident can result. If the motorist is successful in clearing the tracks before the arrival of the train, they may assume that other crossings also have excessive warning time. When they encounter a crossing with the minimum warning time, they may ignore the signal, move onto the crossing, and become involved in an accident. This credibility problem becomes worse if motorists continue to successfully pass through activated signals with excessive warning time.

Train detection systems. There are five basic types of train detection systems in use today: DC track circuitry, AC-DC track circuitry, audio frequency overlay track circuitry, motion sensitive track circuitry, and constant warning time track circuitry. Factors considered in the design and installation of a train detection system include: existing rail and ballast conditions; volume, speed, and type of highway and rail traffic; other train detection circuits possibly used on the same pair of rails for the regulation of train movements; train propulsion currents on electrified lines; track switch locations within the approach warning distances for a crossing; train detection circuits used for other crossings within the approaches; and the number of tracks.

<u>DC Track Circuitry.</u> A relatively simple circuit still used in many crossing warning systems is the DC track circuit. The maximum length of these circuits is more than adequate to provide the necessary warning time for crossing warning systems with today's train speeds. The rails act as conductors of energy supplied by a battery. This energy flows through a limiting resistor to one rail, then through another limiting resistor to the coil of a DC relay, back over the other rail to the battery, thereby completing a simple series circuit. The relay is energized as long as the rails are intact and no train is present on the circuit between the battery and the relay. Insulated joints establish the limits of the circuit; insulated joints are devices placed between adjoining rail sections to electrically isolate them.

In order to provide a means for stopping the operation of the crossing warning system as soon as the train clears the crossing, three track circuits and associated logic elements are required per track. The logic elements are arranged such that, as the train moves through the crossing, the crossing clears for highway traffic as soon as the rear end of the train passes the island section.

All trains activate the crossing warning system as soon as the first set of wheels of the train enters the approach track circuit. This track circuit must be long enough to provide the minimum warning time for the fastest train. A slow train will operate the crossing warning system for a longer period of time. If a train stops before it reaches the crossing, the crossing warning system continues to operate which results in an additional delay to highway traffic.

In order to overcome this problem, approach sections may be divided into several short track circuits and timers incorporated into the logic. This arrangement permits a more consistent warning time. Also, if a train stops in the approach section, a "time-out" feature will deactivate the warning devices to allow highway traffic to move over the crossing.

AC-DC Track Circuitry. The AC-DC track circuit is used quite extensively when approach distances are less than 3,000 feet and no other circuits are present on the rails. The AC-DC circuit is a half-wave rectified AC circuit with all operating equipment located at the crossing. A rectifier is connected across the rails at the far end of the track circuit. As is the case with DC circuits, insulated joints define the limits. An advantage of this circuit is that all control equipment is located in a single house at the crossing. Improved shunting occurs due to the somewhat higher voltages used across the rails.

A simple explanation of the operation of the AC-DC track circuit is that the major portion of the transformer secondary current flows through the rectifier during one-half-cycle and through the relay during the other half-cycle, thus providing a net DC component in the track relay. A shunt on the rails reduces the rail voltage, causing the track relay to release and thereby activating the system. As is the case with DC track circuits, three circuits are normally used to establish train direction.

Audio Frequency Overlay Track Circuitry. The Audio Frequency Overlay (AFO) track circuit is similar to the DC Track Circuit, except it can be superimposed over other circuits which may exist on the rails. Instead of the battery and relay used in the DC circuit, a transmitter and receiver of the same frequency are used for each AFO track circuit. This type of circuit requires no insulated joints.

The AFO track circuit uses an AC signal applied to the rails through a transmitter. The rails transmit the AC signal to a receiver at the opposite end of the track circuit. The receiver converts the AC signal to DC to operate a relay, which performs the function of operating the warning devices via control logic similar to the DC track circuit. Once again, three circuits are required to establish the direction in which the train is moving.

Motion Sensitive Track Circuitry. The Motion Sensitive Track Circuit employs audio frequencies similar to the AFO equipment. It detects the presence, as well as the direction of motion, of a train by continuously monitoring the track circuit impedance. As long as the track circuit is unoccupied or no train is moving within the approach, the impedance of the track circuit is relatively constant. A decreasing track circuit impedance indicates that a train is moving toward the crossing. If a train should subsequently stop, the impedance will again remain at a constant value. If the train is moving away from a crossing, the impedance will increase. Thus, if the train stops on the approach, or moves away from the crossing, the crossing warning system deactivates and the crossing clears for highway traffic.

This type of circuit is advantageous where trains stop or conduct switching operations within the normal approach limits of a particular crossing. All powered equipment is located at the crossing with the additional advantage that insulated joints are not required when applied in a bi-directional manner. Adjacent crossing circuits can be overlaid and overlapped with other train detection circuits. Tuned electrical shunts are required to define the end limits of motion sensitive circuits, and coupling units are required to bridge any existing insulated joints used in conjunction with other types of track circuits, such as might exist for wayside signaling purposes.

Where longer approach zones are required, or where ballast or track conditions dictate, a uni-directional application may be desirable. In this type of application, one device is required for each approach zone, with insulated rail joints used to separate the two approach zones.

Motion sensing devices should be considered for crossings on railroad mainlines, particularly at crossings with variations in train speeds and crossings with a number of switching movements on the approach sections.

Constant Warning Time Track Circuitry. Constant warning time (CWT) equipment has the capability of detecting a train in the approach section, measuring its speed and distance from the crossing, and activating the warning equipment to provide the selected minimum warning time. Thus, regardless of train speed, the system provides a uniform warning time. If a train stops prior to reaching the crossing or is moving away from the crossing, the warning devices deactivate to allow the highway traffic to move over the crossing. With constant warning time equipment, trains can move or switch on the approaches without reaching the crossing and, depending on their speed, never cause the crossing warning devices to activate, thus eliminating unnecessary delays to highway traffic.

CWT devices should be considered for crossings or railroad mainlines, particularly at crossings with variations in train speeds and crossings with a number of switching movements on the approach sections.

Active Advance Warning Sign

A train-activated advance warning sign should be considered at locations where the grade crossing flashing light signals cannot be seen until an approaching motorist has passed the decision point. An activated signal consists of one or two 8-inch yellow Hazard Identification

Beacons mounted above the Advance Warning sign. The beacons connect to the railroad track circuitry and should activate prior to the flashing lights, so that a driver does not pass a dark beacon and then encounter an activated flashing light. Use of activated advance warning signs requires some modification of the track circuitry.

A few states employing train activated beacons also use a supplementary message (either active or passive) with the beacon, such as "TRAIN WHEN FLASHING." The disadvantage of the passive message is that should the beacon fail, then the motorist would not be alerted to the hazardous situation. Figures 4-13 and 4-14 illustrate typical active advance warning sign applications.

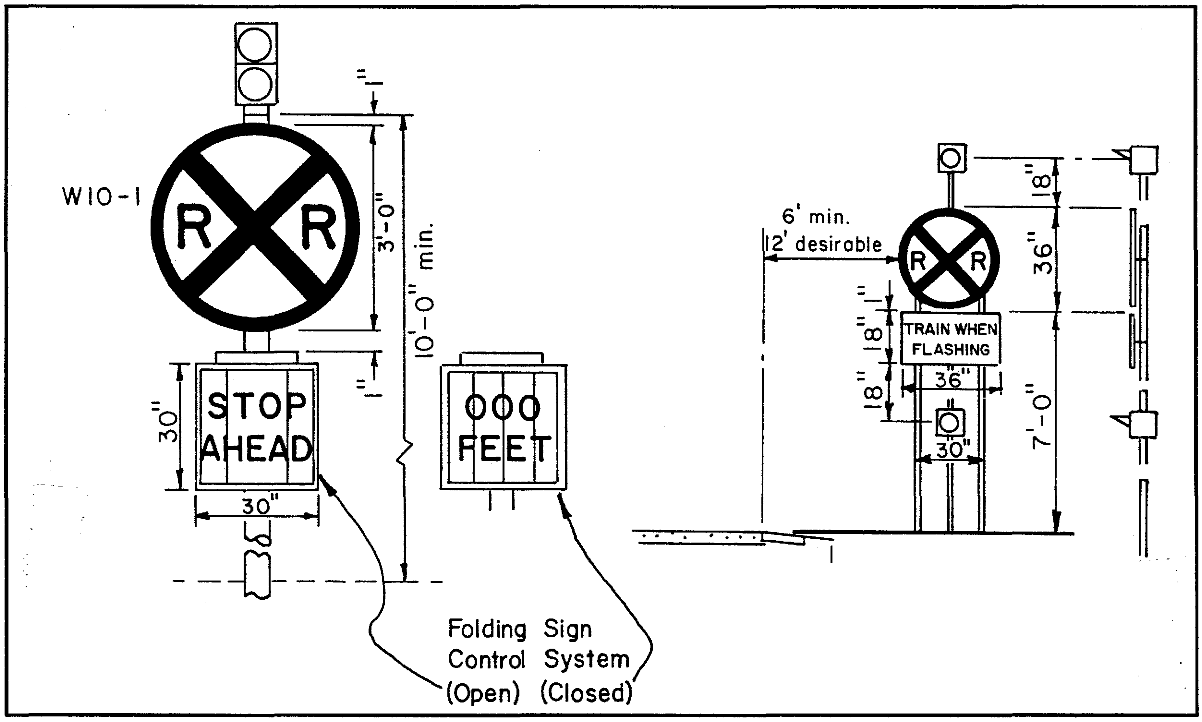


Figure 4-13. Typical Active Advance Warning Signs (4)

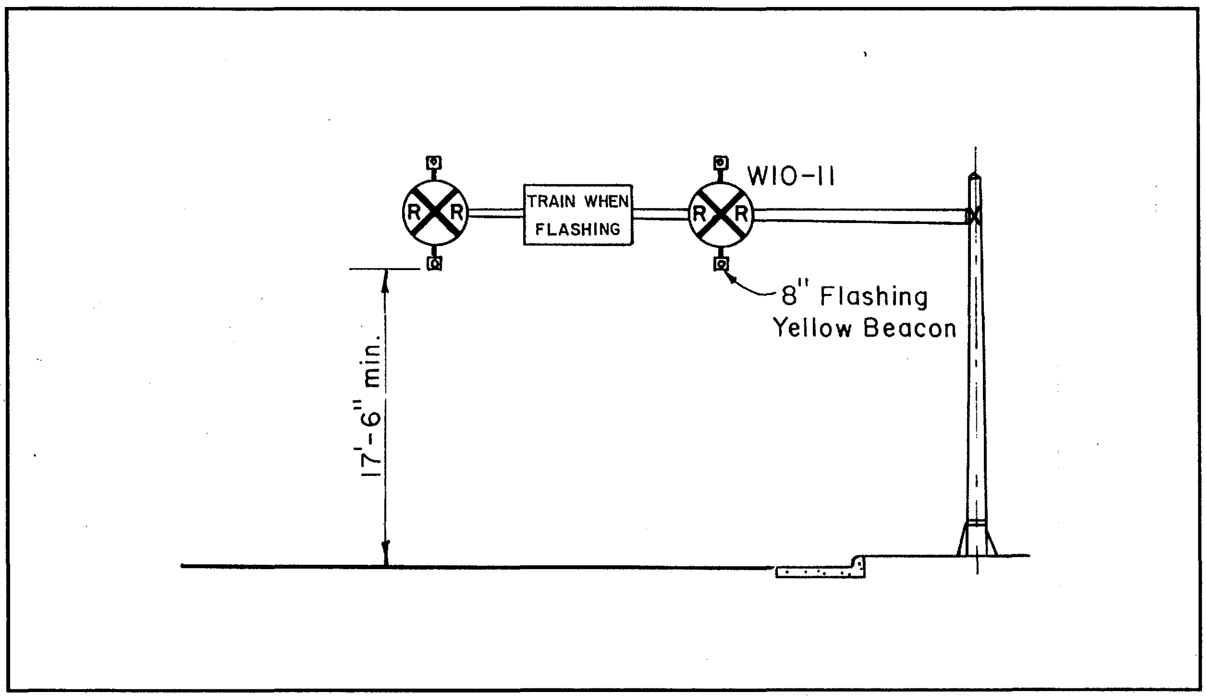


Figure 4-14. Overhead-Mounted Active Advance Warning Sign (4)

Traffic Signals At or Near Highway-Rail Intersections

Texas MUTCD Provisions. *When highway intersection traffic control signals are within 200 feet of a grade crossing, control of the traffic flow should be designed to provide the vehicle operators using the crossing a measure of safety at least equal to that which existed prior to the installation of such signals. Accordingly, design, installation, and operation should be based upon a total systems approach in order that all relevant features may be considered.*

When the grade crossing is equipped with an active traffic control system, the normal sequence of highway intersection signal indications should be preempted upon approach of trains to avoid entrapment of vehicles on the crossing by conflicting aspects of the highway traffic signals and the grade crossing signals. This preemption feature requires an electrical circuit between the control relay of the grade crossing signals and the controller assembly in order to establish and maintain the preempted condition during the time that the grade crossing signals are in operation. Where multiple or successive preemption may occur from differing modes, train actuation should receive first priority and emergency vehicles second priority.

Where a signalized highway intersection is adjacent to a grade crossing not provided with an active traffic control system, the possibility of vehicles being trapped on the crossing remains and preemption of the signal controller is usually required. However, at some locations, the characteristics of the crossing and intersection area along with favorable speeds of both vehicular and train traffic may permit alternate methods of warning traffic. Where preemption of the traffic signal control is determined to be desirable, consideration should be given to the installation of active traffic control devices at the grade crossing, inasmuch as the cost of the grade crossing devices would usually represent a minor addition to the costs of the railroad circuits required for the preemption function.

Except under unusual circumstances, preemption should be limited to the highway intersection traffic signals within 200 feet of the grade crossing.

The preemption sequence initiated when the train first enters the approach circuit, shall at once bring into effect a highway signal display which will permit traffic to clear the tracks before the train reaches the crossing. The preemption shall not cause any short vehicular clearances and all necessary vehicular clearances shall be provided. However, because of the relative hazards involved, pedestrian clearances may be abbreviated in order to provide the track clearance display as early as possible.

To avoid misinterpretation during the time the clear-out signals are green, consideration should be given to the use of 12-inch red lenses in the signals which govern highway traffic movement over the crossing with adequately screened or louvered green lenses in the clear-out signals beyond the crossing.

After the track clearance phase, the highway intersection traffic control signals should be operated to permit vehicle movements that do not cross the tracks, but shall not provide a through circular green or arrow indication for movements over the tracks. This does not prohibit green indications for highway traffic movements on a roadway paralleling the tracks.

Where feasible, traffic control signals near grade crossings should be operated so that vehicles are not required to stop on the tracks even though in some cases this will increase the waiting time. The exact nature of the display and the location of the signals to accomplish this will depend on the physical relationship of the tracks to the intersection area.

Highway traffic control signals shall not be used on mainline railroad crossings in lieu of flashing light signals. However, at industrial track crossings and other places where train movements are very slow (as in switching operations), highway traffic control signals may be used in lieu of conventional flashing light signals to warn vehicle operators of the approach or presence of a train. The provisions of this part relating to traffic signal design, installation, and operation are applicable as appropriate where highway traffic signals are so used.

Application. Preemption of traffic control signals at intersections near or adjacent to highway-rail intersections attempts to prevent entrapment of vehicles upon the crossing immediately prior to the arrival of a train. Queues may form at intersections adjacent to railroad crossings as vehicles await a green signal. In the event that a train arrives before the crossing clears, the potential for a train to strike a vehicle is relatively high.

An Institute of Transportation Engineers (ITE) publication entitled "Preemption of Traffic Signals at or Near Railroad Grade Crossings" provides six criteria for adequate grade crossing preemption and coordination (10). These recommended practices should be considered supplementary to the requirements set forth in the MUTCD. The six criteria do not substitute for any MUTCD provisions regarding the operation of traffic signals at or near highway-rail intersections.

- Every green signal indication shall be terminated with a yellow indication as specified in the MUTCD.

- When preempted by train movements, the traffic signal (after provision of the proper change intervals) shall immediately provide a short green interval to the approach crossing the track to clear any vehicles that may be on or so close to the track as to be in danger or where vehicles may interfere with the operation of crossing gates. The traffic signal shall subsequently display indications to prevent vehicles from entering the track area, while at the same time traffic movements which do not conflict with the railroad movement may be permitted. If, at the time of preemption, the green interval is on an approach that does not cross the track, the green interval would be immediately terminated with a standard yellow change interval in order that green time may be given to the approach crossing the track.

- Conflicting indications shall not be presented.

- "Black-out" signs may be used to good advantage in some instances and for this reason are shown as optional control measures in the figures in Appendix C.

- Optical limiting devices may be employed for traffic signal indications in proximity to railroad grade crossings to preclude driver observance of conflicting or misleading indications.

- Advance signals, flashing beacons or similar signal units may be employed in advance of grade crossings to supplement standard grade crossing signals and to warn approaching motorists of an approaching train or occupied crossing. The justification for such advance warning must be determined by investigation of conditions at the site. Advance warning signals may be used regardless of the use of crossing gates. Advance warning signals should be located in relation to the railroad crossing the same as other advance warning devices are located in relation to the hazard to which they refer.

Appendix C contains typical railroad preemption sequences for various intersection configurations. These figures are representative of most geometric conditions in which preemption may be appropriate.

Supplementary Signs Used With Active Traffic Control Systems

Highway signs often supplement active grade crossing traffic control devices or inform drivers of certain restrictions. The following section describes these supplementary signs.

Railroad Signal Malfunction Sign. *The Railroad Signal Malfunction Sign (R15-4) is intended for use on grade crossing warning systems using flashing lights or automatic gates. It should be attached below the railroad crossbuck sign (R15-1) and have a minimum mounting height of five feet. One sign should be placed for each roadway approach direction. The standard and minimum size is 24 by 12 inches.* Under Texas state law, these signs are required to be in place at all public highway-rail intersections equipped with train-activated signal devices. Section 6.4 contains additional information regarding this sign and the Texas 1-800 Signal Malfunction Program. Figure 4-15 illustrates the Railroad Signal Malfunction Sign.

Figure 4-15. Railroad Signal Malfunction Sign (R15-4)

Turn Restrictions. *At a signalized highway intersection within 200 feet of a grade crossing, where the intersection traffic control signals are preempted by the approach of a train, all existing turning movements toward the grade crossing may be prohibited by proper placement of a NO RIGHT TURN sign (R3-1a) or a NO LEFT TURN sign (R3-2a) or both. In each case, these signs should apply only when the restriction is to be effective.*

Flagging

At certain grade crossings, railroad companies may have a policy to use a flagger to stop highway vehicles and pedestrians before allowing a train to move over the crossing. These crossings typically have only the passive warning signs. Railroad operating rules state that railroad crews should flag crossings which do not have active control devices when railroad cars are not headed by an engine. The flagger may operate stationed on the ground or located on the leading end of the movement. Some railroad companies require flagging when the train has been split or when switching operations necessitate numerous movements across the roadway.

There are no specific instructions on how a railroad flagger is to stop highway vehicles or on the use of fusees or flares; however, railroad operating rules establish a standard flag or lamp signal for train operations.

The appearance of the flagger is important. The ideal flagger is highly conspicuous and easily identified as a person who is to provide traffic directions (authoritative). Not all railroad-highway grade crossings have traffic or environmental conditions that would facilitate flagging. If flagging occurs at night, it is important to illuminate the crossing so that both the flagger and the train can be seen.

New Technology

Several new and innovative technologies are currently being tested in the United States. This section briefly describes two of these technologies, the Automated Locomotive Horn System and Automated Enforcement.

Automated Locomotive Horn System. The *Automated Locomotive Horn System* is an audible traffic control device located at the highway-rail intersection. Upon the approach of a train, the system gives an audible warning to approaching highway traffic which simulates the warning provided by a locomotive whistle. The system was recently introduced and is currently being tested. The automated horn system may be an improvement over traditional locomotive whistles because the warning time and audible pattern are consistent each time the system activates. It is also a relatively low-cost alternative which may have less noise impact upon adjacent property.

Automated Enforcement. Automated enforcement technology is being evaluated in Arkansas and California. A computer-controlled high-speed camera mounted near the highway-rail intersection activates when a train and a highway vehicle approach the intersection simultaneously. If the vehicle strays into a "restricted" area, in other words if the driver violates the law by driving through the crossing in front of the train or around lowered gates, loop detectors in the highway pavement detect this action. The camera activates and provides photographs of the violation taking place as well as the vehicle license plate. The information from the film allows law enforcement authorities to prosecute these violations or issue warning citations.

4.4 OTHER SAFETY IMPROVEMENT OPTIONS

In some instances, active or passive traffic control devices alone may not be sufficient to correct safety deficiencies at highway-rail intersections. The effectiveness of traffic control devices might be enhanced under these circumstances by considering several additional improvement alternatives.

Sight Distance Obstructions

Available sight distances help to determine the safe speed at which a vehicle may approach the highway-rail intersection. Three sight distances must be considered: the distance ahead to the crossing (approach sight distance); the distance to and along the track(s) on which a train might be approaching (quadrant sight distance); and the distance along the track(s) in either direction from a vehicle stopped at the crossing (track sight distance).

Approach Sight Distance. A driver must determine whether a train is occupying the crossing, the type of traffic control at the crossing (e.g., active or passive), and if there is an active traffic control device, its status indicating the approach or presence of a train. The vehicle must be capable of being stopped short of the crossing; the available approach sight distance may be a determining factor limiting the speed of the approaching vehicle.

The relationship between vehicle speed and approach sight distance is given by the formula:

$$d_H = 1.47\ V_v\ t + \frac{V_v^2}{30f} + D + d_e$$

where:

d_H	=	the sight distance, measured along the highway from the nearest rail to the driver of an approaching vehicle, which allows the vehicle to be safely stopped without encroachment of the crossing area, feet
V_v	=	velocity of the vehicle, mph
t	=	perception and reaction time, sec (assumed = 2.5 sec)
f	=	coefficient of friction
D	=	distance from the stop line or front of the vehicle to the nearest rail, feet (assumed = 15 feet)

d_e = distance from driver to the front of the vehicle, feet (assumed = 10 feet)

Values of the coefficient of friction, f, for various vehicle speeds are given in Table 4-3.

Table 4-3. Coefficients of Friction

Speed (mph)	f
10	0.40
20	0.40
30	0.35
40	0.32
50	0.30
60	0.29
70	0.28

Source: Reference (4)

Table 4-4 indicates the minimum safe sight distance (d_H) along the highway for given vehicle approach speeds. These distances are calculated for certain assumed conditions (e.g., 65-foot tractor-trailer combination, level grades). Recognize that the values in Table 4-4 are based upon a "critical" vehicle and wet pavement conditions. The required sight distances, therefore, are rather conservative, and provide a reasonable factor of safety for most types of vehicles. These values may not necessarily represent conditions actually present at the crossing.

Quadrant Sight Distance. The distance to and along the tracks in either direction utilizes a "sight triangle" in the quadrants on the vehicle approach side of the track. The distance of the vehicle driver from the track (d_H), the distance of the train from the crossing (d_T), and the unobstructed sight line from the driver to the front of the train form the sight triangle. The relationship between vehicle speed, maximum timetable train speed, distance along the highway, and distance along the track is stated by the formula:

$$d_T = \frac{V_T}{V_v}\left(1.47V_v\, t + \frac{V_v^2}{30f} + 2D + L + W\right)$$

where:

d_T = sight distance along the railroad tracks to permit the vehicle to cross and be clear of the intersection upon arrival of the train, feet

V_T = velocity of the train, mph

L = length of the vehicle, feet (assumed = 65 feet)

W = distance between outer rails, feet (assumed = 5 feet for single track)

Table 4-4. Sight Distances for Combinations of Highway Vehicle and Train Speeds

Train Speed (mph)	Vehicle Speed (mph)							
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**
	Distance Along Railroad From Crossing, d_T (feet)							
10	240	145	103	99	103	112	122	134
20	480	290	207	197	207	224	245	269
30	719	435	310	296	310	337	367	403
40	959	580	413	394	413	449	489	537
50	1,200	725	517	493	517	561	611	671
60	1,439	870	620	591	620	673	734	806
70	1,679	1,015	723	690	723	786	856	940
80	1,918	1,160	827	789	827	898	978	1,074
90	2,158	1,305	930	887	930	1,010	1,101	1,209
		Distance Along Highway From Crossing, d_H (feet)						
		9	132	221	338	486	659	865

Source: Reference (5)

The remaining variables (V_v, t, f, and D) are as previously defined. Table 4-4 lists the distance d_T for several selected highway speeds and train speeds.

Track Sight Distance. In the case of a vehicle stopped at a crossing (e.g., tanker truck or school buses required by law to stop), the driver needs to see both ways along the tracks to determine whether a train is approaching and estimate its speed. The driver needs to have a sight distance along the tracks that will permit sufficient time to accelerate and clear the crossing prior to the arrival of the train, even though the train might come into view as the vehicle is beginning its departure. The required distance along the tracks is a function of train speeds and various other factors, as shown in the following equation:

$$d_T = 1.47V_T\left(\frac{V_G}{a_1} + \frac{L + 2D + W - d_a}{V_G} + J\right)$$

where:

V_G	=	maximum speed of vehicle in selected starting gear, feet/sec (assumed = 8.8 feet/sec)
a_1	=	acceleration of vehicle in starting gear, feet/sec^2 (assumed = 1.47 feet/sec^2)
J	=	sum of the perception time and the time required to activate the clutch or an automatic shift, sec (assumed = 2 sec)
d_a	=	distance the vehicle travels while accelerating to maximum speed in first gear, feet

The term d_a is given by the equation:

$$d_a = \frac{V_G^2}{2a_1}$$

For the assumed values V_G=8.8 feet/sec and a_1=1.47 feet/sec^2, d_a=26.4 feet. The remaining variables (d_T, V_T, L, D, and W) are as defined previously. Values of track sight distance for given train speeds are given by Table 4-4 under the column heading for vehicle speed of zero.

Removal of Sight Obstructions. Three areas of the highway-rail intersection environment should be kept free from obstructions. The area on the highway approach to the crossing should be evaluated to determine if it is feasible to remove obstructions which prevent the motorist from viewing the crossing, a train occupying the crossing, or the traffic control devices at the crossing. Clutter is often a problem in this area, consisting of numerous and various traffic control devices, roadside commercial signing, utility and lighting poles, and vegetation. Horizontal and vertical alignment can also obstruct the motorists view.

Removal of clutter occurs with minimal expense. Traffic control devices unnecessary for the safe movement of vehicles through the crossing should be removed and/or relocated. Vegetation should be trimmed periodically. Billboards should be prohibited on the approaches altogether.

Changes to horizontal and vertical alignment are usually more expensive. When constructing new highways or reconstructing existing ones, care should be taken to minimize the effects of horizontal and vertical curves at a crossing.

The approach sight triangle should be free of obstructions. It can encompass a rather large area that is usually privately-owned. In rural areas, this sight triangle may contain crops or farm equipment that block the motorist's view. Clearing the sight triangle may be difficult to achieve; however, when possible, vegetation should be trimmed, billboards and parking prohibited, and small hills regraded to permit vehicles to travel at the legal speed for the approach. The area along the track, usually located on the railroad right-of-way, should be free of obstructions. Vegetation should be trimmed periodically. If practical, this area should be free of parked vehicles and standing railroad equipment as well.

Engineering Study for Determining Sight Distance. An engineering study should be conducted to determine if the three types of sight distance can be provided as desired. If not, other alternatives should be considered. The highway speed might be reduced, by installation of an advisory or regulatory speed sign, to a level which conforms with the available sight distance. It is important that motorists understand why the speed reduction is necessary; otherwise, it may be ignored. Enforcement is one option for achieving this objective. At crossings with passive control devices only, consideration might be given to the installation of active traffic control devices.

On the approaches to highway-rail intersections, an area for railroad-related devices should be established and maintained. This area should extend longitudinally along both approaches to the crossing. Where possible, all other roadside appurtenances such as highway signs, utility poles, and lighting poles should be located in advance of, or beyond, this area. In this manner the information presented to the approaching driver is limited to railroad warning and controls, thus enhancing the conspicuity and effectiveness of these devices.

Obstructions in the sight triangle in any of the four quadrants can result in restricted sight distance for at least one approach. If such obstructions are vegetation or other natural features, they should be removed. It may not be feasible to remove other obstructions such as buildings. If this is the case, other alternatives are available.

The first alternative is the installation of active traffic control devices. Another alternative is to reduce motor vehicle speeds, through the use of regulatory or warning signs, to a level which conforms to the minimum sight triangle available; however, this reduced speed should generally not be less than 15 miles per hour. The speed restriction may exist only in one direction, depending on the quadrants in which sufficient sight triangles cannot be established. Use of signing to reduce speeds should be limited to crossings with low exposure rates. Monitoring of these crossings should occur on a regular basis to ensure speed reductions are adequate.

When severe sight restrictions exist, such as in heavily industrialized areas, stop signs are an alternative; however, stop signs at highway-rail intersections must be used only in accordance with the MUTCD and, as with any new traffic control device, only after an appropriate engineering study has been performed. Care should also be taken to ensure that adequate track sight distance is available for stopped vehicles. In the event that track sight distance is less than required, stop signs should not be used. Prior to taking any action at the crossing, beyond removing vegetation or other natural features to reestablish adequate sight triangles, it is desirable to conduct an engineering study of the location with a diagnostic team.

Situations can arise where active crossing devices are necessary; however, due to the horizontal and vertical alignment of the highway, there is not sufficient sight distance for motorists to properly respond. Although such cases may be rare, proper treatment is important. Where conditions are such that neither the minimum sight triangle nor stopping sight distance to the active devices is attainable, flashing yellow beacons may be added to the advance warning sign.

Highway Geometry

The AASHTO *Green Book* (5) and *Railroad-Highway Grade Crossing Handbook* (1) each make recommendations regarding desirable geometric design of the highway-rail intersection.

Horizontal Alignment. Desirably, the highway should intersect the tracks at a right angle with no nearby intersections or driveways. This layout enhances the driver's view of the crossing and tracks and reduces conflicting vehicular movements from crossroads and driveways. To the extent practical, crossings should not be located on either highway or railroad curves. Roadway curvature limits a driver's view of a crossing ahead and a driver's attention may be directed toward negotiating the curve rather than looking for a train. Railroad curvature may limit a driver's view down the tracks from both a stopped position at the crossing and on the approach to the crossings. Those crossings located on both highway and railroad curves present maintenance problems and poor rideability for highway traffic due to conflicting superelevation.

Horizontal alignment should permit drivers to operate their vehicles at posted speeds without unexpected intersections with railroads or other highways. Good geometric design requires:

- Elimination of sharp curves near an intersection,
- Right angle crossings whenever possible, and
- Minimal angle of skew where skewed crossings are required.

Site improvements may require purchase of additional right-of-way. Relocation of one or both traveled ways may be required. The total cost and benefits of such improvements must be compared with the cost and benefits of installing active control devices.

Vertical Alignment. It is desirable that the intersection of the highway and railroad be as level as possible from the standpoint of sight distance, rideability, braking and acceleration distances. Vertical curves should be of sufficient length to insure an adequate view of the crossing.

In some instances, the roadway vertical alignment may not meet acceptable geometrics for a given design speed because of restrictive topography or limitations of right-of-way. Acceptable geometrics necessary to prevent drivers of low-clearance vehicles from becoming caught on the tracks would provide the crossing surface at the same plane as the top of the rails for a distance of 2 feet outside of the rails. The surface of the highway should also not be more than 3 inches higher nor 6 inches lower than the top of the nearest rail at a point 30 feet from the rail unless track superelevation dictates otherwise.

Table 4-5. Rates of Change in Elevation for Given Design Speeds

Design Speed (mph)	Distance Required for 1.0-foot Change in Elevation (feet)
40	175
50	200
60	225
70	250
80	275

Source: Reference (4)

Cross Section. Requirements for the cross section of the highway at grade crossings differ little from that for highway intersections. A few important considerations are:

- The cross section should be designed to ensure that the driver always has some escape route available.

- The pavement surface adjacent to the track should be at the same elevation as the track. This design often requires warping the pavement from its normal cross slope to a plane even with the track. When warping is required, the rate of change in elevation of the pavement edges should not exceed the rates shown in Table 4-5.

Drainage

Good highway and railroad design and maintenance practices meet drainage requirements for most situations. Nevertheless, drainage problems frequently arise. Slope and ditch maintenance and debris removal should always be included in maintenance activities around railroad-highway grade crossings. Also, subgrade drainage is often required when highway construction blocks normal ballast and side ditch drainage along the railroad.

Illumination

Providing adequate lighting, particularly at rural locations, may substantially improve safety at highway-rail intersections by enhancing the motorist's view of the crossing. It may be of particular aid in assisting the driver to detect a train that is already occupying the crossing at night.

Texas MUTCD Requirements. *At grade crossings where a substantial amount of railroad operation is conducted at night, particularly where train speeds are low, where crossings are blocked for long periods, or accident 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 location of luminaires for grade crossing illumination are contained in the American National Standard Practice for Roadway Lighting, RP8. In any event, luminaires shall be so located and light therefrom so directed 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.

Application. The lighting of a grade crossing can be effective in reducing nighttime accidents. It is important to note that illumination at highway-rail intersections primarily lights the railroad tracks, not the highway. The tracks are illuminated to assist the driver in detecting a train at or near the crossing. Illuminating most crossings is feasible since commercial power is available at approximately 90 percent of all public crossings.

The decision to illuminate a crossing should follow an engineering analysis of crossing conditions. Illumination may be effective under the following crossing conditions:

- Substantial nighttime train operations,
- Train speeds are low,
- Crossings are blocked for long periods,
- Accident history indicates motorists have difficulty in detecting the train or grade crossing control devices at night,
- Poor alignment of roadway approach so that the vehicle headlight beam does not fall on the train, or
- Low ambient light levels.

Recommendations for the placement and type of luminaires are available in the Federal Highway Administration's *Roadway Lighting Handbook* (11), the AASHTO's *An Informational Guide for Roadway Lighting* (12), and from the Illuminating Engineering Society's *American National Standard Practice for Roadway Lighting* (13).

On uncurbed roadways, luminaire supports should be erected as far as practical from the traveled way; twenty feet is desirable. On curbed roadways, 4 feet from the curb is desirable, 2 feet is minimum. When located within the clear zone defined in the *Guide for Selecting, Locating and Designing Traffic Barriers* (14), luminaire supports should have breakaway bases. If possible, luminaires should also be located to insure damaged poles will not fall on the tracks.

The luminaires should be carefully positioned to ensure that the motorist or railroad operator is not subjected to glare from the light source. If glare cannot be eliminated, cutoffs should be provided to shield the cone of vision of the motorist or train operator. In rural areas with high train speeds, some lighting should be directed down the tracks to illuminate the sides of an approaching train. Trains and grade crossing devices should not be backlit.

Train-activated illumination circuitry exists, but it should not be used as a substitute for active traffic control devices. Whether the illumination should be activated by an approaching train or should operate continuously during the night depends upon the characteristics of the individual crossing.

Barriers

The use of barriers with grade crossing control devices is generally discouraged. The purpose of a longitudinal barrier, such as a guardrail, is to protect the motorist by containing and redirecting the vehicle, not the traffic control device. Their use should be limited to situations where hitting the object (e.g., control device) is more hazardous than hitting the guardrail and possibly redirecting the vehicle into a train. The following general guidelines reflect some of the limitations and criteria for the use of barriers.

- Longitudinal guardrails should not be used for railroad traffic control devices unless the guardrail is otherwise warranted, as for a steep embankment. The reason for not using longitudinal guardrail is that it might redirect a vehicle into a train.

- The round guardrail installations used by some railroad companies create the same type of hazard to the driver as the signal mast, only a larger one. They do, however, serve to protect the signal mast. Since functioning warning devices are vital to the safety of highway grade crossings, the round guardrail may be used in locations with large truck volumes. Their use should be limited to low speed roadways.

- When installing guardrail around two adjacent masts, the guardrail should be installed according to the requirements of the *Guide for Selecting, Locating and Designing Traffic Barriers* (14).

- On some crossings it may be possible to use crash cushions to protect the motorist from the hazard of the railroad traffic control devices. As crash cushions are designed to capture rather than redirect a vehicle, they will not normally redirect a vehicle into a train.

Driver Education

Nearly all grade crossing accidents involve some degree of driver error. One of the objectives of driver education is to impart the knowledge, skills, habits, and attitudes to enable a driver to perform in a manner that will minimize the probability of causing or being involved in a traffic accident. Education can be divided into three parts: General Public Education, Driver Education, and Elementary School Education.

Over the years there have been many programs aimed at educating the public about the inherent hazards of grade crossings. Public education efforts carefully planned and executed, and aimed at the driving public via the most attractive media possible, are typically most successful. The messages should be presented in prime time, and in the most popular magazines and newspapers. Public officials should endorse and support a public information campaign. The campaign should be coordinated with other traffic safety messages and activities of the state or local communities. Above all, the messages should be positive and informative, with the crossings depicted as dangerous, but necessary.

Driver education is an area that has considerable potential for improving crossing safety. Unfortunately, as presently taught, driver education does not increase the driver's safety potential with respect to grade crossings. The instruction generally consists of teaching recognition of the standard railroad grade crossing signs and pointing out the legal requirement to stop at a flashing light signal or gate. At the very least, a student driver should traverse a grade crossing as part of his or her behind-the-wheel training.

Enforcement

Law enforcement, in the broadest sense of the term, has often been cited as one means of improving grade crossing safety. Law enforcement agencies and associations recognize their potential, and many have taken an active interest in promoting grade crossing safety. Nevertheless, law enforcement practices throughout the nation vary widely, ranging from excellent programs to total inattention.

Accident data have shown that a majority of drivers involved in grade crossing accidents are familiar with the crossing at which the accident occurred. It seems that in spite of a driver's perception of a potential hazard at a grade crossing, a habit of inattention develops after repeated crossings without the presence of a train.

Enforcement can positively affect driver safety potential at grade crossings, but analysis is required to determine whether the benefits justify the costs. The expense of increased patrols, especially at high accident locations, might be cost-effective, since accident data show the frequency of collisions to peak at the times of the greatest commuter traffic. Police patrols could effectively cover a number of high accident locations at peak traffic periods.

Unique approaches to enforcement of grade crossing safety laws have been developed in Texas and around the nation.

- The "Trooper on the Train" program has had some degree of success in ticketing motorists who violate the law at grade crossings (e.g., failure to stop at an activated signal, running around the gates). A state trooper rides in the cab of the locomotive and observes the license plate numbers of violators. The trooper radios this information to a second trooper in a police vehicle, who then stops the driver and issues a citation.

- Automated enforcement has been implemented at a small number of crossings in both Arkansas and California. A computer-controlled, high-speed camera is mounted near the highway-rail intersection. The system activates when a train and a highway vehicle approach the intersection simultaneously. If the vehicle strays into a "restricted" area, in other words if the driver violates the law by driving through the crossing in front of the train or around lowered gates, loop detectors in the highway pavement detect this action. The camera activates and provides photographs of the violation taking place, as well as the vehicle license plate. The information from the film can be used by law enforcement authorities to prosecute these violations.

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5.0 CONSTRUCTION / MAINTENANCE ACTIVITIES

5.1 INTRODUCTION

Traffic control for highway-rail intersection construction is very similar to traffic control for highway construction. The major difference is that the work area is in joint use right-of-way and the possibility of conflict exists between rail and highway traffic, as well as in construction operations. Construction areas can present the motorist unexpected or unusual situations; therefore, special care should be taken in applying traffic control techniques in these areas.

Construction practice, agency policy, labor work rules, and State and Federal regulations all contribute to the complexity of crossing work zone traffic control. When highway construction and maintenance activities at the intersection take place within 15 feet of an active rail, railroad personnel should be present. Railroad maintenance and construction of crossing signals or surfaces will often require some measure of control of highway traffic.

5.2 IMPORTANCE OF COMMUNICATION

An open communication channel between railroad and highway personnel is essential to the coordination of crossing construction and maintenance. The railroad engineering department should notify all highway agencies several weeks in advance of track resurfacing or crossing reconstruction operations that require crossings to be closed to highway traffic. The exact schedule of the track work activity should be confirmed by the railroad engineering department a few days before the actual work takes place. Proper coordination will ensure minimal crossing closure time and reduce the cost of work zone traffic control activities.

Highway personnel should inform railroad engineering departments of any work scheduled within the railroad right-of-way several weeks before the work begins. The schedule of work activities should be reconfirmed with railroad officials a few days before the crews are to be on site.

5.3 GENERAL CONSIDERATIONS

If removal of the entire crossing is necessary, the roadway should be closed and traffic detoured over an alternate route or temporary bypass. Crossing closures on high volume rural and urban highways should be avoided during weekdays or peak hours. Traffic control for the construction or maintenance of crossings should be the same as that for highway construction and should comply with the applicable requirements of the MUTCD.

Traffic safety in construction zones should be an integral and high priority element of every project from planning through design and construction. Similarly, maintenance work should be planned and conducted with the safety of motorists, pedestrians, workers, and train crews in mind at all times. The basic safety principles governing the design of crossings should also govern the design of construction and maintenance sites. The goal should be to route traffic through such areas with geometrics and traffic control devices comparable, as nearly as possible, to those for normal crossing situations.

5.4 TRAFFIC CONTROL GUIDELINES

A traffic control plan, in detail appropriate to the complexity of the work project, should be prepared and understood by all responsible parties before the site is occupied. A traffic control plan is required to be included in the plans, specifications, and estimates for all Federal-aid projects as indicated in the *Federal-Aid Highway Program Manual* (15). Usually, the highway agency develops the traffic control plans. Any changes in the traffic control plan should be approved by an individual trained in safe traffic control practices.

The method of accomplishing traffic control is worked out between the railroad and the State or local highway agency. There is wide latitude as to which party does the work. The individuals who prepare or implement the traffic control in work areas should be trained in the requirements of the MUTCD.

Traffic movement should be inhibited as little as possible. Traffic control in work zones should be designed on the assumption that motorists will only reduce their speeds if they clearly perceive a need to do so. Speed zoning should be avoided as much as possible. Guidelines for determining speed limits in detours, transitions, and median crossovers are as follows:

- Detours and crossovers should be designed for speeds equal to the existing speed limit, if at all possible. Speed reductions should not be more than 10 mph below the speed of the entering highway.

- Where a speed reduction greater than 10 mph is unavoidable, the transition to the lower limit should be made in steps of not more than 10 mph.

- Where severe speed reductions are necessary, police or flaggers may be used in addition to advance signing. The conditions requiring the reduced speed should be alleviated as soon as possible.

Frequent and abrupt changes in geometrics, such as lane narrowing, dropped lanes, or main highway transitions, that require rapid maneuvers should be avoided. Provisions should be made for the safe operation of work vehicles, particularly on high speed, high volume highways. Construction time should be minimized to reduce exposure to potential hazards.

Care should be taken to avoid the formation of queues over railroad tracks. Work zone activities may necessitate stopping traffic. Likewise, the presence of intersections within the work zone may result in queues of stopped traffic. A vehicle stopped on the tracks is at risk of being struck by a train. The situation is worsened by the fact that the vehicle may be "trapped" or unable to move off of the tracks on account of the other stopped vehicles ahead of and behind it. Flaggers and traffic control devices can be strategically positioned to warn drivers and to prevent queues from forming on the tracks. Work zone signing that warns drivers not to stop on the tracks may also be appropriate.

Motorists should be guided in a clear and positive manner while approaching and traversing construction and maintenance work areas. Adequate warning, delineation, and channelization by means of proper pavement marking, signing, and use of other devices that are effective under varying conditions of light and weather should be provided to assure the motorist of positive guidance in advance of and through the work area.

Inappropriate markings should be removed to eliminate any misleading cues to drivers under all conditions of light and weather. On short-term maintenance projects, it may be determined that such removal is more hazardous than leaving the existing markings in place. If so, special attention must be paid to provide additional guidance by other traffic control measures. Flagging procedures can provide guidance to the motorist traversing the work area and should be employed when required to control traffic, or when all other methods of traffic control are inadequate to warn and direct drivers.

Each person whose actions affect maintenance and construction zone safety should receive training appropriate to the job decisions each individual is required to make. Only those individuals qualified by means of adequate training in safe traffic control practices and who possess a basic understanding of the principles established by applicable standards and regulations, including those of the MUTCD, should supervise the selection, placement, and maintenance of traffic control devices in maintenance and construction areas.

To insure acceptable levels of operations, routine inspection of traffic control elements should be performed. This inspection should verify that all traffic control elements of the project are in conformity with the traffic control plan and are effective in providing safe conditions for motorists, pedestrians, and workers.

The maintenance of roadside safety requires constant attention during the life of the construction zone because of the potential increase in hazards. To accommodate run-off-the-road incidents, disabled vehicles, or other emergency situations, it is desirable to provide an unencumbered roadside recovery area that is as wide as practical. Channelization of traffic is accomplished by the use of pavement markings and signing, flexible posts, barricades, and other lightweight devices that will yield if struck by an errant vehicle. Whenever practical, construction equipment, materials, and debris should be stored in such a manner as to not be vulnerable to run-off-the-road vehicles.

5.5 CONTROL OF RAIL TRAFFIC

As with highway traffic, control of train traffic through construction areas must provide for the safety of the labor forces and for safe train operations. Ideally, construction and maintenance at a highway-rail intersection would occur under conditions of no highway or train traffic, however this is rarely practical.

Rail traffic is not as easily detoured as highway traffic. Highway users may be directed over an adjacent crossing which may not be more than one mile away; alternatively, an inexpensive temporary crossing surface may be constructed adjacent to the work site.

Detours for rail traffic may greatly increase the costs of rail operations due to the increased travel time and distance. Temporary trackage is often expensive to construct. At multiple track crossings, work may sometimes be planned to close only one track to train traffic at a time and provide for the continuation of all train traffic over the remaining track. At other times, the high cost of temporary railroad signaling and interlocking may preclude this solution.

Train orders or railroad signal systems notify train crews of construction or maintenance activities. The train dispatcher provides appropriate instructions for operating through the area. A railroad employee is established on the construction site as a flagman to advise of approaching trains so that labor forces may move off the track while the train passes through the area.

5.6 PLANNING TRAFFIC CONTROL FOR WORK ZONES

When planning construction or maintenance work at highway-rail intersections, proper coordination with the railroad is essential. Through the development of a work plan to meet the needs of rail and highway traffic, the safety of highway users, highway and railroad work crews, and train crews can best be provided.

Traffic Control Zones

When construction or maintenance activities affect traffic, traffic control is needed to safely guide and protect highway users and workers in a traffic control zone. Complete road closure during construction activities which detours traffic completely around the highway-rail intersection work zone is preferred from both an engineering and safety standpoint. Lane closure work zones should be undertaken only if a suitable detour route is absolutely not possible.

The traffic control zone is the distance between the first advance warning sign and the point beyond the work area where traffic is no longer affected. Most traffic control zones can be divided into the following parts: advance warning area, transition area, buffer space, work area, and termination area. Figure 5-1 illustrates these areas.

The advance warning area should be long enough to give motorists adequate time to respond to the changed conditions. The length is at least 1500 feet in rural areas, but may be a minimum of one block in urban areas.

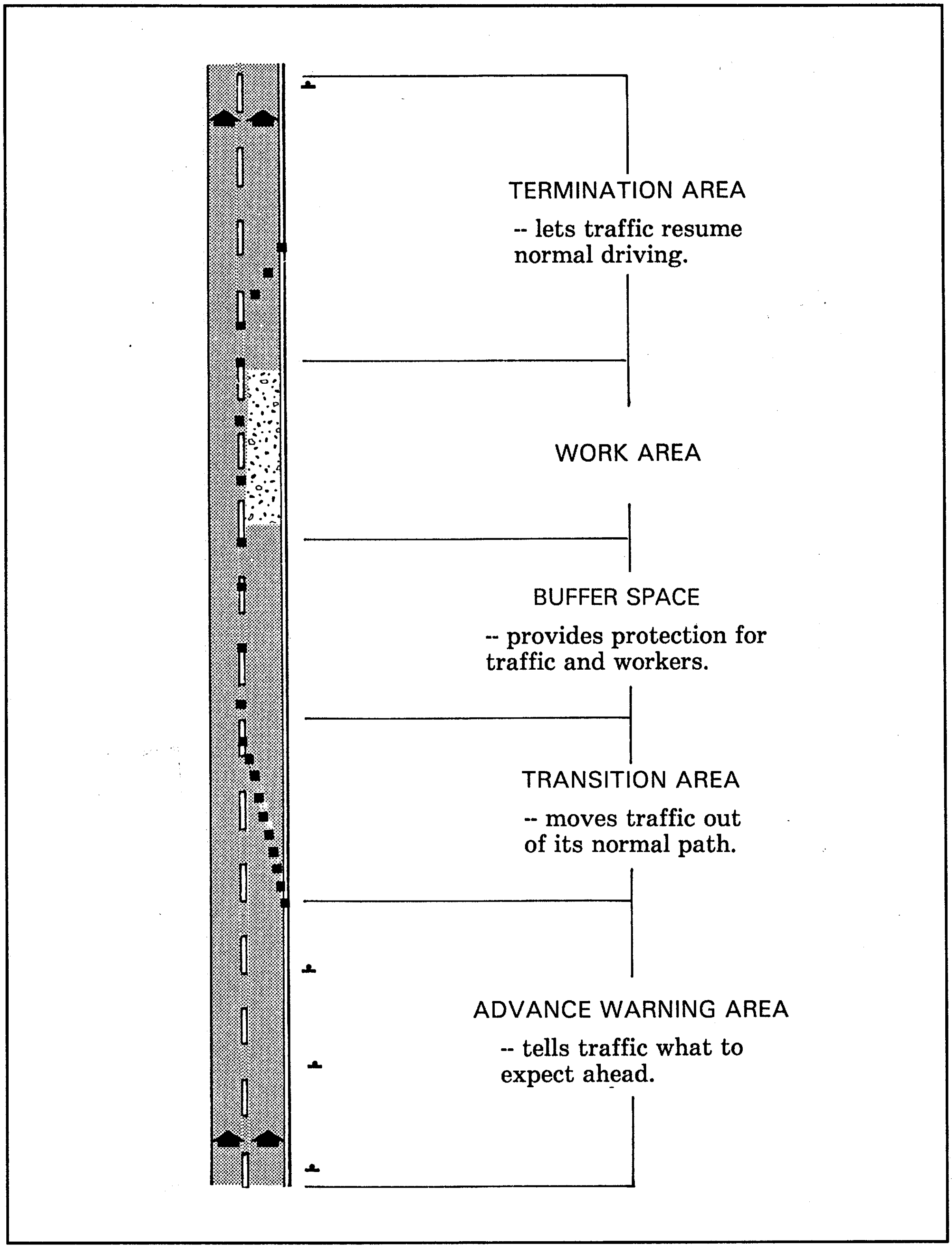

Figure 5-1. Areas in a Traffic Control Zone (4)

If a lane or shoulder is closed, a transition area channelizes traffic from the normal highway lanes to the path required to move traffic around the work area. The transition area contains the tapers used to close lanes. A taper is a series of channelizing devices and pavement markings placed on an angle to move traffic out of its normal path. The speed of traffic and the width of the lane to be closed determine the appropriate taper length. Formulas for determining the length of a taper are, for a posted speed of 40 miles per hour or less:

$$L = \frac{WS^2}{60}$$

and for a posted speed of 45 miles per hour or greater:

$$L = WS$$

where:

L	=	taper length
W	=	width of lane or offset
S	=	posted speed or off-peak 85th-percentile speed

Table 5-1 lists the recommended number and spacing of channelizing devices for various speeds and widths of closing.

A one-lane, two-way traffic taper is applied in advance of a work area that occupies part of a two-way road in such a way that the remainder of the road is used alternately by traffic in either direction. A short taper causes traffic to slow down by giving the appearance of a restricted alignment. One or more flaggers are usually employed to assign the right-of-way. One-lane, two-way traffic tapers should be 50 to 100 feet long, with channelizing devices spaced a maximum of 10 to 20 feet.

The buffer space is the open or unoccupied space between the transition and work areas and provides a margin of safety for both traffic and workers. Channelizing devices should be placed along the edge of the buffer space at a spacing in feet of two times the posted speed limit.

The work area is that portion of the highway that contains the work activity and is closed to traffic and set aside for exclusive use by workers, equipment, and construction materials. Channelizing devices or barriers exclude traffic and pedestrians from the work area.

The termination area provides a short distance for traffic to clear the work area and to return to the normal traffic lanes. A downstream taper placed in the termination area shifts traffic back to its normal path.

Table 5-1. Taper Lengths for Lane Closures

Speed Limit (mph)	Taper Length — Lane Width (feet)			Number of Channelizing Devices for Taper*	Spacing of Devices Along Taper (feet)
	10	11	12		
20	70	75	80	5	20
25	105	115	125	6	25
30	150	165	180	7	30
35	205	225	245	8	35
40	270	295	320	9	40
45	450	495	540	13	45
50	500	550	600	13	50
55	550	605	660	13	55

* Based on 12-foot lane width. This column is appropriate for lane widths less than 12 feet.
Source: *Traffic Control Devices Handbook*, FHWA

Signs

Regulatory signs impose legal restrictions and may not be used without permission from the authority having jurisdiction over the highway. Warning signs are used to give notice of conditions that are potentially hazardous to traffic.

The high conspicuity of fluorescent orange colors provides an additional margin of safety by producing a high visual impact in hazardous areas. Therefore, where the color orange is specified for use in traffic control for construction and maintenance operations, it is acceptable to utilize materials having fluorescent red-orange or yellow-orange colors.

Signs may be attached to posts or portable supports that are lightweight, yielding, or breakaway. Figure 5-2 illustrates typical warning signs used in construction work zone areas and the minimum height requirements for signs attached to posts. Signs on portable supports are required by the MUTCD to be at least one foot above the highway.

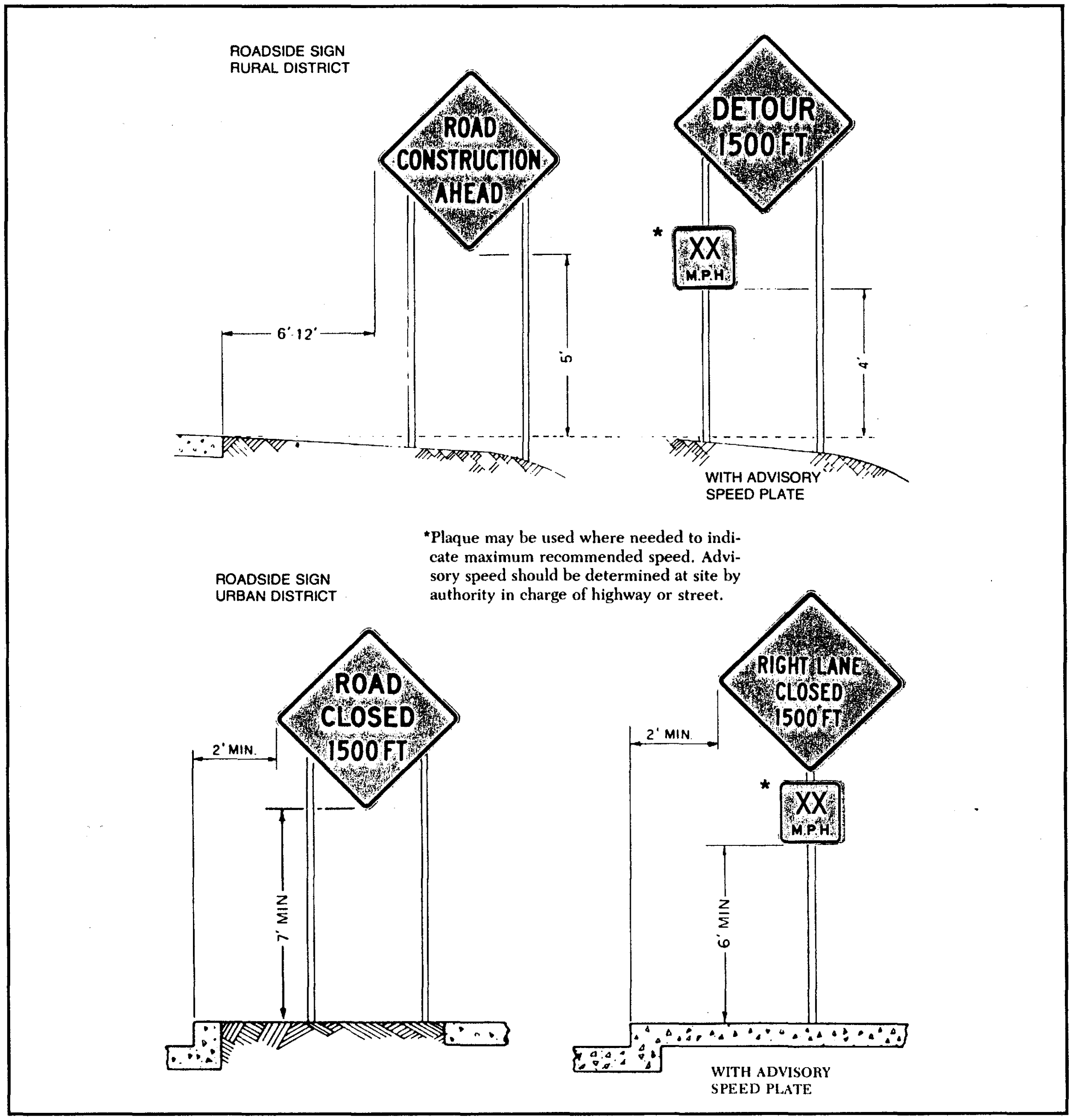

Figure 5-2. Height and Lateral Locations of Signs -- Typical Installations on Fixed Supports (3)

Pavement Markings

Pavement markings and delineators outline the vehicular path, and thus guide the motorist through the construction area. Pavement markings include lane stripes, edge stripes, centerline stripes, pavement arrows, and word messages. Markings consist of paint (with bead reflectorization), raised reflectorized markers, preformed adhesive-backed reflectorized tape, cold preformed reflectorized plastics, hot reflectorized plastics, epoxies, and other materials placed by heating and spraying.

The standard markings placed for a road should be in place before opening a new facility to traffic. If revised lane patterns are planned for the work zone, temporary markings should be placed before the traffic changes. Where this is not feasible, such as during the process of making a traffic shift or carrying traffic through surfacing operations, temporary delineation may be accomplished with lines of traffic cones, other channelizing devices, or strips of adhesive-backed reflectorized tape.

When pavement placed during the day is to be opened to traffic at night and permanent striping cannot be placed before the end of work, a temporary stripe should be applied to provide an indication to the driver of the location of the lane or centerline. Standard marking patterns are most desirable for this use. On rock-screened seal coats, striping should be applied following removal of excess screenings.

For relatively long-term use or when the surface is to be covered later with another layer, reflectorized traffic paint, or preformed adhesive-backed tape, with or without raised pavement markers, should be considered. For relatively short-term use, and when frequent shifts are to be made, adhesive-backed reflectorized tape is useful. Raised pavement markers may be used to form the pavement markings or may be used to supplement marked stripes. High speeds and volumes of traffic may justify raised markers for even comparatively short periods. They are particularly valuable at points of curvature and transition.

Pavement arrows are useful in guiding traffic when the traveled way does not coincide with the configuration of the exposed surface area, such as when the color of the transition pavement is different from the existing pavement. Pavement arrows are especially useful on a two-way undivided roadway to remind the driver of opposing traffic. Two-way traffic signs should be used in conjunction with the arrows for the application. The arrows should be completely removed once the two-way traffic condition is no longer needed.

Whenever traffic is shifted from its normal path, whether a lane is closed, lanes are narrowed, or traffic is shifted onto another roadway or a detour, conflicting pavement markings should be removed. Exceptions to this may be made for short-term operations, such as a work zone under flaggers' control, moving, or mobile operations. Use of raised pavement markings or removable markings may be economical since they are usually easier to remove when no longer needed.

Delineators

Delineators are reflective units with a minimum dimension of approximately three inches. The reflector units can be seen up to 1,000 feet under normal conditions when reflecting the high beams of motor vehicle headlights. The delineator should be installed about four feet above the roadway on lightweight posts.

Delineators should not be used alone as channelizing devices in work zones, but may be used to supplement these channelizing devices in outlining the correct vehicle path. They are not used as a warning device. To be effective, several delineators need to be seen at the same time. The color of the delineator should be the same as the pavement marker that it supplements.

Channelizing Devices

Channelizing devices consist of cones, tubular markers, vertical panels, drums, barricades, and barriers. Cones are lightweight devices that may be stacked for storage, are easy to place and remove, and are a minor impedance to traffic flow. Cones are at least 18 inches high; however, 28-inch cones should be used on high-speed roadways, during nighttime, or whenever more conspicuous guidance is needed. Cones are reflectorized for use at night with a six inch wide reflectorized band placed no more than three inches from the top or with a lighting device.

Tubular markers are lightweight, easy to install, and are a minor impedance to traffic flow. These devices must be set in weighted bases or fastened to the pavement. Tubular markers should be at least 18 inches high, with taller devices preferred for better visibility. Markers should be reflectorized for use at night with two reflectorized bands, three inches in width, placed no more than two inches from the top and with no more than six inches between the bands.

Vertical panels are 8 to 12 inches in width and a minimum of 24 inches in height. These devices are advantageous in narrow areas where barricades and drums would be too wide. The panels are mounted on lightweight posts driven into the ground or placed on lightweight portable supports. The orange and white stripes on vertical panels slope down toward the side that traffic is to pass. The stripes should be reflectorized as barricades and installed such that the top is a minimum of 36 inches above the highway.

Drums are highly visible and appear to be formidable objects thus commanding the respect of motorists. These devices should be marked with horizontal orange and white stripes that are reflectorized, four to eight inches wide. The drum must have at least two sets of orange and white stripes, but can also have non-reflectorized spaces up to two inches wide between the stripes.

Barricades should be constructed of lightweight materials and are classified as Types I, II, and III. Types I and II are used for either channelizing or marking hazards; Type III barricades are used for road closures. The barricade rails have alternating orange and white reflectorized stripes that slope down toward the side traffic is to pass.

Barriers provide a physical limitation through which a vehicle would not normally pass. These devices keep traffic from entering a work area or from hitting an exposed object or excavation. Barriers provide protection for workers and construction and separate two-way traffic. They are usually constructed of concrete or metal, and are designed to contain and redirect an errant vehicle. Exposed ends of barriers should have crash cushions to protect traffic or flared ends provided by extending the barrier beyond the clear roadside recovery area. Two types of crash cushions used in work zones are sand-filled plastic barriers and the portable Guard Rail Energy Absorbing Terminal (GREAT).

Lighting Devices

Three types of warning lights may be used in construction areas. Flashing lights are appropriate for use on a channelizing device to warn of an isolated hazard at night or call attention to warning signs at night. High-intensity lights are appropriate to use on advance warning lights day and night. Steady-burn lights are appropriate for use on a series of channelizing devices or on barriers that either form the taper to close a lane or shoulder, or keep a section of lane or shoulder closed, and are also appropriate on the channelizing devices alongside the work area at night.

Work vehicles in or near the traffic areas are hazards and should be equipped with emergency flashers, flashing lights, strobes, or rotating beacons. The laws of the agency having jurisdiction over the street or highway should be checked concerning requirements for flashing vehicle lights. These lights should be used in addition to other channelizing and warning devices. However, in some emergency situations, where the work will be in progress for a short time, these light may be the only warning device.

Flashing arrow panels are signs with a matrix of lights capable of either flashing or sequential displays. These devices are effective day and night for moving traffic out of a lane to the left or to the right, and may be used for tapered lane closures. Arrow panels should not be used when no lanes are closed, when there is no interference in traffic flow, or when a flagger is controlling traffic on a normal two-lane two-way road.

Flagging

Flagging should be used only when required to control traffic or when all other methods of traffic control are inadequate to warn and direct drivers. The procedures for flagging traffic are contained in Sections 6F-2 through 6F-7 of the TMUTCD (3). Figure 5-3 illustrates the standard signals to be used by flaggers. Flaggers should be in sight of each other or have direct communication at all times.

A number of hand signaling devices such as STOP/SLOW paddles, lights, and red flags are used to control traffic through work zones. The sign paddle bearing the clear messages "Stop" or "Slow" provides motorists with more positive guidance than flags and should be the primary hand-signaling device. The use of flags should be limited to emergency situations and at spot locations that can best be controlled by a single flagger.

Applications

Figures 5-4 through 5-7 illustrate typical applications of traffic control devices in highway-rail intersection work zones. The dimensions shown in these figures may be adjusted to fit field conditions in accordance with the guidelines presented in the MUTCD and the Traffic Control Devices Handbook. When numerical distances are shown for sign spacing, the distances are intended for rural areas and urban areas with a posted speed limit of 45 miles per hour or greater. The location, spacing, size and number of advance warning signs used should be dependent upon various traffic characteristics, including speed, volume, type of work conducted, and the type of roadway. Table 5-2 depicts suggested construction warning sign spacing based upon some of these criteria.

Signs with specific distances shown should not be used if the actual distance varies significantly from that shown. The word message "Ahead" should be used in urban areas and in other areas where a specific distance is not applicable. Standard crossing pavement markings are not shown in the figures for clarity and should be utilized wherever appropriate.

All applicable requirements for traffic control in work areas set forth in the MUTCD must apply to construction and maintenance of crossings. Additional traffic control devices other than those shown in the figures, should be provided when highway and traffic conditions warrant. These devices should conform to the requirements of the MUTCD. All traffic control devices that are not applicable at any specific time must be covered, removed, or turned so as not to be visible to the motorist.

Table 5-2. Typical Construction Warning Sign Spacing

Posted Speed (mph)	Sign Spacing[1] (ft)
30	80
35	120
40	160
45	240
50	320
55	500[2]

[1]Minimum distance from work to first advance warning sign and/or distance between each additional sign.
[2]Distance between signs should be increased as required to provide 1500-ft advance warning.

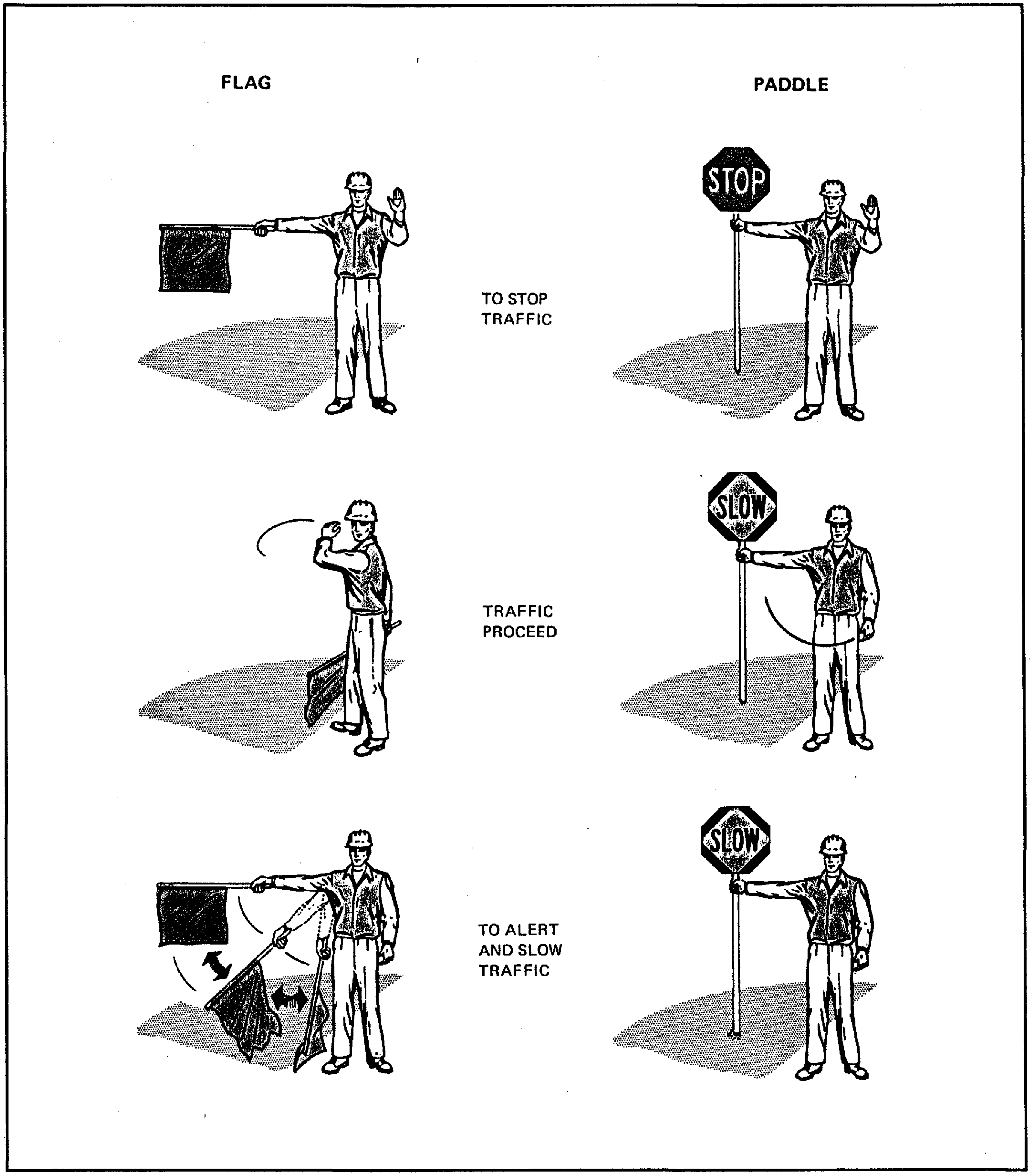

Figure 5-3. Use of Hand Signaling Devices by Flagger (3)

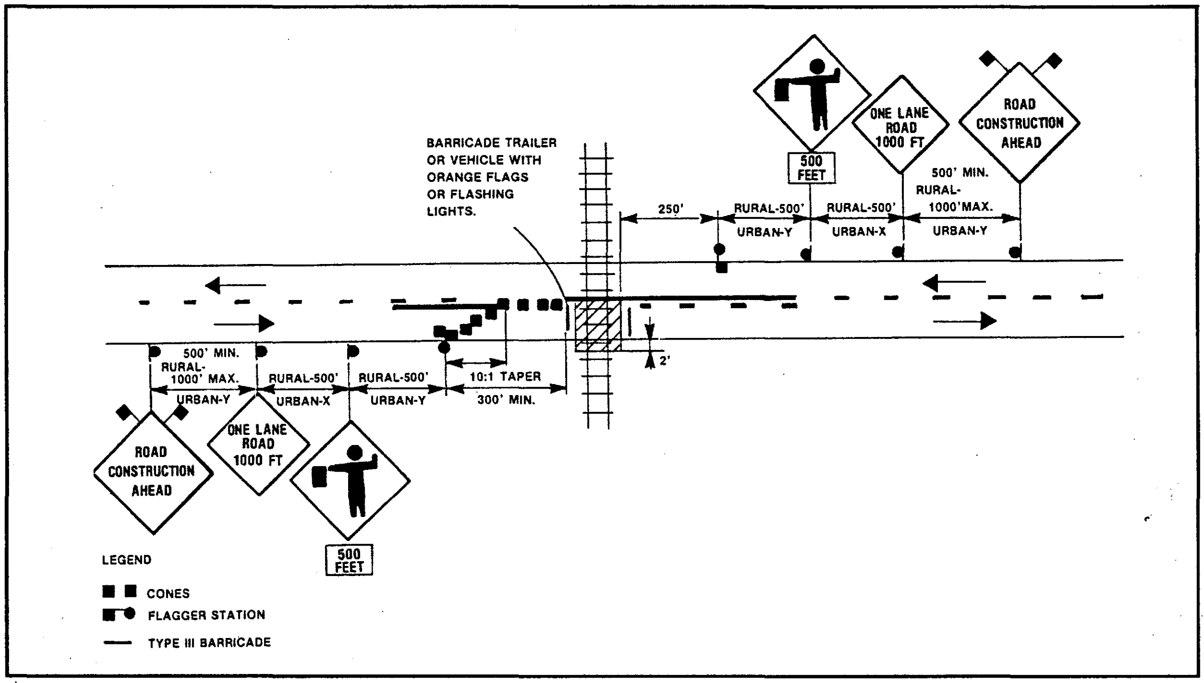

Figure 5-4. Work Activities, Highway-Rail Intersection, Two-Lane Highway With One Lane Closed (4)

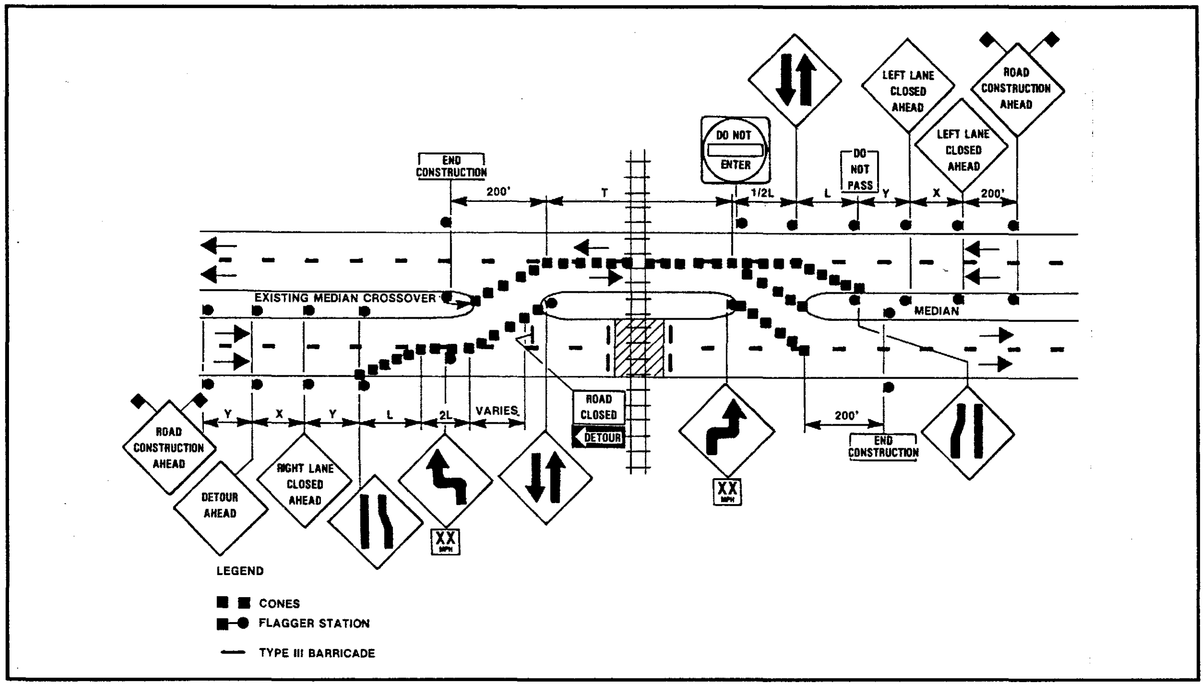

Figure 5-5. Work Activities, Highway-Rail Intersection, Multi-Lane Urban Divided Highway With One Roadway Closed, Two-Way Traffic (4)

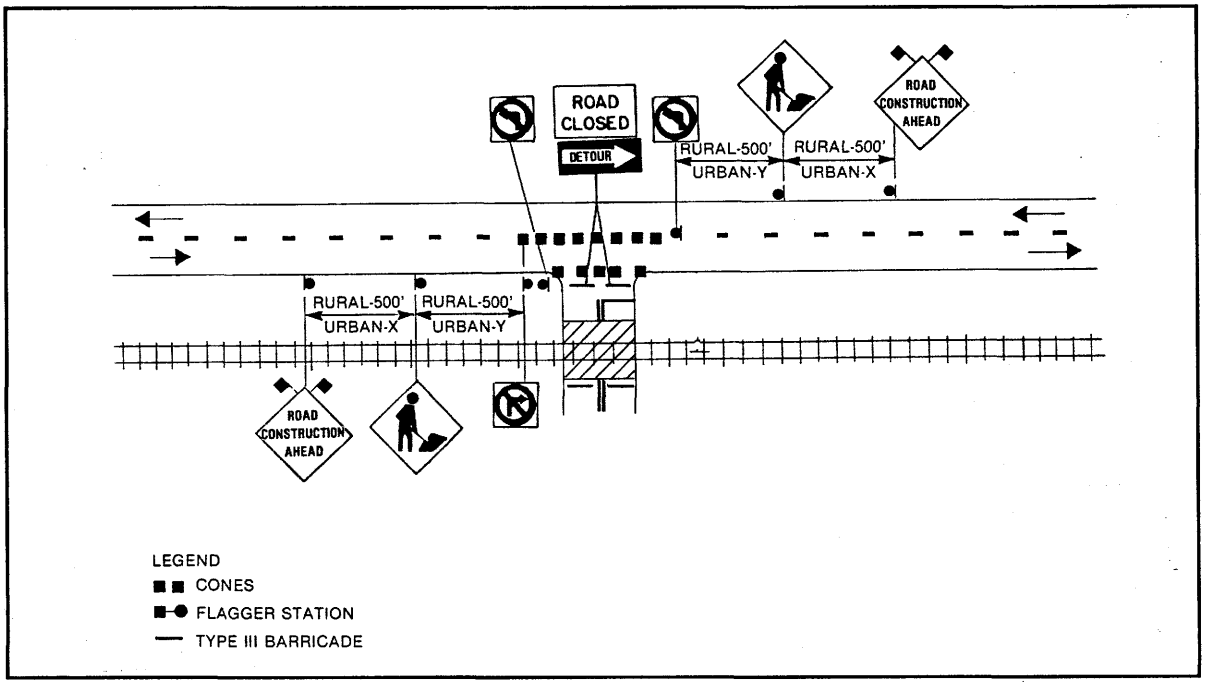

Figure 5-6. Work Activities, Highway-Rail Intersection, Closure of Side Road Crossing (4)

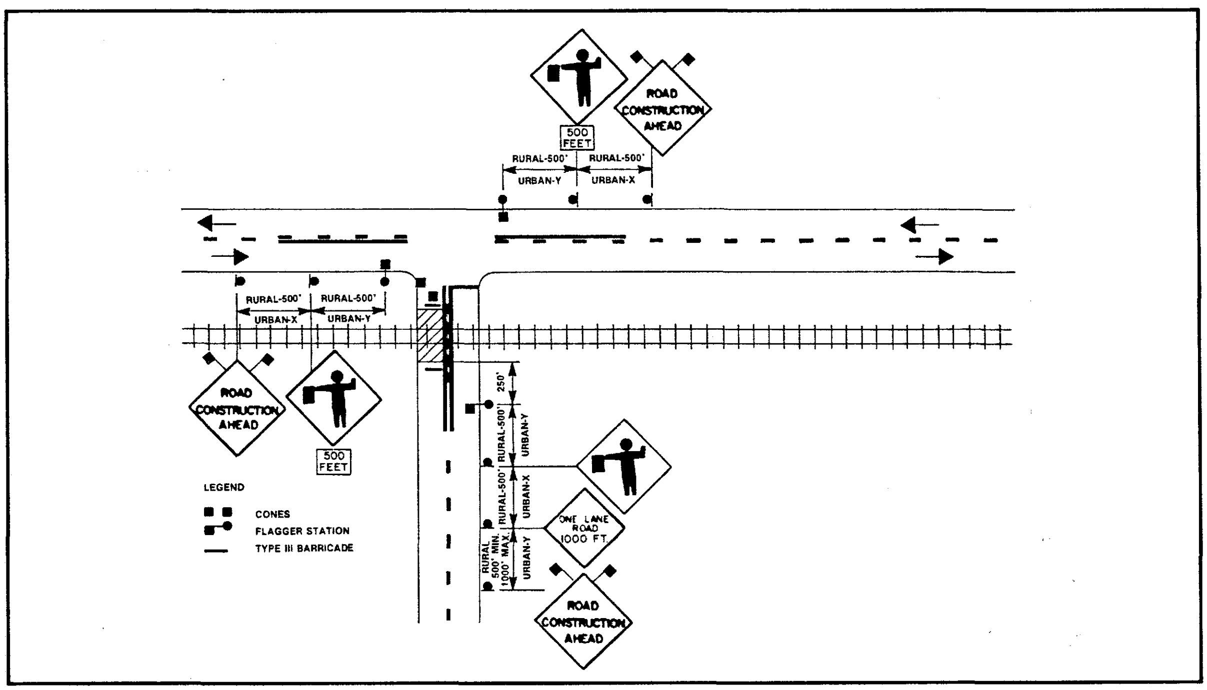

Figure 5-7. Work Activities, Highway-Rail Intersection, One Lane of Side Road Crossing Closed (4)

Non-Railroad Related Construction and Maintenance Activities

The Texas MUTCD, the *Railroad-Highway Grade Crossing Handbook,* the *Traffic Control Devices Handbook,* and other references provide guidelines and requirements applicable to construction and maintenance activities at or near highway-rail intersections. This chapter summarized some of the guiding principles and important practices for safe handling of traffic through construction and maintenance work zones at highway-rail intersections.

Recognize, however, that these guidelines address those situations in which the ***highway-rail intersection*** is the focus of the construction or maintenance activity. Typical examples include repairs to or replacement of crossing surfaces, track maintenance activities, and railroad signal installation. Unfortunately, little guidance is provided for implementing highway work zones that are unrelated to the highway-rail intersection, but which impact traffic operations at the highway-rail intersection nonetheless. Typical examples include highway traffic signal maintenance near a highway-rail intersection, and other highway maintenance activities that require a lane closure or disruption of the normal flow of traffic in the vicinity of the highway-rail intersection.

When non-railroad related construction or maintenance activities occur in proximity to a highway-rail intersection, give careful consideration to the work zone's potential impacts upon traffic flow at the railroad crossing. Queues which extend into the highway-rail intersection are of particular concern. Vehicles queued over the tracks may have no available escape options when a train approaches. Personnel responsible for the design and operation of construction and maintenance work zones are cautioned to be aware of this and other potential safety concerns associated with work zone activities near highway-rail intersections. These concerns should be properly considered and addressed when developing and implementing work zone traffic control plans.

6.0 SPECIAL PROGRAMS

6.1 NATIONAL RAIL-HIGHWAY GRADE CROSSING INVENTORY

The United States Department of Transportation and the Association of American Railroads developed the National Rail-Highway Crossing Inventory in the early-1970s, with the cooperative effort of the Federal Highway Administration, the Federal Railroad Administration (FRA), individual States, and individual railroads. All at-grade and grade-separated crossings, both public and private, in the United States were surveyed, and data recorded on inventory forms. The inventory contains data on the location of the crossing, the amount and type of train traffic, traffic control devices, and other physical elements of the highway-rail intersection. (Note: The Texas Department of Transportation maintains its own inventory as well, with many of the same types of data found in the National Inventory.)

Each crossing was assigned a unique identification number consisting of six numeric characters and an alphabetic character. The alphabetic character provides an algorithmic check of the six numeric characters. To determine the correct alphabetic character, sum the products of each of the first six digits times the digit's position (position one is the left-most digit). Divide this sum by 22 and then interpolate the remainder according to the following:

0 - A	8 - J	16 - T
1 - B	9 - K	17 - U
2 - C	10 - L	18 - V
3 - D	11 - M	19 - W
4 - E	12 - N	20 - X
5 - F	13 - P	21 - Y
6 - G	14 - R	
7 - H	15 - S	

The crossing identification number was installed at each crossing by nailing or strapping a temporary tag to a crossbuck or flashing light post. These temporary tags were designed to last a maximum of five years and should be replaced with permanent tags. The two most common methods used to install permanent tags at the crossing include: a metal tag on which the crossing number is embossed by raised imprinting, and stenciling the number on the post.

The FRA voluntarily serves as custodian of the national inventory file. Data in the inventory are kept current through the voluntary submission of information by the States and railroads. Numerous States and railroads update the National Inventory; systematic and uniform procedures are required to assist the FRA in processing the data. Three basic procedures exist: individual update forms, fill-in-the-blanks list, and magnetic tape.

Individual Update Forms

Whenever a change occurs at a crossing (e.g., installation of traffic control devices), the railroad or the State initiates an update form. The following identification elements on the form are completed: crossing identification number, effective date of the change, state code, county code, railroad code, and type of update (e.g., existing crossing, new crossing, closed crossing). Other data elements are completed only if they have changed or if they were not previously reported.

To ensure that the State and railroad are in agreement on the elements contained in the inventory, each has an opportunity to review the updates initiated by the other. If the railroad initiates the update, it retains one copy (the orange copy) of the four-part form and sends the other three copies to the State agency. The State reviews the information and makes any appropriate changes. It then sends one copy (the pink copy) back to the railroad for its files, retains one copy (the yellow copy) for its files, and sends the original copy (green copy) to the FRA for processing. If the State initiates the update, it retains one copy (the orange copy) and sends the other three to the railroad for review. The railroad then retains one copy (the pink copy) for its files and returns the other two (the green and yellow copies) to the State. The State retains one copy (the yellow copy) and submits one copy (the green copy) to the FRA for processing. This procedure allows both the State and railroad to concur on the crossing information prior to submittal to FRA and establishes the State as the agency that submits all data to the FRA. Both the State and the railroad have a hard copy record of the update that can be placed in a file along with the original inventory record.

Fill-in-the-Blanks List

The fill-in-the-blanks list is a mass updating procedure that consists of a printout of specified information currently contained in the inventory on a crossing, and a series of blanks for those data elements that are to be changed. The list can be obtained from the FRA by request. For example, if a State wanted to change the annual average daily traffic (AADT) for all crossings in a county, the list would consist of the six identifying elements, the current AADT, and a blank. The State can quickly review the crossing information on the list and enter the new AADT if it has changed.

The list is usually sorted by railroad (if it is a State request) or by state (if it is a railroad request) so that a copy of the list can be sent to the other party. The entire list is then sent to the FRA for processing.

Magnetic Tape

Another mass updating procedure involves the submission of data via computer magnetic tape. It is advantageous for those States and railroads that maintain the inventory on a computer. A State or railroad may enter changes onto its own computer file and then periodically send the FRA a magnetic tape of the changes in a prescribed format. This method provides for the updating of the national file with relative ease.

- The information contained on the magnetic tape must be in the prescribed format, since the FRA must be able to process the magnetic tape without having to make any changes to its format.
- The magnetic tape must contain only changed information and not the entire crossing record, since the FRA's procedure creates a new crossing record whenever any data element is changed.
- The other party must be provided with a printout of the changed information on the magnetic tape for its records.

FRA Assistance

A disadvantage of the two mass updating procedures is that a single form is not generated for each crossing which could then be placed in a manual file. To overcome this, the FRA will provide "feedback" to any State or railroad upon request. The FRA can provide information from the national inventory in three ways.

- One page per crossing printout -- a computer-generated printout that contains all information for a crossing on a single 8.5" x 11" sheet of paper.
- Continuous feed form -- a form identical to the individual update form that can be generated by computer.
- Lists -- a list of specified information, generated by the FRA upon request, for specified crossings.

Quality of Data

The data contained in the national inventory and state inventory should be verified in the field by appropriate engineering studies. The national inventory is used not only by the States and railroads in conducting their crossing improvement programs, but also by national and Federal agencies in assessing crossing improvement needs and conducting research. Thus, it is vital that this valuable information be kept up-to-date.

Railroad companies and local governments should coordinate updates to the DOT crossing inventory through the local TxDOT District offices. Local governmental entities may request that traffic counts be conducted by the local TxDOT District office at any public highway-rail intersection. All updates to the DOT crossing inventory should be forwarded to the TxDOT Transportation Planning and Programming Division (TPP) in Austin. The TPP Division is the office of record for all updates to the DOT crossing inventory, and is responsible for coordinating these updates with the railroad companies and the Federal Railroad Administration.

6.2 USDOT ACCIDENT PREDICTION FORMULA

The USDOT accident prediction model is found in the user's guide to the *Rail-Highway Crossing Resource Allocation Procedure* (16). The accident prediction formula combines two independent calculations to produce an accident prediction value. The basic value provides an initial prediction of accidents on the basis of a crossing's characteristics. The second calculation utilizes the actual accident history at a crossing over a determined number of years to produce an accident prediction value. This procedure assumes that future accidents per year at a crossing will be the same as the average historical accident rate over the time period used in the calculation.

The basic accident prediction formula can be expressed as a series of factors that, when multiplied together, yield an initial predicted number of accidents per year at a crossing. Each factor in the formula represents a characteristic of the crossing described in the national inventory. The general expression of the basic formula is:

$$a = k \times EI \times DT \times MS \times MT \times HP \times HL$$

where:

a = initial accident prediction, accidents per year at the crossing
K = formula constant
EI = factor for exposure index based on product of highway and train traffic
DT = factor for number of through trains per day during daylight
MS = factor for maximum timetable speed
MT = factor for number of main tracks
HP = factor for highway paved (yes or no)
HL = factor for number of highway lanes

Different sets of equations apply to each of the three categories of traffic control devices: passive, flashing lights, and automatic gates. Table E-1 of Appendix E lists the equations.

The structure of the basic accident prediction formula makes it possible to construct tables of numerical values for each factor. To predict the accidents at a particular crossing whose characteristics are known, the values of the factors are found in the table and multiplied together. Tables E-2, E-3, and E-4 of the Appendices list the factor values for the three traffic control device categories.

The final accident prediction formula can be expressed as follows:

$$B = \frac{T_0}{T_0 + T}(a) + \frac{T}{T_0 + T}\left(\frac{N}{T}\right)$$

$$A = 0.8644 \times B \qquad \textit{Passive}$$

$$A = 0.8887 \times B \qquad \textit{Flashing Lights}$$

$$A = 0.8131 \times B \qquad \textit{Gates}$$

$$T_0 = \frac{1.0}{(0.05 + a)}$$

where:

- A = final accident prediction, accidents per year at the crossing
- a = initial accident prediction from basic formula, accidents per year at the crossing
- N/T = accident history prediction, accidents per year
- T_0 = formula weighting factor

The formula provides the most accurate results if all the accident history available is used; however, the extent of improvement is minimal if data for more than five years are used. Accident history information older than five years may be misleading because of changes that occur to crossing characteristics over time. If a significant change has occurred to a crossing during the most recent five years, such as the installation of signals, only the accident data since that change should be used.

The USDOT has also developed a formula for predicting the severity of a crossing accident. The probability of a fatal accident given an accident, P(FA|A), is expressed as:

$$P(FA|A) = \frac{1}{1 + KF \times MS \times TT \times TS \times UR}$$

where:

- KF = formula constant = 440.9
- MS = factor for maximum timetable train speed
- TT = factor for through trains per day
- TS = factor for switch trains per day
- UR = factor for urban or rural crossing

The probability of a casualty accident given an accident, P(CA|A), is expressed as:

$$P(CA|A) = \frac{1}{1 + KC \times MS \times TK \times UR}$$

where:

- KC = formula constant = 4.481
- MS = factor for maximum timetable train speed

TK = factor for number of tracks
UR = factor for urban or rural crossing

Table E-5 lists the equations for calculating values of the crossing characteristic factors for the fatal accident probability formula, and Table E-6 lists the equations for the casualty accident probability formula. To simplify use of the formulas, the values of the crossing characteristic factors have been tabulated for typical values of crossing characteristics. These values are found in Tables E-7 and E-8 for the fatal accident and casualty accident probability formulas, respectively.

To obtain predicted numbers of fatal and casualty accidents, the fatal and casualty accident probabilities are multiplied by predicted accidents. The formula for predicted fatal accidents at a crossing is:

$$FA = P\ (\ FA|A\ ) \times A$$

The formula for predicted casualty accidents at a crossing is:

$$CA = P\ (\ CA|A\ ) \times A$$

Basically, injuries and fatalities determine the severity of crossing accidents. On a casualty severity scale, those accidents of lower severity tend to have more injuries, while those of higher severity tend to have more fatalities. The frequency distribution of accident severity tends to be the opposite; injury accidents tend to be more frequent than fatal accidents. Thus, a comprehensive indicator of total accident casualty impacts should take into account both the number and nature of accident casualties. Using this approach, a crossing that has, for example, many injury accidents can be considered on the same scale as one with few fatal accidents. The combined casualty index (CCI) formula was developed to achieve this objective.

The CCI formula is a weighted sum of the predicted fatal accidents per year (FA) and the predicted casualty accidents per year (IA). It is expressed as:

$$CCI = k \times FA + IA$$

This formula can be considered an "equivalent injury" accident function. It converts fatal accidents to equivalent injury accidents using the fatality factor k and adds this value to the number of injury accidents. The units of CCI could be "equivalent injury accidents per year."

The user of the CCI formula must specify a value for the constant k. This value indicates the relative impact of fatal versus injury accidents. The user is best qualified to determine the basis upon which an appropriate value of k is to be selected. Based on results of accident costs, a value of 50 for k may be reasonable for users who are unsure as to which value to use.

Making the substitution for IA, the CCI equation becomes:

$$IA = CA - FA$$

$$CCI = k \times FA + CA - FA$$

$$CCI = (k - 1) \times FA + CA$$

6.3 TEXAS PRIORITY INDEX FORMULA

The Texas Priority Index Formula (1991 version) identifies and prioritizes highway-rail intersections for safety improvements within the state of Texas. Each year, the top 150 to 200 locations as identified by the priority index are selected for diagnostic study. In this way, safety improvement options are evaluated and selected for crossings identified as having the greatest relative hazard potential.

The Priority Index Formula multiplies the number of vehicles per day, the number of trains in a 24-hour period, the average speed of the trains divided by 10, the type of existing crossing signals or crossbuck signs as a weighted factor, by a factor of 0.01, and the number of train-involved accidents in the last five years raised to the 1.15 power.

At locations with more than one track where main line and switching movements occur over the same crossing and at different speeds, a priority index is calculated for both the main line traffic and the switching traffic, then added together to equal the total priority index for the crossing.

The Texas Priority Index Formula is:

$$P.I. = V \times T \times \frac{S}{10} \times P \times 0.01 \times A^{1.15}$$

where:

P.I. = Priority Index
V = average daily traffic (ADT), vehicles/day
T = train volume, train movements/day
S = speed of trains, mph
P = protection factor (see table below)
A = number of accidents in last 5 years

Values for the protection coefficient, P, are as shown in Table 6-1. Also, when the value of A=0 (e.g., no accidents during last 5 years), then an assumed value of A=1 is used in the formula to avoid multiplication by zero. The following example illustrates the calculation of the Texas Priority Index for a typical highway-rail intersection.

Table 6-1. Protection Factors for the Texas Priority Index Formula

Existing Warning System	Protection Factor
Gates	0.10
Cantilever Flashers	0.15
Mast Flashers	0.70
Crossbucks, Other	1.00

EXAMPLE PRIORITY INDEX CALCULATION:

Given:

ADT: 5,000 veh/day
Train volume: 12 trains/day
Maximum train speed: 60 mph
Existing protection: mast flashers (P=0.70)
5-year accident history: 4 accidents during last 5 years

Solution:

$$P.I. = (5{,}000) \times (12) \times \left(\frac{60}{10}\right) \times (0.70) \times (0.01) \times (4)^{1.15} = 12{,}410$$

A new priority index number is calculated for every crossing in the state each year. Because decisions as to which crossings will be considered for improvements are based upon this formula, it is important that the required data (e.g., ADT, train speed, accident history) be kept as accurate and up-to-date as possible.

6.4 TEXAS' 1-800 SIGNAL MALFUNCTION REPORTING PROGRAM

Purpose and Function

In 1983, the Texas Legislature enacted and the Governor signed into law the Railroad Crossing Safety Information Act, which provides the legal framework by which the Texas 1-800 Program functions. The Texas 1-800 Program is a railroad notification program which allows individuals to report, by means of a toll-free number, malfunctions of train-activated rail-highway crossing signals to the Texas Department of Public Safety (DPS), which in turn reports the malfunctions to the appropriate railroad company. The program is an early warning system in which every motorist, law enforcement officer, and highway maintenance worker is a participant or potential participant.

The Act directed the DPS to establish toll-free telephone service for receiving calls reporting malfunctions. The State Department of Highways and Public Transportation (now the Texas Department of Transportation, TXDOT) was required to attach a sign displaying the toll-free telephone number and the USDOT/AAR National Rail-Highway Crossing Inventory number to each train-activated signal on the State-maintained highway system. Railroads operating in Texas were directed to permit TXDOT employees to affix the information sign on their private property. The Act also contained several significant safeguards relating to reported crossing signal malfunctions and data developed in administering the program. These included:

- A court may not hold the State, an agency or subdivision of the State, or a railroad company liable for damages caused by an action taken under this Act or failure to perform a duty imposed by this Act.
- No evidence may be introduced in a trial or judicial proceeding that such service exists or is relied upon by the State or railroad company.
- A State agency is not required to make or retain permanent records or information obtained in implementation of the Act.

The railroad companies are not required to take any action upon receiving notification of a crossing problem from the DPS. Also, there are no follow-up or report back requirements imposed on either the DPS or railroads to determine the disposition or correction of a report.

The success of the program lies in the aspects of the program outlined above. State agencies are not required to monitor the performance of the railroads. Railroads are not burdened by additional record-keeping. No liability is incurred due to the Act. Data relating to reporting crossing problems or malfunctions are not admissible in court. The Act does not contain punitive measures. Subsequent revisions to the original Act now require that Railroad Signal Malfunction Signs be installed at all public highway-rail intersections equipped with train-activated signal devices. The DPS also accepts reports and notifies the railroads about crossing problems which are not signal malfunctions (e.g., crossing surfaces, accidents, train operations, obstructions of view, etc.).

Responsibilities of the Texas Department of Transportation

The Texas Department of Transportation plays an important role in the successful operation of the Texas 1-800 Signal Malfunction Reporting Program. The responsibilities of TXDOT in supporting the Texas 1-800 Program include replacement of damaged or missing signs, installation of signs at non-signalized on-system crossings being upgraded with signals, and providing listings of signalized crossings to the DPS. TXDOT does not currently monitor or track the activities of the program.

Procedure for Reporting Signal Malfunctions

Anyone encountering a malfunctioning railroad crossing signal and/or gates should notify the Department of Public Safety promptly. The following instructions will expedite the reporting process.

- Malfunctioning signals should be reported to the Texas Department of Public Safety at 1-800-772-7677.
- Provide the DPS with the crossing identification number, which is displayed on the sign, to aid in accurate processing of the report.
- Provide the DPS with a description of the malfunction.

6.5 OPERATION LIFESAVER

Operation Lifesaver is a nationwide public education program with the goal of reducing crashes at highway-rail grade crossings. Texas Operation Lifesaver was started in 1977 by the Railroad Transportation Section of the Texas Safety Association. It has the cooperative support of a broad base of public, private, and industry groups. Operation Lifesaver's program emphasizes the so-called "Three E's" of highway-rail grade crossings (2):

- *Enforcement* of existing laws governing highway-rail grade crossings.
- *Engineering* highway-rail grade crossings to provide the greatest safety by working with communities in their efforts to provide additional warning devices.
- *Education* of the public about the inherent dangers at highway-rail grade crossings.

To enhance highway-rail grade crossing safety, Operation Lifesaver, Inc. endorses the concept of reducing the number of crossings through elimination, consolidation, grade separation and restricting the number of new crossings. Appendix F lists contacts for the state and national Operation Lifesaver offices.

7.0 REFERENCES

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APPENDIX A
DIAGNOSTIC EVALUATION PROCEDURE

The highway approach to the crossing is divided into three sections or zones: distant approach and advance warning (Approach Zone), immediate highway approach (Non-Recovery Zone), and crossing proper (Hazard Zone). Traffic cones are placed on or adjacent to the highway to delineate the boundaries of these zones. Figure A-1 depicts the placement of the three traffic cones with respect to the crossing.

Cone A is placed where the driver first obtains information that a crossing is ahead, usually from the advance warning sign, pavement markings, or the crossing itself. The distance from the crossing is based on the decision sight distance, the distance required for a driver to detect a crossing and formulate actions needed to avoid colliding with trains. This distance is also the beginning of the approach zone. Table A-1 provides a range of distances from Cone A to the stop line as a function of design vehicle speed. The maximum distances are applicable to complex crossings.

Cone B is placed where the driver must be able to see an approaching train so that a safe stop can be made if necessary. This point is located at the end of the approach zone and the beginning of the nonrecovery zone. Distances to Cone B are based on design vehicle speed and are also specified in Table A-1. These distances are stopping sight distances to the stop line (typically 15 feet from the track). In calculating these distances, a level grade is assumed. The actual placement distance should be adjusted up or down to account for the positive or negative effects of grade, if the approach is not level.

Cone C is placed at the stop line, which is assumed to be 15 feet from the edge of the nearest rail. This point defines the beginning of the so-called hazard zone.

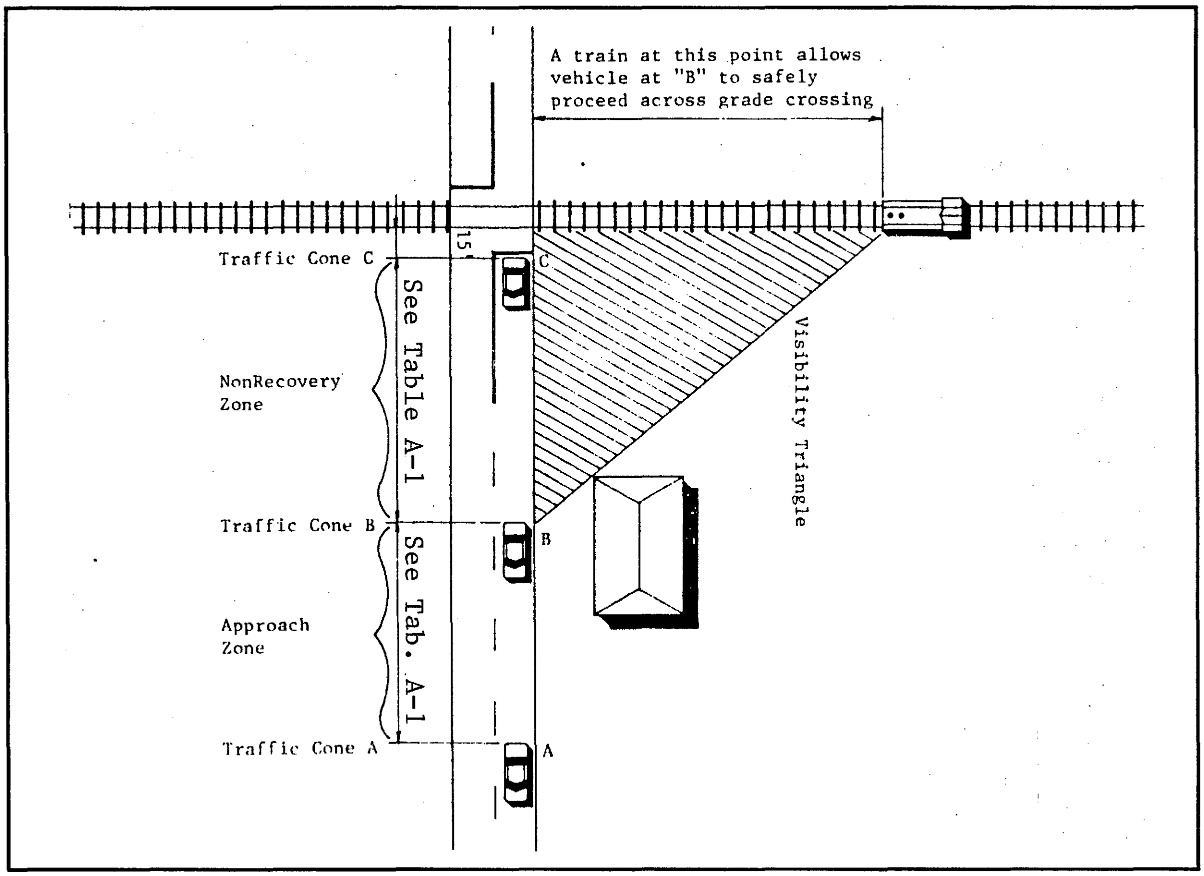

Figure A-1. Study Positions for Diagnostic Team (1)

Table A-1. Cone Placement for the Diagnostic Study

Approach Vehicle Speed (mph)	Distance From Stop Line to Cone A (feet)	Distance From Stop Line to Cone B (feet)
30	450 - 625	210
40	600 - 825	325
50	750 - 1025	475
55	875 - 1150	555
60	1000 - 1275	645
70	1100 - 1450	850

Source: Reference (1)

Section I

The questions in Section I are concerned with driver awareness of the crossing, visibility of the crossing, effectiveness of advance warning signs and signals, and geometric features of the highway. For this part of the study, the observer(s) should be positioned at Cone A, the beginning of the approach zone.

(1) Is advance warning of the highway-rail intersection available?

☐ Yes ☐ No

If so, what devices are used?

(2) Do advance warning devices alert drivers to the presence of the crossing and allow time to react to approaching train traffic?

☐ Yes ☐ No

(3) Do approach grades, roadway curvature, or obstructions limit the view of the advance warning devices?

☐ Yes ☐ No

If yes, how?

(4) Are advance warning devices readable under night, rainy, snowy, or foggy conditions?

☐ Yes ☐ No

(5) Do you feel most drivers would be aware of the crossing?

☐ Yes ☐ No

(6) Do you think the crossing would be noticed by most drivers under nighttime conditions?

☐ Yes ☐ No

(7) How would you rate the effectiveness of the advance warning signs and signals?

☐ Maximum effectiveness achieved
☐ Effective but could be improved
☐ Ineffective under some conditions
☐ Ineffective at all times
☐ Sign is nonexistent
☐ Marking is nonexistent

(8) Would you expect the driver to not notice the crossing due to attention to other traffic conditions?

☐ Yes ☐ No

(9) Do you feel the driver has been given all the information required to be aware of the crossing?

☐ Yes ☐ No

(10) Considering traffic conditions and train frequency, how do you think drivers who pass the crossing several times per week would react to its presence?

☐ More aware of the crossing and more alert for train
☐ More aware of the crossing but less alert for train
☐ Would pay less attention to the crossing
☐ Would tend to disregard crossing altogether

Section II

The questions in Section II are concerned with whether or not the driver has sufficient information to detect an approaching train and make correct decisions about crossing safely. Driver awareness of approaching trains, driver dependence on crossing signals, obstruction of view of approaching trains, diversion of driver attention due to roadway geometrics, potential locations of standing railroad equipment, removal of sight obstructions, and the availability of information for proper stop or go decisions by the driver are considered. For this part of the study, the observer(s) should be positioned at Cone B.

(1) What maximum safe approach speed will existing sight distance support?

(2) Is that speed equal to or above the highway speed limit?

☐ Yes ☐ No

If no, what has been done, or reasonably could be done, to bring this to the driver's attention?

(3) What restrictive obstructions to sight distance might be removed?

(4) Do approach grades or roadway curvature restrict the driver's view of the crossing?

☐ Yes ☐ No

(5) Are railroad crossing signals or other active warning devices operating properly and visible to adequately warn drivers of approaching trains?

☐ Yes ☐ No

(6) Would a train approaching the crossing be obvious to most drivers?

☐ Yes ☐ No

(7) Assuming the driver is aware of the crossing, is the driver totally dependent on the operation of crossing signals to detect a trains presence?

☐ Yes ☐ No ☐ Not applicable

(8) How would you answer questions (6) and (7) for nighttime conditions?

(9) At what distance do you estimate a train approaching from the most obstructed quadrant would be observed by the average driver?

☐ Less than 100 feet
☐ 100 feet to 300 feet
☐ 300 feet to 500 feet
☐ 500 feet to 1000 feet
☐ Over 1000 feet

(10) Could the presence or absence of a legally parked vehicle affect the driver's decision process?

☐ Yes ☐ No

(11) Would the roadway geometry or other traffic require the driver's attention to the extent that it would impair or delay the driver's decision process?

☐ Yes ☐ No

(12) How might standing railroad equipment affect the driver's decision?

(13) If the driver is unable to make a correct decision because of visibility restrictions, what would be necessary to provide adequate sight distance?

(14) Under optimum conditions, does the driver have sufficient information available to make a proper stop or go decision?

☐ Yes ☐ No

(15) Do you think most drivers will be aware of and make proper interpretation of this information if it is available?

☐ Yes ☐ No

Section III

The questions in Section III apply to observations adjacent to the crossing. Of particular concern is the driver's ability to see down the tracks for approaching trains, especially when the driver must stop. Also, intersecting streets and driveways should be observed to determine whether intersecting traffic could affect the operation of highway vehicles over the crossing. This section addresses sight distance down the tracks, pavement markings, conditions conducive to a vehicle becoming stalled or stopped on the crossing, the operation of vehicles required by law to stop at crossings, signs and signals as fixed object hazards, and the opportunity for evasive action by the driver. The observer(s) should be located at Cone C when completing Section III.

(1) From a vehicle stopped at the crossing, is the sight distance down the track to an approaching train adequate for the driver to cross the tracks safely?

☐ Yes ☐ No

(2) Are nearby intersection traffic signals or other control devices affecting crossing operation?

☐ Yes ☐ No

If yes, explain.

(3) Is the stopping area at the crossing adequately marked?

☐ Yes ☐ No

(4) Do vehicles required by law to stop at all crossings present a hazard at the crossing?

☐ Yes ☐ No

If yes, explain.

(5) Do conditions at the crossing contribute to, or are they conducive to, a vehicle stalling at or on the crossing?

☐ Yes ☐ No

(6) Are nearby signs, crossing signals, etc. adequately protected to minimize hazards to approaching traffic?

☐ Yes ☐ No

(7) Is the crossing surface satisfactory?

☐ Yes ☐ No

(8) Is the surface of the highway approach satisfactory?

☐ Yes ☐ No

Section IV

The final section of the study procedure affords the team members an opportunity to list major features that contribute to and/or that reduce crossing safety, suggest methods for improving safety, provide an overall evaluation of the crossing, and provide comments and suggestions relative to the diagnostic study.

(1) List major attributes of the crossing which may contribute to safety.

(2) List major attributes of the crossing which may reduce safety.

(3) List possible methods for improving safety.

(4) Provide an overall evaluation of the crossing.

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APPENDIX B
SIGHT DISTANCE STUDY PROCEDURE

Step 1: Determination of Length of Stride

Prior to collecting data, each member of the team should determine the length of his or her stride, or pacing distance. Determination of one's stride length is accomplished by marking a known distance, say 100 feet, and determining the number of paces to walk this distance. The length of each stride is equivalent to the known distance divided by the number of paces. Likewise, the number of paces or strides required to measure out a given distance is equal to the distance divided by the length of stride.

Step 2: Determination of Quadrants

The highway-rail intersection should be sketched, indicating the tracks, the highway approaches, a North arrow, and any intersecting roadways or other pertinent features of the crossing environment. Each quadrant formed by the intersection of the highway and the tracks should be assigned an identifying number.

Step 3: Estimation of Approach Sight Distance

Approach sight distance is measured from the right-hand lane (driving lane) of both highway approaches. The distance is measured from the critical point on the roadway at a distance d_H from the nearest rail. This distance is a function of highway approach speed and is given in Table B-1.

Table B-1. Determination of Approach Sight Distance

Vehicle Speed (mph)	Required Distance Along Highway From Crossing, d_H (feet)
10	70
20	135
30	225
40	340
50	490
60	660
70	865

Note: All calculated distances are rounded up to the next 5-foot increment.
Source: Reference (1)

If the highway-rail intersection and the warning device(s) at the intersection can be seen from or beyond the distance d_H at a driver eye height of 3.5 feet, then the available approach sight distance is greater than or equal to the required approach sight distance, and should be so indicated on the data collection form.

If the highway-rail intersection and the warning device(s) at the intersection can not be seen from or beyond the distance d_H at a driver eye height of 3.5 feet, then the distance at which they can be seen is determined and recorded. In this case, the available approach sight distance is less than the required sight distance, and should be so indicated on the data collection form.

Step 4: Estimation of Quadrant Sight Distance

The critical point on the highway at a distance d_H from the nearest rail is determined as in Step 3. The critical point along the tracks at a distance d_{T1} from the highway centerline is determined. This distance is a function of highway approach speed and maximum train operating speed, and is determined from Table B-2.

Table B-2. Determination of Quadrant Sight Distance, d_{T1}

Train Speed (mph)	Vehicle Speed (mph)						
	10	20	30	40	50	60	70
	Distance Along Railroad From Highway Centerline, d_{T1} (feet)						
10	145	105	100	105	115	125	135
20	290	210	200	210	225	245	270
30	435	310	300	310	340	370	405
40	580	415	395	415	450	490	540
50	725	520	495	520	565	615	675
60	870	620	595	620	675	735	810
70	1015	725	690	725	790	860	940
80	1160	830	790	830	900	980	1075
90	1305	930	890	930	1010	1105	1210

Note: All calculated distances rounded up to the next 5-foot increment.
Source: Reference (1)

If the critical point along the highway from the nearest rail (d_H) can be seen from the critical point along the tracks from the highway centerline (d_{T1}), then the available quadrant sight distance is equal to or greater than the required quadrant sight distance, and should be so recorded on the data collection form.

If the critical point on the highway cannot be viewed from the critical point on the tracks, then the distance along the tracks from the highway centerline at which d_H is just visible should be determined and recorded. In this case, the available quadrant sight distance is less than the required quadrant sight distance, and should be so indicated on the data collection form.

Step 5: Estimation of Track Sight Distance

The sight distance down the track from a stopped vehicle at the crossing, the track sight distance, is measured for each direction down the track on both highway approaches. The distance d_{T2} to the critical point on the tracks is determined. Values of d_{T2}, which are a function of train speed, are given by the following table. Note that the vehicle speed is zero miles per hour for all cases, since the vehicle is stopped at the crossing.

Table B-3. Determination of Track Sight Distance, d_{T2}

Train Speed (mph)	Distance Along Railroad From Crossing, D_{T2} (feet)
10	240
20	480
30	720
40	960
50	1200
60	1440
70	1680
80	1920
90	2160

Note: All calculated distances rounded up to the next 5-foot increment.
Source: Reference (1)

If an individual standing at the stop bar, or 15 feet from the crossing if a stop bar is not marked, can be seen from the critical point on the tracks (d_{T2}), then the available track sight distance equals or exceeds the required track sight distance, and should be so recorded on the data collection form. If, however, the individual cannot be seen from the critical point, then the available track sight distance is determined by locating the point along the tracks from which an individual at the stop bar can be seen. This available track sight distance is then recorded.

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APPENDIX C
TRAFFIC SIGNAL PREEMPTION

Appendix C contains typical signal preemption sequences for traffic signals at or near highway-rail intersections. These figures were developed by Committee 4W-A of the Institute of Transportation Engineers and published as a recommended practice in *Preemption of Traffic Signals at or Near Railroad Grade Crossings* (10). They are also found in Part VIII of the *Traffic Control Devices Handbook* (4).

A sample of representative intersection geometries are presented in the figures. It should be understood that intersection designs or traffic conditions other than those presented herein may exist. For additional information regarding traffic signal preemption at or near highway-rail intersections, refer to Section 4.3.

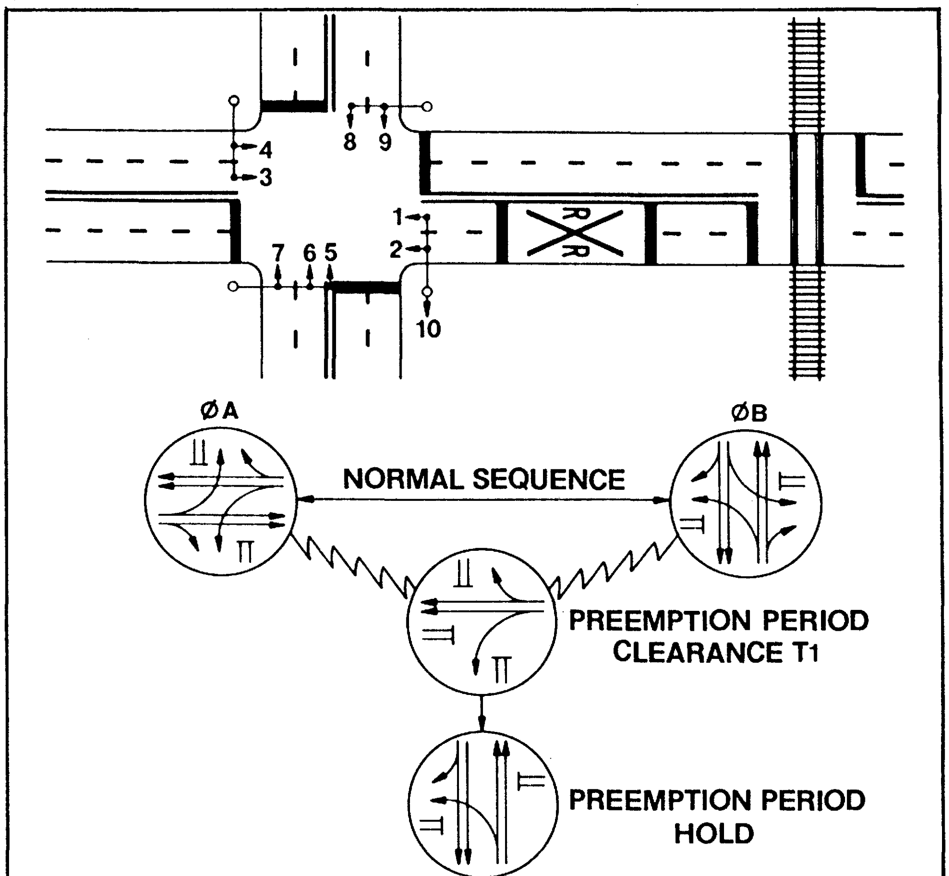
FIGURE KEY

Ø	Signal Phase
●—▶	Overhead Mounted Signal Head
o—▶	Pedestal Mounted Signal Head
R	Circular Steady Red Indication
FR	Circular Flashing Red Indication
Y	Circular Steady Yellow Indication
FY	Circular Flashing Yellow Indication
G	Circular Steady Green Indication
—▶	Steady Green Arrow Indication
Y—▶	Steady Yellow Arrow Indication
W	Steady Lunar White Walk Indication
FDW	Flashing Portland Orange Don't Walk Indication
DW	Steady Portland Orange Don't Walk Indication
R/W	Green Interval
CHANGE	Yellow Change Interval
T_1, T_{1A}, T_{1B},	Preemption Clearance Intervals Prior to Train Approach
T_2	Yellow Change Interval Following T_1 Interval
T_{2A}	Yellow Change Interval Following T_{1A} Interval
T_{2B}	Yellow Change Interval Following T_{1B} Interval
HOLD	Signal Indications During Train Passage
RELEASE	Signal Indications Immediately After Train Passage
BLANK	Signal Indication Extinguished

NOTES

1. Turn prohibition signals are blank-out type and shall conform to the *Manual on Uniform Traffic Control Devices.*
2. Turn prohibition messages shown herein may have to be modified to conform to applicable state or local law concerning right turn on red.

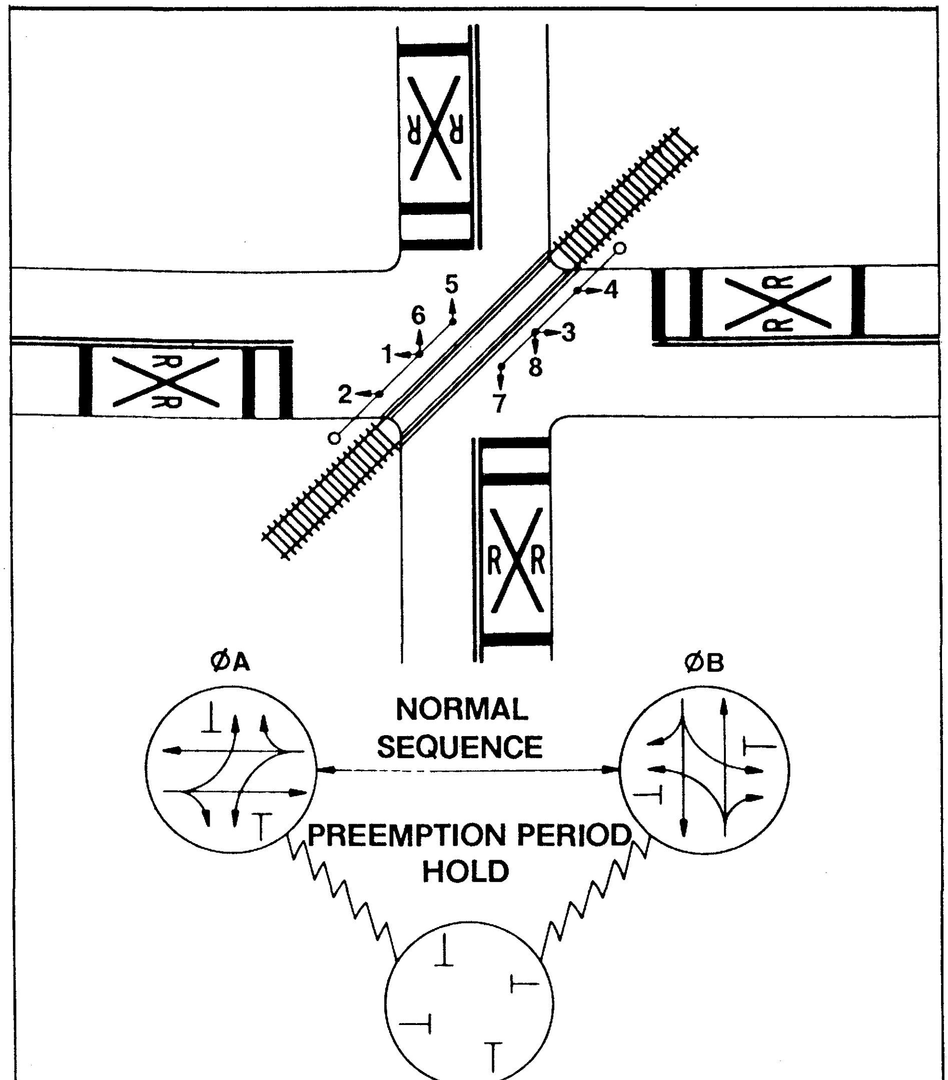
Figure C-1. Figure Key for Figures C-2 Through C-11 (4)



SIGNAL	ØA		ØB		PREEMPTION SEQUENCE						
	R/W	CHANGE	R/W	CHANGE	ØA CHANGE	ØB CHANGE	T_1	T_2	HOLD	CHANGE	RELEASE
1,2	G	Y	R	R	Y	R	R	R	R	R	G
3,4	G	Y	R	R	G	R	G	Y	R	R	G
5 *	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	NO LEFT TURN	NO LEFT TURN	BLANK
6,7,8,9	R	R	G	Y	R	Y	R	R	G	Y	R
10 *	BLANK	BLANK	BLANK	BLANK	NO RIGHT TURN	NO RIGHT TURN	NO RIGHT TURN	NO RIGHT TURN	NO RIGHT TURN	NO RIGHT TURN	BLANK

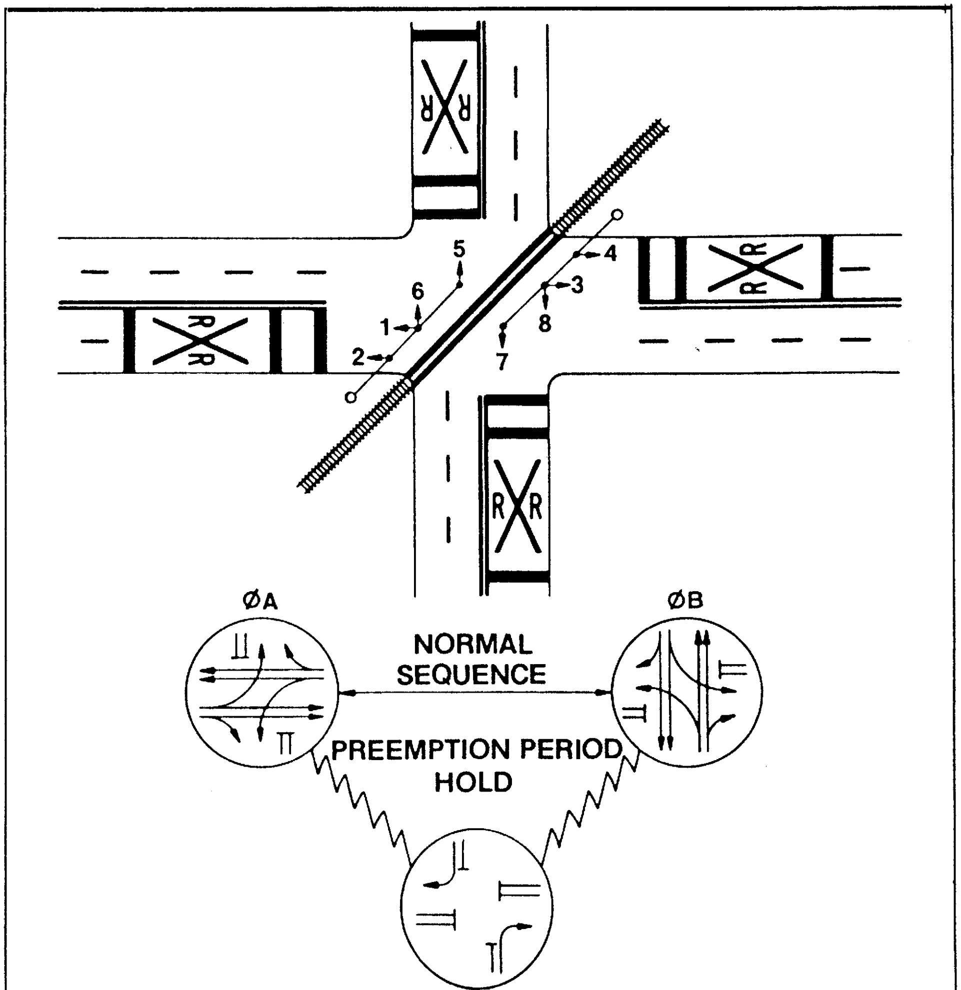
* OPTIONAL

Figure C-2. Typical Railroad Preemption Sequence, Signalized Intersection of 4-Lane Undivided Roadways, Two-Phase Operation (4)



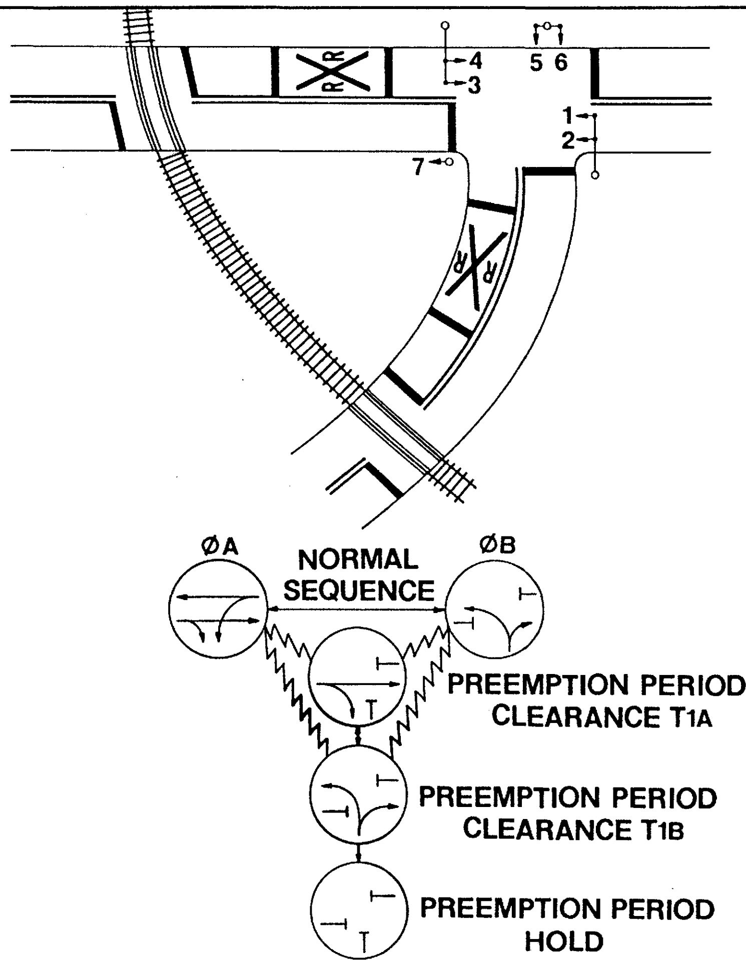
SIGNAL	ØA		ØB		PREEMPTION SEQUENCE			
	R/W	CHANGE	R/W	CHANGE	ØA CHANGE	ØB CHANGE	HOLD	RELEASE
1,2,3,4	G	Y	R	R	Y	R	R	G
5,6,7,8	R	R	G	Y	R	Y	R	R

Figure C-3. Typical Railroad Preemption Sequence, Signalized Intersection of 2-Lane Roadways With Railroad Bisecting Intersection, Two-Phase Operation (4)



SIGNAL	ØA		ØB		PREEMPTION SEQUENCE				
	R/W	CHANGE	R/W	CHANGE	ØA CHANGE	ØB CHANGE	HOLD	CHANGE	RELEASE
1,2,3,4	G	Y	R	R	Y	R	R	R	G
5,7	R	R	G	Y	R	Y	R	R	R
6,8	R	R	G	Y	R	Y	R →	Y R →	R

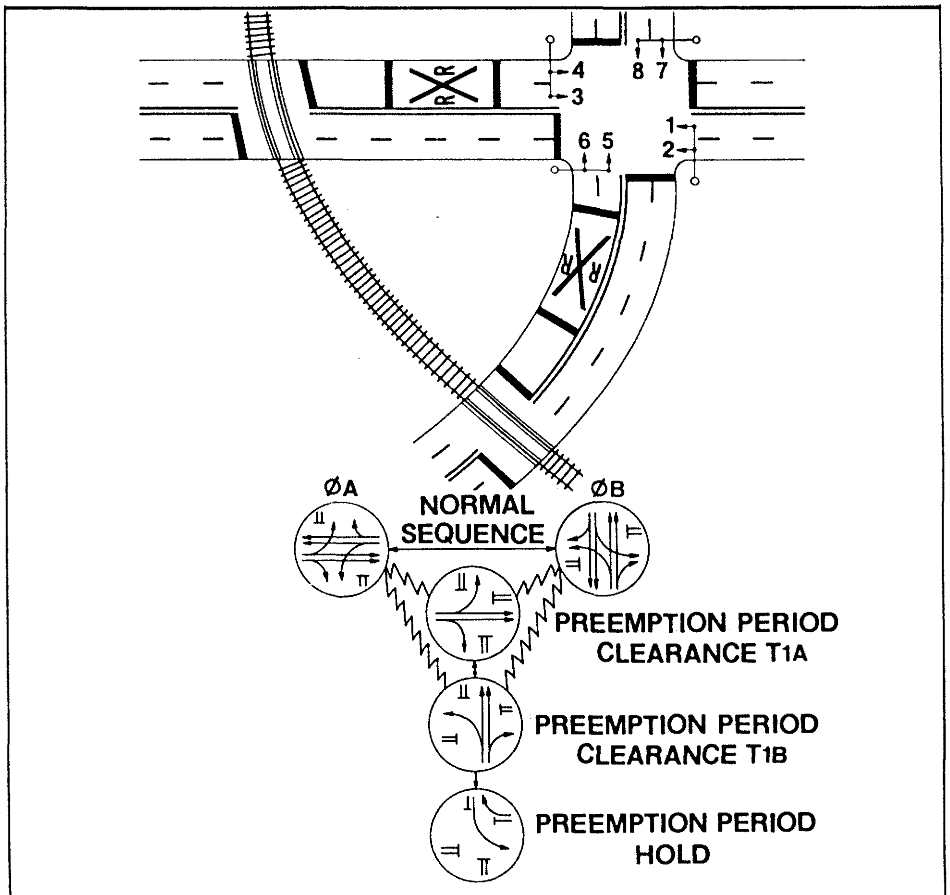
Figure C-4. Typical Railroad Preemption Sequence, Signalized Intersection of 4-Lane Undivided Roadways With Railroad Bisecting Intersection, Two-Phase Operation (4)



SIGNAL	ØA		ØB		PREEMPTION SEQUENCE									
	R/W	CHANGE	R/W	CHANGE	ØA CHANGE FOR T_{1A}	ØB CHANGE FOR T_{1A}	ØA CHANGE FOR T_{1B}	ØB CHANGE FOR T_{1B}	T_{1A}	T_{1B}	T_{2A}	T_{2B}	HOLD	RELEASE
1,2	G	Y	R	R	G	R	Y	R	G	R	Y	R	R	G
3,4	G	Y	R	R	Y	R	Y	R	R	R	R	R	R	G
5,6	R	R	G	Y	R	Y	R	G	R	G	R	Y	R	R
7 *	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	NO RIGHT TURN	BLANK

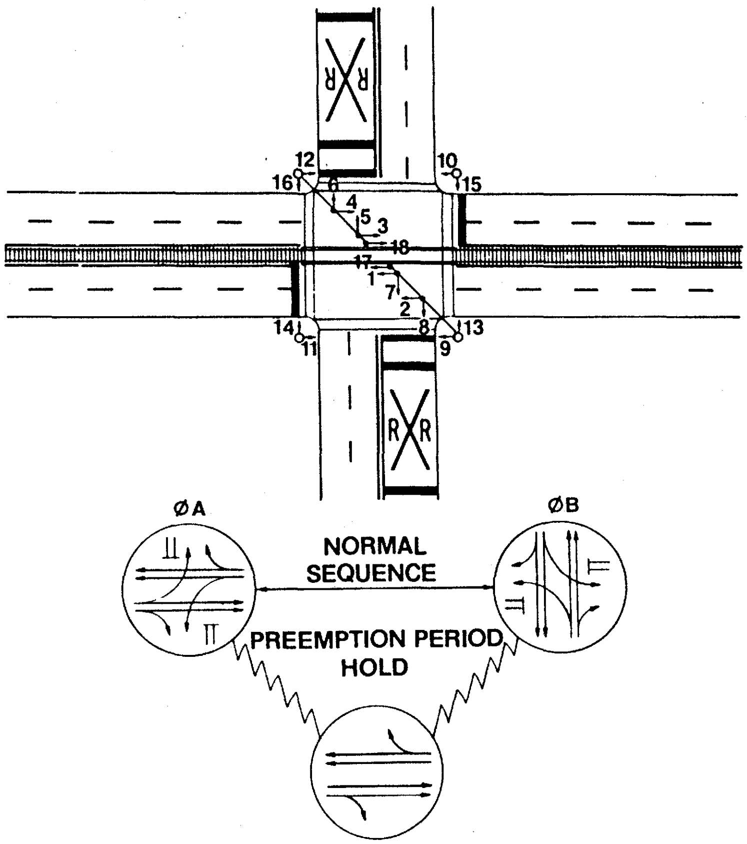
* OPTIONAL

Figure C-5. Typical Railroad Preemption Sequence, Signalized Intersection of 2-Lane Roadways With Railroad Crossings on Two Approaches, Two-Phase Operation (4)



SIGNAL	ØA		ØB		PREEMPTION SEQUENCE										
	R/W	CHANGE	R/W	CHANGE	ØA CHANGE FOR T_{1A}	ØB CHANGE FOR T_{1A}	ØA CHANGE FOR T_{1B}	ØB CHANGE FOR T_{1B}	T_{1A}	T_{1B}	T_{2A}	T_{2B}	HOLD	CHANGE	RELEASE
1,2	G	Y	R	R	G	R	Y	R	G	R	Y	R	R	R	G
3	G	Y	R	R	Y	R	Y	R	R	R	R	R	R	R	G
4	G	Y	R	R	Y	R	Y	R	R	R	R	R	R→	R→	G
5	R	R	G	Y	R	Y	R	Y	R	R	R	R	←R	←R Y	R
6	R	R	G	Y	R	Y	R	Y	R	R	R	R	R	R	R
7,8	R	R	G	Y	R	Y	R	G	R	G	R	Y	R	R	R

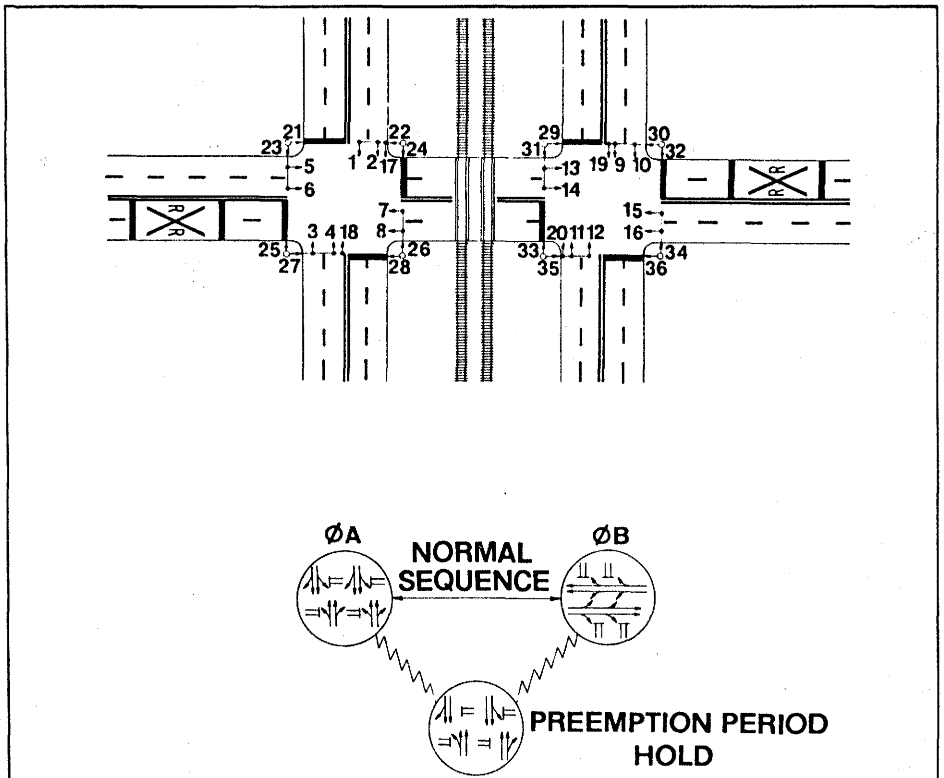
Figure C-6. Typical Railroad Preemption Sequence, Signalized Intersection of 4-lane Undivided Roadways With Railroad Crossing on Two Approaches, Two-Phase Operation (4)



SIGNAL	ØA		ØB		PREEMPTION SEQUENCE				
	R/W	CHANGE	R/W	CHANGE	ØA CHANGE	ØB CHANGE	HOLD	CHANGE	RELEASE
1,2,3,4	G	Y	R	R	G	R	G	Y	R
5,6,7,8	R	R	G	Y	R	Y	R	R	G
9,10,11,12	W/DW	DW	DW	DW	W	DW	W/DW	DW	DW
13,14,15,16	DW	DW	W/DW	DW	DW	DW	DW	DW	W
17,18*	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	NO LEFT TURN	NO LEFT TURN	BLANK

* OPTIONAL

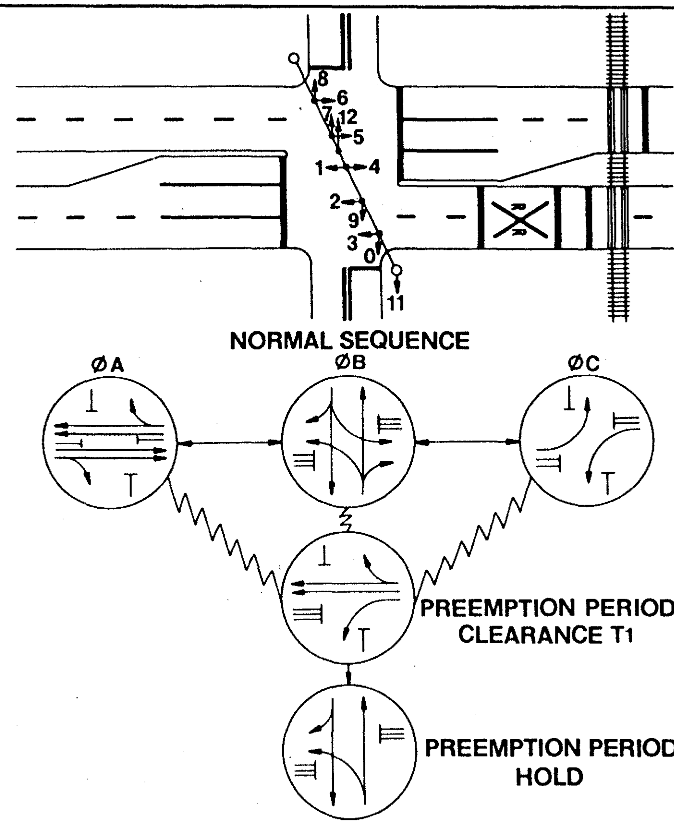
Figure C-7. Typical Railroad Preemption Sequence, Signalized Intersection of 4-Lane Roadways With Railroad Bisecting One Roadway, Two-Phase Operation With Pedestrian Signals (4)



SIGNAL	ØA		ØB		PREEMPTION SEQUENCE					
	R/W	CHANGE	R/W	CHANGE	ØA CHANGE	ØB CHANGE 1	CHANGE ØB 2	HOLD	CHANGE	RELEASE
1,2,3,4, 9,10,11,12	G	Y	R	R	Y	R	R	G	Y	R
5,6,15,16	R	R	G	Y	R	G	Y	R	R	G
7,8,13,14	R	R	G	Y	R	Y	R	R	R	G
17,20*	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	NO RIGHT TURN	NO RIGHT TURN	BLANK
18,19*	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	NO LEFT TURN	NO LEFT TURN	BLANK
21,22,27,28 29,30,35,36	DW	DW	W/DW	DW	DW	DW	DW	DW	DW	W/DW
23,24,25,26 31,32,33,34	W/DW	DW	DW	DW	DW	DW	DW	DW	DW	DW

* OPTIONAL

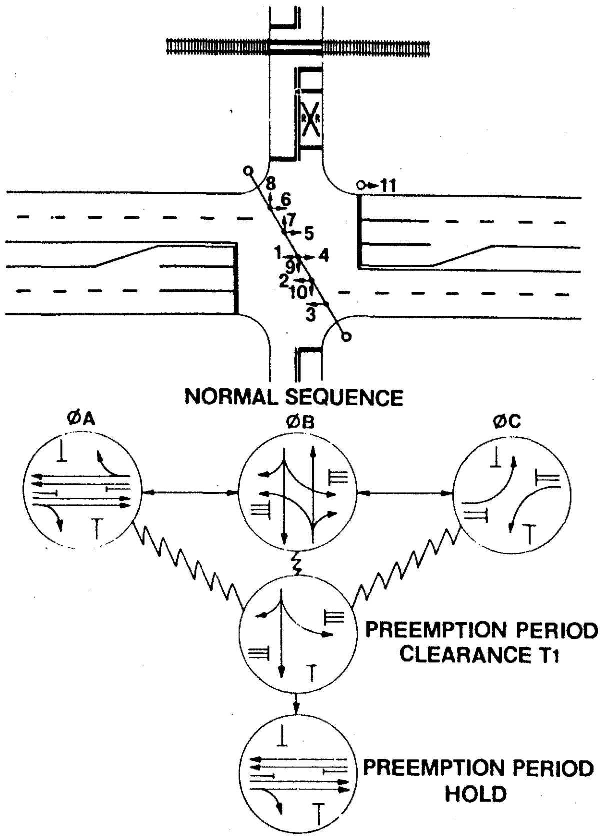
Figure C-8. Typical Railroad Preemption Sequence, Railroad Crossing Between Two Signalized Intersections, Two-Phase Operation With Pedestrian Signals (4)



SIGNAL	ØA		ØB		ØC		PREEMPTION SEQUENCE							
	R/W	CHANGE	R/W	CHANGE	R/W	CHANGE	ØA CHANGE	ØB CHANGE	ØC CHANGE	T_1	T_2	HOLD	CHANGE	RELEASE
1	R	R	R	R	←	Y	R	R	Y	R	R	R	R	R
2	↑	Y	R	R	R	R	Y	R	R	R	R	R	R	↑
3	↑→	Y	R	R	R	R	Y	R	R	R	R	R	R	↑→
4	R	R	R	R	←	Y	R	R	←	←	Y	R	R	R
5	↑	Y	R	R	R	R	↑	R	R	↑	Y	R	R	↑
6	↑→	Y	R	R	R	R	↑→	R	R	↑→	Y	R	R	↑→
7,8,9,10	R	R	G	Y	R	R	R	Y	R	R	R	G	Y	R
11*	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	NO RIGHT TURN	NO RIGHT TURN	BLANK
12*	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	NO LEFT TURN	NO LEFT TURN	BLANK

* OPTIONAL

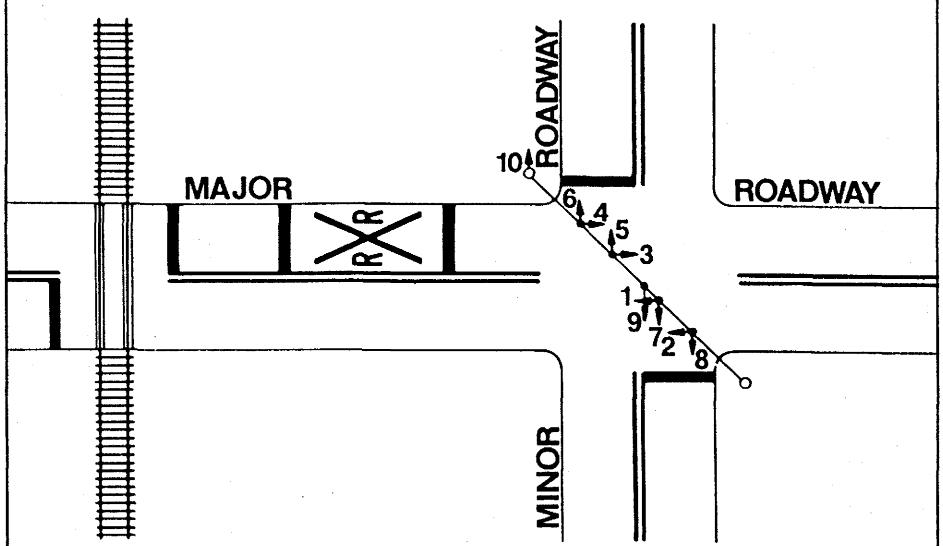
Figure C-9. Typical Railroad Preemption Sequence, Signalized Intersection of 4-Lane Divided and 2-Lane Roadways With Railroad Crossing on Major Approach -- Three-Phase Operation (4)



SIGNAL	ØA		ØB		ØC		PREEMPTION SEQUENCE						
	R/W	CHANGE	R/W	CHANGE	R/W	CHANGE	ØACHANGE	ØBCHANGE	ØCCHANGE	T_1	T_2	HOLD	RELEASE
1,4	R	R	R	R	←	Y	R	R	Y	R	R	R	R
2,5	↑	Y	R	R	R	R	Y	R	R	R	R	↑	↑
3	↑→	Y	R	R	R	R	Y	R	R	R	R	↑→	↑→
6	↑→	Y	R	R	R	R	Y	R	R	R	R	↑	↑→
7,8	R	R	G	Y	R	R	R	G	R	G	Y	R	R
9,10	R	R	G	Y	R	R	R	Y	R	R	R	R	R
11*	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	BLANK	NO RIGHT TURN	BLANK

* OPTIONAL

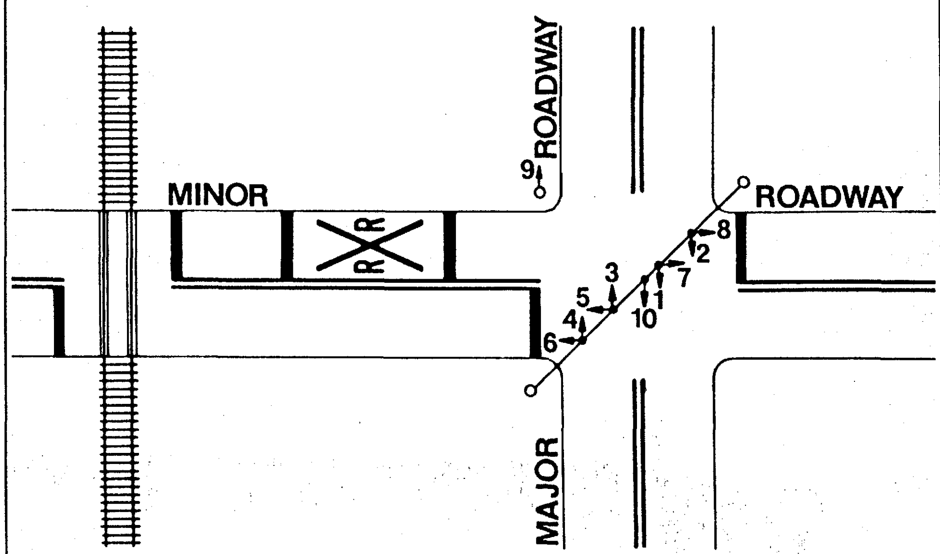
Figure C-10. Typical Railroad Preemption Sequence, Signalized Intersection of 4-lane Divided and 2-Lane Roadways With Railroad Crossing on Minor Approach -- Three-Phase Operation (4)



SIGNAL	NORMAL OPERATION	PREEMPTION SEQUENCE				
		CHANGE	T_1	T_2	HOLD	RELEASE
1,2	FY	FY	G	Y	R	FY
3,4	FY	Y	R	R	R	FY
5,6,7,8	FR	R	R	R	FR	FR
9*	BLANK	BLANK	BLANK	BLANK	NO LEFT TURN	BLANK
10*	BLANK	BLANK	BLANK	BLANK	NO RIGHT TURN	BLANK

* OPTIONAL

Figure C-11. Typical Railroad Preemption Sequence, Intersection With Flashing Beacon Control, Railroad Crossing on Major Approach (4)



SIGNAL	NORMAL OPERATION	PREEMPTION SEQUENCE				
		CHANGE	T_1	T_2	HOLD	RELEASE
1,2,3,4	FY	Y	R	R	FY	FY
5,6	FR	FR	G	Y	R	FR
7,8	FR	R	R	R	R	FR
9*	BLANK	BLANK	BLANK	BLANK	NO RIGHT TURN	BLANK
10*	BLANK	BLANK	BLANK	BLANK	NO LEFT TURN	BLANK

* OPTIONAL

Figure C-12. Typical Railroad Preemption Sequence, Intersection With Flashing Beacon Control, Railroad Crossing on Minor Approach (4)

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APPENDIX D
TYPICAL SIGNING AND PAVEMENT MARKINGS

Appendix D presents illustrations of typical signing and pavement markings at highway-rail intersections, reprinted from Appendix H of the Texas Manual on Uniform Traffic Control Devices (3). For additional information relating to signing and pavement markings at highway-rail intersections, refer to Section 4.2 on passive traffic control devices.

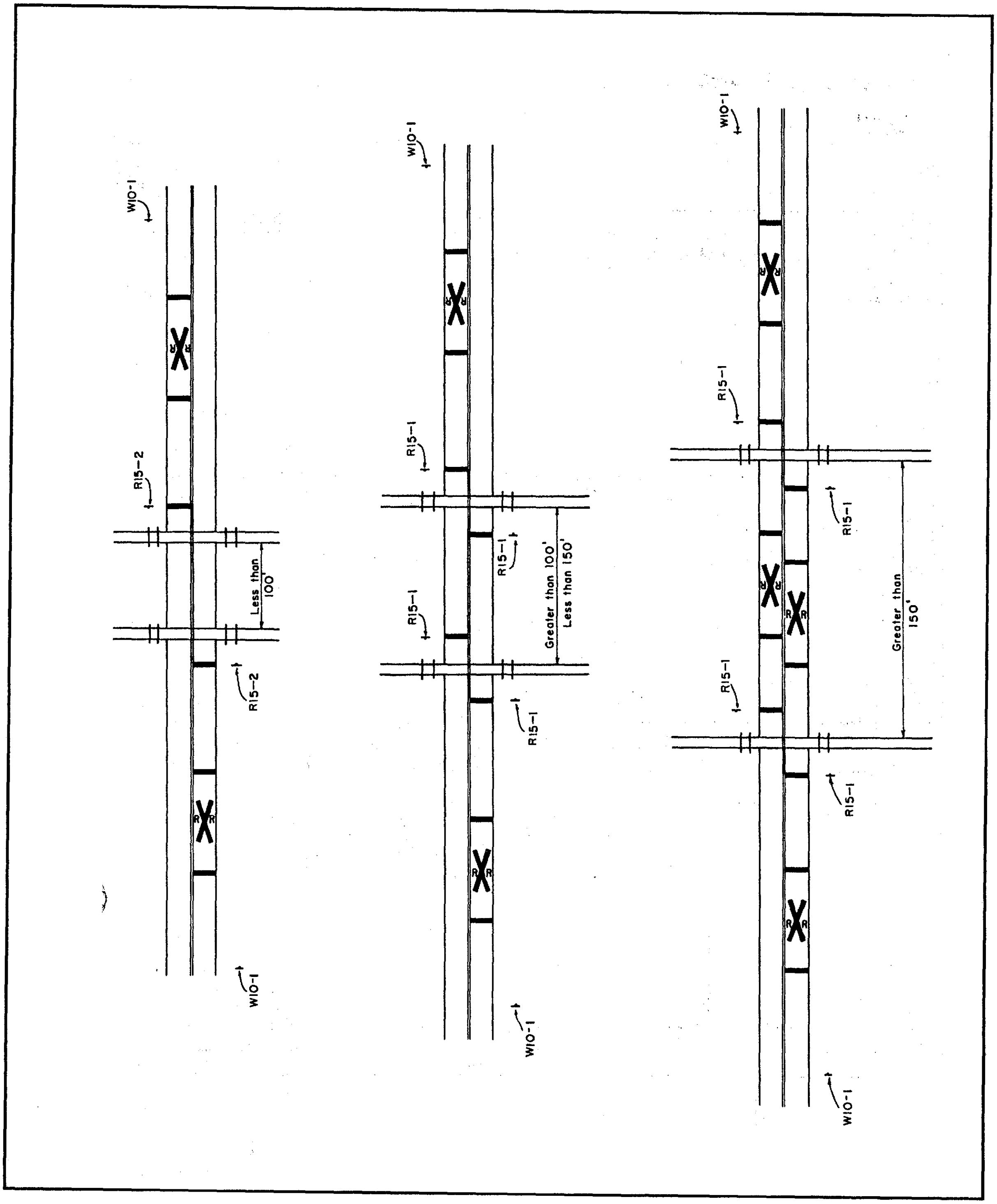


Figure D-1. Typical Signing and Pavement Markings (3)

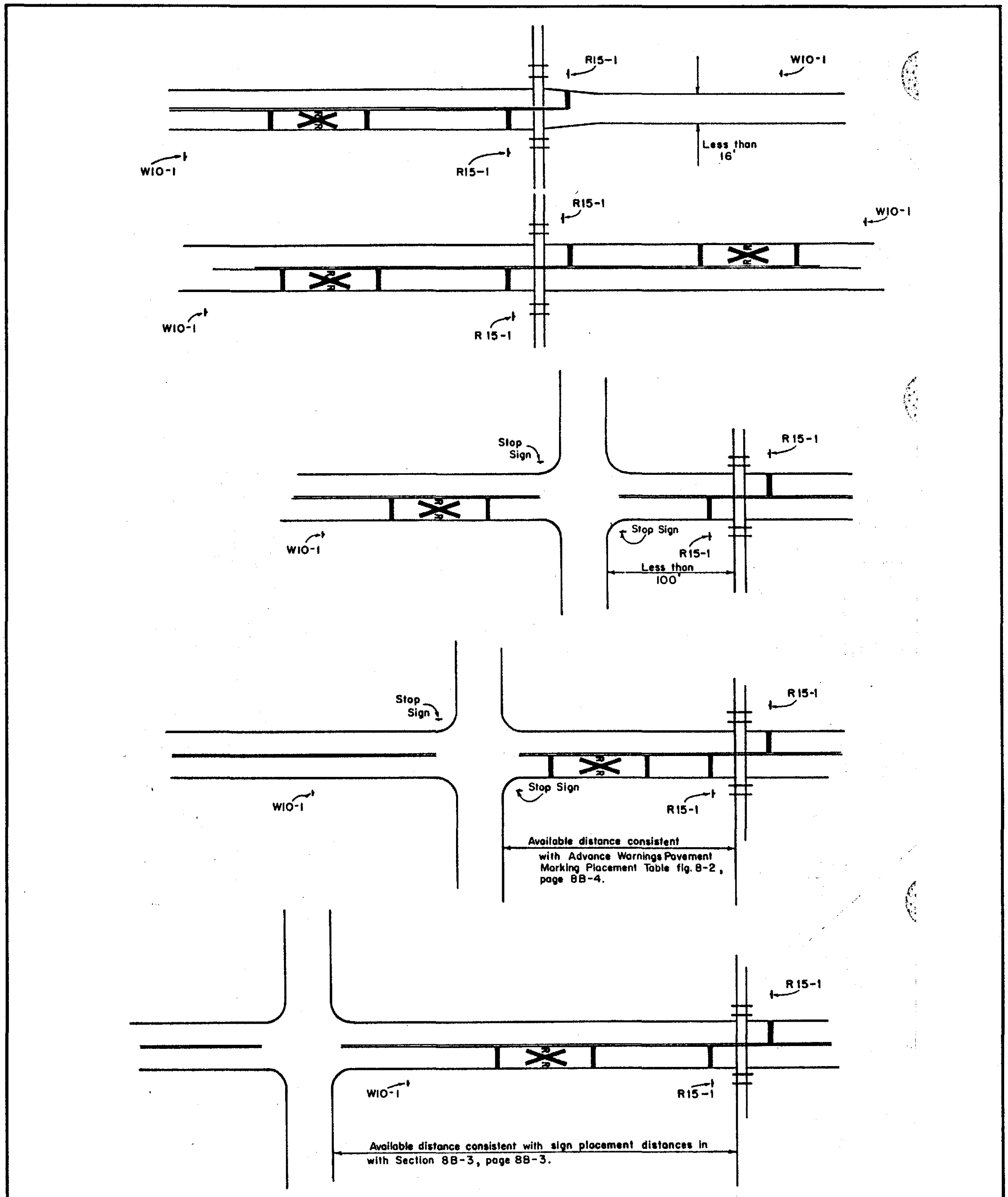


Figure D-2. Typical Signing and Pavement Markings (3)

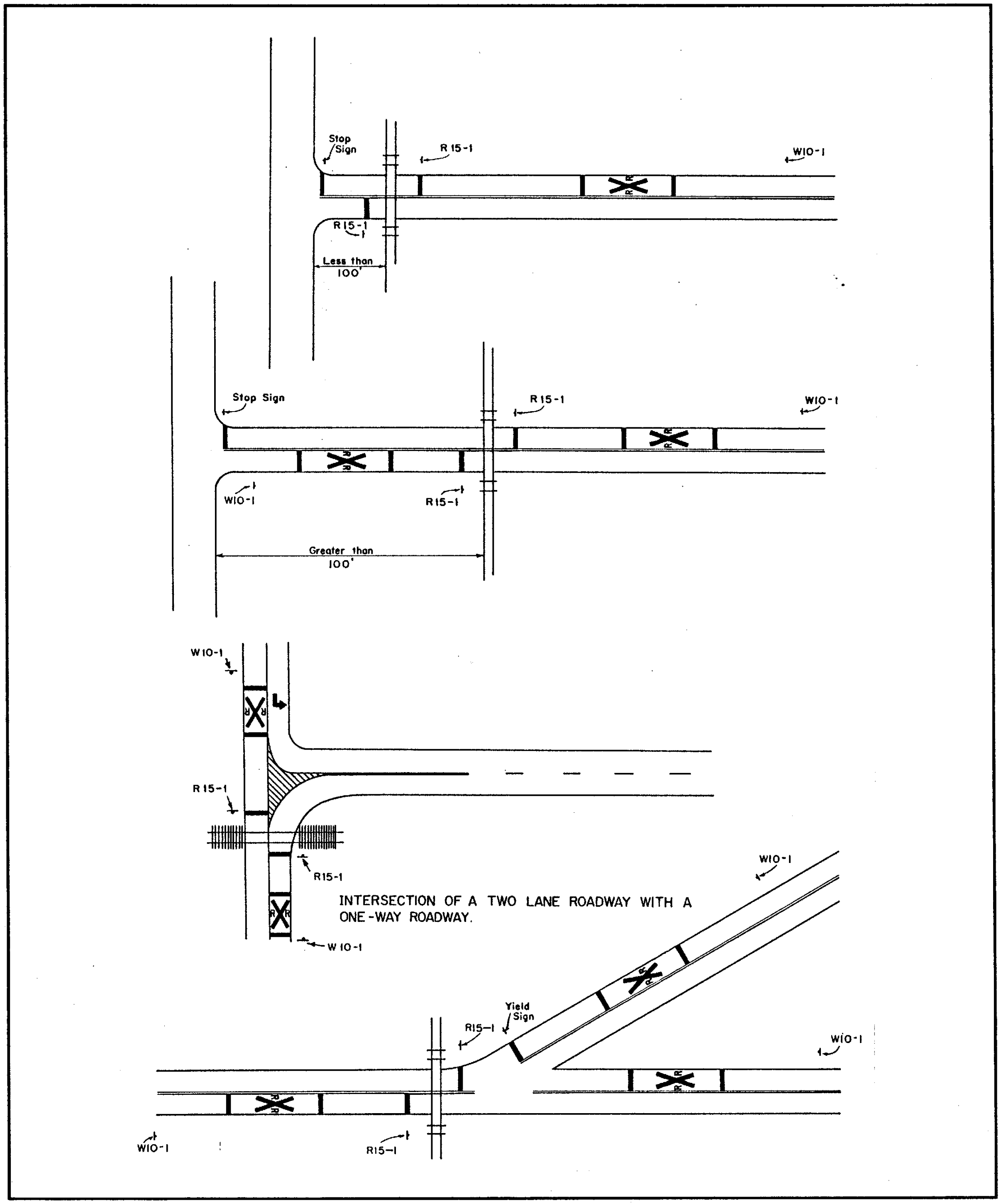


Figure D-3. Typical Signing and Pavement Markings (3)

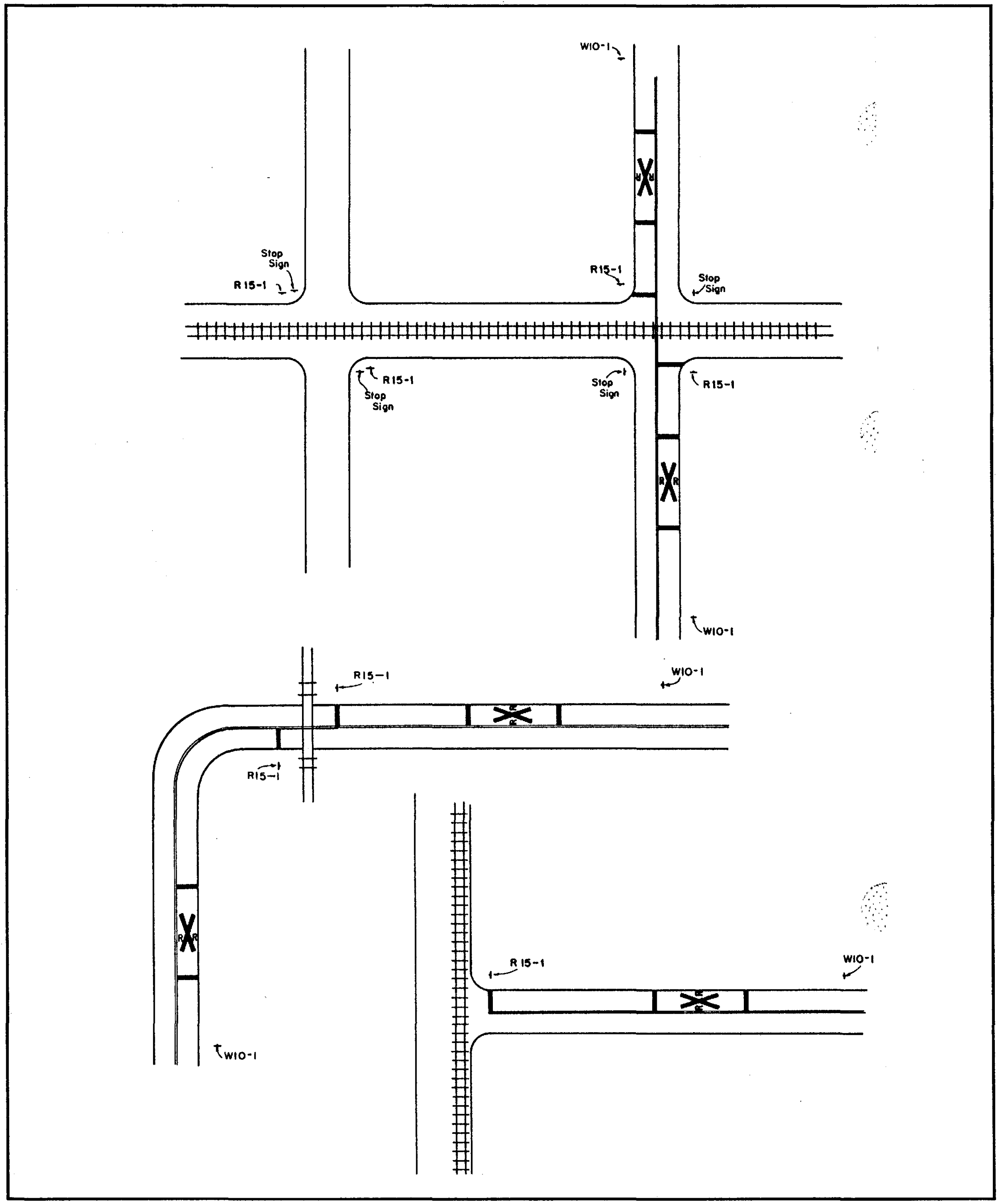
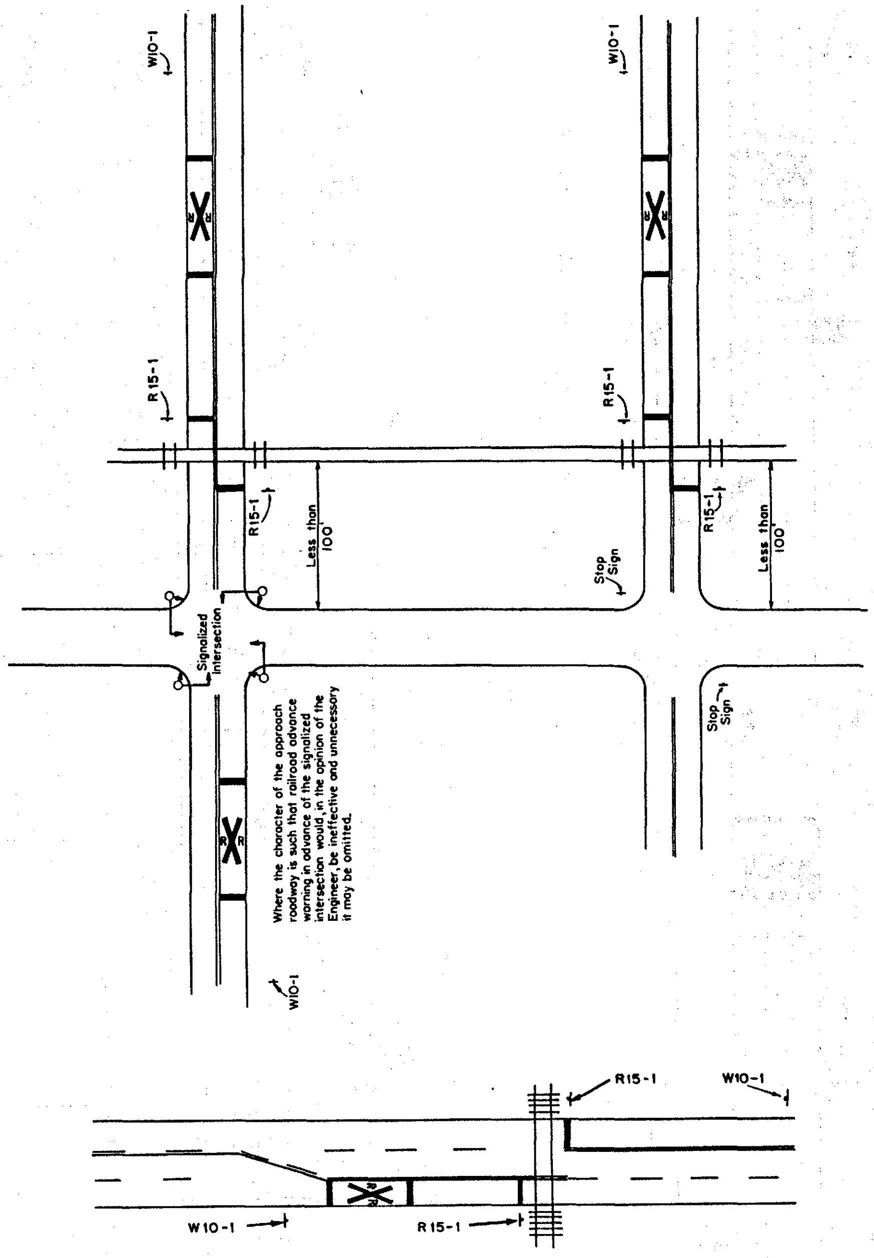


Figure D-4. Typical Signing and Pavement Markings (3)



A THREE LANE ROADWAY (PASSING LANES) SHOULD BE MARKED WITH A CENTERLINE FOR TWO LANE OPERATION ON THE APPROACH TO A CROSSING

Figure D-5. Typical Signing and Pavement Markings (3)

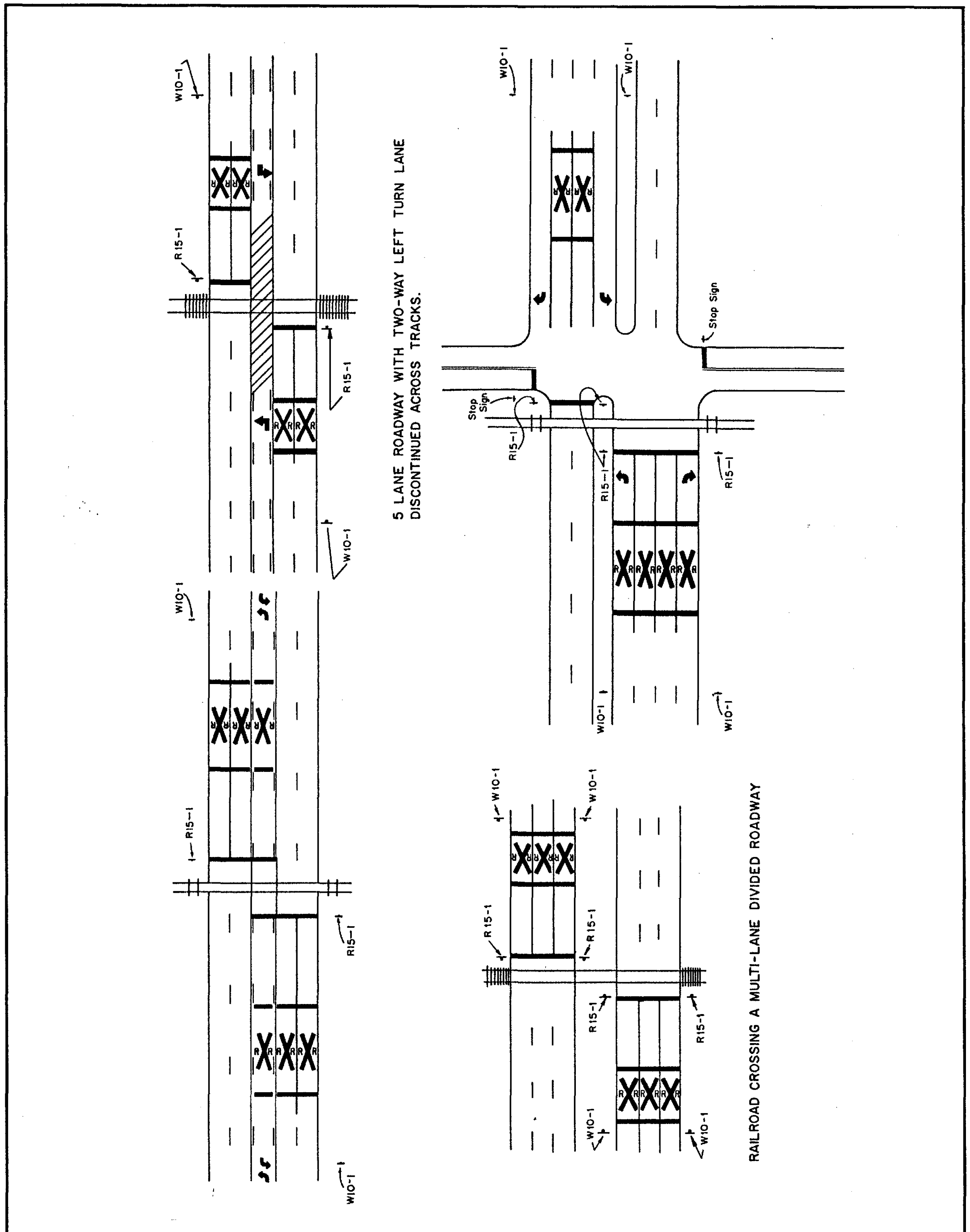


Figure D-6. Typical Signing and Pavement Markings (3)

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APPENDIX E
USDOT ACCIDENT PREDICTION FORMULAS AND FACTORS

Appendix E contains tables of formulas and factors to be used for specific applications of the USDOT Accident Prediction Model. These tables are found in the publication *Rail-Highway Crossing Resource Allocation Procedure* (16). Additional information regarding the various prediction formulas may be found in Section 6.2.

Table E-1. Equations for Crossing Characteristic Factors

GENERAL FORM OF BASIC FORMULA: a = K x EI x DT x MS x MT x HP x HL

	CROSSING CHARACTERISTIC FACTORS						
CROSSING CATEGORY	FORMULA CONSTANT	EXPOSURE INDEX FACTOR	DAY THROUGH TRAINS FACTOR	MAXIMUM TIMETABLE SPEED FACTOR	MAIN TRACKS FACTOR	HIGHWAY PAVED FACTOR	HIGHWAY LANES FACTOR
	K	EI	DT	MS	MT	HP	HL
PASSIVE	0.0006938	$((c \times t + 0.2)/0.2)^{0.37}$	$((d + 0.2)/0.2)^{0.178}$	$e^{0.0077ms}$	1.0	$e^{-0.5966(hp-1)}$	1.0
FLASHING LIGHTS	0.0003351	$((c \times t + 0.2)/0.2)^{0.4106}$	$((d + 0.2)/0.2)^{0.1131}$	1.0	$e^{0.1917mt}$	1.0	$e^{0.1826(hl-1)}$
GATES	0.0005745	$((c \times t + 0.2)/0.2)^{0.2942}$	$((d + 0.2)/0.2)^{0.1781}$	1.0	$e^{0.1512mt}$	1.0	$e^{0.1420(hl-1)}$

c = number of highway vehicles per day

t = number of trains per day

mt = number of main tracks

d = number of through trains per day during daylight

hp = highway paved? yes = 1.0 and no = 2.0

ms = maximum timetable speed, mph

hl = number of highway lanes

Table E-2. Factor Values for Crossings With Passive Warning Devices

GENERAL FORM OF BASIC FORMULA: a = K x EI x DT x MS x MT x HP x HL

K	"c" x "t"	EI	Day Through Trains	DT	Maximum Timetable Speed	MS	Main Tracks	MT	Highway Paved	HP	Highway Lanes	HL
0.0006938	0*-	1.00	0	1.00	0	1.00	0	1.00	1 (yes)	1.00	1	1.00
	1 - 5	2.43	1	1.37	5	1.04	1	1.00			2	1.00
	6 - 10	3.95	2	1.53	10	1.08	2	1.00	2 (no)	0.55	3	1.00
	11 - 20	4.96	3	1.64	15	1.12	3	1.00			4	1.00
	21 - 30	5.99	4	1.72	20	1.17	4	1.00			5	1.00
	31 - 50	7.12	5	1.79	25	1.21	5	1.00			6	1.00
	51 - 80	8.51	6	1.84	30	1.26	6	1.00			7	1.00
	81 - 120	9.98	7	1.89	35	1.31					8	1.00
	121 - 200	11.88	8	1.94	40	1.36					9	1.00
	201 - 300	14.00	9	1.98	45	1.41						
	301 - 400	15.85	10	2.01	50	1.47						
	401 - 500	17.39	11-10	2.16	55	1.53						
	501 - 600	18.73	21-30	2.37	60	1.59						
	601 - 700	19.93	31-40	2.51	65	1.65						
	701 - 1000	22.01	41-60	2.67	70	1.71						
	1001 - 1300	24.61			75	1.78						
	1301 - 1600	26.81			80	1.85						
	1601 - 2000	29.05			85	1.92						
	2001 - 2500	31.28			90	2.00						
	2501 - 3000	33.98										
	3001 - 4000	37.15										
	4001 - 6000	42.39										
	6001 - 8000	48.01										
	8001 - 10000	52.69										
	10001 - 15000	59.49										
	15001 - 20000	67.38										
	20001 - 25000	73.95										
	25001 - 30000	79.65										
	30001 - 40000	87.08										
	40001 - 50000	95.57										
	50001 - 60000	102.93										
	60001 - 70000	109.50										
	70001 - 90000	118.24										
	90001 - 110000	128.42										
	110001 - 130000	137.38										
	130001 - 180000	151.02										
	180001 - 230000	167.48										
	230001 - 300000	187.14										
	300001 - 370000	200.86										

K = formula constant
"c" x "t" - number of highway vehicles per day, "c", multiplied by the number of trains per day, "t"
EI = exposure index factor
MT = main tracks factor
DT = day through trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HL = highway lanes factor

*Less than one train per day.

Table E-3. Factor Values for Crossings With Flashing Light Warning Devices

GENERAL FORM OF BASIC FORMULA: a = K x EI x DT x MS x MT x HP x HL

K	"c" x "t"	EI	Day Through Trains	DT	Maximum Timetable Speed	MS	Main Tracks	MT	Highway Paved	HP	Highway Lanes	HL
0.0003351	0*-	1.00	0	1.00	0	1.00	0	1.00	1 (yes)	1.00	1	1.00
	1 - 5	3.12	1	1.22	5	1.00	1	1.21			2	1.20
	6 - 10	4.59	2	1.31	10	1.00	2	1.47	2 (no)	1.00	3	1.44
	11 - 20	5.92	3	1.37	15	1.00	3	1.78			4	1.72
	21 - 30	7.28	4	1.41	20	1.00	4	2.15			5	2.08
	31 - 50	8.82	5	1.45	25	1.00	5	2.61			6	2.49
	51 - 80	10.76	6	1.47	30	1.00	6	3.16			7	2.99
	81 - 120	12.54	7	1.50	35	1.00					8	3.59
	121 - 200	15.57	8	1.52	40	1.00					9	4.31
	201 - 300	18.70	9	1.54	45	1.00						
	301 - 400	21.46	10	1.56	50	1.00						
	401 - 500	23.79	11-20	1.63	55	1.00						
	501 - 600	25.84	21-30	1.73	60	1.00						
	601 - 700	27.67	31-40	1.79	65	1.00						
	701 - 1000	30.89	41-60	1.87	70	1.00						
	1001 - 1300	34.97			75	1.00						
	1301 - 1600	38.47			80	1.00						
	1601 - 2000	42.04			85	1.00						
	2001 - 2500	46.07			90	1.00						
	2501 - 3000	50.03										
	3001 - 4000	55.23										
	4001 - 6000	63.94										
	6001 - 8000	73.42										
	8001 - 10000	81.40										
	10001 - 15000	93.15										
	15001 - 20000	106.95										
	20001 - 25000	118.58										
	25001 - 30000	128.76										
	30001 - 40000	142.17										
	40001 - 50000	157.62										
	50001 - 60000	171.16										
	60001 - 70000	183.31										
	70001 - 90000	199.62										
	90001 - 110000	218.78										
	110001 - 130000	235.78										
	130001 - 180000	261.91										
	180001 - 230000	293.77										
	230001 - 300000	326.42										
	300001 - 370000	359.40										

K = formula constant
"c" x "t" = number of highway vehicles per day, "c", multiplied by the number of trains per day, "t"
EI = exposure index factor
MT = main tracks factor
DT = day through trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HL = highway lanes factor

*Less than one train per day.

Table E-4. Factor Values for Crossings With Gate Warning Devices

GENERAL FORM OF BASIC FORMULA: a = K x EI x DT x MS x MT x HP x HL

K	"c" x "t"	EI	Day Through Trains	DT	Maximum Timetable Speed	MS	Main Tracks	MT	Highway Paved	HP	Highway Lanes	HL
0.0005745	0*-	1.00	0	1.00	0	1.00	0	1.00	1 (yes)	1.00	1	1.00
	1 - 5	2.26	1	1.38	5	1.00	1	1.16			2	1.15
	6 - 10	2.98	2	1.53	10	1.00	2	1.35	2 (no)	1.00	3	1.32
	11 - 20	3.57	3	1.64	15	1.00	3	1.57			4	1.53
	21 - 30	4.15	4	1.72	20	1.00	4	1.83			5	1.76
	31 - 50	4.76	5	1.79	25	1.00	5	2.13			6	2.03
	51 - 80	5.99	6	1.84	30	1.00	6	2.48			7	2.34
	81 - 120	6.23	7	1.89	35	1.00					8	2.70
	121 - 200	7.15	8	1.94	40	1.00					9	3.11
	201 - 300	8.15	9	1.98	45	1.00						
	301 - 400	9.00	10	2.01	50	1.00						
	401 - 500	9.69	11-20	2.16	55	1.00						
	501 - 600	10.28	21-30	2.37	60	1.00						
	601 - 700	10.79	31-40	2.51	65	1.00						
	701 - 1000	11.68	41-60	2.68	70	1.00						
	1001 - 1300	12.77			75	1.00						
	1301 - 1600	13.67			80	1.00						
	1601 - 2000	14.57			85	1.00						
	2001 - 2500	15.55			90	1.00						
	2501 - 3000	16.20										
	3001 - 4000	17.71										
	4001 - 6000	19.67										
	6001 - 8000	21.72										
	8001 - 10000	23.39										
	10001 - 15000	25.76										
	15001 - 20000	28.44										
	20001 - 25000	30.67										
	25001 - 30000	32.49										
	30001 - 40000	34.87										
	40001 - 50000	37.55										
	50001 - 60000	39.83										
	60001 - 70000	41.84										
	70001 - 90000	44.48										
	90001 - 110000	47.49										
	110001 - 130000	50.11										
	130001 - 180000	54.03										
	180001 - 230000	58.24										
	230001 - 300000	63.26										
	300001 - 370000	67.78										

K = formula constant
"c" x "t" = number of highway vehicles per day, "c", multiplied by the number of trains per day, "t"
EI - exposure index factor
MT = main tracks factor
DT = day through trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HL = highway lanes factor

*Less than one train per day.

Table E-5. Equations for Crossing Characteristic Factors for Fatal Accident Probability Formula

Fatal Accident Probability Formula: $P(FA|A) = 1/(1 + KF \times MS \times TT \times TS \times UR)$

CROSSING CHARACTERISTIC FACTOR	EQUATION FOR CROSSING CHARACTERISTIC FACTOR
Formula constant	$KF = 440.9$
Maximum Timetable Train Speed Factor	$MS = ms^{-0.9981}$
Thru Trains Per Day Factor	$TT = (tt + 1)^{-0.0872}$
Switch Trains Per Day Factor	$TS = (ts + 1)^{0.0872}$
Urban - Rural Crossing Factor	$UR = e^{0.3571ur}$

where:

ms = maximum timetable train speed, mph

tt = number of thru trains per day

ts = number of switch trains per day

ur: urban crossing = 1, rural crossing = 0

ur = FC10 (tens digit of functional classification). See page A-11.

Table E-6. Equations for Crossing Characteristic Factors for Casualty Accident Probability Formula

Casualty Accident Probability Formula: $P(CA|A) = 1/(1 + KC \times MS \times TK \times UR)$

CROSSING CHARACTERISTIC FACTOR	EQUATION FOR CROSSING CHARACTERISTIC FACTOR
Formula Constant	$KC = 4.481$
Maximum Timetable Train Speed Factor	$MS = ms^{-0.343}$
Number of Tracks Factor	$TK = e^{0.1153tk}$
Urban - Rural Crossing Factor	$UR = e^{0.296ur}$

where:

ms = maximum timetable train speed, mph

tk = total number of tracks at crossing

ur: urban crossing = 1, rural crossing = 0

ur = FC10 (tens digit of functional classification). See page A-11.

Table E-7. Factor Values for Fatal Accident Probability Formula

Fatal Accident Probability Formula: $P(FA|A) = 1/(1 + KF \times MS \times TT \times TS \times UR)$

FORMULA CONSTANT KF	MAXIMUM TIMETABLE TRAIN SPEED	MS	THROUGH TRAINS PER DAY	TT	SWITCH TRAINS PER DAY	TS	URBAN RURAL CROSSING	UR
440.9	1	1.000	0	1.000	0	1.000	0 (rural)	1.000
	5	0.201	1	0.941	1	1.062	1 (urban)	1.344
	10	0.100	2	0.908	2	1.101		
	15	0.067	3	0.886	3	1.128		
	20	0.050	4	0.869	4	1.151		
	25	0.040	5	0.855	5	1.169		
	30	0.034	6	0.844	6	1.185		
	40	0.025	7	0.834	7	1.199		
	50	0.020	9	0.818	9	1.222		
	60	0.017	10	0.811	10	1.233		
	70	0.014	20	0.767	20	1.304		
	80	0.013	30	0.741	30	1.349		
	90	0.011	40	0.723	40	1.382		
	100	0.010	50	0.710	50	1.409		

Table E-8. Factor Values for Casualty Accident Probability Formula

CASUALTY ACCIDENT PROBABILITY FORMULA: P(CA|A) = 1/(1 + KC x MS X TK x UR)

FORMULA CONSTANT KC	MAXIMUM TIMETABLE TRAIN SPEED	MS	TOTAL NUMBER OF TRACKS	TK	URBAN-RURAL CROSSING	UR
4.481	1	1.000	0	1.000	0 (rural)	1.000
	5	0.576	1	1.122	1 (urban)	1.429
	10	0.454	2	1.259		
	15	0.395	3	1.413		
	20	0.358	5	1.780		
	25	0.332	6	1.997		
	30	0.308	7	2.241		
	40	0.282	8	2.515		
	50	0.261	9	2.823		
	60	0.246	10	3.168		
	70	0.233	15	5.638		
	80	0.222	20	10.034		
	90	0.214				
	100	0.206				

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APPENDIX F
COORDINATION CONTACTS

TEXAS DEPARTMENT OF TRANSPORTATION

TxDOT district railroad contact personnel may be obtained by writing to the Traffic Operations Division at the address below, or by contacting the local TxDOT District Office (see next page for addresses, phone numbers, and FAX numbers).

Gary Trietsch
Director
TxDOT - Traffic Operations Division
125 E. 11th Street
Austin, Texas 78701

Sam Brooks
TxDOT - Traffic Operations Division, Railroad Section
125 E. 11th Street
Austin, Texas 78701

OPERATION LIFESAVER

Texas Operation Lifesaver
Carolyn Cook, State Coordinator
Texas Safety Association
P.O. Box 9345
Austin, Texas 78766-9345
(512) 343-6525

Leila A. Osina
Executive Director
Operation Lifesaver, Inc.
1420 King Street, Suite 401
Alexandria, Virginia 22314
1-800-537-6224
FAX: 703-519-8267

FEDERAL RAILROAD ADMINISTRATION

Bruce F. George
Transportation Specialist
Federal Railroad Administration
400 7th St., S.W., RRS-21
Washington, D.C. 20590

Table F-1. TxDOT District Office Mailing Addresses and Telephone Numbers

District	Mailing Address	Telephone/FAX
Abilene	P.O. Box 150 Abilene 79604-0150	Phone: 915/676-6802 FAX: 915/676-6901
Amarillo	P.O. Box 2708 Amarillo 79105-2708	Phone: 806/356-3201 FAX: 806/358-4828
Atlanta	P.O. Box 1210 Atlanta 75551-1210	Phone: 903/796-2851 FAX: 903/799-1229
Austin	P.O. Drawer 15426 Austin 78761-5426	Phone: 512/832-7021 FAX: 512/832-7149
Beaumont	P.O. Box 3468 Beaumont 77704-3468	Phone: 409/898-5730 FAX: 409/898-5801
Brownwood	P.O. Box 1549 Brownwood 76804-1549	Phone: 915/646-2591 FAX: 915/643-0306
Bryan	P.O. Box 3249 Bryan 77805-3249	Phone: 409/778-9600 FAX: 409/778-9709
Childress	P.O. Box 900 Childress 79201-0900	Phone: 817/937-7100 FAX: 817/937-7154
Corpus Christi	P.O. Box 9907 Corpus Christi 78469-9907	Phone: 512/808-2300 FAX: 512/808-2313
Dallas	P.O. Box 3067 Dallas 75221-3067	Phone: 214/320-6100 FAX: 214/320-6117
El Paso	P.O. Box 10278 El Paso 79994-0278	Phone: 915/774-4200 FAX: 915/774-4259
Ft. Worth	P.O. Box 6868 Ft. Worth 76115-0868	Phone: 817/370-6500 FAX: 817/370-6787
Houston	P.O. Box 1386 Houston 77251-1386	Phone: 713/802-5000 FAX: 713/802-5400
Laredo	P.O. Box 2248 Laredo 78044-2248	Phone: 210/718-2066 FAX: 210/718-2068
Lubbock	P.O. Box 771 Lubbock 79408-0771	Phone: 806/745-4411 FAX: 806/748-4380
Lufkin	P.O. Box 280 Lufkin 75902-0280	Phone: 409/634-4433 FAX: 409/633-4378
Odessa	3901 E. U.S. Hwy. 80 Odessa 79761	Phone: 915/332-0501 FAX: 915/333-9156
Paris	P.O. Box 250 Paris 75460-0250	Phone: 903/737-9300 FAX: 903/737-9204
Pharr	P.O. Drawer EE Pharr 78577-1231	Phone: 210/702-6100 FAX: 210/702-6110
San Angelo	P.O. Box 61550 San Angelo 76906-1550	Phone: 915/944-1501 FAX: 915/944-1501
San Antonio	P.O. Box 29928 San Antonio 78284-3601	Phone: 210/615-1110 FAX: 210/615-5935
Tyler	P.O. Box 2031 Tyler 75710-2031	Phone: 903/510-9100 FAX: 903/510-9127
Waco	P.O. Box 1010 Waco 76703-1010	Phone: 817/867-2700 FAX: 817/867-2890
Wichita Falls	P.O. Box 660 Wichita Falls 76307-0660	Phone: 817/720-7700 FAX: 817/720-7848
Yoakum	P.O. Box 757 Yoakum 77995-0757	Phone: 512/293-4300 FAX: 512/293-4372