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16. Abstract

The design of at-grade intersections near highway-railroad grade crossings is challenging because of the interaction between the two geometric features. Their designs can have a critical effect on safety and operation at both features. These guidelines provide information helpful in the following specific areas: traffic control devices, signal interconnection, channelization, high-profile or "hump" crossings, and illumination.

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DESIGN GUIDELINES FOR AT-GRADE INTERSECTIONS NEAR HIGHWAY-RAILROAD GRADE CROSSINGS

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DISCLAIMER

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Some of the traffic control device drawings are from R.C. Moeur's *Manual of Traffic Signs*, (http://members.aol.com/rcmoeur/). The drawings are reprinted from the website by permission. The authors thank Mr. Moeur for the use of the drawings.

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CHAPTER 1
INTRODUCTION

The design of at-grade highway intersections and highway-railroad grade crossings is frequently complex and problematic, requiring the designer to examine and respond to many different factors and issues. Their design when both are in close proximity is even more problematic. Designers must respond to physical constraints that sometimes require clearances between the railroad and the parallel roadway edge to be reduced (affecting alignment and traffic control devices), traffic control systems may have to be interconnected to work properly, and warning systems related to the at-grade intersection may conflict or distract from systems related to the highway-railroad grade crossing.

A number of recommendations are incorporated in these guidelines regarding various design features and elements related to the proximity of at-grade intersections and highway-railroad grade crossings. The designer is cautioned, however, that all issues related to each individual feature are not reviewed; rather, those elements made more problematic by the juxtaposition of the two are examined.

CHAPTER 2
TRAFFIC CONTROL DEVICES

Intersections near highway-railroad grade crossings have multiple types of traffic: vehicles, trains, and pedestrians. Special traffic control devices are needed at these intersections to properly coordinate the movements of these various types of traffic. There are several levels of traffic control at highway-railroad grade crossings, divided primarily into passive and active control devices. The most basic of these devices, passive devices, provide static messages of warning, guidance, and perhaps action required by the driver (see Figure 1). Among these passive devices are signs and pavement markings. For more advanced traffic control, active control devices are necessary; these devices give warning of the approach or presence of a train and are activated by the passage of a train over a detection circuit in the track. One of the most predominant forms of active traffic control is the use of automatic gates, which physically block the travel lanes and are used in conjunction with flashing lights. Active control devices are supplemented by the same signs and markings used in passive control.

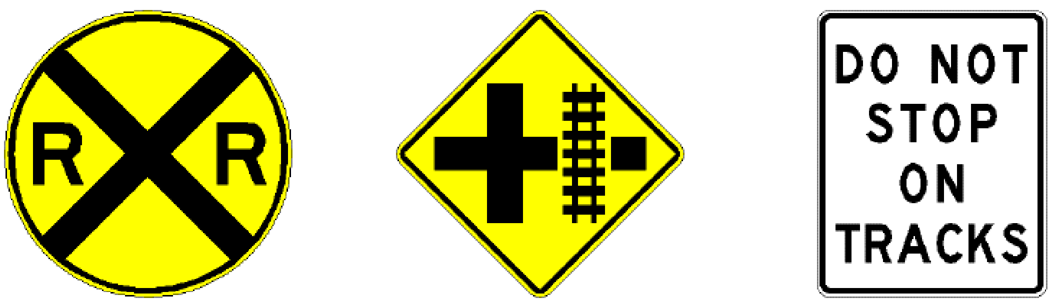

Figure 1. Examples of Traffic Control Devices Used at Highway-Railroad Grade Crossings (*1*).

BACKGROUND

The majority of guidance provided on the proper usage of signs, markings, and gates is provided in the *Manual on Uniform Traffic Control Devices* (MUTCD) (*2*), although other sources contain a limited amount of additional information.

According to the *Railroad-Highway Grade Crossing Handbook* (*3*) published by FHWA, an automatic gate "serves as a barrier across the highway when a train is approaching or occupying the crossing." Regarding the fabrication of gate arms, FHWA stipulates that gates on two-way streets should cover enough of the approach to physically block the motorist from going around the gate without going into the opposing lane. In general, gate arms are not longer than 40 feet (*3*).

A Policy on Geometric Design of Highways and Streets (referred to as the *Green Book*) by the American Association of State Highway and Transportation Officials (AASHTO) (*4*) lists traffic control devices at grade crossings consisting primarily of signs, pavement markings, flashing light signals, and automatic gates. The material in the *Green Book* refers the reader to the MUTCD (*2*) for standards on design, placement, installment, and operation of these devices. AASHTO lists several considerations for evaluating the need for devices such as automatic gates: type of highway, volume and speed of railroad and vehicular traffic, volume of pedestrian traffic, accident history, sight distance, geometrics, number of tracks at the crossing, and volume of school buses or vehicles transporting hazardous materials. AASHTO recommends that even when flashing lights and automatic gates are used, small intersection angles should be avoided (*4*).

The MUTCD contains the same guidelines for gate arms as the *Railroad-Highway Grade Crossing Handbook* (*3*), but it also contains additional material that defines a standard for the design, installation, and use of automatic gates.

In the MUTCD, Part VIII contains the vast majority of information on traffic control devices at grade crossings and is divided into four major sections: General, Signs and Markings, Illumination, and Flashing-Light Signals and Gates. Other references to relevant traffic control devices are found in sections 2A and 5F (*2*).

Section 2A of the MUTCD contains general guidelines and standards for the use of all signs. It states that "the functions of signs are to provide regulations, warnings, and information for road users." It further states that "the use of signs should be based on engineering judgment. Results from traffic engineering studies of physical and traffic factors should indicate the locations where signs are deemed necessary."

Section 8A.1 provides an introduction to traffic control at highway-railroad grade crossings. It states that "traffic control for rail roadway intersections include all signs, signals, markings, illumination and other warning devices and their supports along roadways approaching and at railroad crossings at grade. The function of this traffic control is to permit safe and efficient operation of both rail and roadway traffic at grade crossings." The MUTCD recognizes that any crossing of a public road and a railroad is situated on a right-of-way available for the joint use of both roadway and railroad traffic. This joint occupancy requires joint responsibility in the traffic control function between the public agency and the railroad, in order to consider the safety and integrity of operations by both roadway and railroad users.

Sections 8A.2 and 3 describe the use of standard devices and uniform provisions. It advises that no single standard system of active traffic control devices is universally applicable for all roadway-rail intersections. An engineering study should determine the appropriate traffic control system. A standard is set forth that, prior to installation of a new or modified traffic control system, approval shall be obtained from the public agency with the jurisdictional and/or statutory authority, and the railroad should be notified.

Section 8B provides descriptions and figures for the use and placement of signs and markings used at or near grade crossings. Signs include the crossbuck and round advance warning signs, as well as other regulatory and warning signs. Illumination devices are described briefly in Section 8C, while section 8D outlines the use of flashing-light signals and gates.

Signalized intersections at or near grade crossings possess added concerns over intersections that are STOP-controlled. If traffic signals are not properly coordinated with railroad operations, severe accidents can occur. The Institute of Transportation Engineers (ITE), through the Traffic Engineering Council, developed a recommended practice for the preemption of traffic signals at or near railroad grade crossings with active warning devices (*5*).

According to the ITE recommended practice, where a signalized highway intersection exists in close proximity to a railroad grade crossing, the railroad signal control equipment and the traffic signal control equipment should be interconnected. This interconnection means normal operation of the traffic signals controlling the intersection should be preempted to operate in a special control mode when trains are approaching. A preemption sequence compatible with the railroad grade crossing active warning devices, such as gates and flashing lights, is extremely important to provide safe vehicular, pedestrian, and train movements. Such preemption serves to ensure that the actions of these separate traffic control devices complement rather than conflict with each other.

GUIDELINES

Based on the existing or proposed standards outlined above, the following guidelines are recommended for the use and placement of traffic control devices at highway-railroad grade crossings.

Placement of Signs, Markings, Signals, and Gates

For the placement and use of signs, markings, signals, and gates, it is recommended that the designer follow the guidelines provided in the most current edition of the Manual on Uniform Traffic Control Devices (*2*). The MUTCD contains the most information, guidance, and standards related to this subject, and other agencies refer to the MUTCD in their own documents. In addition, the MUTCD is already widely recognized and used as the standard.

Coordination and/or Preemption of Traffic Signals

Where a signalized intersection exists in close proximity to a railroad grade crossing such that coordination and/or preemption of traffic signals is necessary, it is recommended that the design for the interconnection of railroad signal equipment and traffic signal equipment use the guidelines outlined in the ITE Recommended Practice (*5*).

Active highway-railroad grade crossings (e.g., those with gates or cantilever warning lights) closer than 200 ft to highway intersections with traffic signals are required to have interconnections between the traffic signal controllers and the grade crossing controllers. In certain circumstances, interconnection may be warranted wider separations (see guideline on *Queuing*).

The ITE Recommended Practice identifies many elements necessary for proper preemption and provides references where feasible. Recommendations are provided in a general sense, with applications designed for local conditions. More information can be found within the ITE report.

KEY REFERENCES

- *Manual on Uniform Traffic Control Devices* (2)
- *Preemption of Traffic Signals At or Near Railroad Grade Crossings with Active Warning Devices* (*5*)
- *A Policy on Geometric Design of Highways and Streets* (*4*)

CHAPTER 3
INTERCONNECTION

When a highway-railroad grade crossing is located near a signalized intersection (i.e., Figure 2), it is possible that queues from the intersection could extend over the grade crossing and potentially cause stopped vehicles to become trapped on the tracks. To avoid this entrapment, traffic signals located near highway-railroad grade crossings need to be preempted when trains approach in order to clear vehicles off the tracks before the train arrives. Preemption of traffic signals is normally achieved through an electrical interconnection circuit between the railroad grade crossing warning system and the highway traffic signal controller assembly. The geometric design of any signalized intersection near a highway-railroad grade crossing should consider interconnection and preemption.

Figure 2. Signalized At-Grade Intersection Near Highway-Railroad Grade Crossing.

BACKGROUND

The most important decision about interconnection is whether it should be provided or not. According to Section 8C-6 of the MUTCD (*2*), preemption (and consequently interconnection) should be considered when the distance between the highway-railroad grade crossing and the signalized intersection is less than 60 m (200 ft). According to a recent National Cooperative Highway Research Program (NCHRP) Synthesis of *Traffic Signal Operations Near Highway-Rail Grade Crossings* (*6*), many state departments of transportation believe that the need for preemption should be based on a detailed queuing analysis, considering items such as roadway approach traffic volumes, number of lanes, nearby traffic signal timing, saturation flow rates, motor vehicle arrival characteristics, motor vehicle classes, etc., rather than a prescribed distance such as 60 m (200 ft). The 1997 Institute of Traffic Engineers *Recommended Practice on the Preemption of Traffic Signals At or Near Railroad Grade Crossings with Active Warning Devices* (*5*) also highlights the need for preemption to be based on a detailed queuing analysis. In the draft of the 2000 MUTCD, Section 8D.7 provides additional guidance over the 1988 MUTCD by recommending that “coordination with the highway-railroad grade crossing warning system should be considered for traffic control signals located more than 60 m (200 ft) from the crossing. Factors should include motor vehicle traffic volumes, approach speeds, and queue lengths."

Even though the above-mentioned guidelines focus on traffic operations and traffic control devices, they should form the basis of geometric design guidelines to ensure compatibility between geometric design, traffic control, and traffic operations.

GUIDELINES

The following guidelines are applicable to the geometric design of intersections near highway-railroad grade crossings.

Clear Storage Distance

The distance between the intersection and the highway-railroad grade crossing should be measured in accordance with the definition of the "Clear Storage Distance," as defined by the Technical Working Group (TWG) of the United States Department of Transportation (USDOT) Grade Crossing Safety Task Force (*6*):

> *Clear Storage Distance*: The distance available for vehicle storage measured 2 m (6 ft) from the rail nearest to the intersection to the intersection STOP BAR or the normal stopping point on the highway. At skewed crossings and intersections, the 2 m (6 ft) distance shall be measured perpendicular to the nearest rail, either along the centerline, or right edge line of the highway, as appropriate, to obtain the shorter clear distance.

Figure 3 shows how the Clear Storage Distance is measured at a skewed intersection.

Designing for Interconnection

The decision whether to design for an interconnection between the highway traffic signal controller assembly and the railroad grade crossing warning system should be based on the guidelines in the MUTCD. According to Section 8D.7 of the 2000 MUTCD, preemption should be provided when a highway-railroad grade crossing with an active traffic control system is located within 60 m (200 ft) of in intersection or mid-block location controlled by a traffic signal. Therefore, all intersections with active crossings and a Clear Storage Distance of 60 m (200 ft) or less should be designed for interconnection.

The ITE Recommended Practice (*5*) and 2000 MUTCD recognizes that preemption may be required at traffic signals located more than 60 m (200 ft) from the crossing, as determined by queue lengths, traffic volumes, and approach speeds. The ITE guideline recommends that a queue length analysis be conducted to determine the maximum extent of the queue. Therefore, the design traffic volume on the approach crossing the tracks should be used to perform a queue length analysis to determine the extent of the queue. If the extent of the queue exceeds the Clear Storage Distance in more than 5 percent of signal cycles during the design hour, the intersection should be designed for interconnection.

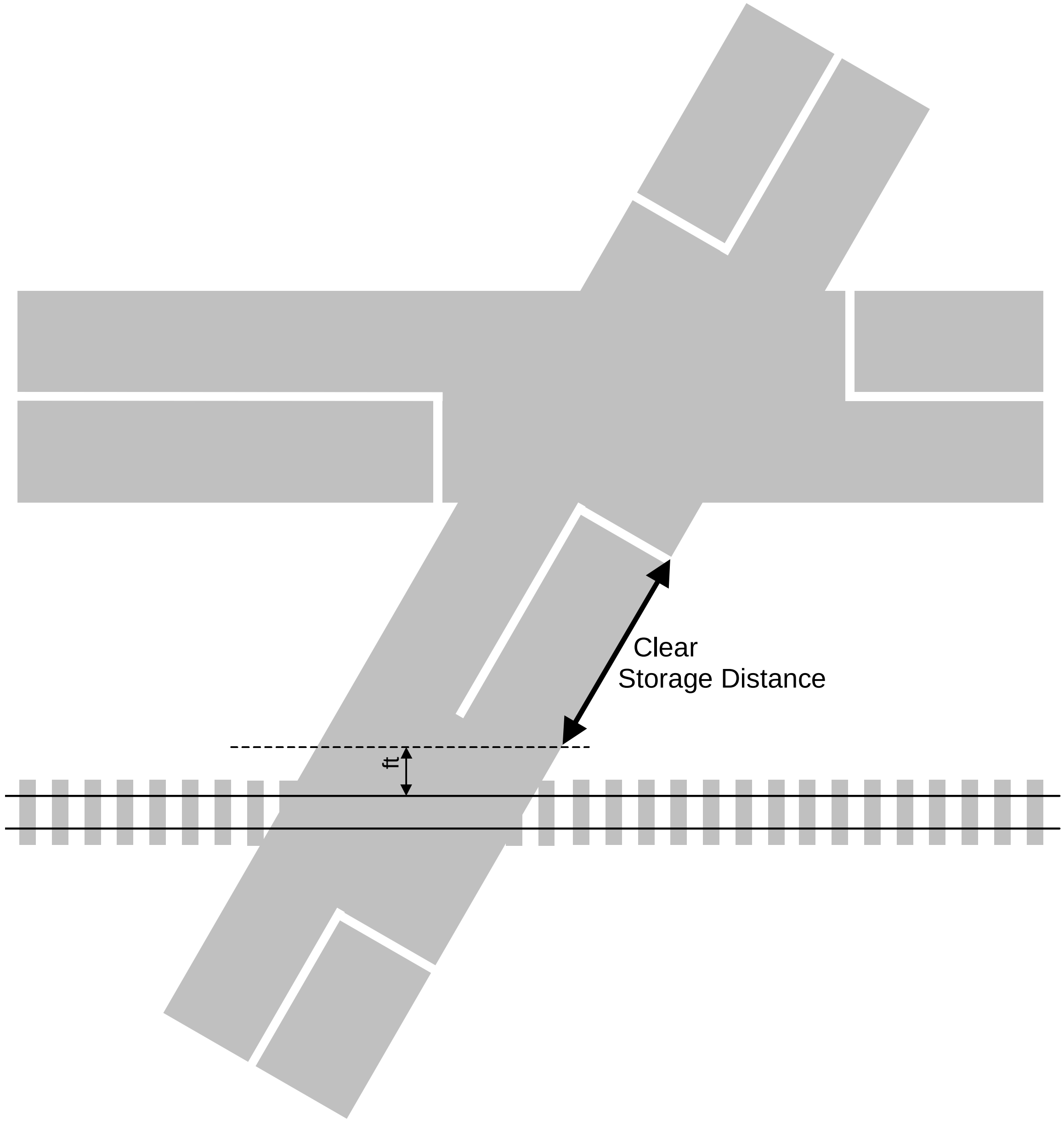

Figure 3. Clear Storage Distance at Skewed Crossings.

The queue length that would be exceeded in 5 percent of signal cycles corresponds to the 95th percentile queue length, which can be estimated either through simulation or analytical methods. Regardless of the methodology used, a queue analysis requires at least the following information:

- lane layout,
- design volume per movement,
- signal cycle length,
- effective green time per movement, and
- saturation flow per movement.

If a simulation analysis is done, these values can be entered into a simulation model such as CORSIM™ (*7*), which will simulate the resulting queue.

It is also possible to use the results from a simulation analysis by Oppenlander and Oppenlander (*8*), which produced a set of tables of queue length distributions (including 95th percentile queue) as a function of traffic volume, cycle length, and effective green time. Keep in mind that the Oppenlander tables are only applicable on a lane-by-lane basis, so it is the responsibility of the designer to determine the traffic distribution across lanes and to identify the critical lane that would result in the longest queue.

The 95th percentile queue can also be estimated analytically through the following equation (*9*):

$$N_{95} = \frac{qC(1-\lambda)}{(1-y)} + \frac{0.5x^2}{(1-x)} + 0.475\sqrt{\frac{(qC)^2(1-\lambda)^3(1+3\lambda-4y)}{(1-y)^2} + \frac{x^3(4-x)}{(1-x)^2}} \qquad (1)$$

where

N_{95} = 95th percentile queue (vehicles per lane)
q = average arrival flow rate (vehicles per second per lane);
C = cycle length (seconds);
λ = green time ratio, $\lambda = g/C$;
g = effective green time (seconds);
y = flow ratio, $y = q/s$;
s = saturation flow rate (vehicles per second per lane), assume a value of 0.5; and
x = degree of saturation, $x = (qC)/(sg)$, $x < 1.0$.

Note that this equation applies to the critical lane and is only valid for undersaturated conditions ($x < 1.0$), where demand (qC) is less than capacity (sg).

Equation 1 requires the designer select realistic values of the signal cycle length (C) and the effective green time (g) for the analysis. If the traffic signal operates in a coordinated system, the cycle length will be the same as that of the surrounding traffic signals, and the cycle length will depend on factors such as traffic volume, traffic speed, and signal spacing. The effective green time will be typically long enough to service the design volume at a degree of saturation (x) less than 0.90, but the effective green time will depend on the geometry of the intersection and the demand on approaches not crossing the tracks. In the absence of any other information, a value of 0.80 can be used for the degree of saturation.

The average arrival flow rate (q) applies to the critical lane design volume and can be calculated by dividing the critical lane design volume (in vehicles per hour per lane - or *vphpl*) by 3600. If the saturation flow rate (s) is not known, a value of 0.5 vehicles per second per lane (equivalent to 1800 vehicles per hour per lane) can be used.

Note that the queue estimate is given in vehicles per lane. To get the actual length of the queue, it is necessary to multiply the queue estimate with the average queue space per vehicle, taking into account the vehicle mix. Use the following equation:

$$L_{95} = N_{95} \sum_{i=1}^{n} p_i L_i \qquad (2)$$

where

L_{95} = 95th percentile queue length (feet)
N_{95} = 95th percentile queue (vehicles per lane)
n = number of vehicle classes in queue
p_i = proportion of vehicle class i (by volume)
L_i = queue space of a vehicle of class i (feet per vehicle)

In the absence of better information the values of L in Table 1 may be used:

Table 1. Queue Space by Vehicle Class.

Vehicle Class	Vehicle Queue Space L
Car	25 ft
Single Unit Truck	36 ft
Truck Combination	66 ft

Tables 2 to 7 provide values for the 95th percentile queue for known lane volumes, cycle lengths, and effective green times. Note that the queue is given in vehicle units, so that Equation 2 must be applied to calculate the actual length of the queue.

Table 2. 95th Percentile Queue (Vehicle Units) for a 60 Second Cycle Length.

Lane Volume (vphpl)	Cycle Length = 60 seconds						
	Effective Green Time (seconds)						
	10	15	20	25	30	35	40
50	2	1	1	1	1	1	1
100	3	3	2	2	2	2	1
150	4	4	3	3	3	2	2
200	6	5	4	4	3	3	2
250	9	6	5	5	4	3	3
300	-[a]	8	7	6	5	4	3
350	-	10	8	7	6	5	4
400	-	13	9	8	7	6	5
450	-	-	11	9	8	7	5
500	-	-	13	11	9	7	6
550	-	-	18	12	10	8	7
600	-	-	-	14	11	9	8
650	-	-	-	17	13	11	8
700	-	-	-	22	15	12	9
750	-	-	-	-	17	13	10
800	-	-	-	-	20	15	12
850	-	-	-	-	26	17	13
900	-	-	-	-	-	19	14
950	-	-	-	-	-	23	16
1000	-	-	-	-	-	30	18
1050	-	-	-	-	-	-	21
1100	-	-	-	-	-	-	25
1150	-	-	-	-	-	-	33
1200	-	-	-	-	-	-	-

[a] Queue estimates only valid for under-capacity conditions.

Table 3. 95th Percentile Queue (Vehicle Units) for a 75 Second Cycle Length.

Lane Volume (vphpl)	Cycle Length = 75 seconds								
	Effective Green Time (seconds)								
	10	15	20	25	30	35	40	45	50
50	2	2	2	2	1	1	1	1	1
100	4	3	3	3	3	2	2	2	2
150	5	5	4	4	4	3	3	3	2
200	9	6	6	5	5	4	4	3	3
250	-[a]	8	7	7	6	5	5	4	3
300	-	11	9	8	7	6	6	5	4
350	-	29	11	10	9	8	7	6	5
400	-	-	14	11	10	9	8	7	6
450	-	-	21	13	12	10	9	8	6
500	-	-	-	16	13	12	10	9	7
550	-	-	-	21	15	13	12	10	8
600	-	-	-	-	18	15	13	11	9
650	-	-	-	-	22	17	15	12	10
700	-	-	-	-	37	20	16	14	12
750	-	-	-	-	-	23	18	15	13
800	-	-	-	-	-	31	21	17	14
850	-	-	-	-	-	-	24	19	16
900	-	-	-	-	-	-	30	22	18
950	-	-	-	-	-	-	74	25	20
1000	-	-	-	-	-	-	-	30	22
1050	-	-	-	-	-	-	-	44	25
1100	-	-	-	-	-	-	-	-	30
1150	-	-	-	-	-	-	-	-	39
1200	-	-	-	-	-	-	-	-	-

[a] Queue estimates only valid for under-capacity conditions.

Table 4. 95th Percentile Queue (Vehicle Units) for a 90 Second Cycle Length.

Lane Volume (vphpl)	Cycle Length = 90 seconds										
	Effective Green Time (seconds)										
	10	15	20	25	30	35	40	45	50	55	60
50	2	2	2	2	2	2	2	1	1	1	1
100	4	4	4	3	3	3	3	3	2	2	2
150	7	6	5	5	5	4	4	4	3	3	2
200	-[a]	8	7	7	6	6	5	5	4	4	3
250	-	11	9	8	8	7	7	6	5	5	4
300	-	-	12	10	9	9	8	7	6	6	5
350	-	-	16	12	11	10	9	8	8	7	6
400	-	-	-	15	13	12	11	10	9	8	7
450	-	-	-	20	16	14	13	11	10	9	8
500	-	-	-	-	18	16	14	13	12	10	9
550	-	-	-	-	24	19	16	15	13	11	10
600	-	-	-	-	-	22	19	17	15	13	11
650	-	-	-	-	-	27	21	19	16	14	12
700	-	-	-	-	-	-	25	21	18	16	14
750	-	-	-	-	-	-	31	24	21	18	15
800	-	-	-	-	-	-	-	27	23	20	17
850	-	-	-	-	-	-	-	34	26	22	19
900	-	-	-	-	-	-	-	-	30	25	21
950	-	-	-	-	-	-	-	-	38	28	23
1000	-	-	-	-	-	-	-	-	-	32	26
1050	-	-	-	-	-	-	-	-	-	41	29
1100	-	-	-	-	-	-	-	-	-	-	34
1150	-	-	-	-	-	-	-	-	-	-	44
1200	-	-	-	-	-	-	-	-	-	-	-

[a] Queue estimates only valid for under-capacity conditions.

Table 5. 95th Percentile Queue (Vehicle Units) for a 120 Second Cycle Length.

Lane Volume (vphpl)	Cycle Length = 120 seconds														
	Effective Green Time (seconds)														
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
50	3	3	3	3	2	2	2	2	2	2	2	2	2	1	1
100	6	5	5	5	5	4	4	4	4	3	3	3	3	2	2
150	-[a]	8	7	7	7	6	6	6	5	5	5	4	4	4	3
200	-	14	10	9	9	8	8	8	7	7	6	6	5	5	4
250	-	-	14	12	11	11	10	10	9	8	8	7	6	6	5
300	-	-	-	16	14	13	12	12	11	10	9	9	8	7	6
350	-	-	-	23	17	16	15	14	13	12	11	10	9	8	7
400	-	-	-	-	22	19	17	16	15	14	13	12	11	10	9
450	-	-	-	-	-	23	20	19	17	16	15	14	12	11	10
500	-	-	-	-	-	33	24	21	20	18	17	16	14	13	11
550	-	-	-	-	-	-	29	25	23	21	19	18	16	14	13
600	-	-	-	-	-	-	-	29	26	24	22	20	18	16	14
650	-	-	-	-	-	-	-	41	30	27	24	22	20	18	16
700	-	-	-	-	-	-	-	-	36	30	27	25	22	20	18
750	-	-	-	-	-	-	-	-	-	35	31	28	25	22	20
800	-	-	-	-	-	-	-	-	-	50	35	31	28	25	22
850	-	-	-	-	-	-	-	-	-	-	43	35	31	28	24
900	-	-	-	-	-	-	-	-	-	-	-	41	35	31	27
950	-	-	-	-	-	-	-	-	-	-	-	58	40	34	30
1000	-	-	-	-	-	-	-	-	-	-	-	-	49	39	34
1050	-	-	-	-	-	-	-	-	-	-	-	-	-	46	38
1100	-	-	-	-	-	-	-	-	-	-	-	-	-	65	44
1150	-	-	-	-	-	-	-	-	-	-	-	-	-	-	54
1200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[a] Queue estimates only valid for under-capacity conditions.

Table 6. 95th Percentile Queue (Vehicle Units) for a 150 Second Cycle Length.

Lane Volume (vphpl)	Cycle Length = 150 seconds									
	Effective Green Time (seconds)									
	10	20	30	40	50	60	70	80	90	100
50	4	3	3	3	3	2	2	2	2	2
100	9	6	6	5	5	5	4	4	3	3
150	-[a]	10	9	8	7	7	6	5	5	4
200	-	14	12	11	10	9	8	7	6	5
250	-	-	15	14	12	11	10	9	8	6
300	-	-	20	17	15	14	12	11	9	8
350	-	-	39	20	18	16	15	13	11	9
400	-	-	-	25	21	19	17	15	13	11
450	-	-	-	33	25	22	20	17	15	12
500	-	-	-	-	29	25	22	20	17	14
550	-	-	-	-	35	29	25	22	19	16
600	-	-	-	-	-	33	29	25	21	18
650	-	-	-	-	-	38	32	28	24	20
700	-	-	-	-	-	55	36	31	27	22
750	-	-	-	-	-	-	41	35	30	25
800	-	-	-	-	-	-	51	39	33	27
850	-	-	-	-	-	-	-	44	37	30
900	-	-	-	-	-	-	-	52	41	34
950	-	-	-	-	-	-	-	97	46	37
1000	-	-	-	-	-	-	-	-	53	41
1050	-	-	-	-	-	-	-	-	69	47
1100	-	-	-	-	-	-	-	-	-	53
1150	-	-	-	-	-	-	-	-	-	64
1200	-	-	-	-	-	-	-	-	-	-

[a] Queue estimates only valid for under-capacity conditions.

Table 7. 95th Percentile Queue (Vehicle Units) for a 180 Second Cycle Length.

Lane Volume	Cycle Length = 180 seconds											
	Effective Green Time (seconds)											
(vphpl)	10	20	30	40	50	60	70	80	90	100	110	120
50	4	4	4	4	3	3	3	3	2	2	2	2
100	-[a]	8	7	7	6	6	5	5	4	4	4	3
150	-	12	11	10	9	9	8	7	7	6	5	4
200	-	-	15	14	13	12	11	10	9	8	7	6
250	-	-	20	17	16	15	14	12	11	10	9	7
300	-	-	-	22	20	18	17	15	14	12	11	9
350	-	-	-	27	24	22	20	18	16	14	13	11
400	-	-	-	-	28	25	23	21	19	17	15	13
450	-	-	-	-	34	29	27	24	22	19	17	14
500	-	-	-	-	-	34	31	28	25	22	19	17
550	-	-	-	-	-	41	35	31	28	25	22	19
600	-	-	-	-	-	-	40	36	32	28	25	21
650	-	-	-	-	-	-	48	40	36	32	28	24
700	-	-	-	-	-	-	-	45	40	35	31	26
750	-	-	-	-	-	-	-	54	45	39	34	29
800	-	-	-	-	-	-	-	-	50	44	38	32
850	-	-	-	-	-	-	-	-	60	49	42	36
900	-	-	-	-	-	-	-	-	-	55	47	40
950	-	-	-	-	-	-	-	-	-	65	52	44
1000	-	-	-	-	-	-	-	-	-	-	59	49
1050	-	-	-	-	-	-	-	-	-	-	70	55
1100	-	-	-	-	-	-	-	-	-	-	-	62
1150	-	-	-	-	-	-	-	-	-	-	-	75
1200	-	-	-	-	-	-	-	-	-	-	-	-

[a] Queue estimates only valid for under-capacity conditions.

Implementing Interconnection

Since the design traffic volumes will most probably be higher than the traffic volumes at the opening of the facility, queues may not reach the tracks when the intersection is opened after (re)construction. In this case, preemption will not be needed, and should not be provided, because of the adverse effect of unwarranted preemption on traffic signal operation, especially coordination. Nevertheless, the interconnection circuit should be provided. Conditions should be monitored, and at the time when queues start to reach the tracks, preemption should be provided at the intersection.

When advance preemption is needed (which is true in most of the cases where the tracks are more than about 75 feet from the intersection) additional railroad equipment will be needed to provide the required functionality. The highway authority is usually responsible for requesting advance preemption from the railroad authority and is also responsible for the cost of the additional equipment required to provide the advance preemption, which can be substantial, especially where grade crossings are closely spaced. It is therefore suggested that advance preemption (if needed) only be requested during the design stage if analyses show that queues will start to reach the tracks within 3 years after opening the facility. If advance preemption will be required later than 3 years after the opening of the facility, conditions should be monitored, and advance preemption requested from the railroad in time to be operational when queues start to reach the tracks. At crossings where gates are not present, the designer may consider installing gates if queues are projected to reach or are within 200 feet.

KEY REFERENCES

- *Manual on Uniform Traffic Control Devices* (*2*)
- *Preemption of Traffic Signals At or Near Railroad Grade Crossings with Active Warning Devices* (*5*)
- *The Implementation Report of the USDOT Grade Crossing Safety Task Force* (*10*)

CHAPTER 4
CHANNELIZATION

Intersections near highway-railroad grade crossings require special attention to coordinate the movements of vehicle, train, and pedestrian traffic. One tool that can be used to improve safety and efficiency is channelization (i.e., Figure 4). According to AASHTO's *Policy on Geometric Design of Highways and Streets* (*4*), channelization is defined as "the separation or regulation of conflicting traffic movements into definite paths of travel by traffic islands or pavement marking to facilitate the safe and orderly movements of both vehicles and pedestrians. Proper channelization increases capacity, improves safety, provides maximum convenience, and instills driver confidence." However, large-scale channelization is not a solution for every problem. Improper or excessive channelization can reduce safety and capacity. Many times the addition of a turning lane, median, or island is sufficient to accomplish the desired improvements. With the added conflict of railroad traffic, care must be taken to ensure that channelization provides guidance and control, not confusion.

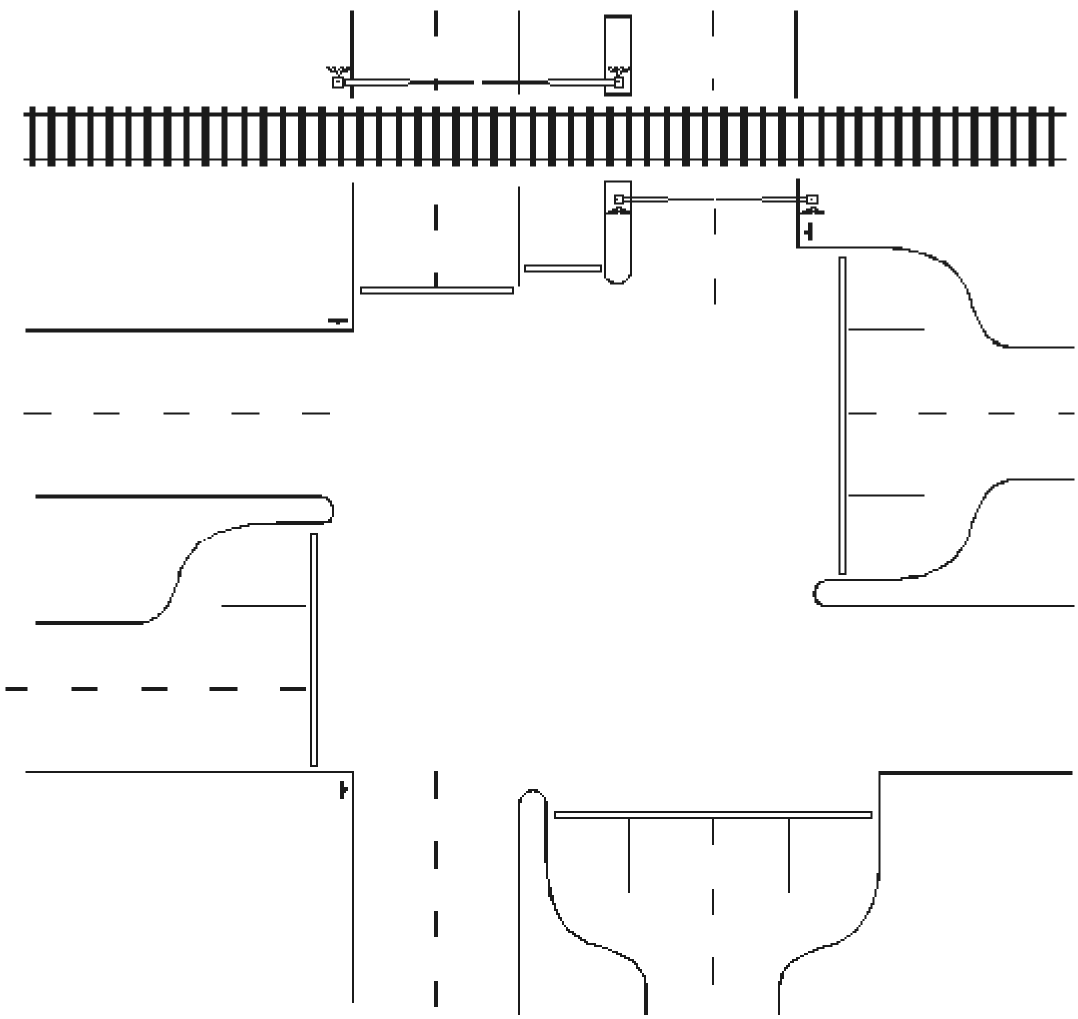

Figure 4. Channelization at Intersection Near Highway-Railroad Grade Crossing.

BACKGROUND

AASHTO's *A Policy on Geometric Design of Highways and Streets* (*4*) lists several factors for which channelization is generally warranted. Intersections at highway-railroad grade crossings can involve several of these warranting factors, which makes channelization a possible solution for improvements to safety and efficiency. Intersections near crossings are often somewhat complex, and additional indications to motorists concerning the proper path to take are beneficial. In many cases turning vehicles form queues while waiting for the passage of a train; it can be useful to provide separated lanes for these vehicles to reduce the conflict with through traffic. On multilane roadways, it is often necessary to improve the visibility of traffic control devices; channelization makes space available in the median for that purpose.

One of the most important needs of an at-grade crossing is to prevent vehicles from crossing the tracks during the impending arrival of a train; proper channelization can control and restrict the movements of vehicles, confining them until a safe crossing can be attempted.

Design of a channelized intersection usually involves a number of key factors, some of which are the type of design vehicle, the cross sections of the roadways, traffic volumes (vehicle and train), vehicle speed, train speed, type and location of traffic control devices, right-of-way, and terrain.

Traffic islands are common tools for achieving channelization objectives. According to AASHTO, an island is a defined area between traffic lanes for control of vehicle movements. Islands also provide an area for pedestrian refuge and traffic control devices. Within an intersection, a median or an outer separation is considered an island (*4*). Islands to control and direct traffic movement should guide motorists into the proper channel for their intended route. The confusing traffic movements resulting from large paved areas can be eliminated by conversion of normally unused areas into islands, which provide guidance and reduce the number of decisions that drivers must make. Channelizing islands may be of many shapes and sizes, depending on conditions and dimensions of the intersection.

NCHRP sponsored a project to develop an *Intersection Channelization Design Guide* (*11*). Designers of traffic islands must consider their intended site-specific functions. These functions may include definition of vehicle paths, separation of traffic movements, prohibition of movements, protection of pedestrians, placement of traffic control devices, or a combination of these.

AASHTO defines a median left-turn lane as an auxiliary lane for storage or speed change of left-turning vehicles located at the left of a one-directional roadway within a median or divisional island. Accident potential, inconvenience, and considerable loss in efficiency of operation are evident on divided highways where such lanes are not provided. Therefore, median lanes should be provided at intersections and at other median openings where there is a high volume of left turns or where the vehicular speeds are high (*4*).

The use of exclusive right-turn lanes at intersections can also significantly affect operations. The addition of a separate right-turn lane or conversion of a through lane to a right-turn lane can result in improvements to the level of service at an intersection. In terms of safety, special treatment for right-turning vehicles is often less critical than that for left-turning vehicles. Right turns have a smaller potential for conflicts and less influence on other traffic flows than left turns. However, there are conditions where the use of exclusive right-turn lanes may be beneficial by removing decelerating turning vehicles from the through traffic lanes. Design and functional requirements for right-turn lanes are similar to those for left-turn lanes.

There has not been a great deal of research specifically related to intersection channelization near highway-railroad grade crossings. However, despite the small number of specific studies related to the topic, there are some issues related to channelization in general that can be applied to conditions at or near grade crossings. The *Railroad-Highway Grade Crossing Handbook* provides more specific instructions for channelization devices at grade crossings (*3*).

GUIDELINES

Establishment of Channelization to Prevent Motorists from Driving around Crossing Gates

If significant numbers of motorists are observed driving around crossing gates at a railroad grade crossing or a safety problem has been demonstrated through an accident study, an engineering analysis should be performed to determine whether a channelization might be an appropriate measure to reduce the problem.

Using the guidelines provided in TxDOT's Design Manual, AASHTO, and the *Intersection Channelization Design Guide*, an engineering study can determine if volumes, capacity, and other conditions are conducive to the installation of islands or auxiliary turning lanes at intersections near the grade crossings. Additional guidance can be found in the *Railroad-Highway Grade Crossing Handbook*. As with any other geometric changes, consideration must be given to the space available at the intersection to ensure that lane lengths and widths are appropriate. Widening of the roadway may be necessary to maintain acceptable design values. Delineation of the islands will also be necessary to comply with required MUTCD guidelines (*2*).

For railroad grade crossings located particularly close to parallel roadways, analyze channelization designs to determine whether motorists turning left onto the roadway with the crossing can complete the turning maneuver without striking the curb of the proposed island (see Figure 5). The end of the island upstream of the railroad grade crossing should extend far enough back from the crossing to contain queues that build up at the crossing and should not have openings or breaks for local traffic (*12*).

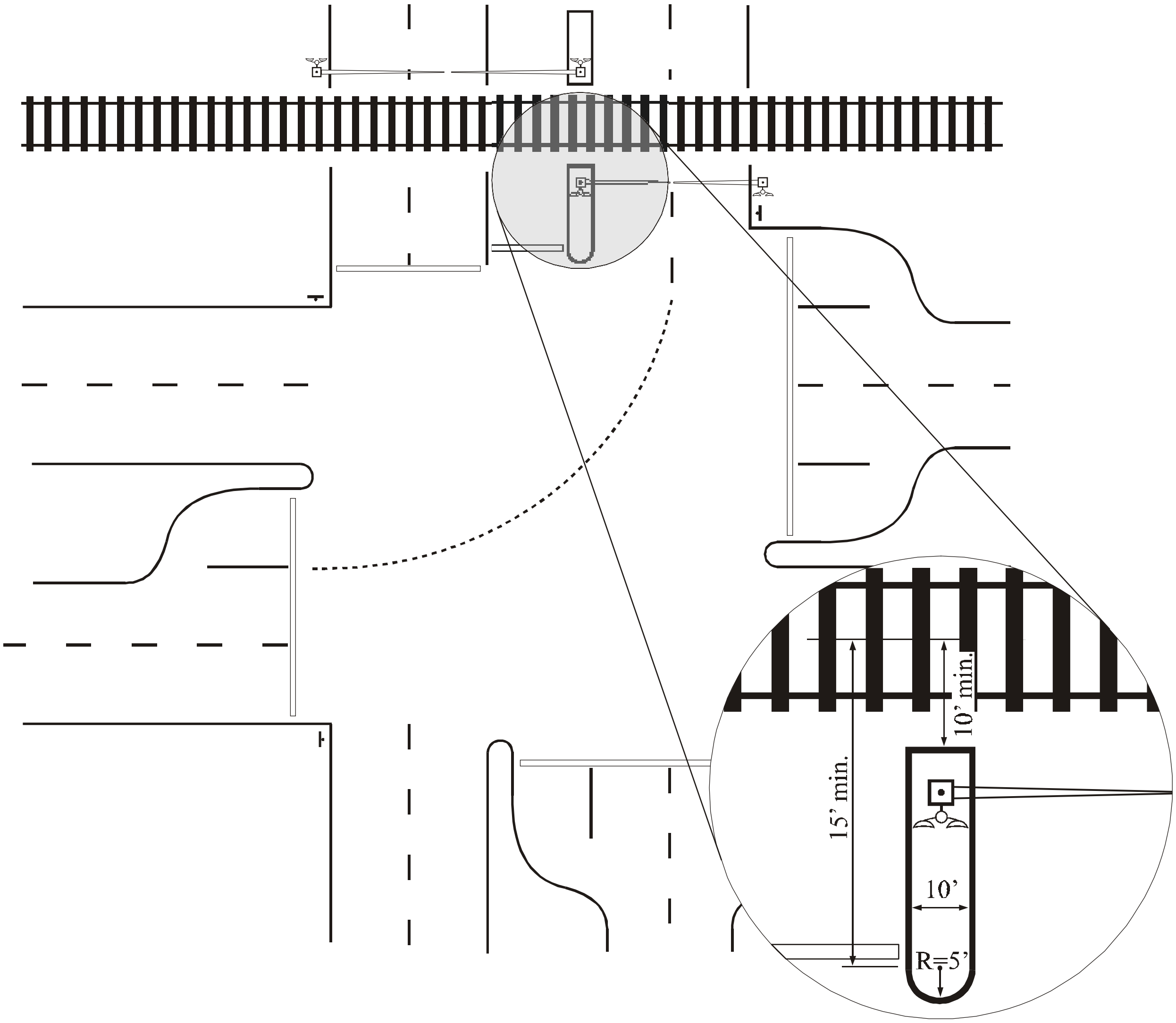

Figure 5. Channelization Design with Clearance to Turning Vehicle.

Islands Provided for Crossing Gate Structure

The use of median islands may be desirable in some locations to limit the length of crossing arms used at the grade crossing. Although longer length crossing arms are sometimes available, common practice limits the arm length to approximately 40 ft. If longer arms are necessary, a median island provides opportunity to lower arms from both sides of the lanes (see Figure 6), reducing the length required.

Figure 6. Gate Arm Located in Median on Raised Island.

KEY REFERENCES

- *A Policy on Geometric Design of Highways and Streets* (*4*)
- NCHRP *Intersection Channelization Design Guide* (*11*)
- *Railroad-Highway Grade Crossing Handbook* (*3*)
- MUTCD (*2*)
- *Geometric Design Criteria for Highway-Rail Intersections (Grade Crossings)* (*12*)

CHAPTER 5
HIGH-PROFILE (“HUMP”) CROSSINGS

When a long-wheelbase or low-ground-clearance vehicle negotiates a high-profile roadway, such as a highway-railroad grade crossing, roadway crown, or driveway entrance, the vehicle may become lodged or stuck on the “hump.” A somewhat common occurrence is one in which a railroad is on an embankment and a low-ground-clearance vehicle on the crossing roadway becomes lodged on the track and is subsequently struck by a train. A set of standards or guidelines for the design of high-profile crossings could reduce these incidents and improve safety; however, guidelines currently in existence are often merely suggestions for desired design values and are either not made readily available to designers or are not practical for application.

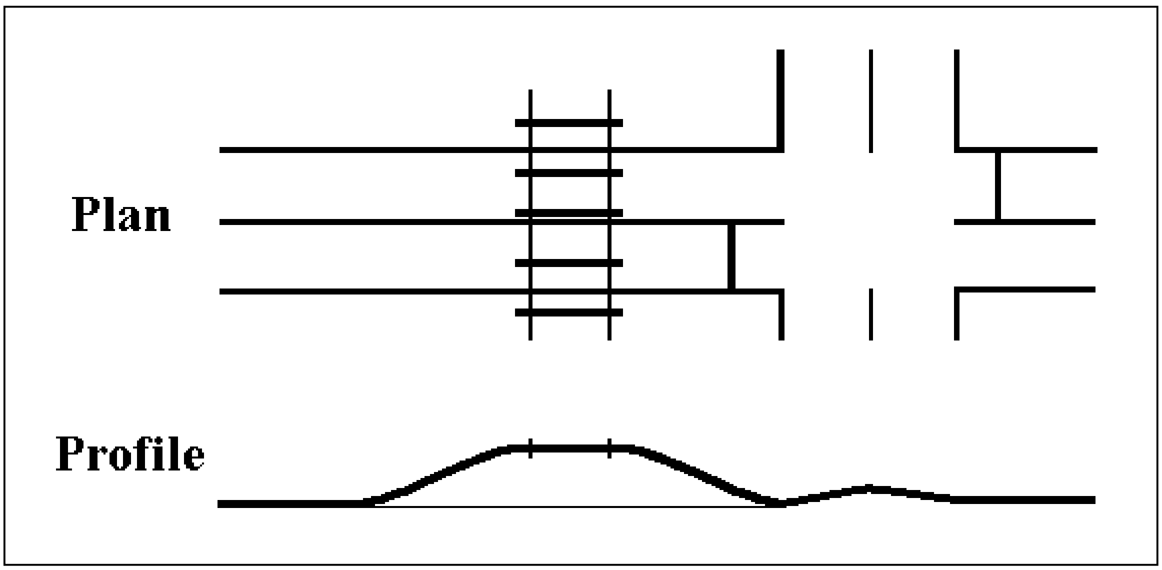

Figure 7. Plan and Profile of Highway-Railroad Grade Crossing Near an At-Grade Intersection.

BACKGROUND

There are two primary sources for guidelines for “hump” crossings: the American Railway Engineering Association’s (AREA’s) *Manual for Railway Engineering* (*13*), and AASHTO’s *A Policy on Geometric Design of Highways and Streets* (the *Green Book*) (*4*). AREA’s *Manual for Railway Engineering* (*13*) states that it is desirable that the surface of the highway be neither more than 3 inches higher nor more than 6 inches lower than the top of the nearest rail at a point 30 feet from the rail, measured at a right angle thereto, unless track superelevation dictates otherwise. The *Green Book* (*4*) has guidelines similar to AREA, converted to metric units, which are supplemented by comments and equations to suggest adequate sight distance for drivers.

The Federal Highway Administration has a section on vertical alignment in its *Railroad-Highway Grade Crossing Handbook* (*3*); however, the handbook does not contain any guidelines unique to FHWA. It does contain a reference to the AREA guidelines, and it makes mention of some practices by specific states and railroad companies.

In 1991, Eck and Kang (*14*) undertook a research project to determine the extent of the problem of "hang-ups" and accidents involving low-clearance vehicles at grade crossings. They also attempted to identify specific classes or categories of vehicles with low ground clearance, develop a computer model for checking whether a given class of vehicle could negotiate certain profiles, and develop design criteria for crossing profile alignments based on the problem classes of vehicles. In their research, Eck and Kang received comments from national, state, and local agencies indicating that the problem of low-clearance vehicles at grade crossings is a significant one.

Because of the lack of data available concerning low-clearance vehicle incidents and characteristics, the researchers decided to collect data on such vehicles. Their intent was to estimate at least the potential magnitude of the problem by determining the types and quantities of low-clearance vehicles on particular highways. The researchers also desired to utilize computer technology to simulate the movement of trucks over grade crossings. They developed their own program, "HANGUP," which plots user-entered roadway profile data and graphically presents vehicle movement over the roadway. The program allows designers to determine sections of roadway where hang-up problems can occur with certain clearance/wheelbase combinations.

In 1993, Eck and Kang followed up on their 1991 study by applying the "HANGUP" software to the development of design standards to accommodate low-clearance vehicles. In this follow-up effort (*15*), the researchers first applied the "HANGUP" software to the AREA design standards. In doing so, they found that hang-ups would not occur for a large number of clearance/wheelbase combinations if the AREA standards were used. Specifically, hang-ups would occur only for 1-inch clearance vehicles with wheelbases longer than 13 feet, for 2-inch clearance vehicles with wheelbases longer than 24 feet, and for 3-inch clearance vehicles with wheelbases longer than 33 feet.

To have a consistent basis for evaluation, the researchers defined a design vehicle for use in this study. They selected a vehicle with a ground clearance of 5 inches and a wheelbase of 36 feet, based on the 85th percentile values of previously observed vehicles. Based on this design vehicle, they developed a set of maximum safe grades and curve lengths for high-profile crossings. Further, they developed a list of considerations involved in the design of crest vertical curves for low-profile vehicles. The researchers also encouraged inclusion of ground clearance measurements as a part of the current permitting process for oversized vehicles and consideration of establishing minimum ground-clearance standards for vehicles operating on public highways.

An additional concern to be addressed is the possibility that as improvements are made and railroad companies re-ballast the tracks, the surface of the tracks can migrate upwards over time, increasing the risk of hang-ups. Designers and railroad officials should evaluate conditions at crossings after improvements are made to verify that the risk of hang-ups has not been significantly changed.

GUIDELINES

Based on a review of relevant literature and research efforts, the following guidelines are recommended for use in the evaluation and design of high-profile grade crossings:

New Designs

It is recommended that, where practical, new designs should follow revised AASHTO *Green Book* guidelines for vertical alignment. Where geometric and topographic conditions allow, the *Green Book* guidelines provide that the crossing surface should be at the same plane as the top of the rails for a distance of 2 ft outside the rails. The surface of the highway should also not be more than 3 inches higher or lower than the top of the nearest rail at a point 30 feet from the rail unless track superelevation dictates otherwise. Vertical curves should be used to traverse from the highway grade to the level plane of the rails.

Design Vehicles

It is recommended that design vehicles be used in the analysis of crossings that have potential problems in meeting AASHTO criteria. Certain crossings receive traffic that has a significant percentage of vehicle types with high potential for striking the rails or the roadway. When considering such crossings, it is recommended that an applicable type-specific design vehicle be used and that the performance of the alignment be analyzed using the HANGUP software program. When analyzing an existing crossing (or a proposed crossing that due to geometric constraints cannot reasonably be constructed to meet AASHTO guidelines) used by many types of vehicles, it is recommended that the analysis be performed using a design vehicle that might reasonably be expected to use the crossing.

The selection of a specific design vehicle depends upon local conditions, but one design vehicle that has been suggested has a wheelbase of 36 ft, a clearance of 5 inches, and 0 ft overhang front and rear (*15*). Typical dimensions for other selected type-specific design vehicles are given in Table 8, although the dimensions may vary somewhat depending on manufacturer. Analysis using the HANGUP software program indicates that the AASHTO guidelines provide a vertical alignment sufficient to avoid striking the rails or the roadway for all such design vehicles with an overhang of 20 ft or less.

Table 8. Potential Low-Clearance Design Vehicles.

Vehicle Type	Overall Length (ft)	Overhang (ft)		Wheelbase (ft)	Clearance (in)
		Front	Rear		
Double Bottom/ Low-Boy Semitrailer[1,2]	35	0	0	30	10
	48	0	0	29	6
Grain Trailer[3]	48	0	3	39	17
Livestock Trailer[3]	48	0	5	39	14

[1] Based on design vehicle used by TxDOT Pharr District for design of typical railroad crossings.
[2] Based on specifications for BlackHawk 5000p Series Trailer, Etnyre Trailer Company, Oregon, IL.
[3] Based on specifications provided by Wilson Trailer Company, Sioux City, IA.

Low-Clearance Vehicles

For existing crossings that have a high potential for problems with low-clearance vehicles, it is recommended that the guidelines for low ground clearance in the MUTCD (Section 8B.11) be followed. MUTCD guidelines state that whenever conditions are sufficiently abrupt to create a hang-up of long wheelbase vehicles or trailers with low ground clearance, the "Low Ground Clearance" (W10-5) warning symbol sign shall be installed in advance of the crossing. Guidelines contained in the MUTCD also state that new warning symbol signs such as this, which may not be readily recognizable by the public, shall be accompanied by an educational plaque which is to remain in place for at least three years after initial installation.

It is further recommended that, where possible, the sign be placed on each approach to the crossing far enough in advance that low-clearance vehicles can turn around before reaching the crossing. The MUTCD guidelines state that a supplemental message such as "Ahead," "Next Crossing," or "Use Next Crossing" (with appropriate arrows) should be placed at the nearest intersecting road where a vehicle can detour or at a point on the roadway wide enough to permit a U-turn.

KEY REFERENCES

- HANGUP software: Contact TxDOT Design Division, Railroad Coordinator, for availability
- *Manual on Uniform Traffic Control Devices* (*2*)

CHAPTER 6
ILLUMINATION

The use of lighting on streets or highways is dependent on a number of design decisions and goals, but is generally intended to improve the visibility provided on the facility (*1*). The installation of roadway lighting at intersections can potentially reduce the higher levels of hazard at these locations; similarly, lighting at nearby railroad grade crossings can increase their visibility and potentially raise the safety level. Lighting provided at intersections may unintentionally affect nearby grade crossings, as shown in Figure 8. The left photograph shows a grade crossing that is illuminated by the street lighting, while the right photograph shows a grade crossing that lies in a relatively dark area between street lights, reducing its relative visibility.

When considering the provision of lighting at a railroad grade crossing, the engineer must weigh the benefit of lighting against other potential safety improvements such as channelization, delineation, signalization, or geometric changes. To make such decisions, the engineer should know the possible benefits to be gained from the installation of lighting (*16*).

Figure 8. Railroad Grade Crossings with Visibility Affected by Roadway Illumination.

BACKGROUND

Providing roadway illumination serves a wide number of interests, although the purposes may vary by facility type and location (*17*):

- View the roadway.
- View roadway appurtenances.
- View other traffic.
- Improve driver and pedestrian visibility.
- Deter crime.
- Promote commercial interests and areas.
- Enhance community pride.

Implicit in several of these purposes is the goal of improving safety. Illumination is frequently provided to enhance safety on facilities, with generally good results.

The visibility of some roadway features may be reduced by contrast with nearby illuminated areas. Transient visual adaptation (TVA) is a potential problem that can occur downstream of illuminated areas (*18*). Because of the visual adaptation of the driver's eyes to the more brightly lit area, the distance between initial perception of objects is reduced in the darker areas downstream. TVA effects have been measured for areas illuminated from 1-4 luminaires, and could reasonably be suspected in situations where railroad grade crossings are on cross-streets that intersect illuminated roadways. Illumination designs should consider these unintended effects resulting from illumination on roadways, providing countermeasures where necessary.

The illumination of highway-railroad grade crossings may serve as an interim measure, or be intended to enhance the effectiveness of other traffic control device strategies. It is a treatment that is not intended to replace other warning devices, but to reduce night accidents at crossings where the lack of train visibility appears to be a problem.

GUIDELINES

The decision to provide illumination at a railroad grade crossing should come as a result of an analysis of the crossing, type of train traffic, and the surroundings of the crossing. Guidelines are provided here to enhance the decision-making process.

Illumination Provided to Aid in the Detection of the Crossing and Trains

Circumstances that could lead to the use of illumination at a grade crossing include (*19*):

- nighttime train operations;
- accident history of nighttime accidents that appear related to visibility of the train;
- accident history of nighttime, side-of-the-train accidents;
- low ambient light levels;
- vertical or horizontal roadway alignments that prevent vehicle headlights from illuminating the crossing such that stopping sight distances are not achieved;
- high-profile crossings where the vehicle headlights may not illuminate the train or oncoming vehicle headlights pass under the train;
- long or slow trains;
- reliable sources of power (although solar-powered lights activated by the train may be considered); and
- restricted sight distance of the crossing.

In the event that illumination of the railroad grade crossing is selected, it is desirable to illuminate the side of the train. Figure 9 shows an effective lighting configuration (*2*) for this purpose; additional recommendations for specific types and placement of luminaires can be found in FHWA's *Roadway Lighting Handbook* (*17*) and the Illuminating Engineering Society's *American National Standard for Roadway Lighting* (*20*).

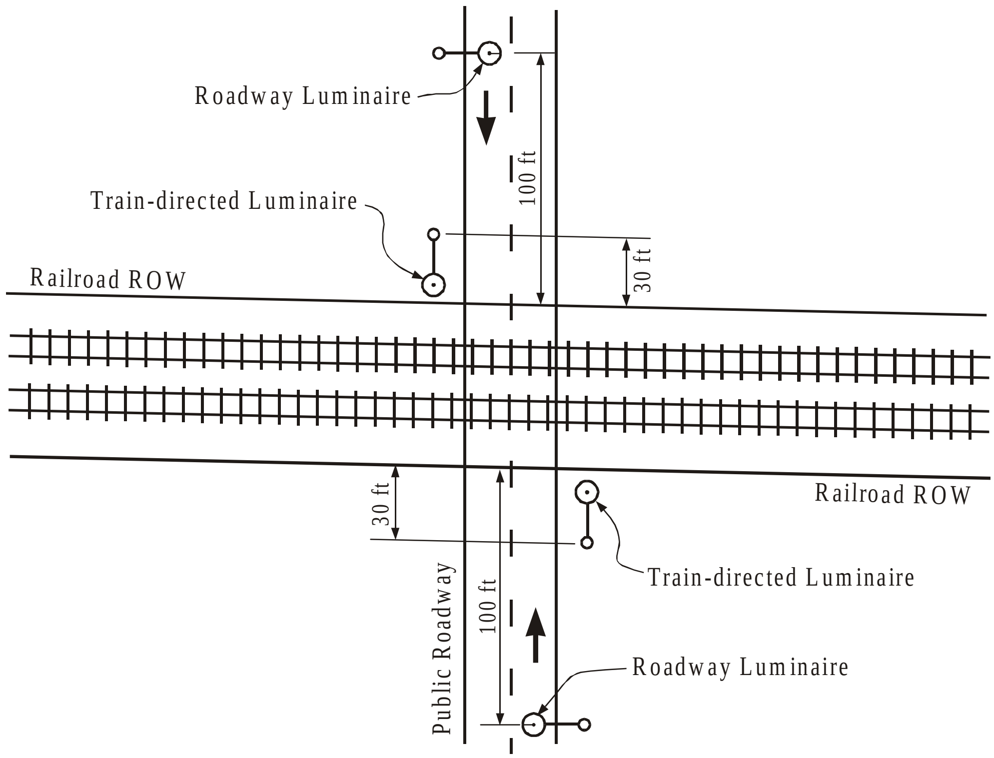

Figure 9. Illumination of Railroad Grade Crossing (*19*).

Illumination Provided to Counter Transient Visual Adaptation

Transient visual adaptation is an issue when proceeding from an illuminated area to a darker area. Areas of particular concern are those where multiple luminaires are used to illuminate a section of roadway prior to areas likely to have objects in the roadway. Research has shown that TVA effects are reduced or eliminated after 2-9 seconds; if the railroad grade crossing is further away from the illuminated area than the distance traveled in that time, then TVA effects are unlikely (*18*).

One alternative available is to use transition lighting extending from the illuminated area. Although not all engineers agree on the need for transition lighting under all circumstances (*17*), it is considered to be good practice to gradually decrease brightness in the driver's field of view when emerging from a lighted section of roadway. The standard for transition lighting is presented in the *American National Standard Practices for Roadway Lighting* (*20*). This may be accomplished by extending the lighting system in each exit direction using approximately the same spacing and mounting height but graduating the size of the lamp.

A recommended procedure is to utilize the design value for the roadway as the calculation base. Using the design speed of the roadway, the reduced lighting-level sectors should be illuminated for a 5-second continuous exposure to the sector illumination level of onehalf of the preceding higher lighted sector, but the average illumination in the terminal sector should not be less than 0.25 footcandle (2.7 lux) or more than 0.5 footcandle (5.5 lux) (*20*).

Another alternative is to use lighting specifically in the area of the grade crossing as shown in Figure 9. This alternative has the added advantage of providing increased illumination at the railroad grade crossing oriented towards the side of the train. The illumination provided will enhance the traffic control devices and the view of the side of any trains at the crossing.

KEY REFERENCES

- *Roadway Lighting Handbook* (*17*)
- *Geometric Design Criteria for Highway-Rail Intersections (Grade Crossings)* (*19*)
- *American National Standard for Roadway Lighting* (*20*)

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