Exhibit No. ___ (KH-2)
Dockets TR-110157, TR-110162
TR-110159, TR-110160, TR-110161
Witness: Kathy Hunter

BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

PUGET SOUND & PACIFIC RAILROAD, **Petitioner,** **v.** **GRAYS HARBOR COUNTY,** **Respondent.**	**DOCKET TR-110157** **DOCKET TR-110162**
. . . . . **PUGET SOUND & PACIFIC RAILROAD,** **Petitioner,** **v.** **CITY OF ELMA,** **Respondent.**	**DOCKET TR-110159** **DOCKET TR-110160** **DOCKET TR-110161**

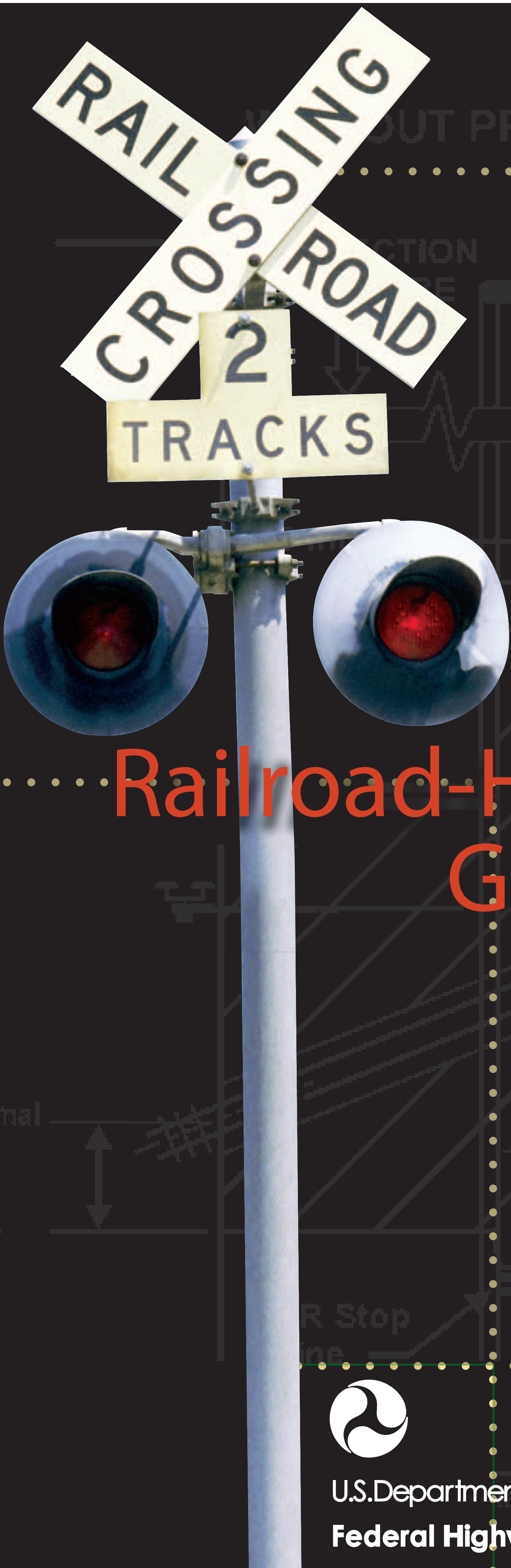
EXHIBIT TO TESTIMONY OF

Kathy Hunter

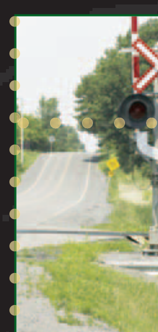
STAFF OF
WASHINGTON UTILITIES AND
TRANSPORTATION COMMISSION

USDOT/FHWA Railroad-Highway Grade Crossing Handbook,
August 2007 ed. (excerpts)

November 10, 2011



Railroad-Highway Grade Crossing Handbook



Revised Second Edition
August 2007

U.S.Department of Transportation
Federal Highway Administration

Table 28. Factor Values for U.S. DOT Injury Accident Probability Formula

Injury Accident Probability Formula:

$$P(IA \mid A) = \frac{1 - P(FA \mid A)}{(1 + CI \times MS \times TK \times UR)}$$

where: P(FA|A) = Fatal accident probability, See Tables 25 and 27
CI = 4.280, formula constant
UR = 1.202, urban crossing
= 1.000, rural crossing, and

Maximum Timetable Train Speed	MS	Total Number Of Tracks	TK
1	1.000	0	1.000
5	0.687	1	1.125
10	0.584	2	1.265
15	0.531	3	1.423
20	0.497	5	1.800
25	0.472	6	2.025
30	0.452	7	2.278
40	0.423	8	2.562
50	0.401	9	2.882
60	0.385	10	3.241
70	0.371	15	5.836
80	0.360	20	10.507
90	0.350		
100	0.341		

Source: Railroad-Highway Grade Crossing Handbook, Second Edition. *Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.*

C. Engineering Study*

Federal requirements dictate that each state shall establish priorities for its crossing program based on:

- The potential reduction in collisions or collision severities.
- The project costs and available resources.
- The relative hazard of each crossing based on a hazard index formula.
- An on-site inspection of each candidate crossing.
- The potential danger to large numbers of people at crossings used on a regular basis by passenger trains or buses or by trains or motor vehicles carrying hazardous materials.
- Other criteria as deemed appropriate by each state.[57]

* Includes previously unpublished materials provided by Ray Lewis, West Virginia Department of Transportation, 2006.

Engineering studies should be conducted of highway-rail crossings that have been selected from the priority list. The purpose of these studies is to:

- Review the crossing and its environment.
- Identify the nature of any problems.
- Recommend alternative improvements.

An engineering study consists of a review of site characteristics, the existing traffic control system, and highway and railroad operational characteristics. Based on a review of these conditions, an assessment of existing and potential hazards can be made. If safety deficiencies are identified, countermeasures can be recommended.

1. Diagnostic Team Study Method

The procedure recommended in earlier editions of this handbook, adopted in FHWA's *Highway Safety Engineering Study Procedural Guide*,[58] and adopted in concept by several states is the diagnostic team study approach. This term is used to describe a simple survey procedure utilizing experienced individuals from several sources. The procedure involves the diagnostic team's evaluation of the crossing as to its deficiencies and judgmental consensus as to the recommended improvements.

The primary factors to be considered when assigning people to the diagnostic team are that the team is interdisciplinary and representative of all groups having responsibility for the safe operation of crossings so that each of the vital factors relating to the operational and physical characteristics of the crossing may be properly identified. Individual team members are selected on the basis of their specific expertise and experience. The overall structure of the team is built upon three desired areas of responsibility:

- Local responsibility.
- Administrative responsibility.
- Advisory capability.

For the purpose of the diagnostic team, the operational and physical characteristics of crossings can be classified into three areas:

Traffic operations. This area includes both vehicular and train traffic operation. The responsibilities of highway traffic engineers and railroad operating personnel chosen for team membership include, among

57 "Railroad Crossing Corridor Improvements." Washington, DC: U.S. Department of Transportation (U.S. DOT), Federal Highway Administration (FHWA), Demonstration Projects Division, June 1986.

58 *Highway Safety Engineering Studies Procedural Guide*. Washington, DC: U.S. DOT, FHWA, November 1991.

other criteria, specific knowledge of highway and railroad safety, types of vehicles and trains, and their volumes and speeds.

Traffic control devices. Highway maintenance engineers, signal control engineers, and railroad signal engineers provide the best source for expertise in this area. Responsibilities of these team members include knowledge of active traffic control systems, interconnection with adjacent signalized highway intersections, traffic control devices for vehicle operations in general and at crossings, and crossing signs and pavement markings.

Administration. It is necessary to realize that many of the problems relating to crossing safety involve the apportionment of administrative and financial responsibility. This should be reflected in the membership of the diagnostic team. The primary responsibility of these members is to advise the team of specific policy and administrative rules applicable to the modification of crossing traffic control devices.

To ensure appropriate representation on the diagnostic team, it is suggested that the team comprise at least a traffic engineer with safety experience and a railroad signal engineer. Following are other disciplines that might be represented on the diagnostic team:

- Railroad administrative official.
- Highway administrative official.
- Human factors engineer.
- Law enforcement officer.
- Regulatory agency official.
- Railroad operating official.

The diagnostic team should study all available data and inspect the crossing and its surroundings with the objective of determining the conditions that affect safety and traffic operations. In conducting the study, a questionnaire is recommended to provide a structured account of the crossing characteristics and their effect on safety. Some states are now using automated diagnostic review forms to facilitate the collection, storage, and analysis of crossing data. Example forms developed and used by various states are reproduced in Appendix G. Figure 6 shows a sample questionnaire, which can be altered to fit individual agency needs. The questionnaire shown in Figure 6 is divided into four sections:

- Distant approach and advance warning.
- Immediate highway approach.
- Crossing proper.
- Summary and analysis.

To conduct the diagnostic team field study, traffic cones are placed on the approaches, as shown in Figure 7.

Crossing approach zone. Cone A is placed at the point where the driver first obtains information that there is a crossing ahead. This distance is also the beginning of the approach zone. Usually, this information comes from the advance warning sign, the pavement markings, or the crossing itself. The distance from the crossing is based on the decision sight distance, which is the distance required for a driver to detect a crossing and to formulate actions needed to avoid colliding with trains.

Tables 29 and 30 provide a range of distances from point A to the crossing stop line, dependent upon design vehicle speeds. The maximum distances are applicable to crossings with a high level of complexity and will generally be applicable on urban roads and streets. These distances correspond to the decision sight distances for stops on rural roads and for stops on urban roads in the American Association of State Highway and Transportation Officials (AASHTO) "Green Book." In calculating sight distances, the height of the driver's eye is considered 1.080 meter (3.5 feet) above the roadway surface for passenger vehicles; the target height is considered 0.6 meter (2.0 feet) above the roadway surface.[59]

Table 29. Distances in Meters to Establish Study Positions for Diagnostic Team Evaluation

Design vehicle speed (kilometers per hour)	Distance from stop line* to cone A (meters)	Distance from stop line* to cone B (meters)
50	155	70
60	195	95
70	235	115
80	280	140
90	325	170
100	370	200
110	420	235
120	470	265

** Note: The distance from the stop line is assumed to be 4.5 meters from nearest rail, or 2.4 meters from the gate if one is present.*

Source: From A Policy on Geometric Design of Highway and Streets, 2004, *by the American Association of State Highway and Transportation Officials, Washington, DC. Used by permission.*

59 *A Policy on Geometric Design of Highways and Streets, 2004 Edition*. Washington, DC: American Association of State Highway and Transportation Officials, 2004.

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Figure 6. Sample Questionnaire for Diagnostic Team Evaluation

LOCATIONAL DATA: Street Name: ______________ City: ______________

Railroad: ______________ Crossing Number: ______________

VEHICLE DATA: No. of Approach Lanes: ________ Approach Speed Limit: ________ AADT: ________

Approach Curvature: ______________ Approach Gradient: ______________

TRAIN DATA: No. of Tracks: ________ Train Speed Limit: ________ Trains Per Day: ________

Track Gradients: ______________

SECTION I—Distance Approach and Advance Warning

1. Is advance warning of railroad crossing available?_______ If so, what devices are used? ______________
2. Do advance warning devices alert drivers to the presence of the crossing and allow time to react to approaching train traffic?
3. Do approach grades, roadway curvature, or obstructions limit the view of advance warning devices? ___ If so, how?
4. Are advance warning devices readable under night, rainy, snowy, or foggy conditions? ______________

SECTION II—Immediate Highway Approach

1. What maximum safe approach speed will existing sight distance support? ______________
2. Is that speed equal to or above the speed limit on that part of the highway? ______________
3. If not, what has been done, or reasonably could be done, to bring this to the driver's attention? ______________
4. What restrictive obstructions to sight distance might be removed? ______________
5. Do approach grades or roadway curvature restrict the driver's view of the crossing? ______________
6. Are railroad crossing signals or other active warning devices operating properly and visible to adequately warn drivers of approaching trains? ______________

SECTION III—Crossing Proper

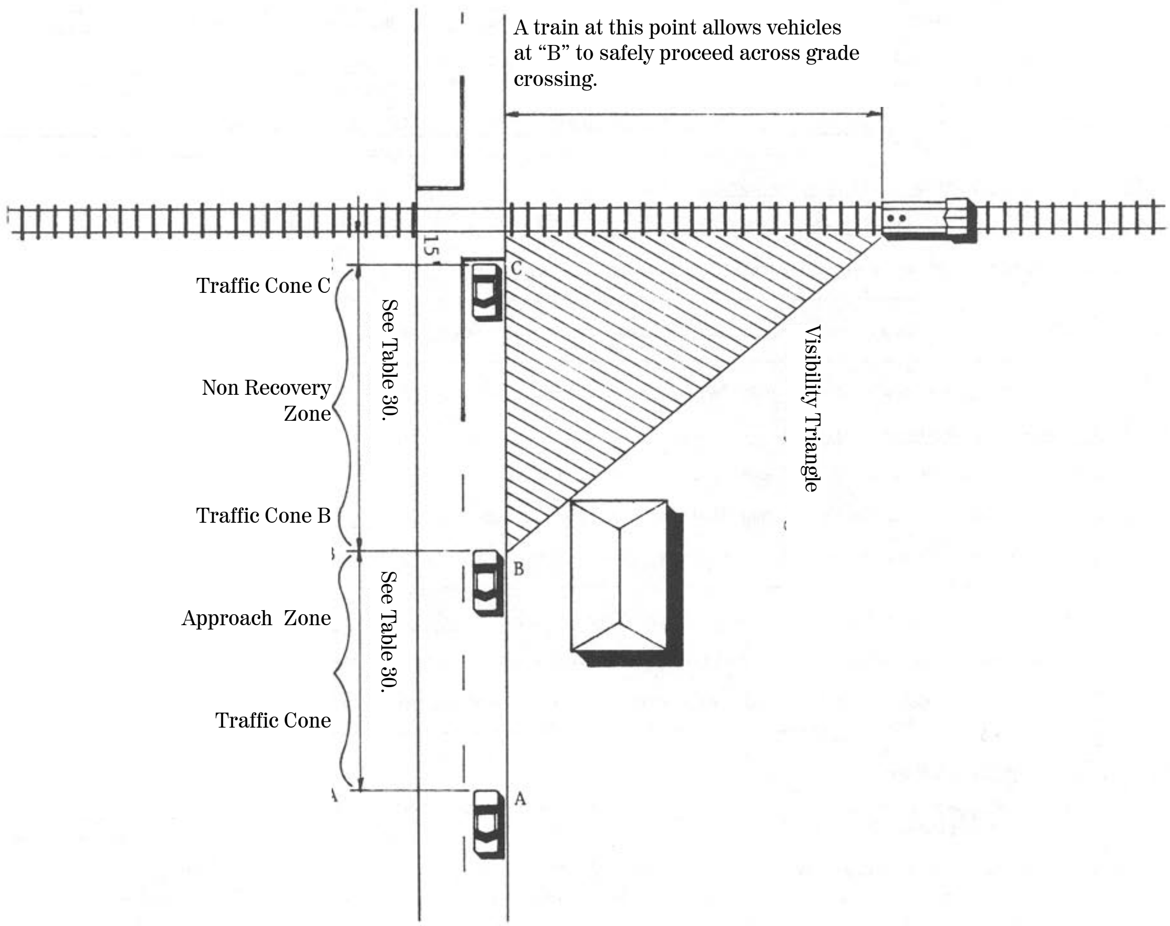
1. From a vehicle stopped at the crossing, is the sight distance down the track to an approaching train adequate for the driver to cross the tracks safely? ______________
2. Are nearby intersection traffic signals or other control device affecting the crossing operation?
   If so, how? ______________
3. Is the stopping area at the crossing adequately marked? ______________
4. Do vehicles required by law to stop at all crossings present a hazard at the crossing? ______ Why? ______________
5. Do conditions at the crossing contribute to, or are they conducive to, a vehicle stalling at or on the crossing?
6. Are nearby signs, crossing signals, etc. adequately protected to minimize hazards to approaching traffic? ________
7. Is the crossing surface satisfactory? ______ If not, how and why? ______________
8. Is surface of highway approaches satisfactory? ______________ If not, why?

SECTION IV—Summary and Analysis

1. List major attributes of the crossing which may contribute to safety.______________
2. List features which reduce crossing safety. ______________
3. Possible methods for improving safety at the crossing: ______________
4. Overall evaluation of crossing: ______________
5. Other comments: ______________

Source: Railroad-Highway Grade Crossing Handbook, Second Edition. *Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.*

Figure 7. Study Positions for Diagnostic Team



Source: Railroad-Highway Grade Crossing Handbook, Second Edition. *Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.*

Table 30. Distances in Feet to Establish Study Positions for Diagnostic Team Evaluation

Design vehicle speed (miles per hour)	Distance from stop line* to cone A (feet)	Distance from stop line* to cone B (feet)
30	490	220
40	690	330
50	910	465
55	1030	535
60	1150	610
70	1410	780

** Note: The distance from the stop line is assumed to be 15 feet from nearest rail, or 8 feet from the gate if one is present.*

Source: From A Policy on Geometric Design of Highway and Streets, 2004*, by the American Association of State Highway and Transportation Officials, Washington, DC. Used by permission.*

Safe stopping point. Cone B is placed at the point where the approaching driver must be able to see an approaching train so that a safe stop can be made if necessary. This point is located at the end of the approach zone and the end of the non-recovery zone. Distances to point B are based on the design vehicle speed and are also shown in Tables 29 and 30. These distances are stopping sight distances to the stop line and are in accordance with the upper end of the range of stopping sight distances in the AASHTO "Green Book."[60] In calculating these distances, a level approach is assumed. If this is not the case, an allowance must be made for the effects of positive or negative approach grades.

60 Ibid.

Stop line. Cone C is placed at the stop line, which is assumed to be 4.6 meters (15 feet) from the near rail of the crossing, or 8 feet from the gate if one is present.

The questions in Section I of the questionnaire (refer to Figure 6) are concerned with the following:

- Driver awareness of the crossing.
- Visibility of the crossing.
- Effectiveness of advance warning signs and signals.
- Geometric features of the highway.

When responding to questions in this section, the crossing should be observed from the beginning of the approach zone, at traffic cone A.

The questions in Section II (refer to Figure 6) are concerned with whether the driver has sufficient information to detect an approaching train and make correct decisions about crossing safely. Observations for responding to questions in this section should be made from cone B. Factors considered by these questions include the following:

- Driver awareness of approaching trains.
- Driver dependence on crossing signals.
- Obstruction of view of train's approach.
- Roadway geometrics diverting driver attention.
- Potential location of standing railroad cars.
- Possibility of removal of sight obstructions.
- Availability of information for stop or go decision by the driver.

The questions in Section III (refer to Figure 6) apply to observations adjacent to the crossing, at cone C. Of particular concern, especially when the driver must stop, is the ability to see down the tracks for approaching trains. Intersecting streets and driveways should also be observed to determine whether intersecting traffic could affect the operation of highway vehicles over the crossing. Questions in this section relate to the following:

- Sight distance down the tracks.
- Pavement markings.
- Conditions conducive to vehicles becoming stalled or stopped on the crossing.
- Operation of vehicles required by law to stop at the crossing.
- Signs and signals as fixed object hazards.
- Opportunity for evasive action by the driver.

Corner sight distance.[61] Available sight distances help determine the safe speed at which a vehicle can approach a crossing. The following three sight distances should be considered:

- Distance ahead to the crossing.
- Distance to and along the tracks on which a train might be approaching the crossing from either direction.
- Sight distance along the tracks in either direction from a vehicle stopped at the crossing.

These sight distances are illustrated in Figure 8.

In the first case, the distance ahead to the crossing, the driver must determine whether a train is occupying the crossing or whether there is an active traffic control device indicating the approach or presence of a train. In such an event, the vehicle must be stopped short of the crossing, and the available sight distance may be a determining factor limiting the speed of an approaching vehicle.

The relationship between vehicle speed and this sight distance is set forth in the following formula:

$$d_H = AV_v t + \frac{BV_v^2}{a} + D + d_e \qquad (5)$$

where:

d_H = sight distance measured along the highway from the nearest rail to the driver of a vehicle, which allows the vehicle to be safely stopped without encroachment of the crossing area, feet
A = constant = 1.47
B = constant = 1.075
V_v = velocity of the vehicle, miles per hour (mph)
t = perception-reaction time, seconds, assumed to be 2.5 seconds
a = driver deceleration, assumed to be 11.2 feet per second^2
D = distance from the stop line or front of vehicle to the near rail, assumed to be 15 feet
d_e = distance from the driver to the front of the vehicle, assumed to be 8 feet

61 Ibid.

This formula is also expressed in SI Metric terms, as follows:

$$d_H = AV_v t + \frac{BV_v^{\,2}}{a} + D + d_e \qquad (6)$$

where:

d_H = sight distance measured along the highway from the nearest rail to the driver of a vehicle, which allows the vehicle to be safely stopped without encroachment of the crossing area, feet
A = constant = 0.278
B = constant = 0.039
V_v = velocity of the vehicle, kilometers per hour (km/hr.)
t = perception-reaction time, seconds, assumed to be 2.5 seconds
a = driver deceleration, assumed to be 3.4 meters per second^2
D = distance from the stop line or front of vehicle to the near rail, assumed to be 4.5 meters
d_e = distance from the driver to the front of the vehicle, assumed to be 2.4 meters

The minimum safe sight distances, d_H, along the highway for selected vehicle speeds are shown in the bottom line of Tables 31 and 32. As noted, these distances were calculated for certain assumed conditions and should be increased for less favorable conditions.

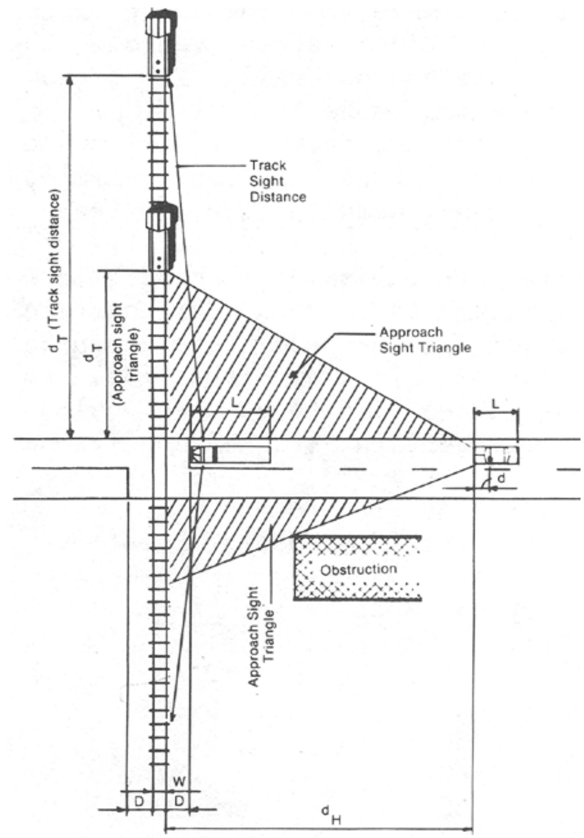
The second sight distance utilizes a so-called "sight triangle" in the quadrants on the vehicle approach side of the track. This triangle is formed by:

- The distance (d_H) of the vehicle driver from the track.
- The distance (d_t) of the train from the crossing.
- The unobstructed sight line from the driver to the front of the train.

This sight triangle is depicted in Figure 8. The relationships between vehicle speed, maximum timetable train speed, distance along the highway (d_H), and distance along the railroad are set forth in the following formula:

$$d_T = \frac{V_T}{V_v}(A)V_v t + \frac{BV_v^{\,2}}{a} + 2D + L + W \qquad (7)$$

Figure 8. Crossing Sight Distances



Source: Railroad-Highway Grade Crossing Handbook, Second Edition. *Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.*

where:

d_T = sight distance along the railroad tracks to permit the vehicle to cross and be clear of the crossing upon arrival of the train
A = constant = 1.47
B = constant = 1.075
V_v = velocity of the vehicle, mph
t = perception-reaction time, seconds, assumed to be 2.5 seconds
a = driver deceleration, assumed to be 11.2 feet per second^2
D = distance from the stop line or front of vehicle to the near rail, assumed to be 15 feet
L = length of vehicle, assumed to be 65 feet
W = distance between outer rails (for a single track, this value is 5 feet)

In SI Metric values, this formula becomes:

$$d_T = \frac{V_T}{V_v}(A)V_v t + \frac{BV_v^2}{a} + 2D + L + W \qquad (8)$$

where:

- d_T = sight distance along the railroad tracks to permit the vehicle to cross and be clear of the crossing upon arrival of the train
- A = constant = 0.278
- B = constant = 0.039
- V_v = velocity of the vehicle, km/hr.
- t = perception-reaction time, seconds, assumed to be 2.5 seconds
- a = driver deceleration, assumed to be 3.4 meters per second^2
- D = distance from the stop line or front of vehicle to the near rail, assumed to be 4.5 meters
- L = length of vehicle, assumed to be 20 meters
- W = distance between outer rails (for a single track, this value is 1.5 meters)

Distances d_h and d_T are shown in Tables 31 and 32 for several selected highway speeds and train speeds.

Clearing sight distance. In the case of a vehicle stopped at a crossing, the driver needs to see both ways along the track to determine whether a train is approaching and to estimate its speed. The driver needs to have a sight distance along the tracks that will permit sufficient time to accelerate and clear the crossing prior to the arrival of a train, even though the train might come into view as the vehicle is beginning its departure process.

Figure 9 illustrates the maneuver. These sight distances, for a range of train speeds, are given in the column for a vehicle speed of zero in Tables 31 and 32. These values are obtained from the following formula:

$$d_T = 1.47V_T\left(\frac{V_G}{a_1} + \frac{L + 2D + W - d}{V_G} + J\right) \qquad (9)$$

where:

- V_G = maximum speed of vehicle in selected starting gear, assumed to be 8.8 feet per second
- a_1 = acceleration of vehicle in starting gear, assumed to be 1.47 feet per second per second
- J = sum of the perception time and the time required to activate the clutch or an automatic shift, assumed to be 2 seconds
- d_a = distance the vehicle travels while accelerating to maximum speed in first gear, or

$$d_a = \frac{V_G^2}{2a_1} \quad \text{or} \quad \frac{8.8^2}{(2)(1.47)} = 26.4 \text{ feet} \qquad (10)$$

d_T, V_T, L, D, and W are defined as above.

Expressing the formula again in SI Metric terms:

$$d_T = 0.28V_T\left(\frac{V_G}{a_1} + \frac{L + 2D + W - d_a}{V_G} + J\right) \qquad (11)$$

where:

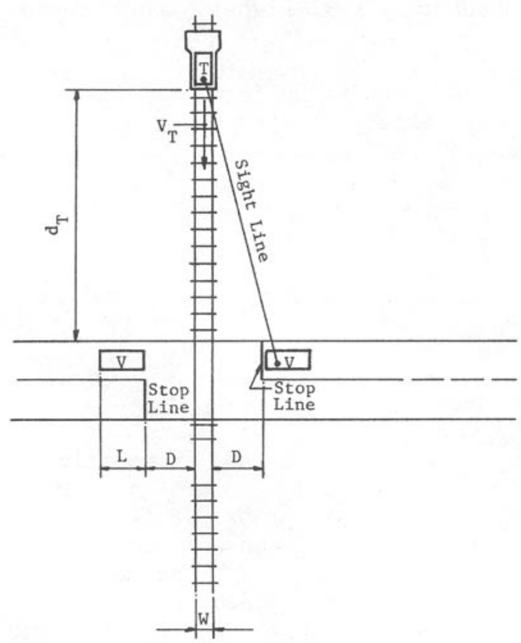
- V_G = maximum speed of vehicle in selected starting gear, assumed to be 2.7 meters per second
- a_1 = acceleration of vehicle in starting gear, assumed to be 0.45 meter per second per second
- J = sum of the perception time and the time required to activate the clutch or an automatic shift, assumed to be 2 seconds
- d_a = distance the vehicle travels while accelerating to maximum speed in first gear, or

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

$$\frac{2.7^2}{(2)(0.45)} = 8.1\,meters$$

d_T, V_T, L, D, and W are defined as above.[62]

Figure 9. Sight Distance for a Vehicle Stopped at Crossing



Source: Railroad-Highway Grade Crossing Handbook, Second Edition. *Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.*

Table 31. Sight Distances for Combinations of Highway Vehicle and Train Speeds, Metric

	Case B: Departure from stop	Case A: Moving vehicle												
	Vehicle speed (km/hr.)													
Train speed (km/hr.)	0	10	20	30	40	50	60	70	80	90	100	110	120	130
	Distance along railroad from crossing, d_T (feet)													
10	45	39	24	21	19	19	19	19	20	21	21	22	23	24
20	91	77	49	41	38	38	38	39	40	41	43	45	47	48
30	136	116	73	62	57	56	57	58	60	62	64	67	70	73
40	181	154	98	82	77	75	76	77	80	83	86	89	93	97
50	227	193	122	103	96	94	95	97	100	103	107	112	116	121
60	272	232	147	123	115	113	113	116	120	124	129	134	140	145
70	317	270	171	144	134	131	132	135	140	145	150	156	163	169
80	362	309	196	164	153	150	151	155	160	165	172	179	186	194
90	408	347	220	185	172	169	170	174	179	186	193	201	209	218
100	453	386	245	206	192	188	189	193	199	207	215	223	233	242
110	498	425	269	226	211	207	208	213	219	227	236	246	256	266
120	544	463	294	247	230	225	227	232	239	248	258	268	279	290
130	589	502	318	267	249	244	246	251	259	269	279	290	302	315
140	634	540	343	288	268	263	265	271	279	289	301	313	326	339
	Distance along highway from crossing, d_H (feet)													
		15	25	38	53	70	90	112	136	162	191	222	255	291

Source: From A Policy on Geometric Design of Highway and Streets, 2004*, by the American Association of State Highway and Transportation Officials, Washington, DC. Used by permission.*

Table 32. Sight Distances for Combinations of Highway Vehicle and Train Speeds, U.S. Customary

	Case B: Departure from stop	Case A: Moving vehicle							
	Vehicle speed (mph)								
Train speed (mph)	0	10	20	30	40	50	60	70	80
	Distance along railroad from crossing, d_T (feet)								
10	240	146	106	99	100	105	111	118	126
20	480	293	212	198	200	209	222	236	252
30	721	439	318	297	300	314	333	355	378
40	961	585	424	396	401	419	444	473	504
50	1201	732	530	494	501	524	555	591	630
60	1441	878	636	593	601	628	666	709	756
70	1681	1024	742	692	701	733	777	828	882
80	1921	1171	848	791	801	833	888	946	1008
90	2162	1317	954	890	901	943	999	1064	1134
	Distance along highway from crossing, d_H (feet)								
		69	135	220	324	447	589	751	931

Source: From A Policy on Geometric Design of Highway and Streets, 2004*, by the American Association of State Highway and Transportation Officials, Washington, DC. Used by permission.*

Adjustments for longer vehicle lengths, slower acceleration capabilities, multiple tracks, skewed crossings, and other than flat highway grades are necessary. The formulas in this section may be used with proper adjustments to the appropriate dimensional values. It would be desirable that sight distances permit operation at the legal approach speed for highways. This is often impractical.

In Section IV of the questionnaire, the diagnostic team is given the opportunity to do the following:

- List major features that contribute to safety.
- List features that reduce crossing safety.
- Suggest methods for improving safety at the crossing.
- Give an overall evaluation of the crossing.
- Provide comments and suggestions relative to the questionnaire.

In addition to completing the questionnaire, team members should take photographs of the crossing from both the highway and the railroad approaches.

Current and projected vehicle and train operation data should be obtained from the team members. Information on the use of the crossing by buses, school buses, trucks transporting hazardous materials, and passenger trains should be provided. The evaluation of the crossing should include a thorough evaluation of collision frequency, collision types, and collision circumstances. Both train-vehicle collisions and vehicle-vehicle collisions should be examined.

Team members should drive each approach several times to become familiar with all conditions that exist at or near the crossing. All traffic control devices (signs, signals, markings, and train detection circuits) should be examined as part of this evaluation. If the crossing is equipped with signals, the railroad signal engineer should activate them so that their alignment and light intensity may be observed.

The *Manual on Uniform Traffic Control Devices* (MUTCD) should be a principal reference for this evaluation.[63] Also, *A User's Guide to Positive Guidance* provides information for conducting evaluations of traffic control devices.[64]

63 *Manual on Uniform Traffic Control Devices, 2003 Edition*. Washington, DC: FHWA, 2003.
64 *A User's Guide to Positive Guidance*. Washington, DC, U.S. DOT, FHWA, Office of Operations, June 1977.

After the questionnaire has been completed, the team is reassembled for a short critique and discussion period. Each member should summarize his or her observations pertaining to safety and operations at the crossing. Possible improvements to the crossing may include the following:

- Closing of crossing—available alternate routes for highway traffic.
- Site improvements—removal of obstructions in the sight triangle, highway realignment, improved cross section, drainage, or illumination.
- Crossing surfaces—rehabilitation of the highway structure, the track structure, or both; installation of drainage and subgrade filter fabric; adjustments to highway approaches; and removal of retired tracks from the crossing.
- Traffic control devices—installation of passive or active control devices and improvement of train detection equipment.

The results and recommendations of the diagnostic team should be documented. Recommendations should be presented promptly to programming and implementation authorities.

Both government and railroad resources are becoming more limited. The *Highway Safety Engineering Studies Procedural Guide* suggests crossing evaluation by an individual, in lieu of the diagnostic team.[65] The guide suggests that this individual be a traffic engineer with experience in highway-rail crossing and traffic safety. A background in signal control and safety program administration would also be advantageous.

2. Traffic Conflict Technique

Highway traffic collisions are a statistically rare event. Typically, an engineer or analyst must assemble several years of collision data to have a large enough sample to identify a pattern of collisions and suggest countermeasures. The traffic conflict technique was developed during the early 1970s by Research Laboratories, General Motors Corporation, to be a measure of traffic collision potential.

A traffic conflict occurs when a driver takes evasive action, brakes, or weaves to avoid a collision. The conflict is evidenced by a brake-light indication or a lane change by the offended driver. Procedures have

65 *Highway Safety Engineering Studies Procedural Guide*. Washington, DC: U.S. DOT, FHWA, November 1991.

been developed to define and record traffic conflicts to permit the performance of formal surveys.[66]

Originally, traffic conflict surveys had to be carried out by a team of observers in the field. The availability of inexpensive and reliable video equipment permits photographic data collection in the field, followed by more accurate and complete data analysis in the office.

3. Collision Study

Vehicle-train collisions are very infrequent at most crossings. Based on 1995 data, the average public crossing would experience a train-involved collision every 56.3 years.[67] As a result, traditional collision analyses techniques are usually of limited utility.

Collision studies may be needed under the following circumstances:

- Some high-exposure crossings may experience sufficient collisions that a pattern can be established.
- It may be necessary to do an in-depth investigation of an individual collision, either as part of a safety evaluation or in preparation for litigation. See Chapter XIII for more information.
- NTSB frequently carries out in-depth studies of certain collisions or of a number of collisions that fit a certain category. NTSB's findings and recommendations may be useful at the individual crossing level or as input to a grade crossing improvement program.
- Traditional collision study methods may be applicable to vehicle-vehicle collisions that are associated with the physical characteristics or the operation of a highway-rail grade crossing.

4. Traffic Study

Important considerations when studying traffic flow and operations at a highway-rail grade crossing are traffic volumes (daily and peak hour); speeds; the mix of vehicle types; intersecting volumes and turning movements at intersections near the crossing; the capacity of the road; delays; and the formation of any traffic queues. These should be reviewed in light of current conditions and how they might be affected by changes at the crossing.

Particular concerns are routing and access for emergency vehicles and the use of the crossing by special vehicles such as low clearance vehicles, buses, and trucks transporting hazardous materials.

If a crossing consolidation is contemplated, the effects on traffic circulation and the impact on the operation of adjacent intersections should be considered. Frequently, the consolidation of crossings also leads to the consolidation of traffic on other facilities and may permit the construction of a traffic signal at a nearby intersection or other improvements that could not be justified otherwise.

The traffic study should also consider the impacts of crossing operations on the community. Considerations include frequency and length of train operations, pedestrian and bicycle access, and the need for crossings to provide adequate access to schools and services.

Standard data collection procedures can be found in several sources, including the *Highway Safety Engineering Studies Procedural Guide* or the *Manual of Transportation Engineering Studies* from the Institute of Transportation Engineers.[68, 69]

5. Near-Hit Reports

Some railroads operate a program under which train crews report "near hits" with or violations by highway vehicles at crossings. These reports can be a valuable source of information regarding problem crossings and will also contain data regarding vehicle ownerships and types, time of day, and other contributing factors.

Where the vehicle can be positively identified, the reports are frequently turned over to the property protection department of the railroad (railroad police) for follow-up. This is particularly true in the case of documented violations by drivers for commercial carriers or for transit and school bus operators.

6. Enforcement Study

An enforcement study is directed at providing an objective measurement of the frequency of violations of traffic control devices and traffic laws. Hidden observers or cameras are used to observe the location or condition under study. Data collected will include total traffic volume, total vehicles encountering the situation under study, and total observed violations.

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66 Perkins, Stuart R. *GMR Traffic Conflicts Technique Procedures Manual*. Research Laboratories, General Motors Corporation, Warren, Michigan, August 11, 1969.
67 *Railroad Safety Statistics 2004 Annual Report*. Washington, DC: U.S. DOT, FRA, November 2005.
68 *Highway Safety Engineering Studies Procedural Guide*. Washington, DC: U.S. DOT, FHWA, November 1991.
69 *Manual of Transportation Engineering Studies*. Washington, DC: Institute of Transportation Engineers, 1994.

The enforcement study must be carried out so that traffic operations and driver behavior are not affected. If an actual law enforcement officer or police car appears on the scene, the study should be interrupted or terminated. The measurements obtained may be used as a basis for later enforcement campaigns and may also be used to justify improvements in traffic control devices, such as the installation of constant warning time devices to improve the credibility of crossing signals.

Various types of specialized photographic equipment are available for conducting enforcement studies or for actual photographic enforcement of traffic laws. Photographic enforcement has been used successfully at grade crossings and along at least one light-rail transit corridor.[70]

D. Systems Approach

The procedures for evaluating highway-rail grade crossings are generally based upon the physical and operational characteristics of individual crossings. A typical crossing safety program consists of a number of individual crossing projects. Funding for crossing safety is approved on the basis of the requirements of these individual projects. Therefore, crossing evaluation, programming, and construction follow traditional highway project implementation procedures.

The concept of using the systems approach to highway-rail grade crossing improvements was enhanced when crossings off the federal-aid system were made eligible for federally funded programs. Because all public crossings are now eligible for improvement with federal funds, the systems approach provides a comprehensive method for addressing safety and operations at crossings.

The systems approach considers the highway-rail grade crossing a part or a component of a larger transportation system. For this purpose, the transportation system is defined as a land surface system consisting of both highway and railroad facilities. The intersection of these two transportation modes affects both safety and operations of the entire system. The objective of the systems approach for crossings is to improve both safety and operations of the total system or segments of the system.

70 *Photographic Enforcement of Traffic Laws*. Washington, DC: National Cooperative Highway Research Program Synthesis of Practice 219, 1995.

The systems approach may be applied to a segment of the rail component of the system. For example, to improve operating efficiency and safety over a specified segment of a rail line, all crossings would be considered in the evaluation. Thus, the systems approach is often called the corridor approach.

The systems approach may be applied to an urban area, city, or community. In this case, all public crossings within the jurisdiction of a public agency are evaluated and programmed for improvements. The desired outcome is a combination of engineering improvements and closures such that both safety and operations are highly improved.

Assume that a segment of rail line is to be upgraded for unit train operations or high-speed passenger service. This type of change in rail operations would provide an ideal opportunity for the application of the systems approach. The rail line may be upgraded by track and signal improvements for train operations that might cause a need for adjustments in train detection circuits of active traffic control devices. Also, modifications of train operations and speeds may require the installation of active traffic control devices at selected crossings.

A systems approach developed for crossings in a specified community or political subdivision allows for a comprehensive analysis of highway traffic operations. Thus, unnecessary crossings can be closed, and improvements can be made at other crossings. This approach enhances the acceptability of crossing closures by local officials and citizens.

Initially, all crossings in the system, both public and private, should be identified and classified by jurisdictional responsibility (for example, city, county, and state for public crossings; parties to the agreement for private crossings). Information should be gathered on highway traffic patterns, train operations, emergency access needs, land uses, and growth trends. Inventory records for the crossings should be updated to reflect current operational and physical characteristics. A diagnostic team consisting of representatives from all public agencies having jurisdiction over the identified crossings and the railroads operating over the crossings should make an on-site assessment of each crossing as described in the previous section. The diagnostic team's recommendations should consider, among other things, crossing closure, installation of active traffic control devices, upgrading existing active devices, elimination by grade separation, surface improvements, and improvements in train detection circuits. In addition, modification of train operations near and at each crossing, removal of sight obstructions, rerouting of special vehicles and emergency vehicles, and railroad relocation should be considered.

Federal, state, and local crossing funding programs should be reviewed to identify the eligibility of each crossing improvement for public funding. Other funding sources include railroads, urban renewal funds, land development funds, and other public or private funding sources.

There are several advantages of the systems approach. A group of crossings may be improved more efficiently through the procurement of materials and equipment in quantity, thus reducing product procurement and transportation costs. Usually, only one agreement between the state, local jurisdiction, and railroad is necessary for all of the improvements. Train detection circuits may be designed as a part of the total railroad signal system rather than custom designed for each individual crossing. Electronic components, relay houses, and signal transmission equipment may be more efficiently utilized. Labor costs may be significantly reduced. Travel time of construction crews may be reduced when projects are in close proximity to each other.

Railroads benefit from the application of the systems approach in several ways. Train speeds may be increased due to safety improvements at crossings. Maintenance costs may be reduced if a sufficient number of crossings are closed. Other improvements may enhance the efficiency of rail operations.

Safety improvements are an obvious benefit to the public. Other benefits include reduced vehicular delays and better access for emergency vehicles.

One impediment to the systems approach is that most federal and state crossing safety improvement programs provide funding for safety improvements only. Also, safety improvement projects may be limited to crossings that rank high on a priority schedule. Another impediment is the involvement of multiple jurisdictions.

FHWA has endorsed the systems approach and its resultant identification of low-cost improvements to crossing safety and operations. FHWA sponsored a demonstration project that utilized the systems approach to improve crossings along a rail corridor in Illinois. To eliminate the need for project agreements with each local agency, the Illinois Commerce Commission issued a single order covering the work to be performed at nine locations. This accelerated the project and reduced labor-intensive work. FHWA and the Illinois Department of Transportation agreed that minimal plan submittals would be required of local agencies, and local agencies agreed to perform the necessary work at mutually agreed-upon lump sum prices under the supervision of Illinois Department of Transportation district representatives.

Improvements made as part of the demonstration project in Illinois included the following:

- Removal of vegetation.
- Pavement widening.
- Reconstruction of approaches.
- Installation of 12-inch lenses in crossing signals.
- Relocation of train loading areas.
- Closure of crossings.
- Removal of switch track.
- Installation of traffic control signs pertinent to crossing geometries.

The Florida Department of Transportation and other states have adopted policies incorporating the systems approach as part of their crossing safety improvement programs. The Florida Department of Transportation selects track segments on the basis of the following conditions:

- Abnormally high percentage of crossings with passive traffic control devices only.
- Freight trains carrying hazardous material in an environment that presents an unacceptable risk of a catastrophic event.
- Passenger train routes.
- Plans for increased rail traffic, especially commuter trains.

The North Carolina Department of Transportation (NCDOT) has used the systems approach often in recent years. Examples of these projects are the Sealed Corridor Program and traffic separation studies.

In the Sealed Corridor Program, NCDOT installed devices such as four-quadrant gates, longer gate arms, median separators, and new signs and pavement markings at every public crossing along the entire railway line between Charlotte and Greensboro, North Carolina. The program is planned to eventually cover the entire corridor between Charlotte and Raleigh, North Carolina. The entire corridor contains 172 public and 43 private railroad crossings.

In traffic separation studies, the NCDOT Rail Division works with communities to study how best to separate railroad and highway traffic. Engineers develop a comprehensive traffic separation study to determine which public crossings need improvements and which need to be closed. During the study phase, the engineering consultant collects traffic data for the public rail crossings in the study area. The consultants also take into account the economic impact of the potential closings.

A draft of the consultants' recommendations is submitted to the Rail Division and the public for review and comment. The recommendations are prioritized to include near-term, mid-term, and long-term improvements. Public hearings are scheduled in each community to give residents a chance to voice opinions about the proposed recommendations. The forums also allow NCDOT to discuss the benefits of enhanced crossing safety.

In the implementation phase, NCDOT officials identify funding for the proposed enhancements (typically, 90 percent is federal funds with a 10-percent local match). The freight railroads sometimes provide additional resources.

Additional information on these and other NCDOT programs can be found on the NCDOT Safety Initiatives Website.[71]

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71 North Carolina Department of Transportation Safety Initiatives Website (www.bytrain.org/Safety/default.html).