ITRE

SUMMARY OF STATE HIGHWAY-RAILROAD GRADE SEPARATION POLICIES

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Rail Division

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Introduction

The Institute for Transportation Research and Education (ITRE) at North Carolina State University prepared this summary document for the North Carolina Department of Transportation (NC DOT), Rail Division. The purpose is to compare North Carolina highway-railroad crossing grade separation guidelines with the policies of other states.

Research Methods

Comparative information on other state's policies was gathered through two means. ITRE conducted telephone interviews with representatives from more than 20 State Departments of Transportation to acquire information on their grade separation policies. Additional information was gathered from a recently published document: *A Procedure For The Provision Of Highway-Railroad Grade Separations: Final Report* by TransTech Group, Inc.

Summary of North Carolina Policy

The North Carolina guidelines for highway-railroad crossing grade separation are based on values calculated for an exposure index, referred to as the Investigative Index. This index is the product of the number of trains operated per day times the highway average daily traffic count projected at the conclusion of the project design period. Engineering judgement is used to evaluate the ranking of crossings generated by the index.

The guidelines recommend that grade separations be constructed in RURAL areas when the exposure index is 15,000 or more, and grade separations should be constructed in URBAN areas when the exposure index is 30,000 or more. The policy notes that these are general guides to establish desirable conditions for highway-railroad grade separations, but "must be implemented with sound engineering judgement, reasonableness, and attention to costs" because grade separation is sometimes impractical even though the index value is greater than the threshold values listed above. Policy also states that there will be no net increase in the number of at-grade crossings on railroad segments having a high volume of train traffic. A copy of the North Carolina guidelines is provided in Appendix A.

Other States' Policies

Most states do not have a written grade separation policy at this time. According to the TransTech Group, Inc. study, twenty-eight states do not have a written policy. This number may even be higher as 9 states did not respond to the survey conducted as part of that study. Most states without a written policy indicated that grade separation decisions are conducted on a case by case basis. In those instances, grade separation decisions are

usually based upon the judgement of engineers and the willingness of the state to pay for construction of a grade separation. This may be a contributing reason for many states not having a written policy, in that they want to maintain greater flexibility in making grade separation decisions. Table 1 lists states reported to have a written grade separation policy and includes brief highlights of each policy.

Table 1: State Departments of Transportation with Written Policies for Highway-Railroad Grade Separation [1]

State	Highlights
Alaska	Accident Prediction Value (APV) equivalent to expected number of crashes. Uses diagnostic team to make a final decision as to what major treatment is required.
California	Extensive procedure using roadway and train volumes, delay, speed limits, accident history, emergency vehicle and school bus use, community impacts, etc.
Delaware	New highway-rail crossings, priority for high-speed lines, case by case analysis for low-sped lines.
Florida	Roadway volumes approaching 30,000 veh/day requires benefit cost study. Separations required for limited access roadways and high-speed rail crossings, recommended for controlled access roadways.
Illinois	When crash frequency and benefit-cost exceed specific values, a grade separation is required when crossing is constructed or reconstructed. Grade-separate rural expressway crossings.
Massachusetts	Separations provided for access-controlled roadways, replacements of deficient roadway-railroad bridges, safety and congestion considered, benefit-cost.
Michigan	Train and vehicular traffic and speed, topography and land use, delay, project cost, benefit-cost. Treats railroad grade separations similar to highway-highway separations. Ranks crossings by exposure index.
Minnesota	Grade separation required on full-access controlled roadways, frequently warranted on arterials. Use of cost-effectiveness analysis; consider road and train volumes, crash potential, community impacts, geometrics, and sight distance.
Mississippi	Roads on new location require a separation.
North Carolina	For new construction, use of exposure index of 15,000 for rural and 30,000 for urban locations for initial consideration, followed by detailed study. New crossings of high-speed rail to be grade separated.
Oklahoma	Roadway classification, new roads with ADT ≥ 10.000. Also considers crossings with exposure index ≥ 25,000 (not official policy).
Utah	Prioritizes crossings based on crash rate, guidelines for separation include rank on priority list and traffic congestion. Cites AASHTO Policy and use of diagnostic team.
Virginia	Uses benefit-cost procedure including structure, right-of-way, and approach roadway cost; cost of crashes and delay to prioritize crossings for separation.
Wisconsin	Use of exposure index of 15,000 for rural (and vehicular speed limit of 50 mph or greater) and 100,000 in urban areas, along with consideration of existing terrain, cost-benefit, and undesirability of an at-grade crossing. Procedure also includes crossing angle, number of tracks, school and commercial buses, and sight distance among others. Provides separations for all freeways.

Written grade separation policies range from qualitative language without detailed factor analysis to use of criteria with quantitative values incorporated into sophisticated formulas. Some states, such as Minnesota and Utah, have general grade separation policies lacking definite criteria for use in deciding whether or not grade separation is

[1] From *A Procedure For The Provision Of Highway-Railroad Grade Separations: Final Report* by TransTech Group, Inc.

needed at a highway-railroad crossing. Other states, such as North Carolina and Florida, have developed simple criteria for use in determining when to construct a grade separation. For example, in Florida, if the average daily traffic at a crossing is approximately 30,000, a benefit cost study is conducted to determine if a grade separation should be constructed.

California, Illinois, Virginia, and Wisconsin have detailed grade separation policies. California's policy utilizes a very detailed formula, and incorporates many criteria through a series of calculations to reach a decision on grade separation. The California formula includes average daily traffic, daily train traffic, costs, delay, vehicle speed limit, and many other factors to derive a priority index number. This number is used as the basis for deciding where separations will be constructed each year. California also uses a similar formula to evaluate improvements to existing grade separations.

Virginia bases grade separation decisions on a cost effectiveness procedure, which requires constructing a separation if the anticipated costs from a highway-railroad grade crossing are estimated to be greater than the costs from constructing a grade separated crossing. The cost effectiveness calculations include costs associated with vehicle delays.

Illinois uses a similar procedure. That state constructs a grade separation if the accident frequency at a crossing is greater than 2 accidents per 100 years and the benefit-cost ratio is calculated to be greater than 1.

Finally, some states have policies that specify when separation is required and do not include cost analysis or engineering judgement in that determination. Mississippi's policy requires all roads on new locations to be separated. Delaware's policy is that all new crossings are to be grade separated and current crossings over high-speed rail lines will be eliminated.

Specific criteria to develop grade separation guidelines as contained in grade separation policies from California, Illinois, Virginia, and Wisconsin are shown in Table 2.

Table 2: Additional Information on Selected States' Grade Separation Policies

Quantitative Criteria or Formula Using:	California	Illinois	Virginia	Wisconsin
Exposure index	No	No	No	Yes
Daily vehicle volume	Yes	Yes	Yes	Yes
Project costs	Yes	Yes	Yes	No
Daily train traffic	Yes	Yes	Yes	No
Accident history	Yes	Yes	No	No
Delay	Yes	No	Yes	No
Vehicle or train speeds	Yes	No	No	No
Emergency vehicle or school buses	Yes	No	No	No
Additional comments on policy	All the above factors above are used in a formula to prioritize which crossings need to be grade separated.	Separations are constructed when the accident frequency exceeds .02 and the benefit-cost ratio equals or exceeds 1.	All crossing decisions are made on the basis of a cost effectiveness study that uses the factors listed above.	Policy gives exposure values and criteria for when separation is "desirable", but the policy is largely qualitative.

Copies of the California, Illinois, Virginia, and Wisconsin grade separation policies are contained in Appendix B.

A summary of criteria that is used in evaluating and ranking crossings for grade separation in these states is as follows:

- Presence of multiple tracks—this increases the likelihood of a motorist being struck by a second train passing immediately after a train in a crossing
- Type of highway (single-lane/multi-lane/limited access)
- Speed of trains and highway vehicles
- Frequent use of crossing by school buses
- Frequent use of crossing by emergency vehicles
- Frequent use of crossing by trucks carrying hazardous materials
- Unusual track or roadway geometrics
- Unusually restricted sight distance
- Accident history
- Presence of passenger trains
- Presence of commuter trains/light rail vehicles
- Crossing blocking delay
- Alternate route availability
- Benefit cost analysis

Appendix A: Current North Carolina Policy

Any project programmed in the Transportation Improvement Program (TIP) which may result in creating a new highway-railroad crossing shall be discussed with the railroad in the early planning (scoping) process. The Rail Division will be notified of all scoping meetings held by the Planning and Environmental Branch. Any Secondary Road, Industrial Access, Small Urban or High Hazard-Safety projects that may result in the creation of a new crossing will also be coordinated with the Rail Division early in the planning process. The Rail Division will be informed of these projects by the Assistant Secretary for Secondary Roads and Economic Development or the appropriate Division Engineer for informational purposes only.

When new highway-railroad crossings are proposed by the Department, the State Highway Administrator will coordinate proposal reviews with the Rail Division and appropriate railroad. It will be the responsibility of the Rail Division to gather data on the number of trains per day and to make recommendations to the State Highway Administrator relative to the potential crossing.

The Board of Transportation (BOT) sets forth the following criteria to serve as guidelines, within the limits outlined below, in the treatment of highway-railroad intersections on new construction projects. These are general guides to establish the desirable conditions for highway-railroad grade separations, but must be implemented with sound engineering judgment, reasonableness, and attention to costs.

The grade separation guidelines are based on use of an exposure index which is the product of the number of trains per day and the projected average daily highway traffic at the end of the design period. Unless information to the contrary is available, such as a pending abandonment of the railroad, the number of trains at the end of the design period should be assumed to be the same as at present.

Separations should be constructed in RURAL areas when the exposure index is 15,000 or more.

Separations should be constructed in URBAN areas when the exposure index is 30,000 or more.

Where two alignments are under consideration and one would make separation feasible, the separation should be considered as one factor favoring adoption of such alignment. It is realized that topography, right-of-way costs, construction costs or other features of the physical situation may make separation impractical even though the index is above the figure set. In this case, the Secretary of the Department of Transportation shall have final authority in decisions to create new at-grade crossings.

It is the policy of the Department of Transportation to permit no net increase in the number of at-grade crossings on the railroad segments having a high volume of train traffic. CSX Transportation's route from Pleasant Hill to Rowland and Norfolk Southern Railway's routes from Pelham to Grover and Pineville are high volume segments.

The railroad will be notified of all final decisions regarding the locations of new at-grade crossings or grade separations. In addition, a coordinating committee consisting of

representatives of the Department and the railroads will meet periodically to discuss upcoming projects that involve both the railroad and highway systems.

1. Any new highway-railroad intersection on the Federally-Designated High Speed Rail Corridor to be grade separated, and redundant and/or unsafe rail-highway at-grade crossings to be eliminated.

2. Reduction of the number of rail-highway at-grade crossings on the State Highway System, through consolidation is encouraged.

Appendix B: Other State's Policies

California

FORMULA FOR CROSSINGS NOMINATED FOR SEPARATION OR ELIMINATION

$$P = \frac{V(T + 0.1 \times LRT)}{C \times F}(AH + BD + SCF)$$

Where:

P = Priority Index Number
V = Average 24-Hour Vehicular Volume
C = Total Separation Project Costs (in Thousands of Dollars)
T = Average 24-Hour Train Volume
LRT = Light Rail Train Volume
F = Cost Inflation Factor
(based on Current Construction Cost Index)
AH = Accident History
BD = Crossing Blocking Delay
SCF = Special Conditions Factor = VS + RS + CG + AR + PT + OF
VS = Vehicular Speed Limit
RS = Railroad Prevailing Maximum Speed
CG = Crossing Geometrics
AR = Alternate Route Availability
PT = Passenger Trains
OF = Other Factors (secondary accidents, emergency vehicle usage, passenger buses, school buses, hazardous materials trains and trucks, community impact)

POINTS IN EACH CATEGORY ARE ASSIGNED ACCORDING TO THE FOLLOWING SCHEDULE:

V = Average 24-Hour Vehicular Volume = 1 point per vehicle
C = Total Separation Project Costs = 1 point per thousand dollars in costs
T = Average 24-Hour Train Volume = 1 point per train
LRT = Light Rail Train Volume = 1 point per train

$$\text{F = Cost Inflation Factor} = \frac{CCI('75\text{-}'76) \times ('75\text{–}'76f'')}{CCI(CurrentYear)}$$

Construction Cost Index (CCI) 1975-76 = 2100
"f" for 1975-76 = 24
Construction Cost Index for Current Year = (see current Engineering News Record Journal)
For this investigation, the Cost Inflation Factor (F) = (2100 x 24) I CCI for current year

AH = Accident History (last 10 years from filing due date)

The Commission records reportable incidents for each crossing under jurisdiction in a form called FORM A. The AH points will be based on accidents which involve trains at the crossing and are

recorded on the Commission's Crossing record, Form A. For each accident the Commission will assign points based on the following:

Points = (1 + 2 x No. Killed + No. Injured) x PF

PF = Crossing Protection Factor based on warning device at crossing:

Standard #	Points
#9	1.0
#8	0.4
#3	0.2
#1	0.1

Note 1: No more than three points shall be allowed for each incident prior to modification by protection factor.

Note 2: Each Incident shall be rated separately and modified by a factor appropriate to the warning devices in existence at the time of incident.

BD = Blocking Delay Per Train (The time by which vehicular traffic is delayed to allow a train to pass at crossing.)

1. To calculate the blocking delay for a typical day, observe when trains pass the crossing and begin timing from the point that warning devices are activated at the crossing and stop timing after the train has passed and warning devices are reset. Measure the elapsed time in minutes. i.e. If delay was 2 minutes and 30 seconds, then the time is 2.5 minutes.

2. Using the above method, calculate a delay time for each train that crosses the intersection.

3. Add all delays and divide the total time by the number of trains that passed the intersection. This average is the Blocking Delay points. Note: The maximum BD points is 10. If the average delay per train is 10 minutes or more, then your agency will be credited with the maximum of 10 points for the BD.

EXAMPLE: At a highway-railroad crossing the following observations were made:

- A train with 100 cars passed the crossing with a blocking delay time of 7.5 minutes.
- Later that day, another train passed the crossing with a blocking delay time of 5.6 minutes.
- In the afternoon, another train passed the crossing with a blocking delay time of 8.1 minutes.
- The BD per train is:(7.5min. + 5.6 min. + 8.1 min.) / 3 = 7.1 (Round off the average to the nearest tenth of a point.)

VS = Vehicular Speed Limit

Posted Speed Limit

MPH	Points
0 - 30	0
31 – 35	1
36 – 40	2
41 – 45	3
46 – 50	4
51 – 55	5

RS = Railroad Prevailing Maximum Speed

MPH	Points
0 - 25	0
26 - 35	1
36 - 45	2
46 - 55	3
56 - 65	4
66 - 75	5
76 - 85	6
86 +	7

CG = Crossing Geometrics

0 - 17 points based on relative severity of physical conditions, i.e. grade, alignment, site distance, etc.

AR = Alternate Route Availability:

The AR is the nearest crossing available that vehicles may cross if the highway-railroad grade crossing is blocked by train(s). i.e. If a train is passing by the Avenue T grade crossing and is long enough that it also blocks Avenue S and Avenue R, then the nearest crossing that vehicles may cross is at Avenue Q. Assume that Avenue Q is 4252 ft. from the Avenue T grade crossing. Therefore, based on the table below, the AR for Avenue T is 4 pts.

Distance in Feet	Points
up to 1,000	0
1,001- 2,000	1
2,001- 3,000	2
3,001- 4,000	3
4,001- 5,000	4
5,001 +	5

Since some crossings are shared by railroads the alternate route may vary depending on the train length and speed. For situations where trains of different lengths utilize the crossing, determine the Alternate Route for each train that crosses on a typical day. Then, average the Alternate Route calculations and use the average number to determine the AR points.

For example, at a crossing three trains traveled on the same day. First, a 100 car train crossed and blocked two adjacent crossings in addition to the proposed crossing for separation. Assume that the nearest alternate route for the train was 4,852 ft. Next, a 10 car passenger train crossed and only blocked one additional adjacent crossing. Assume that the alternate route for the passenger train was 1,734 ft. A two car commuter train then crossed later that day and only blocked the intersection of the proposed grade separation. Assume that the nearest alternate route for the commuter train was 851 ft. The average of the three trains is 2479 ft [(4852 + 1734 + 851) / 3 = 2,479 ft.] . This average corresponds to an AR of 2 points.

PT = Passenger Trains

Number of Trains Per Day	Points
1 - 2	1
3 - 5	2
6 - 10	3
11 - 20	4
21 - 30	5
31 - 40	6
41 - 50	7
51 - 60	8
61 - 70	9
71+	10

OF = Other Factors

Other Factors are valued in a range from 0 to 18 points based on:

Category	Points
Secondary Accidents	3
Emergency Vehicle Usage	3
Passenger Buses	3
School Buses	3
Hazardous Materials Trains and Trucks*	3
Community Impact	3

*NOTE: In past OFs, applicants were counting each and every train and truck that passed by the crossing as carrying hazardous materials because the vehicles operate on a fuel which is considered hazardous (diesel, gasoline, etc.). This is not acceptable. The correct tally is the count of trains and trucks which transport hazardous materials (chemicals, fuels, etc.) and its cargo is clearly labeled as hazardous content by a diamond shaped sign. If the load is not labeled, then the vehicle or train can not be counted as transporting hazardous materials.

FORMULA FOR EXISTING SEPARATIONS NOMINATED FOR ALTERATION OR RECONSTRUCTION

$$P = \frac{V + (T + 0.1 \times LRT)}{C \times F} + SCF$$

Where:

P = Priority Index Number
V = Average 24-Hour Vehicular Volume
T = Average 24-Hour Train Volume
LRT = Average 24-Hour Light Rail Train Volume
C = Total Separation Project Costs (in Thousands of Dollars)
F = Cost Inflation Factor (based on Current Construction Cost Index)
SCF = Special Conditions Factor = WC + HC + SR + AS + PF + AP + DE

Where:
WC = Width Clearance
HC = Height Clearance
SR = Speed Reduction
AS = Accidents at or near structure
PF = Probability of Failure
AP = Accident Potential
DE = Delay Effects

POINTS IN EACH CATEGORY ARE ASSIGNED ACCORDING TO THE FOLLOWING SCHEDULE:

V = Average 24-Hour Vehicular Volume = 1 point per vehicle
C = Total Separation Project Costs = 1 point per thousand of dollars in costs
T = Average 24-Hour Train Volume = 1 point per train
LRT= Light Rail Train Volume = 1 point per train

$$\text{F = Cost Inflation Factor} = \frac{CCI('75–'76) \times ('75–'76"f")}{CCI(CurrentYear)}$$

CCI (Construction Cost Index) for 1975-76 = 2100
"f" for 1975-76 = 24
Construction Cost Index for Current Year (see current Engineering News Record Journal)
For this investigation the Construction Cost Index (F) is (2100 x 24) I CCI for current year

SCF = Special Conditions Factor = WC + HC + AS + PF + AP + DE

Where:

WC = Width Clearance Points: 0-10

Based On:

Width (in Feet)	Points
16' + 12(N)	0
12' but less than 16' + 12(N)	2
8' but less than 12' + 12(N)	4
Less than 8' + 12(N)	6
11 (N)	8
Less than 11(N)	10

Note: N = Number of Traffic Lanes

HC = Separation Height Clearance 0-10

Based On:

Underpass Height (feet)	Points
15' and above	0
14' but less than 15'	4
13' but less than 14'	8
Less than 13'	10

Overpass Height (feet)	Points
22.5' and above	0
20' but less than 22.5'	4
18' but less than 20'	8
Less than 18'	10

SR = Speed Reduction or Slow Order

	Points
None	0
Moderate	2
Severe	5

AS = Accidents at or Near Structure (10 years)

Number	Points
0-10	0
11-20	1
21-30	2
31-40	3
41-50	4
51-60	5
61-70	6
71-80	7
81-90	8
91-100	9
100 +	10

PF = Probability of Failure (10 points maximum) (Taking structure age into account)

	Points
Minimal / None	0
Slight	2-3
Moderate	4-6
Extreme	7-10

AP = Accident Potential (10 points maximum)

	Points
None	0
Slight	2-3
Moderate	4-6
Extreme	7-10

DE = Delay Effects (10 points maximum)

	Points
None	0
Slight	2-3
Moderate	4-6
Extreme	7-10

Illinois

3-201.01 SCOPE

As State highways and railroads are expanded or modernized, it is inevitable that new highway-railroad crossings will need to be established and that existing crossings will need to be modernized, reconstructed or eliminated. Basically, there are two methods of accomplishing these crossings:

A. At-grade crossing - where the highway and railway intersect at the same elevation requiring proper warning to reduce the inherent hazard of collisions between trains and highway vehicles.

B. Grade separation crossing - where the inherent collision hazard is eliminated by the construction of a structure to carry the highway over or under the railroad.

3-201.02 WARRANTS FOR GRADE CROSSING WARNING DEVICES

At railway-highway crossings where grades are not separated, the following types of warning signal devices are warranted and shall be installed when construction or reconstruction of the approach highway is undertaken, or when construction or reconstruction of the crossing is undertaken as the result of a formal agreement between the Railroad and the State, subject to the limitation of available funds.

A. Reflectorized crossbucks, pavement markings and advance warning signs as indicated in the Illinois Manual on Uniform Traffic Control Devices for Streets and Highways shall be the minimum warning devices at all crossings.

B. Flashing light signals shall be installed at crossings where the warrants for gates are not met and when the expected accident frequency equals or exceeds .02. The method determining the expected accident frequency is shown in Figure 3-201.02.

C. Cantilevered flashing light signals shall be installed, in addition to other warning devices, on multilane highways that qualify for active warning devices where the possibility of a truck blocking the view of the roadside signals is present. Cantilevers should also be considered at frequent accident locations that could possibly be improved by more visible signals.

D. Flashing light signals and gates shall be installed when one or more of the following conditions are met:

1. Multiple main line railroad tracks.

2. Multiple tracks at or in the vicinity of the crossing which may be occupied by a train or locomotive so as to obscure from view, the movement of another train approaching the crossing.

3. High speed train operation combined with limited sight distance at either single or multiple track crossings.

4. A combination of high speeds and moderately high volumes of highway and railroad traffic.

5. Either a high volume of vehicular traffic, high number of train movements, substantial numbers of school buses or trucks carrying hazardous materials, unusually restricted sight distance, continuing accident occurrences or any combination of these conditions.

6. The expected accident frequency for flashing lights exceeds .02 and the benefit cost ratio equals or exceeds 1.0. The method for determining the benefit cost ratio is shown in Figure 3-20l.02a.

7. A diagnostic team recommends them.

In individual cases where a diagnostic team justifies that gates are not appropriate, gates will not be required.

E. A higher type of warning device, not justified under any of the preceding warrants, may be provided on the basis of continuing or potential accident occurrence due to:

1. Unusual track or roadway geometrics.

2. Restricted sight distance.

3. Other unusual conditions, such as when there exists exceptional accident consequences to a large number of people as rail or highway passengers or as the result of an accident involving hazardous materials. Conversely, in other instances, a lower level device may be justified if concurred in by a diagnostic team.

When the distance measured along the centerline of the highway between two regularly used adjacent tracks is less than 100 feet , the crossing should be considered as a multiple track crossing and warning devices installed accordingly. When the distance is 100 feet or more, the crossings should be considered as individual crossings with each signalized in accordance with the preceding warrants.

Refinements to activation circuitry should be recommended where the credibility of the warning devices could be beneficially increased. This includes shortening the signal "starts" to the present train speeds or installing or upgrading Constant Warning Time Devices (predictors) or Motion Detectors.

EXPECTED ACCIDENT FREQUENCY = A x B x CURRENT TRAINS PER DAY

VEHICLES PER DAY (10 OR. ADT)	'A' FACTOR
250	.000347
500	.0006Y4
1000	.001377
2000	.002627
3000	.003981
4000	.005208
5000	.006516
6000	.007720.
7000	.009005
8000	.010278
9000	.011435 -
10000	.012674
12000	.015012
14000	.017315
16000	.019549
18000	.021736
20000	.023877
25000	.029051
30000	.034757

EXAMPLE

ASSUME

URBAN AREA
CROSSBUCK PROTECTION
5000 VEHICLES PER DAY
5 TRAINS PER DAY

EXPECTED ACCIDENT FREQUENCY

EA. = .006516 X 3.06 X 5
EA. = 0.10
EA. = 1 ACCIDENT EVERY TEN YEARS

ACCIDENT FREQUENCY IS GREATER THAN 0.02. THIS WOULD INDICATE NEED FOR HIGHER TYPE DEVICE.

TRY FLASHING LIGHTS
'B' = 0.23

EA. = 006516 X .23 X 5
EA. = 0.01

THEREFORE, FLASHING LIGHTS ARE WARRANTED.

"B" FACTOR COMPONENTS
("B" FACTOR BASIC VALUE ADJUSTMENTS)

BASIC VALUES FOR EXISTING DEVICES

A	Crossbucks. highway volume less than 500 per day	3.89
B	Crossbucks, urban	3.06
C	Crossbucks, rural	3.08
D	Stop signs. highway volume less than 500 per day	4.51
E	Stop signs	1.15
F	Wigwags	0.61
G	Flashing lights. urban	0.23
H	Flashing lights. rural	0.93
I	Gates. urban	0.08
J	Gates. rural	0.19

BENEFIT COST RATIO ANALYSIS PROCEDURE

Definitions:

EAF. = Expected Accident Frequency = A x B x T, trains/day (from Figure 3-201.02)

Z = Cost of accident = ratio of deaths and injuries per accident (average for latest 3 yrs. in Ill.) x cost per accident (National Safety Council accident cost data which is documented and also periodically up-dated) = $21,205 (to be revised annually by Central Office)

U = Cost of flashing lights divided by expected life = _____

V = Yearly maintenance cost of flashing lights = _____

Y = Cost of gates divided by expected life = _____

W = Yearly maintenance cost of gates = _____

L = Cost of grade separation divided by expected life = _____

M = Yearly maintenance cost of grade separation = _____

STEP #1 EA. for present installation = A x B x T = _____

STEP #2 EA. for proposed installation = A x B x T = _____

STEP #3 Savings in EA. per year = Step # 1 - Step # 2 = _____

STEP #4 Benefit = Z x Step #3 = _____

STEP #5 Cost of proposed installation = Y+W, or U+V, or L+M = _____

STEP #6 Benefit Cost Ratio = Step 4 divided by Step 5 = _____

Predictors are to be installed at crossings of at least 1000 ADT and an average daily train traffic of at least 5 trains a day or there are concentrations of train or vehicular traffic during "rush hours" when:

A. There are switching moves on the approach circuits or

B. At least 25% of the average daily trains operate at speeds 25 mph slower than the fastest train on the line or

C. There is unusual track and crossing geometry.

Motion detectors are to be installed at crossing where:

A. Gates are involved

1. When there is a stopping or other lengthy occupancy of the approach circuits or

2. When there are new gate installations or

3. When there Is upgrading of crossings with flashing light signals to gate Installations or

4. When there are major control circuitry changes required at existing installations.

B. Flashing light signals are involved

1. When there is stopping or other lengthy occupancy of the approach circuits or

2. When there are new flashing light signal Installations with 1000 ADT or more and 5 or more trains per day or

3. When there are major control circuit changes required by changes in or additions to flashing light signals at crossings with 1000 ADT or more and 5 or more trains per day.

3-201.03 WARRANTS FOR GRADE SEPARATION STRUCTURES

A grade separation shall be constructed when a highway is constructed, or reconstructed across a railroad when the accident frequency for gates exceed .02 and the benefit cost ratio equals or exceeds 1.0

The highway grade separation shall be constructed when an expressway in a rural area is constructed or reconstructed across the railroad.

Virginia

COST-EFFECTIVENESS PROCEDURE

In order to justify the replacement of an at-grade railroad crossing with a grade-separated crossing, the costs associated with retaining the at-grade crossing must be equal to or greater than the costs of constructing the grade separation Relating it more specifically, the costs of train/vehicle accidents and the costs of delay and excess fuel consumption to motorists awaiting the passage of trains must be equal to or greater than the costs of a new bridge or overpass.

This principle is sound in theory, and provides a valid tool for evaluating specific at-grade crossings. It was not practical, however, to evaluate all 2,497 crossings in Virginia. Therefore, a procedure based on rational assumptions and available data was developed which selected those crossings meeting this basic principle. This procedure is described in the remainder of this section.

Definitions of Costs

Costs associated with at-grade crossings include costs which are incurred by those involved in crossing accidents and those delayed by waiting for the passage of a train, both in time of delay and excess fuel consumption. Other costs include those associated with a possible leakage of hazardous materials resulting from a collision and those associated with the delay of an emergency vehicle waiting for a train to pass. Costs associated with a grade separation include that of the bridge or overpass structure, the roadway approaches to the structure, and the right-of-way.

Accident Costs

It is obviously impossible to predict the actual costs of future accidents that might occur at a crossing. Therefore, the standard practice is to use the average cost of railroad crossing accidents that have occurred previously, and multiply it by the expected number of accidents. Based on a total of 70 accidents (29 rural and 41 urban) at public crossings in Virginia in 1989, and on the accident costs recommended by the Federal Highway Administration (FHWA) (4), it was determined that a rural accident costs $141,126 and an urban accident costs $102,942. It is important to note that the FHWA costs are from nationwide data and reflect the average costs of fatal, injury, and property damage only accidents.

The expected number of accidents per year is determined by applying the Hazardous Index Formula. This New Hampshire model generates an expected accident rate (EAR) for a crossing based on certain characteristics of the crossing such as location, number of trains, existence of warning devices, etc.

Total accident costs are then obtained by multiplying together average cost per accident and EAR. This is expressed as:

CA = $C (EAR), where Eq. 1

CA = annual cost of accidents
$C = average cost per accident ($141,126 rural, $102,942 urban)
EAR = expected accident rate per year

Delay Costs

The cost of a person's time is often used in cost~effectiveness analysis when evaluating a proposed improvement. For purposes of this study, average wage rates in urban and rural areas were used. While this varies somewhat among areas, the Virginia Employment Commission reported an average wage in 1989 of $10.85/hour in a representative urban area and $7.80/hour in a representative rural county.

The amount of delay varies from crossing to crossing depending upon the length and speed of a train (6). Mathematically, the time a crossing is effectively blocked by the passage of a train is expressed as:

MT = [(L/S) (60) + 0.6 + 0.05], where Eq. 2

MT = minutes required for passage of a train
L = length of train in miles (a maximum length of 9,000 feet was assumed)
S = speed of train in mph (assumed as 45 mph rural, 25 mph urban)
60 = conversion to change mph to miles per minute
0.6 = average minutes for activation/deactivation of warning devices
0.05 = average minutes for motorists to react and start up after train has passed

By assuming all trains at the crossing are the same length and travel at the same speed, the number of minutes a crossing is blocked during an average day is expressed as:

M = MT (T), where Eq. 3

M = minutes during an average day that a crossing blocked
MT = minutes required for passage of a train (Eq. 2)
T = number of trains/day

The probability that a vehicle will be delayed is expressed as:

P - M / 1440, where Eq. 4

P = probability of a vehicle being delayed during an average day
M = minutes during an average day that a crossing is blocked (Eq. 3)
1440 = number of minutes in a day

The number of vehicles delayed during an average day is expressed as:

N = P (AADT), where Eq. 5

N = number of vehicles delayed during an average day
P = probability of a vehicle being delayed during an average day (Eq. 4)
AADT = average annual daily traffic volume using the crossing

These three equations can then be combined to calculate the total delay to vehicles during an average day:

$$D = [P (AADT)] [MT / 2] \quad \text{Eq. 6}$$

D = total minutes daily delay
P (AADT) = number of vehicles delayed (Eq. 5)
MT / 2 = average minutes of delay per vehicle resulting from the passage of a train (An average is used to reflect the fact that some vehicles will arrive as the train is just coming and some as the train is just leaving.)

In addition to the cost of time, there is also excess fuel consumption resulting from vehicles idling during the passage of the train. For purposes of this study, it was assumed that gasoline cost $1.10/gallon.

An FHWA report indicated that idling vehicles burn 0.013 gallons gasoline/minute (7). Total gasoline consumption due to delay during average day is therefore estimated as:

$$G = 0.013 D, \text{ where} \quad \text{Eq.7}$$

G = daily gallons of gasoline consumed by idling vehicles
0.013 = idling consumption in gallons/minute
D = total minutes of daily delay (Eq. 6)

In order to calculate the annual costs of delay, the equations and unit costs are combined and expressed as:

$$CD = 365 D [(\$1.10) (0.013) + (\$W / 60)], \text{ where} \quad \text{Eq. 8}$$

CD = annual cost of delay
365 = number of days in a year
D = minutes of daily delay (Eq. 6)
$1.10 = cost of gasoline/gallon
0.013= idling consumption in gallons/minute
$W = average hourly wage ($7.80 rural, $10.85 urban)
60 = conversion to change hourly wage to per minute wage

Hazardous Materials Costs

It is very difficult to quantify the costs associated with the leakage of a hazardous material. In fact, there is no known documentation of such costs. Based on the statistics presented earlier, however, grade-crossing accidents resulting in the leakage of hazardous materials are very rare. Accordingly, the validity of the cost-effectiveness analysis is not compromised by eliminating these costs from consideration.

Emergency Vehicle Delay Costs

There is no known documentation of costs resulting from the delay of emergency vehicles at the at-grade railroad crossings. Common sense indicates, however, that the probability of such an occurrence is very small. When the probabilities of an emergency occurring at a location that is

completely isolated by railroad tracks and at a time when a train actually blocks the tracks are combined, there is very little total probability of such an event. Accordingly, the analysis is not compromised by eliminating these costs from consideration.

Grade Separation Costs

These costs were based on the Department's in-house information regarding the general construction costs of a highway bridge and required approaches, and the procurement of additional right-of-way. For the purpose of this study it was assumed that a grade-separated crossing costs $1.2 million in a rural area and $6.0 million in an urban area. Further, an average life of 50 years was assumed.

Development of Selection Criteria

As stated at the outset, a grade-separated crossing is economically justified if the costs associated with the existing at-grade crossing are equal or greater than the costs of constructing the grade separation. This is expressed as:

CA + CD = [or greater than] CB / 50, where Eq. 9

CA = annual cost of accidents (Eq. 1)
CD = annual cost of delay (Eq. 8)
CB = cost of bridge ($1.2 million rural, $6.0 million urban
50 = average life of a bridge in years

Accident Criteria

If costs due to delay are assumed to be zero, and Eq. 1 is substituted, Eq. 9 becomes:

$141,126 (EAR) = [or greater than] $1,200,000 / 50 (rural), and

$102,942 (EAR) = [or greater than] $6,000,000 / 50 (urban)

The sums $141,126 and $102,942 are weighted average costs for all grade crossing accident costs which occurred in 1989 (2).

The accident criteria are determined by solving the above equations for EAR. Thus, the minimum expected accident rate, or EAR, for which a grade-separated crossing is justified is 0.17 in rural areas and 1.17 in urban areas.

Delay Criteria

If costs due to accidents are assumed to be zero, and Eq. 8 is substituted, Eq. 9 becomes:

365 D [($1.10) (0.013) + ($7.80 / 60)] = [or greater than] $1,200,000 / 50 (rural), and

365 D [($1.10) (0.013) + ($10.85 / 60)] = [or greater than] $6,000,000 / 50 (urban).

The delay criteria are determined by solving the above equations for D. Thus, the minimum daily minutes of delays, or D, for which a grade-separated crossing is justified is 455.67 minutes in rural areas and 1,684.92 minutes in urban areas.

Combination Accident and Delay Criteria

If both accident and delay costs are considered, and Eq. 1 and Eq. 8 are substituted, Eq. 9 becomes:

2,679.44 (EAR) + D = [or greater than] 455.67 (rural) and

1,445.41(EAR) + D = [or greater than] 1,684.92 (urban).

Selection of Crossings

The Department maintains a computerized inventory of at-grade public railroad crossings in Virginia. The Department of Transportation's (Federal) Hazardous Index Formula, or New Hampshire model can be run on this inventory to produce expected accident rates (EARs) for each crossing. Additionally, the Department developed a computer program which uses the criteria just described to select those crossings for which a grade separation is potentially justified. The following describes in general terms the Department developed program.

Urban Versus Rural

The inventory was reviewed to separate the urban crossings and rural crossings.

Application of Accident Criteria

The aforementioned Hazardous Index Formula program was run to produce EARs for each crossing. Rural crossings with an EAR = [or greater than] 0.17 and urban crossings with an EAR = [or greater than] 1.17 were selected and set aside.

Application of Delay Criteria

Daily delay is not a value that is maintained on the Department's inventory; accordingly, it has to be expressed in terms of inventory data items. This is done by starting with Eq. 6:

D [P (AADT)] [MT / 2], and substituting Eq. 4 and Eq. 3

D = [((MT) (T) / 1440) AADT] [MT / 2]

$D = (MT)^2 (T) (AADT) / 2880$, and substituting Eq. 2

$D = [(L / S) (60) + 0.6 + 0.05]^2 (T) (AADT) / 2880$, thus

For rural (s = 45 mph), D = 0.003 (T) (AADT)

For urban (s = 25 mph), D = 0.008 (T) (AADT)

The number of daily trains (T) and the daily traffic (AADT) included in the inventory for each crossing is substituted into these formulas to calculate the minutes of daily delay. Rural crossings having a delay ≥ 455.67 minutes and urban crossings having a delay = [or greater than] 1684.92 minutes were selected and set aside.

Application of Combined Criteria

The expected accident rate (EAR) and delay (D) were then used for the combined criteria such that rural crossings with 2,679.44 (EAR) + D = [or greater than] 455.67 and urban crossings with 1,445.41 (EAR) + D = [or greater than] 1,684.92 were selected and set aside.

Check for Duplication

Finally, the crossings selected and set aside from the above procedures were checked for duplications. Duplicates were discarded, and a master list of at-grade crossings for which a grade separation is potentially justified was compiled.

(Report of the Virginia Department of Transportation on Railroad Grade Crossings, House Document No. 12, Richmond, 1991)

Wisconsin

BACKGROUND

The Department has authority under Section 84.05 Wisconsin Statutes to undertake highway improvements which cross railroad tracks. After the highway improvement is determined and the project concept is approved and authorized, the Department shall endeavor to make an arrangement with the railroad and all OTHER persons involved. The Department has authority for making surveys, including soundings, on railroad lands. Figure 1 is a sample letter notice to the railroad for this purpose. The letter notice is generally prepared and sent to the railroad by the district about four weeks prior to the time the survey work on railroad lands is to start.

Projects for the elimination of crossings at grade can be accomplished by the following methods:

- Constructing a grade separation structure.
- Relocating the highway.
- Relocating the railroad.
- Closing the crossing.

The closing of crossings without OTHER highway or railroad changes is seldom done. However, in special circumstances, it can be accomplished for good cause by petitioning the Office of the Commissioner of Transportation (OCT) or by closing the segment of road across the track or by vacating a portion of a street.

Railroad participation in the cost of a highway improvement project is required under the following conditions:

1 The railroad has responsibility for maintenance of the existing grade separation structure, or

2 A rail-highway grade crossing that has train activated warning devices is closed as part of the project.

The railroad's share for conditions described above are as follows:

1. Value based on its future savings in structure maintenance expense that are relinquished. This may be equated to the cost of railroad force work required for the project and the cost of granting the additional highway crossing easement.

2. Five percent of the costs to eliminate the existing highway crossing.

Betterment of the highway is the responsibility of the highway authority. The criteria for determining the cost sharing Is in the Federal-Aid Highway Program Manual 6-6-2-1.

GRADE SEPARATION STRUCTURES

Grade separation project selection is based on a favorable analysis of the following:

1 The existing terrain is economically suitable for separating the railroad and highway grades.

2 The construction of a crossing at grade is deemed uneconomical, excessively hazardous and would not serve the public interests.

3 The construction/maintenance cost analysis indicates a separation structure is cost competitive with an at-grade crossing.

4 The potential hazards of train crossings and delays to highway traffic are generally found to be excessive where the following exposure factors are exceeded:

a. In rural areas separation of grade structures should be considered when the highway design speed exceeds 50 mph and the exposure factor exceeds 75,000. [Exposure factor is the product of highway ADT (Design Year) and the average number of trains per day.]

b. In urban areas, where train/highway traffic speeds are generally lower but the highway ADT higher, separation of grade structures should be given consideration when the exposure factor exceeds 100,000.

Projects to replace existing grade separation structures should also generally satisfy the above criteria. However, the final determination to replace an existing grade separation structure with another structure at crossings which no longer satisfy these exposure factors for a grade separation, should still be decided on a favorable economic analysis, safety and public convenience. The above exposure factors for a grade separation structure could be reduced by one third and still be considered reasonable. However, the removal of an unsatisfactory grade separation structure and the construction of a crossing at grade may also be determined to be economical and in the public interest where traffic operations and safety can be reasonably and adequately accommodated. Exposure factors are an indication of the expected frequency of grade crossing accidents. OTHER factors are also important. In addition to the train crossings, conditions that make an at-grade intersection less desirable include the following:

- Sharp crossing angle.
- Large number of tracks to cross
- Presence of high speed freight and passenger trains.
- Route of school and commercial buses.
- Numerous crossings of trucks carrying hazardous materials.
- Potential for unusually long delays for motorists.
- Poor sight distances.
- Potential for serious accidents.

Future expansion or reduction In railroad and/or highway facilities must also be considered.

Grade separation structures are to be provided on all freeways.

DEVELOPING THE AGREEMENTS

There are usually two agreements made with the affected railroad for grade separation structures. One is termed a STIPULATION and includes all of the items and provisions for the highway crossing, construction, traffic operations, cost sharing and maintenance. The OTHER is an AGREEMENT for the performance of railroad force work and is necessary only when there are railroad facilities to be modified or installed. This usually involves adjustments of the railroad signal and communication lines, the track changes made necessary by the project, the removal of

a grade crossing if one is to be closed and in some instances the construction of a temporary crossing for the contractor's construction operations. (The contract special provisions usually require the highway contractor to make his own arrangements with the railroad for a temporary crossing).

After receiving approval and authorization for the railroad crossing project from the Bureau of Program Management, the District submits the program forms necessary to enter the project in the Master Contract Schedule and the Railroad Negotiations Status Report. The Utilities and Roadsides Section (URS) then negotiates with the railroad to obtain project acceptance and approval for the project including arrangements for work by railroad forces.

1. STIPULATION. The procedure in developing the Stipulation is as follows:

a. The District prepares and sends to the Central Office Design the following materials:

1. Design Study Report.

2. Title Sheet (four copies).

3. Typical Section Sheet (four copies).

4. Plan-Profile Sheet (four copies).

5. Cross Sections for highway approaches to the structure 100 feet. minimum on each side of the crossing (four copies).

6. Drainage Plan (four copies).

7. Right of Way Plat, as needed (four copies).

8. Easement Description, when needed, with adjacent land value or comparable land sales (one copy).

b. Central Office Bridge provides a copy of the Bridge record for the existing structure and the preliminary bridge plan (four copies) to URS.

c. URS sends a project proposal letter to the railroad. The proposal sets forth the concept of the highway improvement, what work is required the proposed structure maintenance responsibility and the proposed' apportionment of costs. The letter may authorize engineering by the railroad for any required railroad force work. Information on railroad flagging for subsequent highway construction may also be requested at this time.

d. If the project proposal is acceptable to the railroad, the railroad will indicate their concurrence in the project concept and provide comments or acceptance of the preliminary bridge plan, cost sharing and right of way.

The railroad will also develop a cost estimate and send it to Central Office Design in accordance with the request contained in the proposal letter.

e. When the railroad and Central Office Design reach agreement on all items, the URS will draft the Stipulation. Two originals and one copy are sent to the railroad (three originals

and one copy if the local unit of government has a project obligation or financial interest). If the Stipulation Is acceptable to the railroad, the railroad will have the originals signed and returned to Central Office Design. The originals of the Stipulation are forwarded to the State Design Engineer who obtains approval of the Division Administrator.

f. If extensive negotiations fail to produce acceptance by the railroad of the project in accordance with the proposal letter and subsequent negotiations, the matter will be placed before the Office of the Commissioner of Transportation (OCT). The OCT will hold a public hearing, investigate the matter, and Issue an order binding upon all persons. The order sets forth the terms for the construction, the apportionment of costs and the party responsible for maintenance of the structure.

   It is the policy of WisDOT to send approved stipulations for grade separation structures to the OCT for its Information. The OCT schedules a public hearing for the named railroad-highway crossing.

g. The STIPULATION includes the following items:

   1. Regulatory provisions of the federal government. (Federal-aid projects).

   2. Description of the work to be done by each party.

   3. The method of payment.

   4. The extent to which the railroad is obligated to move or adjust its facilities at state expense or at its own expense.

   5. The railroad's share of project costs.

   6. The method of performing the work, either with railroad forces or by private contractor.

   7. Structure maintenance responsibility.

   8. Applicable plans and special provisions as exhibits.

   9. Requirements for third-party railroad protective insurance as an exhibit.

   10. Right of Way provision indicating what easements are to be conveyed and amount of reimbursement to the railroad for the easement.

   11. Description of highway appurtenances to be constructed or installed on or removed from railroad property.

   12. Location exhibit, right of way exhibit, structure exhibits and special provision exhibit.

   During the time the formal stipulation is being prepared and processed, the right-of-way conveyance is also prepared and mailed to the railroad for execution. The conveyance document is usually signed after the Stipulation is executed by the railroad. For discussion of responsibilities to acquire interests in railroad property, see Procedure 17-15-20.

2. AGREEMENT FOR RAILROAD FORCE WORK

a. The content of an agreement for work by railroad forces would be similar to OTHER force work agreements. (See 17-15-5 Contents of the Agreement.)

b. The URS requests the plan and cost estimate from the railroad, prepares the agreement and sends it to the railroad for approval and signing. After its return to the URS, It is forwarded to C.O. Construction for final authorization checks and the approval of the Administrator.

HIGHWAY RELOCATION

This alternative would not require an agreement with the railroad unless an existing railroad grade crossing having train activated warning devices is closed as a result of the highway relocation. If such a crossing is closed the railroad share of the cost would be based on five percent of a theoretical structure project to separate the existing crossing (see FHPM 6-6-2-1). There may be other factors to consider in determining the railroad's share of the project costs. The amount would be negotiated and likely a "lump sum" amount would be contributed by the railroad.

A hearing and an order from the Commissioner of Transportation would be required to close a grade crossing and to apportion the project costs, if not agreed to by the parties.

RAILROAD RELOCATION

This alternative would require the approval of the railroad and a formal agreement. The probability of selecting this alternative to eliminate a grade crossing Is unlikely due to the high cost of constructing railroad tracks. The same criteria would apply as contained in the FHPM 6-6-2-1 to determine the apportionment of costs. If such an alternative were determined to be feasible and cost effective, a hearing and an order of the Commissioner of Transportation would be required to close the existing grade crossing.