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NATIONAL COOPERATIVE
HIGHWAY RESEARCH PROGRAM REPORT **288**

EVALUATING GRADE-SEPARATED RAIL AND HIGHWAY CROSSING ALTERNATIVES

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

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EVALUATING GRADE-SEPARATED RAIL AND HIGHWAY CROSSING ALTERNATIVES

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TRANSPORTATION RESEARCH BOARD
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WASHINGTON, D.C. JUNE 1987

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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FOREWORD

By Staff
Transportation
Research Board

This report will be of special interest to individuals who are involved in the decision-making process related to selecting alternative improvements for deteriorated bridges separating highways and railroads. Although written primarily for use by state highway departments, the report should also be of value to public and private railroad agencies. The findings on current practice are based on a literature review and telephone and mail surveys of state government and railroad agencies. A decision-making framework was developed and tested through actual case studies, which are also reported herein.

There are about 37,000 grade-separated rail/highway crossings in the United States, mostly located in New England and in the Midwestern States. Many of these crossings are in a deteriorated condition and pose potential traffic and safety problems. However, because rail and highway traffic patterns have changed considerably since these grade separations were built around 50 years ago, the decision to be made is not simply one of replacement or rehabilitation. Traffic volumes may no longer justify a grade separation. Or, rebuilding an old bridge to current design standards may be too disruptive to the adjacent community. In these cases, serious consideration should be given to the other alternatives including either the elimination of the grade separation structure by replacing it with an at-grade crossing or the closing of the crossing. By selecting the most appropriate alternative, costs may be reduced, providing more funds for other projects.

Grade-separated crossings very often present problems such as deteriorating structures, load limits, horizontal and/or vertical curvature approaching the bridge, occasional slippery bridge decks, and the presence of piers, abutments, and barriers. At-grade crossings, on the other hand, have the disadvantages of traffic conflicts and restrictions, additional roadside obstacles, energy inefficiencies, restricted movement of emergency vehicles, and crossing maintenance. In addition to these technical problems, consideration must also be given to differences in state laws, liabilities, contractual obligations, and administrative policies.

This research was initiated to provide a comprehensive framework for use in evaluating rail highway crossing alternatives. The use of such a framework, including accepted analysis methods, should be of assistance in supporting recommendations made to public administrators, railroad officials, hearing examiners, and the general public. Chapters Two through Five of this report present the overall findings of the project. The current practice regarding the decision-making process used by state governments and railroads is described, as well as an overview of the decision-making framework developed during the research project.

A User's Guide for applying the framework and step-by-step procedures are provided in Appendix A. Case studies that were performed to test the decision-making framework's applicability to existing rail/highway crossing problems are described in Appendix B. The case studies should be useful to potential users because they document the analysis process and illustrate the results that can be obtained.

This research was conducted by Ernst & Whinney and DeLeuw, Cather and Co., and the Federal Highway Administration has incorporated some of the material in this report in its training courses related to rail/highway crossings.

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ACKNOWLEDGMENTS

The research findings and decision-making procedures presented in this report were prepared under NCHRP Project 3-31 by Ernst & Whinney in association with De Leuw, Cather & Company. Principal investigator for the project was Robert "Chip" Taggart. Other major contributors were Paul Lauria of Ernst & Whinney and Gary Groat, Clarke Rees, and Alan Brick-Turin of De Leuw, Cather & Company.

Special thanks are extended to the New York State Department of Transportation and to the Massachusetts Department of Public Works for their cooperation and assistance in coordinating the case studies.

EVALUATING GRADE-SEPARATED RAIL AND HIGHWAY CROSSING ALTERNATIVES

SUMMARY

The research project documented in this report was initiated in response to the need for a systematic and credible tool to make decisions regarding alternatives for improving deteriorated bridges separating highways and railroads. A growing number of these bridges are in need of rehabilitation or replacement, but it is highly questionable if all of them should be retained. Many events have occurred since the justification for the construction of a given bridge was established. Changes in highway traffic patterns, changes in rail traffic volumes, and changes in design standards all combine with resource constraints to raise legitimate questions about the best alternative to implement: (1) replace the structure, (2) rehabilitate the structure, (3) relocate the structure, (4) construct an at-grade crossing in place of the structure, (5) close the road, or (6) close the rail line. The difficulty in deciding a course of action is that there are no widely accepted guidelines for evaluating these alternatives.

The report is divided into two parts. The first part, the research report, provides background information and covers the approach used to address the research objective including, as well, a detailed discussion of the findings dealing with the objective. It describes current practice regarding the decision-making processes used by state governments and railroads regarding deteriorated, grade-separated rail/highway crossings. The findings on current practice are based on a literature review and telephone and mail surveys of state government and railroad officials. It also includes an overview of the decision-making framework developed during the research project.

The second part, consisting of two appendixes, presents the decision-making framework in detail. Appendix A is the *User's Guide* to applying the framework and provides a step-by-step description of how one may use the framework. Case studies (Appen. B) are provided to illustrate the application of the framework.

The framework presented in the report fills the decision-making void described above by providing a set of procedures for the systematic evaluation of alternatives. The framework has the following characteristics: (1) It provides for identification and evaluation of all legitimate alternatives. (2) It incorporates consideration of all factors relevant to the alternatives analysis. (3) It defines ways to measure the value of each factor by alternative, including quantitative and qualitative variables. (4) It provides techniques for examining quantitative and qualitative differences between alternatives to facilitate decision making. (5) It provides for documentation of results to communicate decisions and to retain an audit trail of the decision-making process.

Significantly, the framework also is designed to be applied in the evaluation of alternatives for new crossings and for changes to existing at-grade crossings. Indeed, the framework may be used predominantly in these situations. Since the research project began, many inquiries have been received concerning the framework for alternatives analysis in these situations. The framework has been applied to evaluate the choice between an at-grade crossing and an at-grade separation for an existing crossing, for a proposed new highway, and for a proposed light-rail transit system.

CHAPTER ONE

INTRODUCTION

PROBLEM STATEMENT

There currently are no widely accepted guidelines to assist highway and rail officials in making decisions on improvement alternatives for deteriorated bridges separating highways and railroads. The increase in bridge replacement requirements has been accompanied by construction industry inflation and revenue limitations, putting constraints on public agency and railroad budgets. Many deteriorated bridges are located where the cost of reconstructing them to meet current standards would outweigh potential benefits. In the absence of guidelines, however, it is difficult to support recommendations made to public administrators, railroad officials, hearing examiners, and the general public regarding the treatment of such structures.

RESEARCH OBJECTIVE AND SCOPE

The objective of the research project is to develop a simple, but comprehensive, analysis framework for use in evaluating alternatives and developing recommendations on whether: (1)to retain a grade-separated crossing (through rehabilitation, replacement, or relocation); (2) to replace it with an at-grade crossing; (3) to close the road; and (4) to close the rail line. The framework developed also is applicable to evaluating alternatives for new crossings and for changes to existing at-grade crossings.

RESEARCH APPROACH

The research approach for the project consists of four basic components: (1) to determine what railroads and state and local governments consider to be important in addressing the grade-separation issues; (2) to develop, on the basis of these findings, a decision-making framework that railroads and public agencies can use to undertake the analysis of alternatives; (3) to test and to demonstrate the framework through case study applications; and (4) to prepare a report of findings and a user's guide.

REPORT ORGANIZATION

This report presents the results of the research project. It is divided into two parts. The first part, Chapters Two through Five, presents the overall findings of the project. It describes current practice regarding the decision-making processes used by state governments and railroads regarding deteriorated, grade-separated rail/highway crossings. The findings on current practice are based on a literature review and telephone and mail surveys of state government and railroad officials. This part also includes an overview of the decision-making framework developed during the research project.

The second part presents the decision-making framework in detail. Appendix A is the *User's Guide* to applying the framework and provides a step-by-step description of how one may use the framework. Appendix B includes case studies that were performed to test the decision-making framework's applicability to existing rail/highway crossing problems. The case studies may be useful to potential users, because they document the analysis process and illustrate the results that can be obtained.

CHAPTER TWO

FINDINGS—CURRENT PRACTICE

BACKGROUND

There are about 37,000 grade-separated rail/highway crossings in the United States. As shown in Figure 1 and Table 1, most are located in New England and in the midwestern states. Twelve states shown in the darkest shaded areas account for more than 50 percent of the grade-separated crossings in the country. Nonetheless, there are few states with under 100 grade-separated crossings (the exceptions are Alaska, Hawaii, and the District of Columbia). Of the 12 states that have over 1,000 crossings each, Pennsylvania and Illinois have the most, with 3,647 crossings and 2,958 crossings, respectively, apiece.

Many of these crossings are in a deteriorated condition and pose traffic and safety problems. Based on the percentage of all highway bridges in the country, perhaps 5,000 grade-separated highway crossings are in need of major repair or replacement.

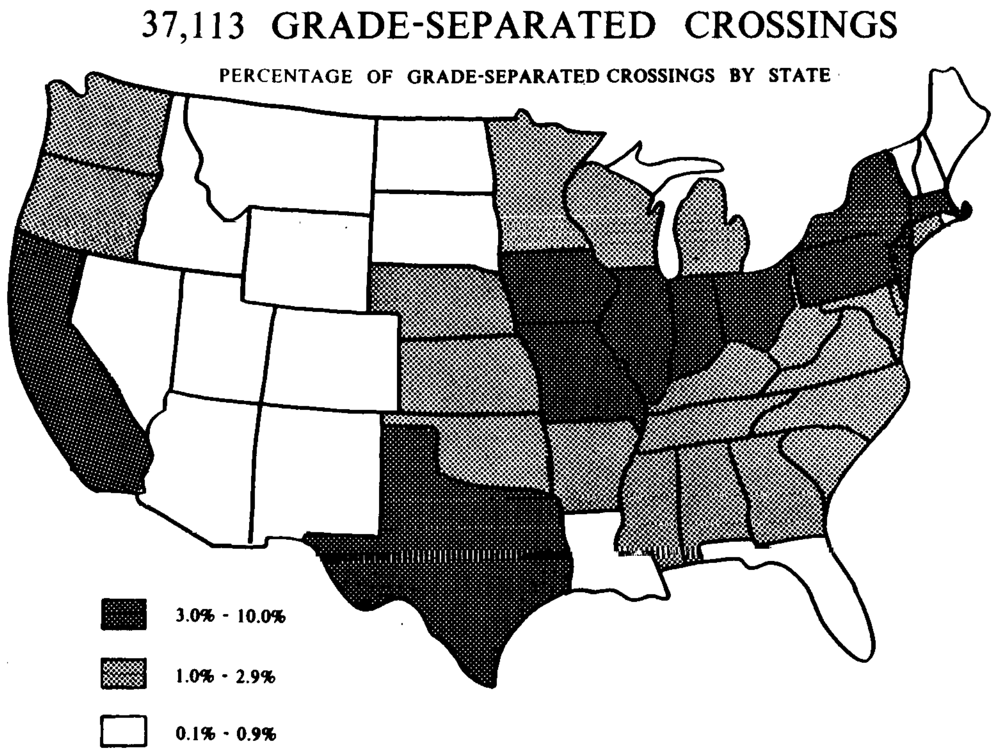


Figure 1. Grade-separated crossings in the U.S.

However, because rail and highway traffic patterns have changed considerably since these grade separations were built 50 years or so ago, the decision to be made is not simply one of replacement or rehabilitation. Traffic volumes may no longer justify a grade separation. Or, rebuilding an old bridge to current design standards may be too disruptive to the adjacent community. In these cases, serious consideration must be given to the other alternatives.

CURRENT PRACTICE

To develop an understanding of how the issue of deteriorated rail/highway grade separations is addressed by states and railroads, a literature review was conducted, followed by a mail survey and telephone interviews with selected state government and railroad officials.

Literature Review

Very little has been published on this specific topic of research. Indeed, an extensive review of the literature yielded only one reference that is related to the issue of evaluating alternatives for deteriorated or functionally obsolete grade-separated rail/highway crossings—a paper written by a student in partial fulfillment of a master's degree program in civil engineering. The paper presents a cost framework for deciding whether to replace an at-grade crossing with a grade separation. The factors included in the framework are delay, safety, and construction and maintenance costs.

Despite the dearth of literature on the specific research problem, the literature review was helpful. It assisted in the development of a list of relevant factors to be incorporated in the framework and in the identification of some methods and data sources to measure and assess these factors. Most of the methods discussed in the literature focus on the examination of at-grade crossing issues and alternatives.

Survey Results

To further document current practice, a short questionnaire was sent to 175 organizations believed to be participants in decisions regarding rail/highway grade separations. Seventy-six responses were received, representing state departments of highways and transportation (33), state public utility commissions (26), railroads (15), and others (2).

When combined with persons interviewed by phone or in person, grade crossing issues were discussed with individuals representing 38 states (in which 87 percent of all grade-separated, rail/highway crossings are located) and 13 of the 22 Class I railroads in the country.

In the mail survey questionnaire, respondents were asked to provide the following information: the nature of the problem—a characterization of crossing cases for which a new decision-making framework would be most helpful; decision-making factors—a prioritized list of the factors (e.g., cost, safety, etc.) which should be considered in selecting grade-crossing alternatives; alternatives—a list of the alternatives considered for grade crossings; and, finally, procedures for addressing grade-separated crossings—a description of the decision-making process (e.g., who is involved, what analytical techniques are used, etc.). To answer the questions, respondents were asked to identify a representative grade-separated crossing case with which they are familiar.

Table 1. Rail/highway grade-separated crossings by state.

STATE	RR UNDER	RR OVER	TOTAL
AL	501	191	692
AK	11	1	12
AZ	84	80	164
AR	174	124	298
CA	935	567	1,502
CO	199	111	310
CT	332	256	588
DE	44	56	100
DC	30	38	68
FL	193	78	271
GA	576	258	834
HI	---	---	---
ID	95	62	157
IL	984	1,974	2,958
IN	496	634	1,130
IO	500	364	864
KS	348	216	564
KY	470	483	953
LA	217	129	346
ME	125	79	204
MD	330	212	542
MA	796	436	1,232
MI	361	414	775
MN	515	406	921
MS	242	116	358
MO	712	443	1,155
MT	137	84	221
NE	223	146	369
NV	50	37	87
NH	159	66	225
NJ	545	738	1,283
NM	68	79	147
NY	1,382	1,127	2,509
NC	525	301	826
ND	83	90	173
OH	1,206	1,177	2,383
OK	269	204	473
OR	290	177	467
PA	1,658	1,989	3,647
RI	101	43	144
SC	403	131	534
SD	102	58	160
TN	516	500	1,016
TX	816	801	1,617
UT	126	53	179
VA	642	480	1,122
VT	78	84	162
WA	394	341	735
WV	291	379	670
WI	457	353	810
WY	102	54	156
PR	---	---	---
TOTAL	19,893	17,220	37,113

SOURCE: Rail-Highway Crossing Accident/Incident Bulletin, No. 8, Calendar Year 1985. Washington, D.C.: Federal Railroad Administration, June 1986.

Nature of the Problem

Respondents characterized the crossing cases in which a new methodology would be most helpful as located in urban as well as in rural areas (see Table 2). However, the predominant number of cases cited, and the crossings for which states and railroads most desire guidance, are located in agricultural settings. These may be cases in which a grade-separated crossing may no longer be justified or affordable because of a reduction in train or vehicular traffic. At the same time, however, the responses indicate that a new methodology would be useful in evaluating alternatives in other settings as well, including industrial, commercial, and residential areas.

The respondents also characterized the crossings for which guidance is desirable as being primarily roadway over rail grade separations involving a single track rail line. These are owned mostly by government agencies, but a sizeable percentage are railroad owned. Vehicular traffic could be high, moderate, or low, but rail traffic is predominantly low or moderate. These traffic characteristics suggest that reductions in rail traffic may have made the question of whether or not to retain grade separations more difficult to answer, and that consequently there is a greater need for an improved decision-making framework.

Decision-Making Factors

The research team learned the following from the survey:

1. Five factors influence decisions and must be addressed in a decision-making process: cost, safety, rail and highway operations, land use and environmental concerns, and institutional issues.
2. Safety and cost were typically of most concern and were often given the most weight, but the deciding factors vary from case to case.
3. Procedures used to address the grade-separated crossing question vary among states. Some states, such as Connecticut, have established formal or informal policies stating that all grade separations will be replaced regardless of circumstances. Other states, like Montana, have adopted warrants based on an exposure index which dictate when a grade separation will be retained. Still other states employ a cost framework. But most states have no set analytical approach to resolving this issue.
4. There is a very strong reluctance on the part of railroads and highway agencies to replace a grade-separated rail/highway crossing with an at-grade crossing. There are three primary reasons for this: (a) There is an attitudinal bias to changing to an at-grade crossing. For many years, those in the grade crossing business have been working hard to eliminate at-grade crossings, not to increase them. (b) Public opinion fosters a conservative view of returning to an at-grade crossing. It is not popular to ask people to give up a bridge in exchange for increased safety risk and delays to traffic and emergency service vehicles, no matter how small the risk or how minor the delay. (c) There are institutional constraints to changing to an at-grade crossing. One aspect of this is the liability exposure in case an accident occurs at the crossing. A second aspect is funding—savings that are realized from choosing a lower cost option may result in increased costs for one of the contributing parties due to differences in funding mechanisms for different types of projects. Finally, the railroad usually goes from a nonliability situation

Table 2. Summary of mail survey responses regarding characteristics of grade-separated crossing cases in which the analytical framework would be most useful.

Crossing Location	
Rural area	58%
Urban area	42%
TOTAL	100%
Agricultural area	50%
Industrial area	8%
Commercial area	15%
Residential area	27%
TOTAL	100%
Traffic Characteristics	
Vehicular traffic	
High	32%
Moderate	36%
Low	32%
TOTAL	100%
Train traffic	
High	17%
Moderate	38%
Low	45%
TOTAL	100%
Number of tracks	
Single	74%
Double	13%
Three or more	13%
TOTAL	100%
Configuration	
Rail over roadway	25%
Roadway over rail	75%
TOTAL	100%
Owner	
Federal	2%
State	42%
Local	16%
Railroad	40%
TOTAL	100%

to one in which it must assume grade crossing maintenance costs. Much more importantly, the railroad exposes itself to the seemingly inevitable lawsuits accompanying grade crossing accidents.

Alternatives for Grade-Separated Crossings

To gain an understanding of the range of alternatives usually considered in addressing deteriorated or functionally obsolete grade-separated crossings, those interviewed were asked to list all options evaluated in the cases they cited. It was found that the primary options evaluated are replacement of the structure with a new grade separation at the same location and replacement with an at-grade crossing. As shown below, however, all options were considered in many of the cases cited.

Option	Percent of Cases in Which the Option Was Considered
Rehabilitate the structure	48
Replace with a new structure at same location	81
Relocate grade separation, demolishing old and replacing with new structure	52
Replace with an at-grade crossing	71
Demolish old structure and close the crossing	19
Demolish old structure and close the rail line	24

Although many options are frequently considered when attempting to resolve a grade-separated crossing problem, typically the replacement with a new structure at the same location and replacement of the structure with an at-grade crossing are the options selected. Of those cases cited and decided, the actions taken are as follows:

	Percent
Rehabilitate the structure	11
Replace with a new structure at same location	39
Relocate grade separation, demolishing old and replacing with new structure	0
Replace with an at-grade crossing	44
Demolish old structure and close the road	6
Demolish old structure and close the rail line	0
TOTAL	100

Procedures for Addressing Grade-Separated Crossings

The last part of the discussion with those interviewed concerned current procedures for evaluating and selecting alternatives for grade-separated rail/highway crossings. It was found that states typically take the lead in the decision-making process. The lead agency is usually the department of highways or transportation; in fewer cases, the lead agency is a public utility or service commission.

The decision process typically involves technical analysis, consultation with the primary parties in interest (the railroad and local government agencies), and public meetings and/or hearings. Decision-making authority typically resides with the state agency; the federal government is the least actively involved of the parties in interest in the process. The federal government, of course, influences the decision through rules and regulations associated with the use of federal funds.

Beyond these similarities, few consistencies were found between the processes described by the persons interviewed. The factors used to evaluate alternatives vary, analytical frameworks and methodologies vary, and analytical techniques vary. Some agencies decide on courses of action to be taken completely independently of other parties in interest; others engage in extensive negotiations.

Most persons interviewed stated that they would find a comprehensive framework for evaluating alternatives to grade-separated rail/highway crossings very useful. Such a framework would provide for systematic consideration of relevant factors, as well as for consistency in addressing grade-separated crossing issues. As such, the framework could result in more cost-effective and more defensible decisions.

On the other hand, those interviewed differed in their opinions concerning the characteristics of the analytical framework. Most persons interviewed expressed a preference for a framework having the flexibility to respond to variations in cases that arise. Some other individuals expressed an interest in a set of nationally accepted warrants that would dictate the alternative to be implemented, for example, a formula that when applied would identify the action to be taken.

DECISION-MAKING FRAMEWORK

OVERVIEW

Based on the research objective and the review of current practice, guidelines to evaluate alternatives for improving deteriorated, grade-separated rail/highway crossings were developed. This set of guidelines, called a decision-making framework, is predicated on the following principles:

1. There are six generic improvement options to consider: (a) rehabilitate the structure, (b) replace the structure at the same location, (c) relocate the structure, (d) replace the structure with an at-grade crossing, (e) demolish the structure and close the road, (f) demolish the structure and close the rail line.
2. Five primary areas of concern should be addressed: (a) cost, (b) safety, (c) rail and highway operations, (d) community and environmental considerations, (e) institutional issues.
3. While some of these areas of concern and factors associated with them are consistently more important than others in choosing between alternatives, their relative significance may vary by situation and this variability should be accommodated.
4. There are no simple formulas for selecting the proper alternative. Rather, choices often will require value judgments as to the trade-offs between quantitative and qualitative differences between alternatives. These trade-offs often necessitate negotiated solutions to crossing improvement issues.
5. Procedures are in place for addressing major transportation improvements (e.g., requirements for environmental impact statements). The guidelines should complement, but not replace, these existing procedures.
6. The guidelines should be straightforward for ease of use and for effective communication of results.
7. The guidelines should be sufficiently thorough to support informed decision-making, but should not require exhaustive, EIS-type analysis.

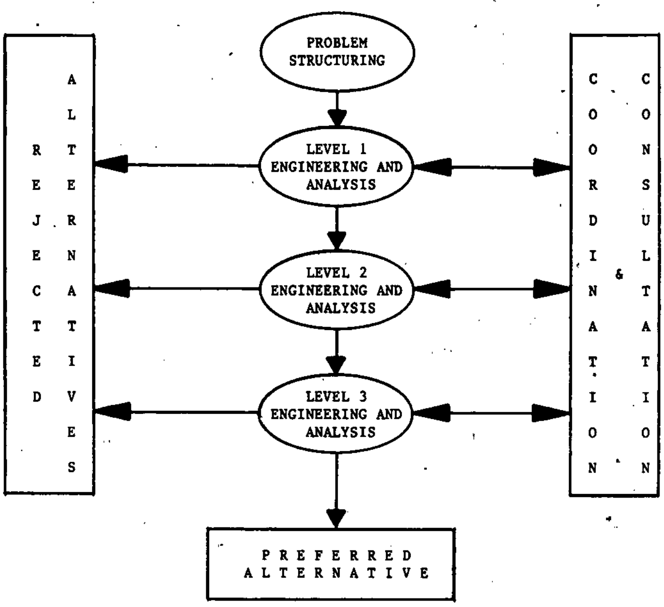


Figure 2. Decision-making framework.

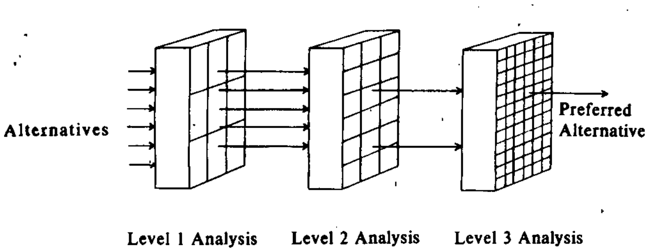


Figure 3. Levels of analysis concept.

RECOMMENDED FRAMEWORK

It is within this context that a decision-making framework was developed to assist highway agencies and railroads make the choice between retaining a grade separation and other alternatives.

The framework consists of four basic steps, as shown in Figure 2: structuring of the problem including definition of the alternatives in engineering terms and three levels of analysis. At the conclusion of each level of analysis, one or more alternatives may be rejected as unreasonable, impractical, or otherwise inferior, relative to the remaining options. The preferred alternative is identified at the conclusion of Level 3 Analysis, or an earlier level if one alternative stands out.

There are two important reasons for having three levels of analysis: (1) to expend as little effort as possible in eliminating the clearly inferior alternatives, and (2) to focus the bulk of the effort on examining closely the differences between truly competitive alternatives. This is accomplished by passing each alternative through a progression of increasingly fine or precise analytical screens (Fig. 3).

In Level 1 analysis, a general review of each alternative is performed to eliminate obviously unacceptable or clearly inferior options. In Level 2 analysis, additional information is developed for each remaining alternative, as shown in the figure by the finer mesh in the screen, and again the inferior alternatives are discarded. The third level of analysis is the most comprehensive—more factors are introduced with which to compare and eliminate the remaining alternatives until the single best alternative is identified.

ANALYSIS FACTORS

The decision-making framework includes consideration of the five areas of concern in selecting alternatives for replacing grade-separated rail/highway crossings which were identified in the review of current practice. These are cost, safety, rail and highway operations, community and environmental considerations, and institutional issues. Within each of these areas of concern, a list of factors to be considered has been developed, along with associated measurement techniques and procedures for the incorporation of these factors in the decision-making process. The factors are presented in Table 3 and were developed on the basis of the mail survey responses and interviews.

In order to integrate the factors into the three-level analysis concept, it is necessary to stratify them by level. The stratification was based on the relative importance for decision-making (the progression goes from factors of greater to those of lesser concern) and level of precision (the progression goes from less precise to more precise measurement of factors). Relative importance was determined by the survey results described earlier and the research team's past experience in addressing grade-crossing issues. Relative importance has a technical dimension; a factor describing an existing condition that is likely to change significantly with implementation of one or more alternatives is more important than a condition that is likely to change little; a factor representing a condition that is significantly different from one alternative to another and therefore provides a basis for comparing alternatives is more important than a condition that varies little by alternative. There also is a political dimension; some factors are simply more important to those making decisions or affected by decisions than are other factors. Some of the factors are the same for all three levels. Other factors are only used at the more detailed analysis levels. The factors are associated with "measures" by which a particular factor can be rated or otherwise valued. In this way the factors are used to evaluate each crossing alternative and select (or reject) alternative solutions.

In general, there are three types of measures: quantifiable and dollar-valued; quantifiable but not dollar-valued; and nonquantifiable. While there is a desire to reduce as many factors as possible to the quantifiable and dollar-valued form, the fact that this is not possible for some factors should not be taken as an indication that those factors are unimportant.

One objective of the research has been to give full consideration to a variety of ways that the factors can be evaluated (measured) in terms which indicate the relative advantage of a particular alternative over others being considered. Thus, the factors, measures, and procedures chosen for the *User's Guide* are the result of careful and deliberate review of both the theoretical basis and practicality of several ways of deriving measures for each factor.

In the following sections, various factors and measures are discussed, along with the basis for the chosen measure at each level of analysis.

Cost

In the survey of agencies and other parties involved with railroad/highway crossings, one of the considerations most often noted was the cost of the various alternatives. Often, the reconstruction or replacement of a separation structure involves costs that amount to more than a million dollars. In the capital budget of a public highway agency or a railroad company, such projects must compete for funding with a myriad of other projects. If the agency or railroad has numerous grade separations in need of attention, and budget limitations dictate that only a few can be treated each year, the cost of each alternative is central to determining whether a project can be undertaken or not. There is also a tendency to want to "spread the money around." Therefore, the cost of less capital-intensive alternatives is also central to programming for improvement. For these reasons, capital cost is one essential measure for evaluating alternatives.

There is little latitude available in measuring costs. The most basic form is the total construction cost, including design, construction, inspection, right-of-way, demolition, and other costs directly related to an alternative.

Since construction may take more than one construction season, one variation is to show the construction cost as it would spread over two or more budgeting years. In some instances it may be necessary to compare alternative expenditures that would occur over future time periods. For example, a low capital alternative, such as demolition of the separation and closing of the crossing, can possibly be accomplished in a single construction season, while replacement of the separation could take several years. To make the expenditures comparable, the outlays should be reduced to their present value at a given point in time. Also, to compare fairly the capital costs of alternatives, annualized costs should be used. The reason for using annualized costs is to account for the differences in the expected life of alternatives; one alternative may last 50 years and another only 25. Annualized cost, the annual cost equivalent of total cost, eliminates the timing differences between alternatives and puts them on equal footing for comparative purposes.

In addition to capital cost, it is important to estimate the annual operation and maintenance costs for each alternative. These costs can vary substantially among alternatives. To aid in direct comparisons with capital costs, operation and maintenance costs are spread over an appropriate economic analysis period and, as desired, converted to their present value for a consistent analysis year.

As shown in detail in the *User's Guide*, cost is an important consideration at all levels of analysis. In Level 1, however, actual costs are not estimated. Rather, the question of "physical feasibility" is addressed, in a judgmental fashion, so as to screen out any alternatives that are judged as not being feasible. The rationale for this approach is that alternatives tend to be rendered infeasible by excessive cost, rather than by physical impossibility.

Alternatives that pass the Level 1 analysis are subject to preliminary engineering in which enough detail is incorporated to develop cost estimates. Those cost estimates are utilized for the Level 2 and Level 3 analyses.

Safety

The research has also indicated that safety is a central consideration in assessing alternatives. Unlike cost, however, a variety of measures for safety may be used.

It is important to specify the scope of the safety analysis as including accidents between trains and vehicular traffic; accidents involving automotive vehicles at the crossing; and accidents involving automotive vehicles along alternate routes which may be necessary in the event of closing of the crossing.

Over the past two decades considerable effort has gone into derivation of hazard indexes for at-grade rail/highway cross-

Table 3. Factors by analysis level.

Subject Areas/Factors	Decision Framework Analysis Level 1	Level 2	Level 3
COSTS			
Physical Feasibility	X		
Capital Costs		X	X
Operations & Maintenance Costs			X
SAFETY			
Accident Exposure	X		
Accident Frequency		X	X
Fatal Accidents		X	X
Injury Accidents		X	X
School Bus Crossings			X
Hazardous Materials Crossings			X
Pedestrian/Bicyclist Accident Potential Crossings			X
RAIL AND HIGHWAY OPERATIONS			
Vehicular Delay			
Probability	X	X	X
Number	X	X	X
Duration	X	X	X
Emergency Response Time		X	X
Traffic Operations			
Vehicular Queuing		X	X
Capacity Constraint		X	X
Street/Highway Classification			X
Signalization			X
Patterns			X
Rail Operations			
Disruption	X		
Quality		X	X
Cost		X	X
Rail Yard Access		X	X
Switching Operations		X	X
COMMUNITY AND ENVIRONMENTAL CONSIDERATIONS			
Land Use			
Displacement	X	X	X
Disruption			X
Activity Patterns			X
Noise			X
Air Quality			X
Water Quality			X
Aesthetics			X
INSTITUTIONAL CONSTRAINTS			
Laws	X		
Warrants	X		
Policies and Guidelines	X	X	X
Contractual Obligations	X	X	X
Cost Distribution		X	X
Ease of Implementation		X	X
Availability of Funds		X	X

ings. This work generally has been approached from the perspective of a state highway agency faced with assessing hundreds of crossings within the state and prioritizing them for improvement. The improvements considered usually involve the addition of flashing lights and possible gates at crossings where only passive warning devices have existed to date. While these hazard index formulas may be useful for setting priorities for the installation of warning devices, for the analysis of a single crossing it is more appropriate to use a formula which is designed to project the expected number of accidents and accident severity. Research sponsored by the U.S. Department of Transportation has developed well-founded relationships by which the projected number of total accidents, fatal accidents, and injury accidents can be derived using information on the physical and operational characteristics of rail/highway grade crossings (*Rail-Highway Crossing Resource Allocation Procedure: User's Guide.* 2nd Edition. Cambridge:MA:USDOT, Transportation Systems Center, July 1986).

Use of the USDOT accident prediction model is recommended for Level 2 and for Level 3 analysis, as this is consistent with the analytical detail incorporated into these components. In Level 1 analysis, some states may elect to use a more rudimentary hazard index or an exposure index (average daily vehicular traffic times average daily train traffic) as a guide to judging whether the at-grade alternative may be unacceptable from a safety perspective. However, 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.

In Level 2 and Level 3 analyses, the DOT methodology, which projects numbers of accidents and accident severity, is used. In Level 3 analysis, the presence of hazardous materials, school buses, and pedestrians also comes into consideration.

In addition to accidents, fatalities, and injuries at railroad/highway crossings, an attempt was made to include the projection of accidents, fatalities, and injuries associated with other alternatives. However, because adequate methods for estimating these nonrail/highway crossing accidents (e.g., accidents on grade-separated crossings and along with other routes) are unavailable, consideration of these other accidents is not included in the framework.

Rail and Highway Operations

When a grade separation is maintained, in most cases roadway and rail traffic will operate with little or no interference from one another. However, for several of the candidate alternatives, such as replacement with an at-grade crossing or closing of either the highway or rail line, there will be impacts on operations of the railroad, roadway traffic, or both. The degree of impact must be measured and incorporated into the analysis.

There are three types of operational impacts: (1) crossing user delay, (2) disruption of railroad operations, (3) indirect congestion.

The first type of impact, crossing user delay, is a function of the volume of traffic on the highway; the amount of time the crossing is blocked by train operations; and the time of day at which the railroad blockage occurs. For alternatives in which the highway crossing is eliminated, or where the blockage due to train operations is so great that vehicular traffic will find alternate routes, the delay due to greater travel times along detour routes, including delay due to train blockages at other crossings, is brought into the analysis. Delay at the crossing and delay due to detours are considered at all three levels of analysis, although in varying degrees of sophistication and detail. Delay at adjacent crossings is not specifically treated in the Level 1 analysis.

Besides crossing delay to routine vehicular traffic, possible effects on intermittent movements of public safety vehicles (police, fire, ambulance) are specifically addressed in Level 2 and Level 3 analyses. Such effects will depend on the duration and time of day of railroad blockage of the crossing, in conjunction with volumes and time patterns of vehicular traffic.

Various site-specific considerations, such as the amount of "storage capacity" on roads adjacent to the crossing and proximity of adjacent, unblocked crossings, will also act to determine the seriousness of delay of normal vehicular traffic and of emergency vehicles for crossing alternatives that involve temporary or permanent blockage.

Generally at a railroad/highway grade crossing the railroad has the right-of-way and the railroad operations will proceed without regard for delays to vehicular traffic. For a 100-car freight train traveling at 30 mph a crossing would be blocked for about 3 min. There can be exceptions. In instances where trains do not pass directly over the line, but must wait for track availability or where switching activity occurs at the crossing, train blockages can become excessive. An at-grade crossing solution could be acceptable if train operations were changed to reduce delay. For example, the railroad may accept restrictions on the time of day of its operations and use of movement patterns which reduce blockage of the crossing.

The alternative of closing of the rail line has been mentioned. There are cases where this would make economic sense from the viewpoint of transportation providers (railroads and highway agencies). That is usually where there is no service on the rail line or where rail service has been reduced to minimal levels. However, in those instances, there are usually one or more shippers/receivers dependent on rail service who may be harmed. Identifying options for mitigating impacts on those firms, including relocation of all or part of their operation to a point where railroad access can continue, may bring about a consensus for closing the rail line. Such an alternative, however, may be contrary to the objectives and programs of state and local parties which see railroad service as essential to attraction of new industry. Thus, short-term, identifiable benefits of closing the rail line may come into conflict with long-range economic development objectives.

Not all deteriorated or outmoded separations are along isolated branch lines where closing of the railroad crossing also means termination of railroad service. There are places where parallel rail lines of one or more railroads exist and coordination of railroad operations may be possible. In this case, trains of one railroad may be diverted to use the line of a second railroad, and thus by-pass grade separations which may then be closed. There may continue to be the need to serve shippers/receivers along the by-passed line with switching service provided by one of the railroads. In such instances there are numerous factors regarding the re-arrangement of physical facilities, coordinated operational patterns, and compensation between the railroads, which would have to be worked out for the particular case.

For a commercial enterprise such as a railroad company, changes in operations usually can be measured in dollars. Most railroads have an operations costing system that is used in operations planning and rate analysis which can incorporate all of the various physical and operational changes into cost, in dollar terms. In assessing alternatives that involve such changes, it may be possible to obtain the railroad's cooperation to provide the costs to the railroad of changes in operations. Alternatively, experts in railroad cost analysis may be engaged to provide that assistance, or the methods and values contained in the state's rail planning manual, for application of cost procedures to line abandonment, may be applied.

One of the factors included in the Level 2 analysis is "rail yard isolation," which may occur under alternatives involving closing of the railroad. This is one of a class of possible effects which might be termed "facilities rendered useless," which can be included in the assessment. One must be cautious here, because the isolation and closing of a facility may give the railroad the opportunity to consolidate operations at other yards. This could result in cost savings. Those savings plus any higher costs due to loss of the isolated yard, and added movement of trains, must be combined to determine the overall effect.

Some of the changes considered for a deteriorated graded separation will directly result in delay to vehicular traffic at the crossing or along detour routes. Some changes will directly affect the railroad operation as well. In addition, there are various indirect effects that are a consequence of the direct congestion effects. For example, vehicular traffic waiting at a crossing can back up into local streets in the vicinity of the crossing and impede local or through traffic not using the crossing. Also, consolidation of railroad operations to permit closing of the railroad line at a problem separation can result in higher levels of train blockages at other crossings and delay to traffic which does not even use the crossing under consideration for remedial action. These secondary congestion effects should be considered to the extent possible, so that the totality of effects of the alternative is seen.

These indirect effects are not addressed in Level 1 analysis; some are treated in the Level 2 analysis; the whole range of indirect congestion effects is addressed in Level 3 analysis.

Community and Environmental Concerns

The effects that a particular project alternative would have on vehicular and railroad traffic are not sufficient to decide on the "best" alternative. A range of direct and indirect effects on the natural and built environment must also be addressed. Most highway agencies have established guidelines and procedures for preparation of environmental assessments and environmental impact statements for projects. Such guidelines may, in fact, indicate that environmental impact studies would not be required where the action will not substantially alter operations, take added right-of-way, or alter the physical environment. This may be the case for rehabilitation or replacement alternatives. However, alternatives often involve some change in either highway or railroad operations, or otherwise alter existing conditions, such that environmental impact analysis will be required.

Detailed environmental analysis would normally follow the alternatives analysis involved in the framework presented here, and would be made at the time of detailed project planning. Nonetheless, environmental concerns must be addressed in screening project alternatives for more detailed consideration. Impacts associated with the generic alternative remedial actions might include displacement of land and structures through right-of-way acquisition; disruption of land uses and community activity patterns; reductions in economic activity and property values; degradation of air, water, and aesthetic/scenic resources; and increased noise levels.

This analysis is limited to land use and accessibility considerations for the Level 1 and Level 2 analysis. At Level 3 the scope of analysis for environmental concerns is broadened to include air quality, water quality, noise, and aesthetic considerations in addition to land use and accessibility. The Level 3 analysis is at a level of detail that would determine the need for a project environmental impact assessment. Impact assessment methods normally used by the responsible agency would be applied if an assessment is indicated.

Institutional Considerations

The selection of the "best" alternative may be limited by certain institutional constraints. For example, at least one state prohibits at-grade rail/highway crossings. Also, in some states, the jurisdiction for crossings may reside with the state regulatory agency (e.g., the public utility or public service commission) rather than the highway agency. There may also be institutional constraints in the laws governing railroads, in the charter of the particular railroad, or in land deeds through which the railroad obtained its right-of-way. There can be a myriad of such conditions in any particular case. It is important that such constraints be known to the analyst so that they can be taken into account throughout the process of analyzing alternatives for a deteriorated grade separation.

While the process of changing institutional constraints may be difficult, it should not be assumed to be impossible. Solutions for deteriorated or outmoded separations that violate such constraints may have compelling economic, safety, operational, or environmental advantages. It would not be wise to eliminate such advantageous solutions because of institutional constraints without considering the possibility of relaxing the constraints. In fact, if the constraint is legal in nature, that is, based on state or local law, the law may be outmoded and in need of review and revision. A range of such institutional factors is suggested for consideration in the analysis.

Another institutional consideration is finding arrangements. Since the solution to a problem of a deteriorated grade separation will most likely involve some level of capital investment, it is also necessary to consider the level of funds available in capital budgets of interested parties. This can include the railroad company plus various federal, state, and local government and possibly economic development interests. In some states, grade separation programs require participation by the railroad and/or local government at some established percent of project cost. Thus, it is useful to identify the amount of funding that will be required of the several parties involved with the particular project.

Summary

An overview of the factors to be addressed within each area of concern and at each level of analysis is given in Table 3. The *User's Guide* focuses on specific methods for treatment of these various factors.

Table 4. Illustration of the balance sheet comparison technique for trade-off analysis.

Measure	Alternative		Difference Between Alternatives (Replace-Relocate)
	Replace	Relocate	
Cost	$2,110,000	$2,100,000	+ $10,000
Safety	0	0	0
Highway and Rail Operations	0	0	0
Land Use	3	10	-7
Institutional Considerations	0	0	0

Table 5. Illustration of unit cost measures for trade-off analysis.

Measure	Alternative		Measures of Effectiveness for Replace Alternative
	Put At-Grade	Relocate	
Annualized Cost	$72,800	$102,100	
Accidents/Yr.			
o Fatabilities	0.01	0.00	$2,930,000/fatality 1/
Delayed Vehicles/Yr.			
o Number	730	0	$40.14/delayed vehicle 2/
o Minutes	730	0	

1/ ($102,100-$72,800)/0.01 = $2,930,000
2/ ($102,100-$72,800)/730 = $40.14

TRADE-OFF ANALYSIS

As noted earlier, there are no simple formulas that will identify the correct choice between grade-crossing alternatives. Rather, choices will require value judgments as to the trade-offs between quantitative and qualitative differences between alternatives.

There are many approaches to trade-off analysis: cost effectiveness, cost, various rating schemes. While each organization must choose the approach that is most consistent with its decision-making processes, the decision-making framework presented here recommends a layered approach, or the use of a succession of techniques, each of which provides new information or a different perspective on existing information.

Thus, after the analyst has prepared the various quantitative estimates and qualitative statements of each alternative's implications in Level 2 or Level 3 analysis, the first step in the trade-off analysis is to make a *balance sheet* comparison of alternatives. The balance sheet simply lists the findings relative to each factor by alternative (see Table 4). Having all relevant information in a single table allows the decision-makers to readily identify the significant differences between alternatives. The differences may be so striking that the preferred alternative is apparent. In the illustration presented in Table 4, for example, the balance sheet shows that at an additional cost of $10,000 the replace alternative will avoid displacement of seven residences associated with the relocation alternative. All other characteristics of these two options are the same and therefore need not be considered in the decision. In the opinion of most people, the trade-off clearly favors the replace alternative, and relocation can be eliminated.

If the balance sheet does not provide a sufficient basis for decision-making, the second technique employed is the calculation of *unit cost measures.* Table 5 presents an example of unit cost measures which can be calculated to compare alternatives. The calculation of such measures allows the decision-maker to define more precisely the nature of the choices to be made. For example, when comparing the replace alternative to the at-grade alternative, the unit costs presented in Table 5 answer the following questions: Are we willing to pay $2.9 million for each fatality avoided? *or* Are we willing to pay about $40 for each one-minute vehicle delay avoided? These questions are posed in an "or" format. Actually, both delays and accidents should be considered simultaneously because both would distinguish the at-grade crossing and structure relocation alternatives shown in Table 5. One way to accomplish this is to distribute the cost difference between delays and accidents and pose the questions above, for example, as follows: Are we willing to pay $1.45 million for each fatality avoided? *and* Are we willing to pay $20 for each one-minute vehicle delay avoided? If decision-makers answer "yes" to these questions, replacing the structure is the preferred alternative. Sensitive tests using various distributions of costs may be used with this approach.

The third technique suggested to support decision-making is a *total cost computation,* including factors amenable to cost estimation. Some analysts and decision-makers object to this type of analysis because of the difficulties in developing acceptable values for some factors (e.g., the cost of accidents) and the inability to include other qualitative considerations (e.g., environmental quality). However, cost analysis, in conjunction with the other techniques described above, will provide additional insight into the nature of the trade-offs between alternatives, particularly if sensitivity testing is employed.

In the final analysis, the decision will still be based on the judgment of those with the responsibility and authority to implement the remedial action. Nonetheless, because value judgments are inherent in the choice among alternatives, the decision-maker should obtain the opinions of other institutions affected by the decision—usually the railroad and local government. The opinions of these other parties, and their voluntary financial commitment to one alternative or another, should be considered in reaching the decision. Indeed, if all parties agree that a specific alternative is preferable, the selection process is greatly simplified.

CHAPTER FOUR

APPLICATION OF RESEARCH FINDINGS

The research project came about in response to the need for a systematic and credible tool to make decisions regarding alternatives for improving deteriorated bridges separating highways and railroads. A growing number of these bridges are in need of rehabilitation or replacement, but it is highly questionable if all of them should be retained. Many events have occurred since the justification for the construction of a given bridge was established. Changes in highway traffic patterns, changes in rail traffic volumes, and changes in design standards all combine with resource constraints to raise legitimate questions about the best alternative to implement: (1) replace the structure, (2) rehabilitate the structure, (3) relocate the structure, (4) construct an at-grade crossing in place of the structure, (5) close the road, or (6) close the rail line. The difficulty in deciding a course of action is that there are no widely accepted guidelines for evaluating these alternatives.

The decision-making framework presented in this report fills this void by providing a set of procedures for the systematic evaluation of alternatives. The framework has the following characteristics: *It* provides for identification and evaluation of all legitimate alternatives. *It* incorporates consideration of all factors relevant to the alternatives analysis. *It* defines ways to measure the value of each factor by alternative, including quantitative and qualitative variables. *It* provides techniques for examining quantitative and qualitative differences between alternatives to facilitate decision-making. *It* provides for documentation of results to communicate decisions and to retain an audit trail of the decision-making process. In summary, the framework possesses all of the components needed to identify the preferred alternative.

The framework also is designed such that it can be applied to the evaluation of alternatives for new crossings and for changes to existing at-grade crossings. Indeed, the framework may be used predominantly in these situations. Since the research project began, many inquiries have been received concerning the framework for alternatives analysis in the context of new crossings and existing at-grade crossings. Also, the research team is currently using the framework to evaluate the choice between an at-grade crossing and a grade-separation for an existing crossing, for a proposed new highway, and for a proposed light-rail transit system.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDED FURTHER RESEARCH

The framework developed in this research project has accomplished its objectives and, indeed, is already being used in practical applications. At the same time, the framework is not without limitations, the most significant being: (1) the absence of a technique for estimating accident potential on bridges and in the vicinity of a new at-grade crossing (i.e., nontrain/vehicle accidents); and (2) the absence of a technique for determining risk assessment for hazardous materials accidents at crossings and on bridges. Neither limitation is considered significant relative to the credibility and usefulness of the framework, but both areas would benefit from further research.

Finally, no decision-making framework will be used unless the right people are aware of it and consider it to be a credible and practical tool to aid public administrators, hearing examiners, and others in making decisions.

In developing the framework, particular emphasis was placed on establishing a practical and credible process, as described below:

1. The framework is based on decision-making requirements and constraints specified by practitioners through a series of extensive interviews with selected government agencies and railroads.

2. The framework is based on a broad-scale consensus of opinion concerning the characteristics of an effective framework, including factors to be considered, the ranking of factors, units of measurement, methods of analysis, and data sources. At the same time, the framework includes procedures for individual users to identify factors, establish rankings, and select measures and decision criteria that may be more responsive to their particular situation.

3. The framework was tested through two case study applications and has been used in other cases outside of the research project.

APPENDIX A

USER'S GUIDE TO THE DECISION-MAKING FRAMEWORK

SECTION I INTRODUCTION

As discussed in the first part of this report, the product of this research project is a framework for deciding the preferred alternative in the case of deteriorated or functionally obsolete grade-separated rail/highway crossings. The framework is applicable for alternatives analysis for new crossings and for changes to existing at-grade crossings as well. Guidelines for a workable decision-making framework are defined and an overview of the framework is presented in the research report.

This appendix presents the framework in detail and serves as a *User's Guide* to applying the framework. The user is taken step-by-step through the framework with explanation of the purpose and content of each framework component and with presentation of the analytical tools and data requirements of each component.

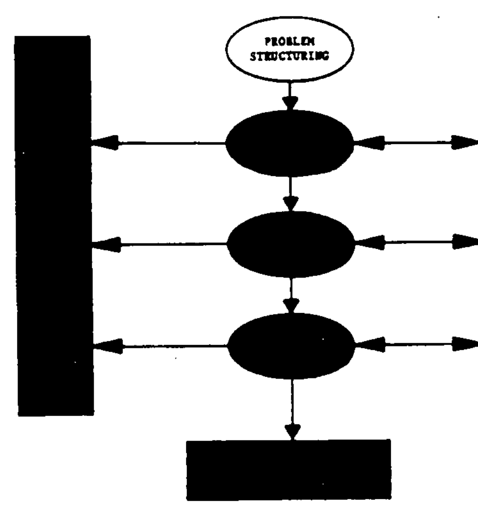
SECTION II PROBLEM STRUCTURING

OVERVIEW

Structuring the problem is the first component of the decision-making framework. In the framework, structuring the problem consists of three elements: (1) a statement of the problem, (2) the identification of alternatives, and (3) development of sufficiently detailed engineering data for each alternative to support Level 1 analysis.

Also critical to successful decision-making is the identification of the parties responsible for highway or rail construction, operation, maintenance, and regulation, or who otherwise have an interest in the action that will eventually be taken. A plan for involving these parties in the decision-making should be developed at this stage in the process.

DECISION MAKING FRAMEWORK



PROBLEM DEFINITION

It is important to establish a clear definition of the problem before proceeding with the identification of alternatives. A problem could arise for a number of reasons. For example, an aging structure has become unsafe, or design standards have changed and the facility does not adhere to common practice. Also, there has been a change in traffic patterns for rail or vehicular services using the facility. There has been an accident. Whatever the reasons, a clear problem statement should be formulated in order to establish the basis for initiating analysis. While most grade-crossing improvement projects arise at single rail/highway intersections, the scale of the project, one intersection or a number of intersections, should be defined. The analysis procedure defined herein is presented in the context of the problem of what to do when a specific grade-separated, rail/highway crossing has reached functional obsolescence or substantial deterioration. However, the framework is readily adaptable to the other crossing problem circumstances noted above and to the "corridor approach" to grade-crossing issues, where multiple crossings are considered in the problem definition and the identification of solutions.

In addition to defining the reasons for initiating an analysis, the problem definition also requires a description of the context or setting in which this problem occurs. A description of the problem context should include the following characteristics of the setting:

1. Location—describe the specific location of the problem crossing and obtain maps of the location. (USGS maps—scale 1:24,000 ft—are sufficient at this stage of the analysis.) Include, for example, the location name, adjacent land uses, and intensity of activity.

2. Crossing characteristics—describe the problem crossing in terms of the rail system and roadway system it serves. This description should include: (a) basic characteristics of rail service (main line/branch line; service area; traffic volume and type of traffic); and (b) basic characteristics of road system (functional class, daily traffic). The description should cover expectations for future conditions as well as current conditions. Only by defining the problem and its context in these terms can one identify potential alternative solutions.

The definitions of the problem need not be elaborate. Indeed, a concise definition, such as the one presented in Figure A-1, better communicates the problem to decision-makers.

REASONS FOR INITIATING AN ANALYSIS

This case study involves a deteriorated grade-separated rail crossing (highway over rail) in New York State. Structural deficiencies were identified through the New York Department of Transportation (NYDOT) Bridge Inspection Program. The inspection revealed that the stringers are completely rotted through and that there is a section loss in the primary members. Also, serious deterioration to the structural deck, primary and secondary members, wearing surface, joints, curbs, sidewalks, facias, railings, parapets, and bearing anchor bolts was found. The FHWA sufficiency rating for the structure was determined to be 26.3, indicating serious deterioration. The bridge was posted for less than its original design loading. Additionally, the structure did not meet current AASHTO standards for rural highways, having a stopping site distance of 200 feet and a roadway width of 24 feet.

PROBLEM CONTEXT

The grade-separated structure carries N.Y. Route 240 over a main line of the Chessie System Railway Company. The line is known as the Buffalo-Salamanca main line. Traffic on the line is one through train daily in each direction. The trains average 60 cars in length and train speed averages 30 mph. The trains carry various commodities (20% to 30% of the traffic is chemicals). There are no switching movements in the vicinity of the bridge. There is no anticipated change in train operations, although traffic has declined in recent years from six to two trains daily.

N.Y. Route 240 is a north-south highway serving recreational areas between the towns of Orchard Park and Elliottville. Current daily traffic over the bridge is 3473 AADT. Peak traffic volumes occur on weekends during the skiing season (AADT of 6700). Future traffic is anticipated to grow gradually over time at a rate of 1.4 percent per year.

Land use in the vicinity of the bridge is rural. An industrial/construction equipment supplier and a private campground are located adjacent to the crossing. Land use along this segment of N.Y. Route 240 is a mix of open land and scattered single-family residences.

Figure A-1. Illustration of a problem definition statement.

DEFINITION OF ALTERNATIVES

As previously indicated, there are six generic improvement options to consider: (1) rehabilitate the structure, (2) replace the structure at the same location, (3) relocate the structure, (4) replace the structure with an at-grade crossing, (5) demolish the structure and close the road, (6) demolish the structure and close the rail line. While it might be possible to exclude an alternative with little or no analysis, it is always useful to perform the basic level of the decision-making framework to avoid making arbitrary decisions and to fully document the decision-making process.

Also, design objectives or standards which will govern the engineering characteristics of each alternative should be identified at this time.

CONSIDERATION OF PROJECTED CROSSING CHARACTERISTICS

A second aspect of preparation for the analysis is to determine how projections of future conditions at the crossings will be used. Throughout the decision-making framework, current and short-term future characteristics are used to identify and estimate the various implications of each alternative. In many cases, this is an adequate basis for decision-making because conditions at many deteriorated, grade-separated crossings are not projected to change materially.

Considerations of future conditions can focus principally on projection of rail and highway traffic volumes. In most, though not all, cases, these are the most influential factors in the analysis of alternatives. The analyst must use his or her judgment in deciding which variables are the critical ones in a given situation and, consequently, for which ones projections will be needed.

One approach to incorporating future changes is to project relevant variables for the analysis period and to apply the framework described below, accounting for the cumulative changes. This approach, however, may be time consuming and unnecessary.

A more pragmatic approach is to conduct the analysis assuming crossing characteristics at a selected point in time and then to test the findings according to the alternative current or future crossing characteristics. If the preferred alternative is the same under both sets of conditions, computation of factors for intermediate years and computation of cumulative totals over the analysis period are unnecessary to making an informed decision.

In proceeding with this approach, it is recommended that one begin the analysis with the crossing characteristics most likely to favor a grade-separation alternative; these characteristics will include the higher highway traffic and higher train movements volumes. If, under these conditions, an at-grade crossing is determined to be the preferred alternative, the analysis need proceed no further; lower highway traffic and fewer train operations would reinforce the choice. Beginning with the lower volumes and concluding that an at-grade crossing is preferable, on the other hand, leaves the question of whether the higher traffic and train numbers would justify a grade separation unanswered.

Thus, at each level of analysis one should complete the analysis using the higher traffic and train volumes and then test the findings, as necessary, using the alternative set of crossing characteristics. For this purpose, a 20- to 25-year time horizon is typically used in analyzing highway investments and is appropriate here. Also, for testing the findings it is probably sufficient to compute only the accident and highway delay factors, which are part of the framework. Most decisions will be based principally on these factors—i.e., number and severity of accidents, frequency and duration of delay—relative to construction and maintenance costs of each alternative.

As noted above, should the test confirm the findings based on the primary set of crossing characteristics, further analysis is unnecessary. On the other hand, should it be found that the decision would be changed by using the lower highway traffic and train operations numbers, intermediate-year data must be developed and analyzed. Estimated values for the quantitative factors should be developed at 5-year increments. Interpolation can be used to develop discounted cumulative totals to support the comparative evaluation statistics. In the case of qualitative factors, evaluations at the 5-year intervals should be made and incorporated into the comparative evaluation process.

PARTICIPATION PLAN

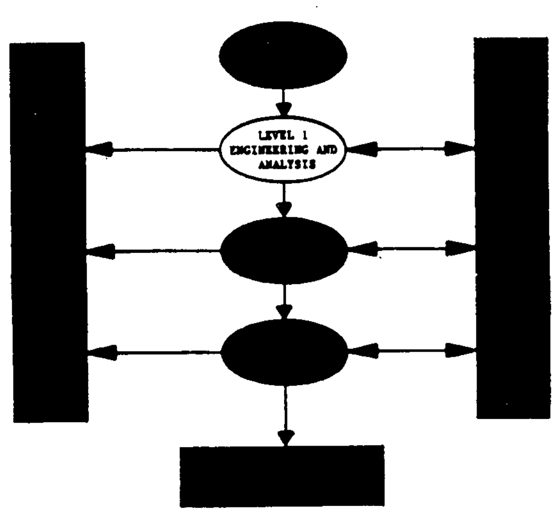
A final aspect of the preparation for analysis of alternatives is the identification of parties in interest and the development of a plan for their involvement in the decision-making process.

This element of the decision-making framework is necessary because information and perspectives needed to evaluate the alternatives must be provided by various parties—state government, railroads, and local interests, primarily. In addition, decisions regarding rail/highway crossing improvements most often are developed through a process of negotiation and consensus building among the parties in interest. Clearly, the more innovative solutions to rail/highway crossings that have emerged in recent years result from group problem-solving and negotiation of trade-offs. In any case, one cannot avoid the fact that value judgments, as well as technical expertise and mathematical formulas, are required to make the ultimate decisions.

In view of this fact, the decision-making framework requires the participation of interested parties during the analysis process. An integral part of such a process is the need to identify and facilitate trade-offs or compromises in order to reach a consensus, especially where conflicting goals may exist. For example, the railroad's desire to minimize continuing operations and maintenance costs may conflict with the government's desire to reduce the level of capital costs associated with the rehabilitation or replacement options. While the decision-making framework is no substitute for discussions on such conflicting goals, it does identify areas where such trade-off discussions are required and will help eliminate peripheral issues that can cloud discussions. The framework provides a systematic, structured basis for such exchanges, thereby expediting the decision.

SECTION III LEVEL 1 ANALYSIS PROCEDURES

DECISION MAKING FRAMEWORK



OVERVIEW

Level 1 analysis constitutes the broadest and least detailed component of the analytical framework. It requires a minimum of information gathering and analysis. In all probability, this level will be the only one in which all improvement options are examined, since the objective is to eliminate options that are clearly infeasible from one or more points of view before detailed alternatives analysis is performed.

The objective of Level 1 analysis is to identify alternatives that are acknowledged, based on current practices, to be eminently practical or impractical from the standpoint of engineering feasibility, safety risks, adverse effects on rail or highway operations, adverse land-use impacts, or compliance with relevant laws and regulations. An example of a clear and compelling obstacle to an alternative would be its physical impracticality—an at-grade crossing may not be practical in mountainous terrain. Conversely, a compelling reason for pursuing a particular type of improvement might be the absence of present or future rail traffic, which would argue for closing the rail line and eliminating the crossing. Unless there is an offsetting reason to reject this alternative (e.g., physical impracticality) or to accept another alternative (e.g., rehabilitate the structure because it is a designated historic site), there would be little reason to explore any other alternatives beyond Level 1 analysis.

Because of the broad scope of this level of analysis, the level of detail required to evaluate each alternative is low. Only those factors involving the greatest impact are considered and then only in sufficient detail to determine an order of magnitude impression of impacts. Analysis techniques rely on quick-response methods using readily available data.

Because the analysis methods used in Level 1 are relatively simple, the force of the findings is less than might be obtained using more precise procedures. Alternatives should be carried to the next level of analysis unless the extent of adverse impacts is *clearly* in the unacceptable range. Consensus of all parties associated with the decision (e.g., state and local governments and the railroad) may be required to judge an alternative as clearly unacceptable in Level 1. In subsequent levels, closer scrutiny may cause rejection of alternatives that border on the unacceptable in Level 1.

LEVEL 1 ENGINEERING

Engineering of the alternatives is performed at a level of detail sufficient to conduct the Level 1 analysis. In this stage of the engineering effort, each of the alternatives is defined in both the vertical and horizontal planes. Ideally, at least one alignment with vertical and horizontal profiles will be prepared for each generic alternative (i.e., rehabilitate, replace, put at-grade, etc.) except for relocation, which may have multiple alignments.

The rehabilitate and replace alignments will generally involve only minimal effort, because the horizontal and vertical position of the bridge is already established. The work involved in the at-grade alternative is primarily in the vertical plane—lowering either the highway or railroad. The close railroad or close highway options will involve no effort at this stage if the facility being closed is the one on the structure. In the reverse case (e.g., close highway where railroad is on the structure), a new vertical alignment will be required.

An appropriate scale (1:2,000 to 1:10,000) should be used to develop alternative alignments. The horizontal alignment should be prepared on a topographic map with a contour interval appropriate to the terrain surrounding the site. A vertical alignment is then developed along the horizontal alignment with additional cross sections at critical points.

The engineer should seek to present the best possible alignment for each alternative. All rejected options should be documented, describing why they were eliminated from further consideration.

Considerations in developing new horizontal alignments and vertical profiles might include avoidance of existing structures, general design specifications (clearances, right-of-way widths, sight lines for traffic safety), noise, and other environmental determinations. Following the preparation of highway and railroad plans and profiles, a conceptual structural design is prepared. Determinants affecting the structural design include profiles, design loads, and clearances (spans) which are related to future traffic volumes and the physical location of the structure. Structure span length and cross sections plus length of cut or fill section, retaining structures, and length of pavement/track when specified will provide the basic data for describing the new facility. The engineering analysis culminates in a concise write-up in which the essential engineering features of each design alternative are described.

LEVEL 1 ANALYSIS

Level 1 analysis involves developing responses to issues that will determine whether there is a compelling reason to select or reject any of the alternatives under consideration. These issues, which are categorized according to the five primary decision factors, are summarized in Figure A-2. The discussion in the remainder of this section presents guidelines for addressing these issues. Each issue includes a discussion of the significance of the issue and the presentation of procedures to be followed in addressing the issue. In conducting Level 1 analysis, all six of the generic alternatives should be examined regardless of initial impressions of feasibility. Furthermore, all issues should be considered to create a complete picture of each alternative's implications.

In addition to examining each alternative relative to all of the issues identified in Figure A-2, alternatives may be compared to one another with the possibility that some may emerge from Level 1 analysis as unequivocally superior or inferior to others. A description of how to proceed with such a comparison follows the issues analysis guidelines. The section concludes with a

COST

Is implementation of the alternative physically impractical from an engineering perspective (and by implication prohibitively high in cost)?

SAFETY

Would implementation of the alternative result in any unacceptable safety risk to motorists?

RAIL AND HIGHWAY OPERATIONS

Would implementation of the alternative result in unacceptable vehicular delay?

Would implementation of the alternative result in unacceptable disruption to rail operations?

COMMUNITY AND ENVIRONMENTAL CONCERNS

Would implementation of the alternative require the destruction of a historic, archaeological, or cultural site listed in a formal federal or state register?

Would implementation of the alternative require the taking of federally protected property (e.g., 4f property) or similarly protected state or local property?

Would implementation of the alternative result in a clearly unacceptable taking of private land and/or displacement of buildings?

INSTITUTIONAL CONSIDERATIONS

Do any federal, state, or local rules or regulations or consistently applied policies or any existing contracts: (a) dictate that a specific alternative or type of alternative be implemented; or (b) categorically eliminate an alternative from consideration?

Figure A-2. Level 1 issues summary.

description of how to document the analysis performed and decisions made to facilitate communication and retain an audit trail.

DATA REQUIREMENTS AND SOURCES

Prior to initiating any analyses, information requisite to the analysis must be obtained. Table A-1 presents a list of data required to conduct Level 1 analysis and potential data sources.

Cost

The Issue

Is implementation of the alternative physically impractical from an engineering perspective?

Project cost has always been a prime consideration when comparing improvement alternatives. The methodology used in this decision framework also employs cost as a factor, but places it on an equal footing with the four noncost factors that must be considered.

The major cost consideration is the actual capital cost of the structure, including its approaches. When structures are involved, capital costs are always high—generally in the millions of dollars. Given the large amounts of money involved, the fact that the funds for such projects are always in great demand,

Table A-1. Level 1 analysis data requirements and sources.

DATA REQUIREMENT	DATA SOURCES
Physical characteristics and constraints of implementing each alternative	Conceptual engineering output (see Chapter II)
Design standards	State or local highway agency
Land uses within 1000' of the site of any alternative - Maps showing property lines, structures, and ownership - Aerial photographs - Listing and location of historic, archaeological, and cultural structures and properties - Listing and location of parklands, recreation areas, wildlife and waterfowl refuges.	Local planning agency; tax assessor's office; state or local historic preservation agencies; state recreation or natural resources agency
Street/highway map of the city, town, or county in which the alternatives are located, including generalized land uses	State or local highway agency, local planning agency, local of commerce
Railroad operations (current and projected 10-year) • Average number of trains • Average train length • Average train speed • Abandonment status and public action, if any • Nature of rail service --Main line/branch line --Passenger/freight --Service area	State rail division; railroad companies; shippers; chambers of commerce
Highway operations (current and 10-year projected) • AADT • Representative trips (O/D pairs) • Travel speeds	State or local highway agency; local planning agency
Safety	
• Exposure or hazard index formula and supporting data	State highway agency or PUC
• Rules, regulations, warrants, policies regarding warning devices	State highway agency or PUC
• Frequency distribution of crossings with gates statewide by exposure index	State highway agency or Federal Railroad Administration, USDOT

and the fact that the amount available for any one project usually is limited, the cost of each project, although treated in this process as co-equal with other factors, becomes a major criterion in evaluating alternatives.

Cost estimates generally are made from engineering plans. Unit prices are multiplied by quantities taken from the drawings to arrive at a total price for that element of the structure. However, in Level 1 analysis, the engineering plans used do not permit this type of cost estimation. As a surrogate for this measure, *physical feasibility* is used.

Physical feasibility serves as a surrogate measure of the cost required to build the structure. If all improvement alternatives are physically feasible, the associated costs will fall within a limited range. Physically infeasible alternatives would entail clearly unreasonable expenditures to permit implementation of the alternative. Even without determining the costs of specific elements of the alternative, it will become clear that the physically infeasible alternative is much more costly than the others.

Methodology

> Analysis Step
>
> Review engineering plans to determine whether implementation of the alternative is within the range of sensible engineering practice.

Physical feasibility is used as a surrogate measure of capital costs—the most important aspect within the cost factor. Physical feasibility requires a determination of whether or not the alternative can be implemented within a reasonable capital cost range. Certain obstacles would indicate a lack of physical feasibility. For example:

1. An alignment requiring extensive reshaping of the topography such as might be necessitated by lowering a rail line situated on an embankment to an at-grade crossing in a densely settled area.
2. Relocation of an alignment within a flood plain.
3. Introduction of grades significantly in excess of maximum standards.
4. Introduction of horizontal curvature significantly in excess of maximum standards.
5. Extensive relocation of buildings or of even a few major structures.
6. Reduction of horizontal or vertical clearances below the limits required for design vehicles.

Assessment of physical feasibility is made from the conceptual engineering plans prepared prior to Level 1 analysis. In general, physical feasibility should be assessed by an engineer experienced in highway and railroad design. However, a specific explanation should be submitted should a finding of infeasibility be made. The infeasibility determination should be applied only where the alternative is clearly beyond the range of sensible engineering practice.

Safety

The Issue

> Would implementation of the alternative result in a clearly unacceptable safety risk to motorists?

Each of the alternatives has implications for highway safety. However, Level 1 analysis focuses on those alternatives—replacing the crossing at-grade and closing the crossing—that may cause the most significant change in exposure of motorists to accident potential. Rehabilitating the structure, replacing it, or relocating it, insofar as road or structure geometrics are improved, could reduce accident exposure. However, while the other alternatives may have a positive or negative effect on accident exposure, the potential change will not be large enough to reject these alternatives or to accept one of them as the preferred alternative during Level 1 analysis, except in unusual circumstances.

Clearly, removing the grade-separated structure and putting in its place an at-grade crossing could increase accident potential significantly. Whether the increase is sufficiently large to warrant elimination of this alternative is a matter of judgment.

All states are required to use a *hazard index* to aid in establishing priorities for funding crossing improvements under the Section 203 program. Some states have further established guidelines or warrants for warning systems based on an *exposure index* (i.e., average daily vehicular traffic times average daily trains). These guidelines or warrants can be used to determine whether the exposure index associated with the at-grade alternative is sufficiently large to eliminate the alternative as an unacceptable safety risk. That is, if the index at the grade crossing, calculated according to state procedures, exceeds the threshold guidelines for at-grade protection, the alternative could be rejected during Level 1 analysis.

This approach, however, is *not recommended* because an exposure index does not adequately characterize safety conditions at crossings. An exposure index does not reveal the number of accidents that could occur at a given crossing or the potential severity of those accidents. Indeed, crossings with the same exposure index can vary considerably with regard to safety conditions and accident history. It is this limitation of exposure indexes that has led all but a few states and the USDOT to avoid the use of exposure indexes as absolute decision-making warrants in grade-crossing protection cases.

As discussed above, a state may choose to use an exposure index or a hazard index as a basis for deciding whether the at-grade crossing alternative presents an unacceptable safety risk. To accomplish this the state would require: (1) an accepted procedure for calculating the index, and (2) an acknowledged decision rule for rejecting the at-grade alternative on the basis of its computed index. A similar approach can be used for the close-the-road alternative should it mean diversion of traffic to an at-grade crossing.

Rail and Highway Operations

The Issues

- Would implementation of the alternative result in clearly unacceptable vehicular delay?
- Would unacceptable disruption to rail service result from implementation of the alternative?

An alternative might be rejected in Level 1 analysis if it results in a substantial increase in travel time for motorists who use the crossing. This could occur if the grade-separated structure is replaced with an at-grade crossing at which motorists would experience delays at the crossing during train operations. Travel time increases also could occur if the crossing were closed and motorists were required to use a more circuitous route to reach their destinations. Similarly, if the grade-separated crossing were relocated, the increase in travel time would be a function of the circuitry of the new route linking origins and destinations.

Rail operations should be considered in Level 1 analysis, particularly regarding the close the rail line alternative. If the rail line is active, closing the line could result in the loss of rail service to shippers along the line and consequent adverse economic effects. Alternatively, the railroad could incur substantial costs if closing the rail line required use of an alternative route. Even if there currently are no rail operations on the line, plans to reinstate service may exist and should be considered. In any case, the rail line cannot be closed in most cases without a formal abandonment proceeding.

Units of measurement include the following:

1. *Highway Operations* (for an average day)
- Probability of delay.
- Number of vehicles delayed.
- Average duration of delay (minutes).
- Percentage change in representative trip times.
2. *Rail Operations*
- Possible rail service change.

Methodology

Highway Operations. To determine whether an alternative should be rejected because it would cause unacceptable vehicular delay, one must first compute some rudimentary measures of expected changes in travel time and the incidence of those changes. It is assumed that rehabilitation or replacement of the grade-separated crossing would cause no change in travel times; the computation procedures provide for estimating the change in typical travel times for the relocation, at-grade, and close the road alternatives.

Analysis Steps—Highway Operations

1. Collect necessary data and compute the probability of delay at the crossing during an average day.
2. Compute the number of vehicles that may be delayed during an average day.
3. Compute the expected duration of delay (average and range) for each vehicle delayed.
4. Compare delay characteristics to typical trip lengths of vehicles using the crossing.
5. Compare delay characteristics to other crossings in the area.

Regardless of the alternatives being analyzed, the first step is to define typical trips of motorists who are using the crossing and then to calculate typical travel times (in minutes) required to make these trips. The purpose of this step is to provide a context in which to evaluate the change in travel times that each alternative may impose on motorists; that is, it provides a benchmark against which to understand the magnitude of change that would occur.

It is sufficient for Level 1 analysis to identify only a few (three to five) representative trips. Current travel times can be estimated simply as distance divided by average speed.

Following this step, delay statistics for the at-grade, relocation, and close the road alternatives are calculated.

For the at-grade alternative, statistics that require computation for this alternative and associated formulas are as follows:

1. Number of minutes the crossing is blocked on an average day, M:

$$M = [(L/S)(60) + 0.6]*\text{ADTT}$$

where L = average train length, S = average train speed through the crossing, ADTT = average daily train traffic, 0.6 represents the amount of time crossing signals are active prior to train arrival and after train departure in the crossing, and 60 = minutes in an hour.

2. Probability of vehicular delay during an average day, P: $P = M/1440$, where 1440 is the number of minutes in a day.

Table A-2. Summary of Level 1 highway operations computations.

Unit of Measurement 1/	Alternatives 2/		
	Relocate	Put At-Grade	Close Road
Probability of Delay			
Vehicles Delayed			
Average Duration of Delay Per Delayed Vehicle (minutes)			
Current Trip Time (minutes)			
• O/D #1			
• O/D #2			
• O/D #3			
Percentage Change in Trip Time			
• O/D #1			
• O/D #2			
• O/D #3			

1/ For an average day.

2/ Other alternatives do not materially affect travel times.

3. Number of vehicles delayed at the crossing on an average day, V: $V = P*\text{AADT}$, where AADT = annual average daily traffic.

4. Average duration of delay per vehicle delayed, D: $D = M/\text{AADT}/2$, where 2 represents the assumption of uniform arrival of vehicles at the crossing during train operations.

For the relocation and close the road alternatives, which may result in more circuitous travel routes, one must first identify probable alternate routes between the selected origin/destination pairs and then compute the travel time in minutes associated with each of these trips (distance divided by speed). The change in travel time for each trip is the travel time under the alternative less the current travel time. All motorists currently using the crossing would experience these travel times; consequently, the probability of delay to these motorists under these alternatives is 1.0 and the number of motorists who would incur added travel time equals AADT.

The statistics calculated for each alternative should be recorded in a table such as Table A-2. The table will present data needed to judge whether the vehicular delay associated with each alternative is or is not sufficient grounds to eliminate it from further consideration.

It is useful in making these judgments to have benchmarks representing acceptable or at least tolerable delay. Such benchmarks may be found through a review of other comparable situations and historical grade-crossing decisions. However, a decision in this area of vehicular delay is difficult at best. No hard and fast rules can be specified to determine whether the estimated changes in trip time are acceptable or not. One must rely on judgment and experience to determine whether the changes are sufficiently large to reject the alternatives. It is an area in which expert judgment and discussions with parties in interest (see Section I) are particularly appropriate. Vehicular delay is more adequately treated in Level 2 and Level 3 analysis and only in cases of extraordinary delay magnitudes (e.g., delay probability in excess of 25 percent, average delay duration in excess of 10 min, and percentage increases in travel time in excess of 100 percent) should an alternative be rejected on the basis of this factor in Level 1 analysis.

Rail Operations. To determine whether implementation of an alternative would result in an unacceptable impact on rail operations, it is first necessary to establish the status of the rail line. This can be determined by answering the following questions: (1) Are there any current or projected rail operations on the line? (2) Is the rail line scheduled for, or a candidate for, abandonment? (3) Would essential rail service be lost if the alternative were implemented or do viable alternate routes exist? (4) Would the railroad incur substantial additional capital or operating costs or be unable to maintain some services if the alternative were implemented?

Analysis Steps—Rail Operations

1. Determine rail line status—current and projected operations, abandonment status, if appropriate, railroad, and state or local plans for rail service.
2. Determine the potential effects of each alternative on rail service quality and costs of operations.
3. Determine importance of rail service—main line vs. branch line status, significance of service to the railroad system, significance of rail service to the local or regional economy.

If the answer to the first question is no, then the remaining issue to be resolved is whether or not the rail line is scheduled or is a candidate for abandonment. Should the rail line be abandoned, the structure, if the railroad is above the highway, can be eliminated. Regardless of abandonment, the at-grade option remains viable.

The importance of service on the rail line, assuming a positive response to the first question, is raised by question 3. Local passenger and freight service should be examined to establish the economic importance of the line. The presence of numerous commercial operations with rail sidings is indicative of heavy dependence on rail service. Similarly, high-volume passenger rail stations along the subject rail line would obviate the need for further study. If the answer to the third question is yes, alternatives that would jeopardize this service, (i.e., close the rail line) should be eliminated at this point.

Even if an alternate would not cause otherwise viable rail operations to be discontinued, it could cause the railroad to incur substantial capital and/or operating costs or cause some operations to be curtailed. There are many ways in which rail operations may be adversely affected. For example, local or state ordinances may stipulate maximum train speed through at-grade crossings; the segment of track including the crossing is used heavily for switching operations; the segment of track including the crossing is used for train storage. In these situations and others, the at-grade crossing could cause considerable disruption to train operations and could require the railroad to incur capital or operating costs to alleviate the problem.

The railroads operating on the line and the shippers they serve should be consulted about the various alternatives and asked to document the implications of each for rail service quality and costs. Based on this information, a judgment must be made regarding the acceptability of these outcomes.

Community and Environmental Concerns

The Issues

- Would the proposed improvement destroy or significantly impinge upon any historic, archaeological, or cultural structure, site, or area recorded in a formal register?
- Would the proposed improvement destroy or significantly impinge upon any publicly owned parks, recreation areas, wildlife or waterfowl refuges, or other formally protected natural habitat areas?
- Would implementation of the proposed improvement result in a clearly unacceptable taking of other land and/or displacement of buildings?

In Level 1 analysis, the destruction or displacement of existing land uses may be a compelling reason for rejecting one or more of the alternatives. To make this determination, three categories of land use are examined: (1) historically, archaeologically, or culturally significant properties; parklands and recreational areas; other significant land uses.

Units of measurement include:

- Potential taking of historically, archaeologically, and culturally significant structures and land (number and amount): Nationally recognized, State recognized, Locally recognized.
- Potential taking of parklands and recreational areas (number and amount).
- Potential disruption of significant structures and land, parklands, and recreational areas.
- Number and type of other structures and land takings.

Historic, Archaeological, and Cultural Resources. Adverse impacts on formally designated historic, archaeological, or cultural resources may occur if the deteriorated grade separation structure and site, adjacent structures and sites, or structures and sites in the vicinity of the relocation alternative are listed in national, state, or local historic registers.

In cases where the grade separation structure itself is a formally designated resource, any improvement other than rehabilitation may be unacceptable from a historic preservation point of view. Alternatives that could partially or wholly destroy adjacent structures and sites are those that would require additional right-of-way (e.g., the replacement and relocation options). If it is clear that an alternative would cause such damage, it normally would be desirable to consider dropping the offending alternative (at least for the time being) from further consideration. Although even structures listed in the *National Register of Historic Places* can be demolished if no reasonable alternative exists, the time, effort, and cost involved in gaining approval for such actions are substantial. State and local protections vary from state to state and may or may not be more flexible. However, unless the improvement of the deteriorated structure absolutely cannot avoid destroying or significantly altering a protected structure or site, every effort should be made, at this point in the analysis, to reject any alternatives that seriously conflict with such formally designated historic, archaeological, and cultural resources.

Parklands and Recreational Areas. Section 4(f) of the Department of Transportation Act (codified as Section 1653(f) of Title 49, U.S.C. and Section 138 of Title 23, U.S.C.) provides special protections to all public park and recreation lands, wildlife and waterfowl refuges, and all designated historic and archaeological sites of federal, state, and local significance affected by federally assisted transportation projects. Because of the difficult procedures required for taking 4(f) type land, alternatives which involve such taking should be considered for elimination early in the alternatives analysis process, unless there are no prudent alternatives. The taking of parkland generally will involve those alternatives that require additional land for roadway or railway right-of-way. The relocation alternative is potentially the most damaging in this regard.

Other Significant Land Uses. While the previous two categories of land use address properties that possess regulatory significance and are somewhat protected from destruction or displacement, this category addresses other land uses—residential, commercial, industrial, and institutional—not normally singled out for special protection. For these land uses, an alternative may be rejected if it would result in taking unacceptable amounts of property or structures, or displacing properties of unique significance to the community. An example of the latter would be the displacement of the only commercial area serving the neighborhood in which the crossing is located.

Methodology

The key consideration in examining land use and environmental concerns is whether or not the improvement would require taking land for new or additional right-of-way. The type of improvement with the greatest potential to take land is relocation of the grade-separated crossing. Replacement of the deteriorated structure with a new bridge, if it involves significant widening, also may require additional right-of-way.

If it is determined that the proposed improvement would take land, the next question to be addressed is whether the threatened land uses are sufficiently important or valuable to reject the alternative, which must be a subjective judgment. If the significance of the potential taking is unclear to the analyst, consultation with interested parties at the local level is recommended. Keeping in mind the overriding objective of Level 1 analysis—to identify compelling arguments for or against alternative improvements—it should be possible to determine, with a minimal amount of discussion among interested parties, if a particular taking is clearly intolerable. If consensus cannot be readily established that displacement of, say, several houses is unacceptable, analysis of land-use impacts should proceed to Level 2.

Analysis Steps

1. Overlay alignments prepared during Level 1 engineering phase of alternatives definition (see Section II) on available maps of the study area(s). These maps should show all existing transportation rights-of-way, property lines, and structures.
2. Determine: (a) whether any improvement alternatives will require additional right-of-way, and (b) whether acquisition of additional right-of-way will require taking land. If no taking of land is required for a given alternative, the community environmental impact analysis of that improvement may proceed directly to *Level 2: Land Use* at the appropriate time, subject to changes in alignment as the engineering is further developed in Level 2.
3. For those improvement options requiring additional land, the significance of each taking should be determined. For sites of historic, archaeological, and cultural significance, this involves determining whether the endangered property is formally listed in any national, state, or local registers. National registers in-

clude: National Register of Historic Places, Historic American Engineering Record, Historic American Buildings Survey, Society of American Archaeology Records, and Society of Industrial Archaeology Records. Such designations can be determined by contacting state and local historic preservation agencies.
To determine whether any other 4(f) properties [4(f) properties include historic and archaeological sites] would be taken, contact the state department of natural resources or its equivalent, local planning officials, and private organizations, such as the Nature Conservancy if necessary, and identify all parks, recreational areas, and wildlife and waterfowl refuges in the vicinity of the improvement.
To determine the significance of other properties, consult with local planning officials to determine the type and condition of threatened land uses and make a subjective determination as to whether or not the taking would constitute an intolerable burden.

Institutional Considerations

The Issue

Do any federal, state, or local rules or regulations or consistently applied policies or any existing contracts: (a) dictate that a specific alternative or type of alternative be implemented; or (b) categorically eliminate an alternative from consideration?

Institutional considerations refer to legislation, policies, and plans adopted by government agencies that dictate or guide decisions regarding changes in the transportation system. Contractual agreements between institutions (public and private) also may influence these decisions.

Consistent with Level 1 analysis, the focus of the analysis of institutional considerations here is on the identification of public laws, rules, regulations, and agreements that may eliminate certain alternatives from further consideration.

Units of measurement include existence of public laws, rules, regulations, warrants, or agreements which categorically exclude any of the alternatives.

There is only one federal regulation that specifies whether certain crossings must be grade separated as opposed to being put at-grade. Federal Regulation 23 CFR 646.214(c) specifies that grade-separated crossings are to be built on all freeways. Otherwise, federal guidelines specify only the design standards to be used for structures and warning devices for at-grade crossings. Also, in reviewing applications for federal funding, federal officials will review the proposed design relative to state standards and guidelines and will question proposals deviating from them. Such federal guidelines and review procedures may be taken into account in analyzing alternatives, but clearly not in Level 1 analysis.

Institutional constraints on the choice of alternatives for rail/highway grade crossings do occur at the state level, although states vary in the strength of these constraints. The State of Connecticut, for example, prohibits the construction of public at-grade crossings. A few other states have adopted warrants for grade-crossing protection, which could be used to determine acceptable alternatives in the case of a deteriorated or functionally obsolete grade-separated structure. As noted earlier, such warrants and similar constraints prematurely foreclose options which, given more deliberate consideration, may prove to be the preferred alternative.

Contractual agreements between railroads and a public agency or between public agencies may dictate the rejection of some alternatives. An example provided in response to the survey conducted for this research project is an agreement between a local government and a railroad, whereby the railroad constructed grade separations and is required to maintain them for the right to operate within the local government's area jurisdiction. Such an agreement may or may not constitute an inviolable impediment to replacing the structure with an at-grade crossing or closing the crossing, and should be researched.

Methodology

Analysis Steps

1. Determine whether any public laws, rules, regulations, warrants, or agreements governing the specific crossing or crossings in general exist.
2. Obtain documentation of relevant items and review them to determine whether any categorically exclude any alternative from consideration. Obtain an opinion from the state or local government attorney's office, if appropriate.

The procedure for determining whether certain alternatives must be rejected on the basis of institutional considerations is to determine whether public laws, warrants, rules, regulations, or agreements governing specific crossings or groups of crossings exist. If such documents exist, a copy should be obtained to determine whether they present categorical exclusion of any of the alternatives under consideration. In addition, interviews with officials involved in, and documents pertaining to, recently completed projects similar to the proposed one may provide valuable information on such institutional constraints. Finally, categorical exclusion of some alternatives should perhaps be challenged. The framework presented in this User's Guide, for example, could be used to reevaluate policies that foreclose consideration of potentially favorable options, possibly leading to policy changes.

COMPARATIVE ANALYSIS OF ALTERNATIVES

Level 1 analysis focuses primarily on examining each alternative independently of the others to determine whether it meets the set of minimum acceptance criteria or tests described earlier. However, even if an alternative passes these tests, it may be so clearly inferior to the other alternatives with respect to cost, safety, highway and rail operations, community and environment, and institutional considerations that it may be rejected during Level 1 analysis.

To illustrate this possibility, consider two hypothetical alternatives: (1) relocate and (2) replace the existing structure. Further assume that both alternatives passed the Level 1 analysis tests. Nonetheless, if it is learned during Level 1 analysis that the relocation alternative relative to the replacement alternative would cost more (e.g., because new right-of-way is required), would involve land-use disruption (e.g., the taking of private land and perhaps commercial properties), and would be less safe (e.g., introduce curved approaches on an otherwise straight road), there may be sufficient cause to eliminate this alternative on the basis of its *relatively* inferior merits rather than on its individual characteristics. A summary of Level 1 results, such as Table A-4, will facilitate identification of clearly inferior alternatives.

DOCUMENTATION OF RESULTS

A critical feature of any decision-making process is the communication and documentation of results. In the first case, effective communication of results is required for decision-makers to benefit from the work of the technical analyst; the analyst's function is to convey his or her findings to decision-makers so that they may make informed choices. The second aspect of communication is to inform the public of the decision.

Documentation of results also is important in that it provides a decision-making audit trail. This audit trail is important in two regards. First, it provides a clear history of information gathered, computations made, a' d conclusions drawn, which is a valuable resource if a decision ꞓquires an informal or formal public defense. Second, the audit trail provides guidance to future alternatives analysis in that it indicates data sources and limitations and analytical procedures and criteria that have been employed—presumably with some effectiveness—in the past.

The results of Level 1 analysis should be documented in a written report or technical memorandum. The report should begin with a statement of the problem (see Section II, "Problem Structuring"), followed by Level 1 engineering work and then

Table A-3. Level 1 analysis report outline.

1. Problem Definition
   - Reason for Project
   - Problem Context (General location map)
     - Traffic
     - Land Use
     - Environmental
2. Alternatives (Options described)
   - Rehabilitate
   - Replace at same location
   - Relocate
   - Replace with at-grade crossing
   - Demolish structure, close road
   - Demolish structure, close rail line
3. Conceptual Engineering (By option)
   - Alignment
   - Profile
   - Structural features
4. Decision-making Framework
   - Institutions affected
   - Participation process
5. Level 1 Analysis (By option)
   - Cost
   - Safety
   - Rail and highway operations
   - Community/environment
   - Institutions
6. Results
   - Comparison of alternatives
   - Recommendation for Level 2 Analysis
   - Rejected alternatives

Table A-4. Level 1 results summary.

ALTERNATIVE	Evaluation Factor						
	COST	SAFETY	RAIL OPERATIONS	HIGHWAY OPERATIONS	COMMUNITY/ ENVIRONMENT	INSTITUTIONAL CONSIDERATIONS	COMPARISON TO OTHER ALTERNATIVES
1. REHABILITATE	X			-			X
2. REPLACE		+			-		
3. RELOCATE				X	X		X
4. PUT AT-GRADE	+	-		-			
5. CLOSE ROAD		-		-			
6. CLOSE RAIL LINE			X				

Legend:

X = basis for rejection
\- = negative attribute
\+ = positive attribute

Notes:

1. Rehabilitate--rejected as physically infeasible. Substantial deterioration means that the structure would essentially require reconstruction at cost roughly equal to replacement. Rehabilitation also would mean retention of geometrics which do not meet current AASHTO standards.
2. Replace--replacement with a structure built to current design standards would have a positive effect on safety. Replacement could involve the taking of private land adjacent to the crossing.
3. Relocate--rejected on the basis of its relative disadvantages vis-a-vis replacement. Relocation adjacent to the existing crossing would require land-taking and possible building displacement and would introduce curved approaches to the bridges on an otherwise straight road.
4. Put At-Grade--is probably the least-cost option. Introduces vehicular/train conflicts and crossing delays.
5. Close Road--introduces vehicular/train conflicts because alternative routes have at-grade crossings. Alternate routes are built to lower design standards. Current crossing users would experience detour delay.
6. Close Rail Line--rejected because of its adverse effects on rail operations. The line is a main line with active operations and no acceptable routing alternatives available at this time.

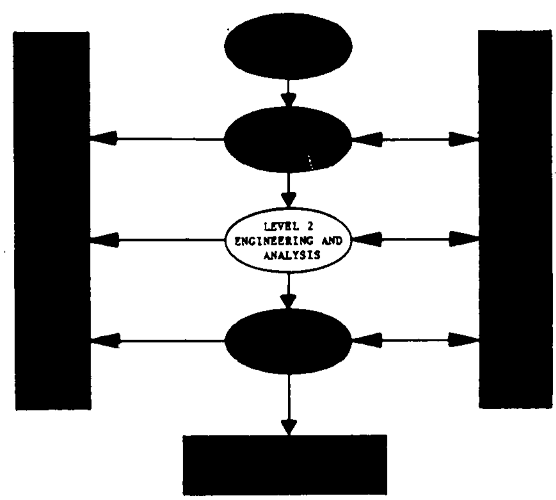
the analysis findings and conclusions. A suggested outline for Level 1 analysis documentation is given in Table A-3.

In presenting the analytical findings, each alternative should be discussed in terms of cost, safety, rail and highway operations, community and environmental concerns, and institutional considerations. The basis for rejecting an alternative also must be specified. Cases where an alternative is rejected as a result of its failure to match the performance of another alternative should be confirmed by discussions with affected parties.

Table A-4 presents an example of how Level 1 analysis results can be documented. The case studies presented in Appendix B provide further suggestions regarding documentation of results.

SECTION IV. LEVEL 2 ANALYSIS PROCEDURES

DECISION MAKING FRAMEWORK



OVERVIEW

As noted earlier, the decision-making framework consists of increasingly detailed and rigorous levels of analysis to which alternatives are subjected. For example, as in Level 1 analysis of highway operations, average daily statistics for the probability and duration of motorist delay associated with the at-grade crossing are calculated and compared to benchmarks to determine whether the at-grade crossing alternative is unacceptable from a highway operations perspective. If it is not clearly unacceptable on this basis, the alternative is to be carried over to Level 2 analysis in which consideration of highway operations proceeds to the estimation of delay statistics on an hourly basis and also is expanded to include other variables (e.g., queuing). Table A-5 lists the evaluation factors considered in Levels 1 and 2 for all areas of concern to provide an overview of this progression for the subject areas.

In addition to providing for more detailed and more rigorous analysis of alternatives in Level 2, the focus shifts from comparing each alternative against minimum acceptable criteria to a relative comparison among alternatives. As noted with the analysis of highway operations in Level 1, the delay statistics for the at-grade crossing alternative are compared to benchmarks to determine acceptability/unacceptability. In Level 2, the highway operations (and other impacts) of each alternative are compared against one another to determine which alternative is preferable.

LEVEL 2 ENGINEERING

In Level 1 analysis, only a conceptual engineering definition of alternatives was needed to support the analytical process. Level 2 analysis, however, requires a more precise definition of the alternatives that survived Level 1 screening. Thus, prior to conducting the second level of analysis a further engineering definition of each of the remaining alternatives is prepared. In addition to more detailed specification of the alternatives, modifications may be made to eliminate or mitigate objectionable characteristics. For example, in Case Study 1 (Appen. B) a turnaround for school buses was incorporated into the at-grade alternative to allow school buses to avoid passing through the crossing for a convenient place to turn around. This change reduced potential school bus/train conflicts and improved the safety of the alternative.

Refinement of the alternatives should be made at a larger scale than Level 1 engineering. A scale of 1:50 is more appropriate for alignments at this level. Also, bridge components of each alternative must be specified in order to support accurate cost estimation and determination of right-of-way requirements. Refer to the sections on cost and land use below, which elaborate these requirements.

LEVEL 2 ANALYSIS

In Level 2 analysis, each alternative is examined with regard to its implications in each of the five subject areas: (1) cost, (2) safety, (3) rail and highway operations, (4) environment, and (5) institutional considerations.

To facilitate use of the framework, this part of the *User's Guide* is divided into six sections. The first five sections present the issues to be addressed in each of the five subject areas. Each begins with a definition of the issues and factors to be addressed

Table A-5. Factors by analysis level.

Subject Areas/Factors	Decision Framework Analysis Level 1	Level 2	Level 3
COSTS			
Physical Feasibility	X		
Capital Costs		X	X
Operations & Maintenance Costs			X
SAFETY			
Accident Exposure	X		
Accident Frequency		X	X
Fatal Accidents		X	X
Injury Accidents		X	X
School Bus Crossings			X
Hazardous Materials Crossings			X
Pedestrian/Bicyclist Accident Potential Crossings			X
RAIL AND HIGHWAY OPERATIONS			
Vehicular Delay			
Probability	X	X	X
Number	X	X	X
Duration	X	X	X
Emergency Response Time		X	X
Traffic Operations			
Vehicular Queuing		X	X
Capacity Constraint		X	X
Street/Highway Classification			X
Signalization			X
Patterns			X
Rail Operations			
Disruption	X		
Quality		X	X
Cost		X	X
Rail Yard Access		X	X
Switching Operations		X	X
COMMUNITY AND ENVIRONMENTAL CONSIDERATIONS			
Land Use			
Displacement	X	X	X
Disruption			X
Activity Patterns			X
Noise			X
Air Quality			X
Water Quality			X
Aesthetics			X
INSTITUTIONAL CONSTRAINTS			
Laws	X		
Warrants	X		
Policies and Guidelines	X	X	X
Contractual Obligations	X	X	X
Cost Distribution		X	X
Ease of Implementation		X	X
Availability of Funds		X	X

in the analysis of each alternative. The methodology and data requirements for addressing each issue are then presented. The methodology consists of step-by-step analytical procedures for developing quantitative and qualitative information about each alternative in terms of each factor. Thus, under the subject area "Rail and Highway Operations," for example, procedures for estimating the magnitude of the "vehicular delay" factors are described.

The sixth section presents techniques for comparatively evaluating alternatives. Various techniques—balance sheets, measures of effectiveness, and cost analysis—are discussed in terms of their usefulness in identifying the preferred alternative.

Cost

The Issues

- What are the costs associated with each alternative?
- How do costs associated with each alternative compare with available funding from federal, state, local, railroad, or other parties associated with implementation of each alternative?

As noted above, additional engineering is undertaken for the alternatives retained for Level 2 analysis. Detail contained in this engineering work is used for the Level 2 conceptual cost estimate. The better understanding of the alternatives at this level permits an assessment of needed funding for each alternative.

The thrust of the cost analysis is a comparison of costs, both to all involved parties, and to each party individually, for each of the alternatives. All other things being equal, the least-cost alternative is generally preferred, although the decision is complicated by considering funding sources and the costs to each participating government agency and to the private source.

Units of measurement include dollars of capital cost, total and annualized; and project cost as percent of available budget.

Methodology

Capital costs refers to all costs associated with construction of the structure and approaches. This would include costs related to the actual construction of the structure such as maintenance of traffic, relocation of utilities, and land takings for both the actual structure as well as for temporary construction uses.

Capital costs are incurred starting from the time engineering design begins to acceptance of the completed structure by the responsible government agency and/or railroad. Beyond this period, costs would fall into the category of maintenance/operating costs, which are not considered until Level 3 analysis.

Determination of Capital Costs
Analysis Steps

1. Obtain initial engineering plans and specifications.
2. Quantify major construction cost elements.
3. Estimate major construction costs by element.
4. Calculate total capital construction costs.
5. Calculate annualized capital construction costs.

In Level 2 analysis capital costs are estimated as a function of major construction cost elements and are not all-inclusive cost estimates. However, the major construction cost elements listed below comprise the majority (e.g., 90 percent) of the total cost for an alternative and, by taking into account a contingency sum (about 15 percent), provide an accurate (within 10 percent) estimate of the ultimate cost of each alternative.

The design plans, developed in the initial engineering phase, are used to determine quantities of construction elements, which are then priced. Elements to be considered include the following:

1. *Right-of-way*—estimate of acreage beyond existing right-of-way; fair market value for this land and structures on the land.
2. *Relocation of residences and buildings*—approximate dollar value, generally based on state policy, of sums paid to residents and business proprietors to vacate their properties and move to another location. Partial land taking which does not require relocation of occupants is not considered. Relocation monies owed actual residents and business owners, not absentee landlords or employees, only are considered.
3. *Grade separation structure*—unit cost prices, often expressed as dollars per square foot of structure, can be obtained from a study of recently built structures of a similar type through state bid tabs, *Engineering News Record,* or other common estimator reference materials.
4. *Roadway and drainage*—approximate cost of the approaches and roadway, obtained from sources cited earlier.
5. *Maintenance of traffic*—a lump sum figure. Cost of maintaining traffic during construction including alternative routes or use of a temporary bridge.
6. *Protection shield*—a lump sum figure, obtained from previously cited sources, included if traffic is maintained beneath the structure. (A *protection* shield is a device used to prevent debris from falling onto traffic operating beneath a bridge.)
7. *Lighting*—per fixture cost. Number of fixtures is estimated at this level.
8. *Major excavation*—approximate unit cost applied to approximate volume. Major excavation costs are considered only where excavation is unusually high, such as lowering the grade of the facility using the structure to create an at-grade crossing.
9. *Demolition*—a lump sum figure, obtained from previously cited sources.
10. *Crossing devices and crossing surface*—a lump sum figure obtained from previously cited sources.
11. *Design*—5 to 10 percent of construction cost based on transportation agency experience.
12. *Other*—estimated costs associated with utility relocation, site preparation, or other items unique to the particular project.

Annualized capital costs refers to the annual cost equivalent of total construction cost in current dollars.

To fairly compare costs of the alternatives, annualized costs should be used. The reason for using annualized costs is to account for differences in the expected life of the various alternatives. Consider the following comparison of two alternatives:

Alternatives	Total Capital Cost	Expected Life (years)	Annualized Capital Cost
A	$1,719,000	50	$80,019
B	$1,024,000	25	$65,548
A-B	$ 695,000	25	$28,000
A/B	1.68	2	1.22

Without accounting for the expected life of each alternative, alternative A is estimated to be 68 percent more costly than B. However, because the expected life of B is only one-half that of A, a more accurate estimate of the difference between the alternatives is 22 percent. That is, the annualized cost accounts for the fact that alternative B will have to be rebuilt at additional capital cost while alternative A will not. Accounting for this additional cost by means of annualized cost puts the two alternatives on equal footing for comparison purposes.

The annualized cost of each alternative can be determined using the following formula:

$$A = C\left[\frac{i\,(1+i)^n}{(1+i)n - 1}\right]$$

where A = annualized cost, C = current construction cost, i = interest rate, and n = lifespan in years.

To make this computation, one must decide what interest rate or discount factor to use. Most states have established such rates for investment analyses and, if available, these rates should be used. Typically, the rates range between 4 percent and 6 percent. These rates are exclusive of inflation and apply insofar as projected costs do not include an inflation component. *OMB CircularA-94,* on the other hand, calls for use of a 10 percent discount rate for economic analysis work done by federal agencies. For a discussion of discount rate, one reference is *The Economic Cost to Society of Motor Vehicle Accidents,* National Highway Traffic Safety Administration, USDOT, Washington, D.C., 1983.

Also, it is useful to estimate annualized costs based on a range of discount factors to test the effect on the outcome.

n	=	Rehabilitation	30 years
		Replace	50 years
		Put at-grade	25 years
		Close the road	100 years
		Close the rail line	100 years

For example, for a $2,500,000 structure to replace an existing structure, the computation would be as follows:

$$\begin{aligned} A &= \$2{,}500{,}000\ [0.04(1+0.04)^{50}/(1+0.04)^{50} - 1] \\ &= \$2{,}500{,}000\ [0.2843/6.1067] \\ &= \$\ 116{,}388 \end{aligned}$$

Safety

The Issue

> What is the expected accident frequency and accident severity for each alternative?

Safety clearly is a very important consideration in deciding among crossing improvement alternatives, and each of the six generic alternatives has safety implications.

Two types of accidents are associated with the alternatives: (1) individual-vehicle and multiple-vehicle accidents that occur on the highway or bridge structure, and (2) railroad/highway crossing accidents involving a train and a vehicle(s). Preferably, one would estimate both types of accidents associated with each alternative so that the alternatives could be compared in terms of safety. Unfortunately, no dependable methods exist to distinguish among alternatives in terms of the first type of accidents noted above. For example, no methods are available to estimate the number of accidents that may occur on a new grade-separated crossing or that would occur in the vicinity of an at-grade crossing. On the other hand, accurate predictions of rail/highway crossings can be made using the USDOT accident prediction formulas.

In this context, only rail/highway crossing accidents are considered under the safety factor. In most situations, the exclusion of other types of accidents from the analysis is not problematic; one can reasonably assume in most cases that these accidents are not as important as rail/highway accidents because of their considerably lesser severity when an accident occurs and that the probability of accidents associated with a grade separation is not materially different from the accident probability in the vicinity of a crossing. If the analyst has available data which may suggest otherwise (e.g., accident histories for similar structures and similar at-grade crossings), it is recommended that this information be incorporated into the analysis. In most situations, however, such data are unavailable or the cost to obtain them is prohibitive.

Units of measurement include: potential number of annual accidents, potential number of accidents and injuries, and potential number of accidents and fatalities.

Methodology

As noted above, only techniques to compute accident potential for grade-crossing accidents are presented. Grade-crossing accidents could occur under the at-grade alternative. Also, with the close-the-rail-line alternative and the close-the-road alternative, crossing accidents could occur should trains or vehicles be diverted to locations with grade crossings.

> At-Grade Crossing Alternative
> Analysis Steps
>
> 1. Apply the USDOT accident prediction formulas to derive estimates of total accidents, injury accidents, and fatal accidents. (See Tables A-10 through A-15.)
> 2. Determine the number of injuries and fatal accidents into number of fatalities, using injury/injury accident and fatalities/fatal accidents obtainable from the Federal Railroad Administration Office of Safety. For 1982-1984, these rates are 1.44 and 1.23, respectively, for all public crossings.
> 3. Record results in the Level 2 Safety Matrix.

At-Grade Crossing. For the at-grade crossing alternative, an in-house accident prediction model can be used if one is available. However, the accident prediction formulas developed by the U.S. Department of Transportation, which can be used to predict total, injury, and fatal accidents at rail/highway grade crossings, are recommended because they have been found to provide results superior to other models. (See, for example, *Evaluation of Methods for Predicting Rail-Highway Crossing Hazards,* Ardeshir Faghri and Michael J. Demetsky, Virginia Highway & Transportation Research Council, Charlottesville, Virginia, March 1986.)

The DOT accident prediction formula predicts the number of annual accidents that may occur at a grade crossing on the basis of physical characteristics of the crossing. The final prediction for a given crossing is a weighted average of the accidents predicted by a basic formula and the annual average of historical accidents. The second element of the accident prediction formula, the annual average of historical accidents, is not included here because it can be applied only in the case of an existing at-grade crossing.

Non-train accidents at grade crossings, such as rear-end vehicular collisions, cannot easily be predicted. Roadway geometrics, vehicle mix, roadway lighting, adjacent land uses, and a variety of other factors make non-train accident prediction too complicated for this analysis.

The basic formula is derived from of three nonlinear multiple regression equations, each of which predicts annual accidents at crossings with a particular category of warning device: passive, flashing lights, or gates. Each of these categories encompasses one or more types of warning device.

The three prediction equations were developed using data on the physical and operating characteristics of grade crossings, contained in the joint USDOT-AAR (Association of American Railroads) National Rail-Highway Crossing Inventory and corresponding accident data compiled by the Federal Railroad Administration's Railroad Accident/Incident Reporting System. Specifically, the aforementioned nonlinear multiple regression techniques were applied to the 1976 accident file and the August 1976 crossing inventory to develop and test the basic formula. (Check with FRA's Office of Safety for updates.)

The data elements required for predicting annual accidents for a crossing are: (1) the exposure index, which is the product of highway traffic (AADT) and train traffic (ADTT), (2) the number of main railroad tracks, (3) the number of through trains per day during daylight hours, (4) the road surface (i.e., whether or not it is paved), (5) the maximum timetable train speed, (6) the road classification (e.g., urban principal arterial, rural minor collector, etc.), (7) the number of travel lanes.

These crossing characteristic factors are incorporated in Tables A-6 through A-9, which enable the user to quickly identify the numerical value of each factor and to compute the predicted annual accidents. The data can be obtained from the railroad and the state or local highway agency.

Once annual motor vehicle accidents at the replacement grade crossing have been calculated, USDOT accident severity prediction formulas can be used to predict annual injury and fatality accidents. The accident severity prediction formula consists of two multiple regression equations (developed with 1978–1980 accident/incident and rail/highway crossing inventory data), which determine the probability that an accident will result in an injury or fatality.

The grade crossing characteristics needed to predict annual accidents involving a fatality are: maximum timetable train speed, the number of through trains per day, the number of switch trains per day, and the urban/rural location of the crossing. The data inputs for the injury probability prediction equation are maximum timetable train speed, total number of main tracks, and urban/rural location. The values of crossing characteristics are provided in Tables A-10 and A-11.

Close the Crossing Alternative
Analysis Steps

1. Determine routes to which traffic using the existing crossing would be diverted if the crossing were closed. Also, compute the volume of traffic diverted to each alternate route.
2. If the alternate routes include at-grade crossings, use the USDOT formulas to compute estimates of the change in accident frequency and severity that might occur. Follow the steps shown for the at-grade alternative, but include the accident history adjustments. The change is the difference in accidents prediction with and without the diverted traffic.

Closing the Crossing. Closing the road will cause a change in accident potential at the existing crossing by diverting traffic to another crossing or less safe/more safe highway segments. The method used to estimate traffic diversion associated with this alternative is presented under "Rail and Highway Operations" Level 2 analysis.

If alternate routes include at-grade crossings, it is recommended that the USDOT prediction formulas be used to estimate accident potential for the close the road option. Instructions for using this method are described earlier under the at-grade alternative analysis methods. In this case, however, the predicted accidents should be adjusted based on historical accident experience of the at-grade crossing(s) through which traffic will be diverted.

Close the Rail Line Alternative
Analysis Steps

1. If there are no train operations on the rail line enter zeroes in the Level 2 Safety Matrix.
2. If there are train operations on the line which would be diverted to another line, use the USDOT accident prediction formulas to calculate expected accidents at all at-grade crossings on both rail lines under current conditions and assuming closure of the subject line.
3. Compute the change in expected accidents (total, fatal, and injury) and fatalities and injuries over all crossings on the two lines. Enter this result in the Level 2 Safety Matrix.

Closing the Rail Line. Closing the rail line involves tearing down the grade-separated structure and paving over the rail line. While accidents may occur at this location after the crossing is eliminated, it is highly likely that the number of such accidents will approach zero and a zero entry for accident potential for this alternative should be recorded. On the other hand, should closing the rail line involve diversion of train operations to other rail lines with at-grade crossings, a change in accidents at these crossings and crossings at other locations on the line to be closed should be considered. This can be done by using the USDOT formulas presented above to compute the predicted before and after conditions at grade crossings on the line to be closed and on the line to which rail operations would be diverted. The difference between the before and after estimates would be included as the expected safety effect of this alternative.

Table A-6. Equations for crossing characteristic factor.

GENERAL FORM OF BASIC ACCIDENT PREDICTION FORMULA: $a = K \times EI \times MT \times DT \times HP \times MS \times HT \times HL$

CROSSING CATEGORY	FORMULA CONSTANT K	EXPOSURE INDEX FACTOR EI	MAIN TRACKS FACTOR MT	DAY THRU TRAINS FACTOR DT	HIGHWAY PAVED FACTOR HP	MAXIMUM SPEED FACTOR MS	HIGHWAY TYPE FACTOR HT	HIGHWAY LANES FACTOR HL
	CROSSING CHARACTERISTIC FACTORS							
PASSIVE	0.002268	$((c \times t + 0.2)/0.2)^{0.3334}$	$e^{0.2094mt}$	$((d + 0.2)/0.2)^{0.1336}$	$e^{-0.6160(hp-1)}$	$e^{0.0077ms}$	$e^{-0.1000(ht-1)}$	1.0
FLASHING LIGHTS	0.003646	$((c \times t + 0.2)/0.2)^{0.2953}$	$e^{0.1088mt}$	$((d + 0.2)/0.2)^{0.0470}$	1.0	1.0	1.0	$e^{0.1380(hl-1)}$
GATES	0.001088	$((c \times t + 0.2)/0.2)^{0.3116}$	$e^{0.2912mt}$	1.0	1.0	1.0	1.0	$e^{0.1036(hl-1)}$

c = annual average number of highway vehicles per day (total both directions)

t = average total train movements per day

mt = number of main tracks

d = average number of thru trains per day during daylight

hp = highway paved, yes = 1.0, no = 2.0

ms = maximum timetable speed, mph

ht = highway type factor value

hl = number of highway lanes

HIGHWAY TYPE	INVENTORY CODE	ht VALUE
RURAL		
Interstate	01	1
Other principal arterial	02	2
Minor arterial	06	3
Major collector	07	4
Minor collector	08	5
Local	09	6
URBAN		
Interstate	11	1
Other freeway and expressway	12	2
Other principal arterial	14	3
Minor arterial	16	4
Collector	17	5
Local	19	6

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Source: Rail-Highway Crossing Resource Allocation Procedure User's Guide Washington, D.C.: U.S. Department of Transportation, 1982, Table 3-6.

Table A-7. Factor values for crossings with passive warning devices.

GENERAL FORM OF BASIC ACCIDENT PREDICTION FORMULA: a = K x EI x MT x DT x HP x MS x HT x HL

K	"c" x "t"	EI	Main Tracks	MT	Day Thru Trains	DT	Highway Paved	HP	Maximum Timetable Speed	MS	Highway Type Code**	HT	Highway Lanes	HL
0.002268	0*	1.00	0	1.00	0	1.00	1 (yes)	1.00	0	1.00	01&11	1.00	1	1.00
	1- 5	2.22	1	1.23	1	1.27			5	1.04			2	1.00
	6- 10	3.30	2	1.52	2	1.38	2 (no)	0.54	10	1.08	02&12	0.90	3	1.00
	11- 20	4.24	3	1.87	3	1.45			15	1.12			4	1.00
	21- 30	5.01	4	2.31	4	1.50			20	1.17	06&14	0.82	5	1.00
	31- 50	5.86	5	2.85	5	1.55			25	1.21			6	1.00
	51- 80	6.89	6	3.51	6	1.58			30	1.26	07&16	0.74	7	1.00
	81- 120	7.95			7	1.61			35	1.31			8	1.00
	121- 200	9.29			8	1.64			40	1.36	08&17	0.67	9	1.00
	201- 300	10.78			9	1.67			45	1.41				
	301- 400	12.06			10	1.69			50	1.47	09&19	0.61		
	401- 500	13.11			11-20	1.78			55	1.53				
	501- 600	14.02			21-30	1.91			60	1.59				
	601- 700	14.82			31-40	2.00			65	1.65				
	701- 1000	16.21			41-60	2.09			70	1.71				
	1001- 1300	17.93							75	1.78				
	1301- 1600	19.37							80	1.85				
	1601- 2000	20.81							85	1.92				
	2001- 2500	22.42							90	2.00				
	2501- 3000	23.97												
	3001- 4000	25.98												
	4001- 6000	29.26												
	6001- 8000	32.73												
	8001- 10000	35.59												
	10001- 15000	39.71												
	15001- 20000	44.43												
	20001- 25000	48.31												
	25001- 30000	51.65												
	30001- 40000	55.98												
	40001- 50000	60.87												
	50001- 60000	65.08												
	60001- 70000	68.81												
	70001- 90000	73.74												
	90001- 110000	79.44												
	110001- 130000	84.42												
	130001- 180000	91.94												
	180001- 230000	100.92												
	230001- 300000	109.94												
	300001- 370000	118.87												

K = formula constant
"c" x "t" = number of highway vehicles per day, "c", multiplied by total train movements per day, "t"
EI = exposure index factor
MT = main tracks factor
DT = day thru trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HT = highway type factor
HL = highway lanes factor

* Less than one train per day.
** For definition of highway type codes, see Table 3-6.

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Source: **Rail-Highway Crossing Resource Allocation Procedure User's Guide** **Washington, D.C.: U.S. Department of Transportation, 1982,** Table 3-7.

Table A-8. Factor values for crossings with flashing light warning devices.

GENERAL FORM OF BASIC ACCIDENT PREDICTION FORMULA: a = K x EI x MT x DT x HP x MS x HT x HL

K	"c" x "t"	EI	Main Tracks	MT	Day Thru Trains	DT	Highway Paved	HP	Maximum Timetable Speed	MS	Highway Type Code**	HT	Highway Lanes	HL
0.003646	0*	1.00	0	1.00	0	1.00	1 (yes)	1.00	0	1.00	01&11	1.00	1	1.00
	1- 5	2.27	1	1.11	1	1.09			5	1.00			2	1.15
	6- 10	2.99	2	1.24	2	1.12	2 (no)	1.00	10	1.00	02&12	1.00	3	1.32
	11- 20	3.59	3	1.39	3	1.14			15	1.00			4	1.51
	21- 30	4.17	4	1.55	4	1.15			20	1.00	06&14	1.00	5	1.74
	31- 50	4.79	5	1.72	5	1.17			25	1.00			6	1.99
	51- 80	5.52	6	1.92	6	1.18			30	1.00	07&16	1.00	7	2.29
	81- 120	6.27			7	1.18			35	1.00			8	2.63
	121- 200	7.20			8	1.19			40	1.00	08&17	1.00	9	3.02
	201- 300	8.22			9	1.20			45	1.00				
	301- 400	9.07			10	1.20			50	1.00	09&19	1.00		
	401- 500	9.77			11-20	1.23			55	1.00				
	501- 600	10.37			21-30	1.26			60	1.00				
	601- 700	10.89			31-40	1.28			65	1.00				
	701- 1000	11.79			41-60	1.30			70	1.00				
	1001- 1300	12.89							75	1.00				
	1301- 1600	13.80							80	1.00				
	1601- 2000	14.71							85	1.00				
	2001- 2500	15.72							90	1.00				
	2501- 3000	16.67												
	3001- 4000	17.91												
	4001- 6000	19.89												
	6001- 8000	21.97												
	8001- 10000	23.66												
	10001- 15000	26.08												
	15001- 20000	28.80												
	20001- 25000	31.02												
	25001- 30000	32.91												
	30001- 40000	35.34												
	40001- 50000	38.06												
	50001- 60000	40.39												
	60001- 70000	42.43												
	70001- 90000	45.11												
	90001- 110000	48.18												
	110001- 130000	50.85												
	130001- 180000	54.84												
	180001- 230000	59.56												
	230001- 300000	64.25												
	300001- 370000	68.86												

K = formula constant
"c" x "t" = number of highway vehicles per day, "c", multiplied by total train movements per day, "t"
EI = exposure index factor
MT = main tracks factor
DT = day thru trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HT = highway type factor
HL = highway lanes factor

* Less than one train per day.
** For definition of highway type codes, see Table 3-6.

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Source: **Rail-Highway Crossing Resource Allocation Procedure User's Guide**
Washington, D.C.: U.S. Department of Transportation, 1982, Table 3-8.

Table A-9. Factor values for crossings with gate warning devices.

GENERAL FORM OF BASIC ACCIDENT PREDICTION FORMULA: a = K x EI x MT x DT x HP x MS x HT x HL

K	"c" x "t"	EI	Main Tracks	MT	Day Thru Trains	DT	Highway Paved	HP	Maximum Timetable Speed	MS	Highway Type Code**	HT	Highway Lanes	HL
0.001088	0*	1.00	0	1.00	0	1.00	1 (yes)	1.00	0	1.00	01&11	1.00	1	1.00
	1- 5	2.37	1	1.34	1	1.00			5	1.00			2	1.11
	6- 10	3.18	2	1.79	2	1.00	2 (no)	1.00	10	1.00	02&12	1.00	3	1.23
	11- 20	3.86	3	2.40	3	1.00			15	1.00			4	1.36
	21- 30	4.51	4	3.21	4	1.00			20	1.00	06&14	1.00	5	1.51
	31- 50	5.22	5	4.29	5	1.00			25	1.00			6	1.68
	51- 80	6.07	6	5.74	6	1.00			30	1.00	07&16	1.00	7	1.86
	81- 120	6.94			7	1.00			35	1.00			8	2.07
	121- 200	8.03			8	1.00			40	1.00	08&17	1.00	9	2.29
	201- 300	9.23			9	1.00			45	1.00				
	301- 400	10.25			10	1.00			50	1.00	09&19	1.00		
	401- 500	11.08			11-20	1.00			55	1.00				
	501- 600	11.80			21-30	1.00			60	1.00				
	601- 700	12.43			31-40	1.00			65	1.00				
	701- 1000	13.51			41-60	1.00			70	1.00				
	1001- 1300	14.84							75	1.00				
	1301- 1600	15.96							80	1.00				
	1601- 2000	17.07							85	1.00				
	2001- 2500	18.30							90	1.00				
	2501- 3000	19.48												
	3001- 4000	21.00												
	4001- 6000	23.46												
	6001- 8000	26.06												
	8001- 10000	28.18												
	10001- 15000	31.22												
	15001- 20000	34.67												
	20001- 25000	37.49												
	25001- 30000	39.91												
	30001- 40000	43.03												
	40001- 50000	46.53												
	50001- 60000	49.53												
	60001- 70000	52.18												
	70001- 90000	55.67												
	90001- 110000	59.68												
	110001- 130000	63.16												
	130001- 180000	68.41												
	180001- 230000	74.63												
	230001- 300000	80.85												
	300001- 370000	86.98												

K = formula constant
"c" x "t" = number of highway vehicles per day, "c", multiplied by total train movements per day, "t"
EI = exposure index factor
MT = main tracks factor
DT = day thru trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HT = highway type factor
HL = highway lanes factor

* Less than one train per day.
** For definition of highway type codes, see Table 3-6.

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Source: Rail-Highway Crossing Resource Allocation Procedure User's Guide Washington, D.C.: U.S. Department of Transportation, 1982, Table 3-9.

Table A-10. Factor values for total accident probability formula.

Fatal Accident Probability Formula: $P(FA|A) = 1/(1 + CF \times MS \times TT \times TS \times UR)$

FORMULA CONSTANT CF	MAXIMUM TIMETABLE TRAIN SPEED	MS	THRU TRAINS PER DAY	TT	SWITCH TRAINS PER DAY	TS	URBAN-RURAL CROSSING	UR
695.0	1	1.000	0	1.000	0	1.000	0 (rural)	1.000
	5	0.178	1	0.931	1	1.074		
	10	0.084	2	0.894	2	1.119	1 (urban)	1.207
	15	0.055	3	0.868	3	1.152		
	20	0.040	4	0.848	4	1.179		
	25	0.032	5	0.832	5	1.202		
	30	0.026	6	0.819	6	2.221		
	40	0.019	7	0.808	7	1.238		
	50	0.015	9	0.790	9	1.266		
	60	0.012	10	0.782	10	1.279		
	70	0.010	20	0.732	20	1.366		
	80	0.009	30	0.703	30	1.422		
	90	0.008	40	0.683	40	1.464		
	100	0.007	50	0.668	50	1.497		

Source: Accident Severity Prediction Formula for Rail-Highway Crossings. Washington, D.C.: U.S. Department of Transportation, 1984, Table 3-3.

Table A-11. Factor values for injury accident probability formulas.

Injury Accident Probability Formula: $P(IA|A) = \left[1 - P(FA|A)\right]/(1 + CI \times MS \times TK \times UR)$

FATAL ACCIDENT PROBABILITY, P(FA!A)	FORMULA CONSTANT CI	MAXIMUM TIMETABLE TRAIN SPEED	MS	TOTAL NUMBER OF TRACKS	TK	URBAN-RURAL CROSSING	UR
See Equation 3-8 and Tables 3-1 & 3-3	4.280	1	1.000	0	1.000	0 (rural	1.000
		5	0.687	1	1.125	1 (urban)	1.202
		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: Accident Severity Prediction Formula for Rail-Highway Crossings. Washington, D.C.: U.S. Department of Transportation, 1984, Table 3-4.

Rail and Highway Operations

The Issues

- How much vehicular delay at the crossing would result from implementing the alternative?
- Would delay resulting from the proposed configuration result in a significant increase in travel time on a daily basis?
- Would delay at the crossing by an emergency response vehicle result in excessive response time?
- Will queuing at the crossing result in the temporary blockage of intersecting streets, alleys, driveways, or vital service facilities such as police stations, fire houses, or hospital ambulance entrances?
- Would traffic diversion resulting from the alternative increase traffic on alternate routes beyond the capacity of the routes?
- Does closing the railroad impair or eliminate access to a rail yard?
- Are switching operations currently performed on the crossing which would be adversely affected by the proposed alternative?
- Could existing service be rerouted to alternative routes or modes?

In Level 2 analysis of rail and highway operations, the scope of the study expands beyond that of Level 1 in two major ways. First, the impacts to users of the crossing, both train and vehicular, are examined in greater detail. For example, rail and highway operations are studied in Level 2 on an hour-by-hour basis over a full, typical day. In Level 1 analysis, daily averages rather than hourly averages are used to estimate impacts.

Level 2 analysis also introduces new factors into the examination of alternatives. Eight factors are considered in Level 2 analysis under rail and highway operations. These eight include three factors initially investigated in Level 1, including: (1) crossing delay, (2) detour delay, (3) rail service quality and cost.

Factors considered for the first time in Level 2 analysis are the following:

1. *Emergency response time* must be determined in the cases of close highway, at-grade, and relocate crossing. Rerouting of the emergency vehicle or emergency response personnel, or delay at an at-grade crossing, will increase total response time. This increase must be considered relative to response times needed for timely delivery of emergency services.

2. *Vehicle queuing* results when a flow of traffic is interrupted, for example, by a traffic signal or passage of a train at-grade across a highway. The resulting queue, in turn, can potentially block other roads, alleys, or driveways and result in delay beyond the confines of the crossing. Queuing is analyzed by determining the length of the queue during the time period considered and determining the extent to which adjacent thoroughfares are affected.

3. *Capacity constraint on detour routes* addresses the carrying capacity of the alternative routes. This sub-factor is used for the highway closure option and relocation if this option changes the connections within the highway network. Traffic diverted from one route to another will be added to existing traffic on the new route. The carrying capacity of the new route may be approached or exceeded indicating future problems for the traffic network and nonfeasibility of the option.

4. *Rail yard isolation* can result where the sole rail line into the yard is removed as part of the close road alternative. If the rail yard serves lines other than the line considered, this sub-factor will preclude the close road alternative unless functions performed in the yard can be located to another facility.

5. *Switching operations* which currently occur on a crossing can be affected if the rail line is closed or an at-grade crossing is installed. The nature of the switching operation and the ability to move it to another location may affect these alternatives.

Units of measurement include the following:

1. *Vehicular Travel Time* (number of vehicles delayed or rerouted per day, increase in trip time per vehicle delayed or rerouted—average and range in minutes, percentage increase in trip time, significance of changes in travel time).
2. *Vehicle Queuing* (number of times per day a queue causing access problems occurs, seriousness of the queuing problem).
3. *Capacity Constraint* (change in volume/capacity ratio on alternate routes, significance of increases in the ratio relative to level of service).
4. *Emergency Services* (change in response time, number of responses affected, percentage of responses affected, significance of change).
5. *Rail Operations* (change in services available, change in service quality, change in operating costs, change in capital costs).

Methodology

Following is a discussion of each rail and highway operations factor considered in Level 2 analysis. The factor is defined and procedures for its consideration delineated. Results of the analysis of each factor may be recorded in the Rail and Highway Operations Matrix shown in Table A-14.

Delay at the Crossing
Analysis Steps

1. Determine duration of crossing closure.
2. Determine hourly rail and highway volumes.
3. Compute total and average delay per train.
4. Sum total and average delay per hour and per day.

Crossing Delay (At-Grade Alternative). Construction of an at-grade crossing to replace a deteriorated grade-separated crossing will result in delays to highway traffic.

In considering delay, the following statistics are calculated: the amount of time the crossing would be closed, the probability of experiencing a delay, the number of vehicles that would experience delay, and the expected duration of delay per delayed vehicle. It is recommended that computations of this crossing delay be made on an hourly basis to capture differences in the effects of delay at various times of the day (e.g., peak vs. off-peak).

Closed crossing time. To compute the amount of time the crossing would be closed to vehicular traffic by a single train movement, the following formula can be used:

$$T = [50 + [(0.682\ L)/(1.5\ S_e - S_x)]/60$$

where T = the amount of time the crossing is closed (in minutes), during the operation of train movement i through the crossing; L = train length in feet; S = train speed in miles per hour; S_e is speed entering the crossing; S_x is speed exiting the crossing; 50 = a constant which represents the number of seconds the protective warning devices are active before the train arrives in the crossing and after the train leaves the crossing (a constant warning time device is assumed); and 0.682 = conversion from miles/hour to feet/second.

The results of this equation are summed over all train operations to determine the amount of time the crossing would be closed during each hour of the day or for the entire day. Also, as indicated, the computation is based on the average day's rail operations.

To use this formula requires development of a train operations profile, which is a characterization of train movements through the crossing on a typical or average day. The characterization must include data on train length and speed and time of operation for each movement. Similarly, an hourly profile of vehicular traffic through the crossing is required.

Probability of delay. To put delay estimates into perspective, it is helpful to compute the probability of delay, i.e., the percentage of time a delay can be expected to occur or the percentage of motorists who can expect to be delayed. (Another context in which to evaluate delay is change in travel time, discussed in a later section.)

The probability of delay can be viewed from two perspectives: (1) the entire day and (2) period of the day. The computations are straight-forward and are as follows: $P = T/m$, where P = probability of delay, T = time, computed in the previous equation, that the crossing is closed, and m = amount of time for the period under consideration.

Vehicles delayed. To compute the number of vehicles that would be delayed at the crossing for a specified train operation, the following formula can be used: $N = P^* V$, where N = number of vehicles delayed by train operations over a given period of time, V = traffic volume through the crossing during the period of time, T = duration that the crossing is closed over the period of time, and P = the probability of delay from the equation immediately above for the period of time.

Duration of delay. To calculate the total delay experienced by vehicles delayed by train operation i, the following formula can be used:

$$D = [(T/2 + 0.10)\, N + (N/n)^2]/60$$

where D = total delay in minutes experienced by vehicles delayed by train operation, N = number of vehicles delayed (= TV from previous equation), n = number of highway lanes, T = duration of crossing closure, and 0.10 = delay (in seconds) attributable to deceleration and acceleration and delay experienced while waiting for traffic to flow freely after the train has passed. For further explanation, $T/2$ is the average delay per vehicle delayed by the train operation and 10 sec is the amount of added delay due to deceleration of the vehicle as it comes to a stop.

After the crossing is again opened there are N/n vehicles in the queue in each highway lane. If the headway between vehicles is two (2) sec, then the delay for the first vehicle waiting for the queue to dissipate is zero and the delay for the last vehicle waiting for the queue to dissipate is two times N/n. The average delay associated with queue dissipation is then $(2 \times N/n)/2$ and total delay from queue dissipation is $(2 \text{ x } N/n)/2$ times N/n. This equation can be simplified to $(N/n)2$. Average delay for each vehicle delayed is computed as follows: $A_i = D/N$, where A = average delay per vehicle in minutes for vehicles delayed.

Data summary. Results of the analysis can be recorded in a format, as shown in Table A-13. Hourly totals of vehicle volume in both directions, vehicles delayed throughout each hour, percent of total vehicles delayed, average delay per delayed vehicle, total vehicle delay time, and duration of crossing closure per hour are listed. Daily totals should be recorded in the summary matrix, Table A-14.

Vehicular Travel Time (Replace At-Grade, Relocate Crossing, and Close the Road Alternatives). Delay, when considering either relocating or closing the road through the crossing is determined by comparing current travel time with travel time that would result from implementation of the alternative. The analysis involves developing estimates of the changes in travel time for vehicles currently using the crossing associated with alternate routings.

Comparison is made between travel time from common origins to common destinations (representative trips) through the crossing before and after the crossing is reconfigured. Representative trips were identified in Level 1 analysis of rail and highway operations; before proceeding with Level 2 analysis, consideration should be given to adding more trips if a more accurate picture is desired.

Change in Travel Time
Analysis Steps

1. Identify representative trips (origin/destination pairs) of traffic currently using the crossing.
2. Identify alternative routes between the principal origin/destination pairs for the alternatives which close the existing crossing (i.e., the close the road and relocate the crossing alternatives). See "Capacity Constraint" for method to identify alternate routes.
3. Estimate the increase in travel time for each representative trip incurred as a result of crossing delay or rerouting of traffic.
4. Calculate the percentage change in travel time for each representative trip.
5. Calculate the daily number of vehicles which would experience the increased time.

Three statistics are calculated for this analysis: (1) the change in travel time for representative trips in minutes, (2) percentage change in travel time for representative trips, (3) number of vehicles delayed per day. No attempt is made to assign traffic among the representative trips. Rather, the analysis reviews each trip to develop an understanding of the range of delay expected by alternative.

Computing the changes in travel times that would be associated with each alternative depends on the alternative. For the close the highway and relocate the structure alternatives, the new travel time is a function of new routes used by motorists between origins and destinations. For the at-grade alternative, the new travel time is a function of the probability of a change in travel time and the change in time through the crossing.

Close the Highway and Relocate Alternatives. Change in travel time is calculated by subtracting current travel time between representative origin and destination pairs from the estimated time using the alternate route. In the example presented below under "Capacity Constraint," 200 vehicles are assumed to travel between point D and point C. Time via route F-A-B-C is subtracted from time via route D-E-F. The difference in time is then multiplied by the number of vehicles to determine total change for this portion of trips through the crossing. This process is then repeated for the 200 vehicles approaching from the east which will use crossing H and the 100 vehicles approaching from the north which will use crossing E. The process is also repeated for the vehicles traveling north through the crossing. The entire process is repeated for the rest of the day on an hourly or time period basis. If one or more adjacent crossings are at-grade, changes in travel time through that crossing should be computed and added to changes caused by rerouting of traffic. The computation is expected (or average) change at the crossing times the probability that travel time will change. Formulas for making this computation are shown above in the section, "Crossing Delay."

Because traffic through the crossing is not allocated equally among the representative trips—this could require an origin/destination study, which is not warranted at this level of analysis—it is not possible to develop a weighted average increase/decrease in trip time for all vehicles. One can, however, select the increase/decrease in trip time which represents the typical case based on an understanding of the roadway network, community characteristics, including the distribution of employment, population, and activity centers, and trip types.

After the addition/reduction in travel time is estimated, the percentage change in travel time is computed. This calculation provides a context in which to evaluate the significance of the change. For example, a 2-min increase in time for a half-hour trip is not as significant a change as a 2-min addition to a 5-min trip. The percentage change in travel time is computed for each of the representative trips and the range recorded in the summary matrix (Table A-14) along with the number of trips affected.

Vehicle Queuing
Analysis Steps

1. Obtain estimates of closed crossing time and number of vehicles delayed for each closed crossing occurrence from the "crossing delay" analysis.
2. Compute queue length for each closed crossing occurrence starting with the occurrence in which the largest number of vehicles are delayed.
3. Plot queue lengths on a map to identify locations where queuing would cause access problems (e.g., emergency services driveways, intersections).
4. Count number of times on the typical day queuing would cause access problems.
5. Rate the significance of the queuing problem.

Vehicle Queuing (At-Grade Alternative). The issue to be addressed here is whether queuing at the crossing will result in the temporary blockage of intersecting streets, alleys, driveways, or vital facilities such as police stations, fire house, or hospital ambulance entrances. This queuing analysis should be made for those train operations determined in the analysis of crossing delay above to cause the highest number of delayed vehicles. Starting with the train operation estimated to cause the largest number of delayed vehicles, the following equation can be used to determine whether a queuing problem would be created by the at-grade alternative:

$$L_q = (V_h\, T_i)/(25 \times 60)$$

where L_q = length of queue in feet, V_h = the number of vehicles per hour per lane in the primary direction using the crossing during the time that the subject train operation occurs, T_i = the amount of time in minutes that the crossing is closed during the train operation i (see "crossing delay" analysis above), 60 = minutes in one hour—translates minutes of closed crossing time, T_i, into the percentage of the hour the crossing is closed, and 25 = the average length (in feet) of a vehicle plus the distance between stopped vehicles.

The statistic V_h requires hourly traffic counts by direction. If directional data are unavailable, one can assume a worst case situation (e.g., a 70 percent/30 percent split) to determine whether a queuing problem is created. If it is not, more accurate directional data are unnecessary.

Hourly traffic flow also must be distributed among traffic lanes, should more than one lane in each direction exist. The following factors, when multiplied by average daily traffic in each direction, can be used to make this distribution:

Number of Lanes	Lane Use Factor
1	1.00
2	0.57
3	0.37
4	0.30

These factors account for the unequal distribution of traffic between available lanes.

The queue should be marked on a map, which contains sufficient detail to see cross streets or alleys. Driveways, particularly to police stations, fire houses, and hospital emergency entrances, if in the vicinity of the road, should be noted. Vehicle queuing across any of these facilities is indicative of a potentially significant operations problem. Despite signage which prohibits blocking an intersection, violations do occur. Blockage can delay cross-street traffic, loading operations, and emergency services.

If it is found that a queuing problem is created with the first train operation, the queuing computation and analysis should be performed for the train operation which causes the second largest number of delays. This procedure should be repeated until no queuing problem is created to establish the number of times on an average day that a queuing problem would arise with the at-grade alternative. The number of times on the average day queuing would block access to driveways, streets, etc., should be noted in the summary matrix (Table A-14). The seriousness of the problem in the judgment of the analyst and the basis of that judgment also should be noted in the table. Consistent with value scales used elsewhere in the decision-making framework, the following may be used to describe the potential problem: very significant (VS), significant (S), somewhat significant (SS), and not significant (NS). Calculations and an annotated map should be retained to document the analysis.

Capacity Constraint on Alternate Routes (Close Highway and Relocate Structure Alternatives). The issue here is whether traffic diversion resulting from the alternative would increase traffic on alternate routes beyond their capacity. This analysis should be performed for the peak period of the day using common origins and destinations for representative trips, which were identified in Level 1 analysis of highway operations.

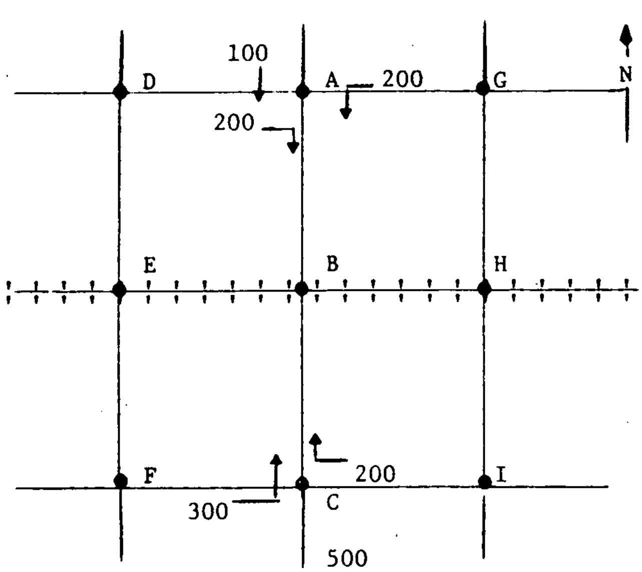
> Capacity Constraint
> Analysis Steps
>
> 1. Identify representative trips (origin/destination pairs) or traffic currently using the crossing.
> 2. Identify alternative routes between the origin/destination pair for the alternatives which close the existing crossing (i.e., the close the road and relocate the crossing alternatives).
> 3. Calculate the current volume/capacity ratio for the alternate routes.
> 4. Calculate the volume/capacity ratio assuming implementation of relevant alternatives.
> 5. Make a judgment regarding the significance of the change.

Identifying alternate routes. Alternate routes for the O/D pairs should be logical connections between the origins and destinations of trips currently passing through the crossing having similar travel times, and offering comparable roadway characteristics. Diversion, for example, from a four-lane arterial onto a two-lane residential street would occur only in cases where larger streets, of width similar to the subject route, do not exist. The peak hour directional volume and number of through lanes for each alternate route should be obtained.

Traffic should then be reassigned from the crossing route to the alternate route using an all-or-nothing assignment. The total volume between each origin-destination pair is assigned to the appropriate detour route. Where numerous detour options exist, traffic counts may be required at each of the intersections between the crossing route and the alternate route.

Traffic volumes through the crossing are reassigned to adjacent crossings based on direction of approach. Reassignment is made to the shortest detour in the case of through volumes. The following simplified example illustrates this procedure.

Considering vehicles approaching the crossing from the north, if crossing B were closed, 200 vehicles would use crossing E



and 200 vehicles would use crossing H. The remaining 100 vehicles would use the shortest route. Assuming that route A-D-E-F-C is shorter than A-G-H-I-C, these 100 vehicles would use crossing E.

Computing volume/capacity ratios. Roadway operation is evaluated through the computation of a volume/capacity (v/c) ratio. Assuming a maximum capacity of 1,500 vehicles per lane per hour, the existing v/c ratio for the crossing and all alternate routes is determined. Diverted traffic is then assigned to the alternate routes and the v/c ratio recomputed.

Traffic operations are evaluated through two related approaches. The v/c ratio should not exceed 1.00 nor should the ratio on one detour substantially exceed that of another detour (assuming similar travel times). If either of these conditions exists, then the reassignment is unrealistic and should be repeated using different routes.

If the v/c ratio on an alternate route increases by a significant amount, say by more than 0.20, this represents a significant increase in congestion and consequently a decrease in highway level of service and should be noted in the summary matrix (Table A-14).

Emergency Services Response Time (Close Highway, Relocate Structure, and At-Grade Alternatives). The issue to be addressed here is whether delay incurred by emergency vehicles as a result of crossing delay, relocation, or closure would result in excessive response time.

Two principal considerations involved in this factor are the probability of experiencing an increase in response time and, given an increase occurs, its magnitude. Information should be obtained from each of the emergency services (police, fire, ambulance) regarding the frequency with which the crossing is used (times per month or year) and the average response time in these cases. It should be noted that in a single emergency more than one crossing may be required (e.g., one crossing to travel to the emergency site and another crossing to travel to the hospital, or one crossing for volunteers to travel to the fire station and another for them to travel to the site of the fire).

Suggested computations for measuring the impact on emergency services are the number and percentage of trips that would be affected, maximum and average time increase, and percentage change in response time. To compute change in response time, the location of calls is needed. If actual data on emergency locations are unavailable, a reasonable surrogate is population distribution.

> Emergency Services Response Time
> Analytical Steps
>
> 1. Obtain data on police, ambulance, and fire services—service area, annual number of responses, number of responses routed through the crossing and number of crossings, average response time through the crossing.
> 2. Estimate absolute and percentage increase in response time associated with rerouting and with crossing delay.
> 3. Estimate number of emergency responses affected.
> 4. Assess the significance of the effect.

For the crossing relocation and close the highway alternatives, all emergency responses previously routed through the crossing will have to be rerouted. In these cases, the delay experienced in responding to emergencies will be equal to the time it takes to use a different route less the time required using the crossing route. Procedures for making estimates of additional time are discussed under "Change in Vehicular Travel Time" above.

For the at-grade alternative, only a portion of the emergency vehicles using the crossing would be delayed. That portion is equal to the percentage of the average day that the crossing is closed by train operations, or $(T_i)/(1440)$, where T_i = the total number of minutes on the average day that the crossing is closed by train operations (see "Crossing Delay" above), and 1440 = minutes in a day. Computation of the average and maximum delay experienced in cases where a delay occurs also is shown in the earlier section on crossing delay.

Evaluation of the effect on emergency services is largely subjective. However, some guidance in making the judgment is available. Regarding fire services, insurance companies can provide information on coverage available as a function of response time. Given this information, one can then calculate current coverage areas and projected coverage areas assuming implementation of an alternative which increases response time.

Regarding medical emergencies, the number of cases in which a delay would be critical for the patient or would otherwise have a detrimental effect on the patient's medical outcome is not large. A study by the Los Angeles Coordinating Council on Emergency Medical Services reports that 5 to 10 percent of medical emergencies are life-threatening situations prior to the provision of emergency medical treatment at the scene. (*Issues and Recommendations Regarding an Emergency Medical Services System for Los Angeles County,* Los Angeles County-wide Coordinating Council on Emergency Medical Services, Los Angeles, California, June 30, 1975, ROP-74E-94-146I.) Once treatment is administered at the scene by the ambulance personnel, this percentage drops considerably. One to 2 percent of all medical emergencies remain life-threatening after receiving on-the-scene treatment and until emergency room treatment is begun. (The statistics for any specific area may vary considerably from these numbers. For example, in St. Paul, Minnesota, the proportion of medical emergencies that are life-threatening prior to on-site treatment is estimated at 25 percent.)

These statistics, then, represent the proportion of patients for whom survival is sensitive to treatment delay. *This does not mean, however, that a delay in treating these victims will be detrimental to them.* For example, one study has found that a lower bound estimate of the proportion of patients for whom prompt emergency room treatment is critical is 0.11 percent of all emergency department patients. "Prompt" in this calculation is defined as receiving on-site treatment within 15 min and emergency room treatment within 70 min of an onset of symptoms or occurrence of injury. The estimate also assumes that the patient would become critical within 30 min of onset of symptoms or occurrence of injury if treatment were not administered.

This calculation reveals the complexity of estimating the consequences of emergency service delays. The consequences depend on the patient's condition as well as the amount of elapsed time prior to administration of treatment. Further, the patient's location relative to the emergency medical service location is important. For instance, in the above example, a 5-min delay at a crossing would not affect patient outcome if the patient is located less than 10 min from the ambulance station. On the other hand, if the patient were located almost 15 min from the station, a delay of only 1 min could be critical.

In the case of police services, delays in response time would seem to cause some reduction in criminal apprehension as well as other services effectiveness. However, unlike fire and ambulance services which operate out of one or a few stationary locations, police services are mobile. This mobility allows police services to be dispatched in a way which can minimize or eliminate rail/highway crossings. Thus, police services are less susceptible to crossing delays than are fire and ambulance services, and need not be considered in the analysis.

Rail Operations

In Level 1 analysis, consideration is given to clearly unacceptable disruption to rail service. In this case, elimination of access to an active rail yard would be cause to reject an alternative during Level 1.

In Level 2 analysis, attention is turned to the magnitude of impact on rail operations in cases where the positive and negative effects of an alternative are not so apparent. Retaining the above example, analysis would focus on the change in rail service and costs if access to a rail yard were reduced rather than eliminated.

Rail Operations
Analysis Steps

1. Collect data on rail operations through the crossing.
2. Obtain from railroads their analysis of the positive and negative aspects of each alternative.
3. Review and confirm railroads' analysis and document the nature and magnitude of the effects—operating effects; potential capital and operating costs to the railroad.
4. Assess the significance of the effect on railroad operations and costs.

To determine the impacts of each alternative on rail operations, the analyst should consult the railroad companies owning the affected rail line and operating on the line. Most railroads have a department within the organization that deals with rail/highway crossing issues. This unit is best equipped to catalogue the positive and negative attributes of each alternative from a railroad operations and cost perspective. Working with this unit, the analyst will be able to document these attributes and develop sufficient information to produce defensible estimates of the magnitude of the effects. Personnel in the rail division of the state transportation agency can assist the analyst both in establishing communication with the railroads and in developing the necessary documentation.

To guide consultation with the railroads, it is first useful to know the types of positive and negative effects each alternative can have on railroad operations. The following examples illustrate potential effects. (Note that operating and maintenance costs of the alternative itself which may be incurred by the railroad are included under the cost area rather than here. Similarly, safety implications are treated under Safety and Institutional Considerations.)

1. Operating speeds—in some cases, train speeds through at-grade crossings must be lower than speeds through grade-separated crossings due to railroad policy or public ordinance.

2. Storage locations—tracks at grade-separated crossings may be used for stopping or temporary storage of trains (e.g., stopping for inspections, to conduct crew changes, to await orders, to await access to a siding or rail yard, etc.). An at-grade crossing

would require these operations to be performed elsewhere.

3. Switching operations—tracks at grade-separated crossings may be used in conducting switching operations. Depending on local and state laws, elimination of the grade-separation may restrict these operations.

4. Routing—closing the rail line or perhaps other alternatives may necessitate the rerouting of rail operations.

5. Clearances—on the positive side increasing clearances by replacing or relocating an existing structure could enable the introduction of more efficient double and triple-stacked rail cars.

To identify these and other types of positive and negative effects on rail operations, the analyst should begin by developing a detailed profile of existing (and planned) rail operations. The profile should include, for example, the following data on train operations through the crossing: number of trains, number of operations, location of operation, number of cars, train length, train speed, day of week, time of day, duration of operation, type of operation/service, and origin and destination of service.

Having established the current operating profile, the next step is to describe how each alternative would affect it, or alternatively what actions the railroad would need to take (e.g., addition of facilities) to maintain current operations. Basically, one would ask: (1) What does each alternative allow the railroad to do that it is not now doing? (2) How does each alternative preclude the railroad's doing what it currently is doing, and why?

Finally, implications for the types and quality of rail service and capital and operating costs would need to be defined and documented. The results should be included in the rail and highway operations summary matrix.

The following tables (A-12, A-13, and A-14) present formats for train operations profile, crossing delay summary, and summary matrix for rail/highway operations.

Table A-12. Sample train operations profile.

Train #	Length (Feet)	Speed Through Crossing (MPH)	Time of Day of Crossing	Type of Operation
1	3,280	25	0001	Through freight
2	971	20	0115	Local freight
3	3,210	20	0630	Through freight
4	305	20	0645	Passenger

Table A-13. Crossing delay summary.

Time of Day	Vehicular Volume	Vehicles Delayed	% of Vehicles Delayed	Total Delay Per Vehicle	Total Vehicle Delay	Duration of Closure
0:00-1:00 a.m.						
1:01-2:00 a.m.						
2:01-3:00 a.m.						
.						
.						
.						
10:01-11:00 p.m.						
11:01-12:00 p.m.						
TOTALS						

Community and Environmental Considerations

The Issue

> Would the alternative displace any structures?

Whereas Level 1 analysis is intended to determine whether any improvement options would result in an intolerable degree of displacement, the objective of Level 2 is to define more precisely the nature, magnitude, and significance of any land uses that would be displaced by each alternative. The overall significance of land uses threatened with displacement is determined by assigning values to a number of quantitative and qualitative measures of significance arrayed in a land use displacement significance matrix (see Table A-15), and assigning an overall significance rating to the threatened land use(s) on the basis of these measures.

As with the questions raised in Level 1, the key consideration here is whether any of the alternatives would require taking land for new or additional right-of-way. The types of improvement most likely to require additional land are relocation and, to a lesser extent, replacement of the grade separation.

Units of measurement include (1) amount of land (acres or square feet) taken by land use, (2) number of structures displaced by type, and (3) significance of land takings and structures displaced.

Methodology

The steps to be followed in identifying and assessing the significance of potential displacements are summarized as follows and further detailed below.

> Analysis Steps
>
> 1. Determine whether any alternative would require the acquisition of new right-of-way.
> 2. If new right-of-way is needed, determine what prop-

erties (land and structures) would be taken (list by owner and land use).
3. Assess the significance of land and structure takings giving consideration to amount of taking and importance of the taking to the business and residential community.

The land use displacement significance matrix (Table A-15) serves a dual function in the analysis. It provides a format for using this procedure and identifies each by parcel and the amount of land taken and structures displaced and the land use of the affected property.

The first step in the land use analysis is to determine whether any proposed improvement would require taking land for additional right-of-way. If no additional land is required for an improvement, enter "NA" (not applicable) in the appropriate column of line 16 in Table A-15. (Eight columns, to accommodate up to eight properties affected by two alternatives, are provided in the table; the analyst should expand the table as appropriate to accommodate additional alternatives and properties.) If an alternative has been eliminated in a previous stage of the alternatives analysis, then enter a "–" or other symbol in the appropriate column of line 16 to indicate that the alternative was not considered. This will be useful in further analysis if the alternative must be later reconsidered.

For those alternatives requiring new right-of-way, overlay the proposed alignment for each alternative on available maps of the study area. The map should show all existing rights-of-way, structures, and property lines adjoining the proposed alignment. The number of parcels and structures that would be affected by each alternative should then be identified. Having identified these properties, the next issue to address is the significance of the land takings. Making this determination requires collecting the following information on each affected parcel: parcel size (acres), amount of land taking (acres), current and proposed land use, existing structures (number and type), number of structures displaced, condition of structures, value of land and structures, level of land use (approximate number of residents, employers, or users, as appropriate), frequency of use, uniqueness of land and structures (historic, cultural, recreational, architectural, etc., significance), and relocation options (e.g., ability to relocate a structure or develop a new recreation facility).

Based on this information, one can complete Table A-15, which will facilitate reaching a conclusion about the significance of the land-use effects of each alternative. The following are instructions for filling out the table.

1. *General.* If a measure of significance does not apply to the land that would be taken by a particular alternative, enter "NA" in the appropriate cell. Ranges of values for those measures of significance marked with asterisks are provided at the bottom of the matrix.

2. *Proportion of Total Property* (line 3) refers to the proportion of each affected piece of property that would be taken by the improvement. For instance, one acre of parkland displaced by an improvement would constitute 2 percent of a 50-acre park. Proportions should be determined for each property affected.

3. *Condition of Structures* (line 5) should be determined on the basis of expert judgment, either through a site visit or an interview with a local real estate agent or tax assessor.

4. *Value of Land and Structures* (line 6) should be the market value of the proportion of land and/or structures that would be taken by the improvement. This can be obtained from a local real estate broker or appraiser. In the event that the improvement would effectively destroy an existing land use, even if it would not take the entire property, the fair market value of the entire property should be used.

5. *Number of Employees* (line 8) should be expressed in terms of full-time equivalent (FTE) employees. For instance, three full-time and five part-time employees in an establishment threatened with displacement would be 5.5 FTE employees.

6. *Number of Users* (line 9) should be estimated on the basis of interviews with knowledgeable local officials and/or site visits. The measure refers to the number of people using the threatened land and/or structure(s) per unit of time (another unit may be substituted for weeks), and applies primarily to institutional, recreational, historic/cultural, and natural habitat land uses. For natural habitat areas, the measure may also apply to intensity of use by wildlife (e.g., "The area is used by approximately 5,000 waterfowl 2 weeks per year").

7. *Development Potential* (line 11) should be determined on the basis of expert judgment through interviews with local economic development planners and other officials and/or a review of relevant land use and planning documents. In particular, it should be determined whether the property owner has received, or the property has been designated part of, any of the following:

- Urban Development Action Grant
- Minority Business Development Award
- Urban Enterprise Zone
- Community Development Block Grant
- Urban Homesteading Program
- Rural Housing Preservation Grant
- Public Housing Project
- SBA Economic Opportunity Loan
- Any other public loan, subsidy, or award for economic development, community revitalization, or similar purposes

8. *Uniqueness* (line 12) refers to the proportion of similar or identical land uses displaced by an improvement. The premise here is that displacement of, for example, the only public park in a community (which is the equivalent of 100 percent of the community's parkland) is more significant than displacement of, say, one of five parks or 20 percent of the local parkland. Thus, uniqueness is a function of the number of substitutes for the threatened land use available in the community.

9. *Historic/Cultural Significance* (line 13) can be determined, for the most part, on the basis of Level 1 analysis. However, since Level 1 focuses on identifying formally designated historic/cultural sites of national, state, and local significance, additional research may be required to determine eligibility for formal listing or purely local significance.

10. *Recreational/Natural Habitat Significance* (line 14) also can be determined on the basis of research performed in Level 1.

11. *Ease of Relocation* (line 15) refers to the relative permanence or impermanence of the displacement, and applies only to those alternatives which would displace a sufficient amount of land to warrant relocation to, or replacement at, a new site of the existing use(s). For instance, if a displaced structure can be physically moved to, or rebuilt at, a new location, ease of relocation may be excellent. (Indeed, in some cases, displacement may constitute a welcome opportunity to replace a dilapidated structure.) Alternatively, the unique nature of a particular land use, in terms of ambience, historic significance, or aesthetic associations, may be such that relocation would be tantamount

Table A-14. Rail and highway operations summary matrix.

Factor	Alternative					
	Rehabilitate	Replace	Put At-Grade	Relocate	Close Road	Close Rail Line
Vehicular Delay/Day						
# Delayed or Rerouted						
• Peak						
• Off-peak						
• Total						
% Delayed or Rerouted						
• Peak						
• Off-peak						
• Total						
Added Trip Time/Vehicle						
• Average						
• Range						
% Change in Trip Time						
• Average						
• Range						
Vehicular Queuing						
# Times/Day						
Problem Significance 1/						
Capacity Constraint						
Current V/C Ratio						
Change in V/C Ratio						
Significance of Change						
Emergency Services						
# Trips Affected						
% of All Trips						
Increase in Response Time--Average and Range						
% Change in Response Time						
Rail Operations						
Service Availability						
Service Quality						
Operating Costs						
Capital Costs						

1/ Note implications of queuing, e.g., potential blocking of fire station access.

Table A-15. Land use displacement significance matrix.

MEASURE OF SIGNIFICANCE	ALTERNATIVE					
1 - TYPE(S) OF LAND(1)						
2 - AMOUNT OF LAND (ACRES OR SQUARE FEET)						
3 - PROPORTION OF TOTAL PROPERTY(IES)						
4 - NUMBER OF STRUCTURES						
5 - CONDITION OF STRUCTURES(2)						
6 - VALUE OF LAND AND STRUCTURES ($$)						
7 - NUMBER OF RESIDENTS						
8 - NUMBER OF EMPLOYEES (FTE)						
9 - NUMBER OF USERS (/WEEK)						
10 - FREQUENCY OF USE (DAYS/WEEK)						
11 - DEVELOPMENT POTENTIAL(2)						
12 - UNIQUENESS(3)						
13 - HISTORIC/CULTURAL SIGNIFICANCE(4)						
14 - RECREATIONAL/NATURAL HABITAT SIGNIFICANCE(4)						
15 - EASE OF RELOCATION(5)						
16 - OVERALL SIGNIFICANCE(6)						

KEY:

(1)
- A - RESIDENTIAL
- B - COMMERCIAL/OFFICE
- C - INSTITUTIONAL
- D - INDUSTRIAL
- E - AGRICULTURAL
- F - RECREATIONAL
- G - HISTORIC/CULTURAL
- H - NATURAL HABITAT
- I - OTHER

(2)
- 3 - EXCELLENT
- 2 - GOOD
- 1 - FAIR
- 0 - POOR

NA - NOT APPLICABLE

(3)
- 3 - UNIQUE
- 2 - UNCOMMON
- 1 - COMMON
- 0 - PREVALENT

(4)
- 3 - NATIONAL LISTING OR ELIGIBILITY
- 2 - STATE LISTING OR ELIGIBILITY
- 1 - LOCAL LISTING OR ELIGIBILITY
- 0 - NONE

(5)
- 3 - IMPOSSIBLE
- 2 - DIFFICULT
- 1 - PROBLEMATIC
- 0 - EASY

(6)
- 3 - VERY SIGNIFICANT
- 2 - SIGNIFICANT
- 1 - SOMEWHAT SIGNIFICANT
- 0 - INSIGNIFICANT

to destruction. The final determination of ease of relocation should be made on the basis of expert judgment and should include consideration of the following factors:

- Physical condition and life expectancy of the current land use
- Historic/cultural/recreational significance
- Availability of substitute site(s)
- Costs of relocation, demolition, reconstruction and/or replacement
- Psychological costs of relocation
- Ability to reproduce essential character of existing location, if necessary

12. *Overall Significance* (line 16) refers to the overall importance to the community of the threatened land use(s), and should be determined on the basis of expert judgment after a careful review and comparison of all other measures of significance for each alternative under consideration.

The process of identifying and evaluating the effects of alternative improvements on land use involves assembling a significant amount of information and data. However, much of the information needed to assess the significance of land uses threatened with displacement also is required for other elements of the alternatives analysis and need not be assembled from scratch.

The principal sources of information for the land-use analysis are the following:

1. Maps showing existing rights-of-way, structures, and property lines. This information can be assembled by using tax maps and aerial photographs or by conducting a site inspection.

2. Amount of land; proportion of total property; number of structures. See Level 1 analysis: Land Use.

3. Condition of structures. Information can be obtained from discussions with officials in, and relevant published and unpublished documents of, local planning agencies, housing authorities, community/civic groups, homeowners' associations, and real estate developers and brokers; and/or from site visits.

4. Value of land and structures. Values should take into account both the assessed value of the property, which can be obtained from the local tax assessor's office, and the market value of the property, which can be obtained from local real estate brokers.

5. Number of residents. Figures can be obtained through a telephone survey of affected homeowners/landlords or from local planning officials.

6. Number of employees. The number of full-time equivalent (FTE) employees working in structures threatened with displacement can be obtained through telephone surveys or interviews with employers; office real estate management companies; local employment security commissions, labor departments, or economic development agencies; or chambers of commerce.

7. Number of users; frequency of use. Public use of a facility—whether commercial, institutional, recreational, or some other land use—can be obtained from interviews with knowledgeable individuals. For instance, use of a church might be estimated on the basis of the average number of, and average attendance at, weekly services and other events, and patronage at a local park or library on the basis of field observations or surveys conducted by the local department of parks and recreation.

8. Development potential; uniqueness. These attributes of threatened land uses should be determined on the basis of interviews with knowledgeable local planners and real estate developers and brokers, and a review of relevant economic development and land use plans and designations.

9. Historic/cultural significance; recreational/natural habitat significance. The principal sources of data for identifying formally designated sites of historic, archaeological, cultural, and recreational/natural habitat significance are discussed above under Level 1 analysis: Land Use. Additional sources of information include:

- Interviews with knowledgeable local individuals
- Local histories and newspaper and magazine articles
- Published and unpublished architectural and historic surveys and inventories
- Records of local chapters of the American Institute of Architects, American Planning Association, American Society of Landscape Architects, National Trust for Historic Preservation, and state and local fine arts commissions and architectural review boards
- State graves registers, for burial places of important individuals
- Museum and library exhibition catalogs and photographic and print collections
- Private records and collections, including those of the D.A.R. and Colonial Dames
- Records on element occurrences of endangered and threatened plant and animal species and significant geological features maintained by the State Natural Heritage Program or its equivalent
- Inventories, research papers, and position papers prepared by local chapters of the Nature Conservancy, Sierra Club, Audubon Society, and similar groups

10. Ease of relocation. The principal sources of information are the same as those for other measures of significance (e.g., uniqueness) on which this measure is based: inventories of similar uses and substitute sites, site visits and/or previous engineering studies (to determine physical condition), and interviews with property owners and local planning officials.

11. Overall significance. A final assessment of the overall significance of the land and/or structures that would be displaced by an alternative should be made on the basis of all other measures of significance. No additional data are required for assigning a value to this measure.

Institutional Considerations

The Issues

- How do costs associated with each alternative compare with available funding from federal, state, local, railroad, or other parties associated with implementation of each alternative?
- How would the costs and benefits of each alternative be distributed?
- Does the decision-making process render some alternatives significantly more difficult to implement than others?

Institutional considerations refer to funding arrangements and availability and legislation, policies, and plans adopted by government agencies which dictate or guide decisions regarding changes in the transportation and related systems. Contractual agreements between institutions (public and private) also may influence what can or cannot be done or what is preferred to be done in a particular situation.

Institutional considerations, as used in this framework, also include the distribution of costs and benefits of an action among organizations.

Finally, institutional considerations include the process of decision-making itself and what effect the process may have on various alternatives. The primary concern here is that elements of the process—environmental analysis requirements, decision appeal procedures, restrictions on the use of funds—may favor one alternative over another.

Units of measurement include (1) availability of funds, costs incurred and benefits accruing to various parties, lead time required to implement each alternative, and likelihood that an alternative will be implemented if selected.

In Level 1, the analysis seeks to identify any federal, state, or local rules, regulations, policies, warrants, agreements, or contracts that dictate either elimination or selection of a specific alternative. Having passed that test, each alternative in Level 2 is examined with respect to funding arrangements and availability, the distribution of costs among various entities, and the effect the decision process may have on its implementation.

Methodology

Availability of Funds. This factor addresses the issue of which agency or party will incur the capital costs of each alternative and the ability of each to pay. Where the highway is carried by the structure, funding of capital expenditures is often shared between the federal, state, and local governments. Railroad structures may involve these government agencies, but will more often be built with railroad funds.

The amount of funds available to each of the participating agencies and their willingness to commit those funds to the subject structure are important issues to be considered. A severe budget limitation will favor lower cost alternatives. Where the decision-making agency is not the only funding source, there may be a disposition to favor selection of those alternatives. For example, a railroad or local government's voluntary willingness to participate in funding a specific alternative could tilt the decision in favor of that alternative. Table A-16 may be used to record the results of the availability of funds investigation.

Source and Availability of Funds
Analysis Steps

1. Determine eligibility of project for various agency fundings.
2. Determine agency operating budgets for this classification of funding.
3. Allocate project costs to each contributing agency, applying distribution formula.
4. Calculate percentage of project share as percentage of agency capital budget.
5. Note voluntary contribution proposals.

Distribution of Costs and Benefits. The distribution of costs and benefits and existing legal arrangements, as well as funding availability, may influence this alternatives analysis.

Analytical Steps

1. Collect costs and benefits information from earlier factor analyses.
2. Review ownership, laws, contracts, rules, and regulations to determine current and future funding responsibilities.
3. Review liability experience.
4. Identify discrepancies between current and projected cost responsibilities and between cost and benefits among parties and assess their significance.
5. Determine the likelihood that an alternative would be implemented if selected and the lead time required.

It is useful to examine the distribution of costs among entities for two reasons. First, sensitivity to costs incurred by everyone affected by a decision will result in a more complete consideration of all implications of a decision rather than only the interest of the party with decision-making authority. Second, the allocation of costs has equity implications, particularly when existing arrangements are changed. Finally, knowing who could be affected by a decision and how they would be affected has implications for who should be consulted in the decision-making process.

The following types of costs are considered in the analysis: capital costs, operating and maintenance costs, and liability costs.

The first cost item is estimated in the section on cost for implementing each alternative. Some of the other costs are identified in the section on rail and highway operations, specifically

Table A-16. Source and availability of funds.

Level	Agency	Share of Cost	Capital Budget	Project as Percent of Budget	Ability to Program the Project	Offer of Voluntary Contribution
Federal		$	$	%		$
State						
Local						
Rail						
Other						

the operating costs and capital costs that may be incurred by the railroad beyond building and maintaining the alternative. Maintenance costs are discussed in greater detail in Level 3. There are no specific calculations for determining maintenance costs of at-grade crossings or grade separation structures. For purposes of this analysis, an assumption of $2,500 per year should be used for maintenance of any grade separation structure or at-grade crossing. Assume no maintenance cost for either close crossing alternative. Maintenance cost allocation should be based on practice in the particular jurisdiction.

The cost for building and maintaining each alternative is a function of ownership, contractual arrangements, laws, historical practice, and rules and regulations regarding use of funds. Each area should be examined to document the current and projected cost responsibilities. Other costs (e.g., railroad operating costs) are allocable to their source, as determined by earlier analysis, and require only summary here.

A large change in potential costs will usually be associated with the change in exposure to liability in the case of the at-grade alternative. The railroad would be expected to experience the greatest change in exposure. The potential cost of this exposure, however, is far from clear. While individual grade crossing accidents have resulted in substantial judgments against railroads or large settlements, the total payments made by railroads to crossing accident victims or their beneficiaries in the context of total grade crossing accidents is well under $20,000. Given the uncertainty associated with the liability issue, the issue should be recognized but should not be the deciding factor in the selection of the preferred alternative.

An important consideration in the decision-making process is the extent to which the selected alternative can be implemented expeditiously. Anticipated delays in obtaining funding commitments from all appropriate parties may argue strongly against selecting certain alternatives. Accordingly, the analyst should attempt to estimate the amount of time required to achieve full funding of each alternative.

COMPARATIVE EVALUATION OF ALTERNATIVES

The preceding sections have described how the analyst can determine the nature, magnitude, and significance of the costs, safety, rail and highway, and community and environmental implications of each alternative. The purpose of this section is to define techniques for using that information to comparatively evaluate the alternatives to support the selection of one or more alternatives for Level 3 analysis.

The overall approach to this comparative evaluation consists of a set of three techniques, successively applied. These techniques are:

1. Balance sheet comparison.
2. Computation of unit cost of relative effectiveness.
3. Total cost comparison.

One additional technique is used in the applications of the other three, that is the "single elimination" technique. In this technique, the analyst compares two alternatives at the same time. The preferred alternative of the two is selected and then compared to a third alternative. This one-on-one comparison proceeds until all alternatives have been considered. At the conclusion the preferred alternative may be selected or a decision to proceed to Level 3 analysis with more than one alternative is made. This technique relies on the assumption that if A is superior to B and C is superior to A, then C is also superior to B. While this assumption may not always be valid, the technique facilitates the comparative evaluation process and sensitivity to its limitations will prevent erroneous conclusions.

Balance Sheet Comparison

After the analyst has prepared the various quantitative estimates and qualitative assessments of each alternative's cost, safety, rail and highway operations, community/environment, and institutional implications, the first step in the trade-off analysis is to make a summary comparison of alternatives. One technique for making this comparison is the balance sheet which simply lists the findings relative to each factor by alternative. As illustrated in Table A-17, the balance sheet shows the *differences* between the two alternatives, the entry being put under the alternative with the estimated greater adverse effect.

The content of the balance sheet is dictated by the results of the factor analyses. All subject areas must be represented in the balance sheet to show that the analysis is complete. However, the amount of information presented by factor is limited by the need to display only those analytical results needed to compare alternatives. Thus, the results of the Land Use analysis are summarized on one line, because no land-use impacts were found for these alternatives. Other subject areas are represented with a few quantitative or qualitative measures depicting the significance of their respective analyses.

Table A-17. Illustration of the balance sheet comparison technique.

Measure	Alternative: Replace	Alternative: Relocate	Difference Between Alternatives (Replace-Relocate)
Cost	$2,110,000	$2,100,000	+ $10,000
Safety	0	0	0
Highway and Rail Operations	0	0	0
Land Use	3	10	-7
Institutional Considerations	0	0	0

Having all the relevant information in a single table allows decision-makers to readily identify the significant differences between alternatives. The differences may be so striking that the preferred alternative is apparent. In the illustration presented in Table A-17, for example, the balance sheet shows that at an additional cost of $10,000 the replacement alternative will avoid displacement of seven residences associated with the relocation alternative. All other characteristics of these two options are the same and therefore need not be considered in the decision. The trade-off clearly favors the replacement alternative, and relocation can thus be eliminated.

Table A-18. Level 2 analysis balance sheet comparison at-grade vs. close road.

Measure	Put At-Grade	Close Road
Cost (Annualized)	$36,700/yr	
Safety --Accidents --Injuries --Fatalities	 +1/37 yrs +1/83 yrs +1/250 yrs	
Highway Operations --# Delayed --Time Delayed --Trip Time Change Regional Local		 +3470/day 3 to 11 min/delay +6% to 10% +0% to 176%
Land Use	N/A	N/A
Institutional Availability of Funds --Main Cost -State -Railroad --Potential Project Delay --Possible Decision Overturn	 +3,600/yr +3,500/yr	 +0 to 18 months High

Table A-19. Computation of unit costs of relative effectiveness.

At-grade vs. Close Road

(a) Delay Unit Cost

($36,700)÷ (3740 vehicles delayed per day) x (365 days per year) x (7 minute average additional delay) = $0.004

(b) Safety Unit Cost

- (3740 vehicles delayed per day) x (365 days per year) x (37 years between the additional accidents) = 50,508,700 vehicles delayed
- (1 injury every 83 years) 113,303,300 vehicles delayed
- (1 fatality every 250 years) 477,785,000 vehicles delayed

Table A-20. Level 2 analysis cost comparison at-grade vs. close road.

FACTOR	AT-GRADE	CLOSE ROAD
Annualized Cost	$72,800	$ $36,100
Safety	1,900	800
Vehicular Delay	200	3,000,000
Total Annual Costs	$74,900	$3,036,900

Computation of costs are as follows:

--Annualized cost--from cost factor analysis above.

--Safety--multiplication of annual accident rates (from safety section above) and (a) cost per fatality, (b) cost per injury, and (c) cost per property damage accidents. In this example, rates used by the New York Department of Transportation were used.

Unit Cost of Relative Effectiveness

If the balance sheet does not provide a sufficient basis for decision-making, the second technique employed is the calculation of *unit cost of relative effectiveness.*

Referring to Table A-18, the at-grade alternative costs more than the close-the-road alternative and would result in a larger number of accidents. For these higher costs in dollars and accidents, one would avoid delays to almost 3,500 motorists each day. The delays experienced would range from 3 to 11 min *greater than* the delays anticipated with the at-grade alternative. Thus, one may ask the following question: Is it worth $36,700 each year and one additional accident every 37 years (one injury every 83 years and one fatality every 250 years) to avoid delays of 3 to 11 min per trip to 3,470 vehicle drivers each day? The answer is not readily apparent.

To clarify these trade-offs, the analyst next calculates the unit costs of each benefit. These unit costs describe how much one would pay to avoid a unit of adverse effect by selecting one alternative over another. The evaluation question is whether the cost is worthwhile.

To develop unit costs, one must first translate the factor estimates into like units of measurement. The common denominator depends on the items involved in the trade-off analysis. The consequent measures are the following for the at-grade relative to the close-the-road option: (1) cost per additional vehicular delay avoided = $0.004; and (2) cost per additional accident every 37 years = 50,508,700 delayed vehicles.

Computation of these unit costs is shown in Table A-19. The first unit cost indicates that by choosing the at-grade alternative one would be paying four-tenths of one cent to avoid each vehicular minute of delay that the close-the-road option would impose on motorists, a very small price to pay. The second unit cost indicates that by choosing the close-the-road alternative one would incur about 50 million vehicular delays to avoid each grade crossing accident, a very steep price to pay. The cost per additional injury and per additional fatality would be 113 million and 478 million delayed vehicles, respectively.

Total Cost Comparison

The third technique suggested to support decision-making is a *total cost computation,* including factors amenable to this type of analysis. Some analysts and decision-makers object to total cost or cost analysis because of the difficulties in developing acceptable values for some factors (e.g., the value of life) and the inability to include other qualitative considerations (e.g., environmental quality). However, total cost analysis, in conjunction with the other techniques described above, will provide additional insight into the nature of the trade-offs between alternatives, particularly if sensitivity testing is employed. To complete the above example, Table A-20 shows the cost comparison of the at-grade and close-the-road alternatives.

In the final analysis, while these techniques may help to focus the discussion on relevant differences between alternatives, the decision will be based on the judgment of those with the responsibility and authority to implement the remedial action. In making this judgment, the decision maker should obtain the options of other institutions affected by the decision—usually the railroad and local government. Remember that who benefits and who pays under each alternative are not the same. The opinions of these other parties, and perhaps their voluntary financial commitment to one alternative or another, could be the deciding factor.

DOCUMENTATION OF RESULTS

As in Level 1 analysis, documentation of results serves to communicate results to decision-makers and to the public while creating an audit trail of the decision-making process. With these objectives in mind, the results of Level 2 analysis should be documented in a written report or technical memorandum. Working papers showing data sources and detailed computations also should be clearly organized and maintained.

The Level 2 analysis report is an extension of the report written at the conclusion of Level 1 analysis. The results of Level 2 analysis are added to the report presenting the results of Level 1 analysis. Also, any updating of information contained in the Level 1 analysis report, such as engineering refinement of the alternatives, should be made.

In presenting the analytical findings, each alternative should be discussed in terms of cost, safety, rail and highway operations, community and environmental concerns, and institutional considerations. The basis for rejecting an alternative also must be specified. Level 2 conclusions should be discussed with affected parties before being finalized.

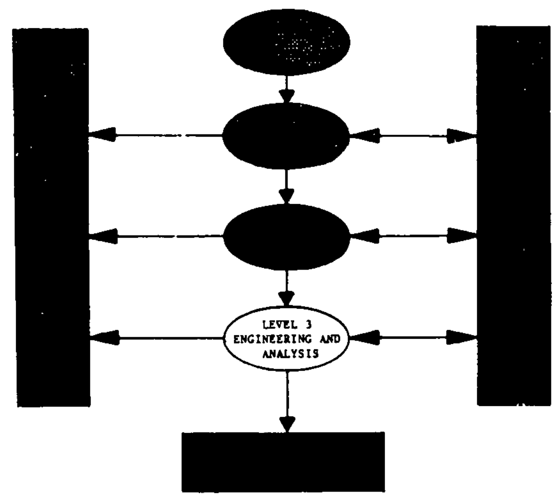
Table A-21 presents an example of how Level 2 analysis results can be documented. The case studies presented in the appendixes to this report provide further examples of documentation of results.

Table A-21. Level 2 analysis report outline.

```
1.  Problem Definition
      Reason for project
      Problem context (general location map)
      Traffic
      Land use
      Environmental

2.  Alternatives (options described)
      Rehabilitate
      Replace at same location
      Relocate
      Replace with at-grade crossing
      Demolish structure, close road
      Demolish structure, close rail line

3.  Conceptual Engineering (by option)
      Alignment
      Profile
      Structural features

4.  Decision-making framework
      Institutions affected
      Participation process

5.  Level 1 Analysis and Results
      Analysis by option
        Cost
        Safety
        Rail and highway operations
        Community and environment
        Institutions

      Results
        Comparison of alternatives
        Recommendation for Level 2
          Analysis
        Rejected alternative

6.  Level 2 Analysis and Results
      Analysis by option
        Cost
        Safety
        Rail and highway operations
        Community and environment
        Institutions

      Results
        Comparison of alternatives
        Recommendations for Level 3 Analysis
        Rejected Alternatives
```

SECTION V LEVEL 3 ANALYSIS PROCEDURES

DECISION MAKING FRAMEWORK



OVERVIEW

Level 3 analysis is the last and most detailed step in the comparative evaluation of alternatives. At this level of analysis most of the alternatives have been eliminated from consideration. In many cases, when Level 3 analysis begins, only two alternatives will remain from the original set considered. Indeed, the preferred alternative may often be decided at the conclusion of Level 2 analysis.

Thus, Level 3 analysis is designed to serve two purposes. First, when the preferred alternative is decided at the conclusion of Level 2 analysis, the third level of analysis is conducted to ensure that considerations not examined in the first two levels of analysis do not alter the decision. In this case, Level 3 analysis involves the examination of the preferred alternative only on the basis of factors not previously considered. Only if a particularly adverse effect of the alternative is discovered is the second best alternative also examined and compared to the first, leading to a final decision.

Second, when a preferred alternative is not identified at the conclusion of Level 2 analysis, the third level of analysis is conducted to seek a basis for decision. That is, alternatives were retained from Level 2 analysis because not enough information was developed by the end of that level to adequately distinguish between the remaining alternatives and to select a preferred alternative. More precise and more comprehensive analysis is required in Level 3 to assist in this decision. Thus, for example, in the area of safety, school buses, hazardous materials, pedestrians and bicyclists safety factors are introduced to provide a more complete view of safety than provided by Level 2 analysis (see Fig. A-3.) At the same time, not all analyses included in Level 3 of the decision-making framework need be included in the final analysis of the alternatives. There are three reasons certain analyses may not need to be performed: (1) The analyses

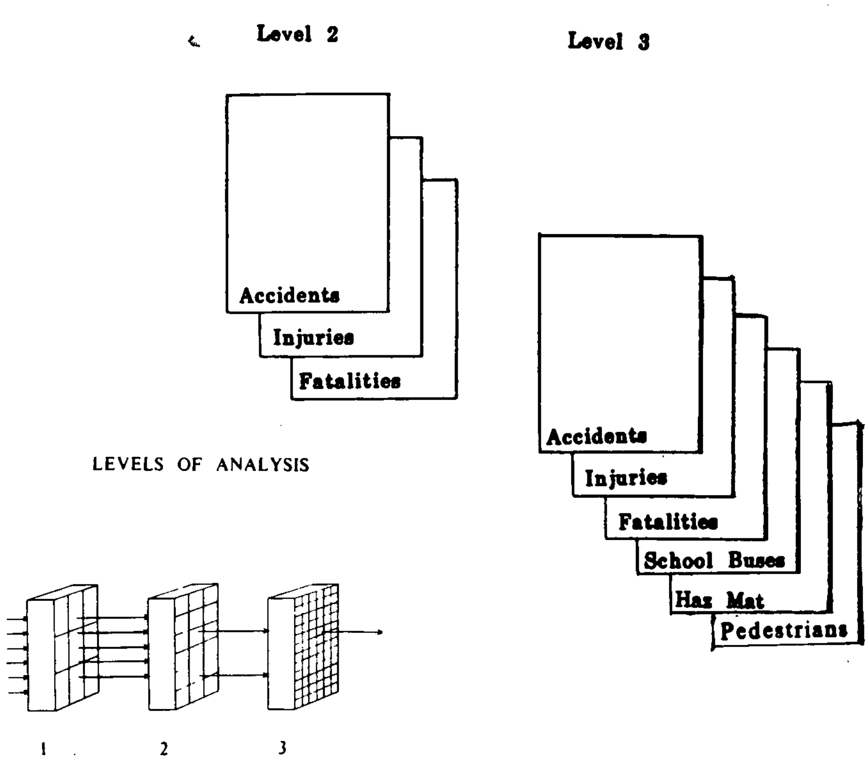


Figure A-3. Levels of analysis—safety.

pertain only to an alternative that was already rejected. (2) The analyses pertain to factors that are inconsequential to the decision (e.g., there is little or no new right-of-way requirement for any alternative making further examination of associated land use factors irrelevant). (3) The analyses provided for the refinement of Level 2 work which is not needed to distinguish the alternatives (e.g., both alternatives were found to have essentially identical effects on highway operations, in which case refinement of the Level 2 highway analyses is moot).

With the purpose of Level 3 analysis in mind, the factors addressed at this level are listed in Table A-22.

LEVEL 3 ENGINEERING

Before proceeding with Level 3 analysis, it may be necessary to do further engineering of the remaining alternatives. Additional engineering definition may be required to support more accurate estimation of the costs associated with the alternatives. Information required to derive these estimates is defined in the section on cost analysis below. Another reason for additional engineering work is to incorporate improvements, or ways to mitigate adverse effects, identified during Level 2 analysis.

LEVEL 3 ANALYSIS

The description of Level 3 analysis procedures follows the same format as used to describe Level 2 analysis procedures in the previous section. Issues are defined and methods and data requirements to address those issues are presented for each subject area in turn. Following this introduction are four sections, one for each subject area considered in the analysis. (No further institutional considerations are introduced in Level 3.) The final two sections discuss: (1) techniques for comparatively evaluating alternatives and selecting the preferred one; and (2) documentation of results.

Cost

The Issues

- What are the detailed annualized capital costs associated with each alternative?
- What are the annual operating/maintenance costs associated with each alternative?
- What are the capital and operating maintenance costs assigned to the federal, state, and local governments and to the railroad?

In Level 3 analysis, detailed annual costs are developed for each alternative. At this level, engineering design for each alternative will be more detailed than those used in the Level 2 analysis. Plans should show sufficient detail to allow quantification of each cost item for computation of price estimates. Specifications should also be detailed enough to allow for estimating of annual maintenance costs.

Units of measurement include: capital cost in dollars, annual operating/maintenance cost in dollars, total annualized cost in dollars, and dollar limits of affected agency budgets.

Methodology

As noted above, Level 3 analysis begins with the engineering refinement of the remaining alternatives.

Analysis Steps

1. Obtain detailed engineering plans, specifications, and unit prices.
2. Quantify cost items from engineering plans.
3. Compute capital cost per item and obtain total capital cost.
4. Annualize capital costs.
5. Estimate annual operating and maintenance (O&M) costs.
6. Combine annualized capital costs and annual O&M costs to derive total annualized costs.
7. Compare capital cost requirements with available budgets by agency.

This more detailed specification of the alternatives is used to refine the capital cost estimates of the remaining alternatives bringing them to within 5 percent of final design costs. This is done by quantifying cost units by construction element applying them to unit cost estimates. A worksheet for this procedure is shown in Table A-23.

Unit prices are taken from state bid tabs, published bid prices such as those found in *Engineering News Record,* published unit prices such as those published annually in *RS Means,* or from suppliers of equipment (e.g., warning devices). Costs obtained in Level 2 analysis for maintenance of traffic, right-of-way, relocation of residents and business, demolition of buildings, and protection shield can be used or further refined if appropriate.

Annualized capital costs for each alternative are derived by cost item group to account for the variation in their lifetimes and then summed to obtain a total annualized capital cost estimate. The following groups are suggested:

100-yr. lifespan:	Right-of-way Relocation of residences and buildings Substructure Maintenance of traffic Protection shield Major excavation Demolition
50-yr. lifespan:	Superstructure
40-yr. lifespan:	Lighting Bridge deck
25-yr. lifespan:	Crossing control devices Miscellaneous highway operations and roadway equipment

The annualized cost of each group can be determined as noted in Level 2 analysis using the following equation:

$$\left[\frac{i\,(1 + i)^n}{(1 + i)^n - 1}\right]$$

where A = annual cost, C = current construction cost, i = interest rate, and n = lifespan in years.

Table A-22. Factors by analysis level.

	Decision Framework Analysis		
Subject Areas/Factors	Level 1	Level 2	Level 3
COSTS			
Physical Feasibility	X		
Capital Costs		X	X
Operations & Maintenance Costs			X
SAFETY			
Accident Exposure	X		
Accident Frequency		X	X
Fatal Accidents		X	X
Injury Accidents		X	X
School Bus Crossings			X
Hazardous Materials Crossings			X
Pedestrian/Bicyclist Accident Potential Crossings			X
RAIL AND HIGHWAY OPERATIONS			
Vehicular Delay			
Probability	X	X	X
Number	X	X	X
Duration	X	X	X
Emergency Response Time		X	X
Traffic Operations			
Vehicular Queuing		X	X
Capacity Constraint		X	X
Street/Highway Classification			X
Signalization			X
Patterns			X
Rail Operations			
Disruption	X		
Quality		X	X
Cost		X	X
Rail Yard Access		X	X
Switching Operations		X	X
COMMUNITY AND ENVIRONMENTAL CONSIDERATIONS			
Land Use			
Displacement	X	X	X
Disruption			X
Activity Patterns			X
Noise			X
Air Quality			X
Water Quality			X
Aesthetics			X
INSTITUTIONAL CONSTRAINTS			
Laws	X		
Warrants	X		
Policies and Guidelines	X	X	X
Contractual Obligations	X	X	X
Cost Distribution		X	X
Ease of Implementation		X	X
Availability of Funds		X	X

Table A-23. Calculation of capital costs.

CONSTRUCTION ELEMENT	COST ITEM	QUANTITY	UNIT COST	TOTAL COST
Highway				
	Roadway	____ sq. ft. of pavement		
	Concrete Slabs	____ cu.yds. of concrete		
	Fill	____ cu.yds. * hauling distance		
	Retaining Wall	____ cu.yds. of concrete		
	Utilities	____ linear feet		
	Lighting	____ fixtures		
	Signalization			
	Marking/Signing			
	RR Crossing Surface 1/			
	Warning Devices 1/			
Substructure				
	Support Piers	____ cu.yds. of concrete		
	Abutment	____ cu.yds. of concrete		
Superstructure				
	Girders	____ lbs. of steel		
	Stiffeners	____ lbs. of steel		
Deck				
	Sidewalk	____ sq.ft. of pavement		
	Roadway	____ cu.ft. of pavement		
	Handrail	____ linear feet		
Other 1/				
	Right of Way			
	Major Excavation			
	Traffic Maintenance			
	Protection Shield			
	Relocation Assistance			
	Demolition			
	Design			
Contingency 2/				
TOTAL				

1/ Lump sum amounts. See Level 2 Analysis, "Cost." (Design preconstruction and construction engineering) costs is 10 percent of all other items.

2/ Contingency is 10 percent of all costs.

This computation represents annualized capital costs. When considering total annual costs, operating and maintenance costs need to be added to capital costs.

Data may be available from the state department of transportation, county engineer, railroad, or other agencies directly responsible for maintenance. In practice, most maintenance authorities do not maintain sufficiently detailed records. Discussions with state highway departments indicate that bridge maintenance costs vary between $100 and $1,000 per year. As such, these amounts may be too small to alter the ranking of alternatives and, if so, may be disregarded.

At-grade crossings are usually maintained by the railroad. This maintenance includes the track area and some additional roadway surface on both sides of the tracks. Estimates of maintenance costs for at-grade crossings may be available from the state highway agency or the railroad; otherwise an annual cost of $3,000 per crossing (automatic gates and flashing lights) is a reasonable figure to use.

After summing all maintenance and operating costs, the total annual value can be added to the annualized capital cost. The total of operating/maintenance costs and annualized capital costs is used to compare alternatives.

Safety

The Issues

- How would pedestrian safety be affected by implementation of each alternative?
- To what extent is the crossing used by school buses (or transit buses) and by carriers of hazardous materials?

In Level 2 analysis, estimates were made of the accident potential at grade crossings in terms of accident frequency (number per year) and accident severity (injury accidents and fatal accidents). In Level 3 analysis, accident potential is further examined by adding consideration of the following factors: frequency of use by school buses (transit buses are included in this category), frequency of use by carriers of hazardous materials (rail and motor carrier), and frequency of use by pedestrians and bicyclists.

These factors are not introduced until Level 3 analysis because accidents at crossings involving school buses, hazardous materials, and pedestrians and bicyclists are rare. On the other hand, crossing accidents involving school buses and hazardous materials are potentially catastrophic because of the number of people who may be affected.

Units of measurement include (1) number of daily school bus crossings with and without passengers, (2) use of the crossing for hazardous materials transport—rail and truck, (3) use of the crossing by pedestrians and bicyclists, and (4) significance of the safety concern.

Methodology

In 1977, train/pedestrian accidents at rail/highway crossings claimed about 50 lives. (Other train/pedestrian accidents, which occurred on posted railroad property away from public crossings, were much more numerous, claiming about 475 lives.) This number is substantially lower than train crossing accidents involving motorists, which resulted in 610 fatalities in 1984.

Accidents involving school buses are quite rare: nine such accidents were reported nationwide in 1982, resulting in seven injuries and no fatalities. Annual accident rates for trains and/or trucks carrying hazardous materials, which include toxic substances, explosives, flammable products, corrosive substances, and radioactive materials, are not readily available. However, in 1975 and 1976, railroad incidents involving hazardous materials claimed 2 lives while truck incidents claimed 43 lives. In 1977, these figures were 4 and 30, respectively.

There are no prediction formulas for crossing accidents involving school buses, hazardous materials, or pedestrians because the occurrences are so few. As a consequence, examination of these factors focuses on developing information on the frequency of use and potential level of conflict rather than prediction of the number of accidents.

The alternatives that require analysis for these factors are: (1) relocation and close the road, because pedestrians may continue to cross the rail line at the "old" crossing location and because alternate routes for school buses and hazardous materials motor carriers may involve at-grade crossings; and (2) replacement with an at-grade crossing because of the introduction of train/vehicles and train/pedestrian accident exposure.

School Bus Safety
Analysis Steps

1. Review school district policy regarding rail/highway crossing.
2. Obtain data on historical school bus accidents/incidents at crossings.
3. Obtain data reflecting exposure to safety hazards—number of crossings; time of day; number of train operations; estimated accidents.
4. Judge the significance of the school bus safety concern.

Use By School Buses. The following information for the school systems affected should be obtained from the school districts or computed and recorded in Table A-24 to determine use of the crossing by school buses:

1. Number of times (daily) school buses use the grade-separated structure. (If school buses are restricted from using the structure because it is posted for weight limitations, one might consider potential school bus use if the structure were not posted.)
2. Number of students on the buses when the structure is used; clearly, there is a substantial difference between crossings made by empty buses and those made by buses with passengers.
3. The number of trains which usually pass through the crossing during busing hours.
4. The percentage of all school bus crossings that are made on at-grade crossings.
5. The history of train/school bus incidents at locations where at-grade crossings are used and on the existing grade-separation structure. (One also could collect information on potential incidents reported by drivers such as stalling on the crossing).
6. Alternative bus routes with grade-separated crossings and the addition to trip time and implications for school transportation schedules and fleet size that use of these routes would require. (Note: Some school districts have policies precluding use of at-grade crossings.)
7. The presence of high hazard locations along alternate routes, including routes required by closing the crossing and routes to which school buses may be diverted if an at-grade crossing is chosen.

One also could calculate the number of crossings by school buses as a percentage of all crossings and apply this percentage to the accident potential of each alternative estimated in Level 2 analysis. While this would not provide a reliable estimate of possible incidents, it would give some indication of the potential level of accident exposure for school buses and passengers.

The information listed above provides an understanding of safety risks for school transportation for each alternative. If school buses do not use the crossing or are empty when the crossing is used, or use the crossing when trains are not present, risk to school children is nonexistent. One should enter an "NA" (not applicable) in the school bus safety matrix (Table A-24) in these cases. If buses with children use the crossing when trains are sometimes present, but use of at-grade crossings by school buses is ordinary (a high percentage of all school bus crossings are made at at-grade crossings), one might enter an

Table A-24. School bus safety analysis.

INDICATOR	ALTERNATIVE: Rehabilitate	Replace	Relocate	Put At-Grade	Close Road	Close Rail Line
# School Bus Crossings						
• All Crossings (district)						
• At-Grade Crossings (district)						
• Subject Crossing						
-With Students -Without Students -# Students						
Time of Crossings						
# Train Operations During Crossing Times						
# Historical Train/Bus Incidents						
# Historical Bridge/Bus Incidents						
Alternative Bus Routes (Travel Time)						
# High Hazard Locations on Alternate Routes						
Exposure Index						
Overall Hazard Rating						

Note: This safety analysis pertains primarily to the at-grade crossing alternative and to the relocate and close the road alternatives when they cause the rerouting of traffic to at-grade crossings. The analysis also should be considered for the other alternatives if they would result in a significant change from current accident rates. This could occur, for example, where the replace alternative is superior to rehabilitation in safety characteristics.

"NS" (not significant) in the matrix. An "NS" entry in this case would be further justified if the historical data reveal no incidents with trains. Similarly, if reasonable alternate routes are available to school bus drivers, an "NS" could be entered in the matrix. In all other cases, a "PS" (potentially significant) should be entered in the matrix to alert decision-makers that a safety issue exists. The reasons for such entries should be documented for the decision-makers' and public's consideration in trade-off analysis. The overall significance rating should be entered in the safety summary matrix (Table A-27) as well as the school bus safety matrix.

Hazardous Materials
Analysis Steps

1. Determine frequency and type of hazardous materials transport through the crossing (rail and highway).
2. Obtain historical data on hazardous materials accidents/incidents (on the structure and in other crossings in the state).
3. Compute an index indicative of the population/land area exposed to an accident.
4. Judge the significance of the hazardous materials safety concern.

Hazardous Materials. As with the school bus use, collection or computation of the following information (usually available from the county or area emergency preparedness agency) will provide the basis for determining whether hazardous materials is an issue in deciding among the alternatives:

1. Listing of the types of hazardous materials transported by rail or truck through the crossing. (One might also list hazardous materials stored near the crossing and the location of the storage facilities. If a train/vehicle collision occurs, these facilities could become involved.)
2. Description of the potential consequences of an accident involving hazardous materials—area exposed, types and density of land uses in the exposed area.
3. Frequency of crossing use (annual) by hazardous materials carriers by mode. (It may be possible only to determine a broad range of use.)
4. Alternate routes that could be used by hazardous materials carriers and added travel time of using these routes and other mitigation measures.
5. Number of reported incidents involving hazardous materials carriers at the existing crossing and on crossings known to be heavily used by hazardous materials transporters in the state.

As with school bus use of crossings, one also could compile the data that would be used in a hazardous material exposure index. The index would include the potential exposed population, the number of crossings of trains, the number of crossings by vehicles carrying hazardous materials, and the accident rate estimated for the crossing. These data would provide a basis for assessing the magnitude of the risk associated with hazardous material crossings.

This information should be entered into Table A-25 and will allow the analyst to determine whether hazardous materials accident potential exists with any of the alternatives and the

Table A-25. Hazardous materials safety analysis.

INDICATOR	ALTERNATIVE					
	Rehabilitate	Replace	Relocate	Put At-Grade	Close Road	Close Rail Line
# Hazardous Materials Crossings (Daily)						
• By Rail						
• By Highway						
Area of Exposure to Accidents						
• Square Miles						
• Sensitive Land Uses						
• Population						
Alternate Routes (Travel Time)						
• Rail						
• Highway						
Historical Accidents/ Incidents						
• On Existing Structure						
• On Other Rail/Highway Crossings						
Exposure Index						
Overall Hazard Rating						

Note: This safety analysis pertains primarily to the at-grade crossing alternative and to the relocate and close the road alternatives when they cause the rerouting of traffic to at-grade crossings. The analysis also should be considered for the other alternatives if they would result in a significant change from current accident rates. This could occur, for example, where the replace alternative is superior to rehabilitation in safety characteristics.

degree of risk associated with such accidents. The following indicators could be used: (1) NA (not applicable) if hazardous materials are not transported through this crossing, or if reasonable alternative routes are available. (2) NS (not significant) if, in the case of an accident, exposure in terms of people and sensitive land uses (e.g., wildlife refuges) is not at issue. (3) PS (potentially significant) in all other cases. This finding should be supplemented by a description of the nature of potential incidents involving hazardous materials.

These findings are entered in the Safety Summary Matrix (Table A-27).

Pedestrian/Bicyclist Safety Analysis Steps

1. Obtain data on current pedestrian and bicyclist use of the crossing.
2. Identify and assess alternative routes.
3. Review historical data on incidents/accidents.
4. Judge the significance of the pedestrian/bicyclist safety concerns.

Pedestrian/Bicyclist Use. One should obtain the following information from the local police and planning agencies to judge the degree to which pedestrian/bicyclist safety may be an issue in choosing between alternatives:

1. Describe the current use of the grade-separated crossing by pedestrians and bicyclists in terms of frequency of use (estimated range of daily crossings), uniqueness as a pedestrian crossing (do pedestrians go out of their way to use this crossing relative to other crossings?), and composition of users (typically children, elderly, or other individuals).

2. Determine times of heaviest use (days of week; times of day) by pedestrians and bicyclists and determine typical number of train operations during those times.

3. Determine alternate routes with grade-separated crossings available to pedestrians and bicyclists, the added distance and time it requires to use these routes, and their relative safety.

4. Determine historical number of pedestrian and bicyclists incidents at the subject crossing and at other nearby crossings.

Based on this information, one can judge whether pedestrian/bicyclist safety is an issue. Information can be recorded in Table A-26. It would be a potentially significant issue (PS) if the structure is frequently used by pedestrians and bicyclists, if there are not reasonable alternatives, and if children and elderly people are the predominant users of the structure. Pedestrian/bicyclist safety would not be an issue if there is no use, or very little use, of the crossing and if the users are mostly not children or elderly and few incidents have historically occurred (an NA or NS entry).

Table A-26. Pedestrian/bicyclist safety analysis.

INDICATOR	ALTERNATIVE					
	Rehabilitate	Replace	Relocate	Put At-Grade	Close Road	Close Rail Line
# Daily Crossings						
• Pedestrians						
-Children						
-Adults						
• Bicyclists						
-Children						
-Adults						
Historical Accidents/ Incidents						
• Subject Crossing						
• Other Crossings						
Time of Use						
• Days						
• Hours						
# Train Operations During High Use Times						
Alternative Routes						
• Travel Time						
• Relative Hazard						
Overall Hazard Rating						

Note: This safety analysis pertains primarily to the at-grade crossing alternative and to the relocate and close the road alternatives when they cause the rerouting of traffic to at-grade crossings. The analysis also should be considered for the other alternatives if they would result in a significant change from current accident rates. This could occur, for example, where the replace alternative is superior to rehabilitation in safety characteristics.

Table A-27. Safety summary matrix.

SAFETY CONSIDERATIONS	ALTERNATIVE					
	Rehabilitate	Replace	Relocate	Put At-Grade	Close Road	Close Rail Line
# Accidents 1/						
• Fatal						
• Injury						
School Bus Use 2/						
Hazardous Materials 2/						
Pedestrian/Bicyclists Use 2/						

1/ Enter estimated total number of accidents, injuries and fatalities, and property damage; only accidents from Level 2 Analysis.

2/ Enter one of the following:

- NA = not applicable
- NS = not of significant concern
- PS = potentially significant problem

Rail and Highway Operations

The Issues

- Would traffic be diverted through areas that cannot support high traffic volumes?
- Would implementation of the alternative redirect highway traffic onto a route or routes with traffic signal systems inadequate or inappropriate to the projected traffic flow?
- Would implementation of the alternative result in rerouting of traffic contrary to the prevailing traffic patterns in the vicinity of the crossing?
- How much vehicular delay at the crossing on a daily basis would result from implementing the alternative?
- Would delay resulting from the proposed configuration result in significant increases in travel time on a daily basis?
- Will queuing at the crossing result in temporarily closed alleys, driveways, or vital facilities such as police stations, fire house, or hospital ambulance entrances?
- Would traffic diversion resulting from the alternative increase traffic on alternate routes beyond the capacity of the routes?
- Does closing the railroad impair or eliminate access to a rail yard?
- Could existing rail service be rerouted to alternative routes or modes?
- Would delay at the crossing by an emergency response vehicle result in excessive response time?

At the third level of analysis, ten factors are considered in evaluating alternatives to the deteriorated grade structure. For seven of these factors, refinements of previous, lower level, analyses are made. Three factors relating to the traffic sensitivity, signalization and traffic pattern of routes to which crossing traffic may be diverted are introduced to identify secondary traffic impacts that are not easily quantifiable.

Traffic-sensitivity is a consideration where the crossing alternative results in redirection of existing traffic patterns. The relocation and close-the-road alternatives may result in traffic diverting to routes which, while not capacity constrained, are not meant to handle the resulting traffic levels. Residential streets, park roads, narrow streets, streets with pedestrian volumes, and streets with low vehicular volumes are all examples of routes that may be traffic sensitive.

Signalization is a consideration when traffic currently operating on an unsignalized route, such as a rural primary route, is diverted to a signalized route. Likewise, if traffic operating on a route that has been signalized to manage the traffic is diverted to an unsignalized route, poor operations may result. This issue is considered for both the close-the-road and relocation options.

Traffic patterns are examined in terms of the diversion of traffic contrary to the normal flow of traffic in the area. For example, if traffic in a city flows radially, redirecting traffic across town could adversely affect traffic operations. This type of situation could result from either the close-the-road or relocation option.

Units of measurement include the following:

1. *Traffic* (sensitivity of routes to which traffic may be diverted, ability of existing signalization to handle rerouted traffic, traffic flow disruption caused by redirecting traffic flows contrary to existing flows, vehicle capacity of the diversion route(s)).
2. *Vehicular Travel* (number of vehicles delayed or rerouted per day, increase in trip time per vehicle delayed or rerouted—average and range in minutes, percentage increase in trip time, significance of changes in travel time).
3. *Vehicle Queuing* (number of times per day a queue causing access problems occurs, seriousness of the queuing problem).
4. *Capacity Constraint* (change in volume/capacity ratio on alternate routes, significance of increases in the ratio relative to level of service).
5. *Emergency Services* (change in response time, number of responses affected, percentage of responses affected, significance of change).
6. *Rail Operations* (change in services available, change in service quality, change in operating costs, change in capital costs).

Methodology

Each of the three new factors examined in Level 3 analysis depends on the identification of traffic rerouting caused by closing the crossing or relocating the crossing. These routes were identified in Level 2 analysis of rail and highway operations and will be updated in Level 3 analysis of "capacity constraint" (see below). As the first step in Level 3 analysis, the routes to which traffic would be diverted should be identified on a map of the community or area in the vicinity of the crossing. The area to include in the analysis consists of that area which encompasses the routes to which traffic is diverted. The map should include the identification of traffic-sensitive land uses (residential areas, recreational areas, schools, hospitals, libraries, etc.), traffic volumes and directional flows, and signalization characteristics. Many of these data may be obtained from the local highway agency, but may require field observation. An alternative approach would be to use street classification as a surrogate for traffic sensitivity and to confirm associated assumptions with knowledgeable local officials. With this mapped data in hand, the analyst can proceed with the factor analysis.

Traffic-Sensitive Detour Routes
Analysis Steps

1. Review routes to which traffic would be diverted to determine whether these routes are "traffic-sensitive."
2. Determine whether the increase in traffic volumes on sensitive routes is large enough to warrant concern.
3. On sensitive routes with significant increases in traffic, estimate the number of adversely affected traffic-sensitive land uses.

New Factor Analysis. The first step in this analysis is to review the routes to which traffic would be directed and the land uses along those routes. If the routes identified are not considered to be traffic-sensitive routes (i.e., few, if any, traffic-sensitive land uses exist along the route), no further analysis is required. The analyst can enter NA (not applicable) into the rail and highway operations summary matrix, Table A-28.

If some routes to which traffic is redirected are considered traffic sensitive, the next step is to determine whether the amount of traffic added to existing traffic would be large enough to warrant concern. Traffic diversion estimates prepared for the capacity constraint analysis below are used for this analysis. The analyst must determine what constitutes a significant traffic

Table A-28. Rail and highway operations summary matrix.

Factor	Alternative					
	Rehabilitate	Replace	Put At-Grade	Relocate	Close Road	Close Rail Line
Traffice Sensitive Detours 1/						
Signalized Detours 1/						
Contra Flow Traffic 1/						
Vehicular Delay/Day						
# Delayed or Rerouted						
• Peak						
• Off-peak						
• Total						
% Delayed or Rerouted						
• Peak						
• Off-peak						
• Total						
Added Trip Time/Vehicle						
• Average						
• Range						
% Change in Trip Time						
• Average						
• Range						
Vehicular Queuing						
# Times/Day						
Problem Significance 1/						
Capacity Constraint						
Change in V/C Ratio						
Significance of Change 1/						
Emergency Services						
# Trips Affected						
% of All Trips						
Increase in Response Time--Average and Range						
% Change in Response Time						
Rail Operations						
Service Availability						
Service Quality'						
Operating Costs						
Capital Costs						

1/ Enter one of the following: (1) NA=Not Applicable; (2) NS=Not Significant; (3) PS=Potentially Significant increase. Suggested thresholds are a 25 percent increase in traffic or an absolute increase of 200 or more vehicles daily, whichever figure is larger. The analyst, however, is encouraged to consult with local officials because they may be more familiar with the characteristics of the routes and the attitudes of residents.

If traffic levels are not deemed large enough to cause concern, the analyst can enter "not significant" (NS) in the summary matrix. Where traffic diversion is considered significant, the analyst should enter in the matrix the number of routes affected, the length of the routes, and the number of sensitive land uses affected. (See the section on noise for a list of sensitive land uses.) The degree of accuracy associated with the subjective traffic assignment procedures suggested in this section may not be suitable for some cases. Where diversion of traffic is considered to be a major concern, the use of formal, traffic assignment modeling techniques may be necessary. Computerized models prepared by regional planning agencies, state and/or local governments, or prepared specifically for this analysis may be required. (See the section on noise for a list of sensitive land uses.)

Signalized Detour Routes
Analysis Steps

1. Review traffic diversion estimates to determine if the amount of diversion is large enough to warrant consideration.
2. Identify routes to which traffic would be diverted and locate traffic signals for existing and detour routes.
3. Obtain phasing and timing data for signalized routes.
4. Assess whether signalization is appropriate for new traffic patterns.

Signalization on the roadway network is designed to facilitate the flow of traffic. Signals are installed in accordance with state and local warrants, which are based on, among other things, minimum vehicular volumes over specified periods of time. Phasing and timing are designed to optimize the passage of major movements. Where closing a crossing or reorienting the connection across the railroad will significantly alter the areawide traffic patterns, consideration should be given to the traffic signal system.

A map showing the affected area should be obtained. Traffic signal locations should be indicated on the map and phasing and timing data accumulated for all signals within the study area. Traffic volumes on major arterials as well as on all likely detour routes should also be obtained. Turning movement volumes during peak periods are required at all signalized intersections.

Significant variations in current and projected traffic by routes are indicative of potential problems with respect to this factor. For example, where through traffic is diverted from a signalized route, timed to accommodate a major traffic flow to an unsignalized route, two problems are posed. First is the fact that the previous minor flow would yield to a minimal or nonexistent movement resulting in unnecessary or inefficient traffic operations. Second, and more importantly, a new major flow is uncontrolled, leaving minor, cross movements to cross the major movement unassisted.

Similar problems arise when traffic on an unsignalized, and probably limited access, route is diverted to a signalized route. Travel times increase, congestion at intersections could ensue, and inefficient traffic operations result.

Contra-Flow Traffic
Analysis Steps

1. Review traffic diversion routes and volumes to determine if the amount of diversion is large enough to warrant consideration.
2. If it is, identify major through traffic routes which intersect with routes to which traffic would be diverted.
3. Assess the potential conflict between diverted traffic and major through traffic as a function of respective traffic volumes.

The concern addressed by this factor is that the rerouting of a major traffic volume could result in conflict with prevailing, areawide traffic patterns. For example, traffic in an area may be highly directed towards the central business district in the morning and away from the CBD in the evening, the flow occurring on one or more arterial roads. When one route is realigned such that traffic flows are in conflict with major movement, traffic operations may be adversely affected.

Detailed, numerical data and accompanying traffic simulations and capacity calculations would likely involve more effort than is appropriate for a study of this type. Instead, on-site observation and qualitative assessment of available data in conjunction with input from local transportation officials is recommended.

Identification of major transportation corridors within the study area can be made from inspection of appropriate mapping and with the assistance of local transportation planners and engineers. The study area, existing traffic routes, and proposed detour routes are defined using the methods described under the factor capacity constraint.

Peak hour, directional traffic counts should be obtained for all major routes within the study as well as for the proposed detour routes. Count locations may be limited to only one or two locations along each route. It is only necessary to identify the areawide traffic patterns rather than to discern any detailed traffic characteristics within the area.

A subjective assessment is then made of future traffic patterns as compared with the present day. This would involve identifying corridors that are in conflict with proposed detour routes. The severity of the impact can be gauged by the volume of the traffic within the corridor and that of the traffic using the crossing. Lower detour volumes will result in less impact on systemwide traffic. Likewise, lower areawide volumes will, when in conflict with diverted crossing traffic, result in less impact.

Refinement of Other Factors. The remaining factors which may deserve consideration in Level 3 analysis are those previously examined in Level 2. These factors are: crossing delay, vehicle queuing, capacity constraint, change in travel time, emergency services response, and rail service quality and costs. If it is desired to further clarify distinctions between alternatives revealed during Level 2, refinement of these factors is appropriate.

Refinements to the analysis of the factors are of two types. First, analytical refinements are achieved by using more accurate data to support the analysis. Second, more detailed or disaggregate analysis of some factors is included.

Enhancements to database accuracy are achieved as follows: (1) Through conduct of an origin/destination survey or use of a simulation model to more accurately identify current trips (by O/D pair) through the crossing and the distribution of trips among O/D pairs. These data would support more precise consideration of capacity constraint, travel change, and other analysis which involve changes in traffic patterns. (2) conduct more extensive field observations to confirm estimated problem magnitudes. These field observations would cover traffic activity along the area identified as subject to potential queuing problems, and train operations on the crossing segment of the rail line which the railroad identified would be subject to significant conflict with an at-grade alternative.

These database refinements require significant effort to accomplish and, consequently, are undertaken only if required to identify the preferred alternative.

Refinements to the capacity constraint analysis also are introduced in Level 3 analysis. Analytical methods for the other factors (crossing delay, vehicle queuing, change in travel time, emergency services response time, and rail service quality and cost) described in Level 2 analysis can be used when refined data are obtained in Level 3.

Capacity Constraint on Parallel Routes (Alternatives considered—close highway, relocate structure).

Capacity Constraint on Parallel Routes
1. Identify parallel or detour routes.
2. Obtain midblock and turning movement volumes at key locations.
3. Compute levels-of-service at critical locations.
4. Reassign traffic through the crossing.
5. Recompute levels-of-service at critical locations.

Common origins and destinations using the crossing as well as the principal paths connecting them are required for this analysis. Traffic volumes should be obtained for both the existing paths and for alternate or detour paths. Turning movement counts should be collected at key intersections for peak periods. Intersection geometry including number of lanes and type of lanes (e.g., designated turn lanes) is required at all key intersections. Number of lanes on existing and alternate routes is also required for this analysis.

Midblock and intersection capacity should be calculated for the morning and evening peak periods and during the midday period. Midblock capacity is evaluated by computing a volume/capacity ratio as described in Level 2 "Capacity Constraint" where free-flow traffic conditions occur.

Intersection capacity is computed using the methods described in *Special Report 209*—"1985 Highway Capacity Manual," or *NCHRP Report 187*—"Quick Response Urban Travel Estimation Techniques and Transferable Parameters, User's Guide." Evaluations should be made at all major intersections, along the diversion routes both as they exist today and as proposed.

The magnitude of diversion in traffic operations along the diversion routes should be evaluated to determine whether it will be acceptable. One possible measure is that traffic service levels should not decline below level-of-service C in rural areas and level-of-service D in urban areas.

The service level on the diversion routes should not be lower than that of the existing route. If they are, opposition can be expected both from the roadway users and residents in areas through which the road passes.

Community and Environmental Considerations

The Issues

- To what extent would implementation of an alternative enhance or disrupt community activity patterns?
- Would implementation of the alternative cause a significant change in noise levels?
- Would the alternative cause ambient air quality standards to be exceeded?
- Would the alternative affect ambient water quality?
- Would the alternative improve aesthetics or cause visual intrusion?
- Would the alternative disrupt, disturb, impinge upon, or otherwise intrude on existing land uses?

Several factors are considered under this subject area in Level 3 analysis: activity patterns, noise, air quality, water quality, aesthetics, land use. Analysis of these factors involves use of some quantitative information (e.g., changes in travel times, changes in described levels) to judge the qualitative implications of each alternative.

Units of measurement include a judgment regarding the degree of positive or negative effect on each community/environmental attribute.

Methodology

To facilitate the analysis, a separate section for each of these factors is presented below. Each section describes the procedures for assessing each factor. The results of the factor analyses should be recorded in the summary matrix, Table A-29.

Table A-29. Community and environmental considerations—summary matrix.

Factor	Alternative				
	Rehabilitate	Replace	Put At-Grade	Close Road	Close Rail Line
Activity Patterns					
Noise					
Air Quality					
Water Quality					
Aesthetics					
Land Use					

Enter one of the following based on each factor analysis:

NA = Not applicable
NS = Not significant
SS = Somewhat significant
VS = Very significant

Use parentheses to represent negative effects, e.g., a "(VS)" entry would signify a very significant negative effect.

Community Activity Patterns. The quality of life in a community or neighborhood can be affected in many ways by a change in the transportation system. Some of the effects of the alternatives for rail/highway crossings are considered through the analysis of rail and highway operations, land use displacement and disruption, and safety. However, the treatment of these other factors is made somewhat in isolation of a community context. The purpose of this factor—community activity patterns—is to determine to what extent each alternative enhances or detracts from the quality of life in communities or neighborhoods in which the crossing is located. This analysis is accomplished by first defining community boundaries and then by determining the extent to which activity patterns within the communities may be affected by each alternative. Results are documented in Table A-30.

> Community Activity Patterns
> Analysis Steps
>
> 1. Define community boundaries.
> 2. Identify activity patterns within the community by linking residential neighborhoods and primary activity centers. Links should identify typical travel routes.
> 3. Determine which activity patterns, if any, would be enhanced or disrupted by implementation of each alternative. Accomplish this by mapping activity patterns and changes in transportation operations and physical features associated with each alternative (e.g., travel delays, crossing closure, route diversions, congestion).
> 4. For those activity patterns positively or negatively affected, define degree of impact in terms of absolute and percent change in travel times for motorists and change in distance traveled for pedestrian and bicycle trips.
> 5. Determine roughly what portion of all primary activity patterns made within the community would be positively or negatively affected.
> 6. Record results in the community activity patterns matrix.
> 7. Based on the above analysis, rate the significance of potential disruption by alternative (NA = not applicable, NS = not significant, SS = somewhat significant, VS = very significant). Enter the result in the Community and Environmental Concerns Summary matrix.

Table A-30. Summary of community activity patterns analysis.

		ORIGINS													
		A	B	C	D	E	F	G	H	I	J	K	L	M	N
	A														
D	B														
E	C														
S	D														
T	E														
I	F														
N	G														
A	H														
T	I														
I	J														
O	K														
N	L														
S	M														
	N														

> Distance (miles):
> Travel time (minutes):
> % increase in travel time:
> Significance of trip (H, M, L):

Defining a community is not a simple matter. Efforts to define what a community is, in a manner fully acceptable to all who use it, may be very difficult. Nonetheless, a working definition is required.

In this methodology, community is defined in terms of patterns of social interactions, or the geographic area within which residents' primary social, recreational, civic, and cultural activities occur. Thus, to define a community, one must identify the location of primary activities. In this analysis, these activity locations include residential areas, schools, libraries, government centers, recreational and community centers, local shopping areas, and other employment areas. These are the locations that people travel to on a frequent basis (at least once a week) for work, social, recreational, civic, cultural, educational, and shopping purposes.

In rural areas and small towns, a community is easily defined. It typically includes the entire contiguous built-up area around the crossing location and is often defined by the jurisdictional boundaries of the town. Thus, for towns or unincorporated areas adjacent to the crossing, the jurisdictional boundary or entire contiguous area is used in this analysis.

In urban areas, the geographic definition of community is much less apparent. Given the definition of community stated above, in urban areas one must discuss community boundaries with individuals familiar with the areas such as local planners and officers of neighborhood associations or civic groups (e.g., the PTA). In the discussions, the first areas to define are residential neighborhoods in the vicinity of the crossing. Land use maps can be used as a starting point by locating residential areas within 1/4 mile of the crossing. Boundaries of residential neighborhoods can be defined by reference to civic association boundaries and, perhaps, elementary school districts and through discussions with individuals mentioned above.

The next step is to define activity patterns between the residential neighborhoods and the larger community. These patterns can be identified by asking knowledgeable local people to identify on a map the locations defined above—schools, libraries, etc. The area encompassing these activity patterns is the geographic boundary of the community for the purpose of this analysis.

Another dimension of community patterns which must be defined is the routes these patterns typically take. With the local contacts, the analyst must define the typical routes used by motorists, bicyclists, and pedestrians to travel to and from the activity centers. Outside of the immediate neighborhood, these routes typically will consist of the major arterials in the city or town.

Having defined the community and the activity patterns within it, the issue is whether any of the alternatives will disrupt these patterns through changes in travel times or the creation or removal of psychological barriers. The alternatives most likely to negatively impact activity patterns are relocation, replacement with an at-grade crossing, and close the road because these alternatives may create more circuitous and/or more time-consuming routes to and from activity centers. In some cases, these alternatives could improve patterns if they eliminate a psychological barrier to interaction or divert traffic from neighborhood streets on to arterials.

To determine whether an alternative may have a positive or negative effect on activity patterns first requires the identification of which patterns may be affected. This is accomplished by superimposing a mapping of positive and negative effects of each alternative on highway and street operations. Data on highway operations effects are developed in the analysis of rail and highway operations. One should include on the map locations where physical and operational changes will occur, such as crossing delay, congestion, and detour routes.

After identifying patterns that may be positively or negatively affected, the degree of effect should be determined. This analysis involves two perspectives. First, is the extent to which overall community patterns are affected—this is a function of the relative significance of the activity patterns affected to all activity patterns. An approximation of the percentage of all trips represented by the patterns affected can be made based on discussions with local officials. Second, is the degree to which the pattern would be affected—this is primarily a function of the absolute and percentage in time required to travel to and from affected activity centers. In this determination, a distinction should be made between pedestrian/bicycle trips and automobile trips. Many of these calculations can be based on factor analyses in the rail and highway operations area.

Noise. Several of the alternatives could cause changes in noise levels at certain locations as a result of their effects on highway and rail operations. Two alternatives most likely to cause changes in noise levels are relocation of the structure and closure of the road. In both cases traffic will be diverted to new streets and highways. If the volume of diverted traffic is large, noise levels along the new routes used by motorists could increase significantly. Alternatively, streets and highways from which traffic is diverted may benefit from reduced noise levels.

The at-grade crossing alternative also could cause noise levels to increase, as train engineers must sound horns near crossings and traffic would stop and start more frequently. The remaining alternatives—rehabilitation, replacement, and close the rail line—are unlikely to cause any significant change in existing noise levels. These alternatives could result in increased truck traffic if correction of the deteriorated condition of the existing structure leads to the removal of bridge use restrictions.

The approach to examining the alternatives for noise effects begins with determining whether any sensitive receptors, or land uses which may be disrupted by noise, are in the vicinity of the crossing and/or affected streets and highways. If no sensitive receptors are in the area, changes in noise levels are not likely to be a significant concern.

If sensitive receptors are in the area, the next issue is whether any of the alternatives would cause changes in traffic operations or rail operations that would cause noise levels to increase or decrease. If the answer is yes, a simple technique is used to determine whether the change in noise would be large enough to affect adjacent land uses positively or negatively.

Noise
Analysis Steps

1. Determine whether a noise analysis is required by: (a) determining if sensitive receptors are in the vicinity of the alternative, and (b) changes in highway and rail operations which affect noise levels would occur
2. If a noise analysis is required because of predicted changes in highway operations, use the FHWA simplified method to determine the possible significance of the impact on noise
3. If a noise analysis is required because of predicted changes in rail operations, use the ICC method to determine the significance of the noise impact.

The first step in the noise analysis is to determine if there are any sensitive receptors within 1,000 ft of the location at which the alternative would be implemented and along streets and highways to/from which traffic may be diverted.

Sensitive receptors include: churches, hospitals, schools, libraries, residences, hotels and motels, meeting rooms, recreation areas, other areas where low noise levels are important. Streets and highways on which traffic levels may change are identified in Level 2 analysis—"Rail and Highway Operations."

If there are no sensitive receptors in the area, one should enter "NA" (not applicable) in the Community and Environmental Considerations Matrix. Otherwise, proceed to the next step.

The second step is to determine whether implementation of the alternative will cause a change in traffic or rail operations that would change noise levels. These changes could include any of the following: highway traffic rerouting, highway traffic volume or speed increases/decreases, roadway or railway gradients increases/decreases, roadway or railway depression, roadway surface smoothing/roughening, rail traffic rerouting, rail traffic operating changes (e.g., sounding horns, location of delays, increase in number of train movements).

If any rail operating changes would occur, proceed to Step 3. If there would be changes in highway operations, proceed to Step 4. If there would be no changes, enter "NA" in the matrix.

To determine whether changes in train operations are significant (Step 3), the Interstate Commerce Commission guidelines for preparing impact statements are that no noise analysis is required (i.e., the impact is not material) unless either of the two following situations exist: (1) the alternative results in an increase of eight or more trains a day on a rail line; or (2) the alternative results in a 100 percent or greater increase in annual gross ton miles on a rail line, and there would be eight or more trains a day operating on the line. Therefore, if train operations are not predicted to be altered by this amount, the analyst can enter "NS" (not significant) in the matrix. If train operations are predicted to exceed the thresholds, the analyst should consult the ICC's Economics and Environment Branch for guidance regarding methods for additional analysis.

The FHWA has developed a nomograph for making first approximations of changes in noise levels as a function of certain highway operating changes—hourly automobile and truck traffic and speed (Step 4).The nomograph and instructions for its use are shown in Figures A-4 through A-6, and Note following Figure A-6.

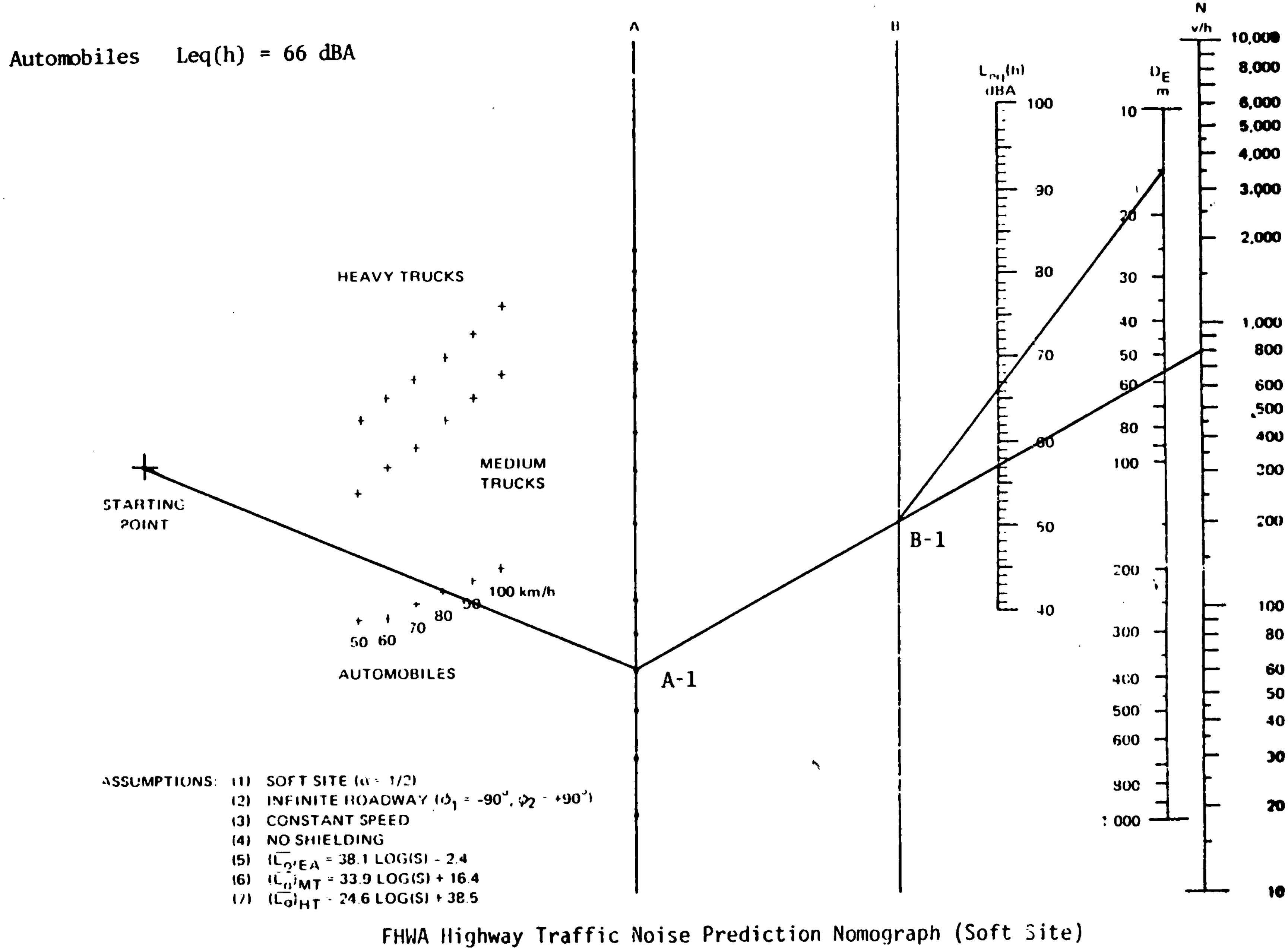


Figure A-4. FHWA highway traffic noise prediction nomograph (automobiles—leg (h) = 66 dBA).

U.S. GOVERNMENT PRINTING OFFICE : 1979 O-292-540/312

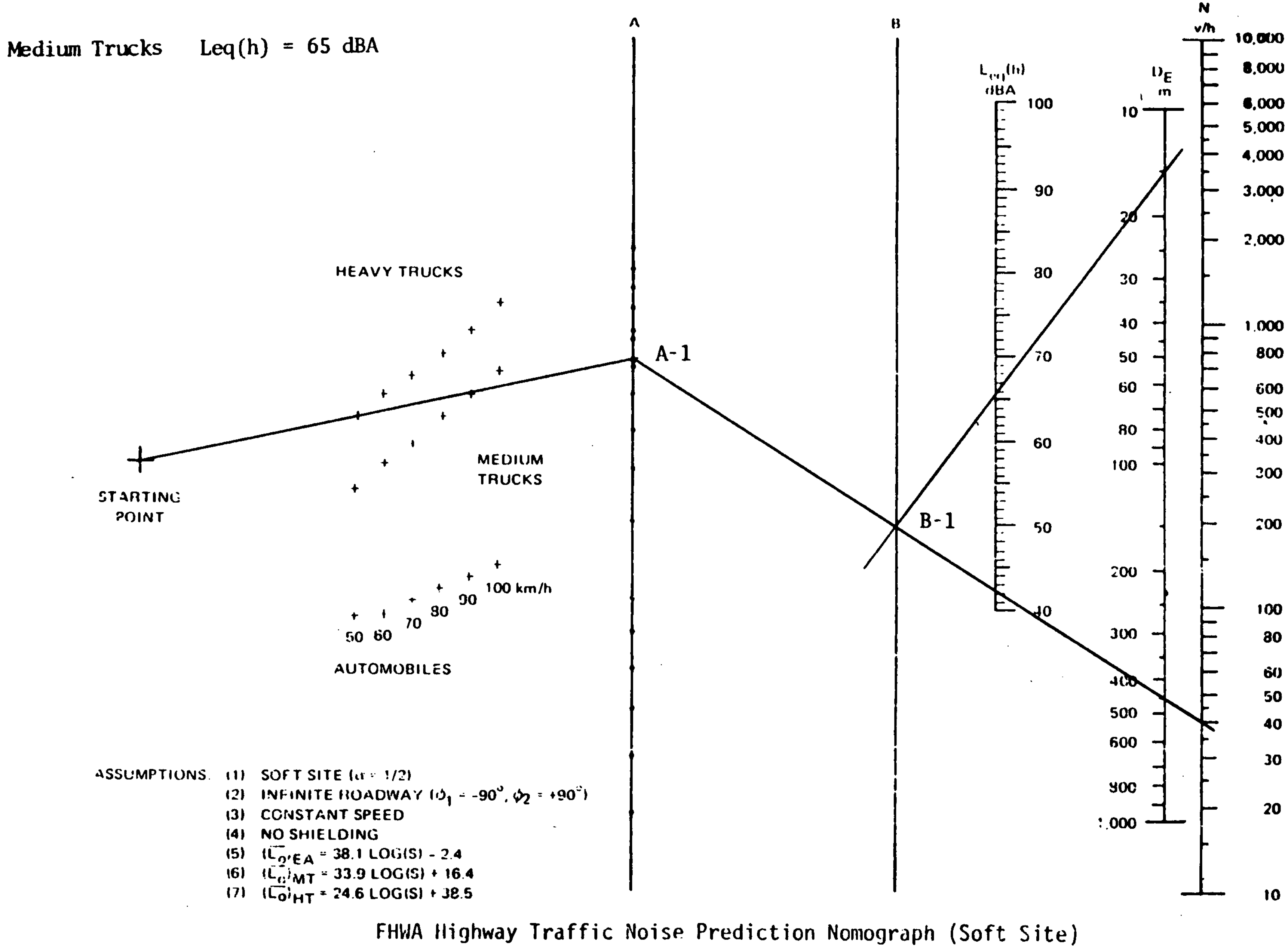


Figure A-5. FHWA highway traffic noise prediction nomograph (medium trucks—leq (h) = 65 dBA).

*U.S. GOVERNMENT PRINTING OFFICE : 1979 0-292-548/35

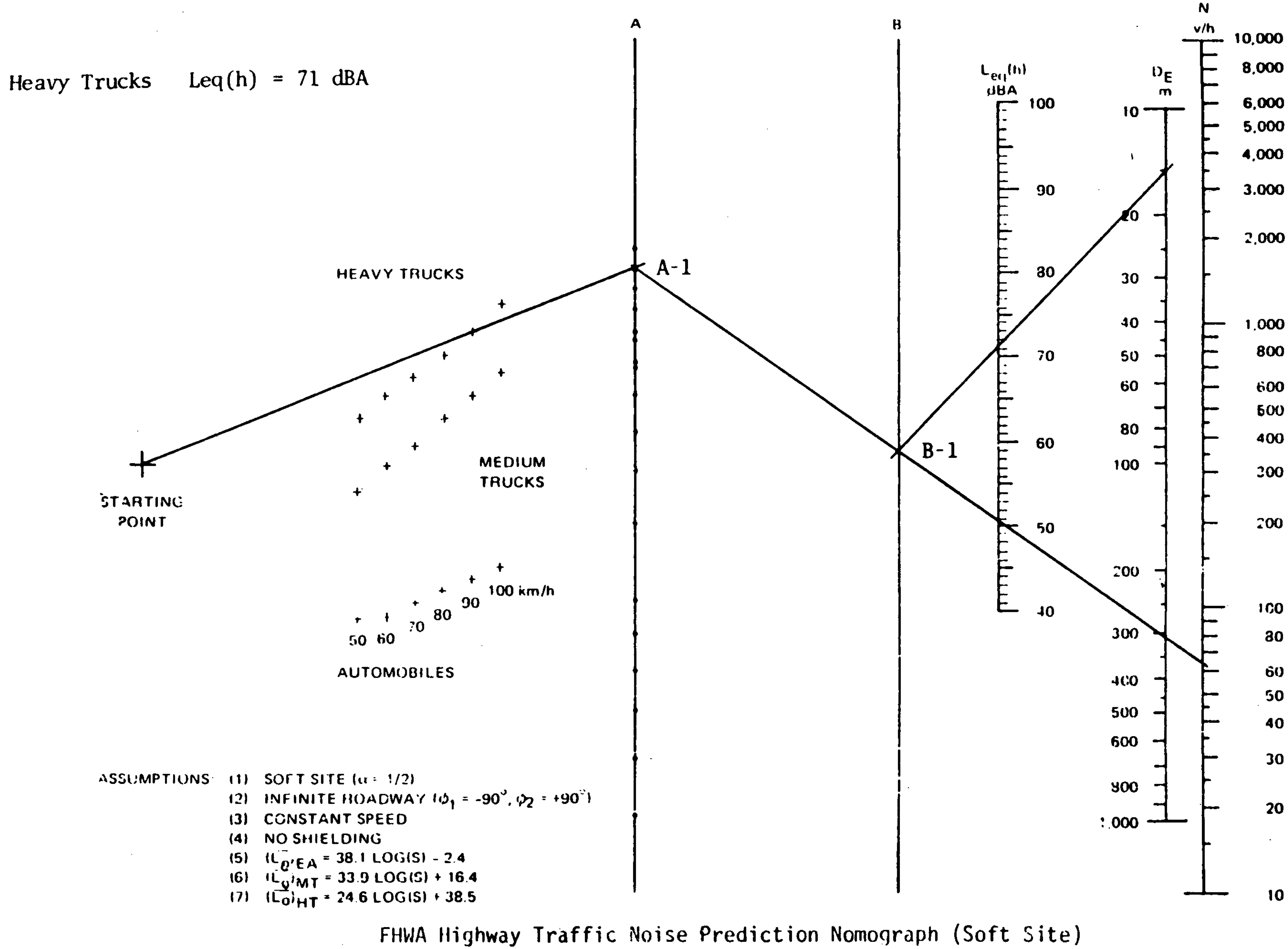


Figure A-6. FHWA highway traffic noise prediction nomograph (heavy trucks—leq (h) = 71 dBA).

U.S. GOVERNMENT PRINTING OFFICE : 1979 O-292-548/815

NOTE

NOMOGRAPH PROCEDURE TO DETERMINE NOISE ABATEMENT CRITERIA DISTANCE FOR LAND USE CATEGORIES

1. Use nomograph to determine Leg(h) for each vehicle group (i.e. autos, medium trucks, heavy trucks) at a distance of 15 meters (50 feet).

   For automobiles:

   (a) Refer to attached nomograph for automobiles. Draw a straight line from the starting point through the 91 km/h point on the automobile speed scale. Extend the straight line to turn Line A.

   (b) Draw a second straight line from the intersection point A-1 to 800 vph point on the volume scale. Mark the intersection of this line with turn Line B as B-1.

   (c) Draw a third straight line from point B-1 to the 15 metre point on the D_E scale. The intersection of the third line with the Leg(h) scale gives the predicted value of 55 decibels for automobiles.

   Predicted noise levels for medium trucks and heavy trucks are computed similarly, except that the speed markings are located higher up on the nomograph.

2. Compute the total Leg(h) for all groups by adding the Leg(h) for each group using decibel addition.

   (a) Use the following rules for decibel addition:

When two decibel values differ by	Add the following amount to the higher value
0 or 1 dB	3 dB
2 or 3 dB	2 dB
4 to 9 dB	1 dB
10 dB or more	0 dB

   (b) Using the above rules, compute the total Leg(h) as follows:

Automobiles	66		
Medium Trucks	65	69	
Heavy Trucks	71		73 dBA

3. For each doubling of distance away from the road subtract 4.5 dBA. (NOTE: the 4.5 dBA reduction should be used for soft sites, a 3 dBA reduction would be used for hard sites).

50'	73 dBA
100'	68.5 dBA
200'	64 dBA
400'	60.5 dBA
800'	56 dBA

4. By interpolation determine the distance for 57, 67, and 72 dBA.

57 dBA

60.5 - 56 = 4.5
60.5 - 57 = 3.5

800 - 400 = 400
$\left(\frac{3.5}{4.5} \times 400\right) + 400 = 711.1'$

67 dBA

68.5 - 64 = 4.5
68.5 - 67 = 1.5

200 - 100 = 100
$\left(\frac{1.5}{4.5} \times 100\right) + 100 = 133.3'$

72 dBA

73 - 68.5 = 4.5
73 - 72 = 1

100 - 50 = 50
$\left(\frac{1}{4.5} \times 50\right) + 50 = 61.1'$

The output of the nomograph is an estimated noise level Leg(h) which can be compared to FHWA noise abatement criteria (see Table A-31). If the estimated change in noise levels associated with the alternative results in projected noise levels lower than the FHWA criteria or if no significant increases in noise levels are predicted (i.e., less than 10 dBA over existing levels), noise is not a significant consideration and an "NS" should be entered in the matrix. If the criteria are exceeded, the analyst should consult the Noise and Air Analysis Division, FHWA, for guidance regarding more detailed analysis procedures and abatement requirements.

Air Quality. As with the other environmental factors, the alternatives under consideration here are unlikely to have a material effect on air quality except perhaps in a very localized area. Each of the alternatives could cause changes in highway traffic characteristics, which could result in changes in vehicular emission levels. However, the magnitude of traffic operations changes are unlikely to be large enough to affect ambient air quality.

The Federal Highway Administration (FHWA), the Noise and Air Analysis Division, issued an air quality analysis discussion paper on April 7, 1986. The paper provides guidance regarding the appropriate level of air quality analysis for projects processed as a categorical exclusion (CE), Finding of No Significant Impact (FONSI), or Environmental Impact Statement (EIS) project. The level of air quality analysis suggested by the FHWA is shown in Figure A-7.

As noted above, it is unlikely that the alternatives under consideration would have a material effect on air quality. Consequently, the analysis procedure presented here is designed to determine whether a potentially significant change would occur with any of the alternatives and hence, whether the simplified analysis or detailed analysis defined by FHWA would be needed. If either of these analyses is needed, the analyst should contact the Noise and Air Analysis Division for guidance.

Air Quality Analysis
Steps

1. Determine whether the alternative is likely to have a material effect on traffic operations. If it would not, enter "NA" (not applicable) in the Community and Environmental Considerations Matrix.
2. If there is some question regarding the significance of the effect of an alternative on traffic operations, use the simplified analysis procedures suggested by FHWA to develop a first estimate air quality effect and compare to air quality standards. If standards are not exceeded, enter "NS" (not significant) in the matrix. If standards are exceeded, consult the FHWA regarding detailed analysis procedures.
3. Based on detailed analyses, if necessary, determine whether the effect on air quality would be somewhat significant (SS), significant (S), or very significant (VS), and enter the assessment in the matrix.

The first step in the analysis is to determine whether there is any likelihood that the alternative would cause a change in vehicular emission levels. Typically, if the alternative would be classified as a categorical exclusion, traffic operating characteristics are unlikely to change enough to effect a change in emissions levels. Actions defined as categorical exclusions, which are relevant to the grade separation issue, are defined in Figure A-8. Also, a review of how similar projects have been processed in the past will guide the analyst. It should be noted that air quality analysis and permitting requirements will vary by state and local government. For example, in some states rail/highway crossing changes may be excluded from air quality analysis, although indirect source permits may be required in certain cases. The analyst should be aware of relevant rules and regulations governing air quality analysis and incorporate these into the analysis procedures presented below.

Usually, classifying a project as a categorical exclusion means that an air quality analysis is unnecessary and the analyst can

Table A-31. Hourly A-weighted sound level, decibels (dBA).

Activity Category	Leg(h)	$L_{10(h)}$	Description of Activity Category
A....................	57 (Exterior)...........	60 (Exterior).......	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purposes.
B....................	67 (Exterior)...........	75 (Exterior)........	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals.
C....................	72 (Exterior)...........	75 (Exterior)........	Developed lands, properties, or activities not included in Categories A or B above.
D....................	....	....	Undeveloped lands.
E....................	52 (Interior)...........	55 (Interior)........	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.

1/ Either $L_{10(h)}$ or Leg(h) (but not both) may be used on a project.

Source: 23 CFR 772 (4-1-86 Edition). Washington, D.C.; U.S. Government Printing Office, 1985.

<———CE———>- - - - - - - - - - - - - >
<——————EA/FONSI——————>- ->
<- - - - - - - - - - <——————EIS——————————————————————————>
No analysis

Simplified analysis
- look-up tables for CO emission rates
- graphical solution for CO concentrations
- assume background levels
- include reasonable receptor site(s)
- conformity statement

Detailed analysis
- "MOBILE" model for CO emission rates
- CALINE3 or HIWAY2 line source models for CO concentration
- TEXIN or CALINE3 (with queuing considered) for intersection CO concentrations (special circumstances only)
- Background levels
  -assume or
  -model or
  -monitor
- Include reasonable receptor sites
- Consider appropriate mitigation measures if violations predicted
- Include evidence of coordination with EPA and state and local air quality agencies
- Conformity statement

LEGEND
<- - -> Normal range
<- - -> Possible range

Source: Noise and Air Quality Division, Federal Highway Administration, USDOT: "Discussion Paper on the Appropriate Level of Highway Air Quality Analysis for a CE, EA/FONSI, and EIS," Washington, D.C., April 7, 1986.

Figure A-7. Suggested level of air quality analysis.

Reconstruction or modification of an existing bridge structure on essentially the same alignment or location (e.g., widening less than a single travel lane, adding shoulders or safety lanes, walkways, bikeways, or pipelines) except bridges on or eligible for inclusion on the National Register or bridges providing access to barrier islands. Reconstruction or modification of an existing one-lane bridge structure, presently serviced by a two-lane road and used for two-lane traffic, to a two-lane bridge on essentially the same alignment or location, except bridges on or eligible for inclusion on the National Register or bridges providing access to barrier islands.

Modernization of an existing highway by resurfacing, restoration, rehabilitation, widening less than a single lane width, adding shoulders, adding auxiliary lanes for localized purposes (e.g., weaving, turning, climbing), and correcting substandard curves and intersections. This classification is not applicable when the proposed project requires acquisition of more than minor amounts of right-of-way or substantial changes in access control.

Source: 23 CFR 771 (4-1-86 edition). Washington, D.C.: U.S. Government Printing Office, 1985. Includes only those actions applicable to alternative considered in this framework.

Figure A-8. Selected actions that qualify as categorical exclusion.

enter an "NA" (not applicable) in the appropriate row of the Community and Environmental Considerations Matrix. If there is some doubt in the analyst's mind regarding the possible effect on air quality, a review of predicted effects of the alternatives on traffic operations (from the rail and highway operations analysis) can be made. If the analyst believes projected changes in traffic routings, delays at crossings, and queuing may be large enough to cause a material change in vehicular emissions, then the simplified analysis procedure suggested by FHWA may be used to clarify potential air quality impacts.

The primary pollutant analyzed at the project stage is carbon monoxide (CO). CO standards are 35 parts per million over a 1-hour period and 9 parts per million over an 8-hour period. The FHWA discussion paper (referenced above) and associated technical advisories describe a simplified procedure for determining whether a project would result in a violation of these standards. The following example, taken from the discussion paper, illustrates the procedures.

Simplified Air Quality Analysis—Example Problem. The project is an east-west link of a four-lane urban at-grade freeway. The lane width is 12 ft (3.7 m) and there is a 30-ft (9.2 m) median. The nearest receptor on this link is a home approximately 100 ft (30 m) south of the centerline of the highway. From recent monitoring studies done in other parts of the city, it has been determined that the background level of carbon monoxide (CO) exclusive of roadway effects is 2 parts per million (ppm). The traffic forecasts indicate an annual average daily traffic (AADT) of 88,000, peak-hour travel of 7,480 vehicles per hour and an average hourly travel over the eight continuous hours of highest travel of 5,610 vehicles per hour.

Find:

(a) The vehicle emission factor for a predicted peak-hour speed of 21 mph, 20.6% cold starts, and 21° ambient temperature for 1985; and

(b) The CO 1-hour and 8-hour concentrations at the receptor for meteorological stability class D and a 10° wind angle.

Determine composite emission factor. Use the emission factor tables contained in Technical Advisory T 6640.10 "Mobile Source Emission Factor Tables for MOBILE 3," to determine the emission rates using the parameters noted above. The proper emission factor is circled on Table 2 of T 6640.10, which is reproduced in Table A-32. For a temperature of 20°, calendar year of 1985, percent cold start of 20.6, at low altitude, the single vehicle emission factor is 70 grams/mile. Note that the closest values for speed, temperature, and percent cold start have been used. It would have been possible, but unnecessary in this case, to interpolate within the range of the tabulated parameters.

Determine 1-hour and 8-hour CO concentrations. In step 1—determine 1-hour unadjusted CO concentration—use the nomographs transmitted with FHWA Technical Advisory T 6640.6 to determine the unadjusted 1-hour CO concentration. For this problem, use the nomograph for Stability Class D (generally used in urban areas), and a wind angle of 10 deg. Note that the chosen wind angle of 10 deg will normally result in the "worst case" concentration levels for any receptors reasonably close to the right-of-way line. For a receptor distance of 30 m and an emission factor of 70 g/mi, the unadjusted CO concentration is 5.8 ppm (see nomograph, Fig. A-9).

In step 2, adjust CO concentration for traffic volume. Because the nomograph is based on an assumption of 4,000 vehicles per hour, the CO concentration obtained from step 1 must be adjusted for actual traffic conditions. Therefore, to obtain the adjusted concentration in ppm, multiply the CO concentration obtained from step 1 by:

$$\frac{\text{actual traffic (vehicles/hour)}}{\text{4,000 vehicles/hour}}$$

Table A-32. Co-emission factors.

FHWA TECHNICAL ADVISORY T 6640.10
January 3, 1986
ATTACHMENT 2

CO EMISSION FACTORS (GM/MI)
Low Altitude

PCCN = 20.6
PCHC = 27.3
PCCC = 20.6

TEMPERATURE (Degrees °)	CALENDAR YEAR	Average Vehicle Speed (mph) 5	10	15	20	30	40	55
0	1985	276	167	121	94	60	41	29
	1987	234	149	111	87	55	37	25
	1990	184	129	98	77	49	32	20
	1995	140	108	85	68	43	28	16
	2000	125	99	79	63	41	26	14
	2005	122	97	77	62	40	26	14
10	1985	238	144	104	81	51	35	26
	1987	201	128	95	74	47	31	22
	1990	157	109	83	65	41	27	17
	1995	118	90	71	56	36	23	13
	2000	104	82	65	52	34	22	12
	2005	102	81	64	51	33	22	12
20	1985	208	125	90	70	45	31	23
	1987	173	110	81	64	40	27	19
	1990	134	93	71	55	35	23	15
	1995	99	76	60	47	30	20	11
	2000	87	69	55	44	28	18	10
	2005	85	67	53	43	28	18	10
30	1985	182	109	79	61	39	27	20
	1987	151	95	70	55	35	23	16
	1990	115	79	60	47	30	20	13
	1995	83	64	50	40	25	17	9
	2000	73	57	46	36	23	15	9
	2005	71	56	45	36	23	15	8
40	1985	161	96	69	53	34	24	18
	1987	132	83	61	47	30	20	15
	1990	99	68	51	40	25	17	11
	1995	70	53	42	33	21	14	8
	2000	61	48	38	30	19	13	7
	2005	59	46	37	29	19	12	7

actual traffic (vehicles/hour) = 7,480 (vehicles, hour)

$$\text{traffic adjustment factor} = \frac{7{,}480}{4{,}000} = 1.87$$

$$\text{adjusted CO} = 5.8 \text{ ppm} \times 1.87 = 10.8 \text{ ppm}$$

In step 3, determine total 1-hour CO concentration: Total 1-hour CO concentration = adjusted CO + background = 10.8 ppm + 2 ppm = 12.8 ppm.

In step 4, determine total 8-hour CO concentration. If the 1-hour analysis predicts a 1-hour CO concentration of less than the 8-hour CO standard of 9 ppm, no separate 8-hour analysis is necessary. If the 1-hour CO concentration is equal to or greater than 9 ppm, an 8-hour analysis should be performed by multiplying the 8-hour average traffic by a meteorological persistence factor (usually 0.6) and dividing by the 1-hour traffic; then multiplying by the 1-hour CO analysis concentration:

$$\text{8-hour CO concentration} = \frac{(0.6) \times (\text{8-hour average hourly traffic})}{(\text{peak hour traffic})} \times (\text{1-hour CO concentration})$$

Since the 1-hour CO prediction is above 9 ppm in this example, use of the above equation is called for.

$$\text{8-hour CO concentration} = \frac{(0.6) \times (5{,}610 \text{ vehicles/hour})}{(7{,}480 \text{ vehicles/hour})} \times (12.8 \text{ ppm}) = 5.8 \text{ ppm}$$

In this example, project-specific data for the 8-hour period were available. In cases where such data are not available, a typical traffic persistence (8-hour average hourly traffic divided by peak-hour traffic) of 0.75 can generally be used, or the tables in *NCHRP Report 187,* Chapter 6, may be used to compute a traffic persistence value.

Aesthetics. The objective of this issue is to determine the extent to which the improvement alternatives under consideration are aesthetically compatible or incompatible with their surroundings. This is accomplished by evaluating the visual contrast of each alternative with its surroundings by estimating changes in existing visual elements such as line, form, color, and texture. While any of the six generic improvement alternatives may affect aesthetics, the alternatives with the greatest potential to bring

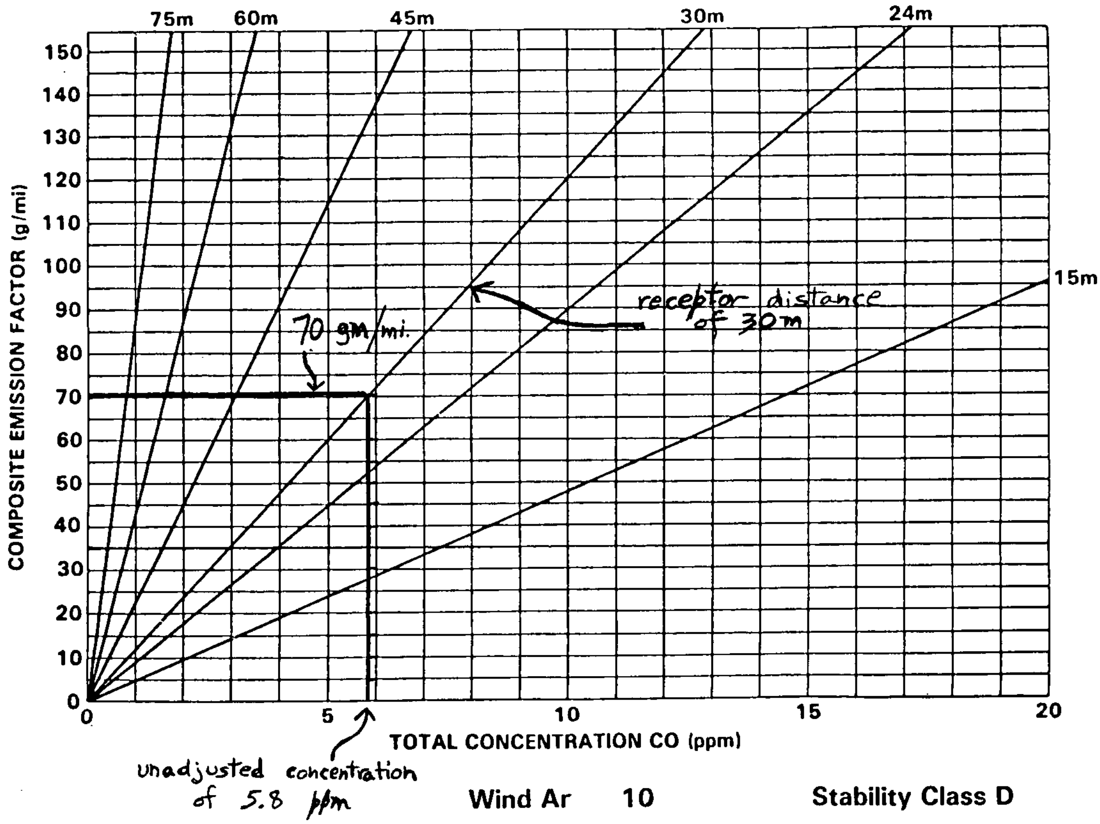


Figure A-9. Nomograph.

about significant changes in the area of concern are relocation of the grade separation, replacement at-grade, and closure of the crossing or rail line.

It should be emphasized that grade separation improvements may affect aesthetics either positively or negatively. Replacement at-grade and closure of the crossing or rail line, to the extent that they remove an obtrusive, dilapidated structure from view, generally will improve aesthetics, while relocation, to the extent that it introduces a structure to an area where no structure previously existed, would tend to create or increase visual intrusion.

> Aesthetics
> Analysis Steps
>
> 1. Determine whether the alternative would be located in an area in which visibility may be an issue.
> 2. If the result of step 1 is "no," enter "NA" (not applicable) in the aesthetics matrix. If the result is "yes" assign the alternative a visual contrast rating.
> 3. Use the rating to judge the significance of the change in the visual environment associated with the alternative.

The first step involved in analyzing the impacts of proposed improvements on aesthetics is to determine for each alternative under consideration whether there is even any need to be concerned about its impact on aesthetics. If a proposed improvement is located in a fairly remote area, appearance may be of little or no concern in selecting an alternative. In a historic preservation district, on the other hand, appearance might be of paramount importance in making such a decision.

Examine maps of the area(s) surrounding each improvement alternative and determine whether the alternative would be located in, or within one-quarter mile of, any existing or planned areas in which visibility of the improvement may be perceived as a visual intrusion. Such areas include: residential neighborhood, commercial/office district, historic/cultural district, recreational/scenic area, natural habitat area or wildlife/waterfowl refuge.

If an alternative is not located in or near such an area, enter "NA" (not applicable) in the appropriate column of the Community and Environmental Considerations Matrix.

If the alternative is located in or within sight of any of the above areas, assign to it one of the following visual contrast ratings:

1. *Insignificant:* The proposed improvement would create visual characteristics similar to those that currently exist in the landscape.
2. *Low:* The improvement would introduce additional visual characteristics into the landscape that would be evident but would not necessarily attract attention.
3. *Moderate:* The improvement would introduce visual characteristics that would be noticeably different in character from existing visual elements.
4. *High:* The improvement would visually dominate the land-

scape and would cause substantial change in the visual character of the landscape.

As discussed above, changes in visual contrast may be positive or negative. Because these ratings only indicate the magnitude of visual contrast associated with a given alternative, they should be enclosed in parentheses if changes in contrast are positive in nature.

In assigning visual contrast ratings to each improvement under consideration, the following points should be borne in mind:

1. *Rail lines and roadways* generally create slight visual contrasts because of their low scale and weak line characteristics.
2. *Trains and motor vehicles,* because of their distinct form and solid colors, generally create strong contrasts with undeveloped landscapes. The degree of their visual impact is a function of both the number of trains and motor vehicles using the crossing per day and the duration of view (e.g., the amount of time it takes to negotiate the crossing or the length of time motor vehicles are queued at the crossing waiting for trains to pass).
3. *Bridges'* degree of visual contrast is largely a function of the scale of the surrounding landscape and the types of materials used in bridge construction. For instance, strong contrasts would be created by a bridge which is out of scale with existing, adjacent structures or land forms and/or is built of materials which contrast sharply, in terms of color and texture, with those found in adjacent structures or land forms.
4. *Cuts,* even if revegetated, can create strong visual contrasts depending upon whether or not they are large (e.g., greater than 10 ft high) and require the removal of large trees or other distinct natural features that are difficult to replace or duplicate.
5. *Fills* may create visual contrasts depending upon their direction and angle in relation to the surrounding terrain. Fills aligned parallel to existing terrain lines generally create weak contrasts with the existing landscape. Fills aligned perpendicular to, or against, existing terrain lines result in significantly greater contrasts. An example of the latter situation is a fill constructed across a flood plain, where the natural boundaries and lines of the plain are sharply broken.

Bearing these points in mind, visual contrast ratings should be assigned to each alternative on the basis of expert judgment after a careful review of detailed plans and drawings for each improvement and photographs of the study area and, if additional information on the surrounding landscape is needed, site visits. It also may be useful to superimpose drawings of alternatives on photographs of their proposed sites in order to assess their consistency with the surrounding landscape.

With the visual contrast rating in mind, rate the significance of the change of alternative (NS = not significant, SS = somewhat significant, S = significant, VS = very significant) noting whether the change would be positive or negative. Enter the result in the Community and Environmental Consideration Matrix.

Water Quality. The objective of this component of the analytical framework is to determine whether any of the improvement alternatives under consideration will result in changes in roadway or railway design or operations that might affect ambient water quality in the vicinity of the crossing. There are several ways in which water quality might be affected by improving a deteriorated grade separation, most of which would be associated with relocating the crossing. For instance, large cuts and fills associated with relocation of the roadway or rail line could increase erosion and sedimentation of surface water bodies or, if located in a flood plain, could disrupt runoff, also leading to sedimentation and eutrophication. Changes in elements of railway or roadway structure or configuration such as curvature, gradient, and sight lines might affect the use of deicing salts and defoliants and their subsequent runoff into bodies of water.

Water Quality
Analysis Steps

1. Determine whether there are any water bodies or flood plains near the alternative. If not, enter "NA" (not applicable) in the Community Environmental Considerations Matrix.
2. Determine current use of water bodies. If surface bodies are used for industrial and/or transportation purposes, enter "NS" (not significant) in the matrix.
3. For water bodies that might be exposed to pollution by the alternative, rate the potential significance of the effect (NS = not significant, SS = somewhat significant, S = significant, VS = very significant) Enter the result in the matrix.

The preliminary task involved in evaluating water quality impacts is to determine whether there are any water bodies or flood plains near any alternative, and whether they are used for industrial and/or transportation purposes only. In performing the first of these tasks, overlay the proposed alignment of each alternative on available maps of the area and determine if there are any streams, ponds, wetlands, aquifers, wells, or other bodies of water, or any flood plains located within one-half mile of the improvement. Maps such as USGS or other topographical maps, which show all surface water bodies, should be used. Other maps and documents regarding geological formations in the vicinity of each improvement should be used to locate subsurface aquifers (groundwater supplies) and aquifer recharge areas.

If the only water bodies located within the specified distance of an improvement are surface bodies, determine whether they are used for industrial and/or transportation purposes only by contacting state or local water resources management, economic development, and/or water transportation agencies. (The underlying premise here is that any possible changes in water quality associated with improving a deteriorated grade separation would have a negligible impact on water bodies used for these purposes, and can therefore be ignored.)

If it is determined that there are no bodies of water in the vicinity of a given improvement alternative, the analysis of water quality with respect to that alternative is complete and "NA" (not applicable) should be entered in the appropriate column of the Community and Environmental Considerations Matrix. If the only bodies of water in the vicinity are surface bodies used for industrial and/or transportation purposes, enter "NS" (not significant) in the impacts matrix. In all other cases, it will be necessary to determine the nature and magnitude of water-related impacts associated with each alternative.

In analyzing these impacts, it is useful to distinguish between effects on water quality and on aquatic ecosystems. The effects on water quality include the introduction of a variety of pollutants, through runoff and/or infiltration, into surface and subsurface water bodies, including traffic-generated fuels, lubricants, and litter; substances accidentally spilled by motor vehicles or trains; maintenance-related deicing salts, defoliants, and pesticides; eroded soils and organic matter; paving materials such as tar, asphalt, and concrete. Other impacts on water quality include changes in surface water flow and turbidity, aquifer recharge rates and capacity, and groundwater flow.

The effects of a transportation project on aquatic ecosystems—the complex of plants, animals, and physical (e.g., aqueous, geological) elements in which they interact—include both direct and indirect impacts of introducing pollutants and altering hydrologic characteristics. While positive effects could occur, the focus here is on adverse effects: killing aquatic organisms or harming them (e.g., changing growth rates or species composition) and interfering with the life-support systems of aquatic species.

Established techniques for measuring impacts on water quality and aquatic organisms and ecosystems are relatively complex and time-consuming, requiring considerable on-site and laboratory analysis. In view of their inconsistency with other components of the analytical framework, in terms of level of detail and effort, and of the fact that permanent water-related impacts associated with improving a deteriorated grade separation generally will be negligible or nonexistent, the evaluation procedure employed here relies on expert judgment rather than on rigorous measurement techniques.

In evaluating water-related impacts, one of the following impact ratings should be assigned, if applicable, to each improvement alternative and entered in the Community and Environmental Considerations Matrix.

1. *Not significant:* The proposed improvement would neither increase the quantity or toxicity of transportation-related pollutants currently introduced to water bodies, nor alter existing hydrologic characteristics.
2. *Somewhat significant:* The improvement would noticeably increase pollutant levels and/or toxicity, and/or noticeably alter hydrologic characteristics, but would not cause any long-term damage to water quality or supply, or to aquatic ecosystems.
3. *Significant:* The improvement would increase pollutant levels and/or toxicity, and/or introduce changes in hydrologic characteristics sufficient to permanently impair water quality or supply, and aquatic ecosystems.
4. *Very significant:* The improvement would increase pollutant levels and/or toxicity, and/or introduce changes in hydrologic characteristics sufficient to destroy all or the majority of adjacent water bodies and aquatic ecosystems.

In assigning water quality impact ratings to each alternative under consideration, several points should be borne in mind. First, changes in pollutant levels are primarily a function of changes in train and motor vehicle traffic patterns and are thus most likely to occur if the deteriorated grade separation is relocated or replaced with an at-grade crossing. Even if traffic volumes do not change, the latter option has the potential to increase the amount of motor vehicle-related contamination at the crossing because it both forces vehicles to stop for passing trains (increasing litter and spillage of fuels and lubricants), and increases the likelihood of train/motor vehicle collisions. The former option may introduce pollutants to new locations by relocating traffic to areas where it does not currently exist.

Second, changes in pollutant levels also may result from modifications to roadway or railway structures or to the surrounding terrain. For instance, eliminating the grade separation structure, either by closing the crossing or putting it at grade, could reduce the amount of deicing salts entering adjacent water bodies through runoff or infiltration. Similarly, changes in curvature and gradient, to the extent that they improve sight lines, might reduce the need for defoliants and their resultant introduction into water bodies.

Significant amounts of cutting and filling, such as might be associated with relocating the grade separation, can affect both pollutant levels and hydrologic characteristics. If cuts and fills are not properly revegetated, they can result in erosion and sedimentation, causing, in turn, disruption of nutrient cycles, eutrophication of downstream receiving waters, turbidity, and changes in surface water flow and runoff. Other changes in hydrologic characteristics may result from the excavation of impervious material protecting subsurface aquifers which could affect recharge capacity and water table levels and facilitate the infiltration of surface contaminants into groundwater supplies, including wells.

All of these factors should be taken into account when assessing the impacts of each alternative on water quality and aquatic ecosystems. Impact ratings, because they rely heavily on expert judgment, should be determined in consultation with hydrologists, biologists, hydrogeologists, or other state and local water resources management officials knowledgeable of the study area. To the fullest extent practicable, all available secondary data on the area from such sources as the state department of natural resources or its equivalent, the Environmental Protection Agency, the U.S. Soil Conservation Service, and the U.S. Geological Survey (USGS) should be assembled and reviewed before assigning impact ratings. If necessary, these should be supplemented with primary data collected through site visits.

Land Use. The principal reason for restricting the analysis of land-use impacts in Levels 1 and 2 to an examination of displacement is that the taking of land is the most serious land-use impact likely to occur in the course of improving a deteriorated grade separation. Level 3 analysis, however, focuses on a related, albeit normally less serious, category of impacts: those involving the disruption or disturbance of existing land uses.

Although all six generic improvement alternatives, with the possible exception of closing the rail line, have the potential to impinge on existing land uses, the relocation and replacement at-grade options are the most likely to be disruptive. Disruption associated with improving a deteriorated grade separation includes both primary effects on the physical environment, such as changes in air and water quality, noise, and aesthetics, and secondary effects, arising from changes in the environment, changes in rail and highway operations, and displacement of land uses associated with activity and community development.

For instance, an increase in noise and air pollution levels at a crossing might generate secondary disruption of adjacent commercial and residential land uses in the form of reductions in property value and property tax revenue, a loss of customers and sales volume, and a reduction in the level of overall satisfaction or perceived quality of life. However, disruption, as defined here, should not be construed only as a negative or undesirable consequence of improving a deteriorated grade separation, because the removal, relocation, or reconstruction of an intrusive structure can have a positive effect on surrounding land uses.

Primary disruptive (i.e., environmental) effects associated with alternative improvements are examined individually in the previous sections of Level 3 analysis. Secondary effects are evaluated in this section, as outlined below.

Because the precise measurement of crossing-related impacts on such unquantifiable community characteristics as perceived quality of life would be both difficult and time-consuming, the significance of disruption associated with each alternative is determined on the basis of expert judgment. The approach employed here is similar to that used in Level 2 analysis: Land Use—values are assigned to a number of quantitative and qualitative measures of disruption arrayed in the Land Use Disruption Significance Matrix below. (See Table A-33.) The overall significance of disruption is determined on the basis of these measures and assigned a subjective rating at the bottom of the matrix.

Because the type of disruption considered in this part of the alternatives analysis generally is a function of changes in the physical environment and/or rail or highway operations, the analysis of land-use impacts outlined here should *not* be undertaken until the examination of these other impacts is substantially complete.

> Land Use
> Analysis Steps
>
> 1. Determine if any land will be taken to implement the alternative or if land use will be disrupted by changes in traffic operations, accessibility, or environmental quality. If not, stop the analysis. If yes, proceed to Step 2.
> 2. Assess the significances of the land use taking/disruption by completing the land use significance matrix (procedures to complete the matrix are presented in the text).

The study area for the analysis of disruption is a function of the geographic range of those primary impacts, such as changes in noise or air quality, identified elsewhere in the alternatives analysis. As such, it would be useless to specify some distance from a proposed improvement within which to explore the effects of, say, noise on property values without first determining, from the analysis of noise in Level 3, whether there are any noise-sensitive receptors in the vicinity of a given alternative, and whether that alternative would generate any significant changes in crossing-related noise.

Thus, in evaluating disruption to existing land uses associated with an alternative, the focus of the analysis should be determined not on the basis of some arbitrarily defined geographic area, but rather on the basis of anticipated land takings and changes in the physical environment and in rail and/or highway operations. For example, only if it is determined that an alternative will displace land and/or bring about changes in traffic operations, accessibility, and/or environmental quality in or adjacent to a particular area or site will it be necessary to examine land-use disruptions in that area. Relevant implications of each alterative are examined in other parts of the decision-making framework. The analyst should refer to the following Level 3 analyses: Rail and Highway Operations—"Traffic Sensitive Detours," Community and Environmental Considerations—"Community Activity Patterns," "Air Quality," "Noise," and "Aesthetics."

If a measure of disruption does not apply to a particular alternative, enter "NA" (not applicable) in the appropriate cell

Table A-33. Land use disruption significance matrix.

	ALTERNATIVE					
MEASURE OF DISRUPTION	1	2	3	4	5	6
1-Change in Property Value ($ and %)						
2-Change in Business Earnings (%)						
3-Change in Employment (FTE and %)						
4-Change in Facility Use*						
5-Change in Development Potential*						
6-Change in Historic/Cultural Character*						
7-Change in Recreational/Natural Habitat Value*						
8-Change in Satisfaction with Neighborhood QOL*						
9-Overall Significance of Disruption*						

Key:

3-Very significant
2-Significant
1-Somewhat significant
0-Not significant
NA-Not applicable

of the Disruption Significance Matrix. For those alternatives that have already been rejected, enter "NA" in the appropriate column of Line 11. Ranges of values for those measures of disruption marked with asterisks are provided at the bottom of the matrix. Guidelines for assigning values to these and the other measures in the matrix are as follows:

1. *Change in Property Value:* Changes in noise and vibration, air pollution, traffic congestion, accessibility and the like can have a substantial impact on property (particularly residential) values. The introduction of new, or increases in current, transportation-related impacts generally will have a proportionally larger effect on lowering property values than the reduction or elimination of such impacts will have on increasing property values. Approximate percentage changes in total property values of all properties affected (other than through taking) should be estimated on the basis of discussions with a local real estate agent or tax assessor. In discussing potential changes, it will be necessary to have on hand all pertinent estimates of expected environmental and traffic-related impacts and land takings associated with each alternative under consideration—most of which will have been developed during other stages of the alternatives analysis. The estimated percentage change in property value can then be multiplied by the current value (estimated by the real estate agent) to determine the dollar amount of the change. Single percentage and dollar figures for each affected property should be entered in the matrix. If it is easier to estimate the absolute rather than the percentage change in property value(s), the above procedures may be reversed.

2. *Change in Business Activity:* Just as transportation-generated impacts such as noise and vibration, air pollution, and congestion may lessen the attractiveness or desirability and, hence, the value of adjacent properties, they may also affect the patronage of stores, restaurants, offices, and other businesses, thereby influencing employment and earnings. For instance, the introduction of queuing and increased levels of traffic congestion

in the wake of placing a crossing at-grade might impede access to a store adjacent to the crossing to such a degree that substantial losses in sales volume and ultimately in employment would ensue. Projected changes in business activity must be, at best, very rough estimates based on expert judgment. In estimating the percentage change in activity that might result from a particular alternative, a number of factors should be considered: (a) The frequency, timing, and duration of crossing-generated queuing or congestion and their relationship to adjacent businesses' hours of operation. (b) Current and anticipated patronage levels. The key question here is whether the threatened business is a marginal operation whose patronage is highly susceptible to changes in accessibility, or a thriving enterprise characterized by strong demand for its goods or services. (c) The number of alternative or substitute providers in the community. Consumer willingness to endure long lines and traffic congestion in order to patronize a business will be influenced by its relative uniqueness in the community. All other things being equal, patronage of the only convenience store in the neighborhood would be less affected by loss of accessibility than would patronage of one of three convenience stores in the neighborhood. (d) The availability of alternative points of ingress and egress. Patronage is less likely to be affected by crossing-generated blockage and congestion if alternative points of access exist or can be provided.

Taking these and other factors that might affect consumer demand into account in consultation with local businessmen and chambers of commerce, better business bureaus, or economic development officials, estimate to the nearest 10 percent the change (if any) that would occur as a result of each proposed improvement. Information on environmental, rail and highway operations, and accessibility impacts can be obtained from other components of the alternatives analysis. Thus, discussions with local officials should focus on assessing both the viability of any threatened businesses (in order to estimate likely changes in patronage), and the site characteristics of each business and their implications for ingress and egress. A review of recent improvements to other rail/highway crossings in the state also may yield valuable information on crossing-related impacts on business activity (as well as other areas of concern). Using the estimate for each, establish an overall assessment of the effect on business activity.

3. *Change in Employment:* To the extent that an alternative causes business earnings to increase or decline, it also may result in employment changes in any affected businesses. Changes in employment should be estimated on the basis of interviews with business owners who would experience changes in earnings as a result of an improvement. The figures entered in the matrix should reflect the combined gains or losses (if any) in full-time equivalent employees of all affected businesses.

4. *Change in Facility Use:* This measure applies primarily to public use of institutional, historic/cultural, recreational and natural habitat areas, facilities, and services (as opposed to commercial establishments, whose patronage is measured above in terms of business earnings). Just as crossing-generated traffic congestion might impede access to a convenience store or other business establishments, it also could impede (or improve) access to a public library or park. Similarly, an increase in traffic-generated pollutants in the wake of relocating a grade crossing might affect the use of a natural habitat area by wildlife and waterfowl. The frequency and magnitude of such changes should be estimated on the basis of interviews with knowledgeable individuals at any such facilities or areas adjacent to the proposed improvement. In developing an estimate of likely changes in facility usage, those factors identified above as influencing business earnings should be taken into account. Rather than attempt to determine precise changes in the magnitude and frequency of facility use, the rating scale at the bottom of the significance matrix should be used.

5. *Change in Development Potential:* The impact of alternative improvements on the development potential of adjacent properties (if applicable) should be determined on the basis of interviews with local housing, community, and economic development planners and/or local real estate developers. It is particularly important to determine whether a given alternative would conflict with the intent, or violate any provisions of, any community development grant or loan program awards, such as: (a) Urban Development Action Grant, (b) Minority Business Development Award, (c) Urban Enterprise Zone, (d) Community Development Block Grant, (e) Urban Homesteading Program, (f) Rural Housing Preservation Grant, (g) Public Housing Project, (h) SBA Economic Opportunity Loan.

6. *Change in Historic/Cultural Character:* Environmental impacts, such as increased noise and vibration, air pollution, and visual intrusion, associated with improving a deteriorated grade separation may alter the integrity or essential character of historic and archaeological sites and other cultural resources. Those improvement options with the greatest potential to alter rail and highway operations—relocation and placing the crossing at grade—are the most likely to generate such impacts. The severity of such disruption should be estimated, using the rating scale, provided at the lower right of the significance matrix, on the basis of findings from those components of Level 3 analysis dealing with environmental concerns. The key considerations here will be the magnitude and frequency of traffic-generated impacts on the physical environment, and the distance between traffic and historic/cultural sites. Estimates should be made in consultation with local historic preservation and other appropriate officials.

7. *Change in Recreational/Natural Habitat Value:* Once again, traffic-generated environmental impacts are the most likely to affect the recreational and natural habitat value of any such properties adjacent to a crossing. Increased traffic congestion also can affect the use and enjoyment of such sites by impeding access to them. The procedures for estimating such disruption are similar to those outlined above for disruption to historic/cultural sites in that they involve reviewing estimated environmental and accessibility impacts identified in other components of Level 3 analysis in consultation with appropriate local officials.

8. *Change in Satisfaction With Neighborhood Quality of Life:* Changes in rail and highway traffic patterns and operations, accessibility, and traffic-generated environmental impacts may all affect perceptions of quality of life in areas adjacent to a crossing. Residential neighborhoods are likely to be more sensitive to such impacts than other land uses such as industrial and commercial areas that are already characterized by heavy traffic and its attendant environmental impacts. Estimates of the severity of crossing-generated disruption should be made in consultation with local land use planners. Telephone surveys of neighborhoods in the vicinity of other crossings in the community, or in other communities, coupled with information on the traffic patterns and environmental impacts associated with

them, may be particularly valuable in estimating the significance or severity of disruption of alternative improvements.

9. *Overall Significance of Disruption:* A rating indicating the overall significance of the disruption associated with each alternative should be assigned on the basis of the measures of disruption contained in the matrix.

COMPARATIVE EVALUATION OF ALTERNATIVES

Comparison of alternatives in Level 3 analysis is done in the same manner as in Level 2 analysis. The evaluation techniques of: (1) balance sheet comparison, (2) computation of unit costs of relative effectiveness, and (3) total cost comparison are applied successively. Alternatives are compared in pairs to determine the preferred one. The comparative evaluation procedure is described more fully in the discussion of Level 2 analysis.

DOCUMENTATION OF RESULTS

As noted previously, documentation serves the purposes of communicating results to decision-makers and to the public and creates an audit trail of the decision-making process.

With this objective in mind, the results of Level 3 analysis should be documented in a written report or technical memorandum. Working papers showing data sources and detailed computation also should be clearly organized and maintained.

The Level 3 analysis report is an extension of the report written at the conclusion of Level 2 analysis; the results of Level 3 analysis are added to the report written at the conclusion of Level 2 analysis. Also, any updating of information contained in the Level 2 report should be made.

In presenting the analytical findings, each alternative should be discussed in terms of cost, safety, rail and highway operations, community and environmental concerns, and institutional considerations. The basis for rejecting an alternative also must be specified. Level 3 analysis conclusions should be discussed with affected parties before being finalized.

Table A-34 presents an example of how Level 3 analysis results can be documented. The case studies presented in Appendix B to this report provide further suggestions regarding documentation of results.

Table A-34. Level 3 analysis report outline.

1. Problem Definition
    - Reason for project
    - Problem context (general location map)
    - Traffic
    - Land use
    - Environmental

2. Alternatives (options described)
    - Rehabilitate
    - Replace at same location
    - Relocate
    - Replace with at-grade crossing
    - Demolish structure, close road
    - Demolish structure, close rail line

3. Conceptual Engineering (by option)
    - Alignment
    - Profile
    - Structural features

4. Decision-making Framework
    - Institutions affected
    - Participation process

5. Level 1 Analysis and Results
    - Analysis by option
        - Cost
        - Safety
        - Rail and highway operations
        - Community and environment
        - Institutions
    - Results
        - Comparison of alternatives
        - Recommendation for Level 2 Analysis
        - Rejected alternatives

6. Level 2 Analysis and Results
    - Analysis by option
        - Cost
        - Safety
        - Rail and highway operations
        - Community and environment
        - Institutions
    - Results
        - Comparison of alternatives
        - Recommendation for Level 3 Analysis
        - Rejected alternatives

7. Level 3 Analysis and Results
    - Analysis by option
        - Cost
        - Safety
        - Rail and highway operations
        - Community and environment
        - Institutions
    - Results
        - Comparison of alternatives
        - Preferred alternative

Appendix B

Case Studies

CASE STUDY 1

Background

This case study involves a deteriorated grade-separated rail crossing (highway over rail) in New York State. Structural deficiencies were identified through the New York Department of Transportation's (NYDOT) Bridge Inspection Program. The inspection revealed that the stringers are completely rotted through and that there is a section loss in the primary members. Also, serious deterioration to the structural deck, primary and secondary members, wearing surface, joints, curbs, sidewalks, facias, railings, parapets, and bearing anchor bolts was found. The FHWA sufficiency rating for the structure was determined to be 26.3, indicating serious deterioration. The bridge was posted for less than its original design loading. Additionally, the structure did not meet current AASHTO standards for rural highways, having a stopping sight distance of 200 ft and a roadway width of 24 ft.

Location

The grade-separated structure carried NY Route 240 over a main line of the Chessie System Railway Company. The line is known as the Buffalo-Salamanca main line. Traffic on the line is one through-train daily in each direction. The trains average 60 cars in length and train speed averages 30 mph. The trains carry various commodities including chemicals (20 percent to 30 percent of the traffic is chemicals). There are no switching movements in the vicinity of the bridge. There is no anticipated change in train operations, although traffic has declined in recent years from six to two trains daily.

NY Route 240 is a north-south highway serving recreational areas between the towns of Orchard Park and Elliottville. Current daily traffic over the bridge is 3,473 ADT. Peak traffic volumes occur on weekends during the skiing season (ADT of 6,700). Future traffic is anticipated to grow gradually over time at a rate of 1.4 percent.

Land use in the vicinity of the bridge is rural. An industrial/construction equipment supplier and a private campground are located adjacent to the crossing. Land use along this segment of NY Route 240 is a mix of open land and scattered single-family residences.

Alternatives

Possible actions to address the problem of the structurally deficient structure include the following: rehabilitation, replacement, relocation, put at-grade, close the road, close the rail line.

In the case of new bridge construction, NYDOT established the following criteria: design speed of 60 mph, capability to carry all legal truckloads, level-of-service "B", minimum clearance compatible with railroad requirements.

Level 1 Analysis Results

Level 1 analysis resulted in the rejection of three of the alternatives—rehabilitation, relocation, and close the rail line. Rehabilitation was rejected because of its physical impracticality. As noted above, numerous stringers were completely rotted; there was section loss in primary members; serious deterioration was found in the deck, primary and secondary members, wearing surface, joints, and curbs. This condition, which would require essentially total reconstruction of the structure at a cost roughly equal to a new structure, and the fact that the structure does not meet existing AASHTO standards, led to the conclusion that rehabilitation should be rejected.

Relocation was rejected because it would result in unnecessary and, therefore, unacceptable cost, safety, and taking of private land, relative to the replacement alternative.

Close the rail line was rejected because this action would cause unacceptable disruption to rail operations. Despite the fact that there are only two daily trains operating on this line, it is a Chessie System main line, connecting Buffalo with locations to the south. From Buffalo the main line heads west to Detroit.

The results of Level 1 analysis are summarized in Table B-1. In addition to establishing the basis for rejecting some alternatives, Level 1 analysis revealed issues of concern with remaining alternatives as shown in the summary table.

Level 2 Analysis Results

Three alternatives were retained for consideration in Level 2 analysis: (1) replace, (2) put at-grade, (3) close the road.

Following is a summary of findings by evaluation factor. The summary is followed by a comparative evaluation of the three alternatives.

Cost

In Level 2 analysis, the cost factor involves consideration of capital costs; operations and maintenance costs are very small relative to capital costs and are considered in Level 3, if necessary, to more precisely distinguish alternatives.

Table B-2 presents the capital costs estimates for each alternative. The costs are stated in terms of current construction cost and annualized cost. The latter provides a more accurate measurement for comparison because it accounts for the differences in the life span of each alternative.

As shown in the table, the alternatives vary in cost from $524,000 to $1,719,000. Annualized costs show a similar relative range (3 to 1) of $36,100 to $102,100.

Table B-1. Level 1 results summary.

ALTERNATIVE	Evaluation Factor						
	COST	SAFETY	RAIL OPERATIONS	HIGHWAY OPERATIONS	COMMUNITY/ ENVIRONMENT	INSTITUTIONS	COMPARISON TO OTHER ALTERNATIVES
1. REHABILITATE	X			X			X
2. REPLACE		+			-		
3. RELOCATE				X	X		X
4. PUT AT-GRADE	+	-		-			
5. CLOSE ROAD		-		-			
6. CLOSE RAIL LINE			X				

Legend:

X = basis for rejection
- = negative attribute
+ = positive attribute

Notes:

1. Rehabilitate--rejected as physically infeasible. Substantial deterioration means that the structure would essentially require reconstruction at cost roughly equal to replacement. Rehabilitation also would mean retention of geometrics which do not meet current AASHTO standards.
2. Replace--replacement with a structure built to current design standards would have a positive effect on safety. Replacement could involve the taking of private land adjacent to the crossing.
3. Relocate--rejected on the basis of its relative disadvantages vis-a-vis replacement. Relocation adjacent to the existing crossing would require land-taking and possible building displacement and would introduce curved approaches to the bridges on an otherwise straight road.
4. Put At-Grade--is probably the least-cost option. Introduces vehicular/train conflicts and crossing delays.
5. Close Road--introduces vehicular/train conflicts because alternative routes have at-grade crossings. Alternate routes are built to lower design standards. Current crossing users would experience detour delay.
6. Close Rail Line--rejected because of its adverse effects on rail operations. The line is a main line with no acceptable routing alternatives available at this time.

Safety

Safety in Level 2 analysis is examined in terms of estimated annual accidents, injuries, and fatalities. Table B-3 presents these estimates for each alternative.

The replacement structure would improve safety conditions at the crossing by replacing the structure with one designed to current AASHTO standards. This would include improved sight distances and a wider roadway through the addition of shoulders. However, techniques to accurately estimate the change are not available and so no estimate is presented.

The annual accident rate anticipated for the at-grade crossing is 0.042. The at-grade crossing accidents are expected to be more serious than those expected with the replacement structure. Whereas no fatalities are expected with the replacement alternative, an annual fatality rate of 0.006 is estimated for the at-grade alternative.

Table B-2. Level 2 cost summary (1986 dollars).

CONSTRUCTION COST	ALTERNATIVE		
	REPLACE	PUT AT-GRADE	CLOSE ROAD
TOTAL	$1,719,000	$1,023,500	$524,200
ANNUALIZED	$102,100	$72,800	$36,100
RELATIVE COST*	2.83	2.02	1.00

*Annualized cost of the alternative divided by the lowest cost alternative. A 4 percent discount rate was assumed.

Table B-3. Level 2 safety summary (estimated annual accident summary).

ALTERNATIVE	ACCIDENTS	INJURIES	FATALITIES
1. REPLACE*	--	--	--
2. PUT AT-GRADE	0.042	0.167	0.006
3. CLOSE ROAD	0.015	0.007	0.002

* As noted in the User's Guide, accidents associated with this alternative cannot be accurately estimated.

Table B-4. Level 2 highway operations.

FACTOR	ALTERNATIVE REPLACE	PUT AT-GRADE	CLOSE ROAD
Delay at Crossing --Amount --# Vehicles	N/A	<1 min/delay 2 vehicles/day	N/A
Detour Delay --Regional Trips -Minutes -Percentage	N/A	N/A	4 4% to 6%
--Local Trips -Minutes -Percentage	N/A	N/A	<1 to 12 3% to 210%
Congestion	N/A	None	None
Queuing	N/A	≈ 0	≈ 0
Emergency Service Delay	N/A	≈ 0	≈ 0

The third alternative, closing the road, has the lowest anticipated accident rate, 0.015, or one accident every 67 years. Accidents associated with this alternative are related to diversion of traffic using the existing crossing to other routes which have at-grade crossings. The estimated accidents for this option are lower than those estimated for the at-grade alternative because research has shown that the accident rate per ADT at-grade crossings declines as ADT increases. The research does not specify why this trend occurs, but researchers suggest that it is associated with an increased level of crossing awareness at higher traffic volumes. As traffic volume increases, motorists become more aware of the danger of the crossing, perhaps through the behavior of other motorists.

Highway Operations

Two of the alternatives, the at-grade option and the close the road option, would change existing highway operations. In the first case, motorists would experience delays when the crossing is closed by train operations. In the second case, diversion to other routes around the closed road may cause detour delays.

Estimated changes in highway operations are presented in Table B-4. For the at-grade alternative, delay at the crossing would be negligible. Assuming that train operations close the crossing during peak travel times, an average of two vehicles would be delayed daily for an average duration of just under 1 min each. This means that 0.5 percent of crossing users would typically experience delays, in a worst case situation. No other adverse effects on highway operations would occur with the alternative. This finding includes effects on emergency service operations. The crossing is located on the boundary between the towns of Aurora and Orchard Park; the boundary coincides with local emergency service areas and emergency service providers typically do not use the crossing. When the crossing is used, e.g., to provide backup under mutual support agreements, the probability of being delayed and the probable duration of delay are insignificant.

Closing the crossing would require crossing users to use alternative travel routes. One can assume that these alternate routes are less desirable than the current one.

Using typical local and regional trips made by users of the crossing, an estimate of additional travel time incurred in using probable alternative routes was prepared. For regional trips (i.e., between Buffalo and Colden, Glenwood, Holland, and Springfield) travel times would increase by approximately 4 min, which represents a percentage increase of 8 percent to 13 percent in current travel times.

Local trips would be more substantially affected, particularly those originating or terminating near the crossing. Table B-5 shows that the increase in travel times between origins and destinations would range from less than a minute to as many as 12 min. Relative travel times for the closed road option would range from 3 percent to 210 percent greater than current times. These increases in travel time are due in part to the added distance required by alternate routes and in part to the lower speed limits permitted on these routes relative to the existing route.

Emergency services would not typically be subject to these travel time increases, because, as noted earlier, service boundaries limit the number of times emergency vehicles must use the crossing.

There are no other noteworthy implications of the close the road alternative in highway operations.

Railroad Operations

As noted earlier, two through-trains operate through the crossing on a typical day. No switching operations are conducted.

These train operations would not be affected by any of the alternatives, with the exception of the requirement for the engineer to sound his horn when approaching the at-grade crossing. The only other time train operations would be interrupted would be when a grade crossing accident occurs, about once every 24 years with the at-grade alternative. An additional accident every 67 years is anticipated for the close the road alternative.

Land Use

Land use is not an issue with the at-grade crossing or close the road alternatives. Neither alternative would require new right-of-way.

Replacing the structure could require some additional right-of-way and could involve the taking of a building of the construction/industrial equipment supply company located next to the crossing. However, these adverse effects would be avoided by incorporating an extended reinforced earth abutment on the northeast quadrant. This element has been incorporated into the replacement alternative.

Institutional Considerations

There are three institutional considerations associated with the alternatives, which are the following: (1) ability to fund the project, (2) responsibility for maintenance cost, and (3) implementation delays.

Regarding the ability to fund each of the alternatives, NYDOT has indicated that each alternative could be funded under the Highway Bridge Repair and Replacement Program, which provides for 80 percent federal/20 percent state funding responsibilities. Region 5 of the NYDOT is allocated $144.2 million under this program for the 5-year period 1986–1991. Additional monies can be allocated to the region. According to the Program Planning Bureau (NYDOT), which reviews program proposals submitted by the region for budget compliance, the project could be accomplished within the existing regional allocation.

The second institutional issue is responsibility for project maintenance. The existing structure is jointly owned by the state and the railroad. Maintenance is also a joint responsibility; the superstructure is the state's responsibility and the piers and substructure are the responsibility of the railroad.

Each of the three alternatives would end this arrangement. Under New York law, structures built by the state after 1966 are the sole responsibility of the state, both in terms of construction cost and maintenance. With the at-grade crossing alternative, New York law provides for the state's assuming construction cost responsibility; the railroad would be responsible for maintaining the crossing, which the railroad indicates runs about $3,500 annually. If the crossing and road were closed, the state would assume construction cost and maintenance responsibility.

The third institutional consideration is that delays in project implementation are likely to occur if the structure is not replaced. In the at-grade crossing case, the railroad may protest the action with the appeal process requiring delays of perhaps 6 to 12 months and NYDOT staff time to participate in the process. Closing the road would be a major action, requiring extensive study and public meetings and hearings with delays of 1 to 2 years not unrealistic. Again staff time and expenses as well as additional construction costs due to inflation would be incurred.

There also is a possibility that a recommendation to build an at-grade crossing or to close the road would be overturned on appeal. This is less likely in the case of the at-grade crossing because there are precedents in New York of replacing a grade separation with an at-grade crossing, and because there are other at-grade crossings on the same line in the area. Closing the road is more of a major action and is likely to encounter substantial public opposition. Institutional factors are summarized in Table B-6.

Table B-5. Close the road alternative effects on local travel time.

Origin \ Destination	WEST FALLS	DAVIS RD/368	DUELLS CORNER	ORCHARD PARK	E. OF CROSSING	W. OF CROSSING	368/SUBDIVISION	CHESTNUT RIDGE PK
WEST FALLS								
DAVIS RD/368								
DUELLS CORNER	6.3 10.2							
ORCHARD PARK	8.7 9.0							
E. OF CROSSING			2.9 9.8	5.3 8.6				
W. OF CROSSING	3.4 9.3	2.9 9.0			1.0 9.8			
368/SUBDIVISION						5.2 7.5		
CHESTNUT RIDGE PK					6.8 13.4			

Legend

x.x (Current Time--min)

x.x. (Close Road Travel Time)

Notes: Only shows travel times between origin/destination pairs that would experience a travel time change.

Overall Comparison of Alternatives

Table B-7 summarizes the analysis of all factors by alternative. To facilitate comparison of the alternatives, the results of the analysis are examined using three techniques: (1) balance sheet comparison, (2) unit cost comparison, and (3) total/cost analysis.

Table B-6. Level 2 institutional concerns.

FACTOR	ALTERNATIVE		
	REPLACE	PUT AT-GRADE	CLOSE ROAD
Availability of Funds	Available	Available	Available
Maintenance Responsibility* --State --Railroad	 $4,500 None	 Normal Roadway $3,500/yr	 Normal Roadway None
Potential Project Delay	None	6-12 months	12-24 months
Possibility Recommendation is Overturned	Low	Low	High

*Note: Maintenance responsibilities for the current structure are split between the railroad and the state in about a 20 percent/80 percent proportion. Assuming $4,500/yr as above, this would indicate a current maintenance cost responsibility on the order of $900 and $3600, respectively.

Table B-7. Level 2 results summary.

FACTOR*	ALTERNATIVE		
	REPLACE	PUT AT-GRADE	CLOSE ROAD
Const. Cost			
--Total	$1,719,000	$1,023,500	$524,200
--Annualized	102,100	72,800	36,100
Safety			
--Accident/yr	—	0.042	0.015
--Injury/yr	—	0.019	0.007
--Fatalities/yr	—	0.006	0.002
Highway Ops			
--Crossing Delay	N/A		N/A
-Amount (min/delay)		<1	4-12
-# Vehicles/day		2	3,473
--Trip Time Change			
Regional		2% to 3%	8% to 13%
Local		15% to 34%	3% to 210%
Land Use	N/A**	N/A	N/A
Institutional			
--Maintenance Responsibility (Cost/yr)			
-State	+900		-$3,600
-Railroad		+$2,600	
--Potential Project Delay (Months)	one	6-12	12-24
--Possible Decision Overturn	Low	Low	High

Notes:

*Includes only factors where a positive or negative effect was found.

**Potential adverse effect resolved through design changes.

At-Grade Vs. Close Road. Table B-8 presents a balance sheet comparison of the at-grade and close road alternatives. The table shows the *differences* between the two alternatives, the entry being put under the alternative with the estimated greater adverse effect.

The balance sheet highlights the trade-offs between the alternatives. The at-grade option costs more and one would anticipate a larger number of accidents with this option. For these higher costs in dollars and accidents, one would avoid delays to almost 3,500 motorists each day. The delays experienced would range from 3 to 11 min *greater than* the delays anticipated with the at-grade alternative. Thus, one may ask the following question: Is it worth $36,700 and one additional accident every year (one injury every 82 years and one fatality every 250 years) to avoid delays of 3 to 11 minutes per trip to 3,470 vehicle drivers each day (1,266,550 delays annually)?

Another perspective on these trade-offs is to calculate unit cost measures. These measures clarify how much one would pay to avoid a unit of adverse effect by selecting one alternative over another. The evaluation question is whether the cost is worthwhile.

To develop unit cost measures, one must first translate the factor estimates into like units of measurement. The common denominator depends on the items involved in the trade-off analysis. The consequent measures are the following for the at-grade relative to the close road option: (1) cost per additional minute of vehicular delay avoided = $0.004, and (2) cost per additional accident = 50,508,700 delayed vehicles.

Computation of these measures is given in Table B-9. The first measure indicates that by choosing the at-grade alternative one would be paying four-tenths of one cent to avoid each vehicular minute of delay that the close the road option would impose on motorists, a very small price to pay. The second measure indicates that by choosing the close-the-road alternative one would incur about 50 million vehicular delays to avoid each grade crossing accident. The cost per additional injury and per additional fatality avoided would be 111 million and 317 million delayed vehicles, respectively.

A final comparison uses cost analysis. This comparison, shown in Table B-10, dramatically reinforces the significant total cost of the close the road option over the at-grade option. Total costs for the at-grade alternative are $74,900 versus $3,036,900 for the close the road alternative.

Table B-8. Level 2 analysis—balance sheet comparison at-grade vs. close road.

FACTOR	PUT AT-GRADE	CLOSE ROAD
Cost (Annualized)	$36,700/yr	
Safety		
--Accidents	+1/37 yr.	
--Injuries	+1/82 yr.	
--Fatalities	+1/250 yrs	
Highway Operations		
--# Delayed		+3470/day
--Time Delayed		3 to 11 min/delay
--Trip Time Change		
Regional		+6% to 10%
Local		+0% to 176%
Land Use	N/A	N/A
Institutional		
Availability of Funds		
--Main Cost		
-State	+3,600/yr	
-Railroad	+3,500/yr	
--Potential Project Delay		+0 to 18 months
--Possible Decision Overturn		High

Table B-9. Level 2 analysis—computation of unit cost measures.

(1) At-grade vs. close road

(a) Delay unit cost

($36,700)÷ (3740 vehicles delayed per day) x (365 days per year) x (7 minute average additional delay) = $0.004

(b) Safety unit cost

- (3740 vehicles delayed per day) x (365 days per year) x (37 years between the additional accidents) = 50,508,700
- (1 injury every 82 years) 111,938,200
- (1 fatality every 250 years) 316,637,500

(2) At-Grade vs. Replace

(a) Safety Unit Cost

($29,300 cost per year) ÷ (0.006 fatalities per year) = $4,883,333 per fatality avoided

(b) ($29,300 cost per year) ÷ (2 vehicles delayed per day) x (1 minute per delay) (365 days per year) = $40.14 per minute of vehicular delay avoided.

Table B-10. Level 2 analysis—cost comparison at-grade vs. close road.[1]

FACTOR	AT-GRADE	CLOSE ROAD
Annualized Cost	$72,800	$ 36,100
Safety	1,900	800
Vehicular Delay	200	3,000,000
Total Annual Costs	$74,900	$3,036,900

1/ Uses NYDOT-stipulated accident values inflated to 1986 dollars. Computations are shown below.

LEVEL 2 ANALYSIS

TOTAL-COST COMPUTATIONS

(1) At-grade alternative

(a) Safety

- Property damage = (0.042 accidents per year - 0.013 injury accidents and 0.005 fatal accidents/year) * ($3,400 per property damage accident) = $82
- Injury accidents = (0.013 injury accidents per year) * ($10,700 per injury accident) = $140
- Fatal accidents = (0.005 fatal accidents per year) * ($339,100 per fatal accident) = $1,695

(b) Vehicular delay

- Delay time = (2 vehicles per day) (365 days per year) (1 minute delay per vehicle delayed) = 730 minutes of delay/year
- Value of a minute delay = ($15 per hour value of time)/(60 minutes per hour) + (0.0108 gallons of fuel consumed per minute idling time) ($1.25 per gallon of fuel) = $0.26
- Cost per year of delay = (730)($0.26) = $189.80

(2) Close Road

(a) Safety

- Property damage = (0.015 accidents per year - 0.005 injury and 0.002 fatal accidents per year) ($3,400 per property damage accident) = $27.20
- Injury accidents = (0.005 injury accidents per year) ($10,700 per injury accidents) = $53.50
- Fatal accidents = (0.002 fatal accidents per year) ($339,100 per fatal accidents) = $678.20

(b) Vehicular delay

- Delay time = (3,470 vehicles per day) (365 days per year) (1 to 12 minutes per delay, assume 6 minutes) = 7,599,300 minutes.
- Additional travel distance = (3,470) (365) (0.2 to 5.1 miles, assume 2.5) = 3,166,375 miles
- Cost = (7,599,300 minutes) ($15 per hour value of time ÷ 60 minutes per hour) + (3,166,375 miles) ($0.35 per mile operating costs) = $3,008,056

The conclusion is that the at-grade crossing option is clearly superior to the close the road option and, therefore, the latter alternative should be eliminated from further consideration.

At-Grade Vs. Replace. Table B-11 presents a balance sheet comparison of the at-grade and replace alternatives. The table shows the *differences* between the alternatives and highlights the trade-offs between them. The replace option costs $29,300 per year more than the at-grade option and would result in fewer accidents. The at-grade option also would cause delays to motorists which the replace option would avoid.

The unit cost measures, which are stated in terms of the replace alternative, are the following (see Table B-9 for computations): cost per fatality avoided = $4,883,300, and cost per minute of vehicular delay avoided = $40.14. The first measure indicates that by choosing the replace option one would be paying the equivalent of almost $5 million for each grade crossing fatality avoided, *or* $40 for every minute of vehicular delay avoided at the grade crossing.

Table B-11. Level 2 analysis—balance sheet comparison at-grade vs. replace.

FACTOR	PUT AT-GRADE	REPLACE
Cost		$29,300/yr.
Safety --Accidents --Injuries --Fatalities	 0.042/yr. 0.019/yr. 0.006/yr.	
Highway Operations --# Delayed --Time Delayed --Trip Time Change Regional Local	 2 vehicles/day <1 min/delay 2% to 3% 15% to 34%	
Land Use	N/A	N/A

Various unit cost combinations can be evaluated by allocating costs between fatalities avoided and vehicles delayed. For example, one could state that by choosing the replace option, one would be paying the equivalent of $2.5 million for each fatality avoided and $20 for every minute of vehicular delay avoided (i.e., a 50/50 distribution of cost to the factors).

However, these measures do not account for nonfatal accidents and do not fully integrate the results. The cost comparison of the options is given in Table B-12. The table shows that the replace option is inferior to the at-grade option, costing $27,200 more each year or 36 percent more than the at-grade option. This conclusion is reinforced by the $4.9 million cost for each fatality avoided (see unit cost measures above), which exceeds the NYDOT benchmark of $340,000 by more than ten times, and by the $40 per delay avoided which is a steep price to pay particularly when each delay is anticipated to last less than a minute.

Table B-12. Level 2 analysis—cost sheet comparison at-grade vs. replace.

FACTOR	AT-GRADE 1/	REPLACE
Annualized Cost	$72,800	$102,100
Safety 1/	1,900	---
Vehicular Delay	200	0
Total Annual Costs	$74,900	$102,100

1/ Uses NYDOT-stipulated accident values inflated to 1986 dollars. Computations are from Table 10.

The conclusion from this analysis is that the at-grade crossing is the preferred option. However, because replacing a structure with an at-grade crossing is usually controversial, both the replace and at-grade options were retained through Level 3 analysis.

Level 3 Analysis Results

At the conclusion of Level 2 analysis, two alternatives were retained for further evaluation: (1) replace the structure, and (2) build an at-grade crossing. The following discussion recounts the final analysis of these two remaining options.

Cost

In level 3 analysis, costs are defined to include maintenance and operating as well as capital costs. The cost estimates are:

	Replace	Put At-Grade
Capital Cost	$1,719,000	$1,023,500
O&M Cost (annual, structure only)	$ 4,500	$ 3,500
Annualized Total Cost	$ 106,600	$ 77,300

Comparison with Level 2 costs, which include only capital costs, shows that the at-grade crossing remains about 30 percent cheaper than the replace alternative.

Safety

Table B-13 presents the Level 3 safety factors. In addition to the accident estimates introduced in Level 2, this analysis considers use of the crossing by school buses, hazardous materials transporters, and pedestrians and bicyclists.

Two of these factors are noteworthy. One is use of the crossing by school buses. School buses from Orchard Park cross over the rail line to reach a turnaround in Aurora. Some children are in the buses when this is done. To eliminate this maneuver, under the at-grade alternative, the turnaround will be built on the Orchard Park side of the crossing. Thus, school bus safety is not an issue with the alternative. A new turnaround is not part of the grade separation option, and while no accidents involving school buses have occurred on the existing structure, the potential for an accident does exist with this alternative.

Hazardous materials represent 20 to 30 percent of the rail traffic on the main line. (Highway transport of hazardous materials is unknown and assumed to be negligible.) Consequently, an at-grade accident involving hazardous materials is a possibility. The probability that an accident involving a train carrying hazardous materials is 0.042 accidents per year times, say, a 25 percent chance that the rail cars carrying hazardous materials are involved; this amounts to an estimated one accident in 95 years involving hazardous materials. If it is further assumed that a major accident occurs (i.e., if an explosion occurs or materials are released during the accident) people within a ½ mile radius of the crossing could be exposed to danger. There may be 50 to 100 persons living or working within this radius. Still, no methodology is available to make even a guess at the likelihood injuries or fatalities would occur. The small number of serious hazardous material accidents that occur at grade crossings in the country suggests the danger is not material.

Highway Operations

No additional analysis was done on this factor, because the delay to vehicles with the at-grade crossing is so small.

Rail Operations

No additional analysis was done on this factor because rail operations were found to be unaffected by these alternatives during Level 2 analysis.

Land Use

There is no impact on land use by either alternative, as noted in Level 2 analysis.

Community and Environment

The alternatives were examined with regard to several environmental factors—air quality, water quality, noise, and aesthetics. It was found that the differences between the alternatives

Table B-13. Safety analysis matrix.[1]

SAFETY CONSIDERATIONS	ALTERNATIVES	
	Replace	At-Grade
# Accidents		
• Fatalities	--	0.006
• Injuries	--	0.019
Total	--	0.042
School Bus Use 2/	NS	NA
Hazardous Materials 3/	NA	NS
Pedestrian/Bicyclists Use 4/	NA	NA

1/ • NA = not applicable
• NS = not of significant concern

2/ School bus use. The crossing is used by school bus drivers from Orchard Park to reach a turnaround in Aurora. Some children are in the bus when this use is made.

The at-grade alternative includes construction of a school bus turnaround on the Orchard Park side of the crossing which will eliminate future use of the crossing by school buses.

Drivers will continue to use the bridge to reach the turnaround for the grade-separation alternative. No accidents involving school buses have occurred, but the buses would be exposed to a higher probability with this alternative.

3/ Hazardous materials --

(a) trucks -- none known
(b) rail -- chemicals represent 20-30% of all traffic

4/ Pedestrian -- not used by pedestrians with regard to these factors are immaterial. Air quality would be unaffected because the number of vehicles delayed at the crossing is so small, and the duration of delay so short. Water quality is not at issue with no bodies of water close enough to the crossing to be subject to pollution through chemical runoff or erosion, which cannot be controlled. The at-grade crossing would be less obtrusive visually than the grade separation; however, concern over aesthetics has not been raised publicly as an issue. Noise will increase with the at-grade crossing alternative because train engineers must sound their horns when approaching at-grade crossings. Given that there are only two trains a day using the crossing typically during daylight hours, noise is not a concern in the analysis. Finally, these two alternatives qualify under federal and state guidelines as "categorical exclusions" relative to environmental analysis requirements.

Institutional Factors

No institutional considerations in addition to those discussed under Level 2 analysis are involved.

Conclusion

Level 3 analysis did not reveal new considerations which would alter the Level 2 conclusion that the at-grade crossing is the preferred alternative. The trade-off between this option and the replace alternative involves safety, vehicular delays, and cost. The replace alternative is generally superior with regard to safety and delay considerations, but the adverse safety and delay consequences of the at-grade crossing are too small to offset the substantially lower cost (40 percent) of the at-grade crossing alternative.

CASE STUDY 2

Introduction

This case study involves a small town in New England with a population of 5,000 people. The town is split by a rail line with 45 trains a day passing through it. It is important to note that most of the trains are through-freight and commuter-rail trains. They are relatively short in length, averaging 1,100 ft, and the average speed through town is 25 mph.

There are two grade-separated (highway over rail) crossings in town—one is on the east end, on a state highway, and is the primary travel route through town. The other grade separation is on the west end of town and is a lesser traveled route, but is the only route connecting the town to points west. About 3,000 vehicles a day use this crossing. The west end crossing is the subject of the case study. Built in 1936, its condition is badly deteriorated.

Figure B-1 shows how the town is laid out. The CBD is at the center of the town. Two industrial areas are located along the rail line. There are several residential areas defined by the major arterials and the rail line. There is a military base on the west end of town.

Level 1 Analysis Results

Level 1 analysis began with the six generic alternatives, which were examined in terms of each of the five factors. It was found that none of the alternatives could be rejected in Level 1 because of safety, community, or institutional considerations. Rail and highway operations and cost, however, did cause some alternatives to be rejected during Level 1 analysis. The rehabilitation option was rejected because it was determined through inspection that deterioration of the structure was too extensive; rehabilitation is physically impractical.

The close-the-railroad alternative also was rejected in Level 1 analysis. There are currently extensive operations on this rail line; there are no plans to terminate service on this rail line; the service is essential and would be lost if the rail line were closed; and the line is profitable and should be retained. From this point of view, closing the railroad was deemed sufficiently infeasible to warrant dropping it from further consideration.

Detour delay is an issue for the "close the highway" alternative. After consultation with the regional planning commission, which identified a variety of likely trips for people using the crossing, it was determined that the only suitable detour route passes through a military base and is not open to the general public; the close-the-highway alternative was therefore rejected.

Delay at the crossing is a factor considered in evaluating the at-grade alternative. Based on existing rail traffic, average delay per delayed vehicle would be about 30 sec and the probability of delay would be less than 5 percent. It was decided that this magnitude of delay would result in inconvenience, but would by no means be intolerable, so the at-grade crossing alternative was retained for Level 2 analysis.

Replacement was considered a viable alternative because the geometrics of the structure as it exists are in accordance with standards. Demolishing the bridge and replacing it in kind posed no particular engineering problems. Similarly, relocating the structure 80 ft northwest of its existing location is feasible, as the required geometry would be well within standards. While limits of land-taking were uncertain in Level 1 analysis, the proposed alignment is not crowded by adjacent development.

In summary, rehabilitation of the bridge was rejected on the basis of engineering infeasibility or cost; closing the rail line was rejected on the basis of adverse impact to rail operations; and, closing the road was rejected because a reasonable alternate route is not available. The at-grade, replace, and relocate options were then considered feasible and carried over into Level 2 analysis for further consideration. (See Table B-14.)

Level 2 Analysis Results

Cost

The first factor considered in Level 2 is cost. It is estimated replacing and relocating the structure would each cost about \$1.8 million. The at-grade alternative was priced at approximately \$450,000. The annualized capital cost of each alternative is \$85,600 and \$59,200, respectively, at a 4 percent discount rate.

Cost at Level 2 is also considered within the context of the availability of funds to implement projects. The cost of a new structure, either at its existing location or at a new location,

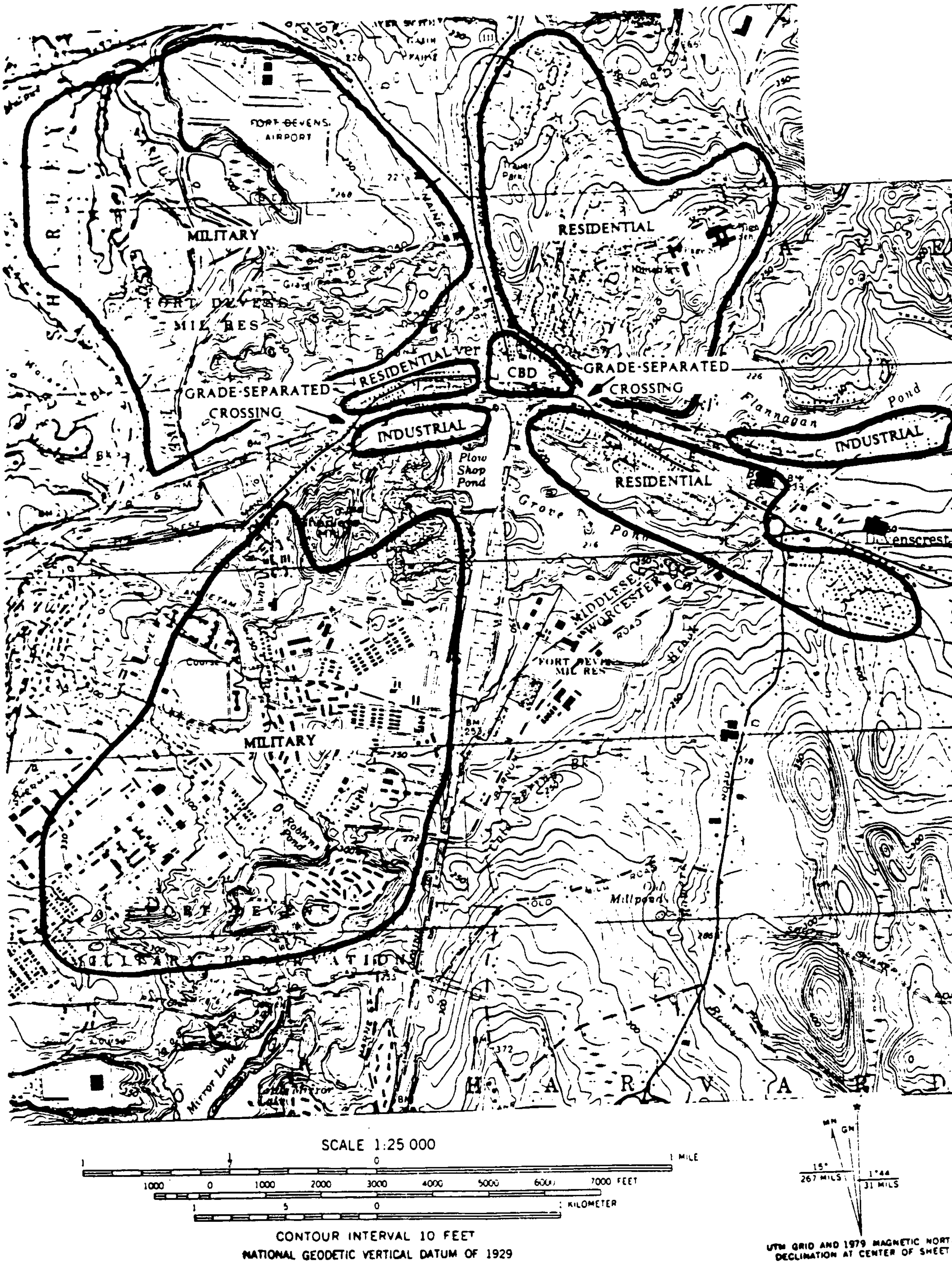


Figure B-1. Case study area land use characteristics.

Table B-14. Level 1 results summary.

ALTERNATIVE	EVALUATION FACTOR COST	SAFETY	RAIL OPERATIONS	HIGHWAY OPERATIONS	COMMUNITY/ ENVIRONMENT	INSTITUTIONS	COMPARISON TO OTHER ALTERNATIVES
1. REHABILITATE	X						
2. REPLACE	-				-		
3. RELOCATE	-				-		
4. PUT AT-GRADE	+	-		-			
5. CLOSE ROAD				X			
6. CLOSE RAIL LINE			X				

Legend: X = basis for rejection
- = negative attribute
+ = positive attribute

Note:
1. Rehabilitate--rejected as physically infeasible.
2. Replace and Relocate--replacement or relocation with a structure built to current design standards is a relatively more costly alternative. Replacement could involve the taking of private land adjacent to the crossing, including some structures.
3. Put At-Grade--is probably the least-cost option. Introduces vehicular/train conflicts and crossing delays.
4. Close Road--Only alternate route is through a military base, which is closed to the public.
5. Close Rail Line--rejected because of its adverse effects on rail operations. The line is a main line with 45 trains a day and no acceptable routing alternatives available at this time.

can be covered 75 percent, according to state engineers, by the federal government under the Bridge Replacement and Rehabilitation Program, with the remaining 25 percent to be paid by the state. The state reported that 100 percent of the cost of the at-grade alternative would be borne by the state in this case, although 90 percent federal funding for this alternative can be obtained through the Section 203 program. Section 203 money also could be used to fund the cost of a new structure, but because of the limited size of this program it is not considered a feasible funding source in this case.

The $24 million allocated to the state under the Replacement and Rehabilitation Program is clearly sufficient to cover the $1.8 million required to replace or relocate the structure. Therefore, these prices would not place an undue burden on the budget. The at-grade funding requirements would come from the budget for highway projects throughout the state and would not represent an undue burden on that budget. While the state as the ultimate decision-maker would consider the impact to its budgets, the 25 percent of $1.8 million or 100 percent of $450,000 are not sufficiently different to reject one alternative in favor of another.

Rail and Highway Operations

The second factor considered is rail and highway operations. Neither replacing nor relocating the structure has any ramifications on rail or highway operations, because all existing rail and highway links would be maintained essentially as they are. Only the at-grade alternative needs to be considered from the point of view of delay to the crossing user, and indirect congestion and delay caused by implementation of the alternative.

Using hour-by-hour vehicular traffic and train volumes, it was found that, overall, one minute delays for 3 percent of the traffic using the crossing would occur.

Using the same hourly traffic data, consideration was given to congestion and to the indirect delay that would result from queuing of vehicles at the crossing, thereby blocking cross streets, alleys, and driveways. It was determined that there would be some queuing, but that it would result only in occasional blocking of one residential property lot adjacent to the structure and was therefore deemed insignificant.

Finally, response time of emergency services—police, fire, and ambulance—was considered. All three services are located on the northern side of the crossing. Delay resulting from trains blocking the crossing could increase response time in a worst case situation by about 4½ min in each direction; the expected or average delay would be 1 minute. In the worst case, this would mean a delay of 4½ min for a fire engine to reach the southern part of town, and a delay of two times that, or 9 min, should an ambulance encounter a train both while responding to a call on the south side of town and while returning the injured person to the hospital. Police might also find a 4½-min delay if a patrolling police car were not on the south side of town when a call is received.

While there are no national guidelines on acceptable response time for emergency service, the delay to firefighters would not exceed 8 min, which was identified by some sources as a preferred upper limit. Furthermore, delays at the crossing would not result in poorer response time than for some of the more distant portions of town on the north side of the crossing. The south side of town would in effect become more distant from emergency services, but not any more so than parts of the north part of town.

Safety

Accidents have occurred on the existing structure. With improved geometrics, relative to the existing structure, one might estimate an annual accident rate of 0.7. The accidents that have occurred have been minor, mostly property damage, and there is no reason to believe that this would change.

The estimated annual accident rate for the at-grade crossing (for rail/highway accidents only) is 0.15 accidents—0.09 property damage-only accidents; 0.04 injury accidents; and 0.02 fatal accidents annually. Over the long term, this would mean on the order of one injured person every 17 years and one fatality every 35 years. Accidents in the vicinity of the crossing are not included because the techniques to make these estimates are unavailable.

Clearly, with respect to safety, there is a significant difference between the three alternatives.

Land Use

The alternatives also differ considerably with respect to land-use impacts. Whereas the at-grade alternative has no land-use impact, the replace alternative would require the use of 0.7 acres of new right-of-way and would displace three existing structures, all residential.

The relocate alternative would require 7.2 acres of new right-of-way and would displace 9 currently used residences and a vacated gas station.

Trade-Off Analysis

To compare the three alternatives, three approaches were used, including the balance sheet, the unit cost, and the total cost comparisons.

First, the balance sheet comparison of the replace versus relocate alternatives shows that the $10,000 additional total cost of the replace option (an annualized cost of $400) would avoid taking an additional 6.5 acres and 7 structures, i.e., the differences between the two alternatives. (See Table B-15).

All other characteristics of these two options are the same and therefore need not be considered. The trade-off clearly favors the replace alternative and relocation can be eliminated from further consideration.

Turning to the replace option versus the at-grade option, the choice is not so apparent, because each option has unique advantages and disadvantages (see Table B-16). To facilitate the comparison, one could weight the relative importance of the factors. For example, the three displacements might be given relatively little consideration, because the three residences involved are not unique within the town and alternative housing for the displaced families is readily available. Thus, one can focus on the cost versus safety and delay differences between the alternatives. For this comparison, one might compute unit cost indicators.

Referring to Table B-16, the analyst can compute unit cost comparison statistics by using the difference between the alternatives, as follows:

1. The difference in annualized cost divided by the difference in annual fatalities, or $1,320,000 per fatality.
2. The difference in annualized cost divided by the difference in injuries, or $660,000 per injury.
3. The difference in annualized cost divided by the difference in minutes of vehicular delay, or $0.75 per minute of delay.

These unit costs may clarify the trade-offs between the alternatives. For instance, if one were primarily concerned with costs and fatalities, the relevant question is whether avoidance of a fatality is worth $1,320,000.

Table B-15. Level 2 analysis—balance sheet comparison replace vs. relocate.

FACTOR	REPLACE	RELOCATE
Cost (Total)	$1,810,000	$1,800,000
Safety	No effect	No effect
Highway Operations	No effect	No effect
Land Use --New ROW (acres) --Displaced Bldgs	 0.7 3	 7.2 10
Institutional	No effect	No effect

Table B-16. Level 2 analysis—balance sheet comparison at-grade vs. replace.

FACTOR	PUT AT-GRADE	REPLACE
Cost (Annualized)	$59,200	$85,600/yr.
Safety --Accidents --Injuries --Fatalities	 0.09/yr. 0.04/yr. 0.02/yr.	
Highway Operations --# Delayed --Time Delayed --% of Trips Delayed	35,000 vehicles/yr. 1 min/delay	
Land Use --New ROW (acres) --Displaced Bldgs	No effect	0.7 3

In the current case, however, there are multiple trade-offs, which are difficult to manage with unit cost comparisons. It would require allocation of the cost difference among fatalities, injuries, and vehicular delay, which is not straightforward.

To overcome this problem, the total cost comparison is used, which requires placing a cost on fatalities, injuries, and delays. The values used in this case study are $750,000 per fatality, $145,000 per injury, $3,000 per property damage accident, and $0.08 per vehicular minute of delay. All four figures are considered high and, therefore, conservative. The results of the total cost comparison (see Table B-17) show a slight preference for the replace alternative.

Table B-17. Level 2 analysis—total cost comparison at-grade vs. replace.

FACTOR	AT-GRADE 1/	REPLACE
Annualized Cost	$59,200	$85,600
Safety 1/	$21,000	0
Vehicular Delay	2,800	0
Land Use	0	Included in cost
Total Annual Costs	$88,400	$85,600

1/ Uses accident values as follows:
Fatality $750,000
Injury $145,000
Property damage $ 3,000

Recommended Action

Clearly, the choice between alternatives comes down to value judgments supported by factual information and objective analysis. Based on the information presented above, replacing the grade-separated crossing was recommended.

To further test this recommendation, both the replace and the at-grade alternatives were retained through Level 3 analysis where further information was found to support the recommendation. For example, it was found that the crossing is used by some school buses, which would be exposed to crossing accidents. Hazardous materials are transported by rail on the line, which would be exposed to crossing accidents. And noise from train horns would be quite disruptive to the community. Indeed, the community has a history of complaints and organized efforts to combat late-night sounding of horns. Consequently, at the conclusion of Level 3 analysis the replace alternative was selected as the preferred option.

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