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RAILROAD - HIGHWAY GRADE CROSSING HANDBOOK

TECHNOLOGY SHARING REPORT

U.S. DEPARTMENT OF TRANSPORTATION

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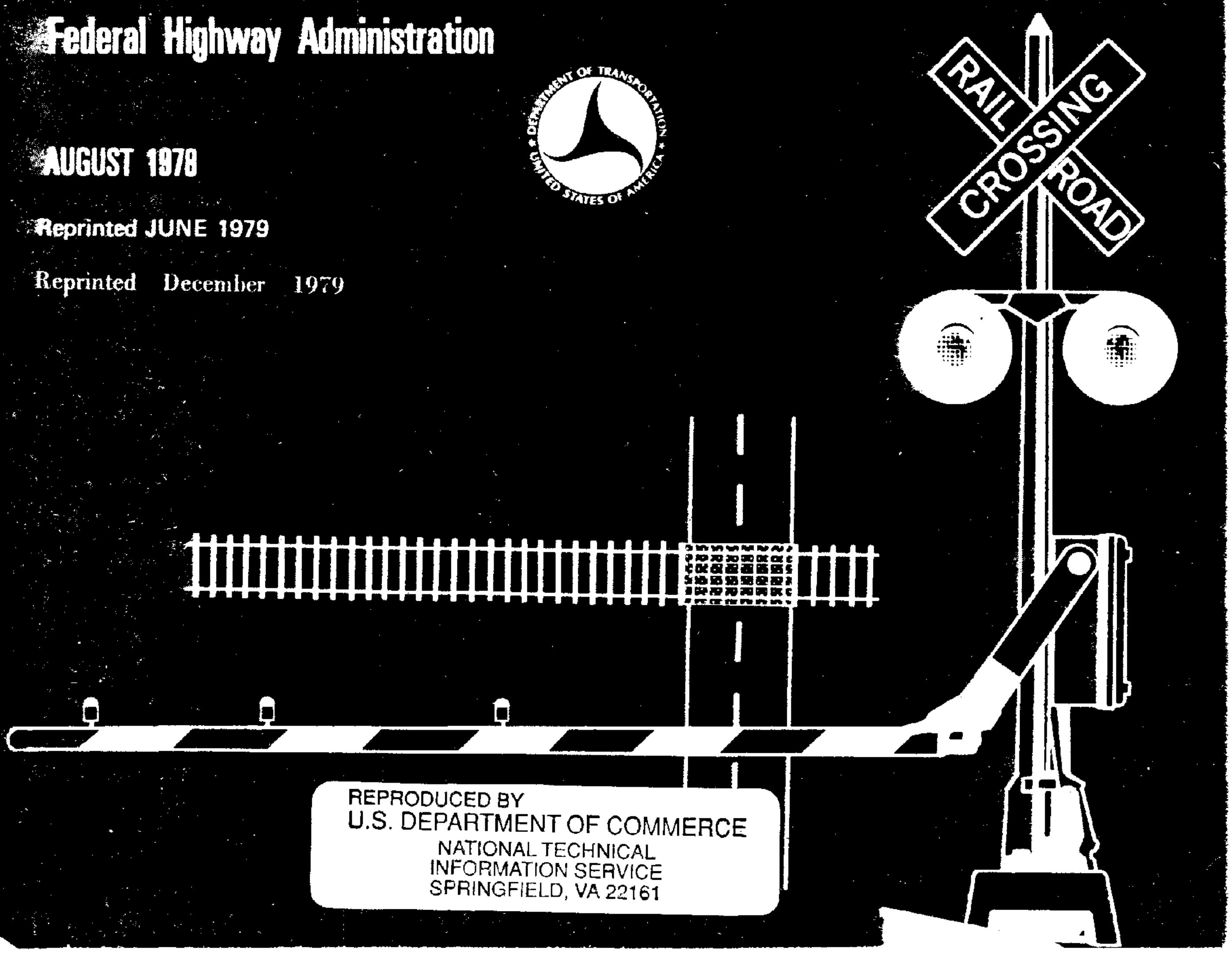

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16. Abstract

This handbook is a compendium of applicable concepts, technology, and practices dealing with the improvement of safety and efficiency of railroad-highway grade crossings. It is written in easy to understand language and is for use by engineers and others engaged in the planning and design of grade crossings.

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RAILROAD - HIGHWAY GRADE CROSSING HANDBOOK

FEDERAL HIGHWAY ADMINISTRATION

OFFICE OF ENGINEERING
Federal Aid Division
Railroad and Utilities Branch

OFFICE OF DEVELOPMENT
Implementation Division

OFFICE OF RESEARCH
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1.0 INTRODUCTION

1.1 BACKGROUND

The railroad industry in the United States began in 1830, and by 1890 there were 163,597 miles (263,391 km) of railroad line in the nation (1). Growth increased until a peak was reached in 1920 when 252,845 miles (407,080 km) of railroad line were in service (see Table 1). The development of the national highway system began about 1920 and by 1973 consisted of 690,000 (1,110,900 km) of interstate, U.S. routes, and state highways. In its August, 1972 report to Congress the U.S. Department of Transportation, Federal Highway Administration (FHWA) and Federal Railroad Administration (FRA) stated:

> There are approximately 220,000 miles (354,200 km) of railroad line with nearly 500 million train-miles of travel annually on those lines. There are also 3.7 million miles (5,957,000 km) of roads and streets carrying over 1 trillion vehicle-miles of travel annually.
>
> Although estimated motor vehicle miles of travel in the Unites States increased by a factor of 25, i.e., by 2400 percent, in the 50-year period from 1920 to 1970, the total mileage of roads and streets increased by only 20 percent. Vast improvements to existing highway routes have accompanied the great expansion of vehicular traffic, but even during the most recent 20-year period, during which the greatest highway improvements have been carried out, the total highway and street mileage has grown at a rate of only 0.5 percent per year.
>
> During the 50-year period since 1920, miles of railroad line in the United States have declined by almost 20 percent, at a reasonably uniform rate of 0.4 percent per year.

Figure 1 shows the trend in highway and railroad mileage.

The construction of railroads was a major factor in accelerating the great westward expansion of the United States by providing a reliable, economical, and rapid method of transportation. Many existing cities and towns made certain concessions in order to obtain a railroad, one of which was to frequently allow the railroads to build their tracks along existing streets and roads at grade. As settlement moved farther west, new towns were developed along the railroad. Later, as the national highway system was being built, the railroads provided an economical means of transporting road building materials and equipment. Highway rights-of-way were easier to acquire adjacent

Table 1. Railroad Line Mileage

Year	Miles
1840	2,818
1850	9,021
1860	30,626
1870	52,922
1880	93,267
1890	163,597
1900	193,346
1910	240,293
1920	252,845
1930	249,052
1940	233,670
1950	223,779
1960	217,552
1970	205,782
1974	200,391

Note: 1 mile = 1.61 Kilometers

Sources: Historical Atlas of the United States (2) and Transport Statistics in the United States, 1974 (1).

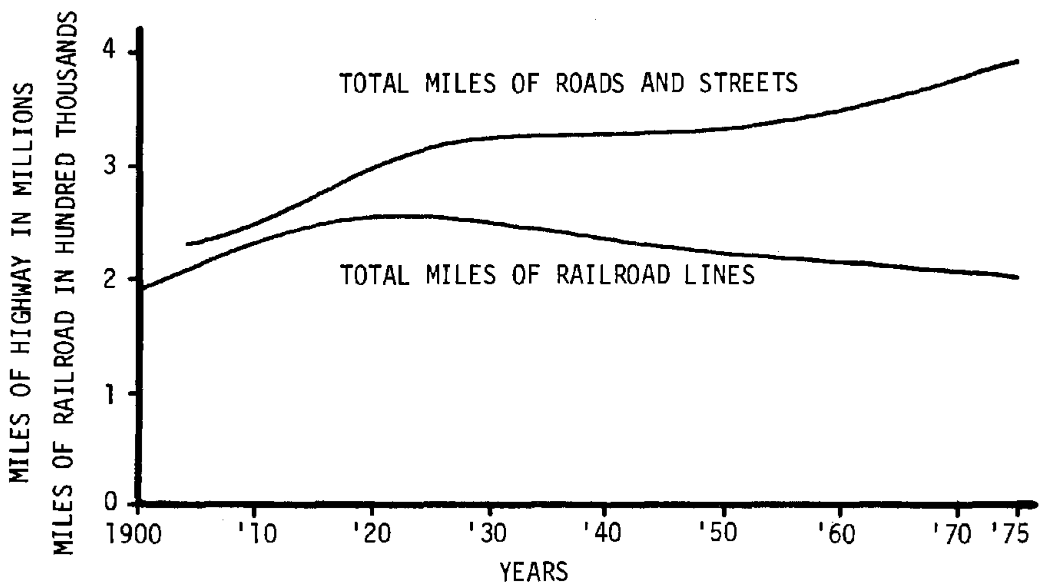

Figure 1. Mileage of Roads and Streets, and Mileage of Railroads in the United States

---

1 mile = 1.61 kilometers

to railroad rights-of-way. Thus many highways were constructed along railroad tracks.

Hence, many existing cities, new cities and highways were all developed along or near railroad tracks. Such developments created a multiplicity of at-grade railroad crossings all over the United States. The National Railroad-Highway Crossing Inventory completed in 1976 listed 219,300 public grade crossings in use (3).

1.1.1 Grade Crossing Accidents

The intersection of railroad lines with streets and highways at-grade introduces serious conflicts. These conflicts introduce the potential for serious accidents as well as troublesome and costly delays. Of primary concern is the loss of life, the serious injuries, and the tremendous amount of property damage that result from vehicle-train collisions at railroad-highway grade crossings.

No national statistics on grade crossing accidents are available for the 19th century, however, grade crossings caused public concern even during this period. For instance, a collision between a train and wagon in Lima, Indiana resulted in a suit which eventually reached the U.S. Supreme Court in 1877. In Continental Improvement Company v. Stead, 95 U.S. 1, the Court held that the driver failed to exercise ordinary care; but, it is also held that the railroad was "bound to give due, reasonable and timely warning of the train's approach." In cities, the railroads had been giving "due warning," usually with flagmen, but this was not always enough. For instance, the October 12, 1883 issue of the Rail Way Gazette reported an accident between a train and horsedrawn street car in Philadelphia. The flagman signaled and called to the driver, "but no heed was paid to his warning." The accident killed three people.

Accidents such as these led to the adoption of methods to reduce crossing accidents. As early as 1885, an automatic, train actuated gate* was in use in New York (4). In 1889, the first automatic control was used to activate a bell at a crossing, and in 1890, the first automatic wig-wag was introduced (5).

The Accident Reports Act of 1910, as amended, required railroad

* Mechanical device long ago outmoded.

carriers to submit reports of accidents involving railroad personnel and equipment. Until 1975, a reportable accident was defined by FRA as follows:

> "A public rail-highway grade-crossing accident is one which results in a reportable casualty to a person or which results in a collision or derailment of a train, locomotive, or car, or other train accident, and in which there is more than $750 damage to equipment, track, or roadbed."

In 1975, FRA released a Guide for Preparing Accident/Incident Reports to carry out the intent of Congress as expressed in the Federal Railroad Safety Act of 1970. In the Guide, reportable accidents are defined as follows:

> "Every rail-highway grade crossing accident/incident must be reported...regardless of the extent of damages or whether a casualty occurred."

This was a significant change, and will result in an increase in reported grade crossing accidents. However, it is also significant that, for reports after December 31, 1974, FRA defines an accident/incident as "any impact between railroad on-track equipment and an automobile, bus, truck, motorcycle, bicycle, farm vehicle or pedestrian at a rail-highway grade crossing." Thus, FRA accident statistics, particularly before January 1, 1975, do not reflect all accidents occurring at grade crossings.

Statistics (see Table 2) are available on grade crossing accidents beginning with the year 1920, as reportable under the Accident Reports Act of 1910. No other statistics are available to show the accident trend for such an extensive period.

In the 1971 Report to Congress: Part I, it was estimated that there are 12,000 train-involved grade crossing accidents each year. In addition, this report estimated that another 28,000 non-train-involved grade crossing accidents occur each year. Further statistical information on grade crossing accidents is available in the 1971 Report to Congress: Part I.

1.1.2 Improvement Efforts

The first Federal involvement with grade crossings occurred in 1916, when Congress passed the Federal-Aid Road Act which allowed funds

Table 2. Number of Accidents and Casualties Involving Trains at Public Railroad-Highway Grade Crossings Reported Under the Accident Reports Act of 1910 - Years 1920 to 1974, Inclusive.

		Number of People Killed			Number of People Injured			Total Number of Casualties		
Year	Number of Accidents	In Accidents Involving Motor Vehicles	In Other Accidents	Total	In Accidents Involving Motor Vehicles	In Other Accidents	Total	In Accidents Involving Motor Vehicles	In Other Accidents	Total
1920-24	23,012	7,341	2,382	9,723	23,561	4,606	28,167	30,902	6,988	37,890
1925-29	28,756	10,070	2,051	12,121	30,907	2,722	33,629	40,977	4,773	45,750
1930-34	19,422	7,210	1,211	8,421	20,915	1,245	22,160	28,125	2,456	30,581
1935-39	19,669	7,092	1,164	8,256	21,578	1,163	22,741	28,670	2,327	30,997
1940-44	20,166	7,830	1,451	9,281	21,483	1,083	22,566	29,313	2,534	31,847
1945-49	19,603	7,404	1,259	8,663	20,115	1,008	21,123	27,519	2,267	29,786
1950-54	18,598	6,563	795	7,358	19,201	647	19,848	25,764	1,442	27,206
1955-59	17,228	5,968	661	6,629	17,365	597	17,944	23,333	1,240	24,573
1960-64	16,676	6,215	526	6,741	16,793	644	17,437	23,008	1,170	24,178
1965-69	19,439	7,440	542	7,982	18,559	540	19,099	25,999	1,082	27,081
1970-74	16,977	6,024	437	6,461	16,038	447	16,485	22,062	884	22,946
TOTALS	219,546	79,157	12,479	91,636	226,515	14,684	241,199	305,672	27,163	332,835

to be used for projects to eliminate hazards at grade crossings. The States had to match the funds on a 50/50 basis; but since the railroads were the dominant transportation industry in the early 1900's, most states placed the major or entire responsibility for grade separations or grade crossing traffic control systems upon the railroads. This situation held true until the 1929 Depression, which brought about changes in the volumes of railroad and highway traffic over grade crossings and led to new ideas relative to the responsibility for grade crossings. For instance, the National Industrial Recovery Act of 1933 authorized $300 million to the states to pay any or all the construction costs of eliminating the hazards of highway-railroad grade crossings. The act also provided that the states did not have to provide matching funds, nor were improvements limited to the Federal-aid highway system. This new role of the federal government apparently had a great influence in the Supreme Court decision in Nashville, C. and St. L. Ry. v. Walters, 294 U.S. 405 (1935), wherein the Court, in effect, placed a criteria of equity, reasonableness, and beneficial interest as possible limitations upon the exercise of police power by the states in their apportionment of responsibility and costs for grade crossing separations and protection.

From fiscal year 1935 through fiscal year 1942, 3844 grade crossings were eliminated, 655 grade separations reconstructed, and traffic control devices were installed at 4652 crossings. This was the first time such a coordinated attack on the grade crossing problem had been made.

The Federal-Aid Highway Act of 1944 provided 100% Federal funding to eliminate grade crossing hazards on the Federal-aid highway system. The act included a provision that any railroad involved in a project to eliminate hazards at grade crossings, paid for in part or full with Federal funds, would be liable to the United States for any net benefits received. This clause, because of the difficulty in measuring railroad benefits, delayed many grade crossing improvement projects.

In 1953, California established the first of its four grade crossing funds to assist in paying the costs at grade crossings. While these funds did not relieve the railroads of financial burden, it was a further recognition of public responsibility at crossings, although the states can legally and constitutionally require the railroads to bear the entire responsibility. The 1972 Report to Congress lists 24 states which then had special funds or legislative authorization to participate in grade crossing construction or maintenance, or both.

Under the Federal Highway Safety Act of 1973, Highway Trust Fund money was first authorized specifically for railroad-highway crossing projects on the Federal-aid highway system, and Federal aid was provided for off-system projects. One portion of the act authorized $250 million for the fiscal years 1974-76, under the Safer Roads Demonstration Program. The elimination of hazards at railroad-highway grade crossings was eligible for funding on a 90/10 basis (90% federal funds and 10% state or local funds). Additional funds were provided in the Federal Highway Safety Act of 1976 (see Figure 2).

The overall effect of the coordinated attack on grade crossing accidents was reflected in the following FHWA news release dated May 19, 1976:

> A 50-percent decrease in the number of deaths resulting from motor vehicle-train accidents in the past decade was attributed today by the Department of Transportation's Federal Highway Administration (FHWA) to a cooperative Federal-State-industry program to reduce accidents and fatalities.
>
> According to Federal Highway Administrator Norbert T. Tiemann, highway-rail crossing fatalities have shown a continuous decrease from a peak level of 1,780 in 1966 to only 910 in 1975. During 1975 alone, fatalities were down 25 percent from 1974.
>
> Administrator Tiemann credited a major responsibility for the decrease to "a continuing joint effort by the FHWA, the States and the Nation's railroad systems to make a positive effort to reduce and prevent accidents and fatalities at rail crossings. This effort" said Tiemann, "has involved a nationwide effort to install such improved warning devices as signs, pavement markings, flashing light signals and automatic gates."
>
> The major effort to reduce highway-rail grade crossing accidents was initiated in 1967 with the establishment of the U.S. Department of Transportation. The fact that such accidents, among transportation-related accidents, ranked second in terms of severity only to aviation accidents gave special impetus to the new program.

Rail-Highway Crossings

Sec. 203. (a) Subsections (b) and (c) of section 203 of the Highway Safety Act of 1973 (Public Law 93-87) are hereby amended to read as follows:

"(b) (1) In addition to funds which may be otherwise available to carry out section 130 of title 23, United States Code, there is authorized to be appropriated out of the Highway Trust Fund for projects for the elimination of hazards of railway-highway crossings, $25,000,000 for the fiscal year ending June 30, 1974. $75,000,000 for the fiscal year ending June 30, 1975. $75,000,000 for the fiscal year ending June 30, 1976. $125,000,000 for the fiscal year ending September 30, 1977, and $125,000,000 for the fiscal year ending September 30, 1978. At least half of the funds authorized and expended under this section shall be available for the installation of protective devices at railway-highway crossings. Sums authorized to be appropriated by this subsection shall be available for obligation in the same manner as funds apportioned under chapter 1 of title 23. United States Code.

"(2) Funds authorized by this subsection shall be available solely for expenditure for projects on any Federal-aid system (other than the Interstate System).

"(c) There is authorized to be appropriated for projects for the elimination of hazards of railway-highway crossings on roads other than those on any Federal-aid system $18,750,000 for the three-month period ending September 30, 1976. $75,000,000 for the fiscal year ending September 30, 1977, and $75,000,000 for the fiscal year ending September 30, 1978. Sums apportioned under this section for projects under this subsection shall be subject to all of the provisions of chapter 1 of title 23, United States Code, applicable to highways on the Federal-aid system, except the formula for apportionment, the requirement that these roads be on the Federal-aid system, and those other provisions determined by the Secretary to be inconsistent with this section.".

(b) Subsection (d) of section 203 of the Highway Safety Act of 1973 is amended by adding immediately before the first sentence thereof the following new sentence: "50 per centum of the funds made available in accordance with subsection (b) shall be apportioned to the States in the same manner as sums authorized to be appropriated under subsection (a) (1) of section 104 of the Federal-aid Highway Act of 1973 and 50 per centum of the funds made available in accordance with subsection (b) shall be apportioned to the States in the same manner as sums authorized to be appropriated under subsection (a) (2) of section 104 of the Federal-aid Highway Act of 1973.".

Figure 2. Excerpt from Public Law 94-280, "Federal-Aid Highway Act of 1976."

In August 1972, the Federal Highway Administration in cooperation with the Federal Railroad Administration, completed a comprehensive study on the railroad-highway safety problem and submitted to the Congress a report along with recommendations for improvements.

The Highway Safety Act of 1973 provided additional Federal funding for grade-crossing safety improvements on Federal-aid highways and, for the first time, authorized funds for grade-crossing safety improvements off the Federal-aid highway system.

The recently enacted Highway Safety Act of 1976 continues these programs. It also authorizes during fiscal years 1977 and 1978 the expenditure of $125 million annually in Federal-aid highway funds for on-system improvements and $75 million annually in General Treasury funds for off-system improvements. During the past decade alone, more than $1.5 billion in Federal-aid highway funds, in addition to other special safety program funds, have been expended for eliminating highway-railroad crossing hazards.

A National Railroad-Highway Crossing Inventory and Numbering Project was also initiated by the Department of Transportation and the Association of American Railroads as a result of the 1972 study and is now virtually complete. Inventory data developed through this project, along with crossing accident information submitted by railroads, will provide a basis for planning and evaluating grade crossing safety improvements.

"A continued, systematic approach to the highway-railroad grade crossing problem," said Administrator Tiemann "should result in further significant reductions in grade crossing accidents and fatalities."

Increasing exposue due to higher railroad and highway volume will have an impact on the fatality rate as indicated by the 1976 toll of more than 1100, thus indicating the need for continued concentration on the grade crossing problem.

1.2 OBJECTIVES

A railroad-highway grade crossing improvment program should have two basic objectives. These objectives are as follows:

1. To reduce the accident frequency and severity at grade crossings; and,
2. To improve operating efficiency.

Only two objectives may seem to be an oversimplification of the improvement problems. These two objectives, however, are broad based in nature and would produce very substantial benefits.

Some accidents will occur at grade crossings even under the very best physical conditions, because of the human element of the problem. However, the major thrust must be toward improving those characteristics at grade crossings that will reduce the probability of train-vehicle accidents. Achievement of this objective will result in reduced loss of life, personal injuries, and property damage.

The objective of improving operating efficiency refers both to vehicle and train traffic. The cost of delay encountered by vehicle traffic at grade crossings can be extensive in loss of time and energy. Also, the deceleration and later acceleration of trains in the vicinity of grade crossings where reduced speeds are required, costs the railroad companies and ultimately the consumer. These costs result from increased use of fuel, wear and tear on equipment, and sometimes crew costs. Any improvements in grade crossings that permit higher operating speeds and less interruption of the operation of trains increases efficiency and reduces costs.

Operating efficiency of highway traffic at grade crossings is also reduced wherever there is a rough crossing surface or poor roadway alignment.

1.3 PURPOSE AND SCOPE OF HANDBOOK

The introduction to this handbook briefly describes how the growth of railroads and highways resulted in a proliferation of grade crossings. Methods have been developed through the years to warn pedestrians and vehicles of approaching trains. The federal grade crossing safety program is as old as federal highway aid to states, having begun in 1916 (6). In recent years it has become apparent that a need exists to put in one document a summary of past accomplishments, existing techniques, and to prepare a compendium of applicable concepts, technology, and practice in the area of grade crossing improvements. A better understanding of available methodology should lead to widespread acceptance and implementation with available funds and an emphasis on securing additional improvement funds.

The Federal Highway Administration (FHWA), U.S. Department of Transportation (DOT), recognized these needs and, initiated a project to develop a Handbook on Railroad-Highway Grade Crossings. This handbook is directed to a wide variety of users. Its development has been aimed primarily at providing railroad, state, and municipal personnel with information which can help them in their cooperative efforts to improve conditions at grade crossings.

Techniques and equipment developed over the years have produced commercially available hardware and research and development efforts are continuing to advance technology in the field. This Handbook, however, does not attempt to report in depth on those research efforts. Instead, it discusses basic concepts, the use of which have proven satisfactory.

Major objectives of the Handbook are to:

- Describe conditions and requirements at crossings.
- Facilitate understanding of elements of crossing systems.
- Provide a compendium of existing grade crossing technology.
- Serve as a guideline to aid in implementing improvements to railroad-highway grade crossings.
- Aid understanding and application of new technology.
- Serve as a basic text for training programs.

It is intended that information contained in this handbook will be useful in achieving the goals of safety and efficiency at railroad-highway grade intersections. In some areas of the nation, railroad passenger-ridership is increasing somewhat on intercity lines and to that extent increasing the exposure of human beings to grade crossing accidents. This is in addition to railroad personnel, highway vehicle operators and vehicle passengers at each of the approximately 220,000 public grade crossings.

1.4 METHOD OF PRESENTATION

Many individuals, companies, and agencies become involved in the improvement of railroad-highway grade crossings. Managers, administrators, engineers, supervisors, and maintenance personnel have responsibilities in such improvements. Railroad companies, federal and state transportation agencies, as well as municipal and county agencies have a variety of responsibilities and interests in crossing improvements. Aimed as it is at the needs of these diverse individuals, companies, and agencies, the information in this handbook describes the process of improving railroad-highway grade crossings.

1.4.1 Railroad-Highway Grade Crossing Improvement Process

The process of improving railroad-highway grade crossing situations begins with consideration of candidates for improvement projects. Listings of such candidates might be compiled at a national, state, regional, or local level; depending upon the location and goals to be met in selecting specific improvement projects from numerous candidate projects.

An improvement process for railroad-highway grade crossings consists of four steps:

I. Establish Improvement Objectives - Provide direction and organization to the improvement process. The question: What benefits in safety and efficiency will result, should be answered.

II. Identify Grade Crossing Components and Interrelationships - Once improvement objectives are established, components of grade crossings and their interrelationships are identified.

III. Define Improvement Projects - Specific projects from among a number of candidate crossings are selected in this step. Priorities are assigned, and amounts and sources of funds are considered in selecting specific improvements to be executed.

IV. Make Improvements - The final step implements the specific improvements at the locations selected. This involves the proper use of technology to accomplish the improvements chosen.

Step III (Define Improvement Projects) involves two phases. The first phase (Program Development) screens a large number of potential sites and selects a reasonable number of these sites as candidate sites for improvement work. The second phase (Program Definition) provides for a detailed analysis of the candidate sites and defines the specifics of improvement projects for these sites.

The overall improvement process might well include the following steps:

I. Program Objectives
II. Grade Crossing Components and Relationships
III. Program Development
IV. Program Definition
V. Program Implementation

1.4.2 Handbook Content

Information in support of and supplemental to the improvement process is set forth in the Handbook in the following eight chapters:

I. Introduction
II. Grade Crossing Components
III. Program Administration
IV. Program Development, Definition, and Implementation
V. Site Improvements
VI. Crossing Surfaces
VII. Traffic Control Devices
VIII. Research and Development

A brief overview of the content of each of these chapters is presented here to aid the reader who may be searching for specific material.

- Introduction - This chapter provides an historical overview of railroad and highway development and a discussion of the railroad-highway grade crossing problem. It also discusses the purpose and scope of the Handbook, the presentation concept, and basic content.
- Grade Crossing Components and Relationships - This chapter discusses the four basic components of the grade crossing, (1) the Human, (2) the Vehicle, (3) the Train, and (4) the

Physical Environment, and indicates their relationship to the improvement process. The chapter establishes basic terminology utilized throughout the Handbook.

- Program Administration - This chapter discusses the administrative aspects of the improvement process. Information is presented in terms of Programs and Plans, Funding Alternatives, Inter-jurisdictional Responsibility, Legal Considerations, Educational Programs, and Enforcement. It is aimed at assisting administrators of various agencies and jurisdictional levels in understanding all aspects of an overall program for railroad-highway grade crossing improvement.
- Program Development, Definition, and Implementation - This chapter provides information on techniques for defining the relatively small number of grade crossings that should receive further investigation and consideration for extensive improvement. It discusses data collection techniques, priority rating systems, improvement alternatives and procedures for defining critical grade crossing sites. Information on site investigations, the diagnostic team approach, and supporting field studies is presented to describe a functional and logical method of specific project definition.
- Site Improvements - This chapter discusses specific improvements to a railroad-highway grade crossing that are categorized as site improvements. Included in this category are improvements such as Sight Distance (considering horizontal and vertical alignment and obstructions), Cross Sections, Drainage, and Illumination.
- Crossing Surfaces - This chapter identifies the various types of crossing surfaces that can be utilized, provides selection guidelines, and presents information on the proper design and installation of the various types of crossing surfaces.

- Grade Crossing Traffic Control Devices - This chapter presents information on the control devices (both passive and active) that can be utilized to increase safety at grade crossings. This information includes material on the types of devices available, guidelines for selecting a desired type of device, and guidelines for installation of the necessary device.
- Research and Development - This chapter presents information on research and development efforts in the field of railroad-highway grade crossings and discusses potential trends regarding new and innovative approaches to the various types of grade crossing problems.

The Handbook has thus been designed as an information source for railroad-highway grade crossing improvement. It does not establish standards and does not imply or suggest inadequacy of any existing installation.

1.5 TERMINOLOGY

There are a few terms that recur with considerable frequency throughout the Handbook. For ease of reading, the terms will be shortened as follows:

- "Railroad-highway grade crossings" will be shortened to "grade crossings."
- "Grade crossing traffic control devices" will be shortened to "control devices."
- "Highway" is used to designate all vehicular traveled ways including roads and streets both rural and urban.

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2.0 GRADE CROSSING COMPONENTS AND RELATIONSHIPS

2.1 INTRODUCTION

The grade crossing improvement process involves several components which through their interactions define and make up the grade crossing problem. This chapter identifies the pertinent components, discusses their importance, indicates the interaction and relationships among the components and presents a working statement of the terminology and design concepts that are involved in the grade crossing improvement process.

Four major interrelated elements must be considered in pursuing the improvement of a grade crossing. These are identified as follows:

- Human Component
- Vehicle Component
- Train Component
- Environmental Component

The human component includes operators of vehicles on the highway, pedestrians, and the train operator. The major concern here is for the highway vehicle operator, who uses the crossing in relatively large numbers. The train operator is very limited in the actions that he can take to avoid a train-highway vehicle conflict. Pedestrians, although generally fewer in number, must also be considered and discussion of this human component is included.

The vehicle component is often large and includes a mix of highway vehicles--bicycles, motorcycles, cars, trucks, and buses--on which emphasis is placed in choosing the design and control measures to be adopted.

The train component may be an important factor. The number of trains, the mix between passenger, freight and switching movements, along with maximum and normal speeds of operation, are all significant. At most crossings at irregular intervals, there will also be movements of work trains and other maintenance and inspection equipment, some of which do not operate train detection circuits in the track.

The environmental component includes a number of elements that can be considered a part of the grade crossing environment. These elements are identified as follows:

- Geometric Design
  - Horizontal and Vertical Alignment
  - Cross Section
- Sight Distance
- Structural Design
- Illumination
- Distractions
- Drainage
- Noise
- Crossing Surface
- Congestion
- Weather Conditions

The following sections of this chapter briefly discuss the various components, introducing basic terminology common to the grade crossing problem to provide background for the more detailed discussion of the overall improvement process that is presented in the following chapters.

2.2 HIGHWAY VEHICLE OPERATOR

Operating a highway vehicle involves many different aspects of human behavior, such as attention, reaction time, emotion, and judgement. Since the operator controls the motor vehicle, his response to and interaction with numerous stimuli and the way he is led to respond determine whether or not an accident occurs. This section discusses basic requirements and limitations of the vehicle operator and indicates the means for considering these limitations in the grade crossing environment.

2.2.1 Driver Behavior At Grade Crossings

The situations faced by a vehicle operator at a grade crossing arise in three basic stages of the track crossing maneuver. These stages are identified as follows:

- Stage I - Approaching the Crossing
- Stage II - Within a Critical Stopping Distance Zone
- Stage III - Crossing the Tracks

2.2.1.1 Stage I - Approaching the Crossing -- At some distance before the crossing, the vehicle operator must be made aware that a grade crossing is ahead. This information is usually provided by an advance warning sign and, in some cases by pavement markings, often through visual observation of the crossing itself and its associated control devices, and sometimes through the sound of the train horn.

The probability that the motorist will perceive that he is approaching a grade crossing depends upon such factors as visual acuity, familiarity with the crossing, visibility of control devices under ambient conditions, with driver attention, fatigue, and age also of importance.

Visual acuity, or the resolving power of the human eye, is not static. A person who may have "20/20" vision and thus be able to discern fine detail at long distances in daylight, may degrade to "20/60" after nightfall. This phenomenon occurs because the pupil of the eye dilates, accentuating the optical errors in the lens system of the eye (the same thing happens when you open up the lens aperture on a camera); thus, an advance warning device which may be readily discernable in the day may not be so at night.

Acuity interacts with visual contrast--the brightness and color differences between objects and their backgrounds which permit them to be detected at all. Generally, the MUTCD standards are engineered to take these factors into account. The railroad crossing control device designer can safely use these guidelines for the specification of signs and markings themselves. But these devices are not perceived in a blank visual field by the motorist. They are sometimes embedded in a visual field which can camouflage these devices and tend to defeat their purpose. The crossing itself can, under some conditions, appear to be an alley, or a highway crossing--or it may not be discernable at all in a busy cluttered urban industrial park, or in a rural setting with trees and shrubbery along the railroad right-of-way.

In order for the driver to react to the advance warning sign, it must first be detected; hence, the use of bright yellow on warning signs to increase the target value. It is often justified to use active advance warning signs to gain the motorists attention, especially if there are other visual distractions which might cause the motorist to miss the normal advance warning sign. An additional aid would be information about whether or not the crossing had active traffic control devices. This is a practice under certain conditions at highway intersections. One study (1) found that almost 21 percent of the drivers believed all crossings had a train-actuated signal or gate! Quite obviously, if the motorist believes that, his looking behavior is going to be quite different than that required for a crossing with passive devices.

The advance warning treatment must compete for the attention of a motorist who may be bored, listening to the car radio, or distracted by passengers within the vehicle. The crossing advance treatment, like all visual objects, depends upon contrast from its environment to be detected.

One approach in advance warning is auditory "signs." Since motorists may be visually loaded (the visual inputs to the driving task are near the driver's processing limit), an abrupt change in road surface may be used to "wake up" the motorist. The only danger here is that such a warning is non specific. It doesn't say "a railroad track is ahead." The unaware motorist may spend precious seconds wondering what that funny noise was, as he hurtles toward the grade crossing. An effective warning should be unequivocal to the motorist: it should tell him what, or at very least, exactly where to find out what the problem is.

If the driver is familiar with the crossing and expects to go across it in a few seconds, he will have some expectancies built up. Based on past experience he may be very cautious in approaching it because train traffic is either heavy or irregular. In other situations he may hardly give it a thought, because his experience is that the crossing is little more than a siding. The advance warning treatment must consider then, not only alerting of the unfamiliar motorist, but also providing information on present circumstances in light of past experience. An infrequently used spur track that suddenly becomes active because a plant is expanding requires a warning treatment

(1) different from that used in the past at that crossing, and (2) appropriate to the present level of service.

The last factor to be considered in the Stage I is short-term memory. The advance warning need not and should not be so far ahead of the crossing that the busy driver forgets it before he reaches the crossing. Traffic control devices are not particularly interesting or memorable objects to a driver. They are more like the instruments on his dashboard. The MUTCD recommends placing warning signs 750 feet (230 m) in advance of the crossing in rural areas and 250 feet (75 m) in advance of the crossing in urban areas. In residential areas with low speeds the minimum recommended distance is 100 feet (30 m).

2.2.1.2 Stage II - Within a Critical Stopping Distance Zone -- The vehicle operator approaching a crossing will reach a point beyond which it is difficult to stop short of the crossing. At that crossing, there may be:

- A train on the crossing
- A train approaching the crossing
- No train in the vicinity

If a train is on the crossing, the motorist's problem is to see it in time to react and take avoidance action. Because of driver inattention, inadequate sight distance, or high speed, there may not be time to stop. But usually, in daytime, with good visibility and adequate stopping distance, the train on the crossing provides all the information the driver needs to make a decision.

When it is dark, or visibility is poor, the driver's task becomes more difficult, especially at crossings with passive control devices. A train that occupies such a crossing can be extremely difficult to detect because of the low reflectance of dark colored, dirty cars; some sort of illuminated warning can greatly ease the motor vehicle operator's detection burden. There is a definite problem in these situations--FRA grade crossing accident data for 1972-74 show that 822 of the 3376 accidents after dark occurred at unlighted crossings with the motor vehicle striking the train. Since the grade crossing designer cannot do much to improve train visibility per se, the treatment must concentrate on providing active devices where warranted, and where not, adequately signing to produce slowing and cautionary response.

A train in the vicinity of a crossing puts the greatest demands on the motor vehicle operator. The principal warning to the motorist approaching a passive crossing comes from the train, through the use of horns and/or headlights. It is vital, therefore, that the motorist detect these warnings. Some of the factors that limit the motorist's ability to detect the train are:

- Relatively high insulation values inside modern motor vehicles, especially with the windows closed and the radio in operation.
- Exhaust noise of trucks masking the train's horn warning.
- Somewhat limited field of view in trucks, buses, and all vehicles under adverse weather conditions.
- Highway alignment, other vehicles, buildings, foliage, signs, etc., having a definite effect on the sight distance that is available to the motor vehicle operator to detect the crossing and the train in time to stop if so required.

At crossings where there are active control devices, the vehicle operator's task is to observe and respond to the devices when actuated by an approaching train. The active devices, flashing light signals, with or without gates are effective because they present the motorist with an unequivocal go-no go decision, which in turn lessens the driver's response time. Also the driver does not have to look for the train, but relies on the automatic device instead.

It is important to note that one of the critical factors is the response time of the driver. This is more than simply the time needed to move his foot to the brake and initiate braking of the vehicle. The motorist takes time to assimilate information, select a response, and put that decision into action. If no advance warning is given (or heeded) from 2.0 to 2.5 seconds may be required for this process. It is this response time that is the basis of sight distance recommendations made in this handbook.

2.2.1.3 Stage III - Crossing the Tracks -- In this final stage, the vehicle operator must safely cross the tracks. This stage can be divided into driver actions at crossings (1) with passive warning devices and (2) with active devices, to gain an understanding of what can go wrong.

When a driver is approaching a crossing with passive devices and has seen an approaching train, three things can go wrong. First, the driver can fail to make a final go-no go decision, that is, he can stop, then start again when he should remain stopped; or, he can go, then stop too close to the tracks. Second, the motorist may decide to stop only to have the brakes lock or fail. Third, there might be engine failure on the tracks. The correct action in this last instance, if a train is approaching, is to abandon the motor vehicle; yet, there are numerous accounts of drivers "freezing" at the wheel (virtually hypnotized by the train), or continuing to try and start the vehicle until the train strikes the vehicle. This stalling problem may be partially alleviated if the crossing surface is smooth and traffic controls are designed not to require vehicles to stop on the track(s).

At crossings with active devices the actuation of the devices makes the decision for the driver. It may not be safe to proceed when the devices are on, however the motorist must be convinced it is in fact not safe to proceed. If the driver expects that the guarded track is a switch track near a classification yard, he may proceed because he anticipates only slow-moving switching operations. He is thus not prepared for a train coming through at high speed. The conservative approach is to adequately warn the motorist in order that he can safely assess the crossing situation. Care should be taken to minimize inadvertent operation of signals when no train is present, to prevent familiar motorists tending to disregard these signals. It is recognized, however, that these devices must be fail-safe, i.e., actuate under abnormal circuit conditions rather than failing to actuate for a train. Where active control devices are present, the motorist in most cases will rely on them and generally surrender decision making to them.

Finally, information presented the driver at the crossing should be

(1) compatible with that which he expects to find at the crossing, (2) compatible with the desired response, and (3) relevant only to the crossing (i.e., information relevant to anything but the crossing should be located elsewhere). Table 3 describes these informational needs.

2.3 PEDESTRIANS

Pedestrian injuries and fatalities constitute slightly more than 2 percent of the total number of casualties at grade crossings, but have a severity index of about 65 percent. For instance, in the period of 1970-1974, FRA reported 522 casualties, of which 342 were fatalities. One major difference between the driver and the pedestrian at grade crossings is the relative ease with which the pedestrian can go under or around actuated gates.

2.3.1 Preventive Measures

It is important to understand four contributing factors which motivate pedestrians to enter railroad rights-of-way, in order to establish effective preventive measures. First, as a consequence of urban development, railroads often act as physical dividers between important, inter-related elements of communities. Second, railroads have always attracted juveniles as "play areas." Third, at or near commuter stations, passengers frequently use short cuts before or after boarding a train. And fourth, some people are prone to vandalism. There are several types of preventive measures which can be employed:

- Fencing. Enclosed right-of-way fencing may be used to restrict access. It commonly consists of 6-8 foot (2-2.5 m) high chain link fencing, sometimes topped with barbed wire. It is usually placed on both sides of the right-of-way, but it can be an effective deterrent to indiscriminant crossing if placed on only one side. The main objection of enclosed right-of-way fencing is its cost, which may be well in excess of $100,000 per mile (km) for construction. Furthermore, it does not bar entrances at grade crossings. Alternatively, a single four-foot

Table 3. Information Needs - Highway Vehicle Operator

Location	Information*	Response Desired
Crossing approach	Crossing is ahead	Look ahead for more data on present conditions
	Train may be present	Look ahead
Near approach	1) Train is in crossing	Stop
	2) Train is approaching crossing	Stop
	3) Train is not in vicinity	Slow down and look to right and left for further information
Within Stopping Distance	(Case 2) Velocity of train, and direction	Go/No go across tracks
	(Case 3) Verify train is not in vicinity	Go across tracks

*The signing, marking and visibility provided at the crossing must adequately present all of this information.

(1.2 m) fence parallel to the track and across a pedestrian crossing route can be lower-priced and somewhat effective deterrent. It is commonly used between multiple tracks at commuter stations.

- Separated Crossings. In order to prevent vandalism of continuous fencing, pedestrian crossings must be provided over or under the track(s) at reasonable intervals. These structures are an expensive addition and, when provided, are frequently not used. If a structure is built, it should be easy to reach.
- Improved Signing. Of constant concern in urban areas with electrified lines, is the problem of cantenaries (the overhead wires used to carry energy to electric locomotives). The electrical potential is so great that shocks can result without actual contact with the wire. Warning signs along electrified segments can reduce juvenile accidents. These signs should provide both symbolic representation (such as lightening bolt) and the warning legend.
- Safety Education. The education of actual and potential trespassers can reduce the incidence of right-of-way accidents. Individual railroads as well as the Association of American Railroads have, for many years, conducted active railroad safety programs through the schools.
- Surveillance and Enforcement. No form of pedestrian protection can be effective without some level of surveillance and enforcement. At present, trespassing is generally considered a misdemeanor, and law enforcement officials are often indisposed to prosecute. A more effective procedure for some forms of railroad trespassing would be to treat it like jaywalking, and issue a citation with automatic imposition of a fine if a hearing were waived. Such a procedure would impose some burden on the trespasser who might otherwise only be reprimanded. It might also shift some of the burden of keeping juveniles

off the right-of-way from the police to parents.

Because of the variety of factors which may contribute to pedestrian hazards, detailed studies are necessary to determine the most effective measures to provide for pedestrian safety at specific locations.

2.4 MOTOR VEHICLE CHARACTERISTICS

At almost all grade crossings, the number of highway vehicles crossing the tracks is far greater than the number of trains crossing the highway. Highway vehicles include bicycles, autos, trucks, motorcycles and buses. The following material will provide information on the pertinent characteristics of motor vehicles as they relate to grade crossing problems.

2.4.1 Motor Vehicles

Motor vehicle drivers and occupants have been the most frequent victims in grade crossing accidents since the early part of this century. Therefore, it is important to be aware of certain vehicle constraints, as well as the present traffic mix, in order to understand the problem and develop effective countermeasures.

2.4.1.1 Size, Weight, and Performance -- The physical characteristics of the vehicle have been a contributing factor in many grade crossing accidents. Vehicle stalling and poor acceleration are often contributing causes especially with trucks and buses, some of which are required to stop at crossings. This leads to a longer exposure time on the crossing itself because of the low acceleration rates of large vehicles, and the up to 72 foot (22 m) length of a tractor/trailer. Buses, particularly school buses, have a high severity potential. Routings of school buses should avoid grade crossings whenever it is possible.

2.4.1.2 Hazardous Materials -- The presence of motor vehicles carrying hazardous materials greatly enhances the potential severity of a vehicle-train collision. Moreover, not only are the users of the crossing affected, those in the general vicinity may also be in potential danger. Therefore, consideration should be given to routing vehicles carrying hazardous materials through grade separations or across crossings located in areas of low concentrations of people.

2.4.1.3 Traffic Mix -- Table 4 shows the number, type, and percentage of motor vehicle accidents involving trains at grade crossings. Table 5 shows the accident rate for all motor vehicle accidents. As is readily apparent, trucks have a much higher accident rate at grade crossings than they have for accidents in general. The number of truck accidents at grade crossings did not vary more than ten percent for the period 1972-74. The probable explanation for the high truck accident rate at grade crossings would seem to be the length, acceleration rate and braking performance of the truck, as well as the exposure factor.

The lack of operator protection provided by the vehicle is the most likely explanation for the high motorcycle fatality rate.

The overall traffic mix for 1974 was as follows (2):

- Passenger cars - 77.20%; 995,544 mvm (1,602,825 mvkm)
- Motorcycles - 1.73%; 22,347 mvm (35,978 mvkm)
- Buses - 0.39%; 5,060 mvm (8,146 mvkm)
- Trucks - 20.68%; 266,694 mvm (429,377 mvkm)

This mix will probably hold true in the foreseeable future, with motorcycles perhaps increasing their percentage if present growth rates continue. While the traffic mix for grade crossings is not available it should be assumed to follow the general distribution.

2.5 TRAINS

Because of their tremendous weight and limitations on braking trains cannot stop quickly. It is not unusual for a freight train to require two miles to stop; and unlike the motor vehicle driver, the locomotive operator cannot take evasive action to avoid a collision. For these reasons, safety efforts involving the train have concentrated on aids to motor vehicle drivers to make the train more noticeable to the highway user, and more recently, on suggested new locomotive designs to lessen impact severity when a vehicle is struck. These efforts analyze the audibility and the visibility and conspicuity of trains.

Table 4. Railroad-Highway Motor Vehicle Accidents - 1974

Trains Striking or Being Struck By	Total Accidents			Total Killed			Total Injured			Registered Vehicles	Veh-Miles of Travel (Billions)	Accidents Per Million Vehicles
	Number	Per Billion Veh-Miles	Percent	Number	Per Billion Veh-Miles	Percent	Number	Per Billion Veh-Miles	Percent			
Automobiles	2,185	2.19	71.0	830	0.83	73.5	2,330	2.34	73.9	104,857,327	995.5	20.8
Buses	13	2.57	0.4	14	2.77	1.3	114	22.53	3.6	446,906	5.1	29.0
Trucks	809	3.03	26.3	247	0.93	21.9	666	2.50	21.1	24,589,078	266.7	32.9
Motorcycles	72	3.22	2.3	37	1.65	3.3	45	2.01	1.4	4,966,399	22.3	14.5
TOTAL	3,079	-	100.0	1,128	-	100.0	3,155	-	100.0	134,859,710	1,289.6	-

Note: 1 mile = 1.61 kilometers

Sources: FRA, Rail-Highway Grade Crossing Accidents, 1974, and FHWA Highway Statistics, 1974.

Table 5. All Motor Vehicle Accidents - 1974

Type of Vehicle	Number of Accidents	Percent of Accidents	Vehicle Miles of Travel (Millions)	Number Registered	Accidents per Million Veh-Miles
Passenger Automobile	20,750,000	83.9	995,544	104,857,327	20.8
Buses	193,000	0.8	5,060	446,906	38.1
Trucks	3,400,000	13.8	266,694	24,589,078	12.8
Motorcycles	376,000	1.5	22,347	4,966,399	16.8

Note: 1 mile = 1.61 kilometers

Sources: U.S. DOT Summary of National Transportation Statistics, June 1976, FHWA Highway Statistics, 1974 and Traffic Safety 1974, NHTSA, Sept. 1975.

2.5.1 Audibility

Air powered horns are almost universally used on locomotives as a basic warning device. Whistles were the universal warning devices in the steam era, and even though locomotive whistles are no longer manufactured in this country, some suppliers still refer to air horns as whistles because of laws that require locomotives to be equipped with a "Whistle". The distance and sounding method for the locomotive horn is set by state law. Bells are used to warn pedestrians, and are used mostly in switching operations in railroad yards and on approach to passenger station platforms.

Aurelius and Korolow (3) conducted a research project to "determine the performance characteristics of commonly used locomotive horns, and to relate these characteristics to the ability of horns to warn drivers in real crossing encounters." The study described adequate audible warnings as a function of three elements:

- Sound Level at the Vehicle. For vehicles going less than 35 mph (56 kph) a sound level of 101db (decibels) is required to alert the driver. The requirement for vehicles going 36-50 (57-80 kph) is 105db, and for 51-65 mph (81-105 kph) it is 109db.
- Required Distance. It is too late to warn a motorist who is closer to the crossing than his stopping distance. The critical stopping distance from the crossing and the train is just far enough away for the motorist to make it across the track. Table 6 shows the Geometry of the Critical Encounter, so that at a speed of 60 mph (96.6 kph) the train will be 88 feet (26.8 m) closer by the time the motorist hears it.
- Sound Attenuations. The Inverse-Square Law is used to describe the attenuation of horn sounds. It states that the power in a sound varies as the inverse square of the distance (3).

To determine the required sound level the three elements are combined.

In conclusion, it must be stated that present railroad horns cannot reliably warn motorists when either the train or motor vehicle is going

Table 6. Geometry Of The Critical Encounter

Distances from train to motor vehicle for respective speeds indicated:

Train Speed	Motor Vehicle Speed 20	30	40	50	60	70
10	171	235	348	491	662	868
20	241	285	390	527	695	899
30	324	351	449	581	746	947
40	411	426	519	648	810	1010
50	501	504	596	724	885	1085
60	591	586	679	807	969	1169
70	683	670	764	895	1058	1261
80	774	754	852	987	1154	1359
90	867	840	941	1081	1252	1463
100	959	926	1032	1178	1354	1570
110	1052	1012	1124	1275	1458	1681

Source: Reference (3)

1 mph = 1.61 kph

over 50 mph.* Table 7 shows horn performance for various train to motor vehicle distances. The decibel level is presently very close to the threshold of pain level for the locomotive occupants (the Federal Register of May 29, 1971, listed the permissible level at 110db for one-half hour in any day), so that horn output cannot be substantially raised. With that in mind, Korolow and Aurelius make the following recommendations:

- Use a high-output horn such as the five-chime type because of its alerting qualities, its ability to override masking sounds, and its lesser nuisance value.
- Horns should be mounted up front and up high to reduce the nuisance of the horn to the crew as well as improving performance.
- Bi-directional locomotives should have a horn on each end.
- At crossings where audible warnings must have a primary role because of poor visibility and/or no active control devices, highway speed limits for the approach to the crossing should be lowered.

2.5.2 Visibility and Conspicuity

The vehicle operator guides his vehicle and avoids others mainly by visual cues. Conspicuity is the property of attracting attention by visual means, and is a vital element at grade crossings where so much of the burden for safe performance is placed on the driver. Therefore, it is vital that the driver detect the train, and the visual sense is the main one used to accomplish this task.

Train conspicuity is of particular concern at crossings with passive devices. Assuming the driver has adequate sight distance, he still must detect the train, and with the multitude of surroundings against which the train can appear, visual detection can be extremely difficult. Rectangular panels of flourescent yellow 3 1/2 feet high by 5 feet wide (1.06 by 1.5 m), located on the nose, front and rear sides of the locomotive have been recommended to increase conspicuity (3). The use of retroflective tape and paint, or plastic reflex reflectors as part of normal car painting and labeling has also been recommended (4).

* 1 mph = 1.61 kmh

TABLE 7. Railroad Horn Performance

Train Speed (mph)	Motor Veh. Speed (mph)	Range (ft)	Angle (degrees)	Req'd Sound Level (dB)	Avail. Sound Level (dB)	Performance Index (dB)
70	70	1261	43	109	87	-22
70	50	895	32	105	90	-15
70	30	670	18	101	93	- 8
50	70	1085	52	109	87*	-22
50	50	724	41	105	91	-14
50	30	504	25	101	96	- 5
30	70	947	65	109	87*	-22
30	50	581	55	105	92*	-13
30	30	351	37	101	99	- 2

Note: 1 mile = 1.61 kilometres
1 foot = .304 metres

Source: Reference (3)

2.5.3 Train Mix

Most researchers tend to agree that the exposure rate (the number of vehicles and trains per crossing per unit of time) is the most important factor in explaining the likelihood or occurrence of grade crossing accidents.

With the completion of the national grade crossing inventory, data are now available on the distribution of crossings by railroad volume class and by highway volume class for each state. This is summarized in Table 8 and Table 9.

Table 10 shows rail-highway grade crossing accidents for 1974 classified by daylight and dark and by those in which the train struck the vehicle and those where the vehicle ran into the train, all further subdivided by the motor vehicle speed. Table 11 breaks down motor vehicle accidents by type of train involved, and shows a relatively high percentage rate for work trains.

2.6 SITE CHARACTERISTICS

The fourth component of the grade crossing is comprised of the physical and environmental aspects of the crossing itself. This component includes such elements as crossing geometry, surfaces, environment, illumination, and sight distance. These elements will be discussed briefly in this section, and in detail in subsequent chapters.

2.6.1 Geometry

The following geometric characteristics of grade crossings are prevalent throughout the United States:

- The railroad is frequently higher than the highway, beyond its immediate approaches to the grade crossing.
- A highway is frequently located parallel and adjacent to the railroad, and highway intersection is often located near the crossing.
- Horizontal alignment in approaches to crossings includes curves with radii less than 1000 feet (300 m).

These characteristics have a great influence on highway traffic behavior

Table 8. Urban Grade Crossings - 1976

Number of Grade Crossings

Highway Volume		0-500	501-1,000	1,001-5,000	5,001-10,000	10,001-20,000	Over 20,000	TOTAL
Class		1	2	3	4	5	6	
Railroad Volume	Class							
Over 40	6	733	337	811	354	232	43	2,510
21-40	5	2,704	1,080	2,448	838	389	88	7,547
11-20	4	5,114	1,906	3,968	1,325	730	182	13,225
6-10	3	8,107	2,401	4,750	1,485	810	174	17,727
3-5	2	7,999	2,359	4,432	1,363	731	204	17,088
0-2	1	25,175	6,718	12,953	4,064	2,064	516	51,490
Column Totals		49,832	14,801	29,362	9,429	4,956	1,207	109,587

Source: National Railroad-Highway Grade Crossing Inventory.

Table 9. Rural Grade Crossings - 1976

Number of Grade Crossings

Highway Volume		0-500	501-1,000	1,001-5,000	5,001-10,000	10,001-20,000	Over 20,000	TOTAL
Class		1	2	3	4	5	6	
Railroad Volume	Class							
Over 40	6	699	105	164	55	26	0	1,049
21-40	5	5,207	487	607	88	59	6	6,454
11-20	4	9,819	897	1,188	237	95	21	12,257
6-10	3	15,868	1,234	1,469	258	110	24	18,963
3-5	2	14,304	1,193	1,576	274	119	17	17,483
0-2	1	44,083	3,441	4,592	882	353	57	53,508
Column Totals		89,980	7,357	9,696	1,794	762	125	109,714

Source: National Railroad-Highway Grade Crossing Inventory.

Table 10. Vehicle Train Accidents by Light Condition, Accident Type, and Highway Speed; 1974

Motor Vehicle Speed	Daylight: Struck by Train	Daylight: Ran Into Train	Daylight: TOTAL	Dark: Struck by Train	Dark: Ran Into Train	Dark: TOTAL
Standing	274	1	275	108	1	109
1 -9	275	34	309	91	21	112
10-19	321	43	364	110	42	152
20-29	254	70	324	106	68	174
30-39	148	82	230	72	83	155
40-49	62	49	111	20	49	69
50-59	36	42	78	13	32	45
60+	14	17	31	5	18	23
High Speed	5	7	12	2	13	15
Not Reported	212	82	294	92	105	197
ALL	1601	427	2028	619	432	1051

Source: FRA, Rail-Highway-Grade Crossing Accidents

1 mph = 1.61 kph

1 mile = 1.61 kilometres

Table 11. Rail-Highway Accidents Involving Motor Vehicles by Kind of Train Involved, 1974-1972

Kind of Train	1974 Number Accidents	1974 Train Miles (Millions)	1974 Number Per Mill. Miles	1973 Number Accidents	1973 Train Miles (Millions)	1973 Number Per Mill. Miles	1972 Number Accidents	1972 Train Miles (Millions)	1972 Number Per. Mill. Miles
Freight	2,566	469,728	5.47	2,653	476,379	5.57	2,682	451,456	5.94
Passenger	152	64,368	2.37	145	61,516	2.37	153	60,993	2.55
Work	60	4,881	15.00	53	4,967	13.25	61	5,119	12.20
Yard Switching	301	194,496	1.55	323	201,606	1.60	326	234,228	1.39
TOTAL	3,079	733,473	4.21	3,174	744,468	4.27	3,222	751,796	4.29

1 mile = 1.61 kilometers

Source: FRA, Railroad-Highway Grade-Crossing Accidents at or near crossings. For instance, the angle at which the highway and railroad intersect can aid or hinder the motorist's ability to detect a train. The ideal crossing is one of 90 degrees, but the National Grade Crossing Inventory as of May 1976, shows the following percentages for crossing angles: 0-30 degrees - 3 percent; 30-60 degrees - 16 percent; 60-90 degrees - 81 percent. The crossing angle has significant effect on the motorist's field of view, and the amount of skew from the ideal of 90 degrees should be minimized.

A related geometric characteristic is the vertical alignment. While there is no national data, it is not uncommon to have poor sight distance on the highway approach to the crossing. A part of the vertical alignment problem is the rise in elevation that frequently occurs at the crossing.

The railroad-highway intersection itself is a compromise of the design of the cross sections of each mode. For instance, a typical railroad cross section permits open drainage through the ties into the ballast and out to the borrow ditches. The highway, on the other hand, has a nearly impermeable surface, and the base and subgrade remain at relatively constant moisture levels. These differences in normal cross sections require a modification of each at a grade crossing. Subgrade drainage should be installed to allow water to flow away from each cross section. A clean vertical separation should be provided between the normal approach pavements and the grade crossing surface at the ends of the track crossties. The highway pavement and the crossing surface must be compatible but they must necessarily be different because the crossing surface must be supported by the track structure rather than by a normal subgrade.

2.6.2 Surfaces

The smoothness of the crossing surface is often one of the major areas of concern to the driving public. In some cases, a rough surface can contribute to an accident, and in any event, it can cause the driver to divert attention from the main task--the detection of a train. Table 12 shows the crossings by surface type as drawn from the National Grade Crossing Inventory. In order to install and maintain a smooth crossing,

Table 12. Crossings by Surface Type, 1976

	Number
Section Treated Timber	30,106
Full Wood Plank	35,021
Bituminous	118,864
Concrete Slab	819
Concrete Pavement	950
Rubber Panels	255
Metal Sections	250
Other Metal	198
Unconsolidated	32,666
TOTAL Crossings	219,129

Source: National Railroad-Highway Grade Crossing Inventory.

the fundamental difference between the two traveled ways must be recognized--the railroad track is a flexible platform and the highway subgrade supports a rigid pavement. There must be a complete separation at the joint between them. And there must be adequate drainage below.

2.6.3 Environment

Aside from the obvious sight distance problems that the environment can cause, its influence is mostly felt in moisture problems. Excessive moisture at grade crossings can cause saturation of the pavement structural section and failure of the pavement adjacent to the crossing, and even for a considerable distance on each side of the crossing. The railroad is also concerned about excessive moisture since it can lead to pumping and a consequent fouling of the ballast from the soil that is brought up. Therefore, both highway and railroad engineers agree that proper drainage is an important consideration in the construction and maintenance of grade crossings.

2.6.4 Illumination

Illumination of crossings can definitely aid the motorist, especially at those crossings with low speed train movements. In 1974, of the accidents involving motor vehicles running into the train, 432 occurred in the dark and 427 in daylight (Table 10). Significantly, automobiles accounted for 367 in the dark and 255 in the daylight. Some motorists apparently have a problem detecting trains moving over a crossing at night, thus illumination should be considered at crossings with passive control devices and accident histories of this type. The National Grade Crossing Inventory reports commercial power available at 197,062 of the 219,301 public grade crossings, so lighting is feasible at most crossings, depending somewhat on the reliability of the power source. Care must be taken, however, to properly design and install luminaires. Among the design requisites is non-interference with the railroad signal system and its visibility to the locomotive crew. Details on illumination can be found in a later chapter.

2.6.5 Sight Distance

Sight distance is the most important single site characteristic, and can be of three types: the distance at which the driver can see the crossing, the distance in the driver's right and left quadrants, and the distance the driver can see along the tracks if he is stopped at the crossing. Adequate sight distance is especially important for trucks; indeed, given a 60 mph (97 kph) train speed and a 50 mph (80 kph) highway speed, Voorhees (5) calculated that a car needed 292 feet (89 m) to avoid the train, while trucks needed 442 feet (134 m). Where trucks are a factor in the traffic stream, the sight distances should be based on their needs. A detailed discussion of sight distance and its computation will be given in a later chapter.

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3.0 PROGRAM ADMINISTRATION

3.1 INTRODUCTION

A successful grade crossing improvement program will require the full cooperation of all affected governmental agencies, the railroad companies, equipment suppliers and the general public. However, one single agency must be assigned the responsibility of administering a program if the goals and objectives of the program are to be attained in an orderly manner. The multi-jurisdictional aspects of the grade crossing problem requires the involvement of both public and private groups as partners in a program. Clear and early identifying of the duties and functions to be performed by each of the partners in an improvement program should be useful in the development of program administration procedures by the responsible agency. It has been suggested that the partners may be divided into the following three groups:

1) Legislative and Judicial
2) Administrative
3) Implementation

It has been further indicated that the Legislative and Judicial group includes the United States Congress and State Legislatures, which have enacted the basic legislation under which grade crossing programs are established. This group also includes the Courts which, by their decisions, have assigned responsibility for grade crossing safety among the various partners. Judges and Jurors who render decisions on individual grade crossing accidents are also partners. They may influence the progress of grade crossing safety programs, both positively and negatively.

The Administrative partners involved in grade crossing improvement programs are the railroad companies, state and local agencies (including the State Highway Departments and State Departments of Transportation), regulatory agencies such as Public Utility Commissions, and the Federal Government. All of these agencies and companies have been deeply involved in developing the partnerships that exist today, and in establishing procedures for carrying out grade crossing improvement programs. The administrative organizations, together with suppliers, contractors, and labor unions, are all involved in the implementation of programs.

Court decisions together with legislative and administrative action at the Federal level by the Congress and the Federal Highway Administration, have been largely responsible for the decline in the railroad's financial responsibility for funding grade crossing improvements over the years.

Legislation enacted at the state level relating to grade crossings varies widely with regard to funding, regulations and jurisdictional authority of different agencies. Special state funding for grade crossing improvements is authorized in some 20 states. Railroad financial participation under state laws varies and in general is not consistent with the participation in Federal-aid projects. Some participation in maintenance has been legislated in a few states; however, as a rule maintenance is not supported by public funding. In most states the Public Utility Commission (or similar regulatory agency) has broad powers over grade crossing matters. In a few states the State Highway Department or State Department of Transportation has almost complete jurisdiction over some grade crossings and has some authority over all crossings. Frequently there is divided authority between the Public Utility Commission and the state highway agency.

Multi-jurisdictional responsibilities on the part of several state agencies contribute to the need for coordinating a program. For example, recent Federal grade crossing funding legislation provides for Federal-aid participation in grade crossing improvements on all roadway classifications within the states. This would include crossings both on and off the Federal-aid system. However, state highway agencies generally do not have jurisdiction over roads and streets not included in the State Highway System or over crossings on those roads, except to channel Federal-aid funds to crossing improvement projects developed by local authorities.

Still another significant reason for the development of well coordinated Program Administration is that railroad labor, through agreements with individual railroads, has divided labor jurisdiction. Agreements between labor and management for the installation and maintenance of warning systems may not be identical on all railroads within a state, thereby requiring unique application of administration procedures to specific projects.

As in most safety programs, another serious problem is the lack of adequate funding to allow systematic improvements to all crossings under the jurisdiction of an agency. Lacking a definite commitment on the part of funding agencies to long term improvement needs, a long range program is difficult to administer. The selection of a small number of projects from a long list requested by cities, counties and railroads increases the difficulty of program administration. The suppliers of warning devices, lacking adequate knowledge of current and potential demand for their products, may limit the availability of materials as programs are expanded. Due to the requirement for highly trained and skilled labor force to install and maintain these devices, an adequate work force may not be available to meet increases in program activity. Lead time must be given to railroad management and labor organizations if the supply of trained labor to implement increased grade crossing improvement programs is to be available.

It is a general principal of management that the larger the number of decision makers, the larger the number of funding sources, the greater the number of applicable regulations and the greater the need for a coordinated effort among organizations, the more difficult the task of program administration. The grade crossing improvement program embraces all of these complicating factors which bring about the requirement that appropriate emphasis be placed upon proper procedures and techniques for administering the program.

3.2 PROGRAM ORGANIZATION

A generalized approach to the organization of a grade crossing improvement program is necessary in order that its administration will provide for a well planned and coordinated attack on the grade crossing problem under the jurisdiction of the agency. A generalized organizational structure for program administration deals with five Program Elements:

- Program Authority and Responsibility
- Program Development
- Program Definition
- Program Approval and Implementation
- Program Coordination, Review and Continuation

In the following definition and discussion of each of these Program Elements no attempt has been made to sequence the sub-elements of the program. This can only be accomplished in accordance with the responsibility and authority that has been given the agency designated to implement the grade crossing improvement program. The sub-elements discussed here are not inclusive of all elements required for a program but are presented only in a generalized format.

3.2.1 Program Element I: Program Authority and Responsibility

This Program Element illustrated in Figure 3 involves the establishment of policy with regard to grade crossing safety. It includes a statement of goals and objectives for grade crossing improvement that have been assigned to, or established by, the designated agency having the responsibility and authority for the program. This Program Element also involves the development of the grade crossing improvement program and the coordination of this program with the other partners identified in the sub-elements. The more multi-jurisdictional the responsibility for grade crossing improvement, the larger the number of sub-elements to be included in this Program Element. If for example, there is a State grade crossing improvement program to be implemented by the responsible agency, then the sub-element under state programs requires a program administration and organizational structure of its own.

Federal programs are not limited to those sections of the Federal-Aid Highway Acts which provide funding for crossing improvements. Where applicable, they should also include Railroad Relocation and Demonstration projects authorized by Federal legislation, the maintenance and update of the National Railroad-Highway Grade Crossing Inventory file

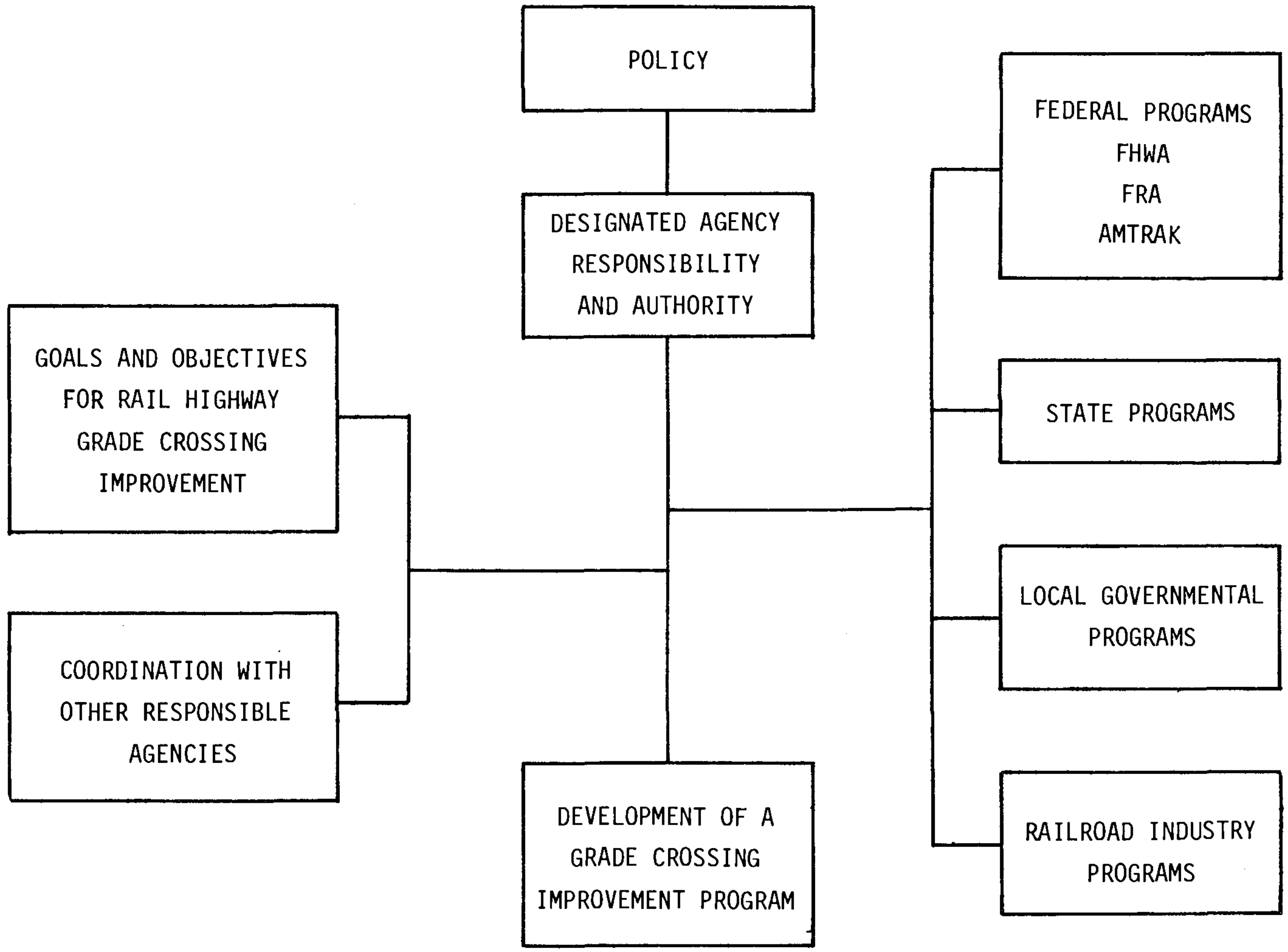

Figure 3. Program Element I: Program Authority and Responsibility

(as administered by the Federal Railroad Administration), and the proposals for crossing improvements or elimination under the Amtrak program. There are also instances where state and local governmental bodies have unique grade crossing programs that should be coordinated within this administrative structure. Some railroads have priority programs for grade crossing improvement over their system. These programs should also be considered as a sub-element of Program Element I.

In summary, this Program Element defines policy, sets goals and objectives, specifies the designated responsible agency, identifies other agencies that will require coordination within the program, identifies funding sources, and identifies and describes other grade crossing improvement programs administered by public and private agencies.

3.2.2 Program Element II: Program Development

This Element of Program Administration is illustrated in Figure 4. It includes the definition of the grade crossing problem in both short and long term program objectives. It identifies the data elements necessary to develop the program. It specifies the need for the development and acceptance of an analytical model, or priority rating, for program definition. Further, this Element classifies improvement alternatives, as well as their associated cost and resulting benefits. All of the sub-elements are necessary steps to achieve a numerical priority rating for all public crossings under the jurisdiction of the agency responsible for the program.

Obviously the administration of this Program Element will require inputs from all partners or agencies that were identified in Program Element I. Major emphasis here must insure that a comprehensive and coordinated approach to the grade crossing improvement program is developed in a format that provides for the continuation of the program.

3.2.3 Program Element III: Program Definition

The basic function of this Program Element, illustrated in Figure 5, is to define individual projects that constitute the agency's grade crossing improvement program. These sub-elements include the

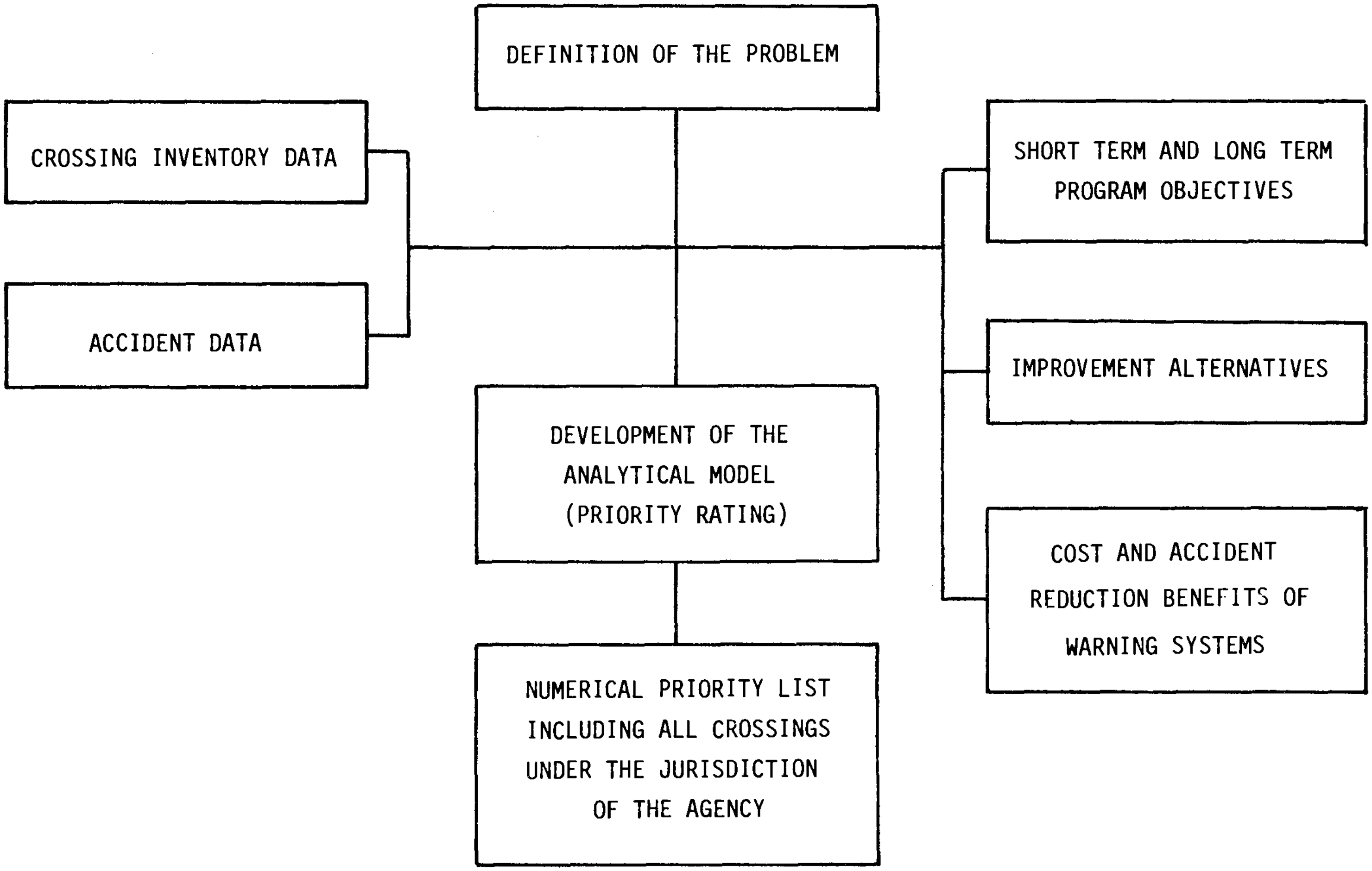

Figure 4. Program Element II: Program Development

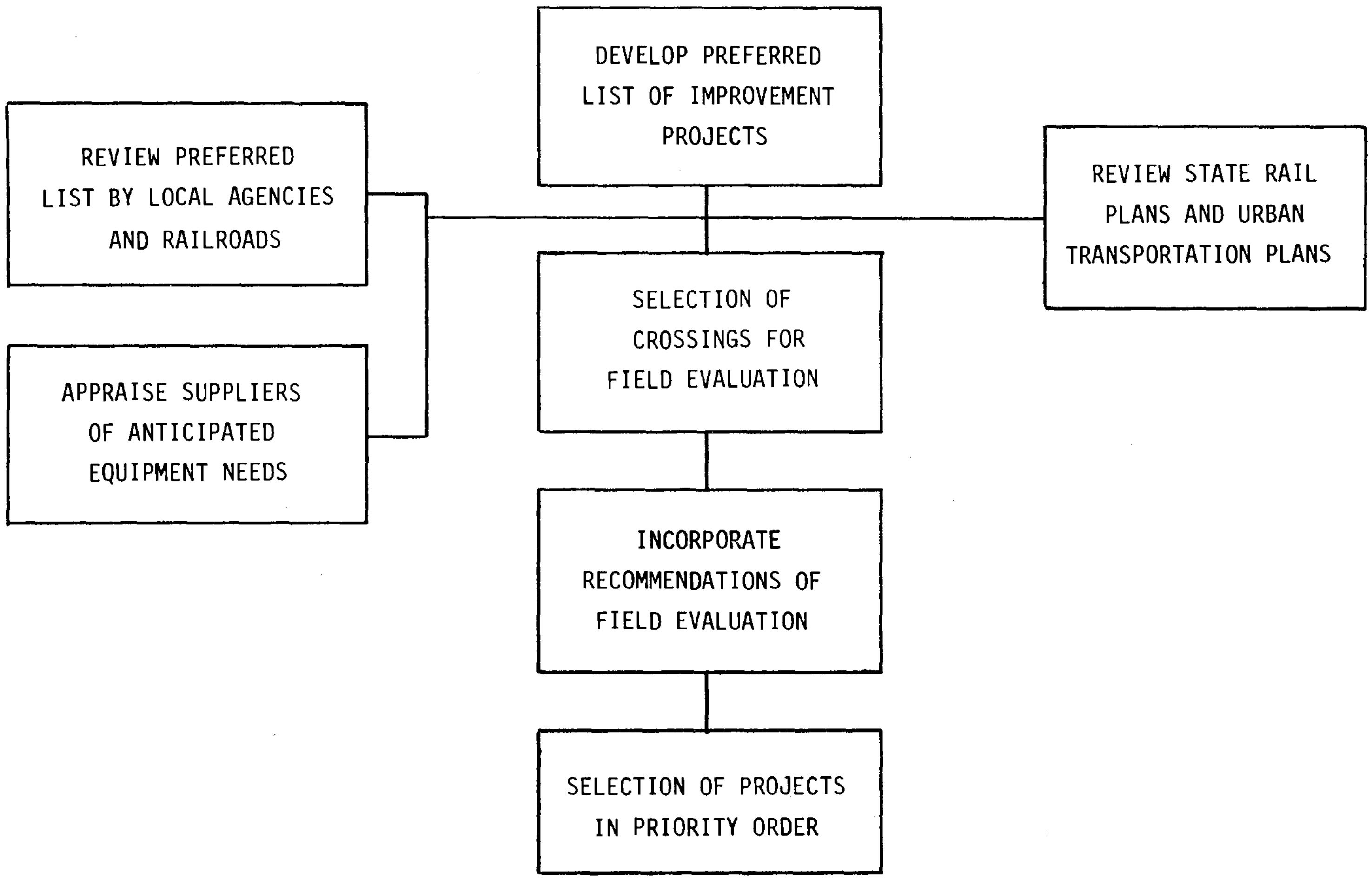

Figure 5. Program Element III: Program Definition

development of a preferred list of improvement projects resulting from the numerical analysis called for in Program Element II. This list may be constrained on the basis of available funding, through sources identified in Program Element I, or on the basis of an "economically justified" level of funding. In other words, benefit/cost ratios would be computed for each grade crossing in the inventory and those that would develop benefit/cost ratios larger than one would be included as a part of the agency's programs. In either instance, it is recommended that a relatively large number of projects, relative to anticipated funding, be included on the preferred list to insure that substitutions can be made in the priority list following field evaluation of the crossings.

Following a field evaluation, a list of specified projects may then be developed. It should include those crossings which will require improvement in connection with scheduled roadway improvement projects. The project list should not only include projects which are being funded to receive grade crossing traffic control device improvements but also should include crossings that are in need of surface improvement, and those in need of site improvements both along the roadway approach and the railroad approach. The total program would include improved maintenance upon the signs and traffic control devices existing within the crossing environment. It would also indicate those crossings that might be closed or where grade separations may eliminate the crossing or the need for the crossing. Also at this point State Rail Plans and Urban Area Transportation Plans should be reviewed to determine whether there are crossings on the list that would be involved in any railroad abandonment, railroad relocation, consolidations or highway realignment.

This list of potential improvement projects should then be ranked for implementation. The priority for implementation may be established either upon the degree of hazard that exists among those crossings included in the program, or according to a construction schedule that is consistent with the availability of materials, equipment, and railroad labor force. At this point, material suppliers can be informed of the anticipated equipment needs for the program and the railroads can be notified as to the anticipated labor needs. Program Element III thus provides the agency with a specific program which is made up of individual projects to be implemented within the funding limitation of the overall program. It also establishes priority for the implementation of these projects over a specific time period.

3.2.4 Program Element IV: Program Approval and Implementation

The first step in this Program Element, illustrated in Figure 6, is to prepare a Master Agreement, if one is deemed necessary. The Master Agreement would contain the specifications, regulations, and provisions required for work performed on all projects. It is important that the State and individual railroads sign a Master Agreement before individual project plans and specifications are prepared. This will allow reimbursement for initial work to develop the Master Agreement. Hopefully, through the adminstration of Program Element I there has been sufficient coordination among the individual railroads to provide a Master Agreement that is compatible for all railroads. Greater efficiency in the allocation of limited resources is achieved when the public agency is, in effect, dealing with a single railroad unit. This is not to suggest that one railroad represent the others, but it is important for all railroads to approve the final form of the Master Agreement for crossing improvements.

Once the Master Agreement has been prepared, the program is submitted to the appropriate operating agency for approval. The agency could be the State Highway Department, local authorities, Amtrak (in some instances), and other agencies responsible for environmental impact studies. In some instances, approval from multiple agencies and the Federal Highway Administration may be required.

The Federal Highway Administration has developed a Simplified Procedure for Accelerating Grade Crossing Improvements (FHPM 6-6-2 par. 10) to advance single or multiple grade crossing improvements. The written agreement between the State and a railroad shall contain as a minimum:

- Identification of each crossing location
- Description of improvement and estimate of cost for each

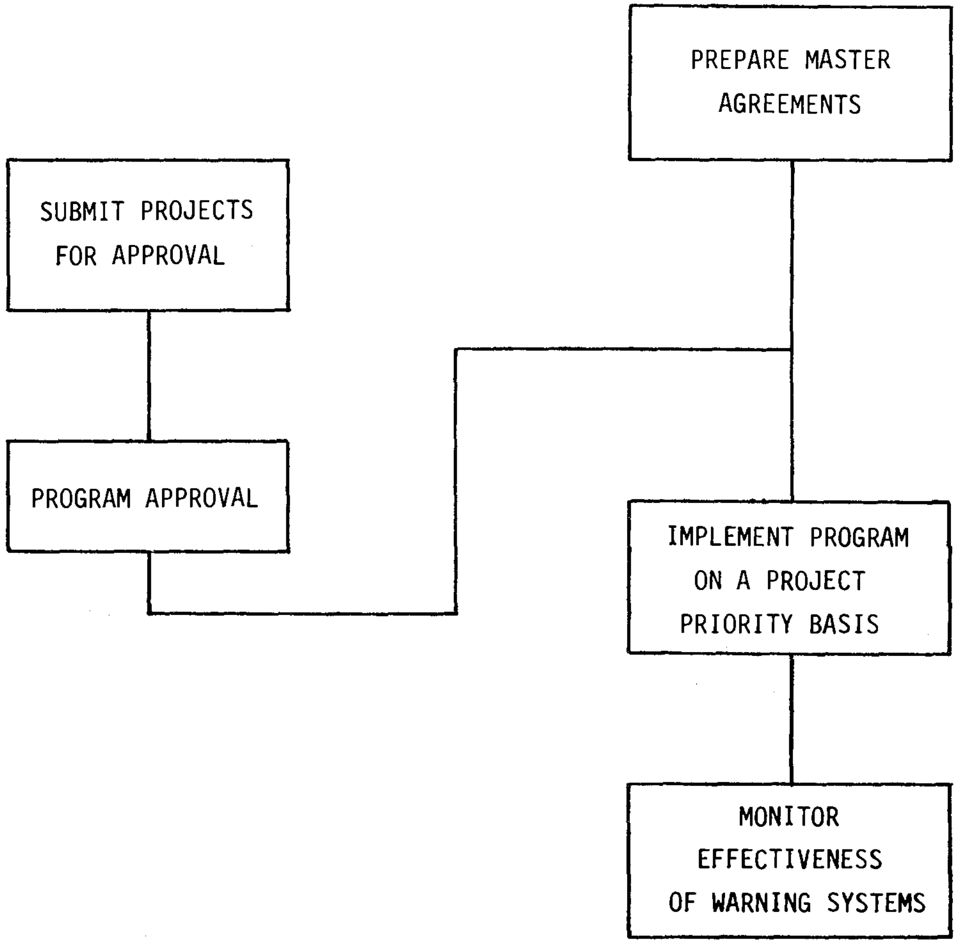

Figure 6: Program Element IV: Program Improvement and Implementation

crossing location

- Estimated schedule for completion of work at each location

Following programming, authorization, and approval of the agreement, FHWA can authorize construction, including the acquisition of traffic control device materials. The work programmed under this simplified procedure should include only those projects which can reach the construction stage within one year, and be completed two years after the initial authorization date.

Prior to, or as part of, the implementation phase, regulatory authority approval must be secured in those States where required by statute. It must be recognized that some State regulatory authorities may require implementation of some projects on their own initiative or as a result of public petitions.

Implementation of individual projects should be on a systems basis following the priority construction schedule that has been established and consistent with the availability of both materials and labor. During this process projects should be monitored for their timeliness as well as expenditure control. In addition, they should be monitored as to the effectiveness of the new control device systems that are being installed. These studies, often times referred to as before and after studies, are an important element of program improvement. Program Element IV then provides for the implementation of the program that has been developed by the designated agency. This Program Element should be a continuing process to gain the greatest amount of efficiency in the expenditure of program funds.

3.2.5 Program Element V: Program Coordination Review and Continuation

The purpose of this Program Element, illustrated in Figure 7, is to insure that a coordinated and efficient railroad-highway grade crossing improvement program is maintained by the agency retaining continuing management jurisdiction. It envisions the continuation of the process of updating all program elements on a periodic basis. Additional sub-elements include: 1) coordination of safety education, 2) enforcement of traffic laws, 3) development of future program recommendations, and 4) review of new and innovative technology for grade crossing safety

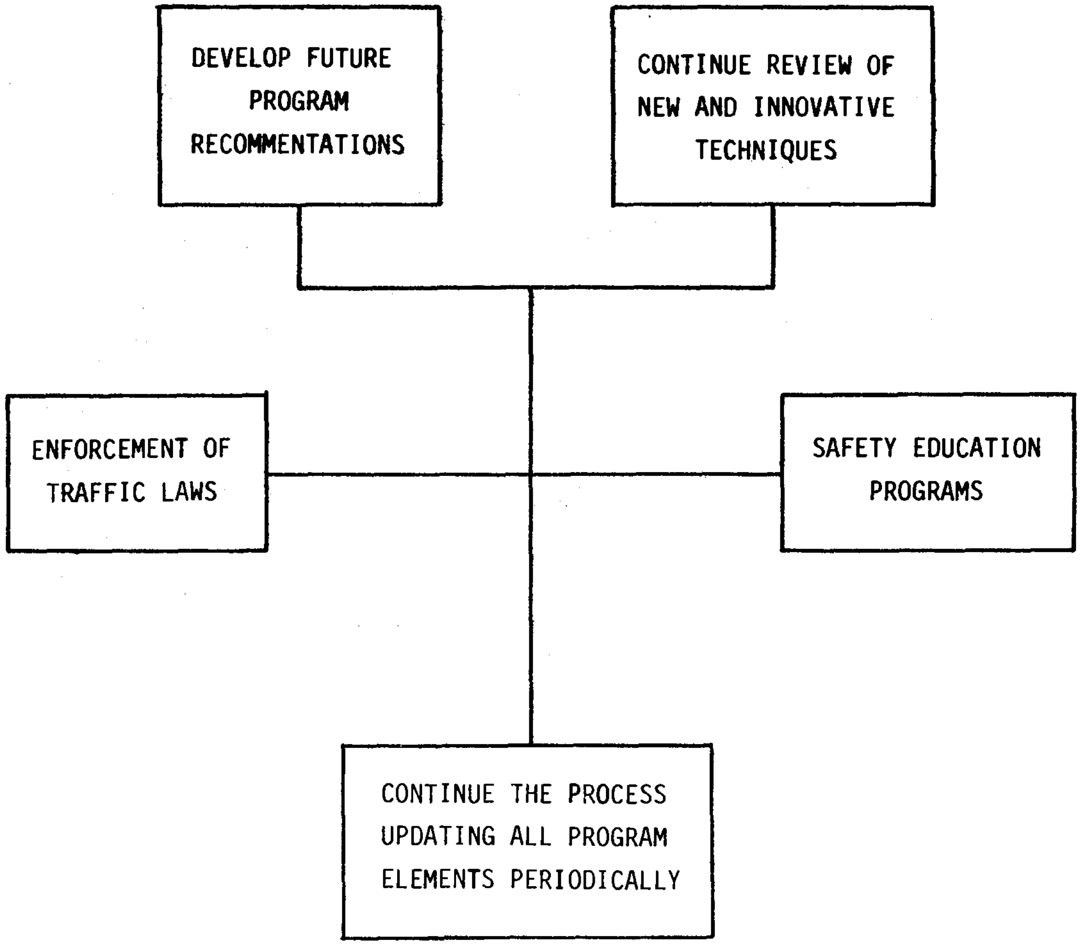

Figure 7. Program Element V: Program Coordination, Review and Continuation

improvements. This Program Element is structured on the basis of the significance of the grade crossing safety program to the total safety program of the agency. It is important, however, that no matter how small the grade crossing program, the need for continuation and improvement of the program still exists.

3.2.6 Staffing

This generalized description of an organizational and administrative procedure for a grade crossing improvement program makes it obvious that it will require staffing. Figure 8 is a generalized management organizational chart for program administration. The program manager should have sufficient authority to implement all phases of the program. Either through his own efforts or through staff assistance he must coordinate the activities of the railroad industry and the governmental agencies involved in the program.

The line functions of the organizational chart are compatible with the Program Elements. For example, they include staff responsible for programming and budgeting, systems analysis, data file maintenance, design and operation of the control device systems, and monitoring and review of the program. It is recognized that small program size may make it infeasible to individually staff each of these functions. In that instance, staffing would be based upon the ability of individuals to perform one or more of the duties described. The requirement for program staffing should be recognized early in order that agency budget recommendations for staffing can precede the implementation budget. A continuing review of program staffing needs is important. For example, the agency may find that its responsibility changes as legislative requirements change. Also, reorganization of state agencies may require some support from agencies outside the jurisdiction of the program manager.

3.3 FUNDING SOURCES

Sources of funds for grade crossing improvements include the Federal-Aid Highway Program, special state funding, local governmental agency appropriations, the railroad industry, and special funding.

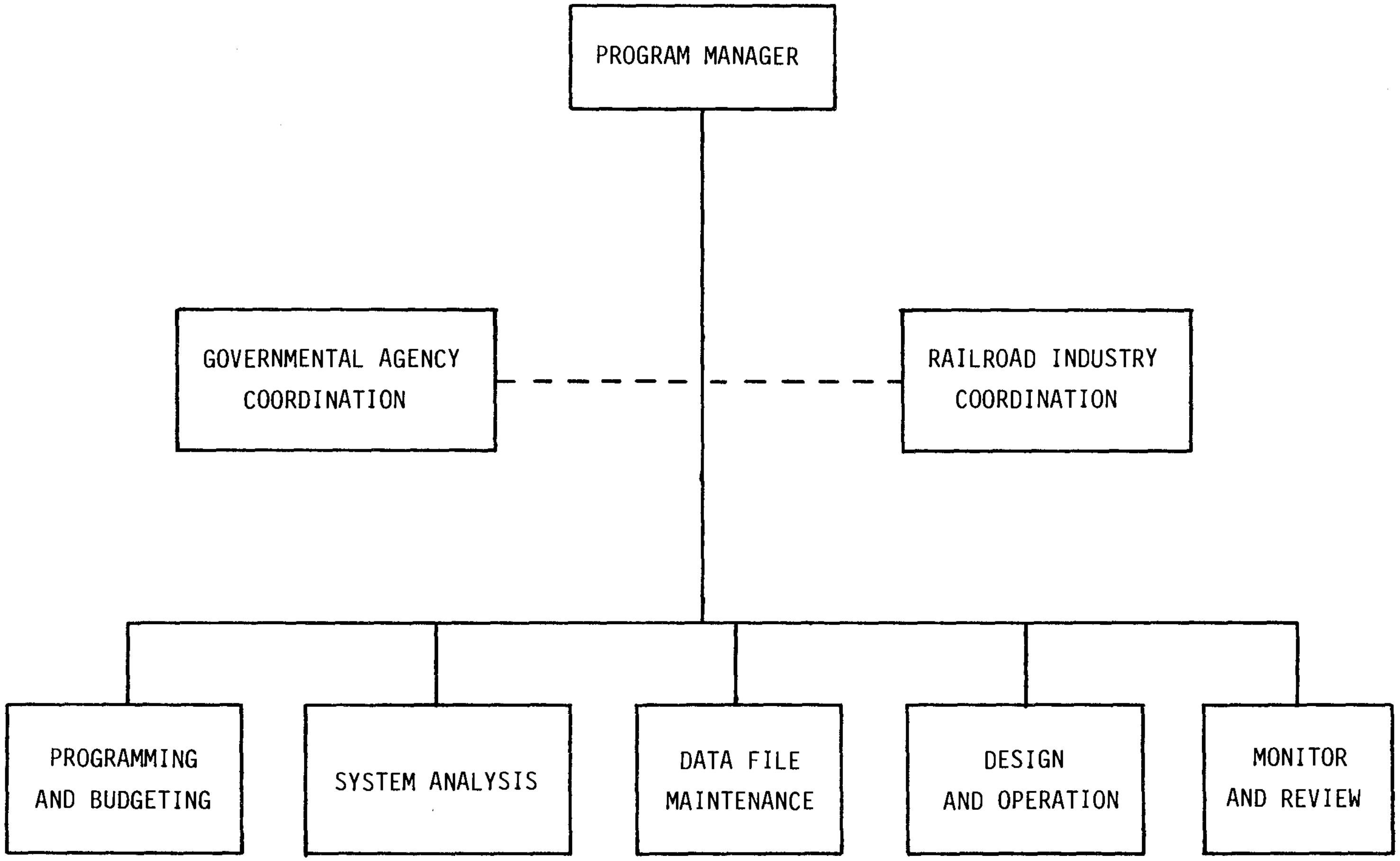

Figure 8. Program Administration: Generalized Management and Organizational Chart

Without discussing specific funding amounts, inasmuch as authorizations and appropriations change periodically, these several funding sources are identified and analyzed.

3.3.1 Federal Sources

The Federal Government involvement in grade crossing safety began many years ago and was significantly expanded by recent Federal legislation. Federal-aid highway funds are available for eliminating hazards at grade crossings both on and off the Federal-aid highway system. These projects may include:

- Grade crossing elimination by:
  - + new grade separation structures
  - + relocation of highways
  - + relocation of railroads
  - + crossing closure
- Reconstruction of existing grade separations
- Grade crossing improvement by:
  - + installation of standard signs and pavement markings
  - + installation or replacement of active grade crossing traffic control devices
  - + upgrading of active control devices, including track circuit improvements and interconnection with highway traffic signals
  - + crossing illumination
  - + crossing surface improvements
  - + general site improvements

The responsibility for establishing priorities and selecting projects to be implemented rests with the individual States. Federal funds authorized by legislation are apportioned to the States in accordance with an apportionment formula. The apportionment of authorizations occurs no less than 6 months prior to the beginning of the fiscal year of the authorization. Except for Interstate funds, apportioned funds are available for obligation for a period of 3 years after the end of the fiscal year for which authorized.

3.3.1.1 On-System Projects --

- Regular Federal-Aid Highway Funds

  For many years Federal-aid highway funds have been available to the States for eliminating hazards at grade crossings. It was the Federal-Aid Highway Act of 1944 which first provided that, at a State's option, up to 10 percent of the total funds apportioned to each State in any year could be used for eliminating hazards at grade crossings at a special Federal share which could go up to 100 percent of construction costs. This provision does not result in additional Federal funds being available to a State, but rather allows a part of its regular apportionment to be used at a greater than normal Federal participation ratio. These provisions are now included in Title 23, United States Code, Sections 120(d) and 130 and projects carried out under these provisions are commonly referred to as "G" funded projects. Theoretically, there is no limit to the amount of regular Federal-aid highway funds that can be used at the regular pro rata share for grade crossing improvements.

- Grade Crossing Safety Funds

  In addition to regular Federal-aid highway funds, Section 203 of the Highway Safety Acts of 1973 and 1976 provided specific and exclusive funding for grade crossing safety projects on the Federal-aid highway system. The Federal share on these projects is 90 percent. All of the types of projects listed are eligible for implementation with these funds, however, the emphasis of this program is on relatively low cost safety improvement projects. The legislation requires that at least half of the funds authorized and expended under this program shall be available for the installation of traffic control devices. FHWA interprets this to include signs, pavement markings, signals, gates, crossing illumination, crossing surface improvements, and general site improvements. The first priority of the program is to provide as a minimum signing and pavement marking in accordance with the MUTCD at all grade crossings.

3.3.1.2 Off-System Rail-Highway Crossing Safety Funds -- Section 203 of the Highway Safety Act of 1976 also provided specific and exclusive funding for grade crossing safety projects off the Federal-aid highway system. The Federal share of project cost is 90 percent. The types of projects which can be implemented and the emphasis on installation of control devices applicable to on-system safety projects also apply to off-system projects. However, Federal funds for the off-system projects are derived from the General Treasury rather than the Highway Trust Fund. The off-system funds must be appropriated by Congress before being made available for obligation.

3.3.1.3 Railroad-Highway Demonstration Projects -- Federal funds are being used to carry out several railroad-highway demonstration projects authorized by Congress in specific locations. One project involves elimination of all public road grade crossings of the high speed rail line in the Northeast Corridor between Washington, D.C., and Boston. Other demonstration projects authorized involve the elimination of conflict points in urban areas. These projects involve various combinations of grade separation, relocation, and consolidation of railroad lines. Presently, Federal funds are available only for projects specifically designated by Congress in Federal legislation.

3.3.1.4 Traffic Control Signalization -- Section 146 of the Federal-Aid Highway Act of 1976 authorizes funding for coordinating traffic control signalization, both on and off the Federal-Aid system. The objectives of this program are to increase the capacity of existing highways, reduce traffic congestion, conserve energy, improve air and noise quality, and improve safety. Although grade crossings are not referred to specifically in that section, it may be interpreted that funds authorized for the improvement of traffic control signalization would include increased coordination between existing or new installations of highway intersection traffic control devices and grade crossing traffic control systems.

3.3.1.5 Other Federal Funding Sources -- The Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act) authorized funding for improvements in the Northeast Corridor between Washington, D.C., and Boston. The National Railroad Passenger Corporation (Amtrak) provides intercity passenger railroad service over facilities within that Corridor. The railroad-passenger improvement goals of that program include the safe operation of railroad-passenger trains, as well as safety at points where those facilities interface with highway facilities. States in the geographic area of the Northeast Corridor should review that program for possible grade crossing improvement funding.

That Act also includes authorization for funding for assistance in the operation of Consolidated Rail Corporation (Conrail), the railroad corporation operating portions of former bankrupt lines in the northeastern and midwestern states. Those states in which the Conrail system operates should work with that organization to determine appropriate grade crossing improvement goals for Conrail lines.

3.3.1.6 National Railroad Passenger Corporation (Amtrak) -- Amtrak has recently established an Office of Railroad-Highway Grade Crossing Safety. Demonstration projects have been explored with six major railroads in the United States, operating through some twelve states, to investigate the possibility of a "systems type improvement" to grade crossings along the Amtrak passenger routes. Although the Corporation has limited funds for this activity, in the event Federal-aid Highway funds, State funds, or local funds are not available for the improvement of a crossing on an Amtrak route, the Corporation should be contacted to determine its interest in the project.

3.3.1.7 Summary -- Federal funds are available for grade crossing improvements. However, those funds are limited in amounts and some of them are otherwise restricted. In addition the particular source of funds provided by the Federal-Aid Acts and the individual states' choice for the use of their Federal-aid fund allotments determine the availability of the funds. Funding sources such as Amtrak and Conrail may be available in some states. Whatever the source there are no

Federal funds currently available for maintenance of control devices at grade crossings. Funds for this purpose must be generated from other sources.

3.3.2 Special State Funds

State legislation regarding grade crossing improvements varies widely with regard to funding, cost sharing and jurisdictional agencies and their authority. Special funding for grade crossing improvements has been authorized in less than one-half of the States. The list changes with each State legislative session. In general, State funds are made available for grade crossings not included in the Federal-Aid system. In several instances, funds are made available to defray a part of the railroad's maintenance cost of traffic control systems. No attempt will be made to describe these special funds.

3.3.3 Local Agency Funding

There are a number of cities and counties that have established grade crossing improvement funds. Although some of these programs are continuing, most have been established only to meet matching fund requirements of State and Federal programs. With the authorization of Federal funds for projects off the Federal-Aid system, local governmental agencies will be encouraged to increase their activity in this area.

3.3.4 Railroad Funding Status

As mentioned in Chapter 1, Federal Highway regulations, national legislation, and court decisions have decreased the railroads' financial obligations for grade crossing improvements. Although the railroads' contribution to the installation of control devices has decreased, the railroads' total financial obligation to crossing safety has increased. This requirement for increased railroad financing arises largely from the increase in the number of crossings that have train-actuated devices, which increases the railroad cost of maintenance.

The financial condition of individual railroads varies significantly. Some railroads are operating under bankruptcy. Other railroads are financially strained to remain in business. The financial conditions of some major railroads is such that their interest in grade crossing improvements is maintained. It may be expected that as the financial condition of an individual railroad deteriorates or improves the company's commitment to grade crossing improvement financing will change. Therefore, no single generalized statement applies to all railroads' ability to, or interest in, participating in grade crossing improvements.

3.4 MASTER AGREEMENTS

The idea of Master Agreements covering a large number of grade crossing improvement projects is not new. Since the 1930's the concept has been employed by some States in programs with individual railroads. The Master Agreement saves valuable time in the negotiation stages involving the installation of control devices. For example, with the Master Agreement, when change orders are required for an individual project these orders can be implemented immediately rather than having to re-negotiate changes on a specific location-by-location basis.

In general, a Master Agreement sets forth the purpose of an agency to engage in the construction or re-construction of some part or parts of its highway system which calls for installation and adjustment of control devices at grade crossings. It requires a railroad to prepare detailed plans and specifications for the work to be performed. These plans and specifications are made in accordance with the agency's procedures previously specified. Master Agreements will also establish responsibility for the procurement of materials for improvements. In some states a Master Agreement specifies approval procedures required in review of plans and other pertinent features by regulatory agency. It will contain provisions for notification of project construction date on individual projects, and other requirements of the agency and railroad company contained generally in contractual agreements.

The Joint Committee on Highway-Railroad Crossings of the Association of State Highway and Transportation Officials and the Association of American Railroads might well develop an example of a Master Agreement that could be adopted by a State agency and the railroads operating within that State. Additionally, since a Master Agreement covers many individual projects, it allows all of them to be treated as a system, with all of the advantages inherent in a systems approach--better scheduling and manpower utilization in particular.

3.5 LEGAL CONSIDERATIONS

An issue as old as the grade crossing problem itself is that of responsibility. Who should provide and pay for the traffic control devices or other improvements needed at grade crossings?

The original concept that railroads have the primary or sole responsibility, financial or otherwise, for the elimination of grade crossings or for providing signs or other devices has gradually changed. Federal-aid highway acts, particularly the Act of 1944, took the lead in shifting the burden from railroads to public highway agencies, although they applied only to Federal-aid projects.

At the state level there also have been significant changes in the old concept of total railroad responsibility. The present trend is toward public highway agency assumption of greater responsibility for improvement of grade crossings. Most states have recognized that the demand and need for grade crossing improvements have been the result of development, growth, and public acceptance of motor vehicles and highways; that grade separation and grade crossing safety improvements are more significantly a part of the highway system rather than the railroad system; and that such safety projects benefit highway users more than railroads. This shifting of responsibility has occurred and still is occurring despite the findings of the courts that the states could legally and constitutionally require the railroads to bear the entire responsibility for grade crossings, as they did for many years (1).

Because many states now have a Tort Claims Act which allows the state to be sued for any negligence on the part of its officers or employees (this usually includes acts of omission as well as commission and errors in judgment), there is a distinct possibility that a new field of law may develop. This is especially true where the state has an agency that is responsible for determining whether crossings are properly signalized and determining the type of signalization to be used.

Potential liability in grade crossing accidents creates a reluctance on the part of the parties to do anything that might leave them open to charges of negligence. Experimentation and in-service trials of new devices might be carried out more frequently if the legislatures and the courts would provide a less penalizing judicial climate.

Due to changing conditions and the magnitude of the railroad-highway crossing problem, an appropriately funded ongoing grade crossing improvement program based upon needs is highly desirable.

3.6 CROSSING EDUCATION

Nearly all grade crossing accidents involve some degree of driver error. One of the objectives of driver education is to impart the required knowledge, skills, habits, and attitudes to enable a driver to perform in a manner that will minimize the probability of his 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. To be successful, a public education effort must be carefully planned and executed and aimed at the driving public via the most attractive media possible. The messages should be presented in prime time, and in the most popular magazines and newspapers. The highest 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, since the time devoted to the subject is usually on the order of 5 minutes, if any, out of 30 class hours. 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 barrier. At the very least, a student driver should traverse a grade crossing as part of his behind-the-wheel training. Every effort should be made to convince those persons responsible for driver education to review their program with respect to the material concerning grade crossings. The following is a recommended starting point for grade crossing performance items as presented in the Guide for Teacher Preparation in Driver Education, NHTSA, 1974:

- DRIVING TASK REQUIREMENTS
  The student should know the procedures, hazards, and laws that pertain to driving across railroad tracks.
- GENERAL
  State laws generally require school buses, tank trucks carrying explosives or flammable liquids, and commercial carriers to stop for railroad crossings except under certain specified conditions. The driver should anticipate stopping when following such vehicles and approaching a railroad crossing. The driver also should:
  Look for signs along the roadway and other indications that a railroad crossing is ahead.
- APPROACHING AND STOPPING
  Seventy-eight percent of the country's grade crossings do not have active traffic control devices to warn drivers of an approaching train. They have only signs to mark the crossing location. When approaching a railroad crossing with no signal, the driver should:
  - Look quickly in both directions and open the window and turn down the radio to enhance the ability to hear the train's warning bell or whistle.
  - If no train is in sight and visibility is clear, maintain speed and cross immediately.
  - If a train is approaching, stop the car within 50 feet (15 m) (but not less than 15 feet (4.5 m)) from the nearest rail.

  When stopped at a multitrack, no signal crossing, the driver should:
  - Cross the tracks if no trains are approaching.
  - If waiting for an approaching train, remain stopped until the first train has completely cleared the crossing and the view is clear in both directions on the other track. The first train may screen another train coming from the opposite direction, and its sounds may drown out the noise of the approaching train.
  - Remain stopped if other trains are approaching.

When approaching a signalized railroad crossing and the signal is activated, the driver should:

Stop completely and remain stopped until the signal indicates the track is clear.

Proceed across the tracks after obtaining a clear view of the tracks in both directions.

Proceed across the tracks, even though the signal is activated, if there are no trains approaching from any direction or if a single train is approaching at a very slow speed and at some distance.

Proceed across signalized tracks if told to do so by a flagman.

- CROSSING TRACKS

  When crossing railroad tracks, the driver should:

  Refrain from stopping on the tracks or between tracks and refrain from crossing the tracks until there is sufficient space on the other side of the tracks for the car to completely clear the tracks.

  Take precautions against stalling by using a low enough gear in manual shift cars and by applying steady pressure on the accelerator pedal.

  Cross as quickly as possible if the flashing signal or automatic gate is activated while in process of crossing.

3.7 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; however, these law enforcement practices throughout the nation vary widely, ranging from excellent programs to total inattention.

Accident data have shown that a majority of those involved in grade crossing accidents are familiar with the crossing. It seems that in spite of the 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 inherent driver safety potential at grade crossings, but analysis is required to determine whether the accrued benefits justify the costs. For instance, Sanders (2) reports an 80 percent increase in gasoline truck compliance with a stopping law once the drivers were aware that a police patrol was watching the crossing. This safe behavior seems to hold for a period of time after the patrol is removed, but then the violation pattern reemerges. The expense of increased patrols, especially at high accident locations, might be cost effective since the accident data shows the frequency of collisions to peak at the times of the greatest commuter traffic (29 percent of the rail-highway accidents in 1974 occurred in the hours 7-9 am and 3-6 pm). Police patrols could effectively cover a number of high accident locations at peak traffic periods.

3.8 EQUIPMENT

The various devices used at grade crossings have been in existence for many years, and it is important to understand the factors that mitigate against improvement in this area in order to understand the reluctance to change accepted practice.

The most important limitation on grade crossing warning equipment design is the fail-safe requirement. Unlike highway traffic lights, grade crossing signals "work" only when a train is present or approaching, so that a non-operating signal does not signify to a motorist that the signal is not in working order as is the case with highway signals. Hence, a grade crossing signal must be "fail-safe," i.e., in the event of a failure of any of its mechanisms, it must assume its most restrictive aspect--it must operate. In the event of commercial power failure it must operate from standby batteries for a reasonable period until repairs can be made. Practical limitations on battery capacity has led to the use of 18 and 25 watt bulbs with a concentrated focused beam, compared to the 60-150 watt bulbs in highway traffic signals. Adherence to the fail-safe principle results in the greatest safety, and limits the liability problems of those organizations responsible for design, installation, and maintenance. There is little possibility that responsible parties will approve or install any devices which do not adhere to this principle.

Because of the effectiveness of existing active devices, particularly the automatic gate, with skillfully designed and competently installed train detection equipment, there has been little incentive to seek alternatives. Nevertheless, because the cost of such devices is continually mounting, there is considerable interest in seeking new or modified devices which would perform as well or better at less expense.

The other equipment limitation concerns the availability of the equipment itself, as well as qualified installation personnel. Historically, each railroad custom-designed its signalization of grade crossings rather than purchasing from "off the shelf". Also, because there never was a large demand for grade crossing signals, manufacturers could not afford to build up inventories. Furthermore, installation crews had to be fairly skilled, and it was expensive to train them to the required level. Since there was no long range grade crossing improvement program on most railroads, it was difficult to do long range manpower planning.

These problems have led some states and railroad companies to develop an extensive grade crossing improvement program and purchase the necessary equipment. The railroads then install and maintain the devices. This method has allowed the railroads to develop the skilled personnel with some assurance they will continue to have jobs, and it has also allowed the state to save money through bulk purchase of signal equipment.

3.9 REFERENCES

1. Federal Highway Administration/Federal Railroad Administration, DOT. Report to Congress. Railroad-Highway Safety. Part I: A Comprehensive Statement of the Problem. Appendix A. 1971. NTIS, Springfield, Va. PB 213 115.
2. Sanders, J. H., Jr.; Kolsrud, G. S. and Berger, W. G. Human Factors Countermeasures to Improve Highway-Railway Intersection Safety. NTIS PB 223 416.

4.0 PROGRAM DEVELOPMENT

4.1 INTRODUCTION

The development, project identification and implementation of a grade crossing improvement program most often will be a state function although local governmental agencies as well as individual railroads may use the same procedures in the development and implementation of their projects. The railroad-highway interface cuts across many different units of government as well as several different departments of an individual railroad company. Depending upon the organizational structure of the state, one or more state agencies will have responsibility for various aspects of the railroad-highway interface.

For example, in one state the Public Utilities Commission will have the responsibility for determining the type of traffic control devices to be installed and allocating the cost between the railroad(s) and the governmental agencies involved in grade crossing improvement programs and individual projects. At the same time the State Highway Agency will have the responsibility for the actual program planning, design and supervision of the construction of projects and the allocation of State and Federal-aid funds. In other states, a single state agency may have total responsibility for grade crossing improvement programs, including the establishment of priorities, selection of projects, and the implementation of the program.

Information necessary for the development of a grade crossing improvement program may be the responsibility of still other agencies of the state. For example, railroad-highway accident data may be available through an agency having the responsibility for railroad safety such as the Public Utilities Commission. On the other hand, highway accident data may be available only through an agency of the state totally responsible for highway safety. Crossing inventory data may be available through a State Planning Agency. Highway traffic volumes, train frequency and other operational data may only be available, in a continuous update format, from local governmental agencies and individual railroad companies.

The initial steps in Program Development are to define policy for grade crossing improvement, identify those agencies responsible for implementation of the program, and identify sources of information. With this documentation, a program may be developed which will provide for a systematic approach to grade crossing improvements that will insure maximum benefits to the users of grade crossings from the expenditure of limited program funds. The next step in the program development process is to identify the methodology that is to be used in the selection of individual projects making up the program. A typical time frame for program implementation is on an annual basis. However, in initiating the program, long range planning for grade crossing improvements should be consistent with long range planning for transportation improvements. The methodology selected should be consistent with the goals that have been described herein before. In addition, the methodology should provide for selection of the number of projects that would be consistent with available funding for the planning period.

The next step in program development is the selection of criteria, or a conceptual framework, for determining priorities for the improvement of individual crossings. Although the agency may wish to design a unique model or conceptual framework for this activity, there are several mathematical formulations that have been previously developed for this purpose. These Hazard Ratings, or Accident Predictive Equations, are discussed in Section 4.3 of this report. Figure 9 is a schematic representation outlining the steps in program development. This is a general purpose activity chart that may be modified and adapted to the individual agency or railroad company's need for development of its improvement program.

A necessary step in the implementation of the grade crossing improvement program is one of problem definition. In order to define the problem, information must be collected that is consistent with the conceptual framework that has been adopted for data analysis.

4.2 DATA REQUIREMENTS AND DATA SOURCES

It is important to remember that not only will the proposed grade crossing improvement program require several levels of approval prior to

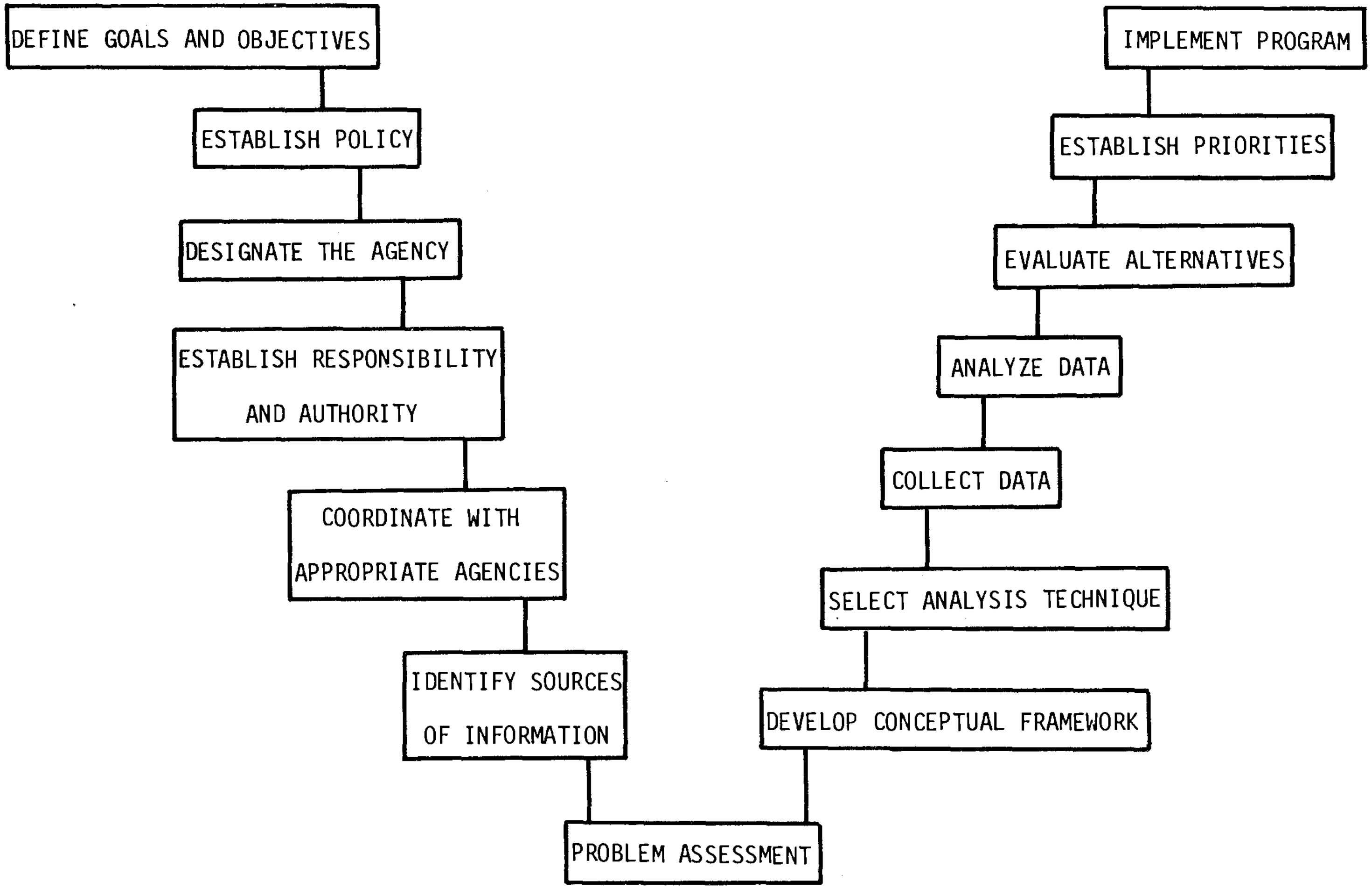

Figure 9. Development of a Grade Crossing Improvement Program

the allocation of funds, but individual projects will also require approval prior to their implementation. Therefore, data used in the selection of projects must be consistent in format and stand the test of credibility with individual approval authorities. Federal highway legislation requires that each state have a systematic procedure for determining individual project improvement priorities. This requirement is interpreted to mean that all public grade crossings within the state must be considered in the "priority rating". The best data source for a total inventory of all grade crossings within the state is the National Railroad-Highway Grade Crossing Inventory that was developed cooperatively through the Federal Highway Administration, the Federal Railroad Administration, the Association of American Railroads and the individual States. It is the objective of the National Inventory to place on computer file all public grade crossings, grade separations, private crossings, and pedestrian crossings. In addition, the Inventory is being updated continuously through a cooperative program established between the states, the railroad industry, and the Federal Railroad Administration.

The Inventory File has been distributed to the individual states. This file, available both in magnetic tape format and data format can be obtained from the states' designated agencies that cooperated with the U.S. Department of Transportation in the development of the National Inventory. An additional benefit of the National Inventory is that individual railroad companies have on file duplicates of the information that is included in the inventory. Therefore, the data are consistent in format and have the credibility of both the railroads and the public agency that participated in the development of the file.

4.2.1 Inventory Data

A complete description of the data elements contained in the National Railroad-Highway Grade Crossing Inventory may be found in the Procedures Manual published and distributed to the individual states at the time the inventory was accomplished. Copies of this manual are available through the Federal Highway Administration. The inventory data elements are divided into four parts: Part 1 includes data relating to the geographic location of the crossing; Part 2 includes detailed information for public vehicular grade crossings, including the number of train movements; Part 3 is concerned with physical data at the crossing; Part 4 has to do with Highway Department information relating to the classification of the highway system and the volume of vehicle traffic.

Figure 10 is a reproduction of the crossing inventory update form. This form provides adequate data to implement several of the priority rating formulas that are available for use in establishing a grade crossing improvement program. It should be pointed out however, that these data elements must be updated if the information included on the forms is to be useful in a continuing effort of project identification. Inventory forms have been made available to the states and railroads for the periodic update of this information. As a part of Program Development it may be necessary for the agency to insure that inventory update procedures are being implemented at the state level.

At the time the National Inventory was conducted, several states and individual railroads chose to supplement this data file by collecting additional information relative to the physical and operational characteristics of the individual public crossings under their jurisdiction and responsibility. These data were necessary in order to implement priority rating systems more sophisticated than those envisioned by the advisory committee which established the data requirements for the National Inventory. It is suggested that should an agency choose to improve the current priority rating system by collecting additional data, that these data should be collected in a format that is consistent with the National Inventory. This will provide for better coordination of program elements and increase the credibility of the data when working with individual railroad companies. Another advantage of the inventory data file is the fact that it is site specific. That is, a unique number in the form of a plastic tag is displayed at the crossing and was attached to the control device existing at the time the inventory was made. This number is included in the crossing inventory data record. The principal advantage of having the number tag displayed at the crossing is that the unique identification of each crossing is

OMB-004-R40.9

U.S. DOT — AAR CROSSING INVENTORY FORM

A. INITIATING AGENCY
☐ RAILROAD ☐ STATE

B. CROSSING NUMBER

C. REASON FOR UPDATE:
☐ CHANGES IN EXISTING CROSSING DATA
☐ NEW CROSSING
☐ CLOSED CROSSING

D. EFFECTIVE DATE
M D Y

Part I Location and Classification of All Crossings (Must Be Completed)

1. Railroad Operating Company
2. Railroad Division or Region
3. Railroad Subdivision or District
4. State
5. County
6. County Map Ref. No.
7. City
8. Nearest City
9. Highway Type and No.
10. Street or Road Name
11. RR I. D. No.
12. Nearest RR Timetable Station
13. Branch or Line Name
14. Railroad Mile Post

DO NOT WRITE IN THIS SPACE
State County
City Nearest City
RR Code Timetable Station

15. Pedestrian Crossing
☐ 1. at grade
☐ 2. RR under
☐ 3. RR over

16. Private Vehicle Crossing
A. ☐ 1. Farm ☐ 2. Residential ☐ 3. Recreational ☐ 4. Industrial
B. ☐ 5. at grade ☐ 6. RR under ☐ 7. RR over
C. ☐ 8. signs-specify ☐ 9. signals-specify ☐ 0. none

17. Public Vehicle Crossing
☐ 1. at grade
☐ 2. RR under
☐ 3 RR over

COMPLETE REMAINDER OF FORM ONLY FOR PUBLIC VEHICLE CROSSINGS AT GRADE

Part II Detailed Information for Public Vehicular at Grade Crossing

1A. Typical Number of Daily Train Movements

Daylight (6 AM to 6 PM)		Night (6 PM to 6 AM)	
thru trains	switching	thru trains	switching
1	2	3	4

1B. Check if Less Than One Movement Per Day ☐ 5

2. Speed of Train at Crossing
A. Maximum time table speed 1
B. Typical Speed Range Over Crossing from 2 to 3 mph

3. Type and Number of Tracks
main 1 other 2 If other specify 3

4. Does Another RR Operate a Separate Track at Crossing?
☐ Yes 1☐ No Specify: RR 2

5. Does Another RR Operate Over Your Track at Crossing?
☐ Yes 1☐ No Specify: RR 2

6. Type of Warning Device at Crossing

A. Signs

Crossbucks		Standard Highway Stop Sign	Other Stop Signs	Other Signs: Specify
reflectorized	non-reflectorized			
01 Number	02 Number	03 Number	04 Number	05 Number 06 07 Number 08

B. Train Activated Devices

Gates		Cantilevered Flashing Lights		Mast Mounted Flashing Lights	Other Flashing Lights Specify	Highway Traffic Signals	Wigwags	Bells
red & white reflectorized	other colored	over traffic lane	not over traffic lane					
09 Number	10 Number	11 Number	12 Number	13 Number	14 Number 15	16 Number	17 Number	18 Number

C. Specify Special Warning Device not Train Activated 19

D. No Signs or Signals ☐ 20

7. Is Commercial Power Available? ☐ Yes ☐ No

8. Does Crossing Signal Provide Speed Selection for Trains? ☐ Yes ☐ No ☐ N/A

9. Method of Signalling for Train Operation: Is Track Equipped with Signals? ☐ Yes ☐ No

Part III Physical Data

1. Type of Development ☐ 1. Open Sp. ☐ 2. Res ☐ 3. Comm. ☐ 4. Ind. ☐ 5. Inst.
2. Smallest Crossing Angle
☐ 0°-29° ☐ 30°-59° ☐ 60°-90°
3. Number of Traffic Lanes Crossing Railroad Number
4. Are Truck Pullout Lanes Present? ☐ Yes ☐ No
5. Is Highway Paved ☐ Yes ☐ No
6. Pavement Markings
☐ Stoplines ☐ RR Xing Sym. ☐ None
7. Are RR Advance Warning Signs Present?
☐ Yes ☐ No
8. Crossing Surface ☐ 1. Sec. Timber ☐ 2. Full Wd. Plank ☐ 3. Asphalt ☐ 4. Concrete Slab ☐ 5. Concrete Pave. ☐ 6. Rubber ☐ 7. Metal Sections ☐ 8. Other Metal ☐ 9. Unconsolidated ☐ 0. Other Specify
9. Does Track Run Down A Street?
☐ Yes ☐ No
10. Nearby Intersecting Highway?
☐ Yes ☐ No

Part IV Highway Department Information

1. Highway System
2. Is Crossing on State Highway System? ☐ Yes ☐ No.
3. Functional Classification of Road over Crossing
4. Estimate AADT
5. Estimate Percent Trucks

I. D. Number

Figure 10. Crossing Inventory Form

readily available. By referencing this number, all inventory and accident data on file, including data collected by state and local agencies and railroad companies, now has a common link. The number also allows law enforcement agencies to provide identifiable accident data from police reports. The number serves as a communication reference between railroad companies and public agencies, as well as between individual railroad companies when discussing specific grade crossings. The coordination of data files pertaining to individual grade crossings is enhanced by this unique numbering system. Additional data collected at the crossing should always be referenced to this crossing number.

4.2.2 Accident Data

Grade crossing data are collected in many forms and by several different agencies. Until recently, the reporting of grade crossing accidents to the Federal Railroad Administration was accomplished in approximately the same format as the reporting of all other railroad accidents. About the same time as the decision to implement a National Inventory and Numbering System for grade crossings, the FRA accident reporting requirements were revised to uniquely identify the location of grade crossing accidents.

A new accident reporting form (now referred to as an accident/incident report form) was developed by the Federal Railroad Administration. This form shown in Figure 11, is now used (since December 31, 1974) for reporting all train-highway-vehicle accidents that occur. Reports are also made on this form to record any accident involving a highway vehicle and any equipment operated on a railroad track even though it may not constitute a "train". A major feature of the form is the fact that the National Grade Crossing Inventory number is included on the form. This provides the link between the inventory file and the accident data file. The railroads were required to use this form beginning in January 1975 when reporting all rail-highway vehicle accidents to the Federal Railroad Administration.

Additional accident data may be obtained from the police officer's report of the accident. Some states are now requiring that police officer's report of the rail-highway vehicle grade crossing accident, or

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION

RAIL-HIGHWAY GRADE CROSSING ACCIDENT/INCIDENT REPORT

FORM APPROVED OMB NO. 04R4033

1 Name of reporting railroad: East West Railroad Company
1a Alphabetic Code: EWRC
1b Railroad Accident/Incident No.: 18247
2 Name of other railroad involved in train accident/incident: N/A
2a Alphabetic Code: N/A
2b Railroad Accident/Incident No.: N/A
3 Name of railroad responsible for track maintenance (single entry): Intercity Transportation Corporation
3a Alphabetic Code: ITC
3b Railroad Accident/Incident No.: 72854
4 U.S. DOT AAR grade crossing identification number: 868 993 M
5 Date of accident/incident: 0 2 | 1 4 | 7 4
6 Time of accident/incident: 10:05 am [X] pm [ ]

LOCATION

7 Nearest railroad station: Union Station
8 County: N/A
9 State: DC
10 City: Washington
11 Highway name or number: 618

ACCIDENT/INCIDENT SITUATION

HIGHWAY USER INVOLVED

12 Type (1 Auto, 2 Truck, 3 Truck Trailer, 4 Bus, 5 School Bus, 6 Motorcycle, 7 Pedestrian, 8 Other (specify)) — Code: 1
13 Speed: 5
14 Direction (geographical) (1 North, 2 South, 3 East, 4 West) — Code: 1
15 Position (1 Stalled on crossing, 2 Stopped on crossing, 3 Moving over crossing) — Code: 3

RAILROAD EQUIPMENT INVOLVED

16 Equipment (1 Train (units pulling), 2 Train (units pushing), 3 Train (standing), 4 Car(s) (moving), 5 Car(s) (standing), 6 Light loco(s) (moving), 7 Light loco(s) (standing), 8 Other (specify)) — Code: 2
17 Position of car/unit in train: 1st car — Code: 2
18 Circumstance (1 Train struck highway user, 2 Train struck by highway user) — Code: 2

19 Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? (1 Highway user, 2 Rail equipment, 3 Both, 4 Neither) — Code: 2

ENVIRONMENT

20 Temperature: 48°F
21 Visibility (1 Dawn, 2 Day, 3 Dusk, 4 Dark) — Code: 2
22 Weather (1 Clear, 2 Cloudy, 3 Rain, 4 Fog, 5 Sleet, 6 Snow) — Code: 4

TRAIN AND TRACK

23 Type of train (1 Freight, 2 Passenger, 3 Mixed, 4 Work, 5 Yard/Switching, 6 Light Locomotive(s)) — Code: 1
24 Track type used by train involved (1 Main, 2 Yard, 3 Siding, 4 Industry) — Code: 4
25 Track number or name: Feed Spur
26 FRA track classification: 1
27 Number of locomotive units: 1
28 Number of cars: 0
29 Train speed: 12 MPH — Est. [X] Recorded [ ]
30 Time table direction (1 North, 2 South, 3 East, 4 West) — Code: 4

CROSSING WARNING

31 Type (place X in appropriate box(es)): 1 Gates; 2 Cantilever FLS; 3 Standard FLS; 4 Wig Wags; 5 Hwy Traffic Signals; 6 Audible; 7 Crossbucks [X]; 8 Stop Signs; 9 Watchman; 10 Flagged by crew [X]; 11 Other (specify); 12 None
32 Signaled crossing warning: Was the signaled crossing warning identified in item 31 operating? (1 Yes, 2 No) — Code: N/A
33 Location of warning (1 Both sides, 2 Side of vehicle approach, 3 Opposite side of vehicle approach) — Code: 1
34 Crossing warning interconnected with highway signals (1 Yes, 2 No, 3 Unknown) — Code: 2
35 Crossing illuminated by street lights or special lights (1 Yes, 2 No, 3 Unknown) — Code: 2

MOTORIST ACTION

36 Motorist passed standing highway vehicle (1 Yes, 2 No, 3 Unknown) — Code: 2
37 Motorist drove behind or in front of train and struck or was struck by second train (1 Yes, 2 No, 3 Unknown) — Code: 2
38 Motorist (1 Drove around or thru the gate, 2 Stopped and then proceeded, 3 Did not stop, 4 Other (specify), 5 Unknown) — Code: 2
39 View of track obscured by (primary obstruction) (1 Permanent structure, 2 Standing railroad equipment, 3 Passing train, 4 Topography, 5 Vegetation, 6 Highway vehicles, 7 Other (specify), 8 Not obstructed) — Code: 8

HIGHWAY VEHICLE PROPERTY DAMAGE/CASUALTIES

40 Highway vehicle property damage (est. dollar damage): 2,800
41 Driver was (1 Killed, 2 Injured, 3 Uninjured) — Code: 1
42 Was driver in the vehicle? (1 Yes, 2 No) — Code: 1
43 Total number of occupants killed: 1
44 Total number of occupants injured: 0
45 Total number of occupants (include driver): 1
46 Is a rail equipment accident/incident report being filed? (1 Yes, 2 No) — Code: 2
47 Typed name and title: John H. Doe, Superintendent of Safety
48 Signature:
49 Date: 02/18/74

FORM FRA F 6180.57 (12-74) REPLACES FORM FRA F 6180.13 (10-67) WHICH IS OBSOLETE

Figure 11. Accident/Incident Report Form

a vehicle accident occurring within the environment of a grade crossing, include the National Grade Crossing Inventory number displayed at that crossing. This provides additional accident data relative to the highway vehicle that is not available from the FRA incident report.

Most railroad companies complete a telegraphic accident report of each accident which involves highway vehicles. Although these accident files are considered to be private information, individual railroads may be willing to provide copies of these reports to the agency. All railroad passenger accident reports involving Amtrak operations may be made available by the National Railroad Passenger Corporation.

Due to the relative infrequency of grade crossing accidents, it is generally accepted that at least five and preferably ten years of accident history is necessary in order to get reasonable statistical data to support an accident trend analysis. Therefore, it is suggested that some consideration be given to the recovery of pre-1975 grade crossing accident history that will identify accident reports with specific crossings. Some railroads have already accomplished this effort. These data may be available to the agency for inclusion in the accident data file.

4.2.3 Summary

The National Railroad-Highway Grade Crossing Inventory provides sufficient data to identify and classify, according to some acceptable Hazard Index or priority rating, each public grade crossing under the jurisdiction of the agency. The accident data file provides an indication of the severity of the grade crossing accident problem within the jurisdiction of the agency. Linking together these two files provides an ability to determine the significance of the grade crossing problem among classes of crossings. Classes may be developed according to crossings located on individual railroads, crossings by governmental jurisdiction such as city streets, county roads, state and federal-aid systems, crossings by type of traffic control systems, and other classifications. For example, it is important to test the credibility of the Hazard Index rating system with the known accident experience of particular classes of crossings.

Although it may be difficult to obtain, and continue to maintain specific accident history for each individual crossing, it is relatively simple to classify the crossings through the National Inventory file; and then aggregate accident history for those classes of crossings in order to determine which classes of crossings may have the greater potential for accidents. The inventory file may be used for: 1) classification by urbanized and rural areas, 2) classification by governmental jurisdiction such as city streets, county roads, military posts, 3) classification by functional class of the highway or street system, 4) classification by AADT frequency distribution, 5) classification by train type and frequency, and 6) by general type of railroad operation, whether main line, branch line, industry track or yard lead.

Classifications are limited only by the data elements that are included in the file itself. The appropriate classification of grade crossings under the jurisdiction of an agency would be dependent upon the specificity of the requirements of the accepted priority rating system of the agency.

4.3 HAZARD INDEX, PRIORITY RATING AND WARRANTS

Although it is desirable for all grade crossings to have optimum warning systems, funding for such capital expenditures is seldom available. Thus, available funds should be allocated to those locations and devices which are most likely to produce the greatest accident and casualty reduction benefit. Most organizations use some type of priority ranking or hazard index formula to indicate which crossings have the greatest need for improvement. Regardless of the techniques employed, it must be remembered that the several ranking concepts are only tools for assisting in the decision making process which is exercised by experienced and qualified engineers or regulatory or administrative agencies.

4.3.1 Improvement Based on Hazard Ratings

There appears to be general agreement that there is some reliability in the various techniques for computing a relative index of hazard for individual or groups of crossings. Bezkorovainy (1) found that eleven of the most popular hazard rating formulas (Table 13) applied to grade crossings in Lincoln, Nebraska resulted in virtually identical rank ordering of crossings. He also concluded that the New Hampshire Formula provided the best fit for the average of the eleven formulas.

The application of most of the selected hazard index formulas, shown in Table 13 to provide a priority system for grouping crossings which demand immediate attention requires the computation of at least three basic variables. These are: 1) the relative effectiveness of various types of traffic control devices, 2) the probability of conflict between trains and vehicles, and 3) sight distance ratings. Values for relative hazards with selected traffic control devices are shown in Table 14. More recent information on relative accident occurrence with traffic control devices was reported in a 1974 study (2) by the California Public Utilities Commission. These data are summarized in Table 15.

The data elements contained in the National Railroad-Highway Grade Crossing Inventory are listed in Table 16. When compared with the list of data elements necessary to compute the 11 selected hazard indices, included in Table 13, it is found that three of the hazard indices may be computed directly from Inventory data. With the addition of accident data and sight distance ratings all eleven hazard indices may be computed, after slight modification, from the Inventory data set.

The Bezkorovainy study found that all eleven hazard indices gave approximately the same results, and that the New Hampshire Formula provided the best fit of the average of the results of the eleven indices. Because of the availability of data and the simplicity of application, the New Hampshire Formula may be applied to the total rail-highway grade crossing inventory list to provide the first approximation of the relative hazard rating of each crossing in the total inventory.

An additional justification for this recommendation is based upon the decision of an advisory committee to the National Inventory Project to include this computation in the software computer program package distributed to each State and railroad company at the close of the

SELECTED HAZARD INDEX FORMULAS

Peabody and Dimmick Formula

$$A_5 = 1.28 \; \frac{V^{0.170} \times T^{0.151}}{P_C^{0.171}} + K$$

Mississippi Formula

$$H.I. = \frac{\frac{SDR}{8} + A_5}{2}$$

New Hampshire Formula

$$H.I. = VTP_f$$

The Ohio Method

$$H.I. = A_f + B_f + G_f + L_f + N_f + SDR$$

Wisconsin Method

$$H.I. = \frac{T\left(\frac{V}{20} + \frac{P^1}{50}\right)}{5} + SDR + A_e$$

Contra Costa County Method

$$H.I. = TZ\left(1 - 2.718^{\frac{-Vt}{1400Z}}\right)$$

The Oregon Method

$$H.I. = [V_1T_1P_f + 1.4V_2T_2P_f]\,\frac{A_e}{A_5}$$

North Dakota Rating System

$$H.I. = [N_f + L_f] + [P_f + D_f + G_f + X_f] + (VT_f) + SDR$$

Idaho Formula

$$H.I. = V_f \times T_f\,(CB_f + SDR + N_f + Y_f)$$

Utah Formula

$$H.I. = \frac{T}{1000}\left[\left(\frac{P}{10} + \frac{F}{20} + \frac{S}{30}\right) + SDR + N_f + X_f + R_f\right] + 2A_e + \frac{P^1}{100{,}000}\left(\frac{P}{10} + \frac{F}{20} + \frac{S}{30}\right) - P_f$$

City of Detroit Formula

$$H.I. = \frac{T}{1000}\left[\left(\frac{P}{10} + \frac{F}{20} + \frac{S}{30}\right) SDR + N_f + X_f + R_f\right](100\% - \%P_f) + 2A_e$$

SYMBOLS

- A_5 = Expected number of accidents in 5 years.
- A_e = Accident experience.
- A_f = Accident probability factor.
- B_f = Train speed factor.
- CB_f = Type and speed of train factor.
- D_f = Alignment of track and highway factor.
- F = Number of freight trains in 24 hours.
- G_f = Approach gradient factor.
- H.I. = Hazard index.
- K = Additional parameter.
- L_f = Angle of crossing factor.
- N_f = Number of tracks factor.
- P = Number of passenger trains in 24 hours.
- P^1 = Number of pedestrians in 24 hours.
- P_c = Protection coefficient.
- P_f = Protection factor.
- R_f = Road approach factor.
- S = Number of switch trains in 24 hours.
- SDR = Sight distance rating.
- t = Time crossing is blocked.
- T = Average 24-hour train volume.
- T_1 = Average daylight train volume.
- T_2 = Average train volume during dark hours.
- T_f = Train volume factor.
- V = Average 24-hour traffic volume.
- V_1 = Average daylight traffic volume.
- V_2 = Average traffic volume during dark hours.
- V_f = Traffic volume factor.
- VT_f = Exposure factor.
- X_f = Condition of crossing factor.
- Y_f = Severity factor.
- Z = Number of traffic lanes.

<u>Source:</u> Reference (<u>3</u>)

Table 13. Selected Hazard Index Formulas

Note: Values of P_f for use with New Hampshire formula

Automatic Gates = 0.1
Flashing Lights = 0.6
Signs only = 1.0

Table 14. Th ^^lative Hazard Relationships For Traffic Control Dev ces At Railroad Grade Crossings.

Type of Device	Relative Hazard
Crossbucks	1.00
Stop Signs	0.58
Wigwags	0.34
Flashing Lights	0.20
Automatic Gates	0.11

Source: Factors Influencing Safety at Highway-Rail Grade Crossings, National Cooperative Highway Research Program, Report 50, 1968.

Table 15. Relative Effectiveness of Traffic Control Devices

Device	Relative Accident Occurrence
Crossbucks	1.00
Wigwags	0.63
Flashing Lights	0.33
Automatic Gates	0.13

Device	Fatalities per Accident		Injuries per Accident	
	Rural	Urban	Rural	Urban
Crossbucks	0.32	0.13	0.82	0.55
Wigwags	0.17	0.08	0.56	0.46
Flashing Lights	0.19	0.10	0.42	0.45
Automatic Gates	0.09	0.04	0.27	0.28

Source: "The Effectiveness of Automatic Protection In Reducing Accident Frequency And Severity At Public Grade Crossings In California". California Public Utilities Commission. 1974.

Table 16. Inventory Data Elements -- National Railroad Highway Grade Crossing Inventory

- Average number of trains per day
  - thru trains per day
  - switching movements per day
- Average daylight train volume
  - thru trains
  - switching movements
- Average night time train volume
  - thru trains
  - switching movements
- Speed of train at crossing
  - maximum time table speed
  - typical speed range
- Number of tracks at the crossing
  - number of main
  - number of other (specified)
- Type of traffic control device at the crossing
  - crossbucks
    - . reflectorized
    - . non-reflectorized
  - number of standard highway stop signs
  - number of other stop signs
  - number of other signs (specified)
- Number of train activated devices
  - automatic gates
    - . red and white reflectorized
    - . other colored
  - cantilevered flashing lights
    - . over traffic lanes
    - . not over traffic lanes
  - mast mounted flashing lights
  - other flashing lights (specified)
  - highway traffic signals
  - wigwags
  - bells only
- Special traffic control device not train activated (specified)
- No traffic control device
- Does crossing signal provide speed selection for trains? (Yes or no answer)
- Is track equipped with signals for train operation? (Yes or no answer)
- Type of development near crossing
  - open space
  - residential
  - commercial
  - industrial
  - institutional
- Angle of Crossing
- Number of traffic lanes over crossing
- Is highway paved? (Yes or no answer)
- Pavement marking
  - stop lines
  - RR symbol
  - none
- Crossing surface type
- Presence of railroad advance warning signs (Yes or no answer)
- Nearby intersecting highway, within 75 feet? (Yes or no answer)
- Highway system code
- Functional classification code
- Estimated AADT
- Estimated percent of trucks of total AADT

National Inventory project. Therefore, each State and railroad company currently has the capability to output each public rail-highway grade crossing included within their respective inventory in priority order according to the New Hampshire Index.

A recent study conducted in Florida (4) developed an accident prediction model that can be used to identify groupings of crossings that will have the most accidents if not improved. It will also predict the accident experience after modifications are performed. The model uses traffic, number of trains, vehicle speed, train speed, number of lanes and presence of control devices as the independent variables. The availability or ready accessibility of the input data makes the model one of the easier to use.

One method of determining what data elements should be considered in determining a hazard index, priority rating or accident prediction equation is to review what data elements are most frequently used by other agencies. A recent survey conducted by the University of Illinois (5) provided the results shown in Table 17.

According to this survey, the data element most frequently used by State Highway Agencies for determining grade crossing hazard indices, accident prediction factors, priority ratings or warrants are in many instances available from the National Inventory data file.

If an agency has in excess of 500 public grade crossings that would be required to be evaluated in a grade crossing improvement program, the survey suggests that consideration be given to a computer base data analysis approach. Although non-computer base calculations may be tedious, the added cost of data recovery, programming and computer time may exceed the more personalized approach cost for crossing evaluation and project selection.

The following is an approach to a non-computer based evaluation of a limited number of rail-highway grade crossings where the improvement is based upon "warrants".

4.3.2 Improvement Based on Warrants

The preceeding discussion describes the use of techniques for ranking a group of crossings according to their priority of need. The

Table 17. Frequently Used Data Elements

Question: What were the data elements most frequently used in Railroad-Highway grade crossing hazard index or accident prediction formula by State Highway Agencies.

	Data Element	Number of States
*	Number of Trains per day	42
*	Number of Vehicles per day	42
*	Existing Traffic Control or Advance Warning Devices	27
	Visibility and Sight Distance	17
*	Speed	12
	Accidents	12
	Angle of Intersection	11
*	Number of Tracks	10
	Highway Approach Grades	6
	Highway Alignment	5
*	Number of Highway Lanes	5
	Surface Condition	3
	Type of Train	2
*	Urban/Rural Land Use	2
*	Nearby Intersections	1

* Indicates data element is included in National Inventory data file.

determination of exactly what device satisfied the stated need and to what extent devices at various crossings must be "juggled" to fit other constraints is a trial and error process. Another technique which incorporates the control device requirements into the decision-making process is the "warrants" technique. There are numerous warranting techniques which are applicable, and it could be argued that the hazard rating formula could be considered as a warranting technique.

Nevertheless, one study (6) reviewed urban grade crossing accidents in Indiana for 1963-64. The researchers performed field investigations on 240 crossings that had accidents during this period and 240 randomly selected urban crossings that were accident-free. Over 100 variables that could influence crossing safety were analyzed. "Protection nomographs" were then developed to determine the potential hazard of individual crossings. The warrants are unique with respect to the very specific line of sight ratios and sum of distractions that were developed.

In any case, use of a hazard rating formula or warrants requires engineering judgement for successful application. These techniques are not in themselves an answer, but rather tools to assist the engineer in reaching a sound, economical solution for a grade crossing priority program.

4.3.3 Computer-Based Hazard Indices

As mentioned earlier, there are numerous hazard indices and variations thereof, with certain ones requiring computer based data and relatively large grade crossing populations to justify their use. One of these is the Pennsylvania Potential Hazard Index (7) which uses NCHRP Report 50 for establishing warrants and priorities, but includes several variations founded on site conditions, and takes the following form:

Potential Hazard-Index Formula

$$PHI = A \times B \times T + (P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 + P_8)$$

PHI = Potential Hazard-Index

A = A Factor - ADT Collision Probability per Train (see Table 18)

B = B Factor - Coefficient of Warning Device (see Table 19)

Table 18. PHI "A" Factors

VEHICLES PER DAY	'A' FACTOR
250	.000347
500	.000694
1000	.001377
2000	.002627
3000	.003981
4000	.005208
5000	.006516
6000	.007720
7000	.009005
8000	.010278
9000	.011435
10000	.012674
12000	.015012
14000	.017315
16000	.019549
18000	.021236
20000	.023877
25000	.029051
30000	.034757

Source: Reference (7).

Table 19. PHI "B" Factors

TYPE OF TRAFFIC CONTROL DEVICE	CODE	URBAN	RURAL
Crossbucks	(A&B)	3.03	3.06
Crossing Illuminated (Night)	(M)	2.66	2.69
Crossbuck and Bells	(C)	1.40	1.43
Watchman (Part-Time)	(E)	2.92	2.95
Flagman (Train Crew Member)	(L)	0.97	1.00
Watchman (24 hours)	(D)	2.44	2.47
Flashing Lights (Manual)	(H)	0.37	1.07
*Flashing Lights (Auto)	(I)	0.23	0.93
*Flashing Lights & Bell (Auto)	(J)	0.21	0.91
Gates (Manual)	(F)	0.13	0.24
Gates (Auto)	(G)	0.08	0.19
*Flashing Lights & Gates (Auto)	(K)	0.06	0.16
No Protection	(N)	5.00	4.00

* These are the standard higher types of grade crossing traffic control devices.

Source: Reference (7).

T = Trains per day

P_1 = Single Track - Multitrack

P_2 = Night Trains 6:00 pm - 6:00 am

P_3 = High Speed Trains

P_4 = Highway Speed

P_5 = Grade Quad 1 & 2

P_6 = Grade Quad 3 & 4

P_7 = Sight Distance Quads 1, 2, 3, & 4

P_8 = Smallest Crossing Angle

A = A Factor: Computed from A Factor Table (ADT from Data Tape)

B = B Factor: Selected from B Factor Table (Coeff. Device)

T = Trains: From Data Tape

P_1 = Single Track: Use 0.000

Multi Track: Use 0.500 times the number main tracks when total main thru tracks are more than one (1) and 0.25 for each additional siding

P_2 = Night/Trains: Use 0.100 x number of thru Night/Trains (6:00 pm - 6:00 am)

P_3 = Train Speed: Use 0.010 x each mile greater than 25 mph*

P_4 = Highway Speed: Use 0.010 x each mile greater than 25 mph*

P_5 = Grade Quad 1 & 2: Use 0.000 for Condition 1 - vertical grade <3%

Use 0.040 for Condition 2 - vertical grade >3%

Use 0.060 for Condition 3 - vertical grade >6%

P_6 = Grade Quad 3 & 4: Use 0.000 for Condition 1 - vertical grade <3%

Use 0.040 for Condition 2 - vertical grade >3%

Use 0.060 for Condition 3 - vertical grade >6%

Note: Where P_5 and P_6 are other than Condition 1 and are combinations of Conditions 2 & 2 - Use 0.120; and where Conditions of P_5 and P_6 are Conditions 2 & 3 - Use 0.180; and where Conditons P_5 and P_6 are Conditions 3 & 3 - Use 0.250.

P_7 = Sight Distance	Control Device	ABCMN		D - L
1 - Adequate all quads:	Use	0.000	Use	0.000

*1 mile = 1.6 km

2 - Inadequate all quads:	Use	0.468	Use	0.358
3 - Adequate 3 of 4 quads:	Use	0.118	Use	0.008
4 - Inadequate 3 of 4 quads:	Use	0.235	Use	0.125
5 - Adequate 2 of 4 quads:	Use	0.050	Use	0.040
6 - Inadequate 2 of 4 quads:	Use	0.050	Use	0.040
7 - Adequate 1 of 4 quads:	Use	0.235	Use	0.125
8 - Inadequate 1 of 4 quads:	Use	0.118	Use	0.008
9 - Congested Areas:	Use	0.500	Use	0.100

P_8 = Smallest Crossing Angle X, Use:

$$\frac{1}{X^2} \times 100 = \text{Crossing Angle Factor}$$

Once the existing PHI has been established, it is possible to determine benefit/cost ratios for upgrading a crossing. Pennsylvania uses the following formula based on a 10-year period:

$$\text{Benefit/Cost} = \frac{10 \times C[P_H - (B_F/B_E) \times P_H]}{10 \times \text{added yearly cost of new device}}$$

Where:

C = Annual cost of an accident

B_F = B factor for possible improvement

B_E = B factor for existing device

P_H = Potential hazard index (PHI) for existing device

To arrive at the benefit/cost ratio the above equation is solved by (1) dividing the coefficient of B_F by the coefficient of B_E and (2) multiplying the quotient by the existing P_H, the product will then (3) be subtracted from the existing P_H and the remainder (4) will be multiplied by the average annual cost of an accident and the product (5) will be divided by the additional annual cost per year of the proposed device.

There is continuing research to develop predictive equations for grade crossing accidents in order to determine improvement strategies. Following are two of the more recent efforts in this area.

Hopkins and Hazel (8) developed a computer-aided analytical approach for estimating the potential benefits, costs, and implementation implications associated with grade crossing improvement. Required inputs are: (a) the grade crossing population, categorized by hazard, location (urban and rural), and existing traffic control systems; (b) traffic control system alternatives, characterized by cost and effectiveness; and (c) criteria for acceptable or preferred resource allocation strategies.

Coleman and Stewart (9) used regression analysis techniques on accident data to predict grade crossing accidents and their severity. In essence, the ratio of the number of accidents for a group of crossings to the number of crossing years of exposure was used as a measure of the accident potential for a group of crossings.

4.4 IMPROVEMENT ALTERNATIVES

4.4.1 Crossing Closure

The first alternative to be investigated for the improvement of a grade crossing is whether or not the crossing can be eliminated. Crossing closure is obviously a high priority of the railroad company. This not only eliminates the possibility that a grade crossing accident will occur on a segment of track, but also may improve traffic flow over the railroad. However, in many instances the closing of a crossing requires the re-routing of vehicular traffic. This may be an unacceptable alternative for vehicular operators in that it may increase travel time and cost. It may also reduce accessibility to certain areas which may bring about economic repercussions as well as a deterrent to the movements of emergency vehicles. Nevertheless, these factors should not preclude the consideration of crossing closure and the resultant benefits, when improvement alternatives are considered.

Crossing closure criteria have been presented in the Part VIII Supplement to the Traffic Control Devices Handbook (10). These criteria are presented as follows:

> Although each grade crossing requires individual analysis, a systems approach can be advantageous in determining recommendations regarding a series of crossings on a single line of railroad or in a community or a defined portion of an urban area. The systems approach should be related to the affected

street system of the area and should have as an objective the elimination of non-essential grade crossings not provided with adequate active traffic control systems. Such eliminations may be accomplished by constructing grade separations where they are justified or closing non-essential crossings. The closing of non-essential crossings may necessitate installing active traffic control systems at crossings not so equipped. In some situations, it may be practical to eliminate or relocate the line of railroad.

When recommended by an engineering study, a pedestrian crossing may be retained where a grade crossing is closed to vehicular traffic.

Closing of a grade crossing(s) may be recognized as a local contribution to a safety systems program of grade crossing traffic control and surface improvements.

The following subjects should be given attention in evaluating the necessity for a crossing:

1. The nature of the area served by the street or highway in the vicinity of the grade crossing, including:
   a. School
   b. Hospital
   c. Fire Station
   d. Police Station
   e. Business Establishment
   f. Other Public Building
2. Growth trends and prospective development along the street based on short-range planning.
3. Daily volume and type of vehicular traffic using crossing.
4. Availability of alternate crossings, route circuitousness, and added traffic distance.
5. Accident experience or potential hazard at the crossing, including:
   a. Number and severity of accidents.
   b. Type and number of trains.
   c. Train speed.
   d. Time crossing is blocked.
   e. Restricted view.
   f. Adverse physical conditions.
   g. Time and volume of vehicle and pedestrian traffic.

Closing of a grade crossing will result in one or more of the following benefits:

1. One point of potential collision between train and vehicular traffic will be eliminated.
2. There will be resulting economy for both the public authority and the railroad in eliminating the cost of maintenance of the crossing surface, roadway approaches, and traffic control devices.
3. In most instances, an alternate vehicular route will be available over a crossing equipped with

superior traffic control devices or a grade separation because that route is a more important road with a greater traffic volume.

4. Regardless of the relative importance of the closed route and its alternate, the potential for grade crossing accidents will be reduced for the combined traffic because it has been demonstrated that the rate of occurrence of accidents increases at a slower rate than increase in traffic volume, other influencing factors being equal.

4.4.2 Railroad Consolidation and Relocation

An additional alternative for improvement, which includes closure, is railroad relocation and consolidation. Planning for such projects is complex and often controversial because of the wide-spread impact of railroad relocation. The nationwide nature and magnitude of the problem has been investigated (11, 12). Railroad relocation and/or consolidation in urbanized areas may reduce the amount of trackage required to operate the railroad system. By the removal of track, crossings are automatically eliminated. Long range plans for relocation and consolidation of railroads in urbanized areas should be reviewed prior to decisions related to crossing improvement either through grade separation or through traffic control systems. Urbanized area transportation plans and railroad studies for mergers and consolidation are two sources of information which should be checked and analyzed.

Another possible railroad-highway crossing closure alternative is the relocation of a highway. As new bypass routes or loops are planned for urbanized areas, crossings at grade should be avoided in the location of the route.

Elimination of some railroad-highway crossings usually occurs when a railroad is abandoned. All states will be participating in the development of state rail plans as prescribed under Title VIII of the Railroad Revitalization and Regulatory Reform Act of 1976. As a part of this plan, railroad lines are often identified for abandonment considerably in advance of the date on which railroad service is discontinued. By coordinating grade crossing program activities with the state agency responsible for state rail planning, crossings on the light density lines to be definitely abandoned may be excluded from future grade crossing improvement programs.

4.4.3 Grade Separations

The optimum improvement to a grade crossing is separation of the grades of the railroad and the highway. Although this alternative requires a large expenditure of funds, the benefits that result from separation of grades in the reduction of highway congestion, the value of time saved by vehicle operators, contribution to energy conservation, improvements to the environment, as well as improvements in railroad operation, may justify these expenditures. The grade separation alternative should be considered specifically in the design of new highway routes, and in improvements to railroad facilities. Lines used for high speed railroad passenger service should have no grade crossings.

4.4.4 Surfaces

Once the alternatives have been considered and rejected for either crossing closure, railroad relocation, or grade separation, the next alternative improvement should be the installation of appropriate grade crossing surfaces and traffic control devices. The improvement of street or highway surface across the track(s) can contribute significantly to the reductions of accidents at grade crossings. A concern for the roughness of the crossing rather than the approaching train or the traffic control device may distract a driver's attention to the extent that warning systems either train mounted or at the crossing will be ignored. Grade crossing surface improvement will also add to the comfort and convenience of motor vehicle users at many locations.

4.4.5 Traffic Control Devices

In the development of a grade crossing improvement program each of the available traffic control devices should be given consideration as an alternative improvement. The choice of devices should be made on the basis of the anticipated reduction in accidents and casualties and the concomitant initial cost of the device plus its annual maintenance cost. The operational effect on vehicular traffic and accidents can be stated in terms of cost. Therefore, benefit/cost ratios can be computed for each control device alternative (13). Relative effectiveness of each of the alternative control devices has been included in separate tables in this report. Therefore, by comparing accident and casuality reduction associated with the effectiveness of the several alternative control systems with the incremental benefit/cost ratios, determination can be made on choice of the appropriate device and on priority for crossing improvement in terms of an investment decision.

4.4.6 Site Improvements

In the selection of crossing improvement alternatives consideration should be given to improvement of the roadway approaches to the crossing. In many instances where the installation of active traffic control devices may not be warranted, improvements in sight distances on the approaches to the crossing may reduce significantly the potential for accidents. In addition, improvements in the maintenance of the control devices at crossings, such as correct alignment of flashing lights, may improve the effectiveness of the devices. Site improvement alternatives are difficult to specify from accumulated data. Field inspection may be the only possible way to identify and specify site improvement needs. Other improvements that may be made to the site include: channeling of vehicular traffic to provide better awareness of hazards at the crossing, spotting of railroad cars away from the crossing to prevent obstruction to the approaching driver's view, removal of abandoned buildings from adjacent railroad properties, modification of crossing approach grades to prevent incidents of stalled vehicles and hanging up of highway vehicles with low surface clearance, removal of distractions which may attract the driver's attention as he approaches the crossing, and cutting weeds and brush. Good subgrade drainage is essential to the proper maintenance of crossing surface and approach highway surface at any grade crossing.

4.4.7 Illumination

Crossing illumination may also be considered as an improvement alternative. Whether illumination is activated by the approaching train (which can be done only with incandescent light sources) or is continuous during night hours will be dependent upon the requirements of an individual crossing. Illumination may be used in conjunction with active traffic control systems to provide an awareness of the presence of a train at the crossing. Again, field inspection may be the best method of determining whether illumination is a viable alternative for improvement. Formulas and hazard indices can be of little assistance in making this judgment.

4.4.8 Summary

Improvement alternatives should be considered in a systems type approach. Once a crossing is chosen to be evaluated, whether it is a part of the total inventory of all crossings or selected for separate consideration, it should be given attention as a part of the entire system. All improvement alternatives, from closure to the do-nothing alternative, should be considered in relationship to the system. Site improvements, choice of control devices, improvements to the crossing surface, improvements to the crossing environment, and operational improvements for highway and railroad traffic should be considered. However, in the early stages of program development, alternatives for improvement are largely based upon accumulated data and it is important that those data elements that are necessary for consideration of alternative improvements be available to the greatest possible extent for all crossings included under the jurisdiction of the agency.

Following these program steps the agency is now prepared, through a numerical analysis of data on file, either in a magnetic data tape format, punch card format or in hard copy, to evaluate a program that meets the grade crossing improvement objectives of the agency and that is within funding available for the program time period.

With the accomplishment of this analysis a preferred list of crossings which should exceed project funding limits may be prepared. For example, if program funding permitted the improvement of 100 crossings a year for a three year period then, it is suggested that the preferred improvement list would include some 200 crossings per year for consideration for improvement. These crossings would then be listed in priority order according to the rating system that had been adopted by the agency for this purpose. The numerical analysis has now been completed. All crossings have been given consideration in the selection of projects to be included in the program. The next step in the program process is the selection of specific crossings for improvements.

4.5 DIAGNOSTIC TEAM

Once an overall program of grade crossing improvement has been developed, it is necessary to define the specific projects to be undertaken. The definition of projects must have some logical basis to ensure maximum cost effectiveness.

There are numerous techniques for defining projects, including subjective evaluations by individuals, and multidisciplinary team evaluations. Both of these techniques have limitations. Subjective evaluations by an individual are limited in that only one viewpoint is considered, and few individuals have expertise in all of the many areas involved. The multidisciplinary, or diagnostic team, approach is handicapped in that it requires the presence of several specially trained individuals to perform the diagnostic study. Because it is one of the best techniques available for selecting projects, use of the diagnostic team is recommended.

The diagnostic study team approach provides an excellent means of focusing the attention of all concerned agencies on the problem. Such an approach brings together representatives of the various agencies involved and immediately establishes lines of communication so that ultimately a functional system of crossing protection may be provided. The "diagnostic study team" is a somewhat sophisticated term used to describe a very simple procedure of utilizing experienced individuals from various agencies and disciplines, bringing their attention to bear on a common problem. To date, the most successful diagnostic team studies have involved professional people from the railroads, the highways, and the cities, representing the disciplines of administration, design, operation, maintenance, and research.

4.5.1 Team Composition

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

In order that each of the vital factors relating to the operational and physical characteristics of the crossing may be properly identified, it is necessary that individual team members be selected on the basis of the specific expertise and experience of each. The overall structure of the team is built upon three desired areas of responsibility: (1) local responsibility, (2) administrative responsibility, and (3) advisory capability.

All operational and physical characteristics of individual or groups of crossings may be classified in one of the three following areas:

1. Traffic Operations
2. Signal
3. Administration

In general, the responsibility of team members within each of these categories may be defined as follows:

4.5.1.1 Traffic Operation -- This area includes both vehicular and train traffic operation. Responsibilities of highway traffic engineers and railroad operating personnel chosen for team membership include, among other criteria, specific knowledge of highway safety and the vehicular and train volume, peak period characteristics, operating speeds, and type of vehicle, such as information on train class and length, and automobile-truck-bus make-up of vehicular traffic.

4.5.1.2 Signal -- Highway maintenance and signal control engineer(s), along with railroad signal engineer(s), provide the best source for expertise in this area. Responsibilities of these team members include special knowledge of grade crossing active traffic control signal systems, interconnection with adjacent signalized highway intersections, traffic control devices for vehicle operations generally and at railroad-highway grade crossings, and highway signs and pavement markings.

4.5.1.3 Administration -- It is necessary to recognize that many of the problems relating to grade crossing safety involve the apportionment of administrative and financial responsibility, and reflect this in the membership of the diagnostic team. Members of the team representing this 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. One of these members may well be the leader of the team.

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

a. Traffic engineer* with safety experience
b. Railroad signal engineer**
c. Railroad administrative official
d. Highway or street adminstrative official
e. Human factors engineer
f. Law enforcement officer
g. Regulatory agency official (where applicable)

*Desirable on all teams

**Desirable where active traffic control devices are present or under consideration.

4.5.2 Diagnostic Study Support Data

The collection of physical data to supplement and support the diagnostic study of railroad-highway grade crossings may be classified by two categories, i.e., operation and site characteristics. Operational characteristics include factors such as these:

1. Train and vehicle speed, volume, types and distributions, including passenger trains and buses
2. Accident records
3. Signalization and signing
4. Adjacent roadway and railroad vehicle and train operations.

Site characteristics include, among other factors, the following:

1. Roadway geometrics
2. Location of buildings, trees and other structures near the crossing
3. Location of adjacent streets, roadways and railroads
4. Topography of immediate area of the crossing
5. Population density

All of these data are available from the data sources described in the previous chapter. The site characteristics can be summarized for the team on the inventory form shown in Figure 12.

4.5.3 Diagnostic Study Questionnaire

The diagnostic team should study each crossing by a group review of all available data and a group inspection of the crossing and its surrounding area with the objective of determining the conditions at the grade crossings which affect safety and traffic operations. Therefore, the objective of the questionnaire is to provide a record of the individual team member's evaluation of these conditions at each study crossing. This discussion relates to questionnaire organization developed in previous studies (14). The overall structure discussed is recommended. Detailed questions are not included here because of the length of the questionnaire. Individual organizations should consider developing a questionnaire suitable to their needs based on these general considerations.

For organizational purposes the questionnaire is divided into three areas. Two sections are to be completed on each roadway approach and one on the crossing in general. Each of the areas which applies to the crossing approaches is further divided into sections in which driver requirements vary. This may be best explained by referring to Figure 13. Traffic cones are placed in the area of the approach as illustrated by the drawing. Cone A is placed at the point where the driver must begin making his decision as to whether of not he may safely proceed over the crossing. Cone B is placed where the driver must begin applying his brakes if he is to stop short of the crossing. Both measurements are based on the maximum legal or practical vehicle speed and stopping distance on wet pavements.

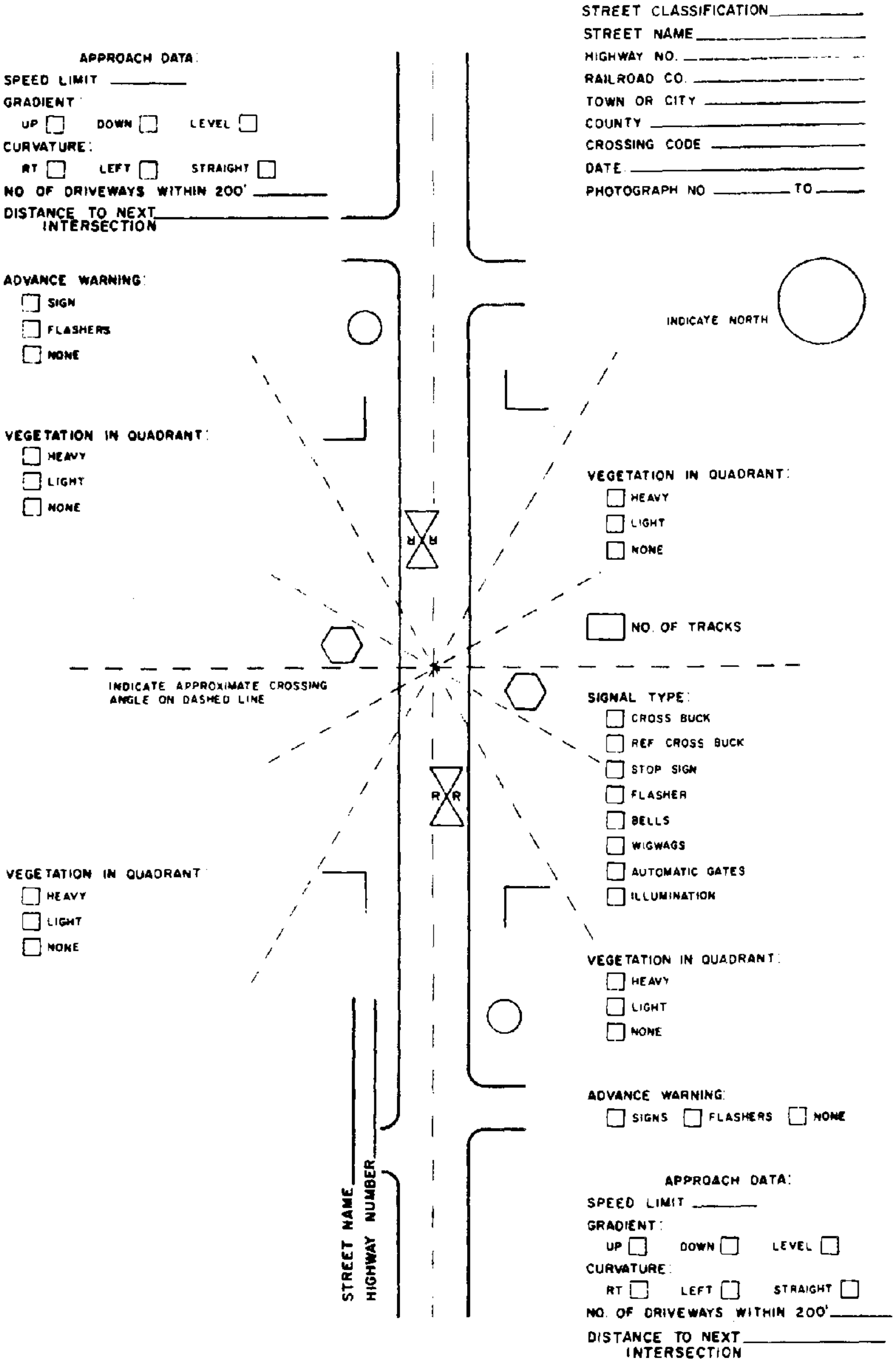

Figure 12. Grade Crossing Facility Inventory

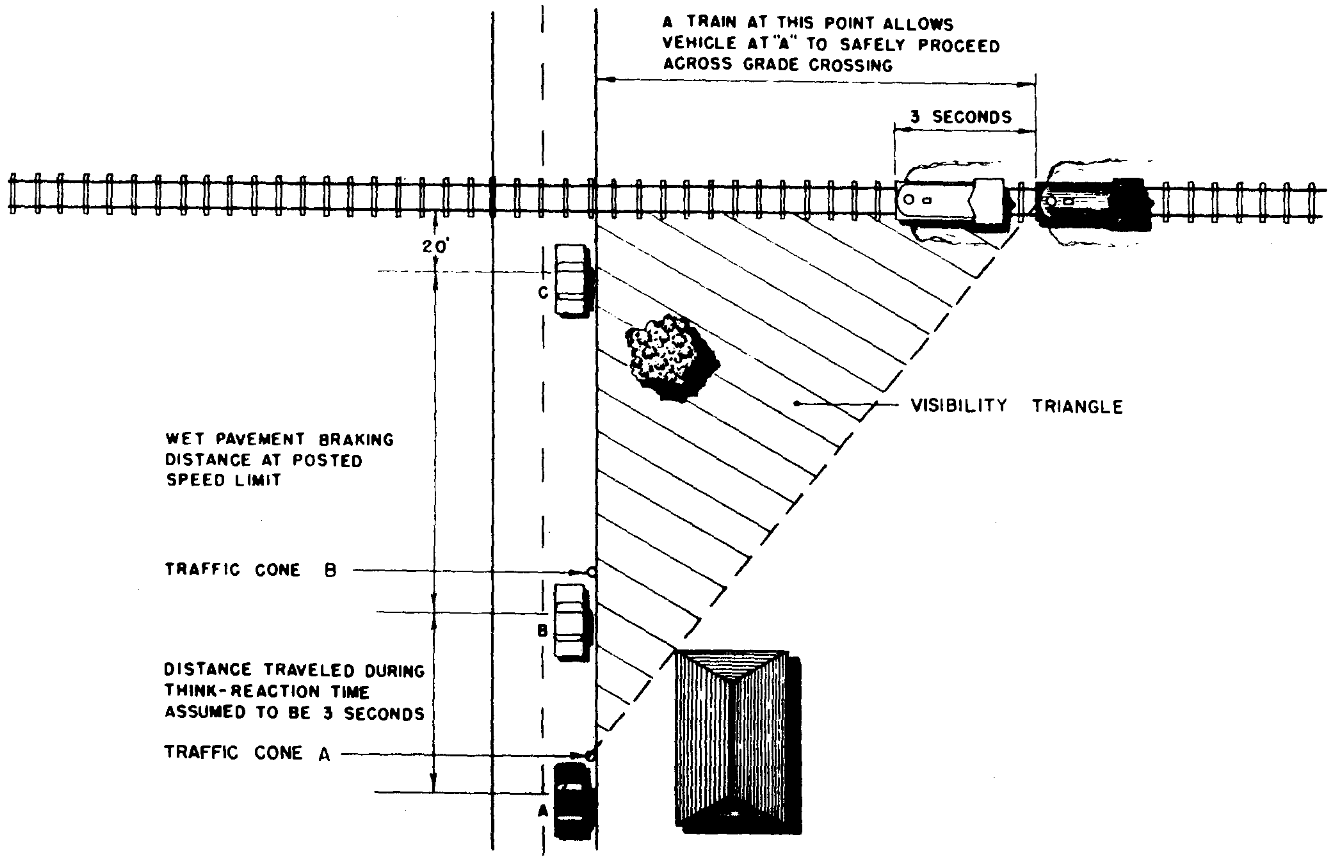

Figure 13. Study Positions for Diagnostic Team

1 ft. = 0.304 m

4.5.3.1 Section I -- The questions in this section are concerned with whether or not the average driver will be aware of the presence of the crossing. This sense of awareness must be established prior to reaching the first traffic cone so that the driver would be prepared to begin his decision-making process. In order to properly respond to questions in this section, the crossing should be observed in an area of the roadway approaching traffic cone A. Items in this section of the diagnostic study questionnaire are related to:

1. Driver awareness
2. Visibility
3. Effectiveness of advance warning signs and signals
4. Geometric features of the roadway
5. "Repeat driver" regard for the crossing

4.5.3.2 Section II -- The questions in this section are concerned with whether or not the driver has sufficient information to make correct decisions while traversing the crossing. Observations for responding to questions in this section should be made in the area between the two traffic cones. Where traffic control devices are installed, for questions in this section it is assumed that the devices have been actuated. Factors considered by these questions include the following:

1. Awareness of approaching trains
2. Driver dependence on crossing signals
3. Obstruction of view of train approach
4. Roadway geometrics diverting driver attention
5. Location of standing railroad cars or trains
6. Removal of sight obstruction
7. Availability of information for proper stop or go decisions on part of the driver

4.5.3.3 Section III -- The questions in this category apply to observations in the section of roadway adjacent to the crossing. Traffic using any adjacent streets or driveways should be observed briefly to determine whether traffic not passing over the crossing could affect traffic over the crossing. Questions in this section relate to these considerations:

1. Pavement markings
2. Conditions conducive to vehicle becoming stalled
3. Other traffic control devices contributing to vehicles stopping on the crossing
4. Hazards presented by vehicles required by law to stop at crossing
5. Signs and signals as fixed object hazards
6. Opportunity for evasive action by driver

4.5.3.4 General Section -- In this section the diagnostic team is given the opportunity to do the following:

1. List major features of the crossing which contribute to safety
2. List features which reduce crossing safety
3. Suggest methods for improving safety at the crossing
4. Give an overall evaluation of the crossing
5. Provide comments and suggestions relative to the questionnaire

4.5.4 Diagnostic Study Procedure

In order to describe the manner in which the diagnostic study is implemented, a discussion of the chronological order of events leading to the complete evaluation of a study site may be useful.

4.5.4.1 Event A - Briefing -- As the diagnostic team assembles at the study crossing, informal introductions of team members, with special emphasis upon individual professional training and job responsibilities, are encouraged. With introductions completed, a member of the project staff (normally the traffic engineer) briefs the team as to the purpose and objectives of the study. The questionnaire is then distributed to team members. Instructions are given for completing the questionnaire. The first page of the questionnaire has space available for vehicle and train operation data. As this information is made available to the team, appropriate agency representatives are asked to verify and update this data. The next step in the briefing is to summarize accident reports and ask for the personal experiences of local team members who are familiar with circumstances surrounding the reported accidents. Aerial photographs (if available) are then reviewed to give team members a better perspective of the total environment of the crossing.

While the briefing is being conducted, a member of the project staff is locating traffic cones on both crossing approaches according to the criteria discussed previously.

4.5.4.2 Event B - Driving the Approaches -- Team members are assigned to vehicles for the evaluation process. Team members then drive each approach several times in order to become familiar with all conditions that exist at or near the crossing. If the crossing is equipped with a signal device, the railroad signal engineer is requested to activate these signals so that flashing light signal alignment, light intensity, awareness of light and audible signal, and traffic operation over the crossing may be observed. When the team members are satisfied with their familiarity with the driver's view of each approach, the signals are turned off and the evaluation is continued.

4.5.4.3 Event C - Completion of the Questionnaire -- Positioning the vehicles according to the instruction provided by the questionnaire, individual team members answer the questions within specific sections of the questionnaire. As each section is completed, the vehicle is moved to the next required location until all questions have been answered.

4.5.4.4 Event D - Inventory of Physical Characteristics -- Concurrent with Event C, a member of the project staff is completing the physical characteristics inventory form shown in Figure 12. When this is accomplished, photographs are taken from specified locations. These data and photographs are for the purpose of reconstructing the crossing at a later date, either with a model or by a drawing.

4.5.4.5 Event E - Critique -- After the questionnaires have been completed the team is reassembled for a short critique and discussion period. At this point the questionnaires have been collected; therefore, opinions expressed during this session do not bias individual team member questionnaire responses. The critique begins with the traffic engineer's summary of his observations of the conditions that exist at the crossing. This generally leads to a discussion by team members of possible ways to improve the safety of the crossing. Other areas are open for discussion during this period, including better means of communication and cooperation among agencies represented by the diagnostic team members. Based on these discussions, the team members reach agreement as to the appropriate improvements.

4.5.5 Documentation

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

1. Site Improvements -- Removal of obstructions in the sight triangle, highway realignment, improved cross section, drainage, or illumination of the crossing may be required.
2. Crossing Surfaces -- These improvements may require rehabilitation of the highway structure, the track structure or both, and the installation of drainage and subgrade filter fabric.
3. Traffic Control Devices -- These improvements may include installation of passive or active control devices, or installation or upgrading of existing control system.

Recommendations should be forwarded through appropriate channels, emphasizing that they are the result of a diagnostic team study and have the concurrence of all interested parties.

4.6 IMPLEMENTATION

The previous material has discussed that portion of the railroad-highway grade crossing improvement process concerned with planning and defining specific improvement projects. Program implementation is that portion of the total process concerned with making specific improvements at specific railroad-highway grade crossings.

Railroad-highway grade crossing improvements can be classified into the following broad categories:

(1) Elimination
(2) Site Improvements
(3) Crossing Surface Improvement
(4) Traffic Control Device Installation or Improvement
(5) Combinations of the Above

4.6.1 Site Improvements

Site improvements usually include the following types of project activities:

- Drainage Improvements
- Horizontal Alignment Modifications to Roadway
- Horizontal Alignment Modifications to Track(s)*
- Vertical Alignment Modifications to Roadway
- Vertical Alignment Modifications to Track(s)
- Cross-Section Modifications
- Sight Distance Improvements
- Illumination Improvements

*Could include removal of one or more tracks, moving or relocation of switch or frog.

4.6.2 Crossing Surfaces

Crossing surface improvement projects are concerned with the area where the highway and tracks intersect as well as the highway surface in the near vicinity of the railroad tracks. These projects seek to minimize the disturbance at railroad-highway grade crossings to either trains or highway vehicles.

4.6.3 Traffic Control Devices

Traffic control device installation or improvements usually consist of the following:

- Passive Devices
  - + Crossbuck
  - + Other Signs
  - + Markings
- Active Devices
  - + Flashing light signals

+ Automatic gates
+ Automatic bells
+ Traffic signal preemption

Separate chapters will follow that discuss (1) Site Improvements, (2) Crossing Surfaces, and (3) Grade Crossing Traffic Control Devices.

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5.0 SITE IMPROVEMENTS

5.1 INTRODUCTION

Oftentimes improvements can be made at a crossing for a relatively low cost which will enhance the safety of the motorist. Such improvements as removing obstructions from the sight triangle, increasing drainage capabilities and illuminating the crossing may be undertaken without excessive investment. Other site improvements such as highway realignment and changing of the cross section are more expensive and must be weighed against other alternative improvements. This chapter details considerations that should, and in some cases must, be made to permit safe and efficient operation of the grade crossing.

5.2 SIGHT DISTANCE

The primary requirement for the geometric design of a grade crossing is that it provide adequate sight distance for the motor vehicle operator to make an appropriate decision as to whether to stop or proceed. This sight distance will be governed largely by roadside sight obstructions, horizontal alignment and vertical alignment.

5.2.1 Minimum Sight Triangle

Speeds of the two vehicles (train and motor vehicle) define the distances at which a driver must be able to see a train. These distances are measured along the track and along the roadway and define a minimum sight triangle (Figure 14). Distances along the highway must as a minimum be the safe stopping sight distance for a given approach speed. Distances along the track are those which would result in a train traveling a given speed arriving at the crossing at approximately the same time as the motor vehicle comes to a stop.

Table 20 shows the required distances along each traveled way used in determining the minimum sight triangle. All areas within the triangle must be clear to afford the driver adequate visibility.

Example:

Maximum train speed = 60 mph (97 kph)

Highway design speed = 60 mph (97 kph)

From Table 20, distance A along the highway in Figure 14,

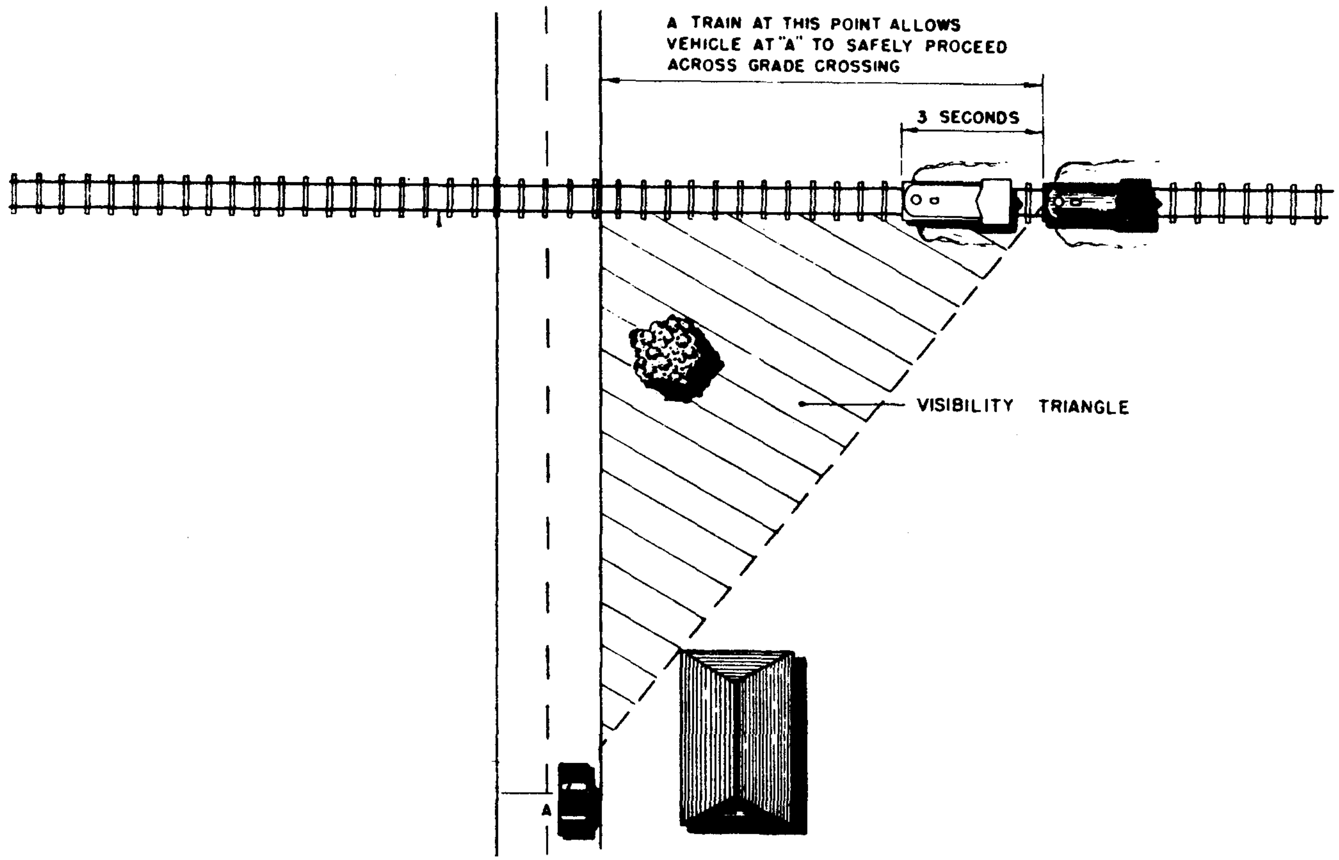

Figure 14. Minimum Sight Triangle

Table 20. REQUIRED DESIGN SIGHT DISTANCES FOR COMBINATIONS OF HIGHWAY AND TRAIN VEHICLE SPEEDS

Train Speed	Highway Speed in MPH							
	0	10	20	30	40	50	60	70
	Distance Along Railroad From Crossing							
10	162	126	94	94	99	107	118	129
20	323	252	188	188	197	214	235	258
30	484	378	281	281	295	321	352	387
40	645	504	376	376	394	428	470	516
50	807	630	470	470	492	534	586	644
60	967	756	562	562	590	642	704	774
70	1129	882	656	656	684	750	822	904
80	1290	1008	752	752	788	856	940	1032
90	1450	1134	844	844	884	964	1056	1160
	Distance Along Highway From Crossing							
	20	65	125	215	330	470	640	840

NOTE: 1 mph = 1.61 kph
1 foot = .304 metres

SOURCE: Reference (1)

would be 640 feet (195 m). Distance B along the track would be 704 feet (214 m). These two distances are the legs of the minimum sight triangle. A line drawn from one point to the other defines the area of the minimum sight triangle.

The American Association of State Highway and Transportation Officials (AASHTO) recommend a somewhat more conservative estimate of the distance measurement along the track. They suggest that for 40 mph highway traffic, the distance along the track should be at least 11 times the maximum train speed, and for 60 mph, 15 times the maximum train speed. In other words, the distance along the track for the speeds used in previous example would be:

15 x 60 mph = 900 feet (2).

The previous calculations assumed the vehicles are approaching the crossing at highway speed. Another condition that should also receive attention is that of vehicles which are required to stop at all crossings. Required sight distances for stopped vehicles can be found in Table 20 in a manner similar to that used previously. AASHTO (2) recommends sight distances in feet not less than 13.5 times train speed in mph for single unit (SU) vehicles (buses, etc.) and 17.5 times the train speed for semi-trailer vehicles. Special attention should be given to the case of stopped vehicles to ensure that adequate sight distance is available as stopped vehicles often include buses which represent a high "risk" factor and reduced operational capabilities.

In the event that it is impossible to achieve the minimum sight triangle, careful consideration should be given to the installation of active control devices.

5.2.2 Obstructions

In many cases, restricted sight distance will be the result of obstructions in the sight triangle. If such obstructions are due to vegetation or other natural features, they should be removed. Other obstructions such as buildings may be difficult to remove. If such is the case, two other alternatives are available. First, advisory speed plates mounted with the advance warning sign may be used to reduce

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1 mph = 1.61 kph
1 foot = .304 metres

motor vehicle speeds to a level at which the minimum sight triangle is available. Such advisory speed should not be less than 20 mph (30 kph). The second alternative, as discussed previously, is the installation of active control devices.

Depending on horizontal and vertical alignment, there may not be sufficient sight distance along the roadway for motorists to properly respond to active devices. 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 active devices is attainable, flashing yellow beacons may be added to the advance warning sign. These beacons should be connected to the active devices so that when a train is approaching the obscured crossing, the beacons flash, giving the motorist adequate time to respond. If flashing beacons are added to the standard advance warning sign, a supplementary plate bearing the legend "BE PREPARED TO STOP WHEN FLASHING" should be added.

5.3 GEOMETRIC DESIGN

The line and grade of most railroads have been established for many years. In addition, resurfacing usually results in an increase in elevation of the running rails. A grade raise of up to six inches (.15 m) is not uncommon when additional ballast is added. The cumulative effect of several even smaller raises can seriously distort the original grade line of the highway. Currently, the use of a traveling mechanical undercutter and ballast cleaner is a practical and economical method of avoiding track raises during track resurfacing operations. This can be an important development in track maintenance operations at and in the vicinity of grade crossings. The horizontal and vertical geometrics of the highway are usually determined by railroad conditions and availability of highway right of way. Highway designers have attempted to locate the highway centerline perpendicular to the track centerline. However, for a variety of reasons, many skewed crossings and crossings on curves have been constructed; and in some cases it has been necessary to construct crossings where both the highway and the track are on curves. This latter situation produces poor rideability for highway traffic when track or highway radii require superevelation. Safety and efficient operations on the highway can be enhanced by following good design practices relative to the following elements:

- Horizontal Alignment
- Vertical Alignment
- Cross Section Interface

Each of these elements of crossing geometry will be discussed. Examination of thousands of crossings has led to some interim observations which were documented at more than 300 sites in Texas during a three year study completed in 1976 (3). Existing conditions found at many locations include:

(1) The railroad is frequently higher than the roadway, often requiring steep grades at the approaches to the railroad.

(2) A highway is frequently located parallel and adjacent to the railroad property, and a highway intersection is located near the grade crossing. Approximately 65 percent of the sites inspected had a highway intersection within 200 feet (60 m) of the railroad crossing.

(3) Horizontal alignment in approaches to crossings often includes curves having radii less than 1000 feet (300 m). In most cases, the highway and the railroad have tangent alignment at the crossing.

Typical geometric conditions at or near crossings are shown in Figure 15. Typical cross sections are shown in Figures 16 and 17. Geometric characteristics such as those just described are common throughout the United States, and have an important influence on highway traffic behavior at or near crossings.

Major revisions in the horizontal and vertical alignment of either the railroad or the highway require large expenditures of money. Construction of specially designed roadway sections at the approaches to

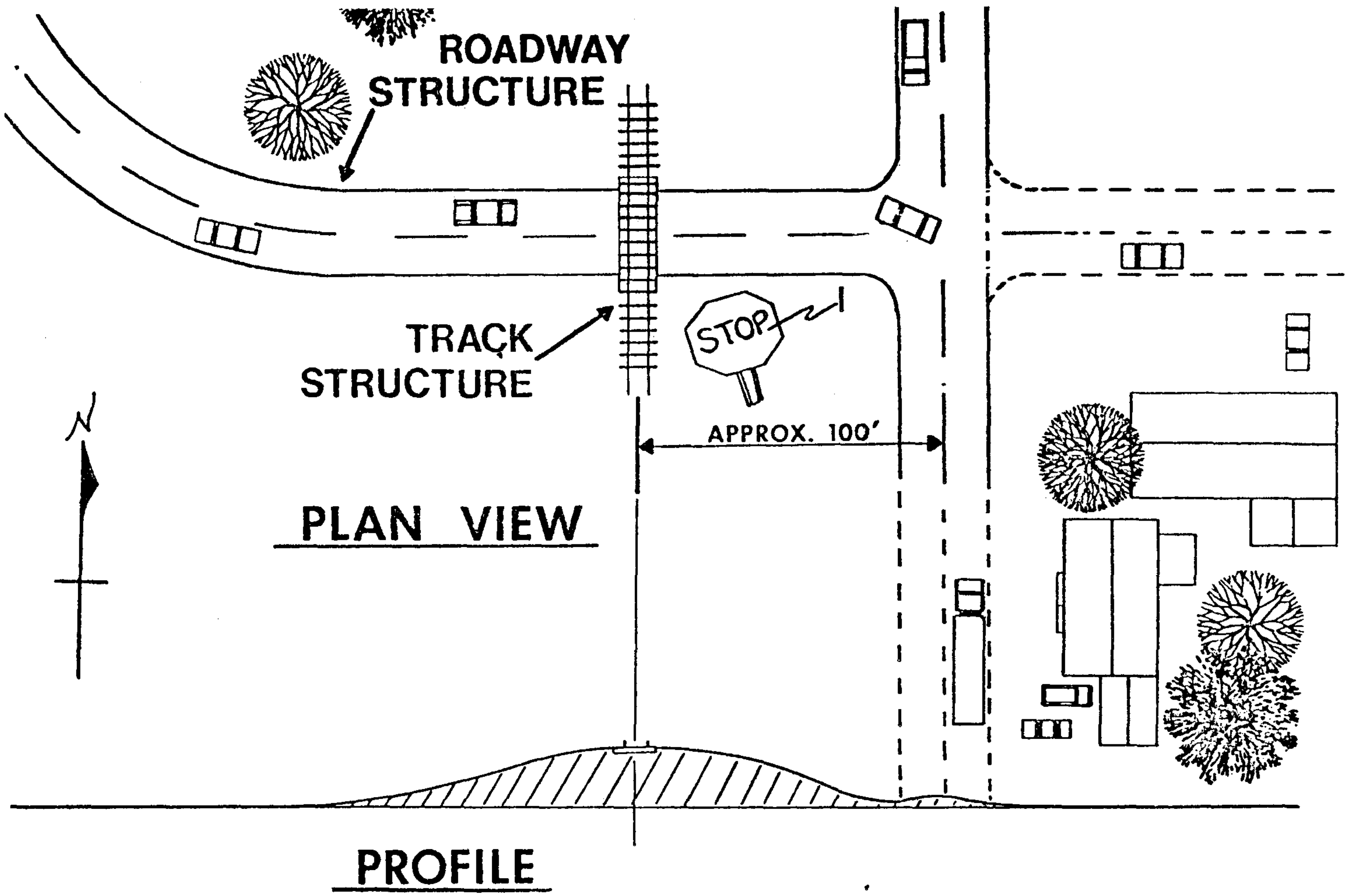
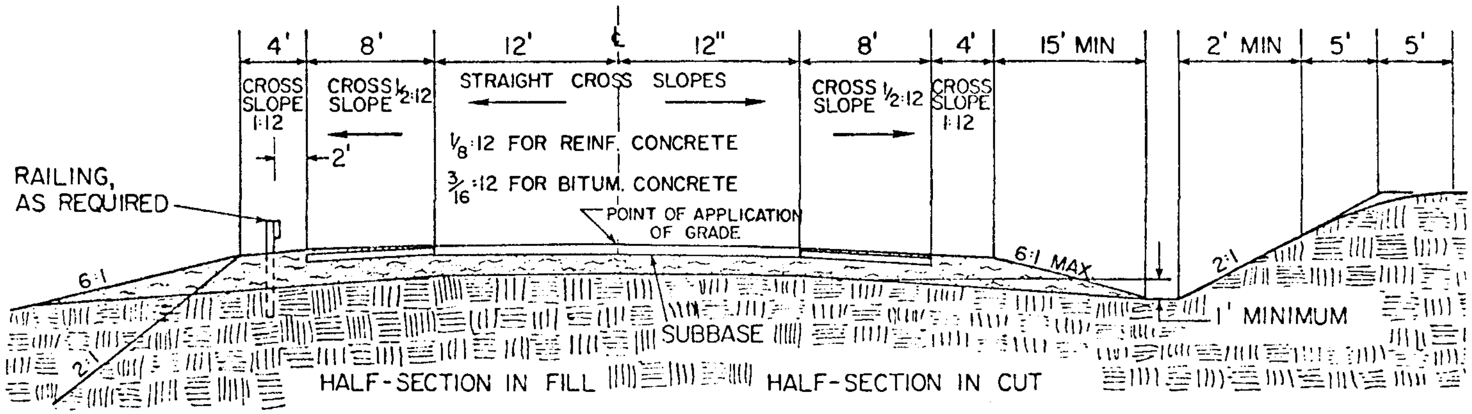


Figure 15. Common Crossing Geometry

1 ft. = 0.304 m



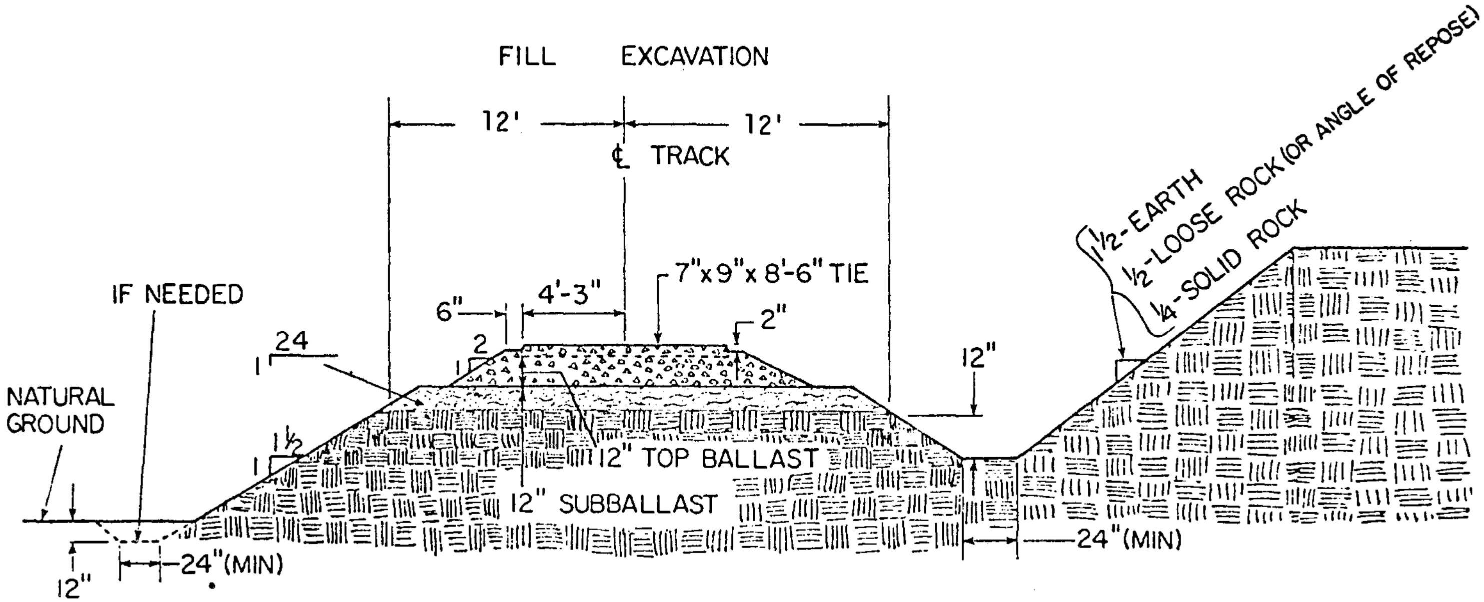
LAND-USE CLASSIFICATION

FILL SLOPE	RURAL	URBAN (RES)	URBAN (COMM. OR IND.)
6:1	15' OR LESS	12' OR LESS	10' OR LESS
2:1*	OVER 15'	OVER 12'	OVER 10'

*WITH GUIDE RAILING

Figure 16. Typical Cross Section of a Highway

1 ft. = 0.304 m



Typical roadbed and ballast cross section for straight single track: topballast, about 3,700 cu. yd. per mile; subballast, about 4,900 cu. yd. per mile (includes 15% shrinkage)

Figure 17. Typical Cross Section of a Railroad

1 inch = 25.4 millimeters
1 foot = 0.3048 meters
1 cubic yard = 0.7646 cubic meters
1 ft. = 0.304 m

a crossing are expensive. Elimination of a major crossing at grade may require construction of frontage roads on at least one side of the railroad.

On the basis of these observations several interim conclusions can be made:

- Usually railroad elevation must be maintained.
- Usually highway locations must be preserved.
- Many crossings could be eliminated.
- Acceleration and deceleration near crossings produce deterioration in the highway pavement.

These interim conclusions show a need for major planning, design and construction through cooperative efforts of governmental agencies and railroad companies.

The following discussion of geometric design elements is based on the proposition that adequate funds are available to permit implementation of programs and, ultimately, projects. Each element of site improvement will be discussed separately, but it should be borne in mind that all elements need to be considered in making improvements. Horizontal and vertical controls should be based on sight distance requirements, both for approaches to the crossing and along the railroad track.

5.3.1 Horizontal Alignment

A grade crossing is an intersection of two carriers which have differing operational characteristics. This fact must be kept in mind when planning improvements. Horizontal alignment should permit drivers to operate their vehicles at posted speeds without unexpected intersections with railroads or other highways. Good geometric design requires:

(1) Elimination of sharp curves near an intersection.
(2) Right angle crossings whenever possible.
(3) Where skewed crossings are required, the angle of skew should be minimized.

It is recognized that such site improvements may require purchase of additional right of way. Relocation of one or both traveled ways may be required. The total cost of such improvements must be compared with costs of installing active control devices.

5.3.2 Vertical Alignment

Careful consideration should be given to revising grades on both the highway and the railroad, as necessary, to improve sight distance, approach characteristics, drainage and intersection conditions. Wherever possible approach grades should be small and resulting vertical curves should be long. Once again, speed, sight distance and the elimination of unexpected conflicts with railroad traffic are the prime conditions to be considered in planning.

Wherever possible the approaches to a grade crossing should be made on a flat grade. The track structure should be surfaced to meet the highway grade, and good drainage must be provided.

5.4 CROSS SECTION

Requirements for the cross section of the highway at grade crossings differs little from that for highway intersections. Because of the multi-varied types of highways, the reader is referred to "A Policy on Geometric Design of Rural Highways" (2) for detailed design requirements. A few important considerations are:

- The cross section should be designed to ensure that the driver always has some escape route available (i.e., maximum desirable side slope of 4:1).
- The pavement surface adjacent to the track should be at the same elevation as the track at all points on the driving surface. This will probably require warping of the pavement from normal cross slope to a plane even with the track. When such warping is required the rate of change in elevation of the pavement edges should not exceed those rates shown below:

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

Note: 1 mph = 1.61 kph
1 foot = .304 metres

5.5 DRAINAGE

Drainage requirements of grade crossings would be satisfied through good highway and railroad design and maintenance practices. However, drainage problems frequently arise. Anytime maintenance activities by either the railroad or highway agency result in debris (pavement, dirt, ballast, etc.) left in the ditches alongside both roadbeds, drainage will be hampered and likely lead to the deterioration of one or both structures. Thus debris should always be removed and slopes properly graded before maintenance activities are complete.

Subgrade drainage is often required because the highway construction blocks normal ballast and side ditch drainage along the railroad. More than normal surface runoff tends to accumulate at a grade crossing.

5.6 ILLUMINATION

In instances where a railroad crosses a lighted roadway, luminaires should be located so that the best illumination is provided for the driver approaching the track. In order to provide illumination of surface detail, luminaires should be placed according to IES Roadway Lighting recommendations (5) (Figure 18).

In situations where the roadway is not lighted the MUTCD states the following concerning illumination at crossings:

"At grade crossings where a substantial amount of railroad

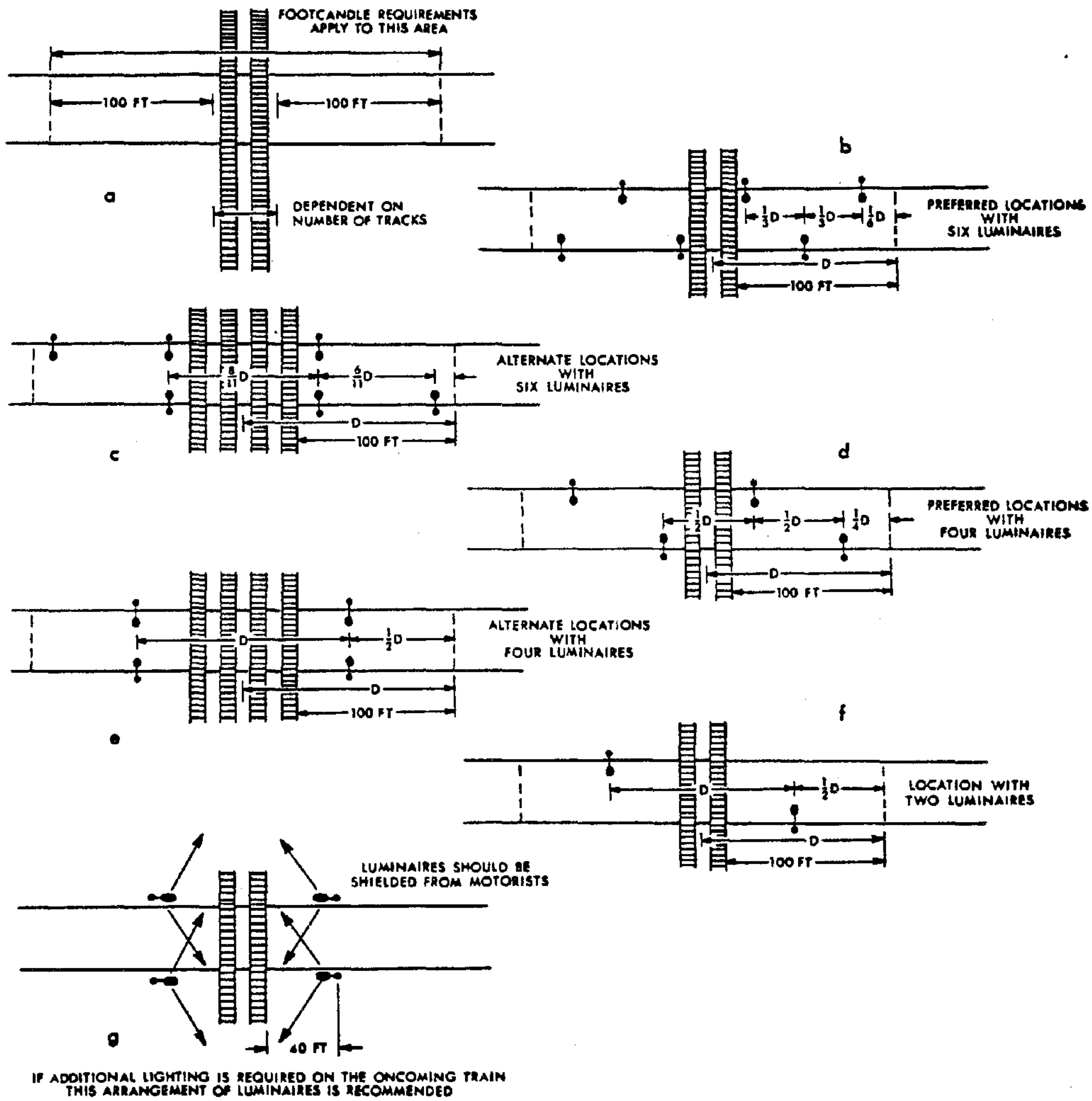


Figure 18. Recommendations for Luminaire Placement at Rail-Highway Grade Crossings (By Illuminating Engineering Society. American National Standard Practice for Roadway Lighting, 1977)

1 ft. = 0.304 m

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 approaches is such that the headlights of an oncoming vehicle shine under or over the cars."

In addition to the suggestions given by the MUTCD, the following are conditions under which illumination may contribute to crossing safety:

(1) Low ambient light level (dark rural or suburban crossings where a train may go undetected by an approaching motorist).

(2) Poor approach roadway alignment so that the headlight beam does not fall upon the train.

Mounting height should be in the range of 30 feet (9 m) to 40 feet (12 m). The luminaire should be located between 1 1/2 and 2 mounting heights from the track. This configuration will provide for maximum illumination of the train.

Desirably, it should be 30 feet (9 m) from the traveled way. Where the recommended clearance cannot be achieved, it should be a minimum of 12 feet (3.6 m) from the traveled way (2 feet (0.6 m) from the shoulder) on uncurbed roadways, and 2 feet (0.6 m) from the curb on curbed roadways. Care should be taken in selecting distribution and mounting height to ensure that the highway or railroad operator is not subjected to glare from the light source. If conditions are such that glare cannot be eliminated, cutoffs should be provided on the luminaire.

Although illumination circuitry can be designed to make the luminaires train-actuated, they are not to be used as a substitute for active traffic control devices. If luminaires are to be train actuated, the light source must be one that requires no warm-up period (i.e., incandescent). It is preferable for continuous illumination to be distinctive in volume, color, or distribution so that it is distinguishable from normal street lighting and railroad signal indications.

Floodlighting should be used only where reliable a.c. power is available at the crossing. Grade crossing illumination should be turned off during daylight hours. Details on lighting design may be found in references 4, 5, 6 and 7.

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6.0 CROSSING SURFACES

6.1 FUNCTION AND SAFETY IMPORT

A grade crossing surface consists of pavement or other highway surface over a railroad track which transmits vehicle wheel loads to the track structure. Within the boundaries of the surface area, the track structure transmits highway and railroad loads to the subgrade.

A grade crossing is a discontinuity in the normal track structure and in the normal highway or street pavement. Poorly maintained grade crossings may constitute a hazard to highway and rail traffic. Maintenance costs at and near grade crossings are greater than maintenance costs along normal sections of each traveled way.

A driver may have his attention diverted from an approaching train if he is preoccupied by poor surface conditions at a grade crossing. The degree of diversion is related to surface conditions. An uneven surface may require considerable attention by a driver in selecting a smooth crossing path; and furthermore, when an uneven surface is encountered unexpectedly, a driver may lose control of his vehicle. Consequently, providing a reasonably smooth crossing surface is viewed as one of the several elements of work contributing to the elimination of hazards at railroad-highway grade crossings.

The Federal Highway Program Manual provides for improvements of crossing surfaces as one means of eliminating hazards at grade crossings. Projects for surface improvements are eligible for Federal-aid funding. The Manual also contains compliance requirements for the use of proprietary products, and emphasizes that adequate control devices must be in place or must be installed where crossing surface improvements are being made. Control devices are required by 23 USC 109(e), which contains the following proviso:

> No funds shall be approved for expenditure on any Federal-aid highway, or highway affected under Chapter 2 of this title, unless proper safety protective devices complying with safety standards determined by the Secretary at that time as being adequate shall be installed or be in operation at any highway and railroad grade crossing or drawbridge on that portion of the highway with respect to which such expenditures are to be made.

6.2 TYPES OF CROSSING SURFACES

Various types of crossing surfaces for railroad-highway grade crossings are reported in a study completed in September 1973 by W. J. Hedley for the U. S. Department of Transportation (1). That report was updated in 1975 and was issued as a part of the Federal-Aid Highway Program Manual (2). Typical crossing surfaces described in the manual include:

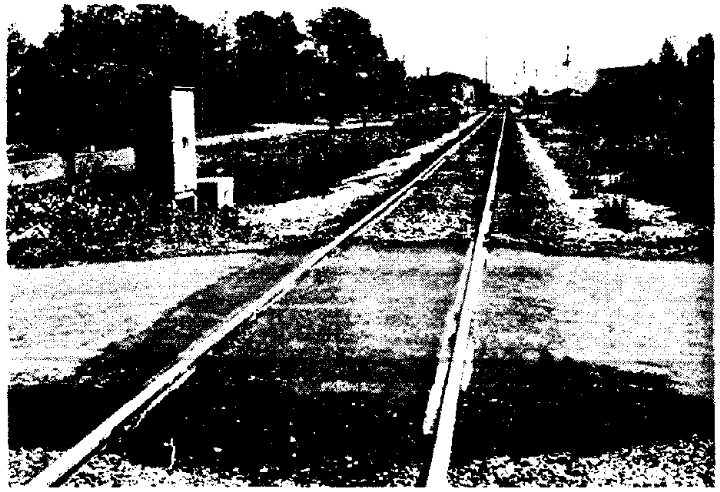
- Plain bituminous (see Figure 19)
- Full-depth timber (see Figure 20)
- Sectional treated timber (see Figure 21)
- Concrete slab (see Figure 22)
- Concrete pavement (see Figure 23)
- Steel sections (see Figure 24)
- Rubber (elastomeric) panels (see Figure 25)
- Linear high density polyethylene modules (see Figure 26)
- Epoxy-rubber mix cast-in-place (see Figure 27)

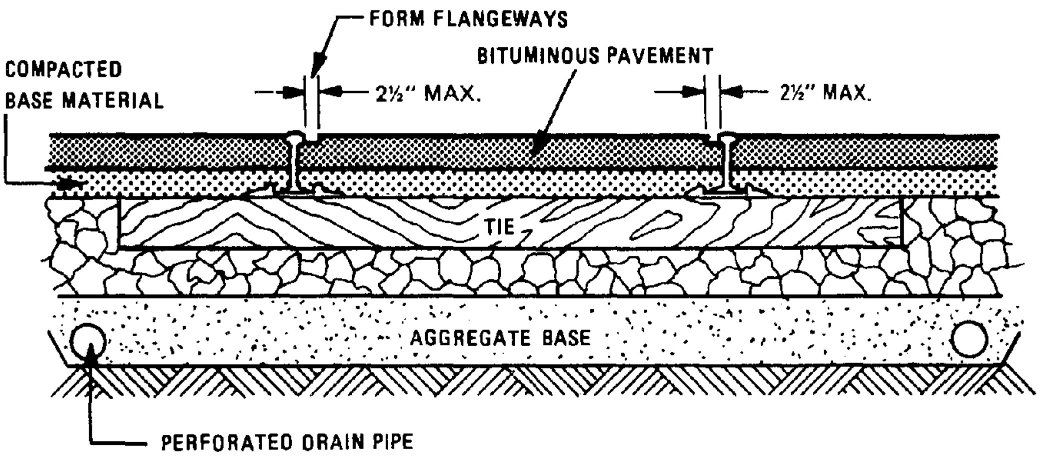
Examples of other types of crossing surfaces which are a modification of some of the above types are shown in Figures 28, 29, 30 and 31. Figure 32 is an unconsolidated crossing. It is included in Hedley's study but should be used only for crossings with very low traffic volume on the highway.

Maintenance procedures require resurfacing of important main line track structure each four to six years. When the track is completely resurfaced each crossing must be removed and reinstalled. Hence, the crossing surface installation must be compatible with railroad operations and maintenance requirements.

A short discussion of each type of crossing surface is presented below each type of crossing surface. Attention to details, such as the installation of filler blocks, is important. Some of the illustrations contain these details, others do not; but proper attention to such details is essential to prolonged, satisfactory surface service life.

Installation of a continuous length of rail through the crossing is another important requirement, as is the use of adequate spikes, rail anchors and other hardware. These details will be discussed in subsequent sections.



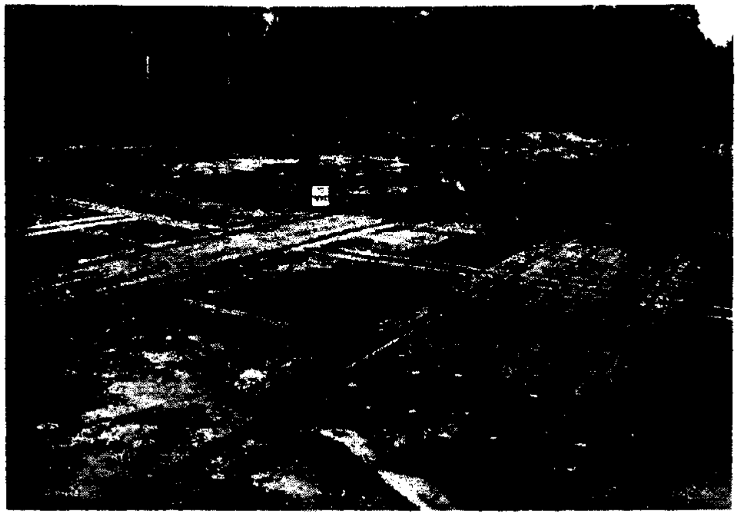


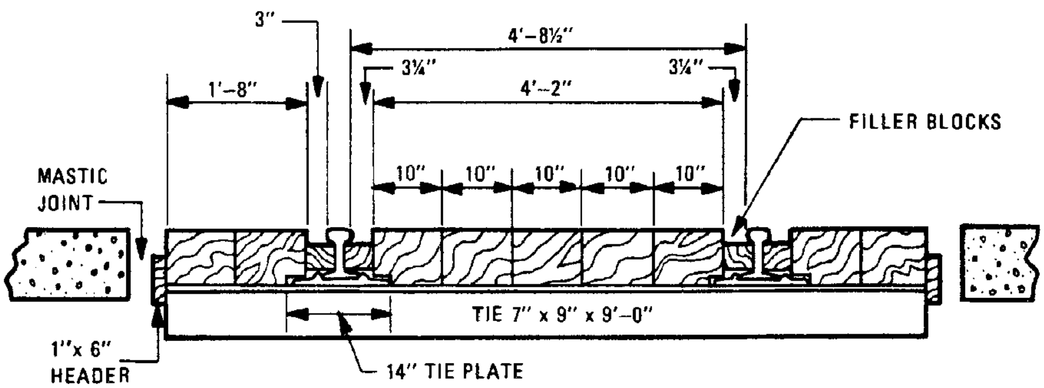
TYPICAL CROSS SECTION

Figure 19. Plain Bituminous Crossing

1 m = 25.4 mm

Either a bituminous surface over the entire crossing area or only in the area between planks or flange rails forming flangeway openings on the inside of the running rails, with a line of planks or flange rails on the outside of the running rails as an optional feature.



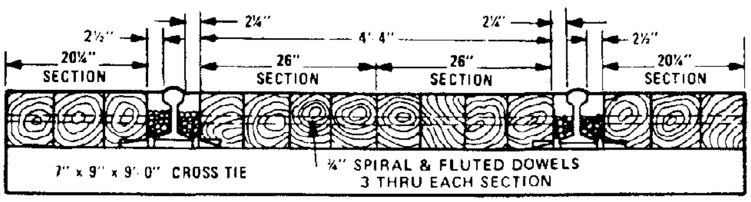


TYPICAL CROSS SECTION

Figure 20. Full Depth Timber Crossing

A wood surface of planks or timbers as individually separate units over the entire crossing area above the crossties.

1 in = 25.4 mm

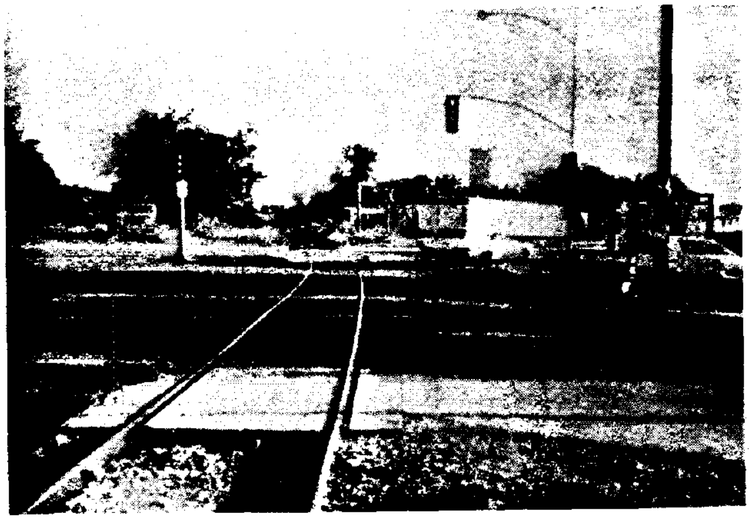


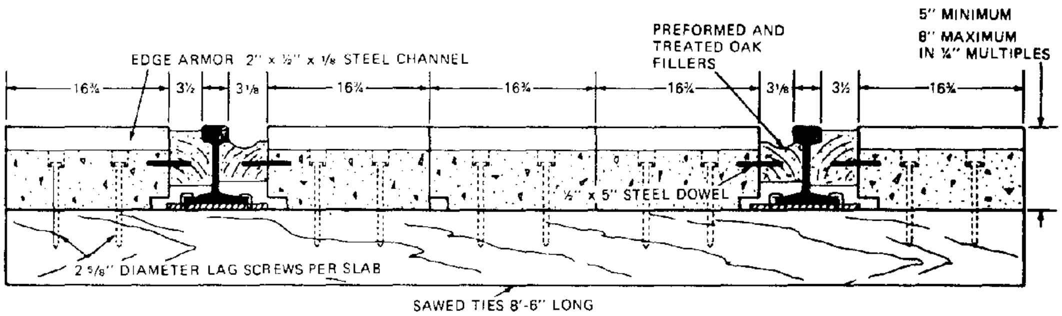
TYPICAL CROSS SECTION

Figure 21. Sectional Treated Timber Crossing

1 in = 25.4 mm

A wood surface consisting of an assembly of prefabricated treated timber panels, usually 8 to 9 feet in length and of such width that two panels form the surface between flangeway openings inside the running rails and one panel covers the crossties outside of each rail. Each section is so assembled and secured that it may be installed and removed and reinstalled individually for track maintenance and crossing surface replacement purposes.



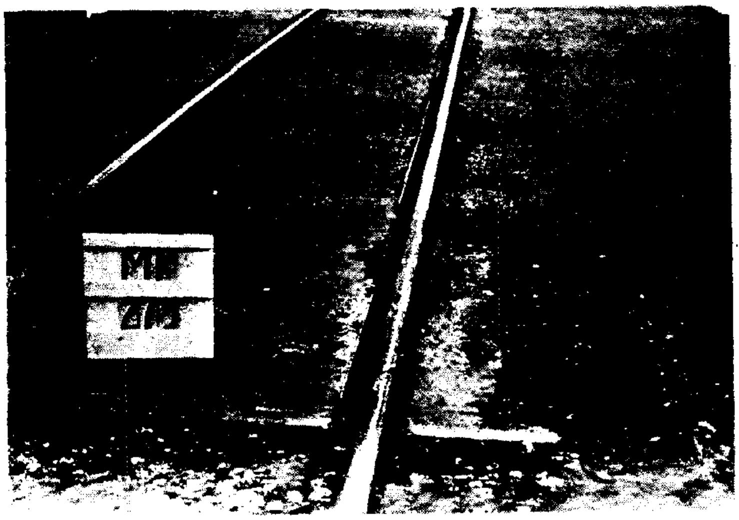


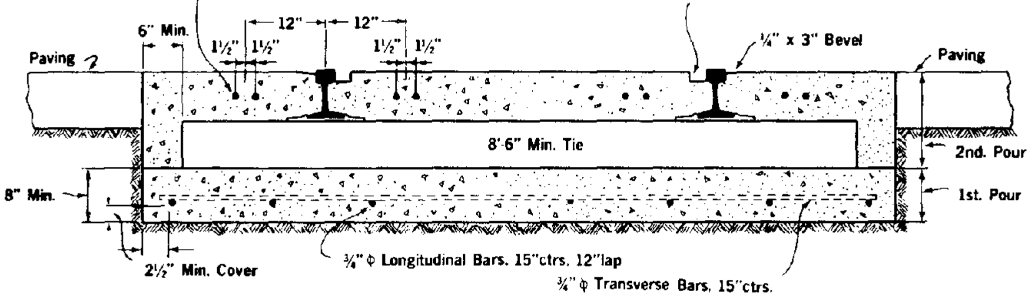
TYPICAL CROSS SECTION

Figure 22. Concrete Slab Crossing

1 in = 25.4 mm

A surface of precast concrete slabs which may be removed and reinstalled individually for maintenance and replacement purposes. Slabs are made in various lengths, ranging from 6 to 9 feet. Some are produced so that one slab is wide enough to fit between the flangeway openings inside the running rails but usually this inside space is filled with either two or three slabs. In all cases only one slab is used on each side to cover the crossties outside the rail.



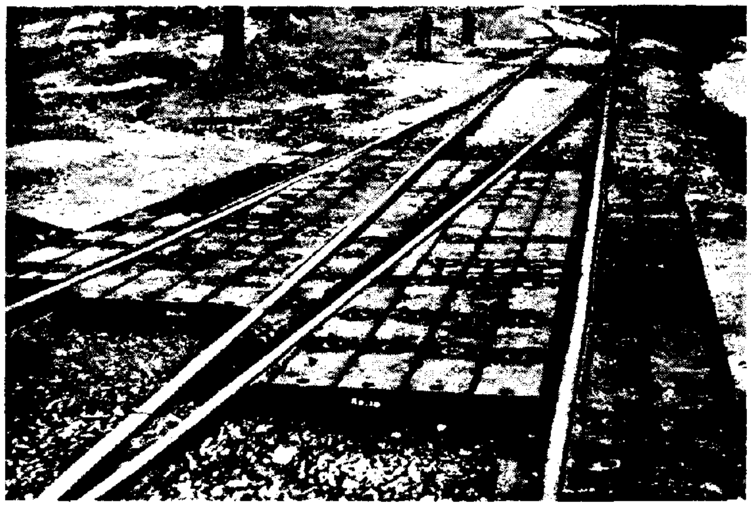


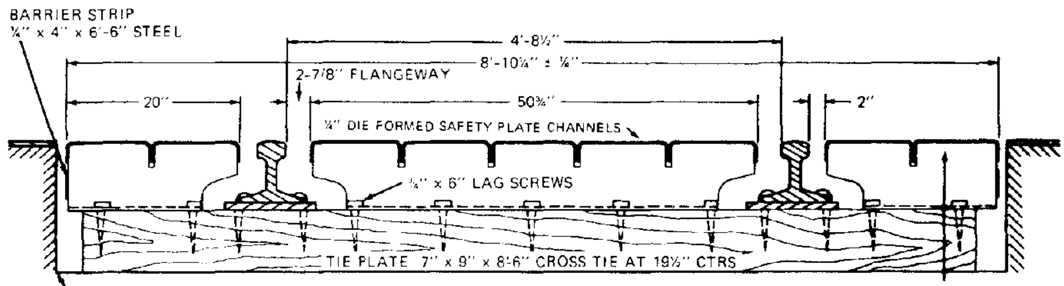
TYPICAL CROSS SECTION

Figure 23. Track in Paved Area

1 in = 25.4 mm

Continuous concrete surface covering the entire crossing area at least from end to end of the crossties, excepting only the space occupied by the running rails and necessary flangeway spaces inside the rails. This surfacing method is recommended for docks, wharves, and locations where the track is located longitudinally in a street.



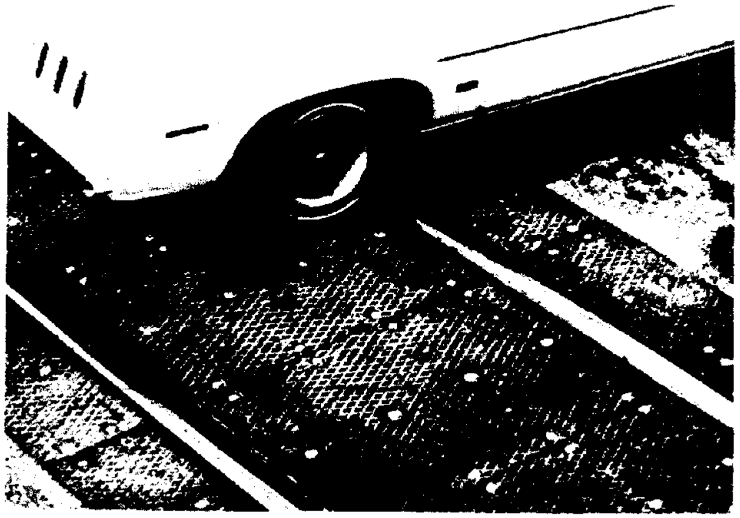


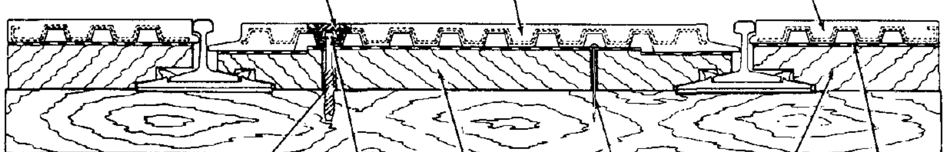
TYPICAL CROSS SECTION

Figure 24. Steel Section Crossing

1 mi = 25.4 mm

Preformed sections of steel which may be removed and reinstalled individually for maintenance and replacement purposes. Some variety of sizes may be used. In the photograph, the outside panels have been damaged and a gap exists at the concrete pavement because the panels were improperly butted against the running rail.



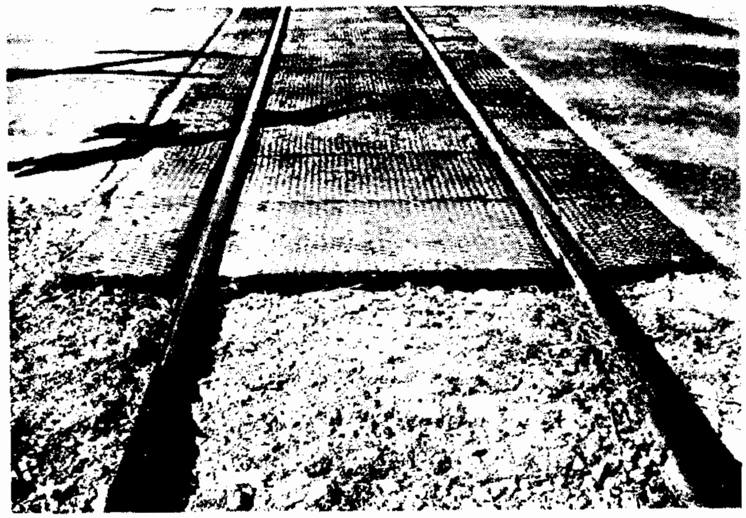


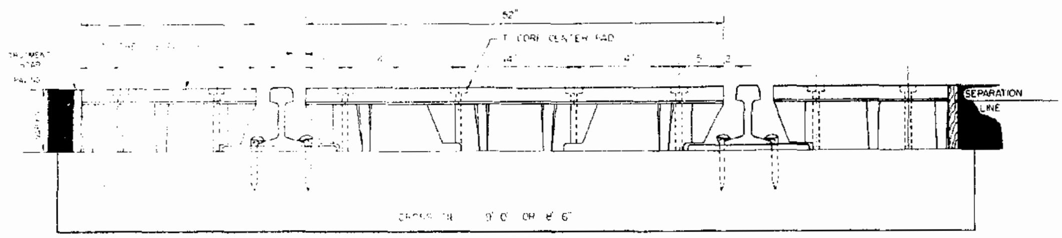
TYPICAL CROSS SECTION

1 in = 25.4 mm

Figure 25. Rubber (Elastomeric) Panel Crossing

Steel-reinforced molded rubber panels with a patterned surface. The inside panels extend from rail web to rail web, with flangeway openings provided. Each outside panel is designed to extend slightly beyond the ends of the crossties. Rubber panels may be removed and reinstalled individually for maintenance and replacement purposes.



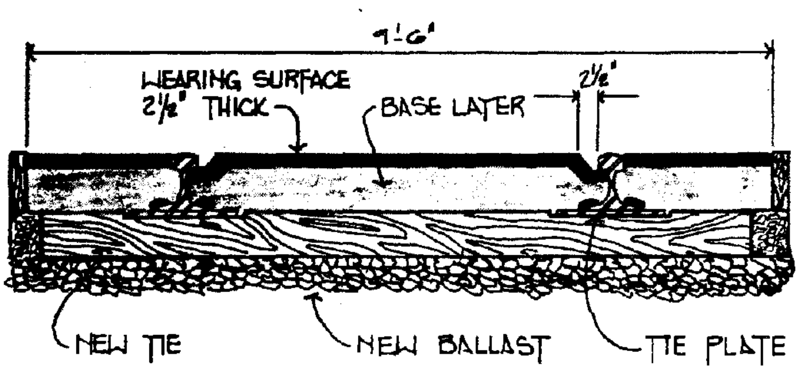


TYPICAL CROSS SECTION

Figure 26. Linear High Density Polyethylene Modules

1 in = 25.4 mm

Molded panels (modules) of expanded linear high density polyethylene. Panels are full depth, extending from top of tie to top of rail and have a patterned surface. One center panel and two side panels form a 3-foot section to fit 18-inch crosstie spacing. Panels may be removed and reinstalled individually for maintenance and replacement purposes.

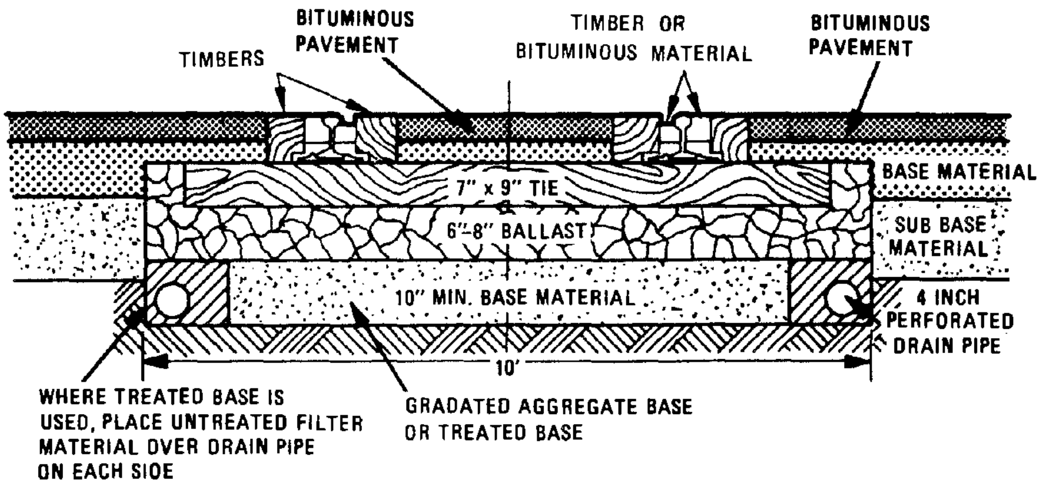


TYPICAL CROSS SECTION

Figure 27. Epoxy Elastomeric Cast-in-Place Crossing

1 ft = 0.304 m

A continuous cast-in-place crossing surface utilizing principally a mix of specially formulated epoxy and scrap rubber tires ground into finely graded particles. The entire surface on the crossing, including contact with the running rails, makes a watertight seal.

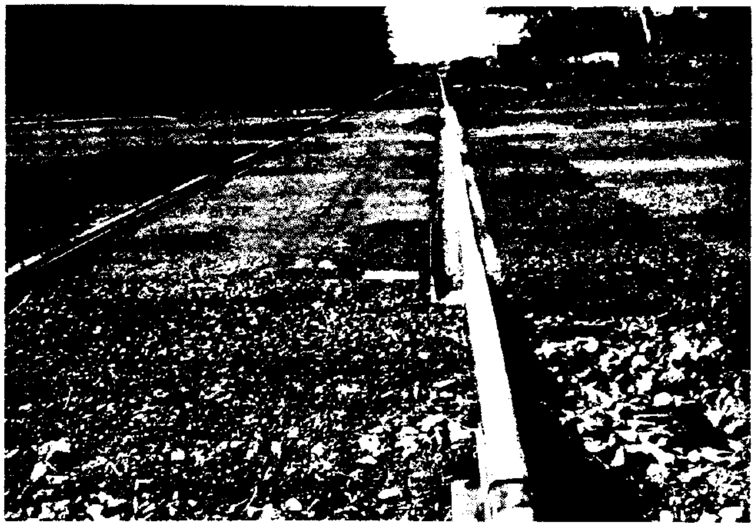


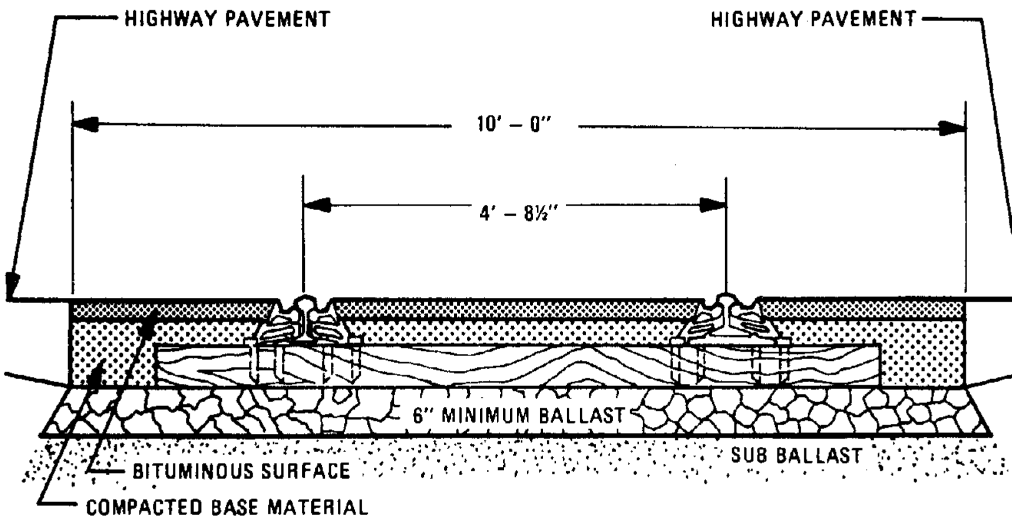
TYPICAL CROSS SECTION

1 in = 0.304 mm

Figure 28. Bituminous Crossing with Timber Headers

Placing timber headers on each side of the rails is a deterrent to damage of the bituminous pavement from movement of the rail.



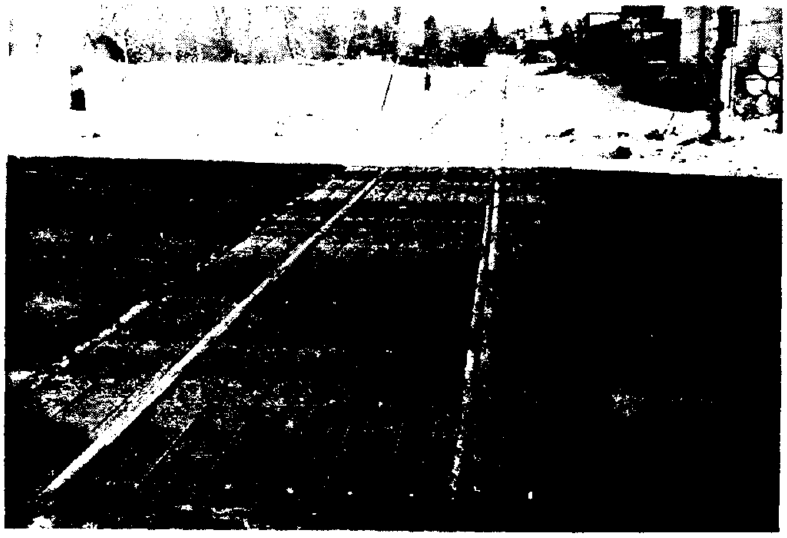


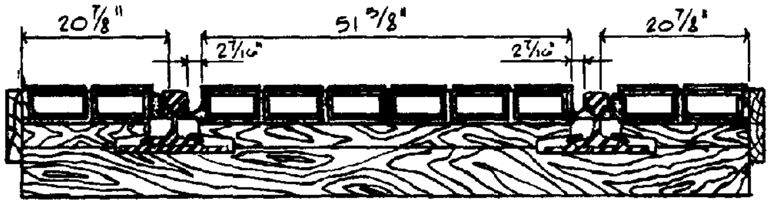
TYPICAL CROSS SECTION

Figure 29. Bituminous Crossing with Flange Rails.

Smaller rails can be used for headers and can be supported by special rail chairs.

1 ft = 0.304 m



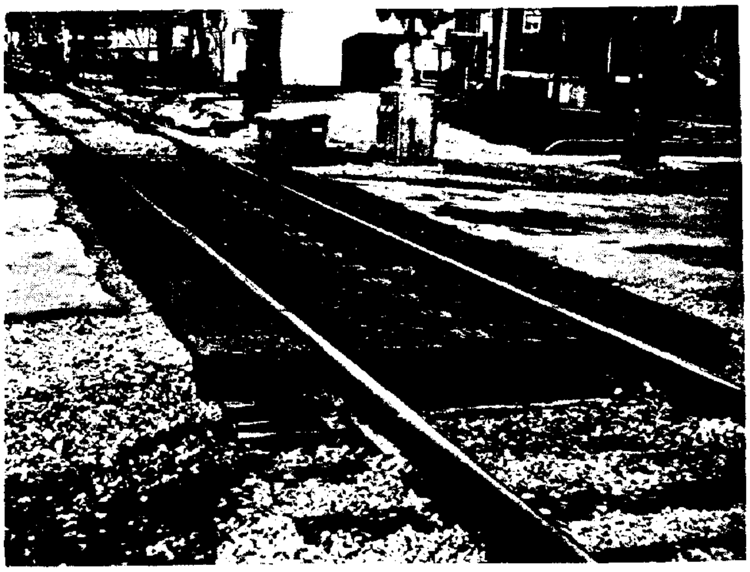


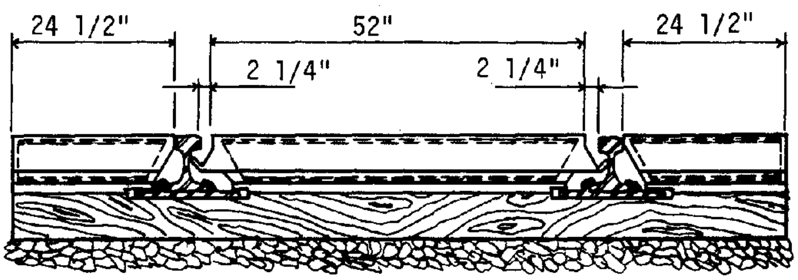
TYPICAL CROSS SECTION

Figure 30. Rubber Covered Steel Box Beam Crossing

Steel box beams bridge the space between the ties. A watertight surface for the crossing is provided by the tonque and groove design of the interfaces of the surfacing parts. Rubber shock absorbing bushings under the head of each drive spike inhibits spike rise. Shock absorbing counterforts bearing against each side of the web of the rail limit the amplitude of track vibrations excited by highway vehicle wheels and dampen the duration of vibration.

1 in = 25.4 mm





TYPICAL CROSS SECTION

Figure 31. Elastomeric Grade Crossing

A structural steel arch is incorporated into the moulded elastomer adding the necessary beam strength to enhance the wear and weather resistance. The unit has the desirable degree of flexibility and cushioning properties, and furnishes insulation against the passage of electrical current.

1 in = 25.4 mm

Figure 32. Unconsolidated (Ballast) Crossing

Ballast, or other unconsolidated material placed above the tops of crossties, with or without planks on one or both sides of the running rails.

6.3 SELECTION GUIDELINES FOR CROSSING SURFACES

Each crossing surface should be compatible with highway user requirements and with railroad operations at the site. For example, highways have a large ADT moving at high speed merits a smooth crossing surface of a type requiring infrequent maintenance regardless of train volume and speed. A track carrying frequent high speed train movements should have one of the sectional or modular panel types which can be easily removed and replaced for track maintenance. On the other hand, where train movements are slow and track resurfacing is infrequent a continuous uniform surface may be satisfactory. Likewise, if a crossing is on a good well-drained subgrade and periodic track surfacing can be carried out on each track approach by the undercutting method without disturbing the elevation of the crossing, a good continuous uniform surface may be most economical. However, it is obviously unwise and uneconomical for a main track to be encased in a continuous concrete pavement which would require a large expenditure for concrete removal and replacement in connection with any element of track maintenance.

Fortunately a rather wide variety of crossing surface types are available, from which choices may be made to best suit the bimodal requirements of a variety of individual crossing locations. The selection of the type of crossing surface to be used should not be a unilateral decision, but should always be made after consultation between representatives of the railroad and the highway agency or agencies involved at the specific location. Consideration should be given to the physical suitability of the available types of surfaces to satisfy the use and maintenance requirements of both modes and to the overall economics of the proposed installation.

6.3.1 Composite Crossings

It has been suggested that there would be some economy in using composites of the crossing surface types at individual crossings, using more expensive and more durable materials for those portions of the crossing within the highway traffic lanes and using less expensive materials at the ends of the crossing which constitute a continuation of the highway shoulder areas. Although under certain circumstances this might be a suitable and economical procedure, it seems generally to be more logical to use the same type of material throughout the crossing area, and for those materials which can be removed and replaced, recognize that the relatively little used sections provide a source of replacement materials which can be utilized to replace worn sections when the latter cease to render satisfactory service. The worn sections, in turn can be moved to the areas that are a continuation of the highway shoulders.

6.3.2 Estimated Costs

A tabulation of estimated costs for several types of crossing material is set out in Table 21. This table is reproduced from FHPM 6-6-2-3 (2). It should be used judiciously and with full attention to the notes contained on the lower portion of the table and in the text of the FHPM, the principal essentials of which are repeated herein. The cost data available was quite limited.

When comparing these cost figures, it must be kept in mind that not all crossing surface types are equally suitable for every situation.

As indicated in the notes in the table, the estimated costs for the several types of crossing surfaces are compared on the basis of having each installation placed at a crossing with similar requirements for periodic track maintenance resurfacing on a 6-year cycle. Rather obviously, a plain bituminous crossing without any type of header is not very suitable for the specified situation, whereas a crossing of that type would be more suitable and have better economic justification at less important crossings. Adjustment in the estimated cost figures would be in order when considering the use of a bituminous crossing, either plain or with timber or rail headers, at less important crossings.

Likewise with the epoxy elastomeric crossing, the estimated annual cost per track foot would be reduced to $32.58 if it could remain in place for an estimated service life of 30 years without having to be removed and replaced for periodic track resurfacing.

With the increasing use of traveling undercutting and ballast cleaning machines in out-of-face track resurfacing operations, the need

Table 21.

TABLE OF ESTIMATED AVERAGE COSTS OF VARIOUS TYPES OF CROSSING SURFACES[1] (1975)

	Estimated Average Life, Years	Costs per Track Foot				Annual Cost Per Track Foot
		Original Cost[2]	6-Year Cyclic Cost[3]	Comparative Annual Total of Original Cost, Replacement & Cyclic Cost[4]	Annual[5] Maintenance	
1. Bituminous, plain	6	$90.	$30.*	$13.25	$15.00	$28.25
2. Bituminous, with treated guard timbers on each side of running rail	12	110.	30.*	15.88	12.00	27.88
3. Bituminous, with rail flangeway	12	100.	30.*	14.31	12.00	26.31
4. Full treated wood plank	15	110.	20.	16.21	10.00	26.21
5. Sectional treated timber, gum	15	130.	15.	17.03	7.00	24.03
6. Precast concrete slabs	20	160.	30.	21.46	7.00	28.46
7. Metal sections	20	170.	15.	22.96	5.00	27.96
8. Linear polyethylene modules	15	175.	15.	22.95	5.00	27.95
9. Rubber panels	30	310.	15.	34.73	5.00	39.73
10. Epoxy elastomeric	20	260.	150.*	46.63	5.00	51.63

NOTES:

1. Based upon a crossing carrying 3,000 to 5,000 vehicles per day and 10 to 15 trains per day under average conditions of subgrade and climatic conditions, requiring a complete track resurfacing at 6-year intervals.

2. Including renewal of all crossties, new ballast and track surfacing, but making no allowance for subgrade compaction and installation of drainage facilities which may be required at some locations. These trackwork items estimated to cost $60.00 per track foot and have a service life of 30 years.

3. Includes cost of removal and replacement of crossing surface material in connection with 6-year cycle of track resurfacing, exclusive of tie renewals or any other cost related to resurfacing of normal track not involving a grade crossing.

4. Based on 10 percent per annum interest charge, with future costs converted to present worth.

5. Estimated cost of continuously maintaining riding surface in good condition.

*Represents complete replacement of bituminous and epoxy elastomeric material. If used for crossings where cyclic track resurfacing is less frequent, longer life may possibly be obtained for some of these crossing surfaces before complete replacement.

SOURCE: Reference 2.

to disturb the track elevation at grade crossings assumes less importance. It might be important to note also that the epoxy elastomeric crossing surface completely seals the crossing area from moisture penetration from rain or snow, and that it requires no attachment through holes bored into the crossties.

In many instances the cost and estimated life figures used in the table are averages of some rather widely varying data available from several sources. For situations where firm figures are available which differ from those in the table, appropriate adjustment should be made in assessing the annual costs.

6.4 INSTALLATION GUIDELINES FOR CROSSING SURFACES

6.4.1 Specification References

Specifications for the construction of some types of grade crossing surfaces are contained in the Manual of Recommended Practice of the American Railway Engineering Association, Volume I, Chapter 9. Currently it contains:

(1) General Specifications for Highway Crossings over Railroad Tracks.

(2) Specifications for the Construction of Bituminous Crossings.

(3) Specifications for the Construction of Wood Plank Crossings.

(4) Specifications for the Construction of Prefabricated Sectional Treated Timber Crossings.

(5) Specifications for the Construction of Tracks in a Paved Area.

6.4.2 Preparation of Track Structure

In all cases, regardless of the type of surface material used, adequate preparation of the track structure and the subgrade, including adequate drainage, is essential to good performance and longer service life of a grade crossing surface improvement.

Surface drainage could be improved at many existing grade crossings where there is adequate difference in elevation between crossing surface and ditches or embankment slopes to permit positive outfall.

Temperature variation has an effect on track subgrade and drainage. Average annual rainfall and average annual rate of evaporation have been quantified for most parts of the country. Research studies are underway to combine these measured parameters with soil criteria to predict foundation strength. Soil suction is a good measure of the subgrade condition relating to impending deterioration (3, p. 60).

Excessive moisture in the soil can cause track settlement, accompanied by penetration of mud into the ballast section. Average annual rainfall is a partial indicator as are cumulative rainfall evaporation rates. The drying rate of the surface and lower strata will vary with the type of foundation material.

In many areas the porosity of the soil and the height of the water table prevent rapid migration of moisture once it enters the soil pores. Here evapotranspiration can be accelerated by an adequate ground cover planting. Even trees and other large plants can be used to speed the water cycle.

In an arid region with low volume, lightweight highway traffic, the asphalt crossing may be quite satisfactory; whereas in a damp area having plastic, clayey soil, special subgrade treatment may be a necessity. A continuous membrane of specially prepared fabric placed between the track ballast and the subballast or subgrade throughout the crossing area can reduce or possibly prevent penetration of soft subgrade material into the ballast section, thereby avoiding pumping track conditions and preserving good drainage of the ballast and reducing to a minimum track settlements requiring resurfacing.

6.4.3 Special Subgrade Treatment

Several fabrics have been produced by the petrochemical industry for use in construction of roads and railroads. Some of the available products are listed in Table 22. Figures 33 and 34 show two uses of these fabrics.

Some of these fabrics have sufficient porosity to allow the penetration of water but prevent movement of even the finest soil

Table 22. Petrochemical Ground Stabilization Materials

MANUFACTURER	PRODUCT	DESCRIPTION
Advance Construction Specialities Co., Inc.	Polyfelt TS Fabric	A nonwoven polypropylene fabric.
Carthage Mills	Poly-Filter X® Poly-Filter GB® Filter-X®	Both fabrics woven of polypropylene monofilment yarn. Woven fabric of polyvinylidene chloride monofilament yarn.
Celanese Fibers Marketing Company	Mirafi® 140	A fabric constructed from polypropylene and nylon continuous filament fibers, randomly mixed and heat bonded.
E.I.DuPont de Nemours & Co. (Inc.)	Typar®	A fibrous sheet structure produced by spinning and bonding continuous filaments of polypropylene.
Kenross-Naue, Inc.	Terrafix®	Needled filter mat of polyamide mixture with synthetic resin binder.
Menardi-Southern Division United States Filter Corp.	Monofilter®	A fabric woven of polypropylene monofilament yarn.
Monsanto Textiles Company	Bidim®	A spunbonded, needlepunched, nonwoven polyester fabric.
Phillips Fibers Corporation	Petromat® Supac ™	Both nonwoven polypropylene fabrics.

NOTE: ® indicates manufacturer's registered trademark

Figure 33. Placing Mirafi® 140 on a Prepared Subgrade between Station Platforms.

Figure 34. Compacting Ballast on Top of Phillips Petromat®

particles through them. In addition to use on top of the subgrade or subballast, these fabrics are useful in the formation of French drains utilizing ballast material completely encased in fabric. At many sites, such French drains would provide an economical and reasonably permanent method of draining the ballast below the grade crossing surface material. Perforated metal pipe placed inside the French drains would accelerate the drainage process.

6.4.4 Track Structural Details

In the track structure bolted rail joints should not be permitted within the crossing area or within 30 feet (9.0 m) of either end of the crossing except where special operating conditions or track circuit design requires otherwise. If the track is not laid with continuous welded rail, adequate lengths of welded rail should be placed in the track through the crossing area to comply with these requirements. If the track is laid with 90-pound rail or lighter weight, the rail through the crossing should be of larger size. When a crossing is being constructed or reconstructed, new crossties should be placed throughout the crossing area. Track ballast should be new or thoroughly cleaned for a minimum depth of 8 inches (0.20 m) below the crossties. Unless already in place, a minimum depth of 6 inches (0.15 m) of subballast should be placed below the ballast section. Figure 35 illustrates the connection of a rail to the crosstie.

The grade crossing surface and the track structure supporting it should have a clean separation from the approach roadways on either side of the crossing. At multiple track crossings the center strip of pavement between tracks should likewise have a clean separation from the crossing surfaces. In each instance these separations should preferably be on a vertical plane about one or two inches from the ends of the crossties. Space between the end of the pavement and the grade crossing surface may be filled with the wood plank, some type of fibre board--usually impregnated with asphalt, or bituminous joint filler. A stiff, hard material is preferable in order to avoid mixing pavement material or pavement subgrade particles with track ballast and thereby reducing the drainage effectiveness of the ballast section. A thickened

1. Eliminate rail joints within roadway and for a distance of at least 30 feet beyond each end of the roadway crossing surface.

2. Install heavier rail within the crossing.

3. Install rail anchors at each tie.

4. Use four spikes in each tie plate. Use double shoulder tie plates to provide adequate bearing.

5. Use rubber tie pads under tie plates on each crosstie within limit of crossing.

6. Support field side panels fully on track ties.

7. Bevel ends of crossing planks.

8. Seal flangeway openings and spaces outside the head of the running rails with bituminous or other material.

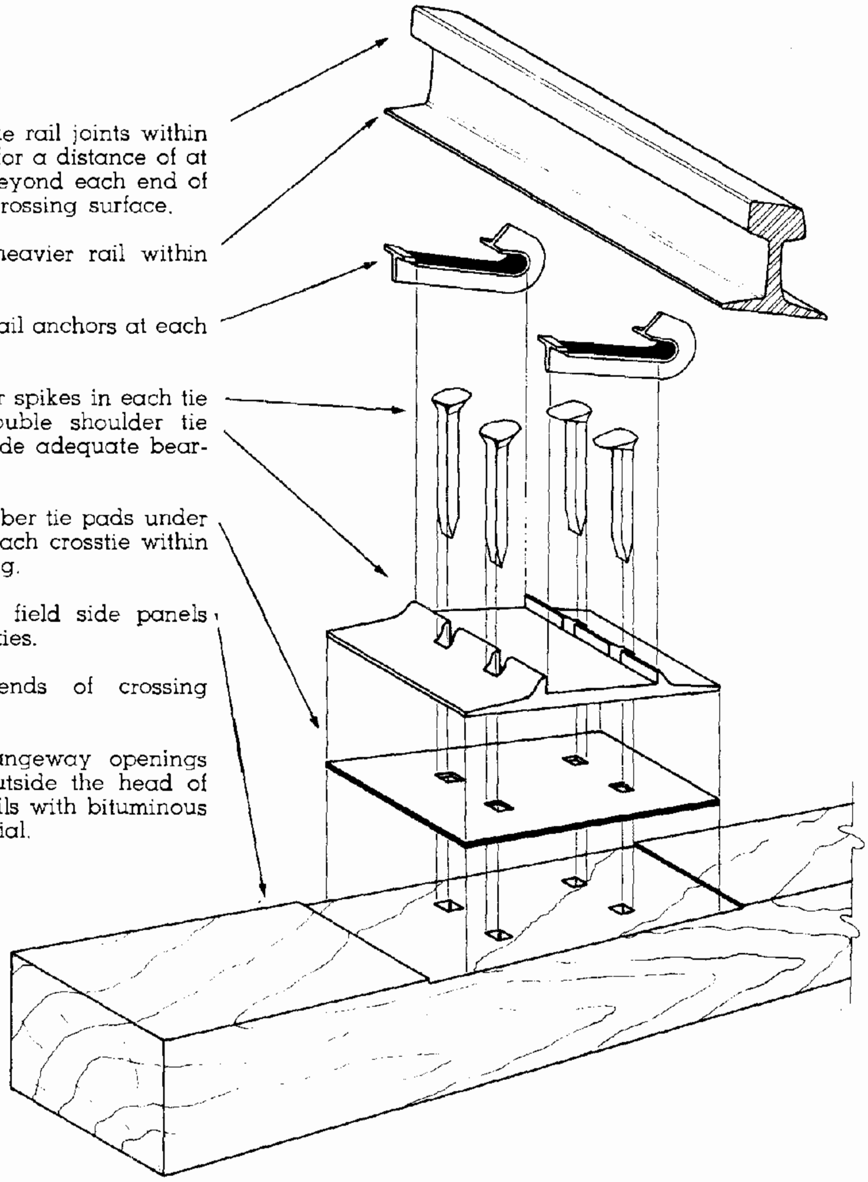


Figure 35. Connection of Rail to Crosstie.

1 ft = 0.304 m

concrete pavement which would have its bottom surface at or below the elevation of the tops of the crossties would serve this purpose quite well.

An open joint at the junction of the pavement and the crossing surface is undesirable because it would form a source of penetration of surface drainage into the ballast section. Likewise, open joints between the head of the running rail and the crossing surface material should be reduced to an absolute minimum in order to prevent excessive flow of surface water into the ballast section. On the gage side of the rail a flangeway opening is necessary but its depth should be no more than 2-1/2 inches (0.06 m). An ideal flangeway width is 2-1/2 inches (0.06 m).

The installed elevation of a grade crossing surface should be in the plane of the tops of the running rails. Installation at a lower elevation would subject the rail head to severe lateral pounding from the wheels of heavy highway vehicles which could in time result in damage to the rail. At the same time vehicles will have a smoother ride over the crossing if the rail does not project above the crossing surface. However, in order to avoid damage to the top surfaces of crossing materials adjacent to the field side of running rails caused by false flanges (resulting from worn wheel treads), all firm materials (as distinguished from bituminous mixes) should have their top surfaces lowered by 1/4 inch (0.006 m) for a distance of 2 inches (0.05 m) outside the rail head. Wood materials may be dapped and other materials formed or ground to accomplish this result as shown in Figure 36. In Figure 23 the typical cross section of the concrete pavement crossing shows the depressed area outside of each running rail. Figure 22 illustrates another treatment of a similar nature.

Grade crossing surface materials should have their top surfaces prepared so as to reduce skidding by motor vehicles. The extreme ends of grade crossing materials in place should be beveled on an angle of approximately 45 degrees for the purpose of reducing the possibility of snagging dragging railroad equipment in moving trains.

An excellent grade crossing surface with excellent roadway

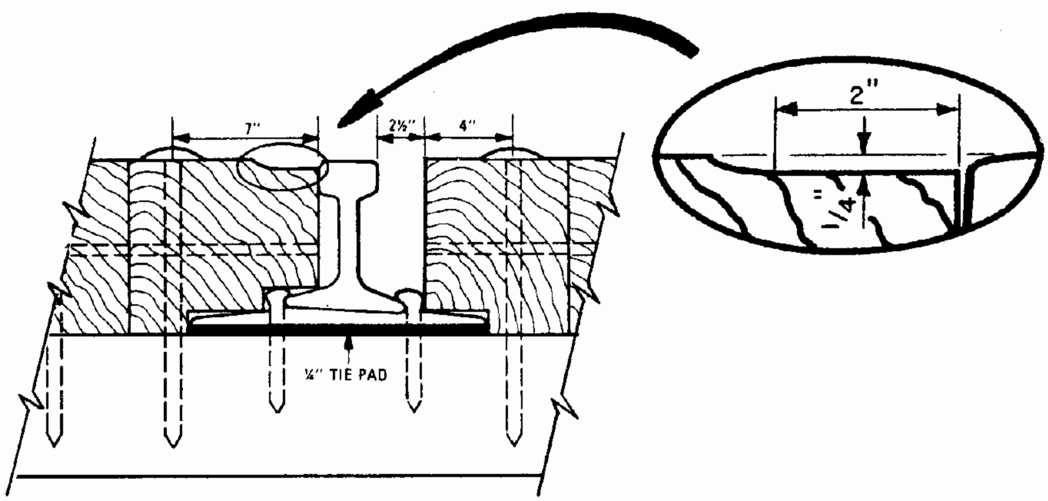


Figure 36. Details of Dapped Area on Top of Sectional Treated Timber Crossing.

1 in = 25.4 mm

approaches will not produce a good ride for the motorist unless they meet at the same elevation. Great care is necessary in constructing the roadway and in surfacing the track to see that there is no vertical offset at the intersection. If time and operating conditions will permit, some railroad traffic should be allowed to move over the track before its final surfacing is completed. At best it may sometimes be necessary to place a thin asphalt pavement runoff to get a final fit. On a track with heavy railroad traffic it is necessary from time to time to resurface the track through the crossing, but this can be kept to a minimum if all initial installation work is carefully done, especially the preparation of the track structure, including subgrade and drainage.

Optimum installation of a grade crossing, reduces the need to change its elevation each time periodic track resurfacings are performed. Even though the railroad line is raised during such an operation, run-offs in the grade line may be made in the vicinity of the crossing by utilizing undercutting and ballast cleaning methods.

Careful attention to details of track installation combined with proper preparation of subgrade and installation of adequate surface and subsurface drainage will enhance good performance of surface materials. Thus optimum benefits may be realized from expenditures for new surfacing materials. Major track rehabilitation projects are underway in many parts of the country. Some of this work is being done by solvent roads as part of regular maintenance of way operations. In the northeast and midwest much work is being accomplished with funds which have become available under the Railroad Revitalization and Regulatory Reform Act (popularly known as the 4R Act) of 1976. In addition, some rehabilitation is being sponsored by AMTRAK, which is also concerned with grade crossing improvements. Improved crossing surfaces placed on good subgrades should be a part of a general track rehabilitation.

6.5 SURFACE CONDITION

Rideability is an important consideration in safe and efficient operations of vehicles on highways. Rough pavement produces poor rideability, smooth pavement produces good rideability.

The Mays Ride Meter, an instrument installed in an automobile, was developed to permit measurement of comparative rideability of highway pavements. Its use can be extended to make comparative measurements at and near grade crossings.

The ride meter consists of a transmitter, attached to the body of an automobile, which produces one electrical impulse for each 0.1 inch (0.0025 m) of upward or downward displacement of the rear axle. Excursions of the axle are recorded on a paper chart actuated by a variable rate feeding mechanism. Perfectly smooth pavement will not drive the chart, whereas rough pavement will drive the chart rapidly. Pavement discontinuities such as railroad crossings are readily observed on the paper record. Three traces are recroded by pens on the paper chart, as shown in Figure 37.

(a) Distance Trace. This square wave record is produced by a special odometer, independent of chart feed; an upward zig or downward zig represents 0.05 miles (80.47 m) traveled by the automobile.

(b) Profile Trace. A record of excursions of the axle with respect to the vehicle body. One-half inch (0.013 m) on the chart represents one inch (0.025 m) of vertical movement of the axle. Axle movements of less than 0.1 inch (0.0025 m) are filtered by the transmitter and are not recorded.

(c) Landmark Trace. An event mark manually placed on the record by the operator. (In this example he would write: RRXing.)

The location of the railroad crossing can be readily observed on the distance trace, the profile trace, and the landmark trace of Figure 37. Some quantitative comparisons can be made between the roadway

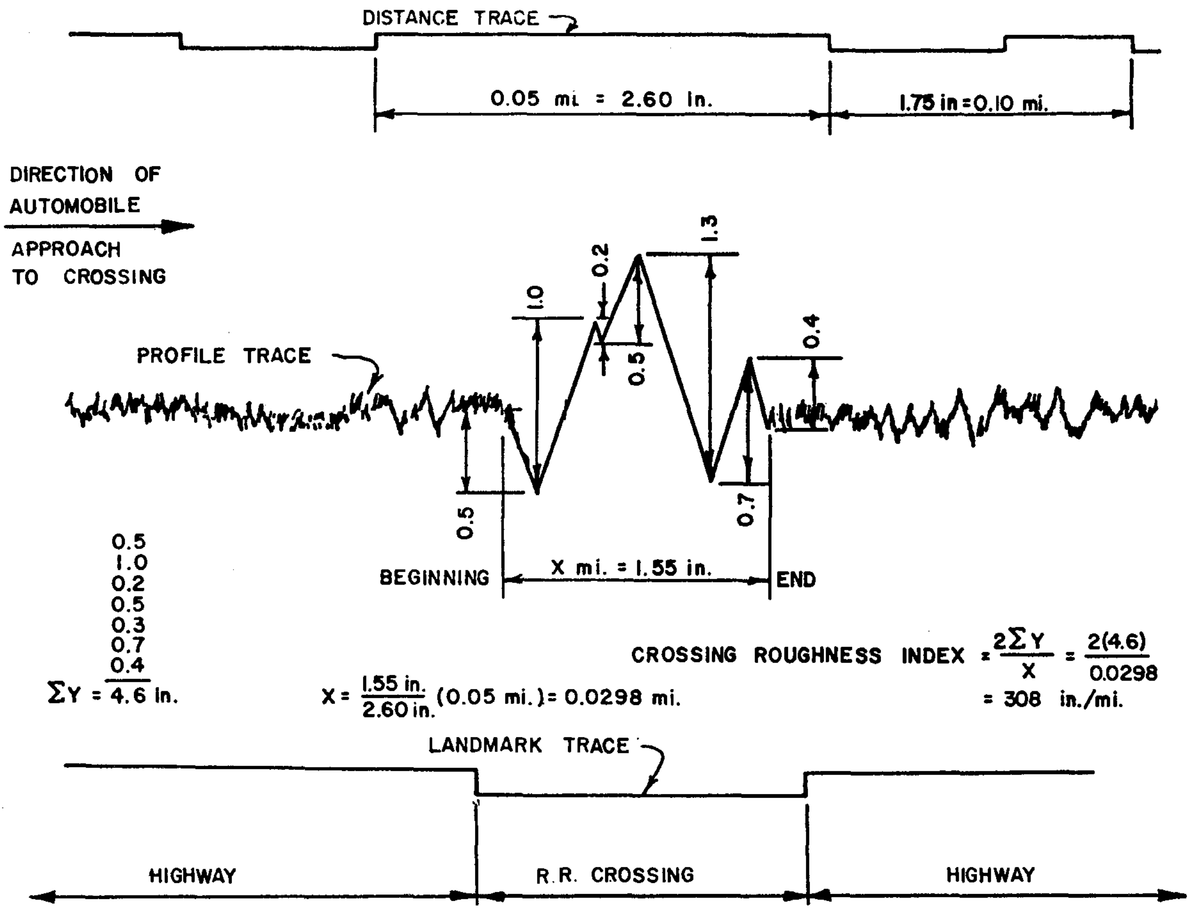


Figure 37. Typical Mays Ride Meter Chart

1 in = 25.4 mm
1 mile = 1.61 kilometres

roughness near the crossing and the roughness of the crossing itself.

A roughness index may be defined as the ratio of the summation of the axle excursions to the distance the automobile travels:

$$\text{Roughness Index} = \frac{\sum_{i=1}^{n} 2y_i}{x}$$

where: y_i = measured excursion of axle, inches
2 = multiplying factor
x = event distance, miles

The measured excursions are doubled because the recording pen moves 1/20 inch (0.0013 m) when the axle moves 1/10 inch (0.0025 m).

The following procedure may be followed to compute the Roughness Index at a crossing:

1. Identify the crossing area; beginning and end of the crossing are shown in the figure.
2. Determine the length of the crossing by using the distance trace and the profile trace:
   a. Measure the event distance
   b. Measure the distance trace
   c. Compute length as shown on the figure
3. Determine total axle excursions by summing y_i.
4. Compute Roughness Index.

In the example shown, the crossing roughness index is 308 inches per mile (4.86 m/km).

An alternative method produces a similar index. The Mays Ride Meter drives the chart 5 inches for 32 inches (0.156 m for 1 m) of total vertical movement of the axle. Thus, the distance trace may be employed to compute the crossing roughness directly:

$$\text{Crossing Roughness Index} = \frac{2.60\text{ in.}}{0.05\text{ mi.}} \times \frac{32\text{ in.}}{5\text{ in.}} = 332\ \frac{\text{in.}}{\text{mi.}}\ (5.24\text{ m/km})$$

The roadway roughness index can also be computed by using the distance trace:

$$\text{Roadway Roughness Index} = \frac{1.75 \text{ in.}}{0.01 \text{ mi.}} \times \frac{32 \text{ in.}}{5 \text{ in.}} = 112 \frac{\text{in.}}{\text{mi.}} \text{ (1.77 m/km)}$$

Many records were reduced using the basic measuring system described previously, and it was found that axle excursions at smoother crossings were difficult to measure, as are axle excursions on smoother highways. Therefore, the alternate method using the distance trace was adapted and employed for comparisons. The indices varied from 70 in./mile (1.10 m/km) (smooth crossing) to 800 in./mile (12.63 m/km) (rough crossing).

Deceleration and braking produce roughened pavement near a crossing. Thus, crossing evaluation must include the pavement adjacent to the crossing. For the example shown in the figure, the effective length of the crossing is 150 feet (45.72 m) to 260 feet (79.25 m).

Comparative measurements using the Mays Ride Meter provide a method for making priority decisions for crossing replacements. A computer program, DYMOL, has been developed which simulates dynamic wheel loads on highway-railroad intersections (3, p. 65). The program provides another method for comparing relative roughness at selected crossings.

6.6 REFERENCES

1. Hedley, W. J. State-of-the-Art Report on Railroad-Highway Grade Surfaces. U.S. Department of Transportation, Federal Highway Administration, 1973.
2. Railroad-Highway Grade Crossing Surfaces, Federal-Aid Highway Program Manual. U.S. DOT, FHWA, Volume 6, Chapter 6, Section 2, Subsection 3, Transmittal 173, December 17, 1975.
3. Newton, T. M., Lytton, R. L., and Olson, R. M. Structural and Geometric Characteristics of Highway-Railroad Grade Crossings. Research Report 164-1, Texas Transportation Institute, Texas A&M University, College Station, Texas, 113 p., August 1975.

7.0 GRADE CROSSING TRAFFIC CONTROL DEVICES

Grade crossing traffic control devices are signs, signals and markings placed on or adjacent to the highway approach to a railroad grade crossing. These include both passive and active devices. Passive devices used include all signs and pavement markings. Active devices are flashing light signals, gates, bells, and all other devices that are train actuated. This chapter presents an introduction to each of the traffic control devices used at grade crossings. Also presented are the types of systems used to control active devices. The chapter concludes with guidelines for the selection, design and maintenance of control devices and control systems.

7.1 PASSIVE DEVICES

Passive grade crossing traffic control devices are all those that do not give warning of the approach or presence of a train, locomotive, or cars on the crossing. That is, their message is always displayed. Passive devices essentially consist of signs and pavement markings. This section presents a discussion of each type of passive device along with guidelines for their design and application. National standards for the use of all passive devices are set forth in the *Manual on Uniform Traffic Control Devices* (MUTCD) (1), much of which is included here.

7.1.1 Signs

Signs are used at railroad-highway grade crossings to identify and direct attention to the location of the crossing and thus permit motorists and pedestrians to take appropriate action. Such signs may include the following:

1) Railroad Crossing
2) Number of Tracks
3) Advance Warning
4) Exempt
5) Stop
6) Advisory Speed
7) Turn Restrictions
8) Do Not Stop on Tracks

7.1.1.1 Railroad Crossing (Crossbuck) Signs -- The MUTCD specifies the following design and placement criteria for crossbucks:

> The railroad crossing sign, commonly identified as the "crossbuck" sign (Figure 38), 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 on each approach to the crossing. Where an engineering study has determined that restricted sight distance or unfavorable road geometrics require, crossbuck signs shall be placed back to back or otherwise located so that two faces are displayed to each approach.
>
> Crossbuck signs should be located with respect to the roadway pavement or shoulder in accordance with the criteria in sections 2A-21* through 2A-27 and figures 2-1 and 2-2 should be located with respect to the nearest track in accordance with signal locations in figure 18-7. The normal lateral clearances (sec.2A-24): 6 feet (1.8 m) from the edge of the highway shoulder or 12 feet (3.7 M) from the edge of the traveled way in rural areas and 2 feet (0.61 m) from the face of the curb in urban areas will usually be attainable. Where unusual conditions demand, variations determined by good judgement should provide the best possible combination of view and safety clearances attainable, occasionally utilizing a location on the left hand side of the roadway.

If adjacent crossings are separated by 100 feet (30.48 m), they should be treated with appropriate compliments of crossbucks.

7.1.1.2 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 in the manner and at the heights indicated in Figure 39, except that use of this auxiliary sign is optional at crossings with automatic gates (MUTCD).

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* NOTE: Citations contained in this paragraph refer to specific sections and figures in the MUTCD.

Figure 38. Railroad Crossing Sign (Crossbuck)

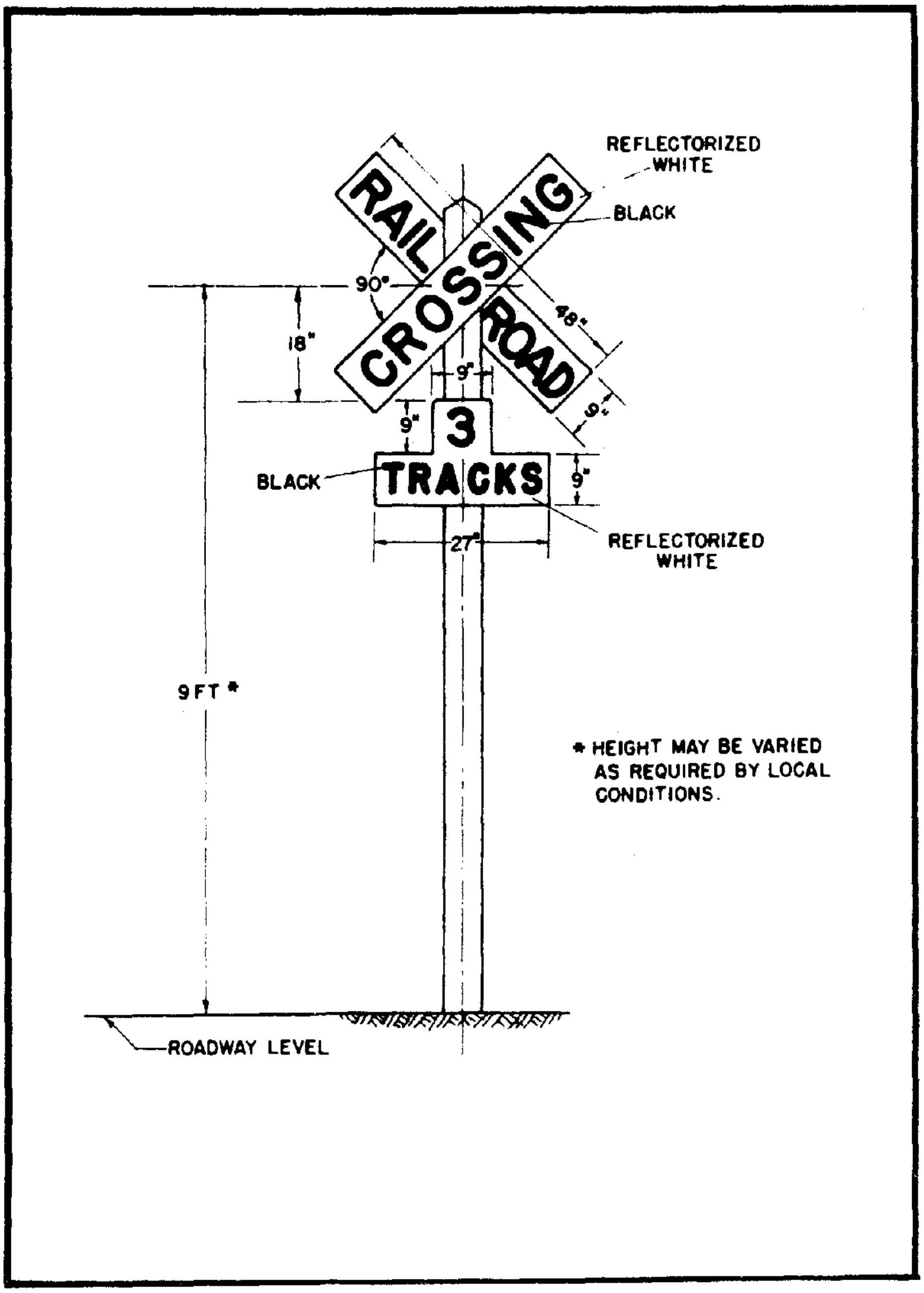


Figure 39. Railroad Crossing Sign and Number of Tracks Sign

1 m = 25.4 mm
1 ft = 0.304 m

7.1.1.3 Advance Warning Sign -- For the advance warning sign, the MUTCD specifies:

> A Railroad Advance Warning Sign (Figure 40) shall be used on each roadway in advance of every grade crossing, except on low volume, low speed roadways crossing minor spurs or other tracks which are infrequently used and which are flagged by train crews, in the business districts of large cities where active grade crossing traffic control devices are in use, or where physical conditions do not permit even a partially effective display of the sign. On divided highways it is desirable to erect an additional sign on the left side of the roadway.
>
> Placement of the sign shall be in accordance with section 2C-3 and sections 2A-21 to 2A-27, normally 750 feet (230 m) or more in advance of the crossing in rural areas and 250 feet (75 m) in advance of the crossing in urban areas except that in a residential or business district, where low speeds are prevalent, the sign may be placed a minimum distance of 100 feet (30 m) from the crossing. If there is a street intersection within 100 feet (30 m) an additional sign or signs may be placed to warn traffic approaching the crossing from each intersected street. Lateral clearance of the advance warning signs are determined by the same criteria as for the crossbuck sign (sections 2A-21 to 2A-27).

7.1.1.4 Exempt Crossing Signs -

> When authorized by law or regulation a supplemental sign (R15-3, figure 41) bearing the word EXEMPT may be used. The crossbuck and track signs at the crossing and a supplemental sign (W10-1a) may be used below the Railroad Advance Warning Sign 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. (MUTCD)

7.1.1.5 Stop Signs -- In 1975 the State of Florida asked for an official ruling on the use of stop signs at unsignalized rail highway grade crossings. The intent of the MUTCD relative to stop signs for rail/highway grade crossings is contained in Item 4, Section 2B-5, of the 1971 MUTCD. The ruling is a clarification and it governs the installation of stop signs at rail/highway grade crossings. The ruling follows:

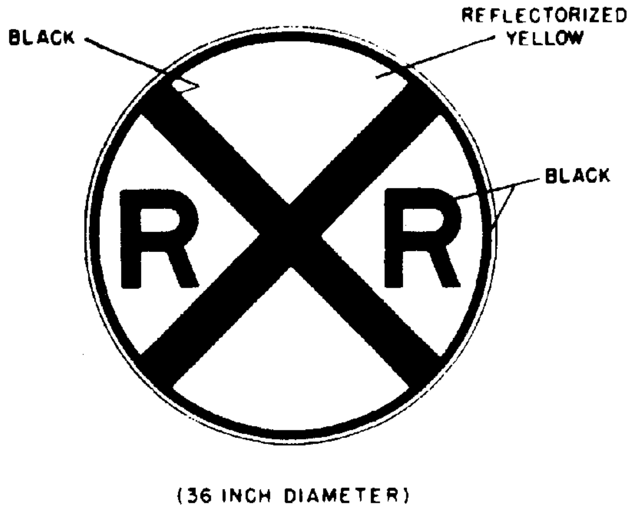


Figure 40. Railroad Advance Warning Sign

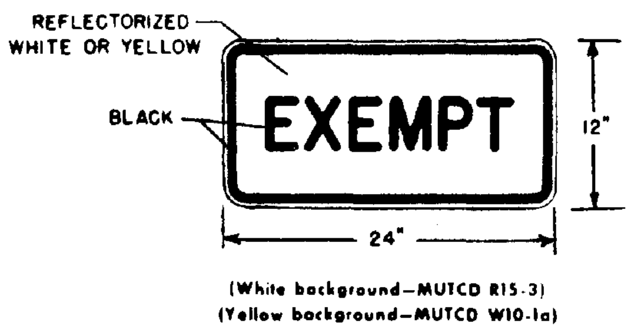


Figure 41. Exempt Sign

1 in = 25.4 mm

The interpretation is that STOP Signs should not be installed indiscriminately at all unprotected crossings. The allowance of STOP Signs at all such crossings would eventually breed contempt for both law enforcement, and obedience to the sign's command to stop. STOP Signs may only be used at selected railhighway crossings after their need has been determined by a detailed traffic engineering study. Such studies should consider approach speeds, sight distance restrictions, volumes, accident records, etc. This application of STOP Signs should be an interim use period during which plans for lights, gates, or other means of control are being prepared (2).

7.1.1.6 Advisory Speed Signs -- An Advisory Speed Sign (W13-1 in MUTCD) should be used in conjunction with advance warning signs when site or geometric conditions are such that ample time can not be provided for the driver to correctly maneuver his vehicle through the railroad-highway intersection (i.e., the minimum sight triangle is not obtainable for highway speed). The advisory speed sign should reduce the drivers speed to no less than 15 mph (24 km/h), preferable 20 mph (32 km/h), to allow the driver sufficient time to safely respond to conditions at the crossing. The sign is usually placed on the same support as the advance warning sign.

7.1.1.7 Turn Restrictions -- The MUTCD states the following concerning restrictions on turns at grade crossings:

> At a signalized highway intersection within 200 feet (60 m) of a grade crossing, where the intersection traffic control signals are preempted by the approach of a train, all existing turning movements toward the gradecrossing should 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 shall be visible only when the restriction is to be effective. A blank-out, internally illuminated, or other similar type sign may be used to accomplish this objective.

In some instances it may also be necessary to utilize the NO TURN ON RED Sign (Figure 42) in order to properly control all turning movements.

7.1.1.8 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 (Figure 43). The sign should normally be placed on the far right side of the grade crossing. One multilane roads and one-way roadways a second sign should be placed on the far left side of the grade crossing.

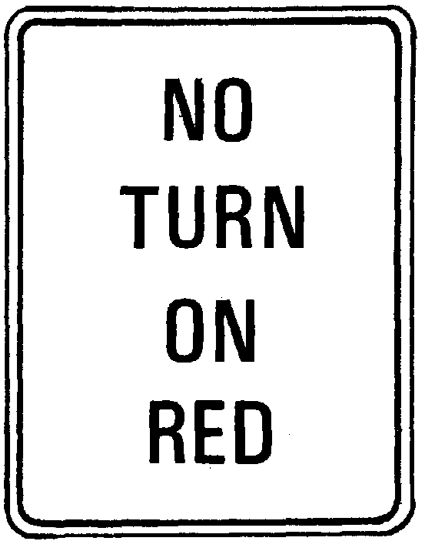


Figure 42. No Turn On Red

Figure 43. Do Not Stop On Tracks

7.1.2 Pavement Markings

The MUTCD states the following with respect to 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 (64 km/h) 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 44. 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.

7.2 ACTIVE DEVICES

Active grade crossing traffic control devices include all signals, bells and gates or other devices or methods that inform motorists and pedestrians of the approach or presence of trains, locomotives or railroad cars on grade crossings. The great majority are train-actuated (automatic). Devices to be discussed in this section include flashing light signals, automatic gates and bells. Preemption of nearby traffic signals on the highway approaches to crossings with active devices is also discussed. Criteria for the application and operation of all active devices is presented.

7.2.1 Flashing Light Signals

The flashing light signal is the basic active grade crossing traffic control device.

7.2.1.1 Application -- Flashing light signals are normally used where highway traffic is of low to medium volume and the highway is bidirectional with a single lane in each direction. Rural roads and urban streets are generally good candidates for flashing lights.

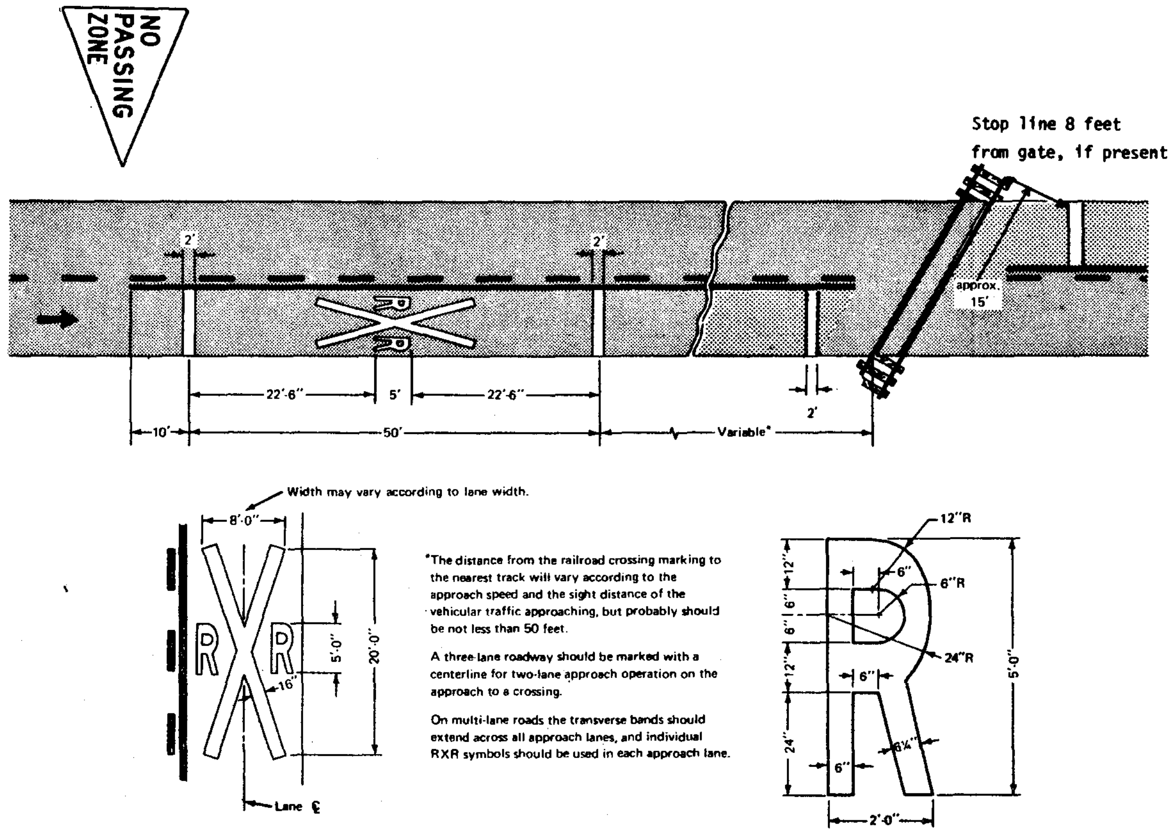


Figure 44. Typical Pavement Markings at Grade Crossings

1 in = 25.4 mm
1 ft = 0.304 m

The speed and volume of train traffic should also be considered. Where train speeds are medium and the number of trains is relatively low, flashing light signals are generally satisfactory. There are, of course, exceptions which will dictate the use of other types of control devices such as gates.

Until a few years ago, the general practice was to use flashing light signals on single track crossings, and gates on multiple track crossings but this is no longer the guiding rule. Under normal circumstances flashing light signals without gates should not be used at multiple track crossings, especially if there are two or more main tracks involved.

7.2.1.2 Description -- Although many wig-wag signals continue in operation, no new ones have been installed in recent years. Flashing light signals have become standard. A flashing light signal (Figure 45) consists of two flashing red electric light units mounted 30 inches (0.762 m) apart on a horizontal crossarm. The crossarm is generally attached to a post seven to nine feet (2.13 to 2.74 m) above the crown of the highway. Depending on the visibility of the roadside signals, it is sometimes necessary to install overhead signals on a cantilever structure extending horizontally from a higher post. Cantilever supported signals are suitable for many multilane roadways.

7.2.1.3 Light Units -- The light unit is the arresting part of the flashing light signal. The main components of the light unit are the hood, background, roundel, lamp, lampholder, reflector, and housing.

The background, which is 20 inches (0.508 m) in diameter, and the hoods are painted a nonreflecting black to provide a contrast for the red light. The roundel, red in color, may be 8-3/8 or 12 inches (21.3 or 30.5 cm) in diameter. The assembly permits easy access to the reflector and lamp. The unit when closed is weathertight, and ventilators are provided for free circulation of air. Each unit is focused by the manufacturer using a signal precision lamp to provide maximum range and efficiency. The focused beam must be installed and maintained to afford best visibility to approaching traffic.

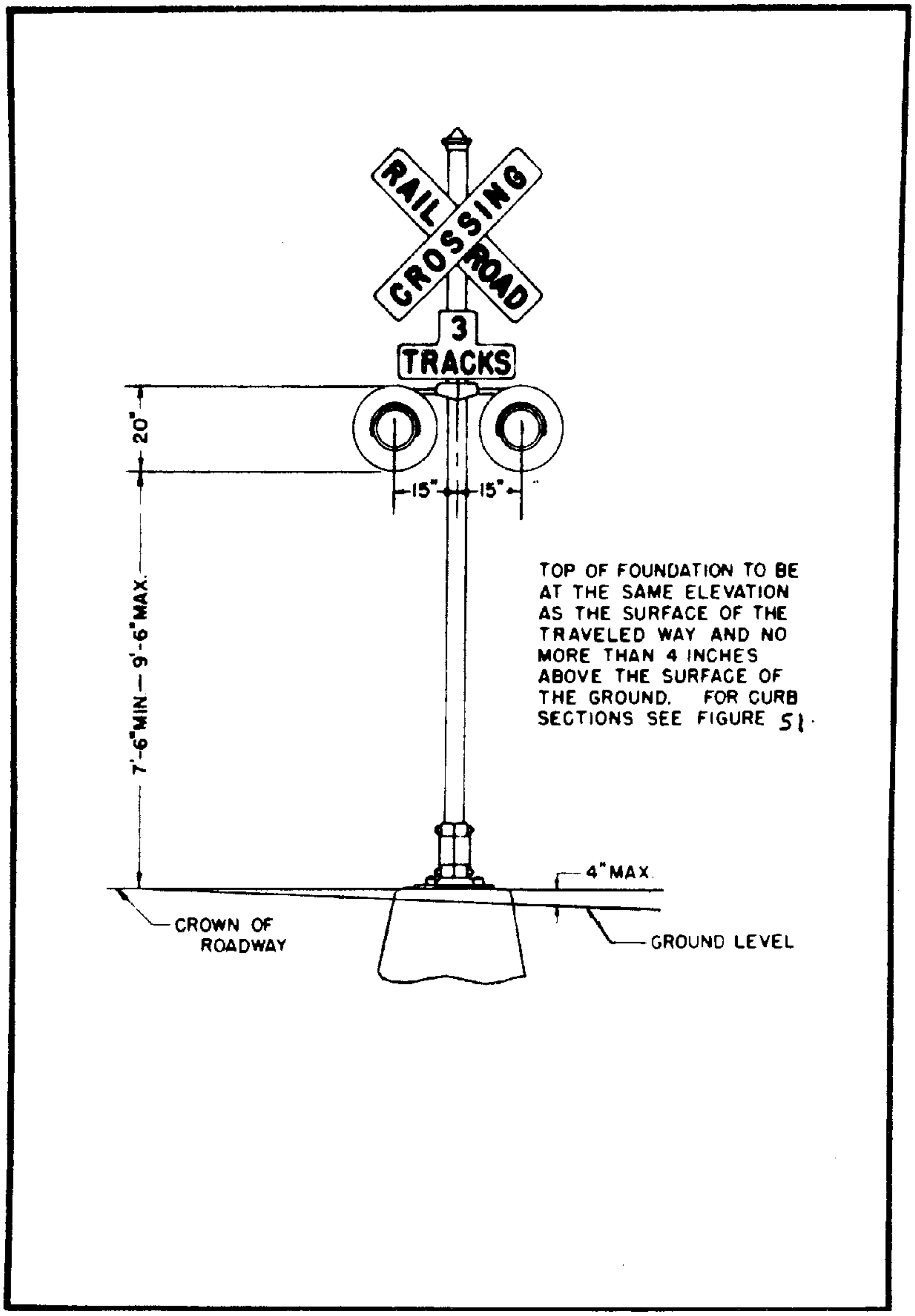


Figure 45. Typical Flashing Light Signal - Post Mounted

1 in = 25.4 mm
1 ft = 0.304 m

The bulbs used in flashing light signals are relatively low wattage. This is dictated by the limitations of standby power. The first bulbs were 11 watt; present practice is to use 18 to 25 watt lamps, some reflectorized, or special quartz-iodide (QI) type of 16 and 36 watts.

The small wattage lamps require a very efficient light unit which makes use of a parabolic mirror to reflect all light possible forward out of the unit. Light distributing roundels are designed to focus most of the available light into a beam of limited spread both horizontally and vertically. Because the light emanating from the light unit is controlled, signal head alignment is important. The head should be very carefully aligned so that the beam is directed at the point where the driver must make a decision. If roadway alignment is such that the flashing light signal is not visible to all approaching drivers (both near and far), additional units should be installed (Figure 46). Additional units on the same posts or on additional post(s) should be focused on approach routes on nearby intersecting streets.

A typical roundel, either glass or break-resistant lexan, is illustrated in Figure 47. Different roundels are used to obtain a particular light distribution pattern to meet the needs at a given crossing. The "spreadlight" roundel distributes light uniformly through the entire angle indicated on the glass, one-half the angle being on each side of the beam axis. A common example of such a roundel is the 30-degree horizonal spread. A deflecting roundel directs a portion of the light from the beam to one side of the axis in the direction indicated on the glass. A roundel having both spreadlight and deflecting features is so designed that the deflection is at a right angle to the spread. An example is the 20-degree horizontal deflection and 10-degree vertical spread in the roundel illustrated in Figure 47. A roundel using a 20-degree spread and 32-degree downward deflection is used on cantilever type signals (3). Other combinations include roundels producing 70 degree and 20 degree horizontal spread with 5 degree and 15 degree downward deflection, respectively. The identification of the characteristics of each is molded in the glass and it is important that the same kind be used in replacement.

Each light is alternately illuminated at a rate of 35 to 55 times per minute. Generally, the light units are installed "back to back" where

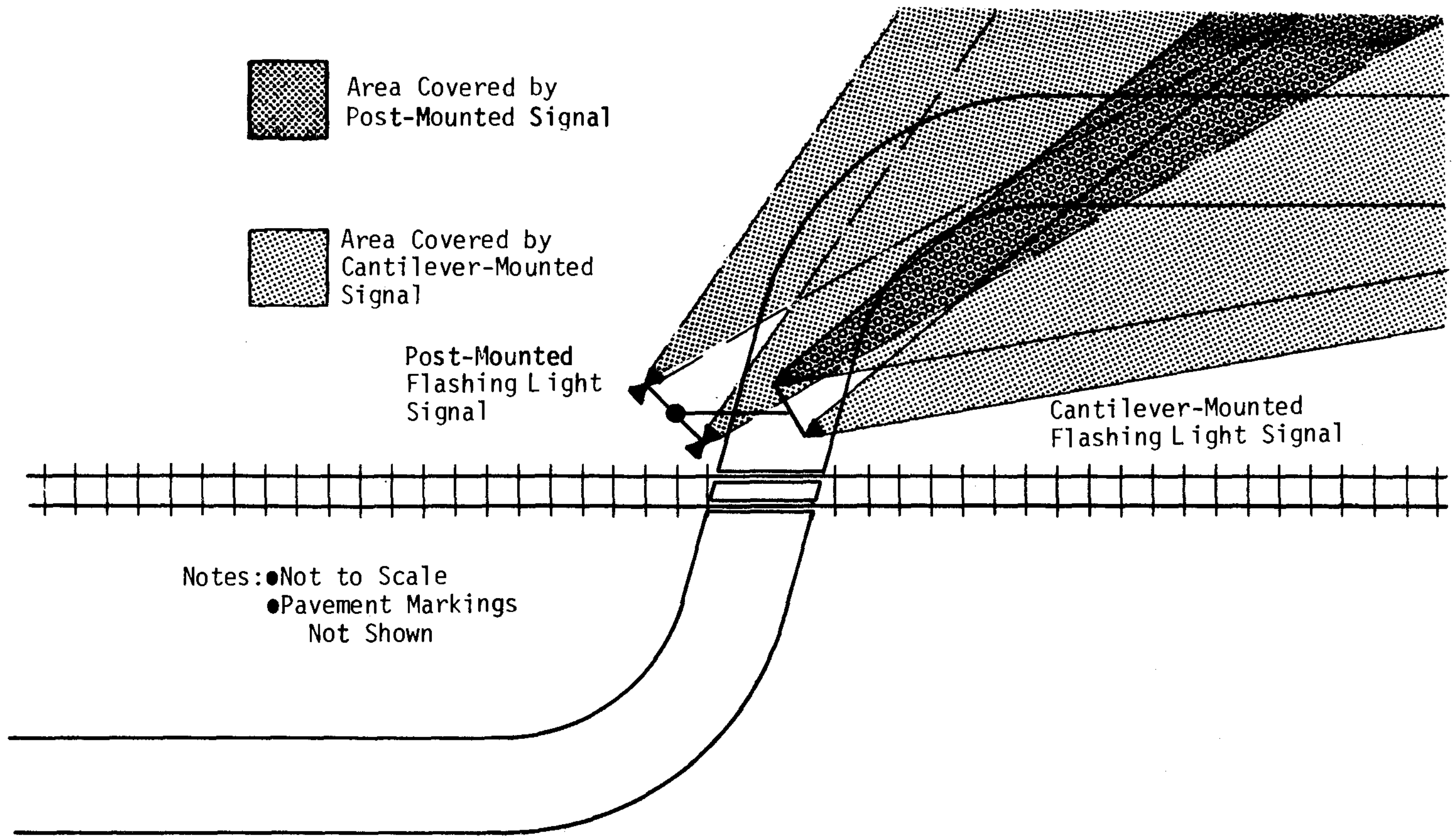


Figure 46. Use of Multiple Signals for Adequate Visibility

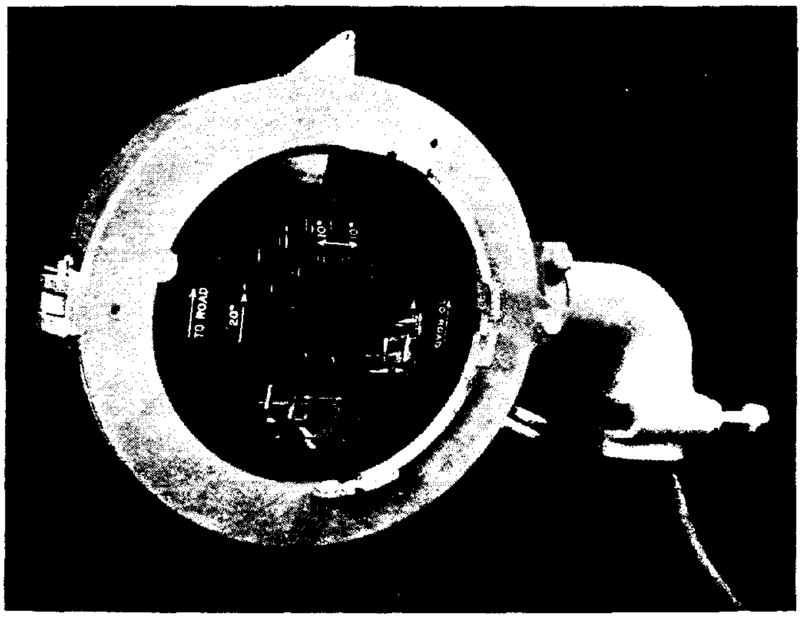


Figure 47. Illustration of a Typical Roundel

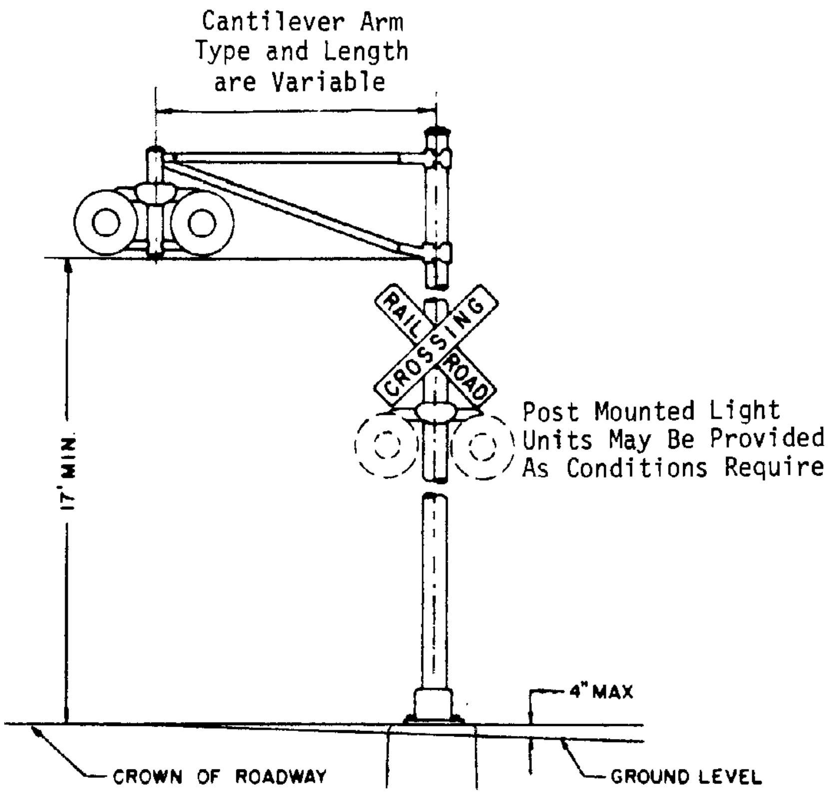
the traffic on the highway is in both directions. Such an arrangement is required by MUTCD Part VIII, Section 8C-2. It provides an indication for the driver when passing another vehicle and when the near signal is obstructed by parked or large vehicles. Roundels with 70-degree spread are frequently used on back lights. Variations in light distribution as well as the location of the signals themselves are often made where in the opinion of qualified engineers such deviation is desirable or required to meet specific conditions.

7.2.1.4 Mounting Configurations -- There are two basic mounting configurations - post mounting and cantilever mounting. Post mountings (Figure 45) are used (with or without gates) where traffic and/or site conditions are such that the approaching driver will have no difficulty in detecting the presence and operation of flashing light signals. Cantilever mountings (Figure 48) should be considered to supplement the post-mounted units when any of the following conditions exist:

- there are a considerable number of distractions near or beyond the crossing which would compete for the driver's attention, and especially when there are other light sources (advertising, etc.) beyond the crossing;
- traffic or parking conditions are such that the view of a post-mounted flashing light signal could be blocked;
- angle of approach to the crossing is acute and post-mounted signals could go undetected;
- on multi-lane highways in order that the flashing light signals will be visible to drivers in all approaching traffic lanes;
- on high speed/high volume rural highways.

The number of flashing light signals to be placed on a cantilever mounting is variable. As the indication on all units will always be identical, usually only one flashing light signal is placed on the cantilever. On multi-lane thoroughfares where overhead traffic signals are mounted separately over each lane at street intersections, flashing light signals should be placed over each lane to avoid confusion in the general control pattern.

Cantilevers are available in fixed, rotatable and walk-out models with arm lengths from 8 to 26 feet (2.44 to 7.92 m). The MUTCD specifies



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 51)

Figure 48. Typical Flashing Light Signal
Cantilever Supported

1 in = 25.4 mm

1 ft = 0.304 m

that cantilever structures shall not have breakaway or frangible bases. Escape areas, attenuators or properly designed guardrail should be used where conditions warrant.

7.2.2 Automatic Gates

The automatic gate is the most restrictive of all grade crossing traffic control devices. When activated this device physically separates the approaching vehicles from the grade crossing. In addition to its physical separation, the automatic gate presents a visible barrier across the highway.

7.2.2.1 Application -- Automatic gates have proven to provide the best warning of any device in use. In almost all cases they include flashing light signals. Crossings with multiple main line or main line and passing siding are candidates for gates except under some special conditions.

Gates should be considered for single track crossings with high speed trains, particuarly passenger trains, and medium to heavy highway traffic. Some areas with special conditions such as poor sight distances, peaked traffic, either highway or railroad, and crossings with a high "risk" factor generated by a substantial number of school buses, trucks carrying hazardous materials, or continuing accident occurrences, should also be considered for gates. Some states have adopted a policy of using gates at all crossings unless there is some specific objection.

Gates normally close off that part of the highway used by approaching traffic; on one-way thoroughfares they block the roadway completely on the approach side of the tracks. Regardless of the arrangement, the leaving side of the crossing is always left open for highway traffic to escape from the crossing (Figure 49).

7.2.2.2 Description -- An automatic gate is a grade crossing traffic control device normally having flashing light signals as a part of the warning display. The device consists of a driver mechanism and fully reflectorized red and white striped gate arm with lights. The gate arm, in the down position, extends across all approaching traffic lanes, approximately four feet (1.22 m) above the pavement. Accompanying flashing light signals may be mounted in any of the previously discussed configurations, either contiguous with the gate mechanism or separately.

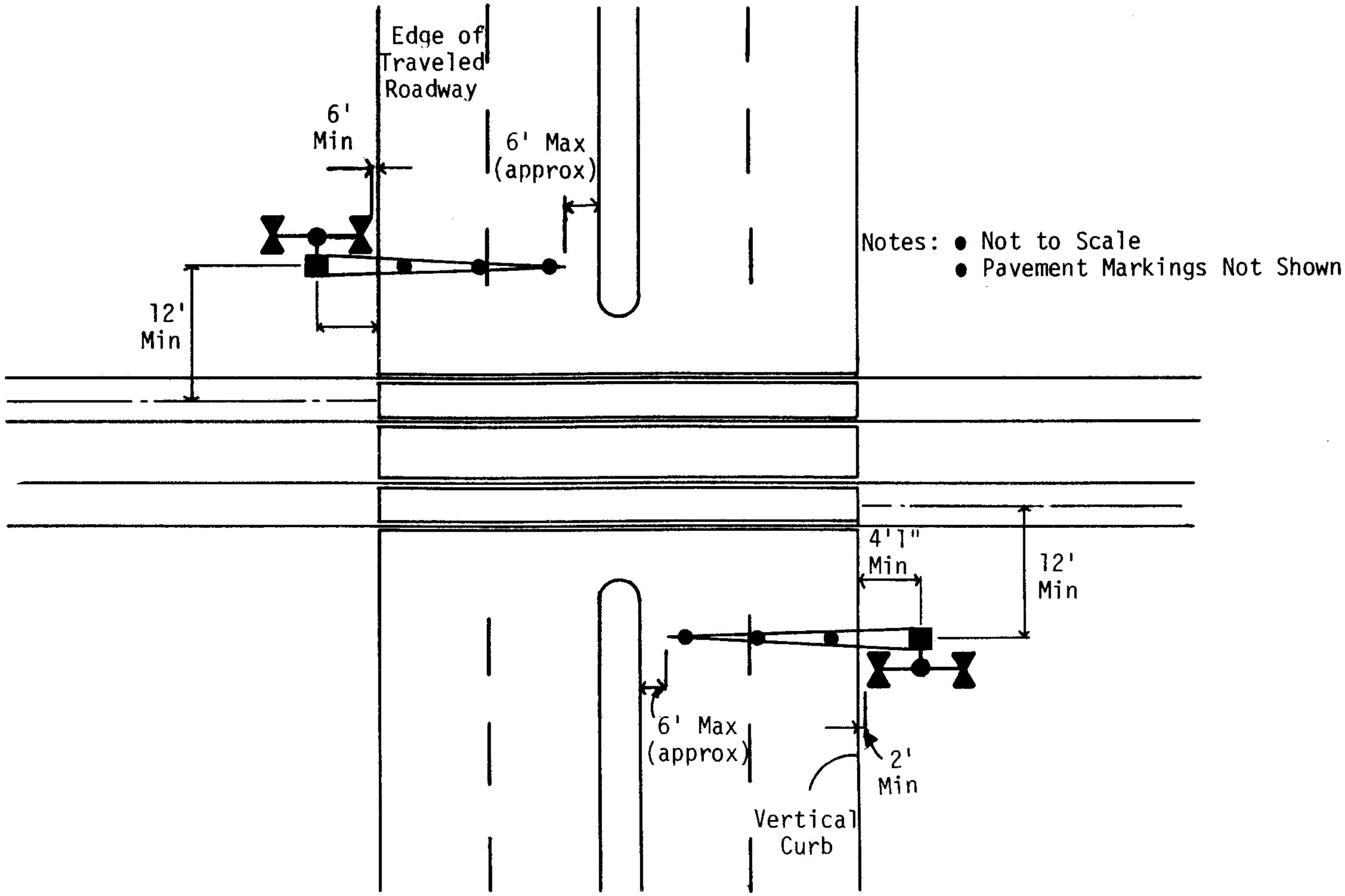


Figure 49. Application of Automatic Gates

1 ft = 0.304 m

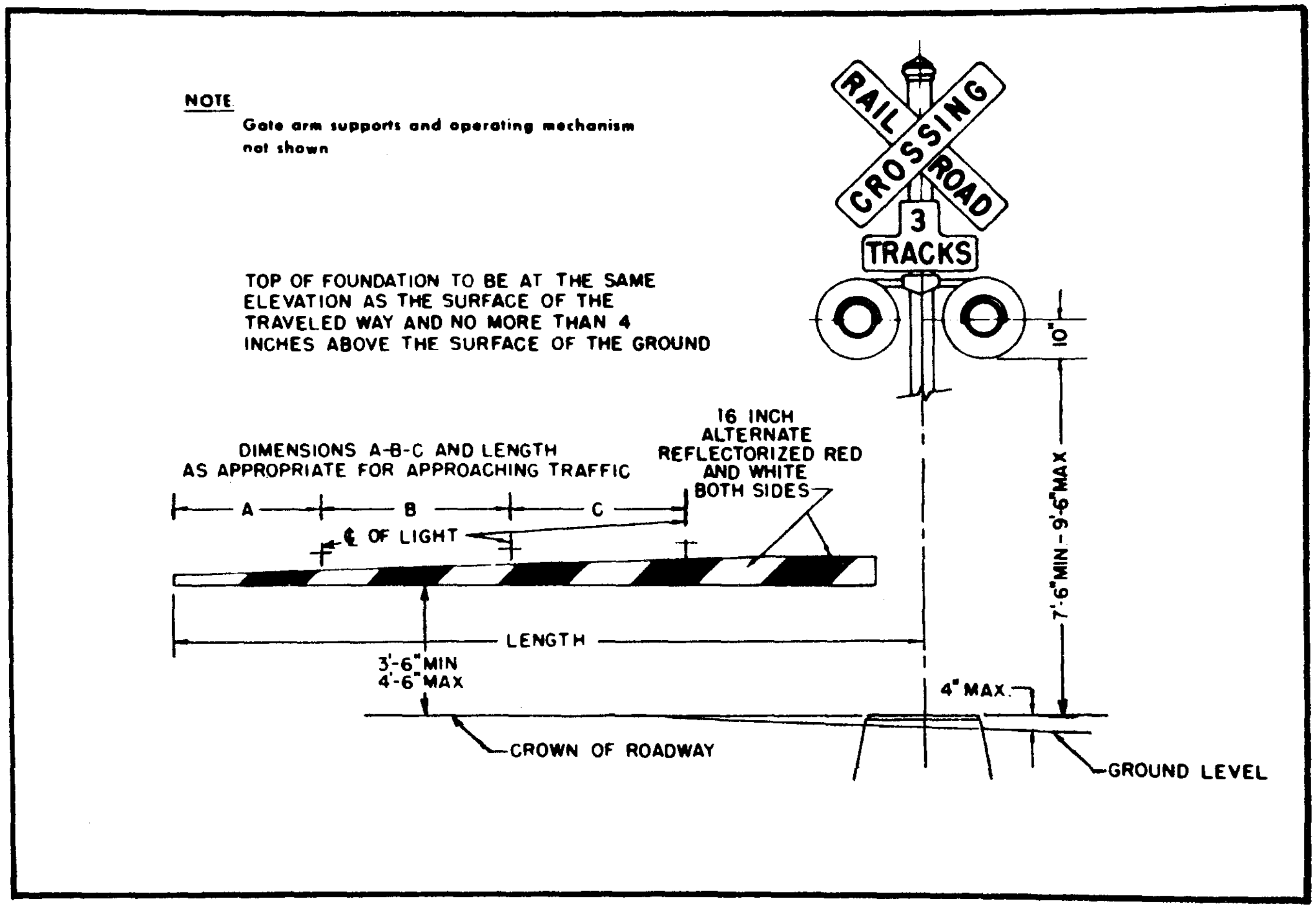


Figure 50. Schematic View of Automatic Gate

1 in = 25.4 mm
1 ft = 0.304 m

A schematic view of the gate in the down position is shown in Figure 50. This view does not show any of the several raising and lower mechanisms.

The gate shown in Figure 50 is often referred to as "short arm" or "half-roadway" to indicate that the gate arm extends only over the approach lane of highway traffic, thereby providing an exit route for the vehicles which are on the tracks when the gates begin to lower. It was developed for the particular purpose of trying to prevent the impatient or absent-minded driver from entering the crossing area immediately after one train has passed when another train is approaching the crossing.

The control of the gate operation is such that the flashing light signals and the lights on the gate arm operate sufficiently (not less than three seconds) in advance of the lowering of the gates to enable those vehicles close to the tracks as well as those on the tracks to continue over the crossing without obstruction. At individual locations, consideration should be given in timing of the gate lowering to the operational characteristics of trucks by allowing more than three seconds of flashing light operation before the gates start down. Once the train clears the crossing and no other train is approaching, the gate arm ascends to its vertical position in not more than 12 seconds. Inasmuch as the lights provide adequate advance warning, control for gate operation provides that they be in a horizontal position only before the train reaches the crossing and remain in that position as long as the crossing is occupied.

When the gate is in its normal upright position, it should be vertical or nearly so to provide minimum clearances as shown in Figure 51.

The assembly consists of the gate arm, gate arm lights, gate mechanism, and counterweights. When in a position to obstruct traffic, the light nearest the tip of the arm is steadily illuminated and the remaining two lights flash alternately. When the gates are in the vertical position, considerable downward torque is present so that the gate arm will lower by gravity when required. In addition to the force of gravity, some mechanisms power-drive down to approximately 45 degree position. Torque is provided by design of the gate arm supports and adjacent counterweights. To the extent practicable, the controlling

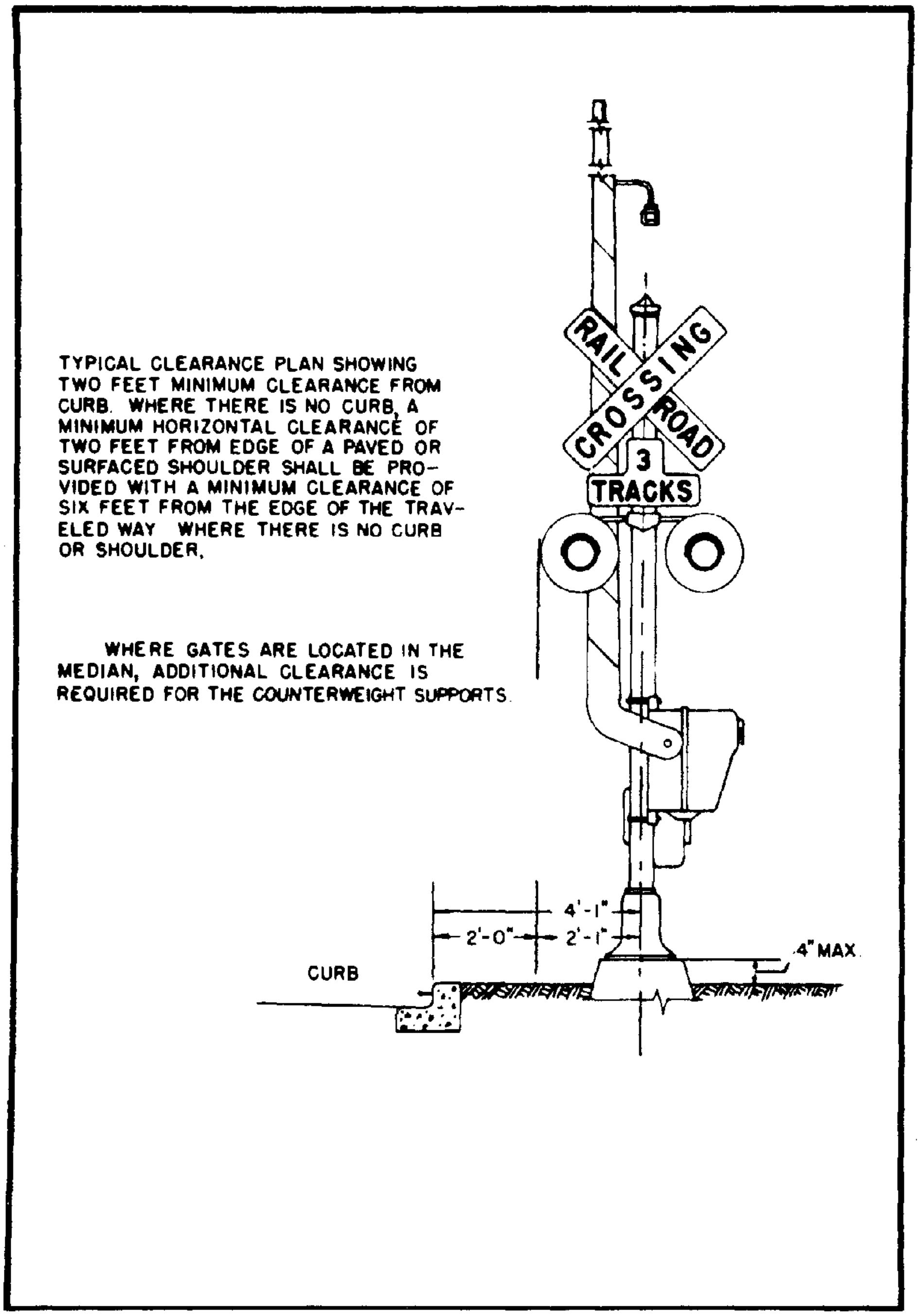


Figure 51. Typical Clearances for Flashing Light Signals and Automatic Gates

1 in = 25.4 mm
1 ft = 0.304 m

circuits are designed so that interruption to the circuit will cause the gate arm to lower.

Mechanisms for raising and lowering of gates include both mechanical and hydraulic devices. Gate arm materials include fiberglass and aluminum for arms up to 32 feet (9.75 m) in length, and wood for longer arms (up to 45 feet (13.72 m)).

7.2.3 Bells

The audible signal, or bell, is a carryover from days of open vehicles wherein the driver could easily hear the sounding of the approach of a train. Although not as effective with automobile traffic as it once was, the bell still plays an important part in safety for pedestrians and bicyclists.

7.2.3.1 Application -- Bells are used along with signs on flashing light signals and gate installations. Bells are particularly helpful for pedestrians and are included on virtually all urban installations. They can be adapted to warn passengers at commuter stations.

7.2.3.2 Description -- There are several different kinds of bells available. The major variations are size, degree of loudness, and operating voltages. The most commonly used bell is one that operates on direct current at approximately 10 volts. Generally, the bell is mounted on top of the supporting mast of the flashing light signal in place of the pinnacle. Maximum loudness of a bell emanates from the rim of the gong and for that reason, the bell is usually mounted so that the gong is parallel to the sidewalk or street.

Component parts of the bell are the door, operating coils, armature and linkage, circuit breaker, adjustable resistor, hammer, gong, and rain shield. The door is provided with a gasket to seal the mechanical and electrical parts from the weather (3).

The bell may be connected in various ways in order that it will sound a warning during the time the signal lights are operating, except that it may be silenced when the head end of the train reaches the crossing or when the gate reaches a horizontal position.

In some areas the sound of the bell may be a source of annoyance to those living nearby, and to minimize the annoyance, either softtone or smaller bells are sometimes used.

7.3 AUTOMATIC CONTROL

An automatic control system is one which operates without direct human input. For grade crossing traffic control, each automatic system utilizes train detection circuits and control logic. As indicated by its name, a train detection circuit is that part of the control system that detects the presence, location, and/or movement of trains. The control logic functions to actuate and time the operation of the grade crossing traffic control devices.

7.3.1 Train Detection Circuits

Among the several types of train detection track circuits used in railroad signaling are d.c. track circuits, rectified a.c. track circuits, coded track circuits and overlay circuits. The d.c., rectified a.c., and overlay circuits are used in crossing control systems, the d.c. circuit being the most common. The following paragraphs from Chapter XXIII of "American Railway Signaling Principles and Practices" (3) (with modifications to indicate application to grade crossing signals) describe the operation of these circuits.

> Figure 52 depicts the fundamental track circuit (unoccupied) used in most signal functions including the control of crossing signals. The current leaves the positive post of the battery, passes through the limiting resistor, which controls the amount of current desired, to the bottom rail. It continues through the rail, as confined by the insulated joints, to the coils of the track relay. After going through the coils of the relay, it passes through a relay series resistor, where used, to the top rail. It returns through this rail, back to the negative post of the battery. The circuit is thus completed, energizing the track relay, causing its front contacts to close. The light circuit is thus completed and the green light is lighted or the grade crossing traffic control signal is held in the inoperative position. Any interruption of this circuit will cause the track relay to become de-energized.
>
> Figure 53 shows the same circuit when occupied by a train. This illustration shows how the wheels and axles of the train cause the track relay to open its front contact. The current is not "cut-off" but part of it is "short circuited" or "shunted." Part of the current now flows through the wheels and axles of the train. Under the conditions shown, the relay has been "robbed" of the current required for its coils to be sufficiently energized to hold its contacts up and, consequently, the front contact opens. Then the current, which formerly fed the green light through the front contact of the track relay,

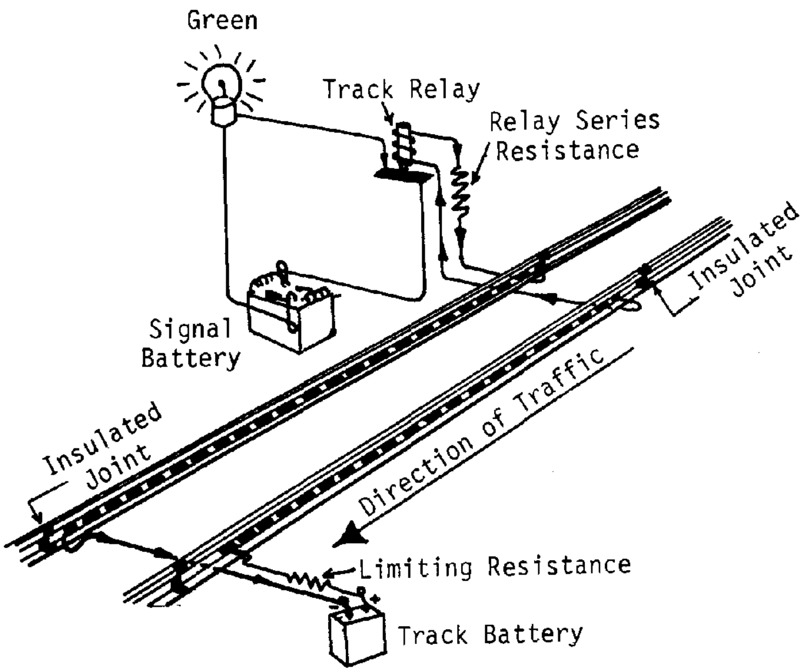


Figure 52. Unoccupied Track Circuit

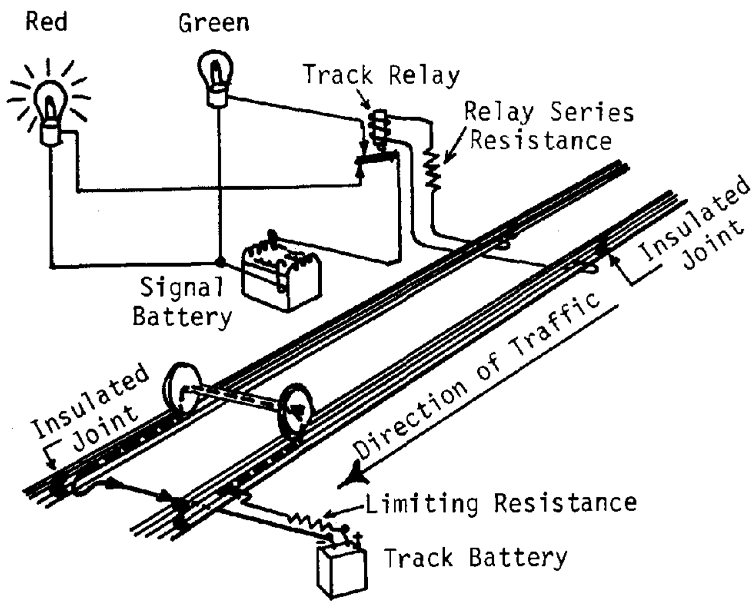


Figure 53. Occupied Track Circuit

flows through the back contact to feed the red light or induce the grade crossing signals to operate. What has actually happened is that most of the current has taken a path of lower resistance through the wheels and axles of the train, instead of a path of higher resistance through the relay coils and the series resistor.

Another type of track circuit, known as an overlay circuit, is also used in control of grade crossing signals in addition to being used in other signal functions. Its operation in detecting the presence of a train is similar to the conventional track circuit described in the foregoing, the principal difference being that instead of applying direct current from a battery to the rails to energize the track relay, a modulated audio frequency signal, generally in the range of 1 kc to 5kc, is used. In place of the battery, a transmitter is used to feed a carrier current to the rails. At the relay end, a receiver, which is inductively coupled to the rails, receives the signal and through its associated apparatus transmits the signal in the form of direct current to the track relay. With a train on the circuit, the carrier current is shunted through the wheels and axles of the train the same as described for the conventional circuit and with the receiver receiving no energy, the track relay releases.

This type of circuit is often used in welded rail territory in that it does not require insulated joints and therefore eliminates the necessity of cutting the rail. Also, while the circuit is used in ordinary applications, it is particularly adaptable in automatic signal territory where it can be used without interference to existing track circuits.

In addition to train detection circuits, other circuits are also used in various control systems. Details on the operation of these circuits may be found in reference 3.

7.3.2 Control Systems

There are several types of control methods available. They vary in concept of operation as well as applicability. These include circuits that provide fixed distance warning, constant time warning and motion detection, as well as special circuits which may be used to add flexibility to fundamental circuits.

7.3.2.1 Fixed Distance Warning -- The fixed distance warning concept was the first control system used for automatic operation of active grade crossing traffic control devices. Each such control system has at least three circuits: one for each approach and an island circuit (Figure 54) (7). When an approaching train is in the confines of its approach circuit or the island circuit, the signals operate. The logic for the system is designed so that when the train clears the island circuit and moves away from the crossing, the signals will cease operation. With overlay track circuits, an overlap of the two approach circuits serves the function of an island circuit.

A major drawback to fixed distance warning systems is that the active devices operate continuously while the train is on the approach track circuit, regardless of the train speed. While the newer control systems to be discussed next have the capability to reduce unnecessary signal operation, there are several modifications that can be made to the basic fixed distance warning systems to improve their efficiency.

7.3.2.2 Selective Speed Timing and Cut-Out Circuits -- One technique for improving control system efficiency is to divide the approach circuits into several shorter track circuits (Figure 55) (7). Timing elements can then be incorporated into the control logic. One scheme, selective speed timing, times the approach of the train and activates the crossing signals at one of several places depending on train speed. Thus a slow train may enter confines of approach circuit without immediately operating the crossing signals. In another scheme, known as time cut-out, the signals begin operation at the extreme end of the track circuit (as in the basic fixed distance warning). However, if the train does not reach a certain point within a given time interval, the signals cease operation and restart when the train is closer to the crossing.

Two other possible modifications are directly related to train operations. The first is a switch stick circuit that nullifies signal operation whenever a switch within the approach circuit is reversed, thus preventing the train from entering the crossing. The second is a signal cut-out circuit that prevents the crossing signals from operating whenever the block signal prevents a train from entering the crossing.

Details on the operation of these special circuits can be found in the Association of American Railroads publication "American Railway Signaling Principles and Practices -- Chapter XXIII, Railroad-Highway Grade Crossing Protection" (3).

7.3.2.3 Motion Sensing -- One type of control system used in areas with considerable switching or stopping is the motion sensing apparatus

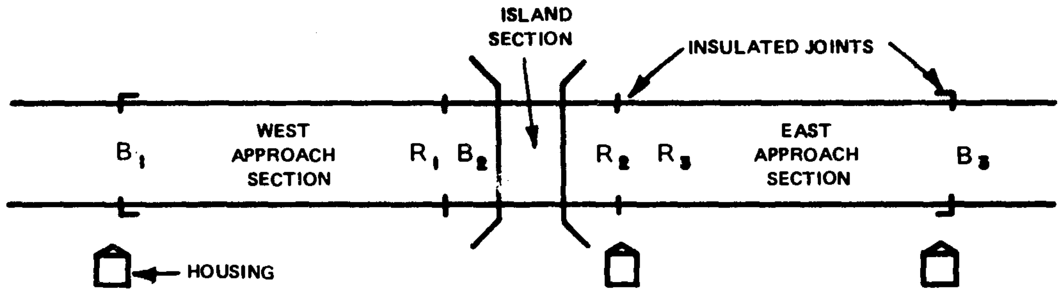


Figure 54. Three Track Circuit System

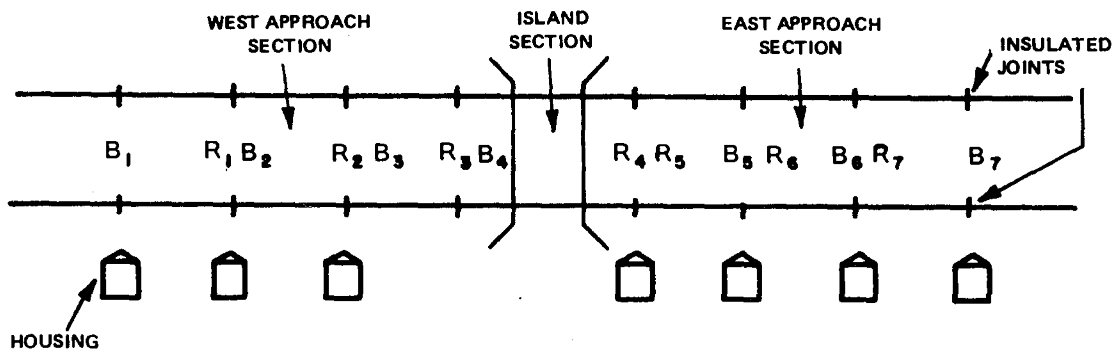


Figure 55. Track Circuits With Timing Sections

(Figure 56) (7). This system is based on the rate of decrease in impedance to sense motion of trains toward the crossing and thus actuate the signals. If the train stops or moves away from the crossing while on the approach circuit, the signals will cease operation. If the train again moves toward the crossing, the signals will begin operation. The motion sensing control is dependent upon motion for actuation; an island circuit is used to keep signals operating while a train occupies the crossing.

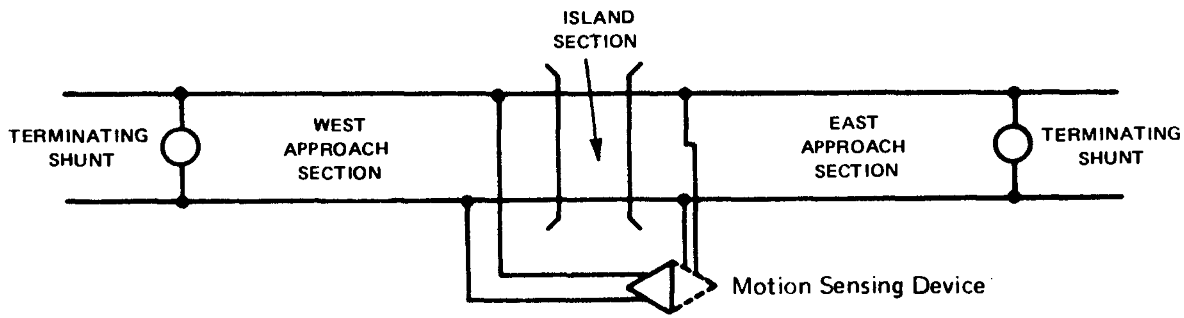
7.3.2.4 Constant Time Warning -- Constant time warning is accomplished through the use of devices which measure the speed of an approaching train and predict the length of time until its arrival at the crossing (Figure 57) (7). When the time until arrival reaches some predetermined amount (usually 20 or more seconds) the signals are actuated.

The operation of this system is based on the amount and rate of change of inductance in the track circuit. The instantaneous amplitude of the voltage indicates the distance of the train from the crossing, and rate of change of voltage indicates the speed of the train. It is possible for a train to enter the approach circuit and stop, and based on its speed, never actuate the signals similar to that provided by selective timing. To provide warning of trains stopped in the crossing or moving toward the crossing after stopping very near the crossing an island circuit is used.

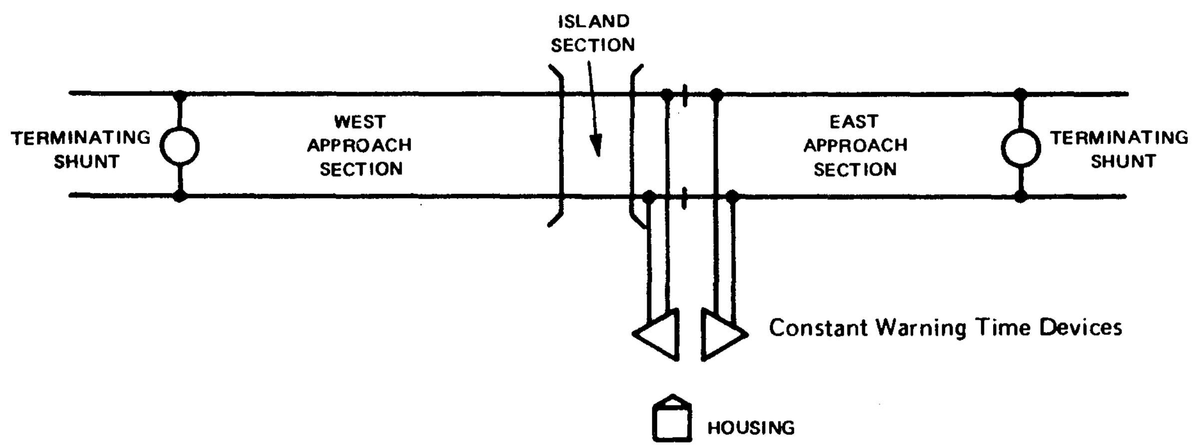
7.3.3 Highway Signal Preemption

The preemption of traffic signals near grade crossings is necessary for driver safety. Conflicting indications of highway and grade crossing traffic control devices not only adds to the confusion at the crossing, but is a considerable detriment to safety. The MUTCD specifies:

> When highway intersection traffic control signals are within 200 feet (60 m) of a grade crossing, control of the traffic flow should be designed to provide the motorist 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



Source: Railway Progress Institute
Figure 56. Motion Sensing Apparatus



Source: Railway Progress Institute
Figure 57. Constant Warning Time Apparatus

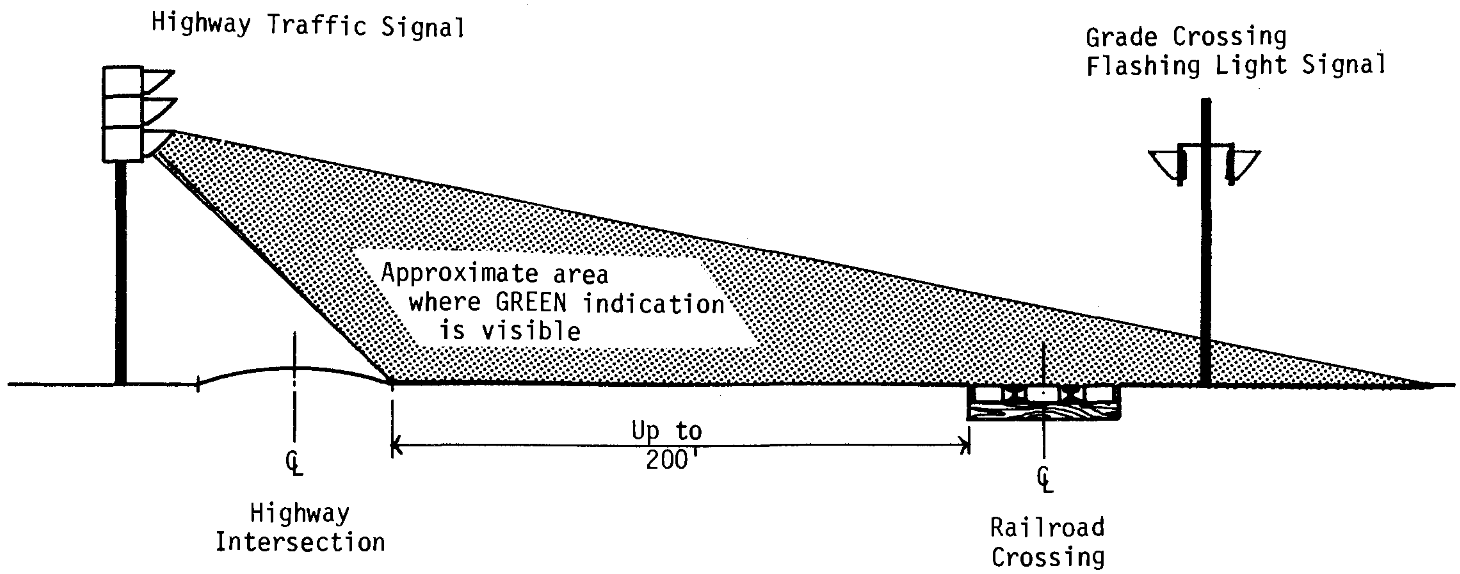


Figure 58. Approximate Coverage Area for Green Indication on Nearby Highway Traffic Signals

1 ft = 0.304 m

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 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.

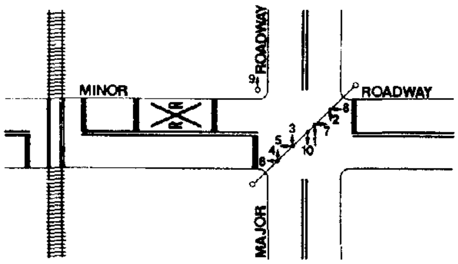
> The preemption sequence initiated when the train first enters the approach circuit shall at once bring into effect a highway signal display which will permit traffic to clear the tracks before the train reaches the crossing. The preemption shall not cause any short vehicular clearances and all necessary 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.

Unless carefully designed, there could be some confusion when the highway traffic signal displays a green indication for the clear-out interval while the grade crossing flashing light signal is displaying a red indication. To minimize confusion, the highway traffic signals should be screened, louvered or optically programmed so that they are visible only to those vehicles on or beyond the tracks (Figure 58).

After the track clearance interval, the highway traffic signals should provide green indications to movements that do not cross the tracks, ". . . but shall not provide a through circular green or arrow indication for movements over the tracks," (MUTCD). This sequencing allows for traffic movements parallel to and away from the tracks, thus partially reducing the overall delay at the intersection. After the train has cleared the crossing and no other trains are approaching, the highway traffic signals should return to normal phasing, generally with the approaches over the tracks moving first. Typical phase diagrams for highway traffic signals during the preemption sequence are shown in Figure 59 (6).

The MUTCD recommends normal signal operation at highway intersections which would avoid requiring vehicles to stop on the tracks at any time. This requires proper signal phasing, which may be assisted somewhat by locating the pavement stop line on the far side of the grade crossing from the highway intersection. Other traffic signalization alternatives which should be considered are:

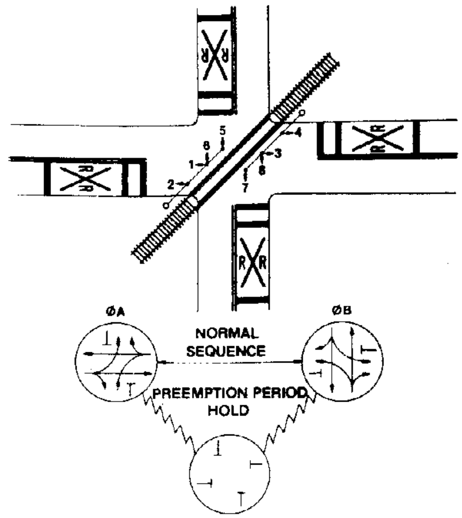
Typical Railroad Preemption Sequence
Intersection with Flashing Beacon Control
Railroad Crossing on Minor Approach



SIGNAL	NORMAL OPERATION	PREEMPTION SEQUENCE				
		CLEAR	T_1	T_2	HOLD	RELEASE
1,2,3,4	FA	A	R	R	FA	FA
5,6	FR	FR	G	A	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

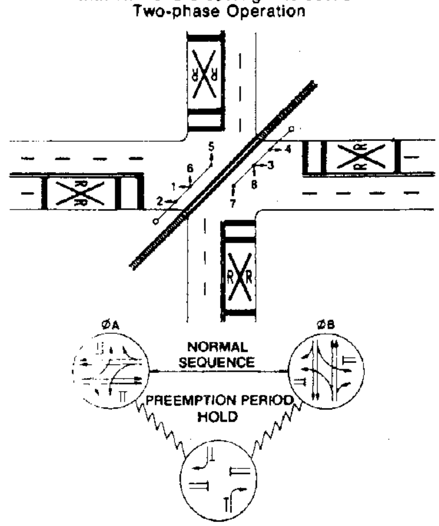
* OPTIONAL

Typical Railroad Preemption Sequence
Signalized Intersection of Two-lane Roadways
with Railroad Bisecting Intersection
Two-phase Operation



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

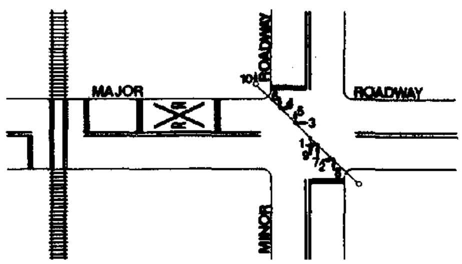
Typical Railroad Preemption Sequence
Signalized Intersection of Four-lane Undivided Roadways
with Railroad Bisecting Intersection
Two-phase Operation



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

Figure 59. Phasing of Nearby Highway Traffic Signals

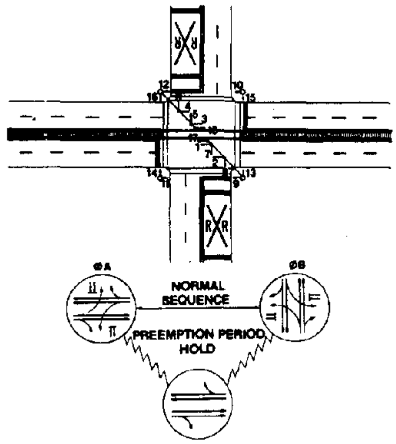
Typical Railroad Preemption Sequence Intersection with Flashing Beacon Control Railroad Crossing on Major Approach



SIGNAL	NORMAL OPERATION	PREEMPTION SEQUENCE				
		CLEAR	T_1	T_2	HOLD	RELEASE
1,2	FA	FA	G	A	R	FA
3,4	FA	A	R	R	R	FA
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

Typical Railroad Preemption Sequence Signalized Intersection of Four-lane Roadways with Railroad Bisecting One Roadway Two-phase Operation with Pedestrian Signals



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

Ø	Signal Phase
●—▶	Overhead Mounted Signal Head
○—▶	Pedestal Mounted Signal Head
R	Circular Steady Red Indication
FR	Circular Flashing Red Indication
A	Circular Steady Amber Indication
FA	Circular Flashing Amber Indication
G	Circular Steady Green Indication
—▶	Steady Green Arrow Indication
A—▶	Steady Amber 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
CLEAR	Amber Clearance Interval
T_1, T_{1A}, T_{1B},	Preemption Clearance Intervals Prior to Train Approach
T_2	Amber Clearance Interval Following T_1 Interval
T_{2A}	Amber Clearance Interval Following T_{1A} Interval
T_{2B}	Amber Clearance 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 59, continued.

1) semi-actuated traffic signal operation in which the movement over the crossing would have a green indication at all times other than when there are actuations on the street parallel to the tracks, and

2) full actuated operation in which signal "recall" is to the movement over the crossing.

More detail on traffic signal operation can be found in reference 4.

At locations where a signalized highway intersection is within 200 feet (60 m) of a grade crossing which has no active traffic control system, traffic signal preemption is still desirable and may be required. Site and operational characteristics will generally dictate what level of control is necessary for adequate warning at such locations. The installation of active control devices should be given careful consideration at such locations as the added costs for the devices and additional circuitry over that required for preemption is minor.

7.4 SELECTION GUIDELINES

Selection of proper grade crossing traffic control devices and control systems is essential for safe and efficient operation over the grade crossing.

7.4.1 Selection of Grade Crossing Traffic Control Devices

Although in many cases the grade crossing traffic control devices to be installed at a crossing will have been identified in the Project Selection phase, some general selection criteria will be beneficial in evaluating crossing requirements. These guidelines are not all inclusive. There will always be situations which are not covered by the guidelines and must be evaluated using good engineering judgement. Several of the hazard indices described previously present, as a final output, recommendations for specific devices. These hazard indices and the following guidelines may be used in a complementary manner to arrive at optimum selection of devices.

7.4.1.1 Need for Active Control Devices -- The following are guidelines for evaluating the need for active devices at a grade crossing. These guidelines and supporting data should be made available to the multidisciplinary team prior to a crossing evaluation.

- Volume of vehicular traffic - an ADT of less than 1,000 would require other significant warrants.
- Volume of railroad traffic - less than six trains per day would normally represent light exposure except where passenger train operations exist.
- Maximum speed of railroad trains - speeds in excess of 50 miles per hour (80 km/h) in rural areas or 35 miles per hour (56 km/h) in urban areas deserve careful consideration.
- Permissible maximum speed of vehicular traffic - speeds in excess of 35 miles per hour (56 km/h) in rural areas or 25 miles per hour (40 km/h) in urban areas deserve careful consideration.
- Volume of pedestrian traffic - pedestrian volume of 150 or more per hour may be a significant determinant.
- Accident record - occurrence of a train-involved accident within the last three years indicates a need for careful analysis
- Reduced sight distances - limited view of tracks should be checked for approaching driver reaction.
- Potential for complete elimination of grade crossings without active traffic control devices - closing lightly used crossings and installing active devices at other more heavily used crossings.

If it is established that active grade crossing traffic control devices are needed, then the basic active device, flashing light signals, would be used unless additional devices, such as automatic gates, are deemed necessary.

7.4.1.2 Need for Automatic Gates -- The following guidelines are recommended for evaluating the need for automatic gates at a grade crossing.

- Multiple main line railroad tracks.
- Multiple tracks at or in the vicinity of the crossing which may be occupied by a train or locomotive so as to obscure the movement of another train approaching the crossing.

- High speed train operation combined with limited sight distance at either single or multiple track crossings.
- A combination of high speeds and moderately high volumes of highway and railroad passenger or freight traffic.
- High speed passenger trains, substantial numbers of school buses or trucks carrying hazardous materials, or continuing accident occurrences.
- Recommendations of a multidisciplinary diagnostic inspection team.
- Any combination of the conditions listed above.

7.4.2 Selection of Control System

Selection of an appropriate active control system is dependent upon numerous factors. Of course, the promotion of safety is of primary importance in the selection process. However, it is also important that the efficiency of operation be acceptable, and cost kept to a minimum. Since the three objectives cannot be simultaneously accomplished, an attempt must be made to find some suitable combination of safety, efficiency and cost for a given grade crossing control system. The major factors to be considered and their potential effects at a crossing are as follows:

- Train speed - Train speeds are categorized as high, low and mixed. The break between high and low speeds is defined in rural areas as 50 mph (80 km/h), as that is the speed above which automatic block signals are required for train operation. In urban areas high speed is defined as train operation in excess of 35 miles per hour (56 km/h). Mixed speeds are any combination of high and low speeds. High speed is normally associated with greatest danger, but mixed speeds may be as critical because the vehicle operator has difficulty in determining how fast the approaching train is traveling. Likewise, mixed speeds produce the greatest efficiency problem in that reasonably uniform warning time becomes increasingly more difficult to achieve as speed ranges are increased.

- Switching or Stopping - Operations requiring switching movements or stopping on the approach circuit require appropriate supplementary controls to eliminate unnecessary operation of signals, in order to increase safety and efficiency as well as respect for the signals.
- Train Volume - The number of trains per day will significantly affect the exposure or "risk," factor as well as the efficiency of the crossing. As the number of trains per day increases, the amount of delay to motorists increases as does the opportunity for collision. The degree of risk and efficiency is also dependent upon the distribution of train movements over the 24-hour period.
- Train Mix - Train mix defines the types of trains using a crossing: passenger, freight or switching, and the number or proportion of each. The presence of passenger trains affects the crossing control system in two ways, both of which require more sophisticated control. First, the presence of train passengers greatly increases the number of people subject to exposure of a collision. Secondly, passenger trains generally operate at higher speeds.
- Distribution - Distribution is important in dividing train movements into (1) daytime and early evening and (2) late night categories. Daytime or early evening movements more often conflict with heavy highway traffic than do late night movements and thus represent a higher exposure and greater vehicular delay. However, crossings near manufacturing or other night shift work industries may have characteristics more like the daytime category and should be carefully evaluated.
- Traffic Volume - Traffic volume may be categorized as high and low, the break points being 3000 ADT for rural crossings and 5000 ADT for urban crossings. Higher volume crossings have a greater potential for excessive delay and high exposure and thus may require more sophisticated control

techniques, depending on other crossing factors.

- Traffic Mix - Traffic mix is divided into those roadways used by buses (especially school buses) and/or trucks carrying hazardous cargoes and those without any such traffic. The rationale for improved control at crossings used by buses is very similar to that for passenger trains. Not only do buses with their high volume person-movement multiply the safety requirements, but they also increase the person time loss economic factor.

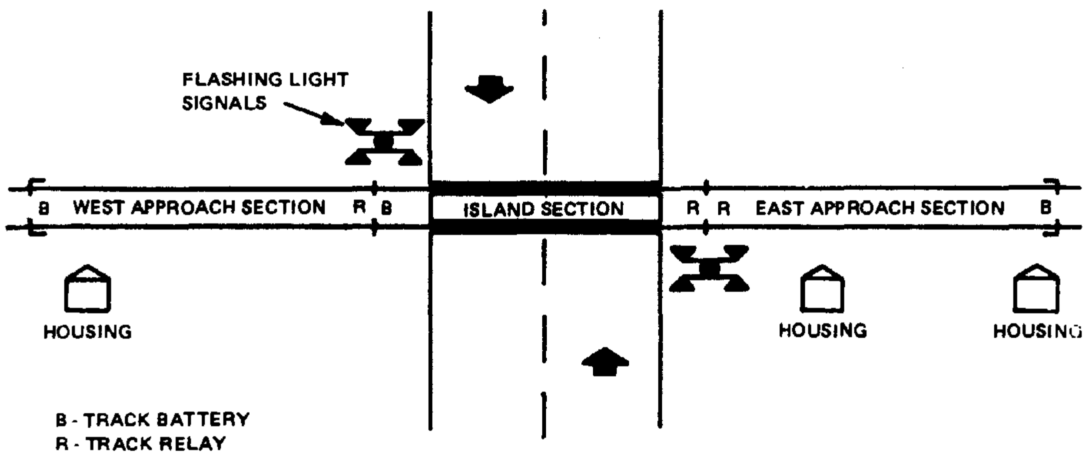
Interactions among the various factors is complex. The following typical applications, as recommended by Railway Progress Institute, provide an illustration of how the various crossing factors interact and of the typical types of control devices and control systems (Figures 60 through 64) (7).

7.5 DESIGN GUIDELINES

In some states, portions of the design process will be governed by statute, requirements of regulatory agencies, highway department and other public agency requirements, or by railroad practices. However, the following guidelines should provide assistance in design and layout of grade crossing traffic control devices. Additional detail may be found in the Traffic Control Devices Handbook (5).

7.5.1 Typical Locations of Grade Crossing Traffic Control Devices

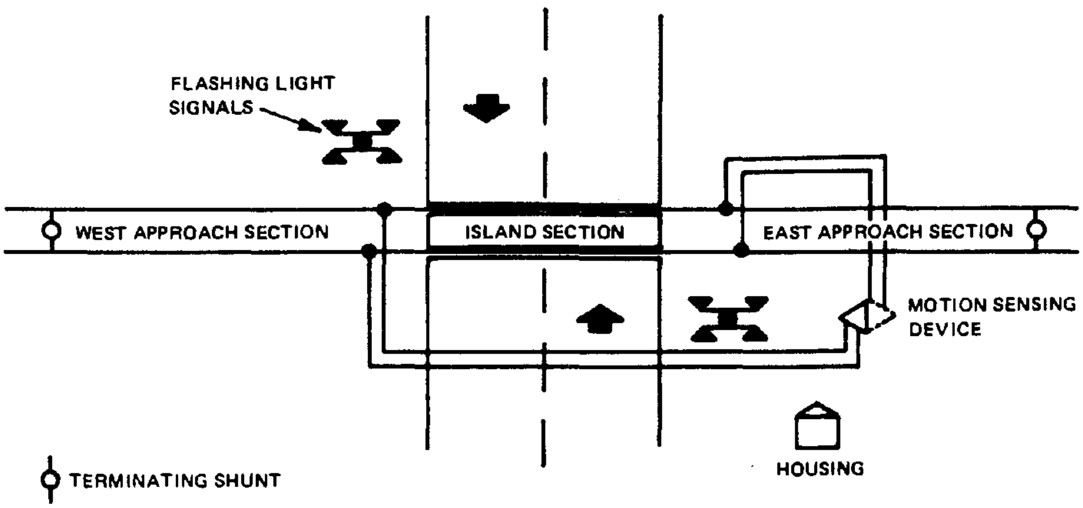
The degree of effectiveness of control devices is influenced considerably by their location. At one time it was considered good practice to install flashing light signals in the center of the street and, from the standpoint of providing an indication to the driver, such a location was effective but ignored the hazard of a major obstruction in the traveled way. Outside of extraordinary conditions, flashing light signals and automatic gates should be located adjacent to the approach lane of traffic. It is essential that the driver have a clear and unobstructed view of the control devices. Therefore, in addition to properly locating the devices, any obstruction which obscures the view



The combination of flashing light signals and track circuits may be used where the following conditions exist:

- Medium highway speeds.
- Medium highway traffic.
- Single track railroad or, if multiple tracks, only one train can occupy the crossing at a given time.
- Fairly uniform train speeds.
- No scheduled train stops in the approach sections.
- No scheduled switching in the approach sections.

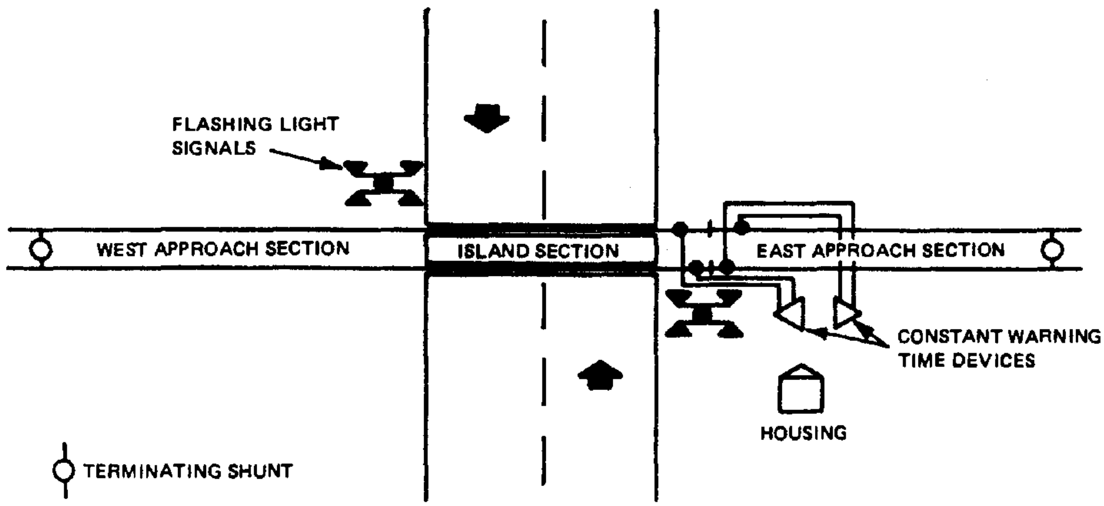
Figure 60. Flashing Light Signals and Fixed Distance Warning



A combination of flashing light signals and a motion-sensing device may be used where the following conditions exist:

- Medium highway speeds.
- Medium highway traffic.
- Single track railroad or, if multiple tracks, only one train can occupy crossing at a given time.
- Fairly uniform train speeds.
- A few scheduled train stops in the approach sections.
- Limited switching in the approach sections.

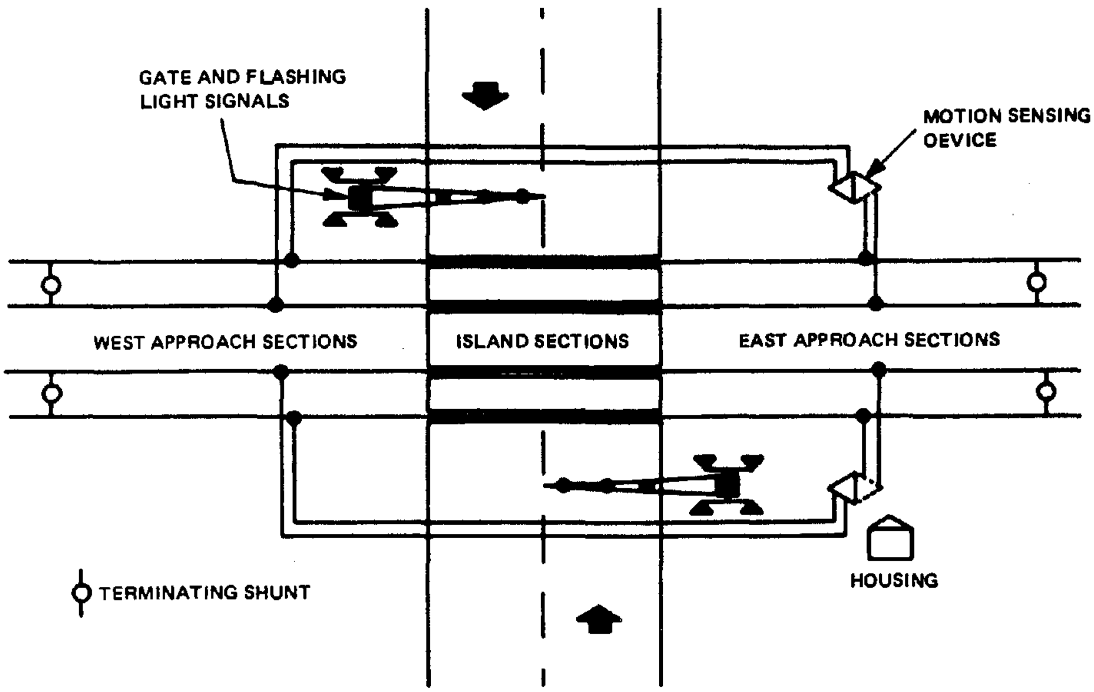
Figure 61. Flashing Light Signals and Motion-Sensing Devices



A combination of flashing light signals and constant warning time devices may be used where the following conditions exist:

- Medium highway speeds.
- Medium highway traffic.
- Single track railroad or, if multiple tracks, only one train can occupy crossing at a given time.
- Widely different train speeds.
- Trains have scheduled stops in approach sections.
- Trains have scheduled switching in approach sections.

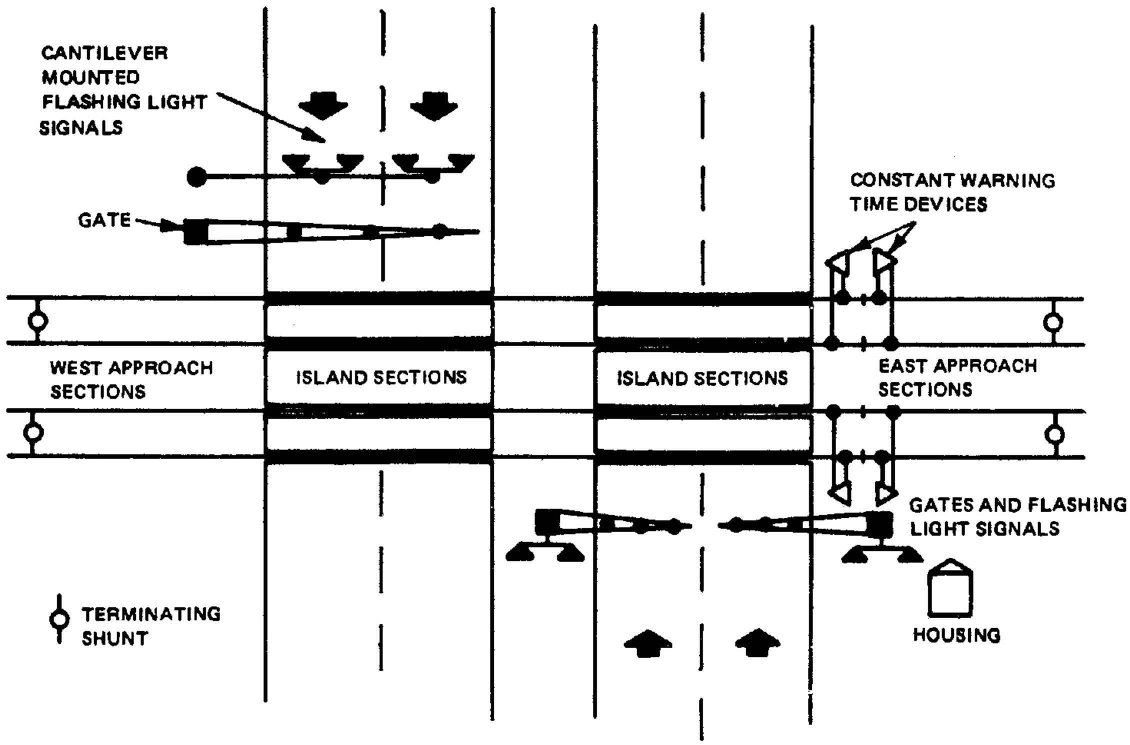
Figure 62. Flashing Light Signals and Constant Warning Time Devices



A combination of gates and motion-sensing devices may be used where the following conditions exist:

- Maximum highway speeds.
- Heavy highway traffic.
- Single or multiple track railroad (two or more trains may occupy crossing at a given time).
- Fairly uniform train speeds.
- A few scheduled train stops in the approach sections.
- Limited switching in the approach sections.

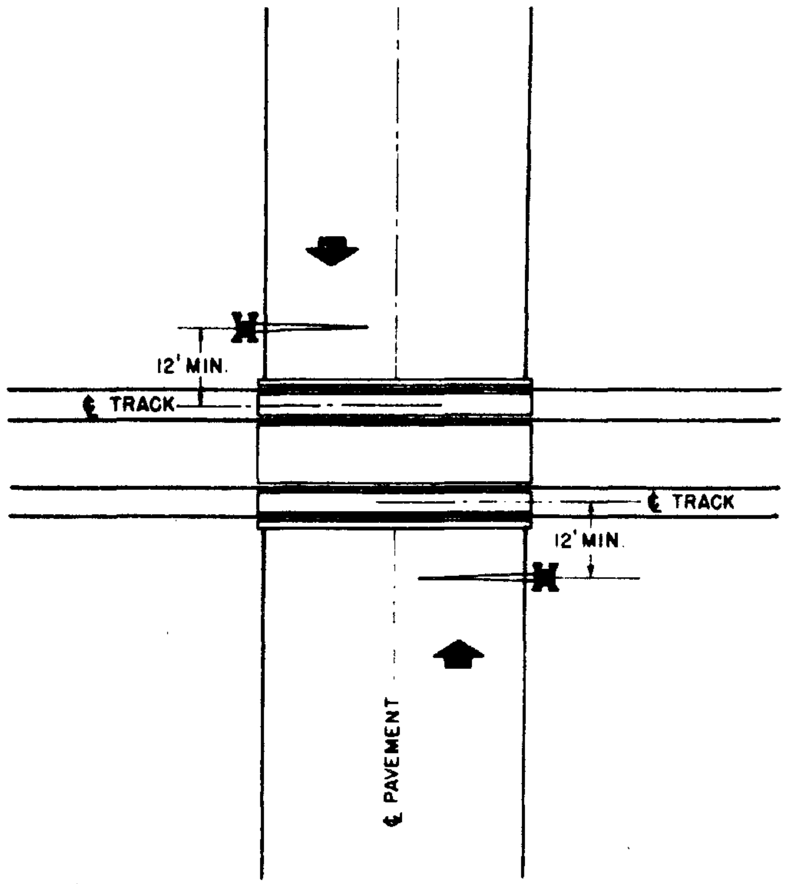
Figure 63. Gates, Flashing Light Signals and Motion-Sensing Devices



A combination of gates and constant warning time devices should be used where the following conditions exist:

- Maximum highway speeds.
- Heavy highway traffic.
- Single or multiple track railroad (two or more trains may occupy crossings at a given time).
- Widely different train speeds.
- Trains have scheduled stops in approach sections.
- Trains have scheduled switching in approach sections.

Figure 64. Gates, Flashing Light Signals and Constant Warning Time Devices

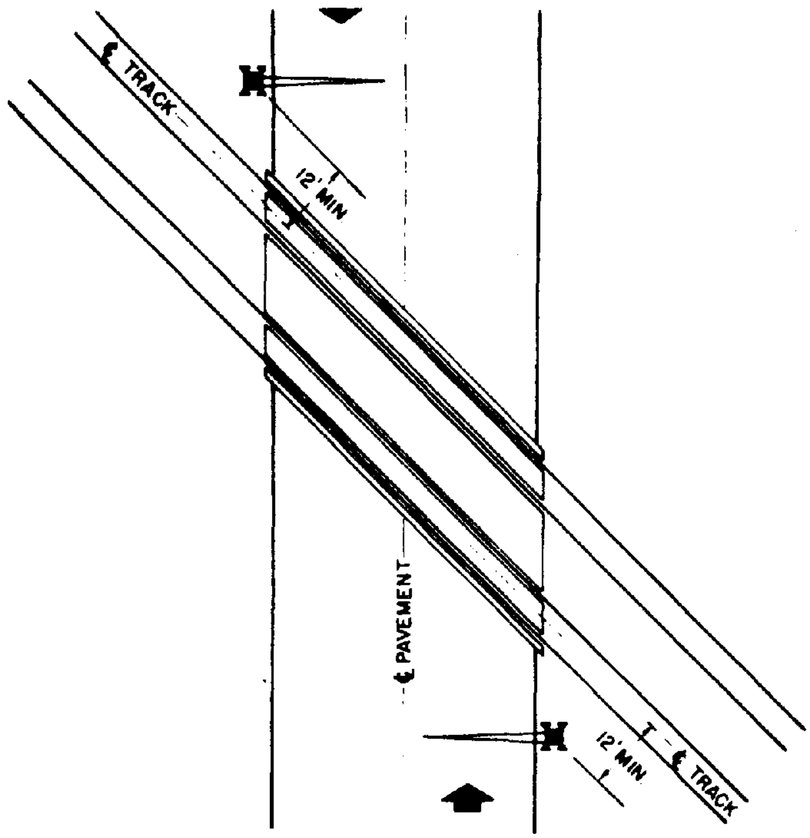


TYPICAL LOCATION PLAN
FOR FLASHING LIGHT SIGNALS
AND AUTOMATIC GATES

RIGHT ANGLE

Figure 65

1 ft = 0.304 m

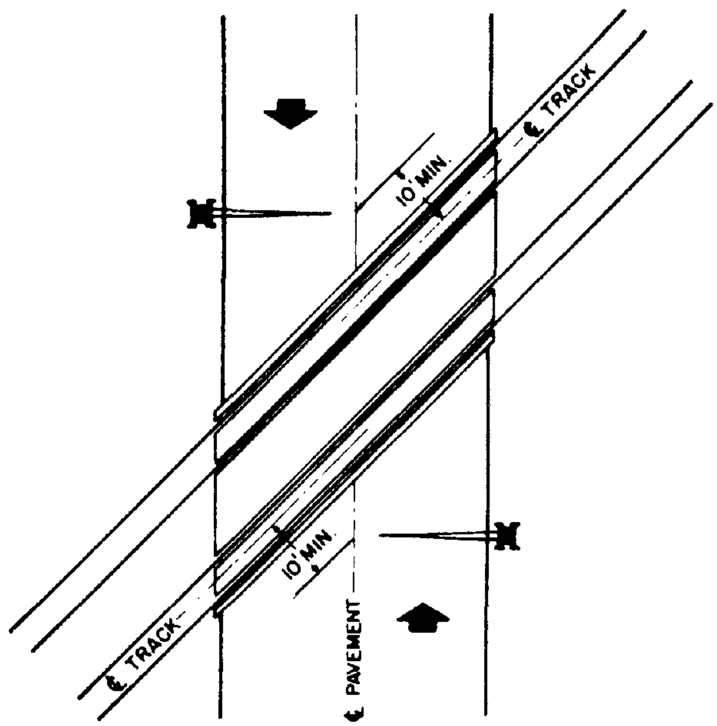


TYPICAL LOCATION PLAN FOR FLASHING LIGHT SIGNALS AND AUTOMATIC GATES

ACUTE ANGLE

Figure 66

1 ft = 0.304 m

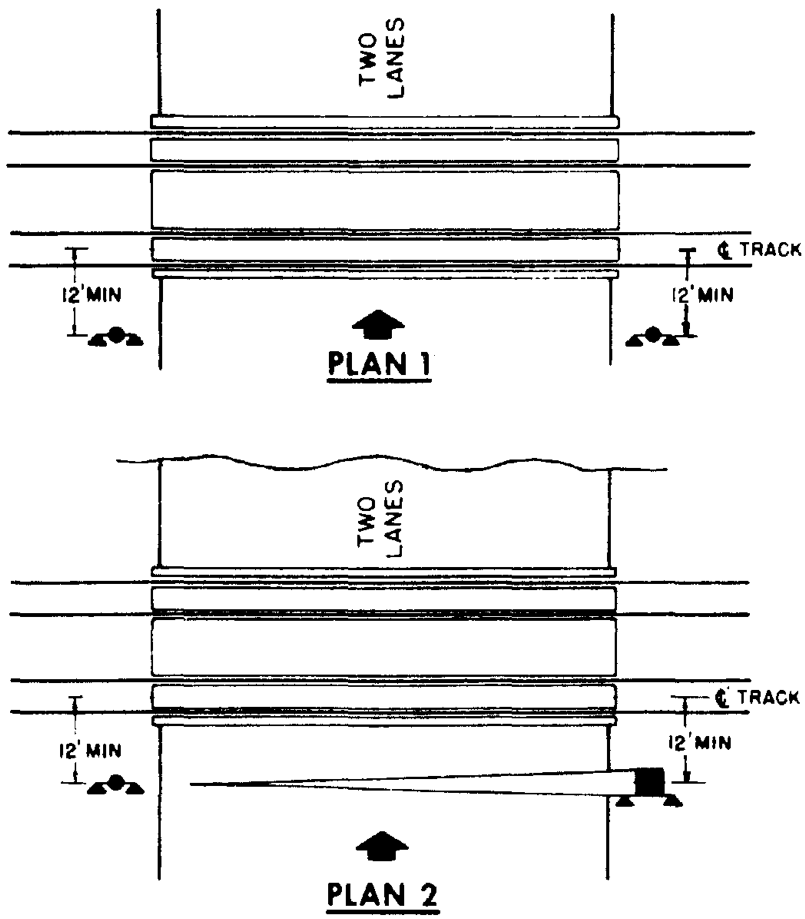


**TYPICAL LOCATION PLAN
FOR FLASHING LIGHT SIGNALS
AND AUTOMATIC GATES**

OBTUSE ANGLE

Figure 67

1 ft = 0.304 m



TYPICAL LOCATION PLANS
FOR FLASHING LIGHT SIGNALS
AND AUTOMATIC GATES
FOR ONE-WAY HIGHWAY TRAFFIC (TWO LANES)

RIGHT ANGLE

Figure 68

1 ft = 0.304 m

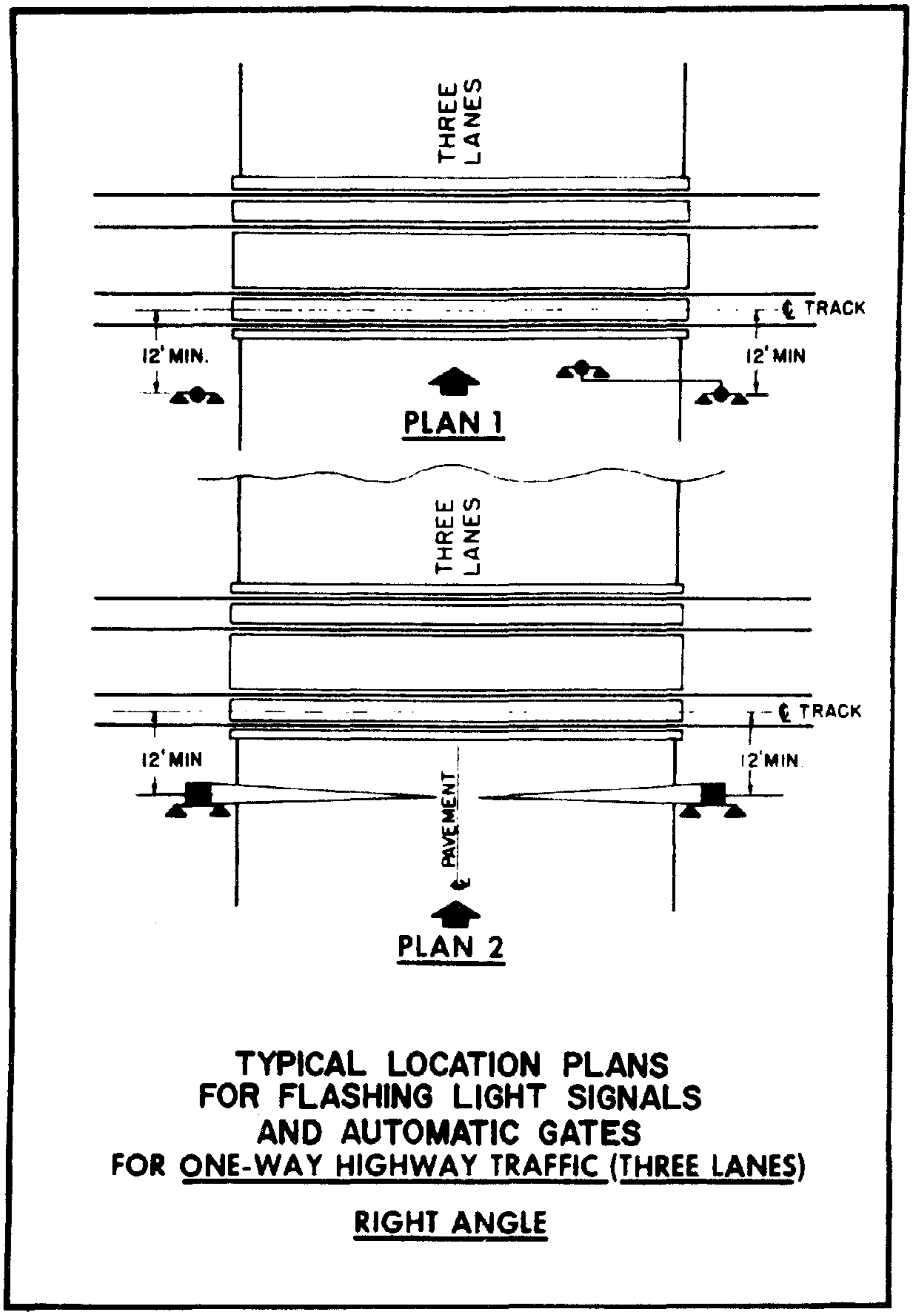
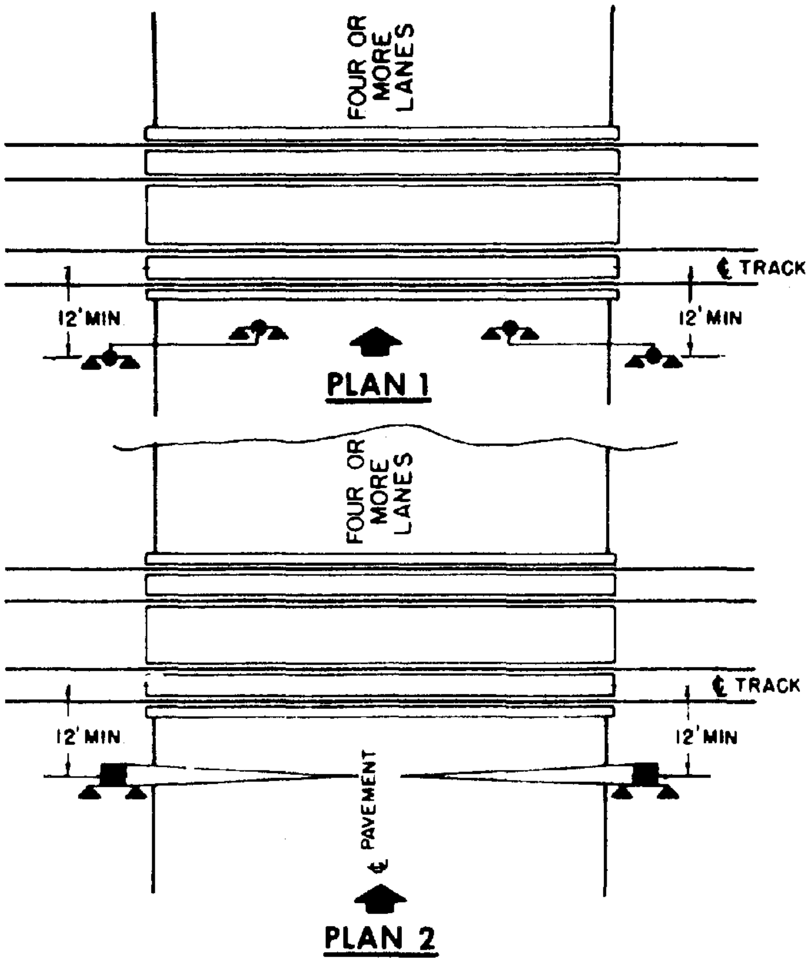


Figure 69

1 ft = 9.304 m

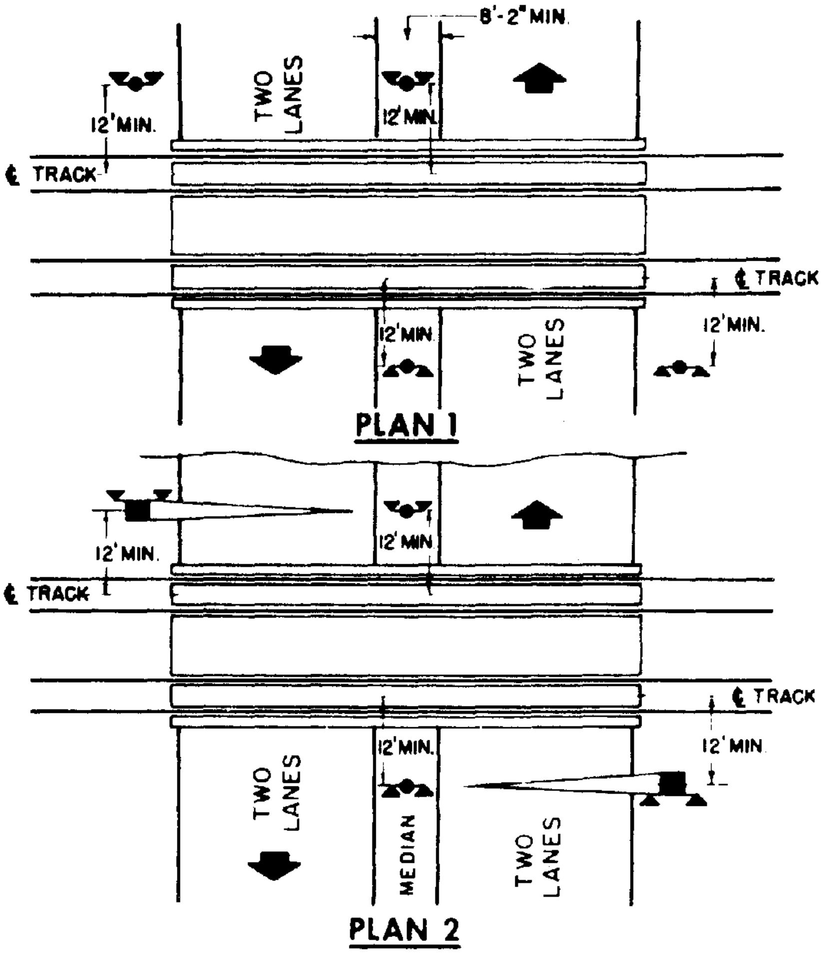


TYPICAL LOCATION PLANS FOR FLASHING LIGHT SIGNALS AND AUTOMATIC GATES FOR ONE-WAY HIGHWAY TRAFFIC (FOUR OR MORE LANES)

RIGHT ANGLE

Figure 70

1 ft = 0.304 m



TYPICAL LOCATION PLANS
FOR FLASHING LIGHT SIGNALS
AND AUTOMATIC GATES
FOR ONE-WAY HIGHWAY TRAFFIC (TWO LANES)

DIVIDED HIGHWAY

RIGHT ANGLE

Figure 71

1 ft = 0.304 m

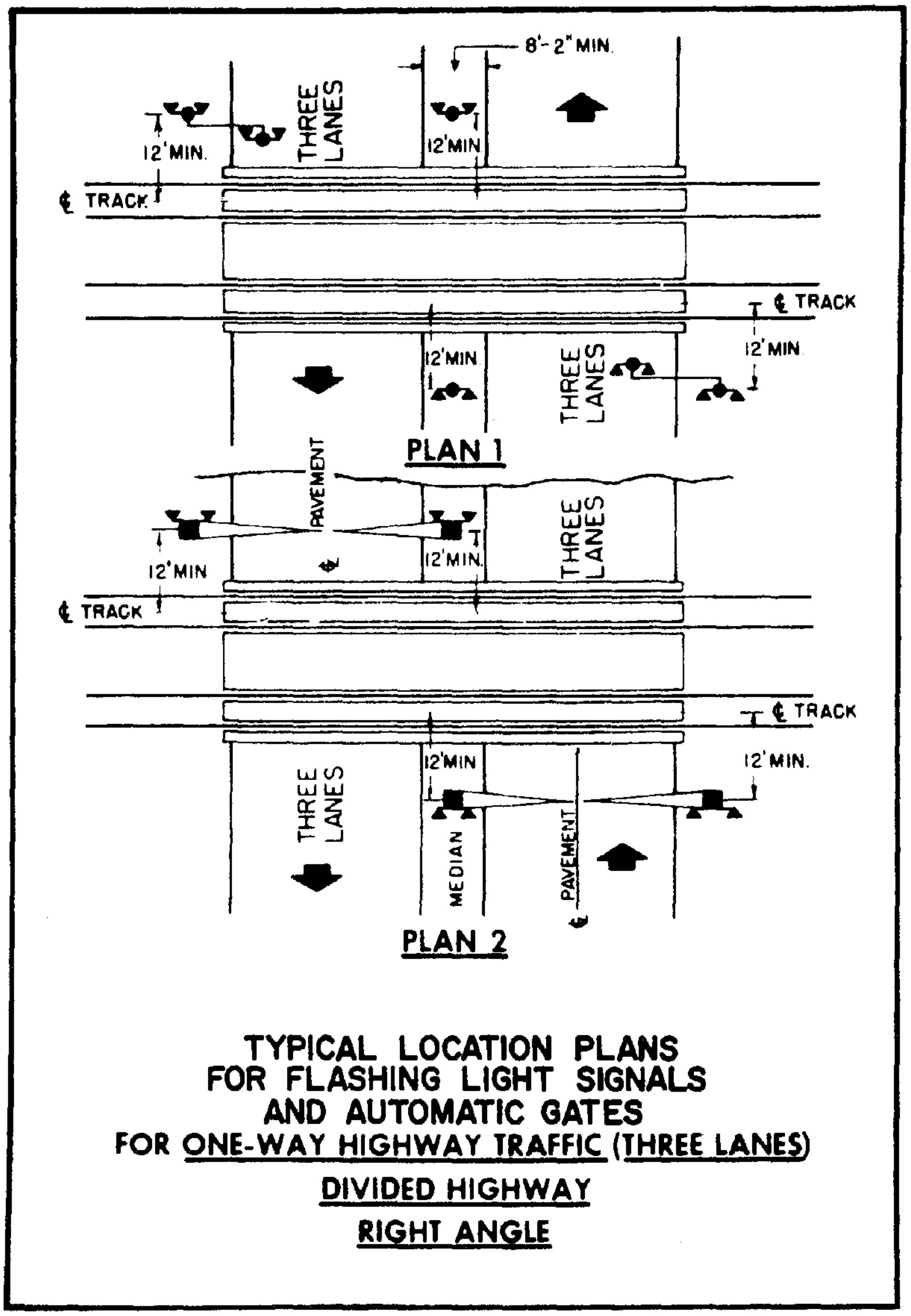
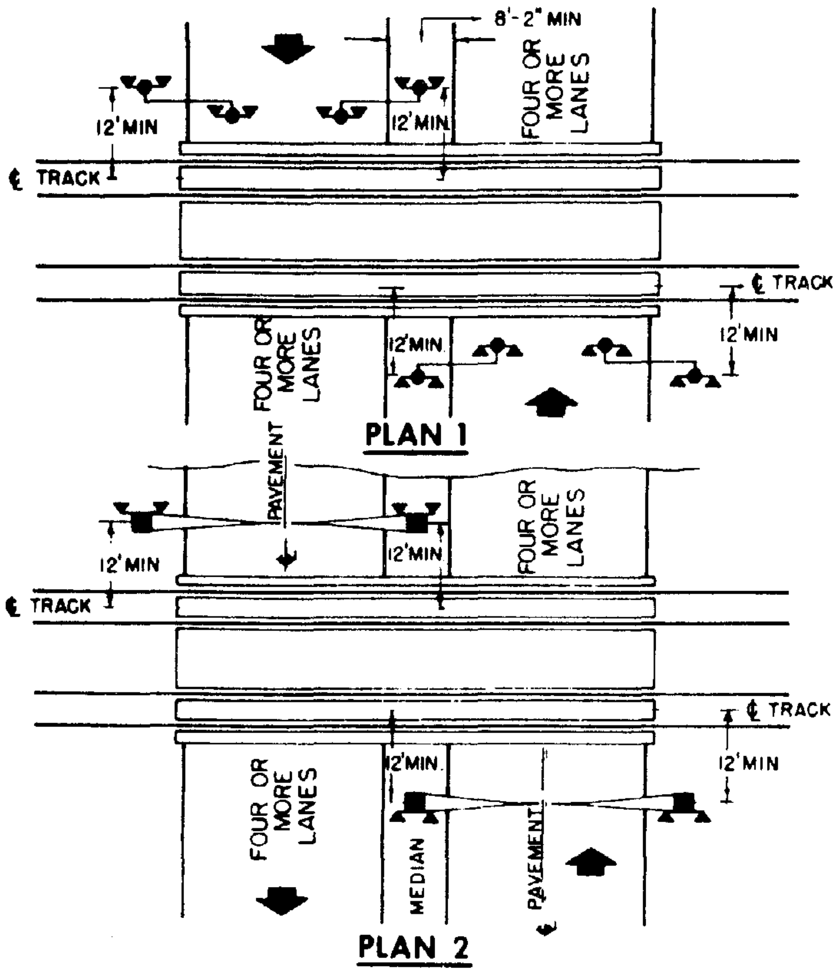


Figure 72

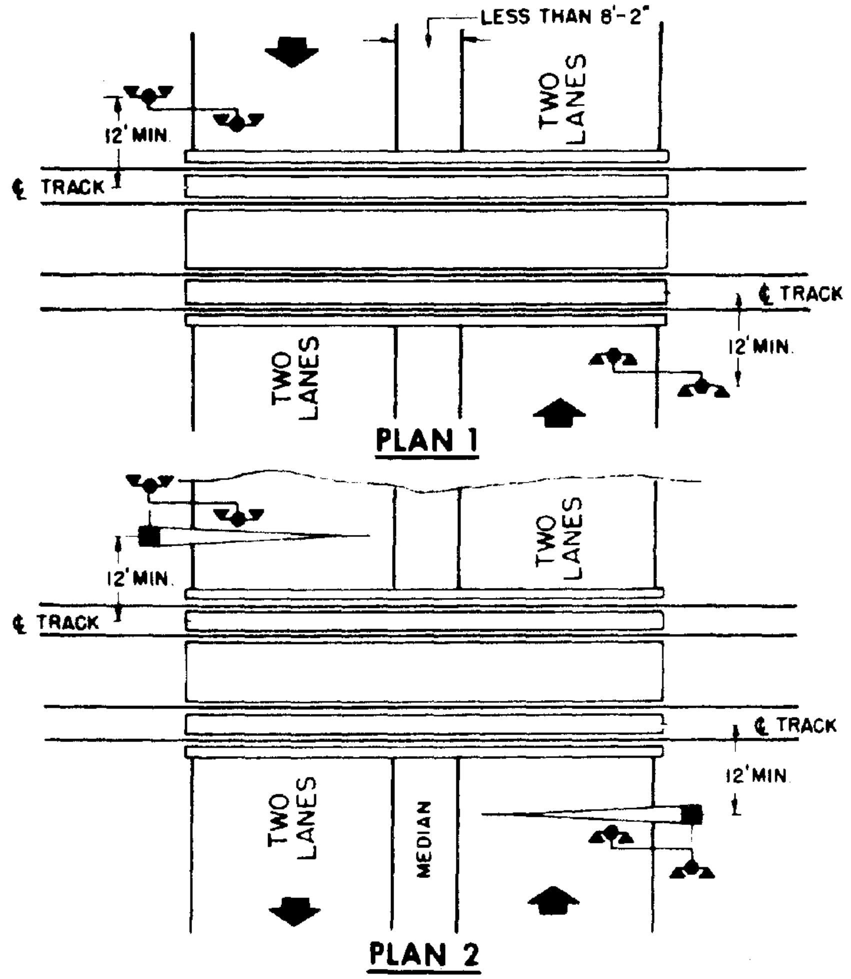
1 ft = 0.304 m



TYPICAL LOCATION PLANS
FOR FLASHING LIGHT SIGNALS
AND AUTOMATIC GATES
FOR ONE-WAY HIGHWAY TRAFFIC (FOUR OR MORE LANES)
DIVIDED HIGHWAY
RIGHT ANGLE

Figure 73

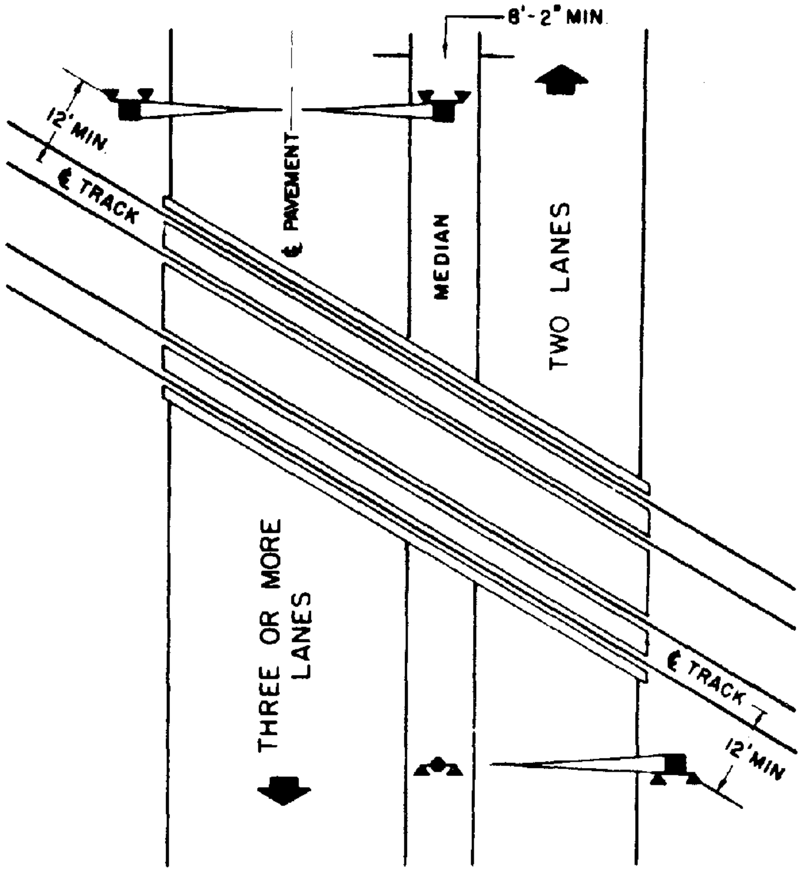
1 ft = 0.304 m



TYPICAL LOCATION PLANS
FOR FLASHING LIGHT SIGNALS
AND AUTOMATIC GATES
FOR ONE-WAY HIGHWAY TRAFFIC (TWO LANES)
DIVIDED HIGHWAY
RIGHT ANGLE

Figure 74

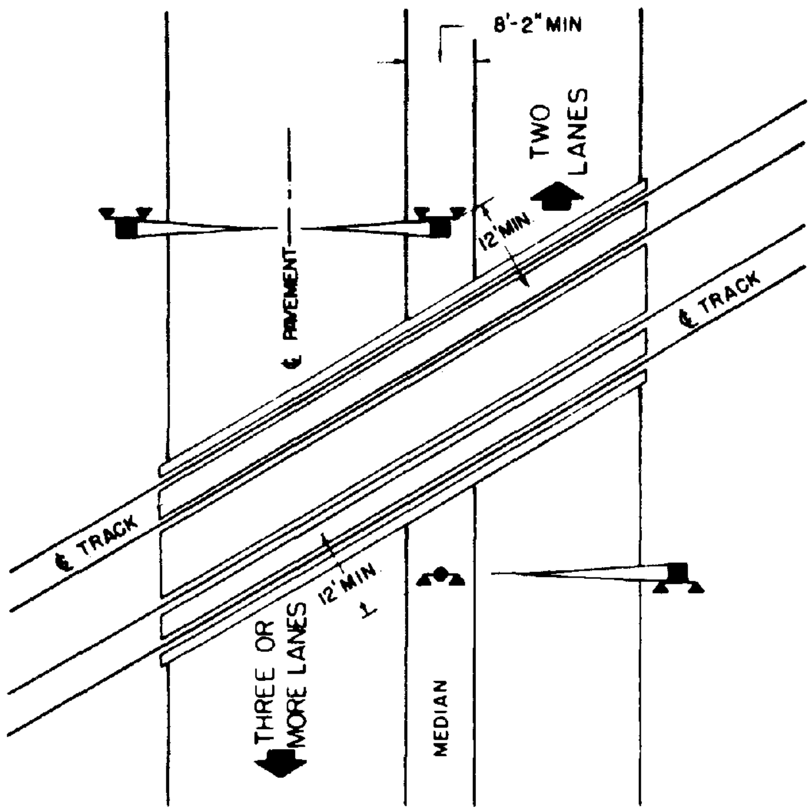
1 ft = 0.304 m



TYPICAL LOCATION PLAN (COMPOSITE) FOR
FLASHING LIGHT SIGNALS AND AUTOMATIC GATES
FOR ONE-WAY HIGHWAY TRAFFIC DIVIDED HIGHWAY
ACUTE ANGLE

Figure 75

1 ft = 0.304 m



TYPICAL LOCATION PLAN (COMPOSITE) FOR
FLASHING LIGHT SIGNALS AND AUTOMATIC GATES
FOR ONE-WAY HIGHWAY TRAFFIC DIVIDED HIGHWAY

OBTUSE ANGLE

Figure 76

1 ft = 0.304 m

of the driver as he approaches the crossing should be removed. Figures 65 through 76 show typical locations of flashing light signals and gates with respect to the highway and track for different situations. The MUTCD recommends a minimum clearance of 2 feet (0.610 m) between the curb and the near edge of the control devices and certain other horizontal clearances (Figure 51).

7.5.2 Computation of Length of Approach Track Circuit

All circuits described previously have a basic requirement that minimum warning time be afforded the fastest moving train. To estimate the distance required to accomplish this requirement, the following procedure should be used.

1) Determine speed of fastest train (S) in miles per hour (km/h).
2) Establish minimum warning time (T), normally 20 seconds or greater.
3) Solve the following equation for distance (D) in feet (m).

$$D = 1.47 \times T \times S \quad (D = 0.278 \times T \times S)$$

Example:

Minimum warning time = 20 seconds = T
Train speed = 70 mph (112.7 km/h) = S
$D = 1.47 \times T \times S \quad (D = 0.278 \times T \times S)$
$D = 1.47 \times 20 \times 70 \quad (D = 0.278 \times 20 \times 112.7)$
D = 2058 feet (627 m), normally rounded to 2100 feet (640 m).

As the speed of the fastest train will vary somewhat depending on the train operator, it is advisable to increase the estimate of the speed of the fastest train by 10 miles per hour (16 km/h). Thus the length of the track circuit from the previous example should be:

$D = 1.47 \times 20 \times 80 \quad (D = 0.278 \times 20 \times 128.8)$
D = 2352 feet (716 m) or 2400 feet (732 m)

Although the recommended 20-second warning will be adequate for nearly all stopped vehicles at nearly all crossings, careful consideration should be given to the needed warning time at crossings with steep approaches or where extremely long vehicles are apt to cross. To calculate for required warning time, use the following equation:

$$T = \frac{D + W + L}{1.47S} \qquad (T = \frac{D + W + L}{0.278S})$$

Where:

T = required warning time (seconds)

D = distance (feet, metres) to nearest track from stopped location (normally 20 feet (6.1 m) or more)

W = width of crossing (feet, metres) from near side of nearest track to 10 feet (3.1 m) beyond far side of farthest track

L = length of vehicle (feet, metres)

S = average vehicle speed in miles per hour (km/h)

7.5.3 Size of Roundels for Flashing Light Signals

Two sizes of roundels, or lenses, are available for flashing light signals, 8-3/8 inches and 12 inches (21.3 cm and 30.5 cm). In choosing an appropriate size, consideration should be given to the following:

Twelve-inch (30.5 cm) lenses normally should be used:

- For crossings with 85 percentile vehicle approach speeds exceeding 40 mph (64 km/h).
- For crossings where signalization might be unexpected.
- For special problem locations, such as those with conflicting or competing background lighting.

7.6 OPERATION GUIDELINES

The operation of the grade crossing traffic control device system should, in most cases, be continuous and completely reliable. As all electro-mechanical devices are subject to malfunction or failure, steps must be taken to ensure that, in the event of some malfunction, safety at the grade crossing is not jeopardized. The two major components which must be considered are the control system and the power supply.

7.6.1 Fail-Safe Operation

As mentioned previously, all control systems are designed essentially on a fail-safe principle. Normally, the operation is, to the extent practical, on a closed circuit basis. If the circuit is interrupted for any reason (usually a train) the active crossing devices operate. Thus if there is any malfunction in the track or control circuits there will be an adequate, if not totally credible measure of warning indicated at the crossing. To reduce any losses in credibility, signals should be silenced as soon as possible and manually operated until the malfunction is located and repaired.

7.6.2 Standby Power (from Reference 3)

> Unlike ordinary street intersection traffic lights, which are operated solely by commercial power, railroad-highway grade crossing signals are inherently required to have two sources of power in the event of failure of the commercial source. This requirement means that additional apparatus is needed to provide an alternate source of power whenever the commercial power fails. Figure 77 shows a typical arrangement of a power transfer circuit.
>
> This illustration shows the primary and secondary windings of the transformer and the power transfer relay.
>
> The power transfer relay is connected to the low voltage side of a transformer, the primary of which is permanently connected to the 115 or 230-volt a.c. power source. The mechanical and electrical construction of a power transfer relay is in general similar to a regular neutral direct current relay with half-wave rectifiers added across each of the operating coils of the relay.
>
> It is important that the power transfer relay should not be connected across the same transformer taps that carry the lamp load. Should it be necessary to connect the relay across taps already carrying a load, those taps should be selected whose load is almost constant and unaffected by the operation of power transfer relay. This should be kept in mind to prevent oscillating or pumping action of the armature and buring contacts due to variation in lampload demand.
>
> The illustration shows the stand-by power source (usually storage battery) terminating at the back contacts of the power transfer relay. Normally, (with a.c. power on) alternating current from the secondary winding is fed to the load circuit through the front contacts of the power transfer relay. However,

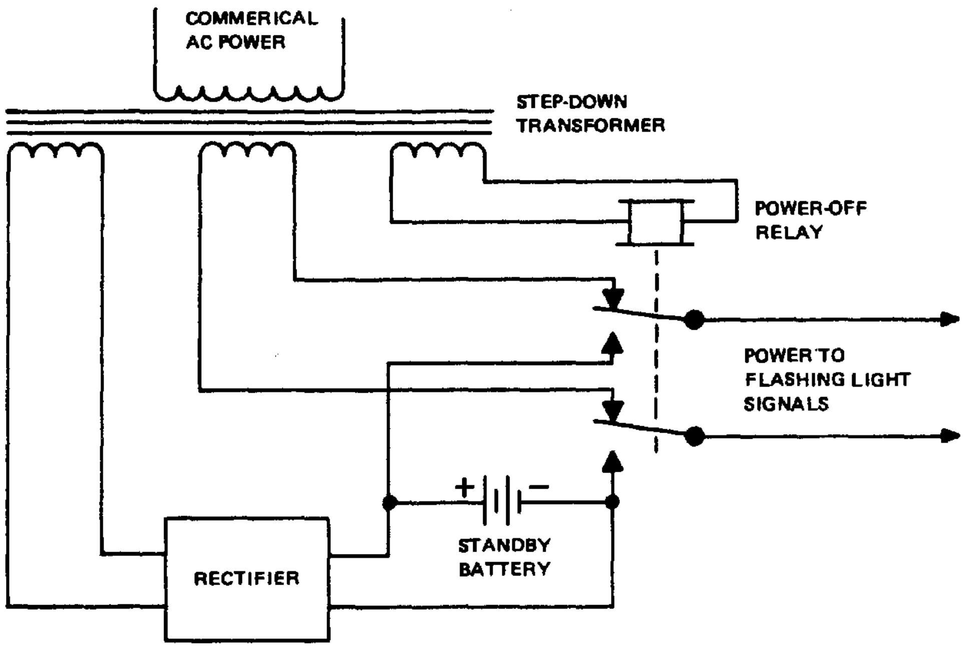


Figure 77. Power Transfer Circuit

in the event of loss of energy from the transformer, the armature by force of gravity drops and closes its back contacts thereby connecting the lamp circuit to the stand-by power source which carries the load until a.c. power is restored.

During one-half of each a.c. cycle, current flows through one relay coil and that leg of the rectifier in parallel with the second relay coil, while during the second half of each cycle current flows through the second relay coil and that leg of the rectifier in parallel with the first relay coil.

Notwithstanding this alternating action, the relay is quiet at all impressed voltages since the mutual inductive coupling of the two legs, and the inductance and low resistance of each leg of the circuit, causes the current flowing therein to have a direct current component. Although the current through each coil pulsates, the sum of the currents in both coils is practically constant. This means that the electromagnetic flux acting on the armature is practically constant, therefore there is no tendency for the armature to vibrate and the effect is equivalent to action of direct current.

The necessity of depending on battery stand-by power for grade crossings signals limits the wattage of the lamps used.

7.7 MAINTENANCE

With due regard for safety and for the integrity of operations by highway and railroad users, the highway agency and the railroad company are entitled to jointly occupy the right-of-way in the conduct of their assigned duties. This presumes some joint responsibility in the traffic control function between the public agency and the railroad. Under current procedures the railroads design, install, operate, and maintain the traffic control devices at the crossing, although in some states the railroads receive reimbursement for a part of the maintenance costs.

Most of the traffic control devices used at grade crossings function to control highway traffic in a manner very similar to other highway traffic control devices. Although maintenance of grade crossing traffic control devices and their circuitry is performed by railroad personnel, highway authorities have a concern about the quality of maintenance performance. Signs not adjacent to a crossing and pavement markings are maintained by the highway agency having jurisdiction over the highway on which the crossing is located. Railroad maintenance personnel and highway agency personnel should perform their work cooperatively.

7.7.1 Cost-Effectiveness

There are essentially two types of maintenance - preventive and emergency. Seemingly without fail, emergency maintenance occurs after hours. Thus not only is emergency maintenance expensive, it is time and a half expensive. Yet the National Advisory Committee on Uniform Traffic Control Devices estimates that 90 percent of emergency maintenance can be eliminated with an adequately supervised preventive maintenance program.

7.7.2 Responsibility and Jurisdiction

The first step to be taken by cooperating railroad and government agencies after the completion of a grade crossing improvement is the designation of responsibility to expedite preventive maintenance programs, and to cooperate in the efficient dispatching of emergency maintenance crews. The appropriate agencies should maintain highly skilled personnel and adequate equipment for proper preventive and emergency maintenance.

Included in railroad maintenance are crossbucks, bells, signals, gates, and associated control equipment. The preemptor for nearby signalized highway intersections is maintained by the agency having jurisdiction over the intersection.

Highway agency responsibility includes exempt crossing, do not stop on tracks, and stop signs in addition to all signs and pavement markings on the highway approaches. These devices include all advance warning signs and centerline markings.

7.7.3 Traffic Control During Maintenance Operations

Traffic control generally includes detours, lane closures and other maintenance functions which disrupt or affect the normal flow of highway traffic. Part VI of the MUTCD details practices and procedures to be followed for all construction and maintenance activities that effect the traveling public. Adherence to the guidelines will provide safe and efficient traffic control. At locations where active warning devices are inoperative for maintenance activities, special emphasis is placed on the need for flagmen at, and in advance of, the crossing to signal the approach of a train. Responsible agencies must make every effort to provide for the safety of all personnel involved in maintenance activities.

7.7.4 Scheduling

Due to an extremely wide variety of environmental and traffic conditions, it is difficult to set specific inspection intervals. In general both signs and pavement markings should be inspected at night every 3-6 months to determine that not only are they in good condition, but also that their reflectivity is adequate. Any deficiencies should be immediately reported and corrected.

Pavement marking experience at a particular locale may indicate an approximate interval between repainting operations. Such a determination will permit the programming of repainting into the overall striping program for the area. However, periodic inspection should not be eliminated in any case as spilled loads, resurfacing and other occurrences may obliterate the markings.

Sign deterioration is only one of several factors to be considered in sign maintenance. Of equal or greater importance are vandalism and inadvertent damage. Careful choice of material (plywood) mounting height (7 feet) (2.13 m) and mounting technique (metal straps) can reduce damage from vandalism. Damage caused by accidents is difficult to avoid and can be controlled only through regular inspection and repair.

7.7.5 Coordination

As the railroad-highway grade crossing is a complex interaction between two very different traffic streams, coordination of activities at the crossing is essential. Each of the two agencies is well versed in the safety and control of their respective traffic streams. Thus each should be responsible for safety during maintenance operations. Highway maintenance activities do not always require the presence of railroad personnel to be effected safely. The notable exception is when such activities take place on the tracks or within the railroad right of way. However, railroad activities which involve the testing and operation of warning devices may often require some control of highway traffic to provide for adequate safety.

To successfully coordinate maintenance activities, an open channel of communication must be established between railroad and highway maintenance foremen. For long-range programming, similar communications should be set up between the respective maintenance engineers. However, on a day-to-day basis, and especially on an emergency basis, the immediate maintenance supervisors, and foremen, must have a good working relationship. In all cases, each foreman should contact the other prior to maintenance activities in the proximity of the crossing. At that time the two should agree on the necessity and level of effort of participation of each agency during maintenance activities.

7.7.6 Identification and Reporting

One of the major problems in maintaining traffic control devices is that of knowing of their disrepair. Regardless of the quality of scheduled inspection, many devices will become damaged without the knowledge of the responsible agency. For this reason, all highway and railroad crews should be encouraged to be on the lookout for damaged devices and report any damage at their first opportunity. The travelling public will probably also be a good source of damage information. Most calls will be directed to the highway agency. The channel of communication set up for maintenance coordination should also be used for reporting needed maintenance to the appropriate agency.

7.8 REFERENCES

1. Manual on Uniform Traffic Control Devices. U.S. DOT, FHWA.
2. Manual on Uniform Traffic Control Devices--Official Rulings on Requests. Federal Highway Administration, Volume VI, page 30, June 1975.
3. Association of American Railroads. American Railway Signaling Principles and Practices. Chapter XXIII - 1962.
4. Traffic and Transportation Engineering Handbook, ITE, 1975.
5. Traffic Control Devices Handbook - An Operating Guide, Part VIII Supplement - Railroad-Highway Grade Crossings, National Advisory Committee on Uniform Traffic Control Devices, U.S. DOT, FHWA

6. ITE Technical Council Committee 4W-A, "Coordination of Traffic Signals with Railroad Grade Crossing Protection," Traffic Engineering, Volume 46, No. 12, December 1976.

7. Rail-Highway Grade Crossing Warning Systems - Equipment and Application, Railway Progress Institute, January 1977.

hand, have a continuous green or flashing amber light to identify them. Hopkins and Holmstrom (1) have proposed a flashing amber light to indicate the absence of trains. The use of low intensity xenon lamps would meet the power constraints.

8.3 REFERENCES

1. "Railroad Grade Crossing Passive Signing Study - Final Report" by Joseph S. Koziol, Jr., and Peter H, Mengert, U.S. Department of Transportation, 1978.

2. "Safety Features of Stop Signs at Rail-Highway Grade Crossings" by James H, Sanders, Hugh W. McGee, and Chang S. Yoo, BioTechnology, 1978.

3. "Motorists' Requirements for Active Grade Crossing Warning Devices" by Robert Ruden, MBAssociates, 1978

4. Hopkins, John B. and Holmstrom, F. Rose. "Toward More Effective Grade-Crossing Flashing Lights." Transportation Research Records 562. Washington, D.C. 1976.

5. Coulombre, Robert E. New Concepts for Grade Crossing Gates, prepared for TRB Commission on Socio-Technical Systems. August, 1975.

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8.0 GRADE CROSSING RESEARCH AND DEVELOPMENT

The material that has been presented in the previous seven chapters represents technology that has been utilized in actual practice for many years. There are numerous research and development efforts underway in the field of railroad-highway grade crossings, however, and it will be the purpose of this chapter to briefly identify and discuss these efforts. Also, a brief review of potential new and innovative control devices will be presented.

8.1 DOT RESEARCH AND DEVELOPMENT

Currently there are a number of Federal and State funded research studies underway to improve grade crossing safety. In Federally funded research efforts, the following areas are being studied:

1) Passive Signing - A study (1) funded by the Federal Highway Administration (FHWA), the Federal Railroad Administration (FRA), and 25 participating States to test and evaluate improved passive signing for use at grade crossings is now underway. Experimental advance warning signs and crossbucks have been tested in 15 States. Driver head movement data and speed profile data were used to evaluate the new signs.

2) Stop Signs - An FHWA funded study (2) is underway to determine the safety features of stop signs at grade crossings. This contract investigates the advantages and disadvantages of stop signs at grade crossings. The research analyzes drivers' behavior at grade crossings with stop signs and at neighboring highway intersections with stop signs to determine if motorists' disregard of grade crossing stop signs results in a disregard of stop signs at other intersections. The study includes the importance of law enforcement in the effective use of stop signs at grade crossings.

3) Active Devices - An FHWA funded study (3) is underway to improve the visibility of grade crossing active devices. Drivers' reactions to modifications to existing active devices were

studied in a laboratory under daylight, late afternoon fog, and night conditions. The most promising modifications, the addition of three white strobe lights to the flashing light units and the addition of red, white, and blue strobes to the gate arm, were field tested under actual operating conditions.

4) Strobe Lights - FRA funded research now being conducted by the Transportation System Center (TSC) is investigating the use of red strobe lights to supplement the existing grade crossing flashing lights. TSC is also investigating the use of red strobes on locomotives to help improve the visibility of locomotives at and in the vicinity of grade crossings. Demonstration work is now underway with a number of railroads.

5) Grade Crossing Illumination - A study funded by the Office of the Secretary of Transportation (OST) is underway to evaluate the effectiveness of illumination at grade crossings, to determine if illumination improves safety, and to determine guidelines for the conditions where illumination is most effective. This study is being conducted by Kansas State University. The work includes a review of illumination standards and criteria, laboratory testing of illumination strategies, and analysis of accident data for crossings with and without illumination.

6) Structural and Geometric Design of Grade Crossings - The objective of this study was to develop implementable structural and geometric design criteria for highway-railroad grade crossings. This three year study was an HPR study conducted by the Texas Transportation Institute.

7) Measures of Effectiveness of Grade Crossing Improvements - The objective of this study is to establish appropriate methodology for measuring and evaluating effectiveness of safety improvements

at grade crossings using available crossing inventory, accident and economic data.

8) Constant Warning Time Devices for Use at Grade Crossings - This study is jointly funded by FHWA and FRA. The objectives are to improve grade crossing safety through the effective use of constant warning time devices, to improve the reliability of such devices, and to lower their costs. Constant warning time devices, have the capability of sensing the presence of a train, measuring its speed and distance, and, through the use of a small computer, begin operation of the warning device when the train is a certain time (20 seconds or more) away from the crossing. The constant warning time device provides a uniform warning time for all trains regardless of speeds. High costs and high power requirements currently limit the increased installation of these devices.

9) Grade Crossing Active Advance Warning Signals - The objectives of this study are to identify grade crossing environments where active advance warning signals are needed, to evaluate the effectiveness of such devices, and to develop, test, and evaluate prototype active advance warning devices. This effort is funded by FHWA and FRA. With existing grade crossing warning systems, motorists do not know what type of warning to expect as they approach a crossing. Data is needed about driver behavior at active and passive crossings. There is also a lack of information about the motorists' acceptance of advance warning signals (credibility). This study will analyze drivers' attitudes towards active advance warning signals, study driver behavior data and speed profile data, analyze costs of providing active advance warning signals, and test and evaluate various active advance warning signals.

10) Off Track Train Detection and Warning Devices for Use at Grade Crossings - This study is funded by FHWA and FRA. The objectives are to demonstrate the feasibility of off-track train detection and warning devices and to develop and field test prototype devices. Approximately 22% of all grade crossings have some form of active warning device. The track circuit is used for train detection in all forms of active warning devices. Previous work by the Transportation Systems Center (TSC) indicated that off-track train detection may be feasible but further work is needed. This study will involve an analysis of existing technology for use in providing off-track train detection and warning. The study will also include an analysis of alternate ways of providing effective off-track detection and the design and field testing of prototype devices.

11) Grade Crossings Institutional Study - Three areas are being investigated in this Federal Railroad Administration (FRA) funded study conducted by TSC and scheduled for completion in late 1977:

A. Grade Crossing Inventory/Accident Data Analysis
The objective of this task is to develop a computer program and capability to facilitate categorization and stratification of national grade crossing inventory and accident data. A detailed statistical characterization of the national grade crossing inventory will be performed to provide such information as the number of public crossings by protection class, level of train and highway traffic, and location. Computergraphic techniques will be applied to display the results in easily interpreted formats. Detailed analysis and development of prediction equations will be performed. Results from this task will be used in development of criteria for installation of alternative grade crossing motorist warning systems, based upon estimation of both accident probability and cost of warning systems.

B. Grade Crossing Institutional Study, Railroad Industry

This task will investigate causes of railroad institutional resistance to the acceptance of grade crossing research results. Emphasis will be placed on determining means of alleviating this resistance and enhancing the acceptability of research results which show potential for effectively improving grade crossing safety. A major factor to be investigated which influences railroads willingness to implement new warning systems has been the issue of liability. This task will review legal cases, accident records, and specific situations where new, innovative or nonstandard grade crossing equipment was a factor in establishing actual or potential railroad liability for accidents.

C. Grade Crossing Institutional Study, State Governments

State and local administrative agencies have an important role in the implementation of grade crossing equipment. The control exercised by these agencies can affect the installation, financing, inspection and legalization of grade crossing equipment. This task will investigate the degree to which this control impacts the implementation of existing and innovative equipment. States, through authority delegated to their administrative agencies are confronted with liability problems for other transportation modes. A study of these analogous liabilities and how they are managed by State agencies will be performed to provide useful information for subsequent application to accident experience at grade crossings.

A number of States are conducting studies investigating: new passive signing, active advance warning signals, the use of reflectorized panels at crossings, improved maintenance procedures, and grade crossing accident and inventory data.

8.2 INNOVATIVE GRADE CROSSING TRAFFIC CONTROL DEVICES

Because of the serious nature of the responsibility and potential liability of agencies involved in grade crossing safety, there is a reluctance to install unproven control devices. The Manual on Uniform Traffic Control Devices sets forth a procedure for the use of new devices. However, approval should also be obtained from a state regulatory agency or similar authority before installing a device which has not previously received approval and been used. Research and study efforts to find control devices that are more economical and efficient and can contribute to greater safety at grade crossings should be encouraged. A brief review of some studies on new and innovative control devices will be presented here to provide the reader with information on the continuing efforts in this area.

8.2.1 Flashing Lights

The fundamental limitation on flashing lights is the very low power consumption permitted, as they must operate from batteries for several days in the event of commercial power failure. This has led to the use of 18-25 watt bulbs, compared to 60-150 watt bulbs in highway traffic signals. As a result, adequate intensity can only be obtained through focusing of the lights to a narrow beam.

One approach that has received considerable attention is the use of xenon lights in place of incandescent lamps. The benefits gained through the use of xenon lamps may be summarized as follows:

- Useful lamp life of 3,000 to 10,000 hours.
- Greatly reduced need for precise alignment.
- Increased alerting effectiveness through short-duration flashes.

These lights utilize standard railroad flashing light heads, mountings, and roundels. The only additions are the sealed-beam xenon lamps and a power supply, which should cost (1976) about $250 per pair (4).

8.2.2 Crossing Gates

Automatically operated gates at grade crossings have been found to be the most effective type of control device, but they are also the most expensive to install and maintain. A recent study (5) listed specific changes that should be considered to place more emphasis on performance requirements and less on design configuration; one such item was the gate arm:

> A gate-arm support which allows the arm to swing out of the way when struck and then immediately return to its intended position without significant damage to the arm, or drive mechanism, while possibly costing more to purchase initially, may have potential for substantial overall cost saving by reducing the number of arm repairs and replacements. It is, therefore, the combination of swingaway support and a very strong, lightweight, inexpensive arm that shows the greatest promise of overall cost saving. The gate-arm material recommended uses a cellular paper core impregnated with phenolic resin and encased in a sprayed coating of chopped fiberglass reinforced polyester resin.
>
> The gate-arm swingaway feature consists of a two-piece aluminum arm support. The gate-arm is mounted so that it is free to rotate about a pivot that is inclined at an angle with respect to the gate drive mechanism output shaft. The result is that when the gate-arm is struck by an automobile the entire assembly will rotate forward and upward out of the way . . . unless subjected to the impact of an automobile, the gate-arm is held in the normal position by a detent device consisting of a spring loaded plunger operating on a rotating latch and pawl. This latching assembly prevents unintended motion of the arm under wind or other miscellaneous loading but allows the arm to move freely when forced by a collison.

8.2.3 Advance Warning Signs

A major difference between grade crossings and highway intersections with active control devices is the advance warning. In the purely highway situation, it is common practice to provide signs indicating "SIGNALS AHEAD", or signs showing a highway traffic signal. At grade crossings, the advance warning rarely distinguishes between passive and active crossings, even though quite different driver looking behavior is required. This problem requires only that a simple set of warnings be adopted and standardized. In certain cases, especially those with high speed traffic and obscured crossings, active advance warnings may be necessary.

When a motorist approaches a crossing at night, he usually does not know whether it is active or passive. Highway intersections, on the other

FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent, national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by keeping the demand-capacity relationship in better balance through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

* The complete 7-volume official statement of the FCP is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161 (Order No. PB 242057, price $45 postpaid). Single copies of the introductory volume are obtainable without charge from Program Analysis (HRD-2), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

6. Prototype Development and Implementation of Research

This category is concerned with developing and transferring research and technology into practice, or, as it has been commonly identified, "technology transfer."

7. Improved Technology for Highway Maintenance

Maintenance R&D objectives include the development and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.