GRADE SEPARATIONS
WHEN DO WE SEPARATE?

1999

Texas Transportation Institute
INTRODUCTION

Beyond any issues of safety, one of the main functions of traffic control devices at highway-railroad grade crossing intersections is to regulate the efficient movement of traffic. As the old “stop, look, and listen” procedure for all traffic has become redundant, the use of various types of both passive and active traffic control devices has influenced the movement of traffic. As the required degree of roadway traffic regulation and control at a grade crossing increases, the point is reached where physical separation of roadway and train traffic is feasible. This is accomplished by provision of a grade separation structure or bridge, usually carrying the roadway over the railroad.

In accordance with current law and procedures in most jurisdictions, decisions about the types of traffic control devices, including when to construct a grade separation are that of the agency having jurisdiction over the crossing roadway. While a railroad should always participate, the ultimate decision is that of the roadway agency. This is in accordance with the Manual on Uniform Traffic Control devices.

Although some jurisdictions have guidelines, there are no adopted standards concerning when and how a highway-railroad grade separation should be provided. This is due primarily to the unique nature of each grade separation proposal, which makes a universal standard non-applicable, overly disruptive, or merely meaningless. An analysis guideline is an entirely different matter. An analysis guideline is not an engineering standard. Rather, it presents a suggested procedure to help ensure that all pertinent issues or factors are examined, documented, and used in reaching a decision whether and how to proceed.

For any highway-railroad grade separation proposal, it is vital to understand that the decision process has many required administrative decisions that cannot be covered in a purely technical analysis. However, a technical analysis methodology, sufficiently flexible to be applicable to each unique circumstance yet complete enough to encompass all issues, can be very useful in the decision process.

The Trans Tech Group, Inc. has prepared a generalized technical analysis procedure for the analysis of proposed highway-railroad grade separations. This effort has included a
brief literature survey, a questionnaire survey to all state DOTs, examination of “rules of thumb” and has resulted in a recommended procedure for a technical analysis.

LITERATURE SURVEY AND GENERAL POLICIES

NCHRP Report 288 addressed the subject and presents analysis methodologies for grade-separated crossings being considered for modernization, replacement, or abandonment (1). Even though much useful information is presented, the report does not present any guidance as to how a particular decision should be reached, standards or recommended policy regarding the decision to provide a new separation or converting an at-grade crossing to a grade separation.

- Five factors were highlighted in the grade-separation decision process: cost, safety, rail and highway operations, land use and environmental concerns, and institutional issues, with safety and cost being normally of most concern.

- Procedures varied among the states, ranging from a policy that all grade separations will be replaced regardless of circumstances, to warrants based upon exposure index. Few states had analytical approaches for the issue.

- A three-level analysis was recommended, with emphasis on eliminating clearly inferior alternatives, and conversely focusing on examining the differences between competitive alternatives (1).

Other than NCHRP 288, there is little specific guidance on the subject. More recently, Haakert and Gitelman presented a methodology for highway-railroad grade separation, based on an analysis of grade crossings in Israel (2). The authors postulated four criteria for consideration:

- Volume of daily vehicle traffic

- The product of daily vehicle traffic and the number of trains per day

- The product of daily vehicle traffic and the number of hours per day the crossing is closed for road traffic

- The total daily vehicle delays at the crossing.

Based on a statistical analysis, the authors chose daily vehicle traffic times hours per day the crossing is closed to rank the Israeli grade crossings. They emphasized that an in-depth investigation is required for grade separation (2).

The Railroad-Highway Grade Crossing Handbook provides only general advice about highway-railroad grade separations: "...grade separations [should] be considered as an alternative for heavily traveled crossings. However, costs and benefits should be carefully weighed as grade separations are expensive to construct and maintain. In some cases, it
may be feasible to separate grades at one crossing in a community or town and close most of the remaining crossings" (3).

AASHTO’s Geometric Design Policy (4) provides only general guidance on the subject. This document does note that while it is desirable to grade separate railroad crossings on arterial roadways, practical aspects require many crossings to be at-grade. Matters as amount and speed of rail and roadway traffic, sight distance, and safety benefits are highlighted for consideration.

The Federal Railroad Administration (FRA) has published guidelines for high-speed rail lines. This recommendation calls for all highway-railroad crossings with train speeds over 125 MPH (200 KPH) to be closed or grade separated (5).

STATE DOT PROCEDURES FOR GRADE SEPARATION

Current policies of state departments of transportation on the subject were surveyed via a mailed request regarding the existence of written procedures for highway-railroad grade separation. Letters were mailed to each state’s DOT in March and April 1998, with a follow up letter in May 1998.

Written responses were received from 42 states and the District of Columbia. A verbal response was received from one additional state. Thirteen states indicated some type of written guideline regarding the provision of grade separations. No state reported the use of any type of guideline as an absolute decision to provide a highway-rail grade separation, but rather noted its use as an initial indicator to warrant further detailed engineering and planning studies.

Several states (without a general policy) noted they separate rail crossings on fully or limited access roadways, and use a case-by-case analysis for other roadways. Four states reported specific exposure index values guiding the provision of grade separations. Eight states reported use of an exposure index method without giving any threshold values. Finally, 12 states noted use of accident experience in their methodology.

PROCEDURES FOR A TECHNICAL ANALYSIS OF GRADE SEPARATIONS

The request for a grade separation to replace an existing crossing or for a new roadway can arise from several sources, including a state or local government, a citizen advocacy group, or occasionally a railroad.

Regardless of the source of the request, it will usually fall to the roadway agency to prepare the required analysis. Among others, a uniform procedure has several benefits:

- **Stepwise Analysis**: Provides a thorough, stepwise analysis, that preserves and expends available resources in an efficient, logical manner.
• **Screening Tool:** Provides an initial quick process to screen out unsuitable proposals, highlight more promising ones, and possibly prioritize crossings where future separation may be feasible.

• **Complete Analysis:** Provides a framework for a complete analysis at different technical levels, to ensure that all required areas and subjects are addressed and properly covered.

• **Scope of Services:** Provides the basis for a typical scope of services that can be tailored to the particular circumstances of the specific crossing.

• **Due Notice:** Reveals the issues and analysis steps that the public agency will follow, thus providing proper due notice to interested parties.

**Overall Grade Separation Policy Statement**

As a basic policy, a highway-railroad grade separation for any type of crossing roadway is indicated when it is:

• **Physically Feasible:** Physically feasible from a topographic, land development, and railroad/roadway geometric standpoint.

• **Economically Justified:** Justified from an economic standpoint.

• **Compatible:** Compatible with administrative requirements, including all financial details.

The technical decision to proceed with a specific grade separation proposal should be made through at least a two-level engineering analysis. These two levels or phases include a preliminary feasibility analysis, covering a “fatal flaw” type investigation oriented to revealing projects that simply cannot or should not be considered further. A second phase includes a more detailed technical analysis, exploring full details of the physical and economic feasibility of the proposal.

Two additional analysis steps may include an initial screening procedure, and following the decision to proceed, a preliminary engineering and environmental mitigation design phase. An overview of the entire process is presented in Figure 1.

Beyond the technical analysis, administrative details, such as the key issue of project financing must be covered. These issues should be dealt with outside the technical analysis.

**Initial Screening**

Several states use an “exposure index,” defined as the product of daily highway traffic and the number of trains as a simplified method or quick check to indicate the potential for
a grade separation. The exposure index serves as a surrogate for vehicular delay and crash costs, the elimination of which represents the main benefit of provision of a grade separation. When a predetermined value of the index is reached, further investigation is triggered. Examples of predetermined values range in one state from 15,000 for rural conditions to 30,000 for urban conditions, in another from 50,000 for roads on the state highway system to 100,000 for all other roads), and in a third, by speed (15,000 for rural conditions where roadway vehicle speeds are greater than 50 MPH).

Use of the exposure index method was considered in NCHRP 288: "while a few states have established warrants for crossing protection based on an exposure index, this approach is not recommended because an exposure index does not accurately reflect safety conditions at crossings, and, consequently, does not provide an adequate basis for decision-making" (1).

The authors agree with this statement only to the extent that the exposure index method is used as a stand-alone decision tool for provision of a grade separation. However, investigation described in this section has shown that this method is quick, easy, and sufficiently accurate to represent an adequate initial or general screening tool to be used prior to proceeding with more detailed technical analysis. In addition, the method serves as one method of setting rough priority among similar but competing projects.

To establish the practicality of this methodology, calculated costs of crashes and delays at crossings by various combinations of vehicular and train volumes were compared to the cost of provision of typical grade separations for urban and rural conditions. The formulas used in computing the exposure values were drawn from methods of calculating delay set forth in NCHRP Report 288 (1), and for crashes, from NCHRP Report 50 (6).

Calculations were performed for both rural and urban conditions. Roadway vehicular volumes were varied from 500 to 50,000 vehicles per day, train frequencies from 1 to 20 trains per day. An average train length of 1.2 km (0.75 mi), rural train speed 72.5 km/hr (45 mi/hr), and urban train speed 40.3 km/hr (25 mi/hr) were used. Resulting exposure values ranged from 1,000 to 105,000 exposures per day for rural conditions, and from 3,000 to 150,000 for urban conditions. The calculated exposure index values were then compared to the expected cost of a grade separation. It has been indicated that a rough cost of an urban grade separation is approximately $3 to $5 million, and for a rural separation, approx. $1 to $1.5 million. Capital recovery factors (CRF) for 3, 5, and 7 percent, and for periods ranging from 10 to 25 years were applied to the estimated average expenditure for separation to determine an annual cost that was then compared to the projected savings.

Comparing the 5 percent - 20 year project life capital recovery amount of approximately $100,250 per year for rural conditions indicated this value falls within a range of from about 24,000 to 28,000 daily exposures. In other words, when the product of highway and train volume reaches a value of about 25,000, a threshold feasibility of a grade separation is indicated. This, of course, is based upon the example values described here, but a sensitivity analysis using a range of different input values indicates the overall validity of the method. A similar comparison for urban conditions yields an exposure index value of about
48,000 for a grade separation feasibility threshold (with the greater cost for an urban grade separation project). Both of the ranges are within the “rules of thumb” values that have previously been used. Results of the example comparison are shown graphically in Figure 2.

The exposure index procedure should be calibrated for use in a particular state or regional area, to provide better results. Particular refinements would include such matters as past crash and delay experience, percent of commercial vehicles, values of operation and maintenance cost, construction cost, and similar variables.

**Preliminary Technical Analysis**

The preliminary technical analysis can be thought of as the “Can it be built?” portion of the analysis. With or without the screening process described previously, the preliminary technical analysis either forms a framework for further, detailed analyses, or may be used to rule out proposals that cannot be implemented from a physical, practical, or common sense basis. The preliminary analysis will reveal major problems that would limit provision of the grade separation, allows quick examination of alternatives, and allows a preliminary decision to stop or proceed to be reached with confidence.

The preliminary analysis should only be used to eliminate proposals with fatal flaws, and not those that merely appear to be undesirable. Care, however, should be expended to ensure that any reasonable alternatives, modifications, offsetting benefits, or other provisions that would render a seemingly impossible proposal feasible have been included in the overall consideration.

The first level or preliminary technical analysis should include, but not necessarily be limited to investigations of:

- **Physical Feasibility:** Whether the proposal is physically possible and compatible with existing topographic conditions, based upon reasonable engineering judgment.

- **Surrounding Land Development:** The probable impact on adjacent development from a grade separation including denial of access to adjacent properties, impacts upon protected or sensitive lands, or condemnation requirements for major or historic structures

- **Highway Traffic:** Expected changes in volume and character of traffic, and any identified deficiencies in roadway capacity.

- **Rail Traffic:** Rail traffic and operations includes changes in train volume, length, any abandonment or other plans that might affect rail traffic at the crossing, and effects from any unique rail operations, such as a nearby rail yard or intermodal transfer facility.

- **Crash Experience or Exposure:** Past or estimates of the expected crash experience for the crossing intersection.
• **Crash Frequency:** Whether there is a regular pattern of crashes at an existing crossing, as opposed to a spectacular crash that has triggered a call for remediation.

• **Vehicular Delay:** Vehicular delay costs or savings for the proposal versus maintaining the status quo, estimated using simplified procedures.

• **Cost of Improvements:** An initial rough estimate of the total cost of construction and maintenance.

• **Life Cycle Cost Analysis:** A life cycle cost procedure estimating cost for a particular alternative over a period corresponding to the life of the program, and including continuing operation and maintenance costs.

• **Excessive Cost:** Excessive cost, unless it can be determined to be prohibitive, should be dealt with carefully, because a thorough analysis may indicate offsetting benefits or alternatives that would reduce the cost impact to a favorable value.

• **Project Economics:** Project financing, availability of funds, or priority issues should not be included in the technical evaluations, as these matters are administrative in nature and are normally considered separately.

**Detailed Technical Analysis**

Once a proposal passes the preliminary level, a detailed technical analysis can then be prepared. This is the “should it be built” portion of the analysis. Occasionally there will be some issues that cannot be decided without a detailed analysis, but most improbable proposals can be eliminated after the preliminary effort.

In general, the detailed phase should expand upon the initial subject areas by refining the preliminary analyses, cost and benefit elements, and other project issues to the degree necessary for the specific proposal. The detailed analyses should also include additional factors necessary in a full technical determination, but not necessarily critical in an initial phase examination. These include, but are not limited to refinements in:

• **Traffic Projections:** These include both highway and rail traffic, and any changes in character.

• **User Cost Elements:** Estimates of delay, crash cost, motor vehicle operating cost, and similar components.

• **Project Costs:** Including construction, right-of-way, maintenance, and utilities.

• **Social and Environmental Impacts:** Evaluate impacts upon the natural and man-made environment.
Completion of the detailed investigation should result in a consideration of all important technical issues before the final decision to proceed. The next step, although not usually part of the technical process, is consideration of administrative issues.

OTHER STUDY CONSIDERATIONS

Administrative Issues

Administrative requirements include further details of public involvement and support, availability of funding, priority of other projects, scheduling, work program or agency financial programming input, preliminary engineering, and the myriad details necessary before a public construction project can begin. It remains possible that an administrative requirement could not be met, and would delay the project or render it not feasible. Such an event is outside the technical process envisaged by the proposed procedure, and lies within the administrative decision process of the agency that would implement the proposed improvements.

Public Involvement

Public involvement has become a required ingredient of almost all transportation investigations. In accomplishing a preliminary engineering study for a proposed grade separation, an agency may favor use of a technical (or “multidisciplinary”) committee, which can help to ensure that all necessary technical subjects are covered. If public involvement is not considered in the preliminary steps, it should be provided early enough to include any public-generated alternatives in the analysis process. If there is a strong public advocacy group, they could be invited to appear before the committee or otherwise participate in the process.

Preliminary Design Phase

A final phase, while not covered in this document would consist of pre-engineering or preliminary design. This detail would only be conducted when the decision has been made to proceed. This final phase allows a selected and administratively approved alternative to be subjected to final environmental analysis and completion of design plans to perhaps the 30 percent level (or other procedures of the implementing agency). In this way, intensive engineering or environmental mitigation design effort will be postponed until the decision to proceed has been made.

Priority Ranking

Priority ranking of a project is a separate issue from project feasibility. The decisions are separate. For any jurisdiction, a larger number of projects will more likely be feasible than can be provided with available funding. Nevertheless, many of the analyses described herein are useful in setting priorities of competing projects. Preparation of both a cost feasible plan, matching proposed projects with available funding, and a needs plan, delineating projects regardless of funding availability are both within the prerogatives of a public agency.
ANALYSIS OF COST ELEMENTS

Cost of grade separation improvements compared to the value of expected benefits is an important component of the technical analysis. Most transportation engineering agencies are well versed in estimating the cost of proposed construction. Estimating the benefits of such construction is more difficult, and some of the intangible costs defy accuracy. This section presents some considerations for a cost-benefit evaluation.

Cost and Benefit Analysis

Engineering cost-benefit analysis for railroads has a long history. A.M. Wellington’s *The Economic Theory of Railway Location*, published in 1877, is considered by many to be the first text on the subject. Of interest that is more current is guidance published in *Executive Order 12893*: "benefits and costs should be measured and appropriately discounted over the full life cycle of each project. Such analysis will enable informed tradeoffs among capital outlays, operating and maintenance costs, and nonmonetary costs borne by the public" (7).

The Federal Highway Administration implemented this requirement through an interim and final policy setting forth guidelines for the application of life cycle cost analysis to highway and related infrastructure investment decisions (8).

Improvement Costs

The cost of building a new highway-railroad grade separation projects extends over a broad range. Costs may range from several hundred thousand dollars for projects in rural areas to many millions of dollars in urban areas. Careful analysis of all pertinent expected costs is required.

Several considerations for the cost equation are listed below. It should be emphasized that each may have both positive and negative benefits. For example, an environmental clean-up will have costs to accomplish the necessary work, but will also offer benefits to the public. Although some costs or benefits will be difficult to quantify, attempts should be made to fairly evaluate them for inclusion in the life-cycle calculations.

- **Topography and Site Conditions:** Certain topographic conditions such as rolling terrain may aid construction of a grade separation, but flat terrain may have the opposite effect. Surrounding development, in urban locations, will create extra costs. A nearby river or stream may require a longer bridge structure.

- **Structure:** The cost of the bridge structure required to separate highway from rail traffic may constitute only a minor part of the total project cost.

- **Approach Roadway:** Analysis of the grade separation issue for general roadway widening projects should include only the differential costs allocable to the grade separation. Costs due to unusual grade runouts from the bridge to the original roadway elevation, or the need for side slopes or retaining walls can have major cost impacts.
• **Right-of-way:**  Right-of-way costs for approach roadway modification can be significant. Costs in urban areas with surrounding development will generally be greater than in rural areas. Construction of retaining walls or side slopes may require the purchase of access rights to adjoining property, or require the construction of alternative access.

• **Drainage:**  Drainage of roadways or adjoining properties can be a major contributor to cost.

• **Maintenance of Roadway Traffic:**  Maintenance of roadway traffic may require establishing or improving a bypass route for roadway traffic. Temporary access to commercial activities may have to be provided during construction.

• **Maintenance of Railroad Traffic:**  For projects involving changes to the railroad track grade or alignment, train traffic will likely have to be maintained using a shoo fly (bypass track) or other trackage arrangements. This can be a significant cost burden for the public agency.

• **Engineering Costs:**  The cost of engineering design, construction engineering inspection and administration, and any similar costs should be included.

• **Environmental Mitigation:**  Certain projects may require extra environmental mitigation. Hazardous waste removal or adjacent waterway crossings may require special consideration and extra expense.

• **Special Impacts:**  Any expected cost impacts, such as elimination of at-grade crossing maintenance (surface and traffic control), or maintenance of any new structure should also be included.

For any of the above items to constitute a fatal flaw, their impact must be so severe, alone or in combination, to render the project impractical or impossible from an engineering standpoint. Each should be investigated to the level of detail necessary to allow a decision concerning the feasibility of the project.

**Maintenance Costs**

Many times, decisions about transportation improvements are made without consideration of all costs. For example, a highway agency may only include initial construction costs or costs accruing only to the public agency in the economic analyses. On-going maintenance, vehicular delay, or other similar costs incurred by the railroad, the highway agency, or the public users are examples of costs that should be properly included in a life cycle analyses. The extent of any shifts or other impacts of such costs should be included in the decision analysis, with proper input from all involved agencies.
Use of Unit Costs

Use of unit or average costs (an average cost per crossing, without consideration of complexity) is not recommended for either the preliminary or the detailed technical analysis. Rather, a rough cost estimate of improvements should be made for preliminary evaluations. In most cases except for first-cut area-wide priority evaluations, each potential grade separation project will likely be sufficiently different to warrant a separate cost estimate. Preliminary estimates may use unit costs for elements of the total cost estimate such as roadway, embankment (cut or fill), bridge structure or maintenance of traffic, but the overall cost estimate should take into account the actual conditions likely to be encountered. Timing of expenditures should also be evaluated.

Automated Procedures

The Federal Railroad Administration has sponsored development of an automated methodology for analysis of highway-railroad grade crossings. The procedure, GradeDec, requires use of a personal computer with the Microsoft Windows or DOS ® operating systems, and is: "a decision support tool designed to assist public decision makers in evaluating the benefits and costs of highway-rail grade crossing upgrades, separations and closures. The model adopts standard benefit-cost techniques which are currently used by the public sector to evaluate highway-rail grade crossing investment alternatives at the corridor level." (9).

SUMMARY

Provision of a highway-railroad grade separation can offer many benefits to the public, the operating railroad, and the highway agency responsible for the crossing. Considering the probable expense and effort involved in establishing the need for a grade separated crossing, a straightforward, uniform evaluation process is needed. Such a process will help to ensure all pertinent matters are analyzed. Initial screening can be used to indicate when a more detailed technical study would hold promise. Then, a two-phase study effort, composed of a preliminary and a more detailed examination will provide an efficient way to evaluate the proposal.

REFERENCES


____________________________

Figure 1

*A General Analysis Procedure for Grade Separation Proposals*
New Road with New Grade Separation Proposed

Exposure Index Quick Check

Conduct Preliminary Feasibility Analysis

Can Road or Other Conditions Be Modified to Allow Grade Separation?

Yes

Conduct Detailed Technical Analysis

Provide or Maintain Grade Crossing, Abandon Road Plans, Grant Exception, Etc.

No

Is Grade Separation Physically and Technically Feasible?

Yes

Are Administrative Requirements Met?

Yes

Grade Separation May be Provided

Administrative Details

Preliminary Engineering Design

No

Existing Deficient Grade Separation Proposed For Replacement
Figure 2

Delay and Crash Cost by Exposure Index