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NATIONAL
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REPORT 456

Guidebook for Assessing the Social and Economic Effects of Transportation Projects

TRANSPORTATION RESEARCH BOARD

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Guidebook for Assessing the Social and Economic Effects of Transportation Projects

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SUBJECT AREAS
Planning and Administration • Energy and Environment • Transportation Law • Highway and Facility Design • Safety and Human Performance

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

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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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The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration, U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical committee according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

To save time and money in disseminating the research findings, the report is essentially the original text as submitted by the research agency. This report has not been edited by TRB.

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FOREWORD

By Staff
Transportation Research Board

This report presents guidance for practitioners in assessing the social and economic implications of transportation projects for their surrounding communities. Presented in guidebook format, the report identifies current best methods, tools, and techniques, based on an extensive literature review and comprehensive survey of state departments of transportation and metropolitan planning organizations. Additional resources are contained in the appendixes, including a discussion of geographic information system applications for social and economic impact analysis, tips on designing effective survey questionnaires, an overview of the travel demand modeling process, and a brief review of relevant legislation that provides the legal basis for impact assessment requirements. The guidebook should be particularly valuable to transportation planners in conducting assessments and producing results that are easily understood by residents, stakeholders, and decision makers. The guidebook will help planners not only to comply with applicable laws, executive orders, and regulations, but also to employ best practices for good participatory planning.

Transportation planning practitioners find it difficult to accurately assess the social and economic effects of transportation investments on communities. This difficulty stems from insufficient methods, tools, and techniques for the scale, context, and complexity of the projects. The result is that planners and decision makers have limited information and understanding of the full range of effects that may be attributed to a transportation project's development. These limitations make it difficult for state departments of transportation (DOTs), metropolitan planning organizations (MPOs), and other agencies to fully meet the intent of requirements for Federal-Aid Highway funding recipients to conduct social and economic analyses of their programs and projects. Much of this analysis was mandated initially by Title VI of the Civil Rights Act of 1964 and the Federal-Aid Highway Act of 1970. In 1991, the Intermodal Surface Transportation Efficiency Act further emphasized the need to address social and economic issues within state and metropolitan planning as well as during project development. In 1994, Executive Order 12898 on environmental justice elevated the emphasis on assessing impacts on minority and low-income populations and communities.

Under NCHRP Project 25-19, "Evaluation of Methods, Tools, and Techniques to Assess the Social and Economic Effects of Transportation Projects," a research team led by the University of Iowa developed a guidebook to assist transportation planners in acquiring a broad perspective on how a proposed transportation project might affect the community. The report begins with a discussion of the National Environmental Policy Act 1969 review process and describes how the analysis of social and economic effects fits within the broader context of impact analysis. The guidebook then identifies and describes methods for assessing impacts in two major cluster areas: transportation system effects and social and economic effects. Transportation system effects include changes in travel time, safety, and vehicle operating costs; transportation choice; and accessibility. Social and economic effects include community cohesion, economic development, traffic noise, visual quality, and property values. The guidebook also includes a discussion of distributed effects: how the various positive and negative impacts are experienced by different subgroups within the community.

For each of the potential impact areas, the guidebook provides guidance on determining when analysis is relevant and necessary, the required steps in the analysis, and a description of appropriate analysis methods. It does not attempt to combine the various elements of analysis into a single index or measure. Planners must be able to predict and evaluate the full range of effects, analyze the anticipated benefits of the project, and determine what should be done to mitigate or minimize the negative effects.

NCHRP Project 25-19 also resulted in a final report entitled "Assessing the Social and Economic Effects of Transportation Projects." The final report provides background material used in the development of the guidebook, including the results of a detailed literature review and analysis of a comprehensive survey of state DOTs and MPOs; discusses the current state of practice in economic and social impact analysis; and identifies future research needs. The final report on NCHRP Project 25-19, published as *NCHRP Web Document 31*, and the guidebook are available in portable document format (PDF) on CRP's website (www.nationalacademies.org/trb/crp.nsf).

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AUTHOR ACKNOWLEDGMENTS

Professor David Forkenbrock, Director of the Public Policy Center at the University of Iowa, served as principal investigator of NCHRP Project 25-19, and Glen Weisbrod, President of the Economic Development Research Group, served as co-principal investigator. They are the primary authors of this guidebook. Other contributing authors include Lisa Schweitzer and Shauna Benshoff of the Public Policy Center and Susan Moses of the Economic Development Research Group. Two consultants to the project, Shirley Loveless and Todd Litman, were contributing authors as well. We thank Professor Edward Beimborn for contributing Appendix C on travel demand modeling, Donald Vary for providing materials on accessibility measurement methods in Section 6, and Roger Burkart for supplying the graphical images presented in Section 10. The chair of the review panel, Dr. Thomas Harvey, guided the review process with great skill and fairness. He and the other members of the review panel provided us with numerous helpful ideas. Six senior practitioners evaluated a draft of the guidebook and offered excellent suggestions: Annette Coffey, Susan Fox, Leigh Blackmon Lane, Ben Orsbon, Matt Selhorst, and Barbara Stevens. Kyle Kroner provided valuable research assistance. We are especially grateful to Teresa Lopes for her superb editorial and graphical contributions.

SECTION 1: GUIDEBOOK OVERVIEW

INTRODUCTION

Potential transportation projects traditionally have been evaluated on the basis of a combination of engineering and economic criteria. Projects are generally selected according to how significantly they would improve such important performance measures as total travel time through a network and safety. In recent years, however, increased attention has been given to the effects of transportation projects on members of society other than users of the facility to be improved. The social and economic effects of transportation projects should be fully considered because (1) these effects can be substantial and (2) they often are important to the quality of people's lives.

Because the social and economic effects of transportation projects have received only limited attention, a need exists to increase the capabilities of transportation professionals to predict and assess these effects. This guidebook defines 11 general types of social and economic effects and provides insights into, and evaluations of, the methods, tools, and techniques available to assess them.

It is important to apply the best possible methods of analysis because comprehensive assessments of the social and economic effects of proposed transportation projects are inherently complex for at least four reasons:

1) A balance has to be drawn between benefits to users of the facility and effects on other community residents.

2) Even among community residents, numerous effects (some positive, some negative) interact and must be traded off.

3) Various population groups within the community may be affected quite differently in terms of mixes of effects.

4) People vary in their preferences and opinions, so that what is acceptable or even desirable to some may be unacceptable to others.

Methods for assessing the different types of social and economics effects vary as much as the effects vary. Some effects, such as changes in user costs, lend themselves to extensive quantification. The issue in the case of such effects is often what values to assign to key parameters, such as the value of travel time or the value of lives saved and injuries prevented by a safety enhancement. Other effects tend to be far more amorphous and abstruse. Effects such as a change in visual quality or community cohesion are bound to be rather subjective in nature. What is visually appealing to one person may not be so to another, and it is difficult to assign a numerical value to such things. In fact, many social and economic effects are qualitative in nature and must be treated as such in impact analyses.

The key implication of the diversity of social and economic effects is that it is fruitless to attempt to combine them into a single cumulative index or measure. Each effect must be examined separately using the most suitable method and presented in a comprehensible manner. Affected residents and system users can then evaluate these various effects, determining which are most important and what should be done to mitigate negative effects as positive effects are pursued.

Ultimately, then, the purpose of this guidebook is to improve the capacity of transportation professionals to take into account a wide array of social and economic effects when evaluating possible projects. Emphasis is placed on the methods, tools, and techniques most likely to produce analyses that can be understood by community residents and decision-makers.

TYPES OF EFFECTS ADDRESSED

To complete a thorough analysis of the likely effects of a proposed transportation project, many different types of impacts need to be considered. An assessment of probable social and economic effects is a key component in assessing the full range of effects, but it is only one of several efforts that need to be carried out. We begin by placing the analysis of social and economic effects in the broader context of impact analysis. Figure 1.1 presents the sequence of steps in a comprehensive impact assessment of a proposed transportation project. Notice that we stress the importance of community involvement in all steps of the impact assessment process. Each of the steps is briefly discussed in turn.

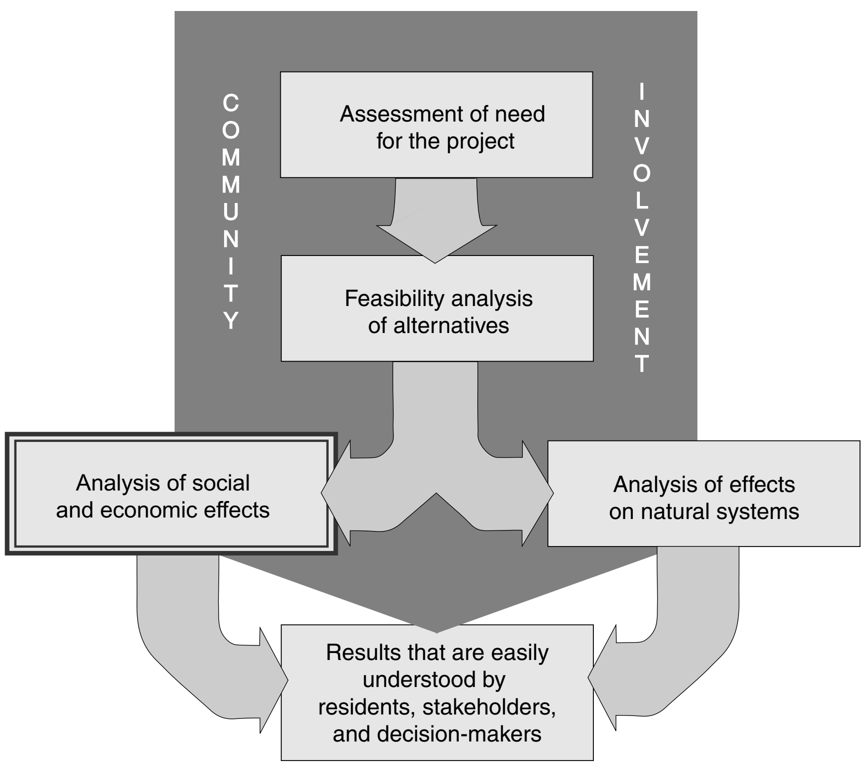

Figure 1.1. Components of a comprehensive project impact analysis

Assessment of need for the project. One or several problems or opportunities usually serve as the impetus for proposing a specific transportation project. It is at this initial stage that one should consider the issue of whether the project would advance community development and land use goals as stated in the community's adopted comprehensive plan. A preliminary study will help determine possible alternatives to the project, such as encouraging use of an alternative transportation mode, applying traffic management techniques, or influencing travel behavior by adopting different land use policies. At this stage, one should consider both short-run and longer-term effects on the community's development patterns.

Feasibility analysis of alternatives. If the project is deemed necessary, one must then determine whether it is feasible from an engineering perspective—can it be constructed or implemented without undue cost or complexity? Would other approaches to addressing the particular problem or opportunity be more cost-effective? If this analysis results in a negative assessment, further assessments of likely effects are not necessary.

Analysis of social and economic effects. This analysis is completed to serve two intertwined purposes: (1) provide residents, stakeholders, and decision-makers with as much information as possible as to the effects, positive and negative, the project would have on the community; and (2) enable the federal requirements to be met regarding impact assessments called for in such provisions as the National Environmental Policy Act of 1969 (NEPA), the 1970 Federal-Aid Highway Act, the Civil Rights Act of 1964 (as amended), and President Clinton's Environmental Justice Order 12898 of 1994 (EO 12898).

Analysis of effects on natural systems. A parallel analysis is carried out to consider how the proposed project would affect natural systems. Included in this analysis would be effects on (1) air and water quality, (2) endangered species and other wildlife, (3) greenhouse gas emissions, and (4) archeological and other cultural sites. NEPA prescribes the types of potential impacts one must address regarding effects on natural systems. We do not address these effects in this guidebook.

Results that are easily understood by residents, stakeholders, and decision-makers. The results and findings of the foregoing analyses must be effectively communicated to (1) persons who might be affected by the proposed project and (2) applicable state and federal agencies. Applicable agencies are those charged with assessing whether the project would create unacceptable impacts and what mitigation measures would be necessary to protect the public's health, safety, and welfare. This guidebook is intended to help one conduct analyses of social and economic effects that can be effectively presented to residents, stakeholders, and decision-makers. Actual communication techniques and strategies, however, are beyond the scope of this guidebook.

The key point is that an analysis of the likely social and economic effects of a proposed transportation project is a vital component of a comprehensive assessment, and facilitating such an analysis is the purpose of this guidebook. Figure 1.2 presents the general types of social and economic effects the guidebook addresses. In presenting a series of methods, tools, and techniques for assessing social and economic effects, we proceed from the premise that the ultimate purpose of changes in transportation systems is to enhance quality of life (center of Figure 1.2).

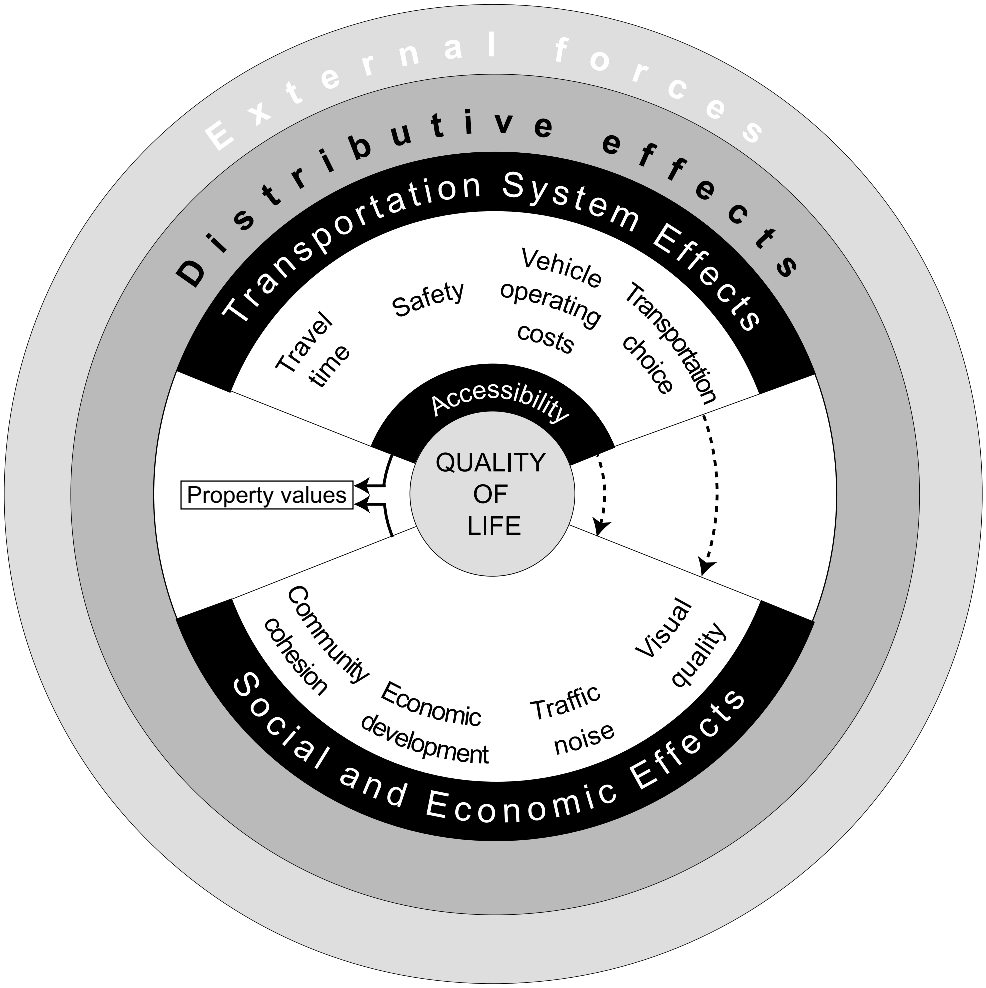

Figure 1.2. Interrelationships among social and economic effects

Of course, quality of life is a very general term that can mean different things to different people. Although any given person might place greater emphasis on some of the effects addressed in this guidebook than on others, in the aggregate the effects we examine are bound to be important to quality of life. Being able to move about easily and safely, having a choice of how to travel, being able to reach important destinations, and living in a pleasant, cohesive community with a robust economy all are part of how we define “quality of life.”

At the most fundamental level, we divide the effects we examine into two clusters: transportation system effects and social and economic effects. In brief, transportation system effects pertain to changes in how well the transportation system serves its users. Social and economic effects generally relate to how a transportation project affects people in the community other than those actually using the transportation system.

Transportation system effects

Sections 2 through 6 of the guidebook address effects on transportation system performance; these effects principally are experienced by the users of a transportation facility. We explore methods for assessing transportation system effects before presenting methods for assessing social and economic effects for two reasons:

1) To a certain extent, social and economic effects are dependent upon changes in the conditions facing those traveling by automobile, transit, and non-motorized transportation (primarily bicycle riders and pedestrians). For example, economic development is substantially influenced by changes in transportation costs. These costs include travel time, safety, and vehicle operating costs.

2) Some of these travel conditions, particularly those faced by pedestrians and cyclists, generally have not been addressed in feasibility and impact studies, but they could be included in a broader view of transportation system effects.

There are three traditional system performance effects: (1) changes in travel time, (2) changes in safety, and (3) changes in vehicle operating costs. Although relatively well-established methods exist for estimating these effects, deciding what economic values to attach to them can often be problematic.

The other two system effects are transportation choice and accessibility. Transportation projects may change the modal choices available to travelers. Especially in the case of disadvantaged persons, additional travel options are often highly valued. Making alternative transportation modes more readily available and convenient can be an important aspect of transportation system performance in its own right by helping to reduce automobile dependency. Particularly in congested cities or in those with environmental problems, expanded travel options can be among the most important effects of a transportation project.

In a sense, changes in accessibility are the cumulative user-related effect of changes in transportation systems. It is important to distinguish accessibility from mobility. “Accessibility” relates to the ease with which specific locations or activities can be reached; “mobility” refers to a person’s ability to move about. Mobility is largely a function of a person’s economic circumstances, as well as of any disabilities he or she may possess. Although we certainly advocate full consideration of how proposed transportation projects would affect persons with disabilities, this type of evaluation must by nature be project-specific. Rarely will a transportation project directly affect a person’s economic circumstances, such as the ability to purchase and operate an automobile or pay bus fare. The economic development stimulated by a project may, however, indirectly increase the income of a resident, thereby enabling him or her to experience greater mobility.

Accessibility is affected by changes in travel time, safety, vehicle operating costs, and transportation choice. The foregoing user effects combine and interact to change the accessibility of multiple destinations within a community. The accessibility of work locations, schools, public services, friends and family, houses of worship, and entertainment is a fundamental dimension of quality of life.

Social and economic effects

Figure 1.2 shows that there are four possible separate but interacting social and economic effects that a transportation project may have on a community: (1) community cohesion, (2) economic development, (3) traffic noise, and (4) visual quality. Although each of these effects should be examined individually—because the best methods for estimating them vary—they are certainly interrelated. For example, improving the visual quality of a community may well strengthen its prospects for economic development. Likewise, elevated noise levels can interfere with community cohesion, as people spend less time conversing near the street. Certain other effects, such as pedestrian safety, are addressed in several different sections because they are closely linked to other effects. A factor that may influence some of these social and economic effects, particularly economic development, is changes in accessibility. In Figure 1.2, a dashed arrow indicates the potential nature of this influence. Another dashed arrow denotes that transportation system effects may influence certain social and economic effects. For example, expanding a roadway to reduce travel time may well increase noise levels.

Changes in property values are a product of changes in accessibility and various social and economic effects, including community cohesion, economic development, traffic noise, and visual quality. If a transportation project would not bring about any of these other effects, it would not be likely to influence property values. We discuss property value effects separately because methods exist that distill various other effects into practical estimates of changes in the values of affected properties. Closely related to property values is land use, which we address in the section on property values. When the value of a land parcel is altered through, for example, a change in accessibility or noise levels, the land market will adjust. More expensive land will tend to be used intensively; that is, in time taller buildings and a generally higher ratio of floor space to land area will appear. Projects that increase accessibility of undeveloped areas will tend to promote lower-density land use patterns due to the availability of relatively inexpensive land.

Distributive effects and external forces

Distributive effects is perhaps the most important and far-reaching single category. Figure 1.2 indicates that distributive effects surround all other types of effects. At issue is how the various effects, positive and negative, are experienced by different subgroups within the community. In other words, who would benefit and who would bear the costs of a transportation project?

Distributive effects analysis contributes to the public discussion about the fairness or equity of a particular project. Because public policy draws on several concepts of equity, what people believe is fair can be varied and complex. Equity can be defined in terms of at least three very different types of distributions:

1) **Hold-harmless:** if we compensate those who bear the costs sufficiently, they would in theory be indifferent to the transportation change, while others who benefit can compensate those who would bear the costs and still experience net benefits.

2) **Worst needs first:** giving highest priority to projects that benefit those with the greatest disadvantage.

3) **Egalitarian allocation:** everyone receives the same allotment of transportation resources, regardless of need or utility.

Most people probably would describe "fairness" as a combination of these three components. When applied to real-world projects, equity criteria such as these yield vastly different outcomes, depending on the emphasis placed on hold-harmless, worst needs first, or egalitarian allocations of transportation services. Both NEPA and EO 12898 recognize that characteristics and issues important to a given community will shape its members' perceptions of benefits, harms, and equity. This is one reason why both NEPA and EO 12898 stress public involvement during the process of assessing potential effects of a project. What is fair (or unfair) depends on whom we ask (and when and how we ask).

The equity of a given project must be decided through a continuing dialogue among those who have a stake in the project such as agencies, members of affected communities, planners, and decision-makers—all of whom bring to the discussion their own conceptions of equity. Thus, the question of equity is answered largely through political and institutional means that are informed by public voices, as well as by analyses like those found in this guidebook.

Surrounding any analysis of social and economic effects are external forces. Factors not included in any analysis of social and economic effects will influence the ultimate impact of a proposed transportation project on a community. Among these external forces are the strength of the local economy, discovery of new technologies or new hazards, and actions by private entities such as major employers. Although forecasting or assessing these external forces is beyond the scope of this guidebook, one should always be attentive to them because they can definitely change the social and economic efficacy of a project.

PHILOSOPHY OF THE GUIDEBOOK

This guidebook is intended to facilitate a far more comprehensive analysis of probable social and economic effects than is common practice today. To help improve the state of the practice, we emphasize practical methods, tools, and techniques. Below are several specific ways in which the guidebook has been designed to be as useful as possible to transportation professionals. We begin with an explanation of how the guidebook relates to the NEPA review process and then move on to discuss how specific methods were selected for inclusion, the book's predictive orientation and presentation structure, and how examples were added to illustrate specific methods of analysis.

Relationship to the NEPA review process

NEPA has established procedural requirements for assessing the impacts of federally funded projects on the environment. Its objective is to provide planners, policy makers, and the public with a means for comparing alternative courses of action. To attain compliance with the provisions of NEPA, various levels of analysis may be required, depending on the nature and significance of the specific impact. NEPA clearly specifies that social and economic effects must be addressed, as well as other aspects of the environment; historically, however, many agencies charged with complying with NEPA have focused on impacts on human health and natural systems. More recently, increased attention has been paid to social and economic effects, but the methods for assessing them in general are less well developed than for those effects traditionally given greater emphasis.

It is worth stressing that Section 1508.8 of the Council on Environmental Quality (CEQ) regulations for implementing NEPA states that effects to be taken into account include "ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health" (CEQ 1986). Thus, social and economic effects are given the same standing in the CEQ regulations as other effects on the human environment, even though Section 1508.14 states that "economic or social effects are not intended by themselves to require preparation of an environmental impact assessment." One of our two objectives in this guidebook is to assist in addressing the social and economic effects that may arise from transportation-proposed projects in a fair and comprehensive manner and in conformance with NEPA. The other objective is to help facilitate good, balanced transportation planning.

Many of the social and economic effects addressed in this guidebook are directly relevant to the impact categories specified by NEPA for environmental impact statements (EISs). The methods contained in this guidebook also are useful in determining the "significance" of impacts, and therefore the classification of a project (i.e., whether an EIS is needed, a briefer environmental assessment [EA] would suffice, or a categorical exclusion [CE] would be appropriate). That said, in the interest of clarity, we categorize certain effects somewhat differently than the EIS impact categories. For example, an EIS requires separate discussions of community cohesion and residential dislocations or relocations. We have included the two in a single category. The point we stress is that a comprehensive analysis of social and economic effects generally will address the same phenomena as required for an EIS.

The key legal bases for analyzing the likely social and economic effects of a transportation project are highlighted in Appendix D. In our presentation of methods for assessing social and economic effects, however, we rarely cite legal requirements, preferring to stress the analyses that are vital to good planning. This guidebook is most likely to benefit a transportation professional who (1) has a working knowledge of the applicable laws, executive orders, and regulations and who wants to comply with them; and (2) is committed to good, participatory planning.

Other considerations

To enable the guidebook to be of maximum value in the planning process, we have incorporated several features that are briefly noted in turn.

Selection of methods. This guidebook is designed to assist the reader in acquiring a broad perspective of how a transportation project might affect a community. To this end, it seeks to guide the reader in the selection of methods, tools, or techniques for addressing various sorts of effects. It is not meant to be a textbook—it alone cannot teach all that must be known to carry out the numerous types of analysis discussed in the sections to follow. Rather, we provide information to assist in the choice of methods and offer advice in the proper application of the methods. When appropriate, we suggest resources that can be consulted to enhance one's capability to carry out certain types of analyses.

Predictive orientation. Because social and economic effects have traditionally received short shrift in analyses of potential transportation projects, there are few methods available to examine some types of effects. Moreover, some methods have generally been applied for post-project assessments: how did a completed project affect the community? Whenever possible, we have adapted these methods to be predictive. Predictive methods are especially important in the case of adverse effects: it is far better to have a reasonably good idea of how a potential project would affect people than to know exactly how a completed project is affecting them. Our emphasis is on helping communities make good choices when selecting transportation projects.

Examples. Throughout the guidebook, we make liberal use of examples to illustrate the application of the various methods, tools, or techniques. We have worked to keep the examples short and to the point. It is inevitable that some methods are more amenable to brief examples than are others. Certain qualitative approaches, for example, are best explained by describing the steps in their application, rather than by using examples. This variability in the applicability of examples only serves to underscore the highly diverse nature of social and economic impacts that can arise from transportation projects.

Presentation structure. Each of the remaining 11 sections of the guidebook contains several elements. We begin with an overview of the general type of effect under discussion. A segment called "When to do the analysis" provides guidance as to the conditions under which the particular type of analysis is advisable. The analysis is then broken down into generalized steps, common to the several methods presented in the section. Finally, the methods are discussed.

Because many of the approaches in this guidebook build on material presented in other sections, we include a series of cross-references contained in small, outlined boxes. These boxes reference other locations in the guidebook where supplemental information can be found that is relevant to the material being discussed.

Although the methods, tools, and techniques we include are highly diverse, we structure the discussions of all 52 methods similarly. Our intention is to provide a parallel structure to facilitate comparisons and, as applicable, tandem use of methods. The common components for all approaches include:

- **Information collection**—types of data needed, possible sources of these data, and, if applicable, pointers on data management and assembly.

- **Analysis**—the process of applying the method, including steps in carrying out the assessment, key assumptions and their importance, and helpful information in such matters as selecting variables and interpreting results. As noted earlier, examples are included where useful and feasible.

- **Measurement and presentation**—a brief explanation of the output the analysis will provide and how this output can be presented.

- **Assessment**—evaluation of the method, including critical assumptions, strengths, and limitations.

- **Resources**—whenever possible, we present brief annotations of select articles, books, reports, and Internet sites containing insights likely to be helpful in understanding and applying the method. The resources were chosen with an eye toward providing the reader with a basic understanding of the topic.

The guidebook also contains four appendices: geographic information systems, survey methods, travel demand modeling, and distributive effects laws and regulations. These appendices are resources that supplement the more specific presentations of methods, tools, and techniques. Although not technical in nature, the appendices are intended to assist the reader in applying concepts and principles that cut across the various sections of the guidebook.

USING THE GUIDEBOOK

This guidebook is oriented toward problem solving. The most efficient use of it is to first consider which of the 11 general effects are applicable to the analysis at hand. Which effects are applicable may depend on the motivation or context for analyzing social and economic effects:

- When the analysis is conducted as part of an EIS or EA, state or federal regulations and the type of project may dictate that specific types of effects should be individually assessed to determine whether any of them would lead to potentially unacceptable conditions.

- When the analysis is carried out as part of a project selection or prioritization process, the effects to be studied may, at least in part, be defined by the state Department of Transportation (DOT), based on its need to compare overall ratings of project benefits and costs. In such cases, concern about double-counting may dictate that some types of effects be measured and others discussed but not actually measured.

- When the analysis is conducted as part of the community planning process, consultation with affected residents and community leaders is critical to identify which types of effects are likely to be of greatest importance or concern.

Depending on the analysis context, some effects are likely to warrant more extensive examination, perhaps using more advanced methods. It stands to reason that the effects that residents of a community feel are important should be addressed with special thoroughness and rigor. Effects that are likely to be consequential but not of paramount importance often can be examined using more basic methods. In most cases, then, some effects will warrant extensive study, others will warrant a less exhaustive analysis, and still others may not require any attention.

Consider distribution of various effects. In every case, the distribution of both benefits and costs among population subgroups, particularly low-income populations and minority populations, should be assessed. Throughout the guidebook we note that although many different types of effects may benefit one group of people, the associated costs may fall upon a different group. If the incidence of costs disproportionately affects persons of color or those with low incomes, a redesign of the project or mitigation of negative effects is essential (see Section 12 and Appendix D).

Avoid excessive summing and double-counting. This guidebook addresses numerous types of social and economic effects that collectively affect the residents of a community. Many of these diverse effects cannot be added together because it is not possible to express them in the same units. One should avoid the tendency to convert all effects into, for example, monetary units. A better approach is to inform decision-makers and affected populations of effects in the clearest possible manner without adding the effects together.

Also, one must be careful not to double-count effects. Often, a given effect may bring about one or more other effects, and adding them all together may overstate the cumulative effect. For example, a reduction in transportation costs may contribute to business growth. If a particular business passes along these savings in terms of lower prices, the business's customers would then realize a savings also. It would be doubling-counting to add the original travel cost savings to the effective income gain on the part of the customers.

Consult with affected populations. A related point pertains to the process of determining which effects are important and likely to be sizable. We must stress that perceptions of importance are necessarily subjective—what may not appear critical to even a thoughtful transportation analyst may be absolutely crucial to a neighborhood or a particular population subgroup. The *only* way to determine which effects are important is to consult early and often with those who would be affected by a proposed project. One should never rely entirely on professional judgment or even experience when assessing the importance of the various social and economic effects that would arise from a transportation project. Rather, one should give the highest priority to the effects that are of greatest local interest.

Again, one must also be sure the analysis is easily understood. Even a rigorous assessment of social and economic effects is of limited value if those who would be affected cannot comprehend it. Similarly, local decision-makers must be informed in a way that (1) allows them to understand the several effects and their magnitude, (2) enables them to participate in choosing among alternatives and approaches to mitigation, and (3) helps them make the tradeoffs among effects to improve the balance between benefits and costs for specific population groups.

In selecting methods, tools, and techniques to include in this guidebook, we have taken into account their amenability to clear and understandable presentation. Whenever possible, we demonstrate the use of maps and related graphics. To the fullest extent possible, we avoid methods that are so technically advanced that comprehension might be a problem. Even with more basic approaches, however, it is good practice to carefully and deliberately explain how one's conclusions have been reached.

REFERENCE

Council on Environmental Quality (CEQ). 1986. "Regulations Implementing NEPA (National Environmental Policy Act of 1968)." 40 CFR, Parts 1500–1508 (July). Available at: http://ceq.eh.doe.gov/nepa/regs/ceq/toc_ceq.htm.

SECTION 2: CHANGES IN TRAVEL TIME

OVERVIEW

Steps in the analysis	Methods
• Select a method to evaluate travel time savings • Collect the necessary data • Estimate the savings in travel time • Evaluate the time savings of the project	• Highway Economic Requirements System (HERS) • Shortcut method based on HERS • Stated preference surveys • Travel time variability model

Definition

A savings in travel time is usually the primary user benefit of a transportation project; such savings typically constitute well over half of the total user benefits. In some cases, such as an increase in transit services, variability in travel time may be reduced without a significant reduction in the mean travel time. Reductions in the variability of travel time also have become a major consideration in projects serving freight transportation.

The value of travel time savings, and of the reduced variability of travel time, can be thought of in terms of reduced opportunity costs. In other words, savings in time can be used for activities other than traveling, allowing individuals and firms to be more productive or to have more time for recreational activities. For example, when a business reduces its delivery times as a benefit of a transportation improvement, it may become more competitive and gain a larger customer base. The saved time can then be used in production activities. Savings in travel time can also be valuable for commuters who gain additional time for work, household activities, and recreational activities as travel times to destinations are reduced.

Transportation factors affecting travel time savings

Transportation projects can directly affect the amount of time required for traveling in the following ways:

- Projects that expand road system capacity and improve traffic controls allow motorists to journey from their origin to their destination more quickly due to reduced congestion on the roadway.
- Expanded capacity on an existing road, or the construction of a new road, relieves strains on other roads; as a percentage of motorists choose to take the expanded or new road, travel times throughout the network are reduced.
- Projects that reduce congestion—and thereby reduce the number of incidents—will reduce the travel time variability associated with the occurrence of incidents on a roadway.

- Reduced congestion and the resulting increase in certainty of arrival time allow alternative modes to remain on a tighter schedule, thereby saving travel time for individuals who choose not to drive.

Special issues

Estimating travel time savings is an essential component of virtually any economic analysis of a proposed transportation investment. Despite the obvious desirability of definitive values for this key factor, there are several significant issues that make a precise assessment of the value of travel time savings elusive.

Valuing travel time. According to Wardman (1998), the value of travel time savings has two components: the opportunity cost of the time spent traveling and the relative disutility of that time. For example, waiting 10 minutes for a bus produces greater disutility than riding the bus or traveling in an automobile. Mohring et al. (1987) found that people value the time spent waiting for a bus quite differently (more negatively) than the time actually spent en route. Disutility also may increase over the course of a journey. For example, disutility may be low for the first quarter-hour of a commute, but may subsequently increase as the traveler begins to experience discomfort and boredom.

A loss in time may be inconvenient and may require individuals to take time away from other activities. A small time savings may not be significant enough, however, to apply to any other activity. In other words, an increase in the travel time may well be of greater cost than a comparable savings in travel time is valued as a benefit (Wardman 1998).

No single method could possibly provide the exact value of travel time savings resulting from a transportation project. Many different travelers use any given facility, each with their own unique valuation of time (due to their economic productivity or personal views toward time use). Likewise, businesses using a transportation facility vary in the urgency with which their vehicles must arrive at their destinations. Thus, by necessity, fairly aggregate valuations of time are unavoidable. That said, it is advisable to break types of travelers and trip purposes down as much as practicable.

The most commonly used estimate of the value of travel time is the prevailing wage rate in the area surrounding the facility. A wage rate includes salaries and fringe benefits and serves as an indication of the price that is sufficient to induce people to forego discretionary free time and work instead. The Federal Highway Administration's (FHWA's) Highway Economic Requirements System (HERS) calculates that the value of on-the-clock (i.e., when one is working) travel time to drivers is equal to the wage rate for civilian workers (including wages and fringe benefits), while the value of off-the-clock travel time to drivers is approximately 60 percent of the wage rate exclusive of benefits, and the value of time for passengers is 45 percent of the wage rate (FHWA 1999, pp. 7–4 to 7–5). These fractional values are the product of literature surveys by HERS consultants. Reasonable minds can differ as to the appropriateness of the fractions, but they are a useful point of departure.

Another issue related to travel time valuation pertains to trucks carrying freight. For trucks, travel time estimation includes three components: driver wage, vehicle operating cost, and inventory. Typically, the driver wage can be estimated quite easily using local union scales, which include fringe benefits. The per-mile cost of operating a truck in the particular locale also can be estimated using local data. A rule of thumb for the inventory cost of cargo is to apply $.80 per hour for each $100,000. This figure is based on the hourly interest cost of that value at 7 percent. (Seven percent of $100,000 is $7,000; divided by the 8,760 hours in a year, the result is $.80 in interest costs per hour.)

Travel time budgets. The valuation of travel time views time as an economic resource that all individuals have in the same fixed quantity. Individuals choose to allocate time in different quantities, recognizing that time cannot be stored, only transferred among different activities. Travel time valuation assumes that different allocations of time among activities may have different values, which may be measured in monetary units. As noted earlier, waiting for a bus may be more unpleasant than riding in the bus en route to one's destination, so the implicit value of time for the former is greater than for the latter.

People tend to allocate units of their time to certain activities, including travel time. This being the case, a reduction in the time needed for a certain activity may have little value if the period of time already devoted to the activity is within the person's "budget." Suppose, for example, that a person informally allots 15 minutes for travel to work, but the trip currently takes only 12 minutes. If a transportation improvement reduced travel time to 8 minutes, the value of the savings in travel time to this person would not be very substantial.

A related issue is the notion that very small increments of travel time savings experienced by many people may not be as valuable as the same total amount of time saved by a smaller number of people but in larger increments. The opportunity cost per person may well be less in the former case. Researchers vary in their opinions on the issue of whether very small increments of time savings should receive the same unit value as larger increments. For example, 20,000 vehicles per day may save 10 seconds each due to a minor road improvement, or 200 vehicles per day may save 17 minutes each (about 1,000 seconds) due to a more substantial project. In both cases the same total amount of time is saved, but the question is whether 10 seconds per traveler is a usable savings and thus equal on a unit basis with the larger time increments that can enable other, productive activities to take place.

Travel time variability. A high level of variability implies a less-than-reliable transportation system and requires individuals to leave early and allow extra time for traveling or face the consequences if they do not arrive at their destination on time. Leaving early may result in the traveler arriving at the destination early and spending an excessive amount of time.

Much of the variability in travel time occurs as a result of unexpected delays caused by incidents on the road. Incidents include events such as crashes and fires, abandoned vehicles, debris, and vehicle breakdowns. Such incidents can have significant effects on travel time because they are unpredictable and can cause delays ranging anywhere in length from a few minutes to many hours, depending on the nature of the incident (Schweitzer et al. 1998). Various estimates suggest that incidents account for up to 60 percent of freeway and arterial delays; predictable congestion represents the other 40 or so percent. This is an especially important point for the trucking industry that serves just-in-time businesses, which require deliveries to be made with minimal deviations from a predetermined schedule.

Impact area. Although the methods to measure travel time savings look specifically at the road or road segment where a project would occur, effects may also be felt network-wide as the strain is relieved on other roads. Focusing only on the improved road may understate total travel time savings.

Equity concerns. At least two equity concerns are central to travel time valuation. First, travel models commonly used to estimate the travel time effects of a particular project generally do not take into account non-motorized transport. As a result, the effects of transportation system changes on the travel time of bicyclists and pedestrians rarely are considered. Second, travel demand models usually are not sensitive to chained trips. Trips that involve multiple stops en route to a destination may be especially important to parents with young children, whose trips are more likely to involve stops for work, shopping, and childcare.

WHEN TO DO THE ANALYSIS

Estimating changes in travel time is a vitally important aspect of assessing the social and economic effects of any major street or highway project, including expansion of capacity and construction of new facilities. Speed and certainty of arrival time are precious commodities to most road users, and because time saved has an economic value, estimating the amount of time that will be saved if a project moves forward is fundamental to assessing the economic value of the project.

Travel time savings analyses are commonly performed whenever the objective of a project is to reduce traffic congestion on a roadway. The results of such analyses are then often used to evaluate accessibility or economic development effects. This is due to the fact that although the construction of a new road or the addition of new on-ramps may reduce travel times to certain destinations, it may also increase accessibility of certain areas. Increased accessibility may attract businesses, thus influencing economic development.

The key input to travel time analyses is the results of travel demand models. These models enable estimates to be made of the time en route between origin and destination pairs along a corridor without and with a proposed upgrade. Normally, the product of a travel time valuation effort is combined with analyses of vehicle operating cost savings and crash cost savings to provide a comprehensive picture of the benefits to road users of a project.

STEPS IN THE ANALYSIS

Step 1. Select a method to evaluate travel time savings.

The choice of method one uses to estimate travel time savings is influenced by the necessary level of detail, and this level can vary greatly. For most projects, a fairly aggregate analysis using travel demand models to estimate total time savings is likely to be sufficient. If economic development considerations are present, an analysis of travel time variability may be advisable, as well.

Step 2. Collect the necessary data.

The key input to travel time analyses is total travel time for both the unimproved (i.e., base) case and the improved case. Data also are needed on the average wage and fringe benefit rates for the affected area. Data on trucking wage and fringe benefit rates and cargo value may be germane as well.

Step 3. Estimate the savings in travel time.

Using an appropriate level of traveler disaggregation, the selected value(s) of time is applied to the number of traveler hours saved. The trend is toward considering on-the-clock trips separately from others, and automobile trips are usually separated from truck trips. When congestion is an issue, separate travel time comparisons between the base and improved cases are made for peak and off-peak periods.

Step 4. Evaluate the time savings of the project.

Travel time savings generally are aggregated on a year-by-year basis. Annual increases in traffic volumes and the resultant travel time estimates can be computed for the unimproved and improved cases via a travel demand model. Savings in travel times compared with the base case values can then be discounted and summed to yield a present value for the expected life of the improvement.

METHODS

Method 1. Highway Economic Requirements System

The Highway Economic Requirements System (HERS) was developed for the Federal Highway Administration by Jack Faucett Associates. It is a computer model designed to estimate the benefits of potential transportation improvements using incremental life-cycle benefit-cost analysis (McElroy 1992). A key component of HERS is its ability to compare aggregate travel times of a base case with the times of an improved case. HERS uses several computer algorithms to estimate, and then place an economic value on, travel time savings. Our objective in this discussion is to provide a summary of the HERS model, not to include a full presentation of all of the model's workings. If the model seems appropriate to one's needs, the HERS manual (FHWA 1999) can be consulted for technical details.

Information collection. HERS requires that specific data be obtained to estimate the value of time savings. These data include the wage rate (including wages, salaries, and total benefits), the average hourly wages for truck drivers, fringe benefits for truck drivers, the average vehicle occupancy for on-the-clock and off-the-clock trips in automobiles and light trucks, initial vehicle costs for automobiles in commercial motor pools and four-tire trucks, the average vehicle cost per year of heavier trucks, the average value of commodities shipped by axle combination, the percent of automobiles that are in commercial fleets of four or more, the percent of vehicle-miles that were on-the-clock for four-tire trucks, and indices to adjust 1995 dollars to those of any other year.

Analysis. HERS values time savings for on-the-clock trips (trips for one's employer) on the basis of the savings to the employer, including wages, fringe benefits, and for some types of trucks, vehicle cost and inventory carrying costs. Off-the-clock (personal travel) time savings are estimated using choice situations that ask travelers to select between saving time versus saving money or having a safer roadway.

Table 2.1 summarizes the major cost components of estimates of the value of travel time for each of seven vehicle types. HERS uses these values to develop estimates of travel time costs for each vehicle type.

Table 2.1. Value of one hour of travel time
(Year 2000 dollars)

Category	Vehicle class						
	Small automobile	Medium automobile	4-tire truck	6-tire truck	3- or 4-axle truck	4-axle comb.	5-axle comb.
On-the-clock							
Labor/Fringe	$28.36	$28.36	$19.45	$23.62	$19.67	$23.69	$23.69
Vehicle	1.86	2.18	2.35	3.32	9.49	8.01	8.61
Inventory	0.00	0.00	0.00	0.00	0.00	1.78	1.78
Total	$30.22	$30.54	$21.80	$26.94	$29.16	$33.48	$34.08
Other Trips							
Percentage of miles	90	90	69	0	0	0	0
Value	$13.79	$13.79	$13.79	NA	NA	NA	NA
Weighted average	$15.44	$15.47	$16.28	$26.94	$29.17	$33.48	$34.09

SOURCE: FHWA 1999, Table 7-1, updated by the guidebook authors.

HERS uses the following equation to estimate travel time costs:

$$TTCST_{vt} = \frac{1000}{AES_{vt}} \times TTVAL_{vt}$$

where:

$TTCST_{vt}$ = average travel time cost (in dollars per thousand vehicle-miles) for vehicles of type *vt*

AES_{vt} = average effective speed of vehicle of type *vt* on the highway section being analyzed

$TTVAL_{vt}$ = average value time (in dollars) for occupants and cargo traveling in vehicles of type *vt* (as shown on the bottom line of Table 2.1)

On-the-clock trips. HERS values the travel time for on-the-clock trips based on the costs to the employer. These costs include wages and fringe benefits paid, costs related to vehicle productivity, inventory carrying costs, and spoilage costs. No adjustment is made to reflect the tax deductibility of these costs.

To compute employee costs per hour of on-the-clock travel time, multiply wages and fringe benefits per vehicle occupant by average vehicle occupancy. HERS assumes that combination trucks have an average of 1.12 occupants. The first row in Table 2.1 presents the labor and fringe benefit costs per hour by type of vehicle.

To compute vehicle costs per hour for automobiles in commercial motor pools and 4-tire trucks, HERS divides the average vehicle costs per year (assuming a 5-year life, with a 15 percent salvage value at the end) by 2,000 hours per year of sign-out time (the day shift or other shift when maximal vehicle use occurs). HERS computes the vehicle costs per hour for heavier trucks as the average vehicle cost per year divided by the number of hours in service per year. The second row in Table 2.1 presents the vehicle costs per hour by type of vehicle.

To calculate inventory costs for 5-axle combination trucks, HERS computes an hourly discount rate and multiplies it by the value of a composite average shipment. Payload for 4-axle combination trucks is lower than for 5-axle combination trucks, but the value of cargo is likely to be higher, so the value per shipment is assumed to be the same for both types of trucks. Finally, the inventory cost for 3- and 4-axle single unit trucks and for 6-tire trucks is assumed to be negligible. Automobiles and 4-tire trucks are not assumed to transport significant values of goods.

Off-the-clock trips. Off-the-clock trips include trips for commuting to and from work, personal business, and leisure activity. HERS uses a value of 60 percent of the wage rate exclusive of benefits for the value of off-the-clock travel time to drivers. Additionally, automobile passengers' time is valued at 45 percent of the wage rate. (Refer to the sixth row of Table 2.1.)

Travel time values. To calculate the travel time savings resulting from a transportation improvement, it is necessary to develop travel time values for use in HERS. Heavy trucks are assumed to be used only for work, so the value of time equals the on-the-clock value. Lighter vehicles are used both for work and other purposes. The value of their travel time therefore equals the sum of the percentage of travel by drivers as part of their work multiplied by the value of work travel time plus the percentage of off-the-clock travel multiplied by the value of non-work travel time.

The sixth row of Table 2.1 presents the off-the-clock costs per hour by type of vehicle, and the fifth row presents the percentage of miles that are off-the-clock. Finally, the seventh row presents the average travel time cost per hour that is used in HERS, updated to year 2000 dollars.

Measurement and presentation. HERS applies estimates of the average value of travel time for each of seven vehicle types by trip purpose (i.e., on-the-clock or off-the-clock). Using the values presented in Table 2.1, estimates are generated in year 2000 dollars. This value of time may be indexed from 1995 dollars to dollars of any other year using the Bureau of Labor Statistics (BLS) data on average hourly earning of civilian workers. For trucks, one can use BLS data on mean hourly earnings of truck drivers (by truck type).

It is also possible to calculate new values of travel time for each of the seven vehicle types by trip purpose using the methods developed by HERS.

Assessment. HERS is becoming one of the more commonly used tools for calculating travel time savings. As we noted, it values time savings for on-the-clock trips on the basis of the savings to the employer and off-the-clock time savings at 60 percent of the wage rate exclusive of benefits. The value of passengers' time is assumed to be 45 percent of the wage rate. In some cases, this estimate may cause inaccuracies in the resulting estimates and raise equity concerns regarding the value of time of passengers who may be carpooling together or of employed spouses who are traveling together. It is worth stressing that there cannot be a "correct" fraction for off-the-clock time values versus those on-the-clock; likewise, the relative value of a passenger's time versus that of the driver is by nature somewhat arbitrary.

HERS uses data from national, state, and private sources, which can be obtained on the Internet and input into equations to calculate travel time savings. The value of travel time savings can be obtained using the provided parameter estimates in 1995 dollars, or new values can be generated following the procedure described in HERS. The calculations are simple, and one should not require outside sources to perform the analysis.

It is not necessarily appropriate in all cases to use national data on wage rates and the like. Wages vary widely among the states and regions of the United States, and national averages may deviate considerably from the actual figures in a particular area. It is likely that the model will be further developed to enable the user to replace national data values with those of the specific jurisdiction in which the transportation project is being contemplated.

Method 2. Shortcut method based on HERS

Information Collection. The same general types of data are needed to conduct the shortcut method as are necessary for HERS, but the detail need not be nearly as great. Specific data needs are described below. Although we simply break vehicles down into automobiles and trucks, several categories of trucks could be used.

Analysis. HERS modeling of travel time savings is quite comprehensive and sophisticated. Much of the same logic can be applied in a simpler fashion, albeit with some loss of precision. In the most basic form, an analysis of travel time savings could involve a five-step process:

Step 1: By direct observation, measure the current travel time and average annual daily traffic (AADT) on the unimproved facility. Then, using a travel demand model, estimate the change in travel time required to traverse a corridor if it were to be improved, as well as the change in AADT. For greater accuracy, it is advisable to use a network travel model to take into account the travel time savings of those who divert from other routes to the upgraded facility. It may be a good idea to run the travel demand model with peak and off-peak conditions separately.

Step 2: Using cordon-line surveys or observers, estimate the vehicle occupancy rate of current travelers along the corridor. Also, estimate the vehicle mix between automobiles and trucks.

Step 3: Estimate the number of vehicle hours (automobiles and trucks separately) saved on an annual basis, using the values derived in Step 1 above. Using the occupancy rates in Step 2, calculate separately the total number of automobile and truck person hours that would be saved annually if the project were carried out. When applying the occupancy rates, multiply the person hours by 45 percent to adjust for the lower valuation of their time. The result is the "effective" person hours saved for valuation purposes.

Step 4: Apply the HERS fraction of person hours saved calculated in Step 3 above that are related to automobile trips on the clock (10 percent of all vehicle hours and, hence, person hours), and apply the current average wage rate plus fringe benefits for the area. For person hours pertaining to other automobile trips, use 60 percent of this wage rate. The result is the annual value of time savings for automobiles.

Step 5: For trucks, assume a single occupant, so that the number of person hours saved is equal to the number of vehicle hours saved. Apply the average wage for employees of trucking companies plus the fringe benefit rate. This wage information normally can be obtained directly from trucking companies. Add an average figure of $7 per hour for truck operating costs and another $.80 for inventory. The result is the annual value of time savings for trucks.

Measurement and presentation. The shortcut method of estimating the value of travel time savings will provide the dollar value of annual travel time savings for automobiles and for trucks. Because estimates of these dollar values require several judgment calls as to which values to use (as is the case with HERS), it is important to state explicitly the parameter values used in each case. It is good practice to vary key parameter values to see how much the ultimate total annual value of travel time savings varies as a result.

Assessment. This shortcut method will provide an approximate figure for the annual value of travel time saved due to a transportation project. It is a fairly aggregate approach, and so may be less precise than one that breaks vehicles into smaller categories. To improve its accuracy, it may be advisable to rerun the travel demand model with traffic growth estimates in 5-year increments. Doing so will improve the estimates of aggregate travel time over time. Annual travel time savings can then be discounted and summed to yield total travel time savings over the project's life.

If the resources exist, the HERS model is a more flexible and refined mode of analysis, but this shortcut method will provide reasonable approximations.

Method 3. Stated preference surveys

Stated preference surveys provide a method for estimating the value of travel time savings based on individuals' responses to choices that involve different combinations of characteristics, including varied travel times. These surveys were originally developed by marketing researchers as a means for estimating the relative value consumers place on different product attributes.

Information collection. Stated preference surveys require general demographic and travel information, in addition to indications of preference for certain scenarios. The types of general information that may be of interest include gender, personal and household income, miles traveled to work or school, normal travel time, normal departure time from home, desired work arrival time, workplace tolerance for lateness, mode choice, frequency of carpooling, and the number of persons in the car pool. Additionally, if interest exists in a specific road, other relevant variables might include frequency of use, departure time, distance traveled, door-to-door travel time, day of week of the most recent trip, and number of persons in the vehicle.

Analysis. Stated preference surveys ask travelers to choose from a number of alternative travel options. Using fictitious route choice experiments, individuals choose among route choices with different attributes and travel times. Questions can further probe how people value travel time by including levels of congestion, tolls, and early or late arrival times in the choices. The experimental design requires each participant to select one route or scenario from the choices available. This provides an indication of an individual's preference for a given set of options. More specifically, it indicates how important travel time is compared with other desirable attributes.

One commonly used version of the stated preference survey assesses willingness to pay (WTP). WTP surveys set up choice situations that ask respondents to express how willing they would be to pay to reduce their work travel time or to keep or lengthen their recreational travel time. Respondents can also indicate changes in willingness to pay for travel time reductions contingent on changes in distance traveled, as well as the maximum amount they would be willing to pay to reduce travel time by a marginal amount (see Walsh et al. 1990).

Measurement and presentation. There are three general designs for stated preference surveys: ranking-based, ratings-based, and choice-based. In the ranking-based design, individuals rank a given set of options. In the rating-based approach, participants choose between several pairs of options and indicate the strength of their preference for one option in each pair. Finally, the choice-based method requires participants to note their preference for one option in the choice set. This is usually repeated as the option attributes are varied in a predesigned manner (Ortúzar and Garrido 1994).

Depending on the design of the survey, different statistical methods can be used to analyze the data, including multinomial logit models, linear regression, ordered probit, and binary logit models. Statistical analysis results in parameter estimates for the role of variables that influence travel time and other demographic and socioeconomic influences. These estimates can then be used to derive purpose-specific time values (Hensher et al. 1990).

Assessment. Stated preference surveys allow time to be assigned a value based on respondents' preferences for certain situations. The method thus overcomes some of the equity concerns associated with using a fixed percentage of the wage rate to value different types of trips. It relies on the key assumption that respondents understand the choice situations and are able to express a preference based on their current circumstances. Furthermore, stated preference surveys require a significant amount of data and are therefore quite time-consuming. To recover the value of time, statistical methods must be employed that are comparatively sophisticated. Unless one is quite knowledgeable about the applicable statistical methods, technical assistance will very likely be needed. Technical assistance in statistical analysis can generally be readily obtained from faculty at colleges and universities.

Given the necessary technical assistance, however, stated preference surveys can be a reasonably accurate means for estimating the value of time for a particular group of travelers. When a precise valuation of time is a high priority in judging the economic feasibility of a project or in judging how it would benefit a targeted population group, stated preference surveys can be among the most satisfactory approaches.

Method 4. Travel time variability model

When evaluating the anticipated effects of an urban highway project on economic development, the issue of reliability of arrival time becomes particularly important. Often, a reduction in the variability of travel time is even more important than changes to the mean time en route. Traditional analyses of travel time valuation generally ignore the key issue of variability. This is partly because analyses of travel time variability are inherently complex. To estimate variability, one must first predict the frequency and severity of incidents that make a congested roadway grind to a halt. The most usable and accurate approach for predicting travel time variability has been developed by Cohen and Southworth (1999). They have worked out a model for estimating the mean and variance of delay caused by incidents on major highways as a function of a volume-to-capacity (V/C) ratio. Rather than present a detailed explanation of the model, we explain its general features and analytic approach. A detailed presentation is contained in an article by Cohen and Southworth (1999).

Information collection. To calculate the various components of the travel time variability model, it is necessary to obtain data on the average volume on the major highway in question, the capacity of the freeway, and the effects of a typical incident on delay—such as the capacity reduction factor due to the incident, the average getaway volume, and the incident duration. These data are not likely to be routinely maintained by most of the transportation agencies responsible for the highway system. Some analysts have found that using data from other comparable highway systems enables a reasonable approximation of travel time variability to be made. Sullivan et al. (1995), for example, have analyzed incident data from several metropolitan areas.

Analysis. The model considers the following to be incidents that affect delay: crashes, debris on the roadway, and vehicle breakdowns. It does not consider daily variations in traffic volume, weather conditions, or roadwork.

Cohen and Southworth's model contains three major sections. First, the total delay due to a type of incident is calculated. Next, the mean and variance of incident-related delays experienced by individual motorists are calculated. Finally, using two different approaches, a user benefit (or cost) is assigned to the model of delays due to incidents.

The following variables are used in calculation of the model:

V = average volume on the freeway (in vehicles per hour), the rate at which vehicles arrive at the back of the queue after an incident occurs

C = the capacity (level of service E) of the freeway prior to the incident (in vehicles per hour)
r = capacity reduction factor due to the incident (Note: the quantity rC is the rate at which vehicles pass the incident before it is cleared. If $r = 0$, the freeway is completely blocked by the incident)
g = average getaway volume from the queue after the incident is cleared, expressed as a fraction of C
T_i = incident duration (in hours)
T_g = duration of the getaway period during which the queue dissipates (in hours)
Q = maximum queue length (vehicles)
D_i = total delay incurred by all vehicles during the incident (in vehicle-hours)
D_g = total delay incurred by all vehicles during the getaway period (in vehicle-hours)
D = total delay incurred as a result of the incident (in vehicle-hours)

D is calculated as a function of V, C, r, g, and T_i.

Total vehicle delay. A queue will occur if the freeway volume V is greater than the available freeway capacity during the incident (i.e., if $V>rC$). The queue will continue to grow until the incident is cleared (T_i hours after the incident occurred). The growth rate is equal to the rate at which vehicles arrive at the end of the queue (V) minus the rate at which they pass the incident (rC). A very brief summary of the model's workings follows:

- The maximum queue length (the point in time when the queue is cleared) is calculated. The queue grows from a length of zero to a length of Q. Therefore, the average queue during the incident is $Q/2$.

- The rate at which the queue dissipates after the incident clears is dependent on the getaway capacity and the volume.

- While the queue dissipates, the delay incurred by vehicles is calculated.

- Finally, total delay caused by the incident is calculated.

It is important to note that the total delay caused by an incident varies with the square of incident duration. In other words, if the duration of incidents is reduced by 10 percent, the total delay is reduced by 19 percent ($[1.0–0.9]^2=0.19$).

Mean and variance of incident-related delays. Following estimation of total delay to all vehicles due to an incident, the mean and variance of incident-related delays experienced by individual motorists is calculated. This requires certain assumptions to be made for each class of incident (k):

- The occurrence of incidents is governed by a Poisson process such that the expected number of incidents is equal to $\lambda_k VL$, where λ_k is the incident rate, V is the volume, and L is the roadway section length.

- Incident durations follow a Gamma distribution with mean m_k and variance s_k^2.

- Not all motorists experience the same amount of delay. Delays experienced during a given incident follow a uniform distribution ranging from zero to twice the expected delay.

Two methods for valuing travel time variability. Following estimation of the mean and variance of delays due to an incident, the model provides two methods for valuating the benefits (or costs) of more (or less) reliable travel times. Both methods attempt to quantify the benefits associated with improved system reliability. They rely on data from stated preference surveys where travelers choose between hypothetical trip-making options that offer trade-offs between trip time, trip time variability, and trip costs. The first method assigns an additional cost of travel directly to a measure of trip time variability. The second method assigns the additional cost of travel to that part of a trip in which delays caused by congestion occur.

Measurement and presentation. The first method tends to result in higher costs for short trips, whereas the second is more likely to result in higher costs for long trips, other things being equal. This occurs because the second method is based on incident delay only, while the first considers both incident delay and the standard deviation of trip time. The result is that expected incident delay increases in direct proportion to trip distance and the standard deviation increases in proportion to the square root of trip distance.

Assessment. Estimating travel time savings due to a reduction in incidents is an advanced method that requires significant resources. The method estimates the mean and variance of delay caused by freeway incidents as a function of a V/C ratio. The analysis can provide an expanded understanding of the role of transportation projects in reducing travel time and travel time variability. A better understanding of travel time variability, its magnitude, and influencing factors, can be an important element in making an area conducive to business location.

In the Cohen and Southworth method, estimates of the benefits of more reliable travel times are derived using stated preference surveys. This feature helps quantify the economic value of increasing travel time reliability; how well it replicates the value businesses place on certainty of arrival time is less clear. Data on the magnitude, frequency, and consequences of freeway incidents would take time to assemble for a given metropolitan area, but available data from other areas can enable one to develop reasonable estimates.

Although inherently complex, analyses of travel time variability are likely to become increasingly important as just-in-time economic activity grows.

RESOURCES

To derive estimates of the value of travel time using methods such as HERS, it is necessary to obtain the basic wage rate, vehicle occupancies, vehicle operating costs, and other related data. The following list describes some of the necessary data and how to obtain it.

1) The wage rate can be obtained from the *Employment Cost Trends Home Page* of the Bureau of Labor Statistics (BLS) at http://www.bls.gov/ecthome.htm. The wage rate is available in the *New Releases* section under *Employer Costs for Employee Compensation*. Hourly compensation, including wages and salaries, and total benefits, is available in *Table 1: Civilian workers, by major occupational group*. March 1999 data can be accessed at http://www.bls.gov/news.release/ecec.t01.htm.

2) The average hourly wage for truck drivers can also be obtained from the BLS at the *Occupational Employment Statistics Home Page* located in the *Surveys and Programs* section. The wage estimates are available in the *Data* section under *View Occupational Employment and Wage Estimates*. Select the data for the year of interest and level of government. For the chosen year and level of data, select *Production, Construction, Operating, Maintenance, and Material Handling Occupations*, and then choose *Transportation and Material-Moving Machine and Vehicle Operators*. National estimates for 1998 can be obtained at http://www.bls.gov/oes/national/oes_prod.htm. Fringe benefits for truck drivers are then derived using the national average for fringe benefits as a percent of wages. The result is added to the wage rate to produce total hourly compensation.

3) The average vehicle occupancy for on-the-clock and off-the-clock trips in automobiles and light trucks can be obtained from the U.S. Department of Transportation, Nationwide Personal Transportation Survey (NPTS) located at http://www.fhwa.dot.gov/ohim/nptspage.htm. The entire NPTS databook can be downloaded using Adobe Acrobat at http://www-cta.ornl.gov/npts/1990/doc/pubs.html. Alternatively, Table 7.16: Average Vehicle Occupancy by Trip Purpose 1990 NPTS can be downloaded from *Frequently Asked-for Tables* at http://www-cta.ornl.gov/npts/1990/fat/index.html.

4) Initial vehicle costs for automobiles in commercial motor pools and for 4-tire trucks can be obtained from the American Automobile Manufacturers Association, *Motor Vehicle Facts and Figures*. For heavier trucks, the average vehicle cost per year can be obtained from the *Federal Highway Cost Allocation Study* at http://www.fhwa.dot.gov/policy/12-hmpg.html.

5) The average value of commodities shipped by axle combination can be obtained from U.S. Bureau of the Census, 1992 Census of Transportation, *1993 Commodity Flow Survey* at http://www.census.gov/econ/www/se0700.html.

6) The percent of automobiles that are in commercial fleets of four or more can be obtained from the Motor Vehicle Manufacturers Association, *Motor Vehicle Facts and Figures, 1991*.

7) The percent of vehicle miles that were on-the-clock for 4-tire trucks can be obtained from U.S. Bureau of the Census, Census of Transportation, *Vehicle Inventory and Use Survey* at http://www.census.gov/econ/www/viusmain.html.

8) Finally, indices to adjust 1995 dollars to dollars of any other year can be obtained from the BLS. For trucks, refer to the BLS data on the mean hourly earnings of truck drivers by truck type.

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SECTION 3: SAFETY

OVERVIEW

Steps in the analysis	Methods
• Select a method to evaluate safety benefits and costs • Collect the necessary data • Estimate the safety benefits • Evaluate the chosen alternative in terms of satisfying user benefits	• Analysis of national data • Comparison approach • Regression analysis • Bicycle safety index

Definition

Safety improvements are an important form of user benefit that derive from changes to transportation systems. These benefits take the form of reductions in the rate of fatal, injury, and property-damage-only (PDO) crashes. Crashes occur for a combination of reasons, including over-crowded and over-burdened roadways. As congestion increases, the driving environment becomes more stressful, and it also allows less room for error. Various transportation projects have the potential to reduce the number of crashes by creating less stressful driving environments, or by improving conditions for cyclists or pedestrians. Often, upgrading a road to a higher functional class will produce these results.

Predicting the safety effects of a transportation project involves developing a methodology to predict the benefit of the project, based on a set of pre-existing conditions and anticipated conditions. This requires the use of geometric and crash data, and involves estimating the number of crashes per unit of time, based on crash rates and the forecast annual vehicle miles traveled (VMT) for a particular roadway.

Depending on a roadway's functional class, as well as on whether it traverses an urban or rural area, certain types of crashes are more likely to occur. For example, higher rates of injury crashes occur in urban areas than in rural areas on the basis of VMT.

Transportation factors affecting safety

Transportation projects can directly affect safety in the following ways:

- Projects that expand road system capacity and reduce congestion will likely reduce incidents that might lead to a crash, such as a stalled vehicle blocking the roadway.

- Changes in signalization, turning lanes, and passing restrictions can reduce the number of potential opportunities for conflict between vehicles.

- Improvements to the condition of a roadway, such as resurfacing to remove potholes, create a safer driving environment and thereby reduce the number of crashes.

Special Issues

Factors contributing to crashes. Various factors can contribute to crashes, including human factors, meteorological conditions, environmental factors, and the mechanical failure of vehicles. Additionally, the location and functional class of the roadway can contribute to driver error, making certain types of crashes more likely to occur. The type of roadway is a major factor in determining the kind of crashes that take place and the crash rate. In part, this variation in crash rate is due to the varying speed limits of the different functional classes, as well as to the increased capacity of higher functional classes. For example, more crashes per 100 million VMT occur on principal arterials in urban areas than on freeways and expressways. The likelihood of conflicts between vehicles and pedestrians or cyclists is a key factor in crashes involving them.

Data limitations. As with other methods used to estimate user costs, methods to estimate safety effects suffer from limitations related to the availability and accuracy of data. Certain data are not included in the available databases, and there is a lack of uniformity in the types of data obtained at various crash locations. Factors other than road characteristics—such as meteorological conditions, mechanical failure of vehicles, or human factors—often are not taken into account directly in methods that estimate safety based on crash rates by functional class of roadway.

Definition of impact area. The methods for measuring safety benefits look specifically at the road or road segment to be improved. Often, however, there is a related impact on other segments of the transportation network in that traffic may divert from less safe roadways to the improved segment, thereby reducing the number of crashes on unimproved roadways.

Equity concerns. Evaluations of the safety effects of a transportation project generally are carried out at an aggregate level. In reality, it may well be that some population groups derive substantially greater safety benefits than others. For example, a freeway constructed through an inner-city neighborhood may improve the safety of those traveling through the neighborhood, but do little for those beginning or ending their trips there. Origin-destination studies can help one deduce the extent to which specific groups would benefit from the project.

WHEN TO DO THE ANALYSIS

Estimating changes in safety—in the form of a reduction or increase in the number of crashes—is recommended for any major street or highway project, including new road construction, reconstruction, capacity expansion, road maintenance, rehabilitation, and resurfacing, as well as safety and traffic flow improvements.

It is particularly important to estimate changes in safety whenever a road is being upgraded to a higher functional class with a greater capacity and higher speeds. Because such an upgrade may reduce congestion, a reduction in the number of fatal and injury crashes may occur, despite the increased capacity and higher speeds of the upgraded roadway. Increasing the flow speed of a highway, however, may contribute to an increase in crash rates.

Safety effects also should be estimated when one is attempting to reduce a specific type of safety problem, such as conflicts between vehicles and bicycles. The analysis may point to the types of improvements that are best able to reduce the particular safety problem.

STEPS IN THE ANALYSIS

Step 1. Select a method to evaluate safety benefits and costs.

Depending on the available resources, certain methods will be more appropriate to use for estimating safety benefits. The most comprehensive methods are very data intensive and time-consuming. Methods that rely on national aggregate data are more easily performed, but they may be less precise estimators of safety impacts.

Step 2. Collect the necessary data.

The available methods vary considerably in terms of the data needed. The simplest method only requires one to use values contained in Table 3.1. More complex methods may require detailed data on roadway geometry, traffic volume, and crash history.

Step 3. Estimate the safety benefits.

Each of the methods for estimating the safety benefits of a transportation project involves four steps:

1) Predict the change in crashes per 100 million VMT on the affected roadway. Generally it is preferable to predict the three categories of crashes (i.e., fatal, injury, and PDO) separately.

2) Estimate the AADT on the roadway currently and if the project were completed. Multiply the AADT by the roadway length to estimate daily VMT. Multiply this figure by 365 to yield annual VMT on the roadway.

3) Divide the total annual VMT by the crash rate to yield the predicted number of crashes per year, both with and without the project.

4) Apply an economic value to the change in number of crashes per unit of time (normally a year). The result is an estimate of the annual economic value of the project.

Step 4. Evaluate the chosen alternative in terms of satisfying user benefits.

Safety benefits and costs must be assessed in the context of other user benefits that are likely to occur, as well as other economic, social, and livability benefits. It is possible that a transportation project would diminish the safety of a particular road segment by slightly increasing the number of certain types of crashes. This may be perceived, however, as a minimal effect when considered within the context of other benefits.

METHODS

Method 1. Analysis of national data

A very basic method for estimating the safety impacts of transportation system changes involves using national data on crashes to determine the effect of a transportation improvement.

Information collection. To compare an existing road with a proposed upgrade using national data on crashes, it is necessary to obtain data on crash rates by roadway functional class. These data are available in *Highway Statistics* from the FHWA at http://www.fhwa.dot.gov/////ohim/hs98/roads.htm. Table 3.1 contains crash rates by functional class of road for 1997.

Analysis. The analysis of project impacts involves estimating the number of crashes that are likely to occur if the roadway is converted to a different functional class and then assigning a monetary value to the importance of preventing a single additional fatal crash or serious injury.

Estimating crashes. The crash data in Table 3.1 are presented in rates of crashes per 100 million VMT. The use of these rates allows one to estimate safety impacts of improving the current roadway by multiplying the current annual VMT by the forecast VMT on the upgraded road. For example, if a 10-mile urban principal arterial has 26.1 million VMT per year and is to be upgraded to an urban Interstate with a forecast 34.3 million VMT per year, the change in fatal crashes would be 34.3 million VMT/100 million times 0.56 minus 26.1 million VMT/100 million times 1.30. The difference between the value of the upgraded road and the existing road represents the safety benefits/costs. In this example, there would be 0.14 fewer fatal crashes per year, even taking into account the increase in traffic volume.

Assigning a monetary value. After estimating the increase or reduction in the number of crashes, it is necessary to assign a monetary value to the change in crashes. The monetary value represents the economic value of preventing a single additional fatal crash or serious injury.

Many indicators exist for assigning a value to preventing further crashes. Miller et al. (1991) present one set of estimates by crash severity in per-person and per-crash dollars. Original values are in 1988 dollars; in Table 3.2 these values have been inflated to 2000 dollars using the gross domestic product (GDP) deflator. They can then be multiplied by the previously obtained increase/decrease in the number of crashes to obtain the annual dollar value of preventing future crashes. For our example, the reduction of 0.14 fatal crashes per year would equate to an annual savings of 0.14 ($3.6 million) = $504,000.

Measurement and presentation. The foregoing annual dollar values can be discounted and summed over the life of the improvement. If VMT are forecast to increase, the calculation of annual dollar values should be repeated to reflect this increase.

Table 3.1. Motor vehicle traffic fatalities and injuries by functional class, 1997

(Crashes per 100 million VMT)

Highway category	Injury crashes		Persons injured		Most serious injuries	Pedestrians injured	
	Fatal	Nonfatal	Fatal	Nonfatal		Fatal	Nonfatal
Rural Interstate	1.05	25.08	1.26	41.11	6.38	0.09	0.60
Other principal arterial	1.96	50.87	2.35	87.85	12.69	0.14	1.04
Minor arterial	2.33	70.52	2.73	118.25	16.00	0.18	1.24
Major collector	2.51	86.79	2.85	135.33	18.94	0.15	1.59
Minor collector	3.16	106.02	3.52	159.57	18.83	0.16	2.04
Local	3.52	147.49	3.89	222.82	20.14	0.32	4.31
VMT-weighted average—rural	2.15	69.10	2.49	110.35	14.15	0.16	1.51
Urban Interstate	0.56	46.56	0.63	72.48	5.24	0.10	1.18
Other freeways & expressways	0.75	68.60	0.82	107.20	7.49	0.14	2.68
Other principal arterial	1.30	124.69	1.40	199.06	14.57	0.35	5.42
Minor arterial	1.08	126.89	1.17	197.95	16.26	0.25	6.72
Collector	1.00	104.95	1.07	159.18	14.31	0.18	7.42
Local	1.33	194.40	1.42	295.74	15.86	0.36	16.78
VMT-weighted average—urban	1.01	109.50	1.09	170.48	12.17	0.24	6.19

SOURCE: FHWA 1998, Table FI-1.

Table 3.2. Estimates of crash costs by police-reported severity

Severity	Per person (1988$)	Per crash (1988$)	Per person (2000$)	Per crash (2000$)
Fatal	2,393,742	2,722,548	3,165,484	3,600,297
Incapacitating injury	169,506	228,568	224,154	302,258
Evident injury	33,227	48,333	43,939	63,915
Possible injury	17,029	25,228	22,519	33,361
Property damage	1,734	4,489	2,293	5,936
Crash unreported to police	1,601	4,144	2,117	5,480

SOURCE: Miller et al. 1991, p. 39, updated by the guidebook authors.

Assessment. This method relies on the use of aggregated data that represent an average for the nation. Consequently, it assumes that any roadway conversion to a different functional class will follow the same path as the national average. It should be stressed that a VMT rate that is higher or lower than average (i.e., different from the national traffic density) may substantially affect crash rates. One should regard the results of this analysis as a general approximation.

The data presented here do not include rates for estimating increases or decreases in PDO crashes because they were not available in the annual FHWA publication, *Highway Statistics, 1997*. If the user chooses to include estimates for PDO crashes, these estimates should be in the form of a rate of per 100 million VMT rather than in raw numbers.

Despite the concerns associated with using aggregate national data, this computation of safety benefits from roadway conversions is an easily implemented method that does not require significant technical skills. It presents clear, easily understandable results in the form of the difference in the costs associated with specific types of crashes for each roadway functional class.

Method 2. Comparison approach

A fairly basic comparison approach can partially overcome the limitations associated with using national data. This method entails comparing crash rates on a roadway where potential changes are being considered—and other roadways comparable to it—with existing roads in the region that are representative of the improved road.

Information collection. The first step of the comparison approach involves collecting information on the road where the improvement is being considered. This includes data on traffic volume, capacity, and road geometry. Crash data are then obtained on roads that share similar characteristics and surrounding land uses. The idea is to obtain a large enough pool of comparable roads to enable a meaningful sample of crash data to be assembled. Finally, a series of roads with characteristics comparable to those the road will have when improved are identified. Crash data for these roads are assembled to facilitate comparison.

Analysis. The first step of the analysis involves setting up a base case for the road that is the focus of the proposed improvements. The base case includes information on the number and types of crashes currently seen on the road, as well as its physical and geographical characteristics. The base case is then compared with the example roads to determine whether the alternative improvements are likely to produce safety benefits. This comparison involves considering whether the rate of crashes will increase or decrease and what types of crashes can be expected to occur.

Measurement and presentation. The analysis presents estimates of expected crashes from a road improvement by comparing the roadway with improved roads that have similar characteristics. The resulting estimates can be expressed as reductions in crashes per 100 million VMT, or as reductions in crashes on a given roadway per year.

Assessment. The comparison approach requires data on other regional roads for comparison purposes. If such data are available, the method provides a simple means of evaluating safety impacts. It overcomes the limitations associated with using aggregate national data by concentrating on regional data. One should strive to acquire data on a sufficient number of road segments of both functional classifications to enable reliable crash rates to be estimated. Crashes are a rare event on virtually any type of road, so stable rates require data on numerous segments. Multi-year data files greatly improve the accuracy of crash rates because many more cases are included.

Method 3. Regression analysis

Regression analyses are a more advanced technique for estimating changes in crash rates if a transportation project were undertaken. Data on road segment characteristics (e.g., grade, curvature, lane width, pavement quality, shoulder composition and width, and traffic volume) are merged with data on crashes occurring on each segment. Using crash rates as the dependent variable, it is possible to predict these rates on the basis of road segment characteristics. The strength of the approach is that one can change the various characteristics and see how these changes influence crash rates.

In this guidebook, we present an equation derived using the approach just described, as well as the procedure for estimating such an equation in one's own state. The equation we present was estimated using data on the 17,767 two-lane and four-lane (non-Interstate) rural primary road segments (average length of about 0.4 mile) in Iowa. Data on a total of 21,224 crashes over a 3-year period were included. The relationship between roadway attributes and crash rates is probably quite similar in other states, so the existing equations can provide a preliminary estimate of safety effects.

Information collection. To use the regression equation presented in this guidebook, data on the current characteristics of each road segment to be improved are needed. The analysis also requires information on the changes in characteristics that would result from the project in question. The data should be segment-specific. Fortunately, most state DOTs maintain data files on the primary roads within their states. Likewise, most DOTs maintain crash data files that link crashes to specific road segments.

Analysis. The crash-rate predictive model was estimated as a semilog regression equation. It was necessary to transform the dependent variable to a natural logarithm because almost one-third of the road segments had no crashes over the 3-year period analyzed, and a standard linear regression model would have been inappropriate. Full documentation of the analysis methods is contained in Forkenbrock and Foster (1997).

Table 3.3 contains the dependent and independent variables included in the regression model. The 7 independent variables pertain to physical characteristics of the 17,767 road segments. Each of these characteristics can be changed by a project to upgrade a road.

Table 3.3. Variables used in regression model of crash costs

Dependent variable

- Natural log of number of crashes (fatal, injury, and PDO) per million VMT.

- **Independent variables**
- PSR: present serviceability rating, ranging from 0 (poor) to 5 (excellent), is a measure of the general surface quality of a road segment.
- TOPCURV: the number of degrees of arc subtended by a 100-foot length for the sharpest curve on the segment (see AASHTO 1990, p. 151). Scaling of the variable is as follows: 0 = no curve, 1 = 0.1–1.4 degrees,
  2 = 1.5–2.4 degrees, 3 = 2.5–3.4 degrees, 4 = 3.5–4.4 degrees, 5 = 4.5–5.4 degrees, 6 = 5.5–6.9 degrees, 7 = 7.0–8.4 degrees, 8 = 8.5–10.9 degrees, 9 = 11.0–13.9 degrees, 10 = 14.0–19.4 degrees, 11 = 19.5–27.9 degrees, and 12 = 28.0 degrees or more.
- PASSRES: a dummy variable coded 1 if a passing restriction exists anywhere on the road segment and 0 if no passing restriction exists.
- ADTLANE: average daily traffic in thousands per lane.
- RIGHTSH: width of the right shoulder in feet.
- LANES: a dummy variable coded 1 if the road segment has 4 traffic lanes and coded 0 if it has 2 lanes.
- TOPGRAD: the change in elevation, as a percentage of the horizontal distance traversed for the greatest slope in the segment. Scaling of the variable is as follows: 0 = no grade, 1 = 1.0–1.9 percent, 2 = 2.0–2.9 percent,
  3 = 3.0–3.9 percent, 4 = 4.0–4.9 percent, 5 = 5.0–5.9 percent, 6 = 6.0–6.9 percent, 7 = 7.0–7.9 percent, 8 = 8.0–8.9 percent, 9 = 9.0–9.9 percent, 10 = 10.0–11.9 percent, 11 = 12.0–14.9 percent, and 12 = 15.0 percent or more.

SOURCE: Forkenbrock and Foster 1997, Table 1.

After fitting a semilog regression equation (dependent variables transformed to a natural log) to the data just described, we took antilogs of the result. The latter step restored the dependent variable to its original form, thus allowing crash rates to be predicted. The crash-rate equation is as follows:

$$\frac{\text{crashes}}{\text{million VMT}} = 0.517\left(0.972^{\text{PSR}}\right)\left(1.068^{\text{TOPCURV}}\right)\left(1.179^{\text{PASSRES}}\right)\left(1.214^{\text{ADTLANE}}\right)$$
$$\left(0.974^{\text{RIGHTSH}}\right)\left(0.933^{\text{LANES}}\right)\left(1.051^{\text{TOPGRAD}}\right)$$

All coefficients are statistically significant at the 0.001 level except PSR and LANES, which are significant at the 0.100 level. The r^2 is 0.66.

Example. The crash rate model enables one to compare the expected crash rate per million VMT of the current standard roadway with the expected crash rate if the roadway were upgraded. To illustrate the practical use of the model, we apply a case in which a 2-lane highway is a candidate for upgrading to 4 lanes. Table 3.4 presents the attributes of the base case and improved roadway.

Table 3.4. Application of the cost model to a typical upgrade

Variable	Base 2-lane	Improved 4-lane
PSR	3.0	4.0
TOPCURV	5	3
PASSRES	1	0
ADTLANE	2.5	1.25
RIGHTSH	7.0	10.0
LANES	0	1
TOPGRAD	4	2
Crash rate (per million VMT)	1.28	0.56

SOURCE: Forkenbrock and Foster 1997, Table 4.

Plugging the values of each case into the equation allows expected crash rates to be derived:

$$1.28 = 0.517\left(0.972^{3.0}\right)\left(1.068^{5.0}\right)\left(1.179^{1.0}\right)\left(1.214^{2.5}\right)\left(0.974^{7.0}\right)\left(0.933^{0.0}\right)\left(1.051^{4.0}\right)$$

In this case the crash rate would fall from 1.28 to 0.56 crashes per million VMT. Multiplying these values by the annual VMT of the roadway enables one to predict the change in crashes per year.

Suppose that a 30-mile stretch of the 2-lane highway with the characteristics of the base case in Table 3.4 is being upgraded to a 4-lane highway as in the improved case in the table. The highway has an AADT of 8,000; after the upgrade, it is forecast to have an AADT of 10,000.

Using the same crash data upon which the regression model is based, Table 3.5 shows the breakdown of crashes by type. We can use the crash cost data from Table 3.2 to construct a weighted estimate of the annual crash costs of the base and improved cases. The cost difference reflects the annual crash cost savings that the improvement would bring about.

Table 3.5. Types of crashes by number of lanes*
(Values in parentheses are row percentages)

	Crash type			
Number of lanes	Fatal	Personal injury	PDO	Total
2	369	5,491	13,552	19,412
	(1.9)	(28.3)	(69.8)	(100.0)
4	18	476	1,318	1,812
	(1.0)	(26.3)	(72.7)	(100.0)

*The figures in this table are 3-year totals for 1989, 1990, and 1991 on 2- and 4-lane rural primary non-Interstate segments. Two-lane roads account for 96.0 percent of the system mileage and 89.2 percent of the VMT on the road segments represented in this table.

For the 2-lane base case, the weighted crash cost is

0.019 ($3,600,297) + 0.283 ($63,915) + 0.698 ($5,936) = $90,637

For the 4-lane improved case, the weighted crash cost is

0.010 ($3,600,297) + 0.263 ($63,915) + 0.727 ($5,936) = $58,406

With an AADT of 8,000, the annual VMT on the base case highway is 8,000 vehicles/day x 365 days/year x 30 miles = 87.6 million vehicle-miles/year. With a crash incidence of 1.28 per million VMT, there are 112.1 crashes per year. With a weighted average crash cost of $90,637, the annual crash cost for the base case is $10.16 million.

The improved case would have an annual VMT of 109.5 million. A crash incidence of 0.56 for the improved case yields 61.3 crashes per year. Applying the weighted average crash cost for the 4-lane improved case of $58,406, the annual crash cost is $3.58 million. The annual savings in crash costs resulting from the improvement would be $6.58 million.

Measurement and presentation. The approach just discussed can be applied at two levels. One can use actual road system and crash data for a particular state to estimate a regression equation, or one can use the Iowa equation as an approximation. Because the equation provided above was estimated using many observations, it is quite stable. We should emphasize that it is suitable for rural primary roads, not for Interstate highways or urban streets. Although a four-lane urban street may share certain specifications (e.g., lane width) with its rural counterpart, the nature of traffic flows and the general operating environments are sufficiently different that it would be inappropriate to use the equation to predict crashes in an urban setting. Note that the predictive regression equation does not address intersections, per se; intersections were treated as part of the nearest road segment in the data file on rural primary roads.

Assessment. The primary advantage of this method is that one can estimate the effect of changing one or more road attributes while holding all other attributes constant. Few other methods to estimate safety effects have this capability. Because urban streets vary considerably in such important characteristics as curbs cuts (i.e., driveways, alleys, and parking facilities), a model of this sort may not be a useful tool within urban areas.

Method 4. Bicycle safety index

There are few methods available to estimate the likely effects on the safety of non-motorized transportation of roadway projects. The bicycle safety index (BSI) is perhaps the best approach for estimating how bicycle safety might be affected by changes to a series of road attributes. The original BSI was developed by Davis (1987) and modified by Epperson (1994). We present the modified version.

Information collection. As the list of included variables below indicates, to apply the BSI, one must assemble data on the physical attributes and general condition of the roadway in question and estimate the same measures for the roadway following the proposed improvements. Data also are needed on AADT and flow speeds. None of these data are difficult to acquire.

Analysis. The BSI is estimated using the following function:

$$BSI = [AADT/(L \times 3100)] + (S/48) + \{(S/48) \times [(4.25 - W) \times 1.635]\} + PF + LF$$

where:

BSI	=	Bicycle safety index for a specific road segment
AADT	=	Average annual daily traffic
L	=	Number of traffic lanes
S	=	Speed limit (kilometers per hour)
W	=	Width of the outside lane (meters)
PF	=	Pavement factors (derived from Table 3.6)
LF	=	Location factors (derived from Table 3.7)

Pavement factors include such elements as pavement surfaces and conditions that may constitute a hazard to cyclists. Epperson has assigned a value to each of these factors, as shown in Table 3.6. The table indicates that cracks in the pavement, rough railroad crossings, and the presence of drainage grates are the most serious pavement-related hazards to cyclists.

Table 3.6. Pavement factor values

Factor	Value
Cracking	0.50
Patching	0.25
Weathering	0.25
Potholes	0.25
Rough road edge	0.25
Railroad crossing	0.25
Rough railroad crossing	0.50
Drainage grates	0.50

SOURCE: Epperson 1994, Table 2.

Location factors pertain to conditions that affect the generation of cross traffic, limit sight distance, or restrict the safe operation of bicycles (see Table 3.7). A lower total score indicates that the road segment is comparatively safe for bicycle travel. Negative location factors imply that a feature would improve bicycle safety. For example, a raised median restricts left-turning cross traffic. The most serious location factor is angled parking, and the best safety feature is a paved shoulder.

Table 3.7. Location factor values

Factor	Value
Angled parking	0.75
Parallel parking	0.25
Right-turn lane (full length)	0.25
Raised median (solid)	–0.50
Raised median (left turn bays)	–0.35
Center turn lane (scramble lane)	–0.20
Paved shoulder	–0.75
Grades, severe	0.50
Grades, moderate	0.20
Curves, frequent	0.35
Restricted sight distance	0.50
Numerous drives	0.25
Industrial land use	0.25
Commercial land use	0.25

SOURCE: Epperson 1994, Table 2.

The appropriate factor values are plugged into the BSI function, and an index value is obtained. Table 3.8 provides a basis for interpreting the resulting index value.

Table 3.8. Interpretation of BSI values

Index Range	Classification	Description
0 to 3	Excellent	Denotes a roadway extremely favorable for safe bicycle operation.
3 to 4	Good	Refers to roadway conditions still conducive to safe bicycle operation, but not quite as unrestricted as in the excellent case.
4 to 5	Fair	Pertains to roadway conditions of marginal desirability for safe bicycle operation.
5 or above	Poor	Indicates roadway conditions of questionable desirability for bicycle operation.

SOURCE: Epperson 1994, Tables 1 and 2.

Example. A roadway is upgraded in the following ways: (1) pavement is resurfaced to eliminate cracking (reduction of .50) and potholes (reduction of .25); (2) a solid raised median is added (reduction of .50), and angle parking is converted to parallel parking (.75 down to .25); and (3) the speed limit is reduced from 50 km/hr to 40 km/hr, and the outside lane is increased from 3 to 4 meters. Other parameters remain unchanged (AADT = 5,000 and L = 4). Let us assume that the sum of pavement factor values before the project is 1.00, and the sum of location factor values is 1.75. The improvement would reduce the sum of pavement factor values by 0.75 (i.e., .50 + .25), and the sum of location factor values would be reduced by 1.0 (i.e., .50 + .50).

Original case:

$$BSI = [5000/(4 \times 3100)] + (50/48) + \{(50/48) \times [(4.25 - 3) \times 1.635]\} + 1.00 + 1.75$$

BSI = 6.3, well into the "poor" category.

Improved case:

$$BSI = [5000/(4 \times 3100)] + (40/48) + \{(40/48) \times [(4.25 - 4) \times 1.635]\} + 0.25 + 0.75$$

BSI = 3.9, in the "good" category.

Measurement and presentation. The BSI enables a composite index to be estimated with and without a transportation project that would entail several improvements to a roadway. It is possible to estimate the effects of individual improvements that might be included in the project in order to see whether these improvements would materially improve bicycle safety.

Assessment. The BSI is a relatively simple indicator that helps one gain a sense of how specific changes to a roadway may affect the safety of cyclists. Epperson (1994, p. 12) cautions, however, that his index explained only 18 percent of the variation in severe bicycle crashes on various roadways in his test area. He attributes this limited predictive ability to differences in bicycle use patterns and the diverse nature of cyclists. Regarding the latter point, Epperson suggests that the BSI is likely to more accurately predict crash rates of experienced cyclists than those of young children riding bicycles.

RESOURCES

Interactive Highway Safety Design Model. The Interactive Highway Safety Design Model (IHSDM) is being developed by the FHWA in cooperation with various state DOTs and private sector civil design software vendors. When completed, it will include a variety of evaluation tools for assessing the safety impacts of geometric design decisions. This will aid planners in maximizing the safety benefits of highway projects, while considering costs and environmental constraints. The complete model will contain several analysis modules, including a crash prediction module, a design consistency module, a driver/vehicle module, an intersection diagnostic review module, a policy review module, and a traffic analysis module.

The initial model will focus on two-lane rural highways, but subsequent phases will include the capability to evaluate multilane design alternatives. Release of the full model is scheduled for 2002.

One of the primary elements within the IHSDM is the Crash Prediction Module. This module has the capability of estimating crash potential for design alternatives for all roadway segments and intersections. Estimates include the number of crashes and the percentage of fatal and severe crashes. The estimates are based on horizontal and vertical curvature measures, lane and shoulder widths, exposure (i.e., roadway length and average daily travel), driveway density, the percentage of commercial vehicles, and the roadside hazard rating.

The module will enable the user to compare the number of crashes for a specified time period for different design alternatives or to perform a sensitivity analysis on a single alternative, assessing the lane or shoulder width, average daily traffic, and other variables on the frequency of crashes.

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SECTION 4: CHANGES IN VEHICLE OPERATING COSTS

OVERVIEW

Steps in the analysis	Methods
• Select a method to evaluate vehicle operating cost savings • Collect the necessary data • Estimate the savings in vehicle operating costs	• Estimating vehicle operating costs as a function of speed • Estimating vehicle operating costs as a function of grade • Highway Economic Requirements System (HERS)

Definition

One of the user benefits associated with transportation system changes is a reduction in the costs to drivers of operating their vehicles. Vehicle operating cost (VOC) savings derive from improved roadway conditions that impose less stress on vehicles.
VOC savings are rarely a major contributor to user benefits; rather, VOC analyses should be conducted as one element of an assessment of the overall benefits of a particular project.

Three broad classes of variables affect VOC:

- **Road attributes**—pertain to the geometric and surface characteristics of the road, including vertical and horizontal alignments, road width, and surface profile irregularity or "roughness."

- **Vehicle attributes**—related to the physical and operating characteristics of vehicles, including weight, payload, engine power, suspension design, and the number of hours operated per year.

- **Regional factors**—the economic, social, technological, and institutional characteristics of the region, such as the speed limit, fuel prices, relative prices of new vehicles, parts and labor, stage of technological development, and driver training and driving attitudes.

Transportation factors affecting VOC savings

Transportation projects can directly affect the cost of operating a vehicle in the following ways:

- Projects that make improvements to road surfaces, including rehabilitation and resurfacing efforts, reduce VOC due to the smoother road traveling conditions.

- The construction of new roads reduces VOC by offering drivers the choice of a facility with better operating conditions.

- Projects that improve traffic flow conditions reduce VOC by allowing vehicles to operate in more free-flow conditions and to avoid the stop-and-go traffic that puts strain on a vehicle.

Special issues

Estimation of VOC. VOC are based on a combination of variables, including fuel consumption, tire wear, maintenance and repair, oil consumption, capital depreciation, license and insurance costs, and operator labor and wages. Road geometry, road surface type and condition grade, environmental factors, and vehicle speed also affect VOC. It is these later attributes that can be changed through road projects.

Uncertainties. Uncertainty exists in the calculation of VOC because models rely on numerous assumptions regarding the variability of key VOC parameters estimated from present vehicle fleet characteristics and price trends. According to Bein (1993, p. 43), uncertainty in estimating VOC stems from:

- Advancements in motor vehicle technology;
- The general condition of roadways;
- Public policies regarding vehicle flow speeds and whether congestion will worsen; and
- Vehicle depreciation trends.

VOC models are also limited by the reliability of available data sets. These data sets contain variable costs that may not include all influences or may suffer from inaccuracies in how they were measured. Additionally, VOC models do not necessarily cover all aspects of road conditions, features of vehicles, and driver characteristics that may affect costs. Finally, data on vehicle types, utilization, and road conditions, which are the most crucial variables in the analysis, are too expensive and time-consuming to be collected in any form other than the aggregate.

WHEN TO DO THE ANALYSIS

VOC may change when a major highway project is carried out, including new construction, reconstruction, rehabilitation, and resurfacing, safety improvements, and traffic flow improvements. As a practical matter, surface condition is less of a factor in VOC than it once was because most road segments now are paved and pavement quality is less of a determining factor of vehicle costs than are vehicle flow speed and grade of the road. In this guidebook we focus on the latter two factors.

STEPS IN THE ANALYSIS

Step 1. Select a method to evaluate VOC savings.

Depending on the available resources of the agency, certain methods are more appropriate to use when estimating VOC savings. Each method is based on some combination of the costs associated with the operation, maintenance, and repair of vehicles, as well as with factors associated with the condition of the road. The more basic methods focus on effects of road improvements in an aggregate sense, rather than on reductions in VOC for users of a particular road having specific attributes.

Step 2. Collect the necessary data.

Methods vary in terms of data to be input, including information on fuel, oil, tires, maintenance parts and labor, vehicle depreciation, road geometry, pavement surface condition, and traffic control. Most data are available from national sources in the form of averages for the nation.

Step 3. Estimate the savings in VOC.

Using the chosen method, estimate the savings in VOC due to particular transportation project alternatives.

METHODS

Method 1. Estimating vehicle operating costs as a function of speed

Hepburn (1994) developed a model for estimating VOC in urban areas as a function of flow speed. We present Hepburn's model results as a simple look-up table that allows one to evaluate the effects on VOC of a change in average vehicle speed on a particular roadway.

Information collection. The necessary data for the model include yearly estimates for cost items for passenger automobiles (e.g., the price of tires, maintenance, and fuel consumption), the retail price of fuel and fuel tax rates, and other vehicle-related parameters. We present Hepburn's estimates as an approximation that can be used in lieu of collecting one's own primary data.

Analysis. The model separates VOC into tire costs, vehicle depreciation, maintenance costs, and fuel costs. It assumes that tire prices reflect differences in the life of the tires, therefore making estimates of cost similar despite differences in the retail price of new tires. With regard to depreciation, the method makes the simplifying assumption that use is the only cause of a vehicle's depreciation and that the rate of depreciation is constant over the life of the vehicle.

The model assumes that road roughness is constant and that the average gradient of the road is zero. Additionally, all costs are assumed to vary with distance, but only fuel cost varies with speed. Finally, the model estimates VOC as both a financial cost and as a resource cost. Financial cost is the actual amount paid by drivers, including any taxes, whereas resource costs are the financial cost less any taxes.

The model reduces VOC to a simple function of average travel speeds. For average travel speeds less than 50 mph, VOC are calculated as follows:

$$VOC\,(in\ cents/mile) = C + D\,/\,v_s$$

For average travel speeds 50 mph and over, the model can be approximated as follows:

$$VOC\,(in\ cents/mile) = a_0 + a_1 v_s + a_2 v_s^2$$

where:

v_s = Vehicle speed in miles per hour

a_0, a_1, a_2 = Constants that were estimated using ordinary least squares regression

Table 4.1 provides values for *C, D*, a_0, a_1, and a_2. These coefficient values were derived by Hepburn (1994) through an extensive modeling process. We have updated Hepburn's values to year 2000 units.

Table 4.1. Parameters for VOC functions (Year 2000 units)

Vehicle type	*C*	*D*	a_0	a_1	a_2
Small automobile	22.0	40.3	24.1	-0.031	0.00019
Medium automobile	25.3	84.5	29.7	-0.051	0.00026
Large automobile	26.4	144.8	33.8	-0.082	0.00029

SOURCE: Hepburn 1994, Table II, updated by the guidebook authors.

Example 1. Suppose that prior to a transportation project, the average traffic flow speed on a roadway is 22 mph. If the project is carried out, the forecast flow speed would be 29 mph.

Base case (small automobile)

$VOC = C + D/\,v_s =$

22.0 + (40.3 ÷ 22) =

23.8 cents per vehicle mile

Improved case (small automobile)

$VOC = C + D/\,v_s =$

22.0 + (40.3 ÷ 29) =

23.4 cents per vehicle mile

Example 2. A proposed transportation project would increase the average traffic flow speed from 50 mph to 58 mph.

Base case (large automobile)

$VOC = a_0 + a_1\, v_s + a_2\, v_s^2 =$

$33.8 + [-\,0.082\ (50)] + 0.00029\ (50)^2 =$

30.4 cents per vehicle mile

Improved case (large automobile)

$VOC = a_0 + a_1\, v_s + a_2\, v_s^2$

$33.8 + [-\,0.082\ (58)] + 0.00029\ (58)^2 =$

30.0 cents per vehicle

Measurement and presentation. This simple model is based on a statistical analysis of a series of factors that influence VOC. These factors are not discussed in any detail here; only the various coefficients for three general sizes of automobile are provided. Thus, to estimate the change in VOC given a specific change in traffic flow speed, one must merely plug into the equation the flow speed before and after the road improvement. Subtracting the resultant cost after the improvement from the cost before provides a very basic estimate of the change in VOC brought about by a proposed project that would change the traffic flow speed.

Assessment. This technique is useful when considering transportation improvements that result in a change in average travel speeds for a major transportation facility. The model provides an approximation of VOC based on tire costs, maintenance costs, and fuel costs. Because the analysis is reduced to two simple functions for each vehicle type, it is easy to estimate impacts of changes in average speed from a transportation project on VOC. It is a good idea to obtain estimates of the mix of automobile types for maximum accuracy.

Method 2. Estimating vehicle operating costs as a function of grade

In a somewhat dated document, the FHWA provides general guidance on how to include changes in the grade of a road segment when estimating VOC (FHWA 1982). In this case, we focus on a single table that provides values that can be used to estimate how VOC vary with traffic flow speed and grade.

Information collection. The information needed to apply this very basic technique is limited to two data elements: the slope and flow speed before and after a roadway project is carried out. Generally, the data will be for a series of relatively short road segments, perhaps a half-mile in length.

Analysis. This technique is best applied using a spreadsheet. For each road segment under consideration, the following 10 steps are taken:

Step 1: Determine the current AADT along the route, noting any variations among specific road segments.

Step 2: Using a travel demand model, estimate the forecast AADT if the transportation project in question were completed. Normally, many of the short road segments along the route will have the same forecast AADT.

Step 3: Determine the current grade for each road segment and the current average traffic flow speeds.

Step 4: Estimate the grade for each road segment of the proposed facility.

Step 5: Using Table 4.2, for each current road segment, estimate the cost per 1,000 vehicle miles, taking into account both flow speed and grade.

Table 4.2. Automobile speed and gradient cost relationships, 2000

(Costs at constant travel speeds—medium automobile
Year 2000 dollars per 1,000 vehicle miles of travel)

Grade (%)	**Speed (mph)**													
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**
8	524	449	400	367	357	350	353	360	367	374	394	414	423	436
7	489	422	376	347	336	327	327	333	341	348	370	394	402	414
6	466	402	360	330	320	308	307	312	321	330	353	374	381	394
5	442	386	345	317	307	295	294	297	307	314	333	350	363	380
4	426	373	336	308	295	283	281	285	292	300	312	325	343	365
3	407	360	323	297	285	274	272	275	281	285	294	301	325	350
2	386	343	308	283	272	263	259	263	267	268	278	283	307	334
1	357	321	288	263	255	247	241	241	247	250	259	267	285	307
0	333	300	268	241	234	226	219	219	225	228	242	254	267	283
-1	325	292	255	225	215	208	206	208	210	212	225	235	250	265
-2	316	283	242	205	188	192	194	198	199	199	210	218	234	252
-3	341	305	259	221	202	185	175	169	188	189	199	208	222	239
-4	374	333	285	242	222	201	188	179	173	168	192	199	212	226
-5	409	361	310	267	245	221	205	192	188	182	181	175	202	215
-6	442	389	336	290	267	242	222	208	202	198	205	189	186	202
-7	476	417	360	312	288	265	242	226	219	210	206	201	198	194
-8	810	446	387	336	310	287	263	247	235	226	221	212	208	202

SOURCE: FHWA 1982, updated by the guidebook authors.

Step 6: Repeat the procedure in Step 5, using the flow speed and grade of the proposed roadway to estimate the cost per 1,000 vehicle miles.

Step 7: Subtract the result of Step 6 from Step 5 for each segment. The result is the saving in VOC per 1,000 VMT by segment.

Step 8: For each segment, multiply the segment length by AADT to estimate daily VMT for the segment. Divide by 1,000.

Step 9: Multiply Step 7 by Step 8 to estimate the total daily VOC savings for each segment. Sum the results of all segments.

Step 10: Multiply the results in Step 9 by 365 to estimate the total annual VOC saving if the project were carried out.

The result is an estimate of the VOC savings that result from changes in the grade of various segments of an upgraded stretch of road. The present value of these savings can be calculated for the anticipated life of the improvement (i.e., normally 20 to 30 years).

Example. A stretch of road is 0.8 mile in length, with 0.4 mile uphill at an 8 percent grade and 0.4 mile downhill at the same grade. The current traffic flow speed is 40 mph. A road project would reduce the grade to 4 percent both ways and enable a flow speed of 60 mph. The AADT is 6,000 and would not change significantly if the improvement were made.

Base case
(0.4 mi. x $360/1,000 *VMT* x 6,000 *VMT* x 365 *days/year*) +
(0.4 mi. x $247/1,000 *VMT* x 6,000 *VMT* x 365 *days/year*) = $531,732/ *year*

Improved case
(0.4 mi. x $325/1,000 *VMT* x 6,000 *VMT* x 365 *days/year*) +
(0.4 mi. x $199/1,000 *VMT* x 6,000 *VMT* x 365 *days/year*) = $459,024/ *year*

With an AADT of 6,000, the reduction in grade and increase in traffic flow speed would result in a VOC savings of $72,708 per year.

Measurement and presentation. To use the data in Table 4.2, one needs only to know the flow speed and grade of the unimproved (i.e., current) road and of the road if the proposed project were carried out. This basic technique is appropriate if a road improvement would (1) result in a change in traffic flow speed on road segments that have significant slopes or (2) change the grade of one or more road segments.

Assessment. This technique only addresses the effect on VOC of changing the grade of a road segment. The previous method took into account only changes in flow speed. To avoid double-counting the effect of speed, it would not be advisable to apply the two methods in tandem. If significant grade changes are anticipated, this method is preferable, but if the main effect of the project would be a change in flow speed, the previous method is likely to be superior.

The table enables a quick estimate of VOC, provided that segment grades are known. Where grades are steep enough to warrant consideration, it is likely that such data will be available; most state DOT road segment databases do include segment-specific grade data.

Method 3. Highway Economic Requirements System

A more advanced approach to estimating VOC involves HERS, which was developed for the FHWA (FHWA 1999). It is a computer model able to estimate the benefits of potential transportation improvements using incremental life-cycle benefit-cost analysis. Benefits are estimated based on the difference between the base case VOC and the costs associated with an improvement to the transportation system. HERS also helps calculate the capital and system operating costs of the improvement.

Information collection. The information needed to estimate VOC is widely available on the Internet. Necessary data for HERS includes federal and state gasoline taxes, the retail price of gasoline and diesel fuel, price indexes to determine the values for the cost of oil and tires, estimates of maintenance costs per mile for new automobiles, and vehicle prices for medium and heavy trucks.

Analysis. HERS uses three categories of operating costs to derive estimates of VOC:

1) Constant-speed operating costs as a function of average effective speed, average grade, and pavement serviceability rating (PSR);

2) Excess operating costs due to speed-change cycles; and

3) Excess operating costs due to curves.

We present equations for each of the three categories for the purposes of illustrating the process. Additional equations are needed to complete the process; these equations are available in the HERS manual. It is important to stress that our purpose here is to provide the basis for an agency to make an informed decision about obtaining the manual and applying HERS, not to provide a complete step-by-step guide to using the model.

- Operating costs are calculated for each of seven vehicle types: small automobile, medium automobile, 4-tire truck, 6-tire truck, 3- and 4-axle truck, 4-axle combination, and 5-axle combination.

- HERS calculates operating costs based on five components: fuel consumption, oil consumption, tire wear, maintenance and repair, and depreciable value.

- Table 4.3 provides estimates of component prices in year 2000 dollars for use in estimating operating costs.

- All five components are included in the calculation of constant-speed costs and excess costs due to speed-change cycles. Only fuel, tire wear, and maintenance and repair are included in the calculation of excess costs due to curves. The 1995 values in the HERS documentation were updated to year 2000 dollars using the appropriate consumer price index components.

Table 4.3. Component prices
(Year 2000 dollars)

Vehicle type	Fuel ($/gallon)	Oil ($/quart)	Tires ($/tire)	Maintenance and repair ($/1,000 miles)	Depreciable value ($/vehicle)
Automobiles					
Small	$1.03	$3.74	$44.03	$91.25	$16,385
Medium/Large	$1.03	$3.74	$69.61	$110.73	$19,325
Trucks					
Single units					
4 Tires	$1.03	$3.74	$76.72	$140.77	$20,827
6 Tires	$1.03	$1.50	$180.97	$263.42	$31,120
3+ Axles	$0.84	$1.50	$412.00	$372.55	$68,465
Combination					
3-4 Axles	$0.84	$1.50	$412.00	$385.84	$79,307
5+ Axles	$0.84	$1.50	$412.00	$385.84	$86,234

SOURCE: FHWA 1999, Table 7-2, updated by the guidebook authors.

Constant-speed operating costs. For each vehicle type (*vt*), constant-speed operating cost per thousand vehicle-miles (*CSOPCST*) is estimated as the sum of five cost components representing costs for fuel, oil, tires, maintenance and repair, and vehicle depreciation. Equations for estimating constant-speed consumption rates are available in Appendix E of the HERS manual.

$$\begin{aligned} CSOPCST_{vt} = {} & CSFC \times PCAFFC \times COSTF_{vt}/FEAF_{vt} \\ & + CSOC \times PCAFOC \times COSTO_{vt}/OCAF_{vt} \\ & + CSTW \times PCAFTW \times COSTT_{vt}/TWAF_{vt} \\ & + CSMR \times PCAFMR \times COSTMR_{vt}/MRAF_{vt} \\ & + CSVD \times PCAFVD \times COSTV_{vt}/VDAF_{vt} \end{aligned}$$

where:

$CSOPCST_{vt}$	=	constant speed operating cost for vehicle type *vt*
$CSFC$	=	constant speed fuel consumption rate (gallons/1,000 miles)
$CSOC$	=	constant speed oil consumption rate (quarts/1,000 miles)
$CSTW$	=	constant speed tire wear rate (% worn/1,000 miles)
$CSMR$	=	constant speed maintenance and repair rate (% of average cost/1,000 miles)
$CSVD$	=	constant speed depreciation rate (% of new price/1,000 miles)
$PCAFFC$	=	pavement condition adjustment factor for fuel consumption
$PCAFOC$	=	pavement condition adjustment factor for oil consumption
$PCAFTW$	=	pavement condition adjustment factor for tire wear
$PCAFMR$	=	pavement condition adjustment factor for maintenance and repair
$PCAFVD$	=	pavement condition adjustment factor for depreciation expenses
$COSTF_{vt}$	=	unit cost of fuel for vehicle type *vt*
$COSTO_{vt}$	=	unit cost of oil for vehicle type *vt*

$COSTT_{vt}$	=	unit cost of tires for vehicle type *vt*
$COSTMR_{vt}$	=	unit cost of maintenance and repair for vehicle type *vt*
$COSTV_{vt}$	=	depreciable value for vehicle type *vt*
$FEAF_{vt}$	=	fuel efficiency adjustment factor for vehicle type *vt*
$OCAF_{vt}$	=	oil consumption adjustment factor for vehicle type *vt*
$TWAF_{vt}$	=	tire wear adjustment factor for vehicle type *vt*
$MRAF_{vt}$	=	maintenance and repair adjustment factor for vehicle type *vt*
$VDAF_{vt}$	=	depreciation adjustment factor for vehicle type *vt*

The effect of speed-change cycles. Excess operating costs due to speed-change cycles or speed variability are calculated for sections that have stop signs or traffic signals using the following equation. More information on estimating excess operating costs may be found in Appendix E of the HERS manual.

$$\begin{aligned} VSCOPCST_{vt} = & VSFC \times COSTF_{vt}/FEAF_{vt} \\ & + VSOC \times COSTO_{vt}/OCAF_{vt} \\ & + VSTW \times COSTT_{vt}/TWAF_{vt} \\ & + VSMR \times COSTMR_{vt}/MRAF_{vt} \\ & + VSVD \times COSTV_{vt}/VDAF_{vt} \end{aligned}$$

where:

$VSOPCST_{vt}$	=	excess operating cost due to speed variability for vehicle type *vt*
$VSFC$	=	excess fuel consumption rate due to speed variability (gallons/1,000 miles)
$VSOC$	=	excess oil consumption rate due to speed variability (quarts/1,000 miles)
$VSTW$	=	excess speed tire wear rate due to speed variability (% worn/1,000 miles)
$VSMR$	=	excess speed maintenance and repair rate due to speed variability (% of average cost/1,000 miles)
$VSVD$	=	excess depreciation rate due to speed variability (% of new price/1,000 miles)
$COSTF_{vt}$	=	unit cost of fuel for vehicle type *vt*
$COSTO_{vt}$	=	unit cost of oil for vehicle type *vt*
$COSTT_{vt}$	=	unit cost of tires for vehicle type *vt*
$COSTMR_{vt}$	=	unit cost of maintenance and repair for vehicle type *vt*
$COSTV_{vt}$	=	depreciable value for vehicle type *vt*
$FEAF_{vt}$	=	fuel efficiency adjustment factor for vehicle type *vt*
$OCAF_{vt}$	=	oil consumption adjustment factor for vehicle type *vt*
$TWAF_{vt}$	=	tire wear adjustment factor for vehicle type *vt*
$MRAF_{vt}$	=	maintenance and repair adjustment factor for vehicle type *vt*
$VDAF_{vt}$	=	depreciation adjustment factor for vehicle type *vt*

The effect of curves. For sections with average effective speeds below 55 mph, the effects of curves are estimated using the individual tables from Zaniewski et al. (1982). HERS equations enable a single table to be constructed that presents the excess costs due to curves for each vehicle type as a function of curvature and speed.

For sections with average effective speeds above 55 mph, the effects of curves are estimated using equations fit to the Zaniewski values given for speeds of 55 to 70 mph and for 2 degrees of curvature or more. The excess cost due to curves (*COPCST*) for each vehicle type on sections with average effective speed greater than 55 mph is calculated with the following equation:

$$COPCST_{vt} = CFC \times COSTF_{vt}/FEAF_{vt} + CSTW \times COSTT_{vt}/TWAF_{vt} + CSMR \times COSTMR_{vt}/MRAF_{vt}$$

where:

$COPCST_{vt}$	=	excess operating cost due to curves for vehicle class *vt*
CFC	=	excess fuel consumption rate due to curves (gallons/1,000 miles)
$CSTW$	=	excess tire wear rate due to curves (% worn/1,000 miles)
$CSMR$	=	excess maintenance and repair rate due to curves (% of average cost/1,000 miles)
$COSTF_{vt}$	=	unit cost of fuel for vehicle type *vt*
$COSTT_{vt}$	=	unit cost of tires for vehicle type *vt*
$COSTMR_{vt}$	=	unit cost of maintenance and repair for vehicle type *vt*
$FEAF_{vt}$	=	fuel efficiency adjustment factor for vehicle type *vt*
$TWAF_{vt}$	=	tire wear adjustment factor for vehicle type *vt*
$MRAF_{vt}$	=	maintenance and repair adjustment factor for vehicle type *vt*

Equations for estimating *CFC*, *CSTW*, and *CSMR* are available in Appendix E of the HERS manual.

Measurement and presentation. HERS calculates total operating costs through two nested loops. The outer loop moves the model through each vehicle type, and the inner loop calculates the three categories of operating costs. Once the model calculates operating costs for all vehicle types, it aggregates them using the Fleet Composition Model to arrive at total operating cost per vehicle mile over the section. The model is discussed in Paragraph 6.4 of the HERS manual.

Assessment. HERS was released in 1999 and represents the latest VOC model developed for the United States. The required data for the analysis are obtainable from national, state, and private sources. HERS assumes that VOC can be estimated using constant-speed operating costs, combined with excess operating costs due to speed-change cycles and excess operating costs due to curves.

Changes in VOC are not particularly difficult to calculate once the data are obtained, and the HERS manual contains the additional equations needed to perform the analysis. Using the HERS algorithm, it is possible to estimate the effects on vehicle fleet operating costs of changes in speed and curvature of roadways quite accurately. Because it requires a fair amount of data to be collected and input and has numerous equations, the process of making cost estimates can be quite time-consuming.

On balance, HERS is the most comprehensive method currently available for estimating the change in VOC that would result from a particular roadway project. FHWA continues to improve HERS, and it will very likely become an even better resource for VOC estimates.

RESOURCES

Depending on the method chosen, different variables are necessary to derive estimates of VOC. The following list provides necessary data and information on how to obtain them.

1) Federal and state gasoline tax rates can be obtained from the Federal Highway Administration, *Highway Statistics*, published annually. The Highway Statistics Series also can be obtained from the Federal Highway Administration, Office of Highway Policy Information, at http://www.fhwa.dot.gov/ohim/ohimstat.htm.

2) A summary of the retail price of gasoline can be obtained from the American Petroleum Institute. It can be ordered free of charge at http://www.api.org/programs_services/cat/abstracts/doc2171.html.

3) The average self-service cash price of diesel fuel can be obtained from the U.S. Department of Energy, Energy Information Administration. Weekly on-highway diesel prices can be obtained at http://www.eia.doe.gov/oil_gas/petroleum/data_publications/weekly_on_highway_diesel_prices/wohdp.html.

4) It is necessary to obtain the appropriate price indices to calculate current year values for the cost of oil and tires. These indices can be accessed at the Bureau of Labor Statistics. The index for oil and tires for 4-tire vehicles is the Consumer Price Index and can be accessed at http://www.bls.gov/cpihome.htm. For larger vehicles, the appropriate index for tires is the producer price index, which can be accessed at http://www.bls.gov/ppihome.htm.

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SECTION 5: TRANSPORTATION CHOICE

OVERVIEW

Steps in the analysis	Methods
• Define the study area • Perform a preliminary inventory of modes and facilities • Examine the demand for alternative modes • Evaluate how mobility and safety would be affected by a project	• Case studies • Qualitative analysis • User demand and evaluation surveys • Improved transportation surveys and models • Bicycle compatibility index • Pedestrian street crossings • Barrier effect analysis

Definition

Transportation choice refers to the quantity and quality of transportation options available to residents of a particular area. Because most communities have automobile-oriented transportation systems and land use patterns, transportation choice often focuses on the availability of alternatives (e.g., walking, bicycling, transit, ride-sharing) to using a personal automobile .

Quite frequently, a transportation project will affect the ability of people to use other transportation modes in the affected area, either positively or negatively. In turn, the range of available transportation choices can affect people's quality of life. More specifically, there are at least four reasons individuals and communities may value having choices among transportation modes:

- **To help achieve equity goals.** A lack of transportation choice limits the personal and economic opportunities available to people who are physically, economically, or socially disadvantaged. Often, such individuals have less access (or less reliable access) to an automobile, and so may face barriers to mobility in automobile-dependent communities. For example, in such communities, non-drivers may have difficulty attending school or working.

- **To serve as a back-up option for those who can drive.** People who do not habitually use an alternative mode may value its availability at some point in the future or in the case of an emergency. Most people can expect to go through periods when they must rely on alternative modes of transportation, due to age, physical disability, financial constraints, vehicle failures, or major disasters that limit automobile use.

- **To increase transportation system efficiency.** Use of alternative modes can help achieve certain transportation demand management (TDM) objectives, including reduced traffic congestion, facility cost savings, and environmental quality.

- **To increase livability.** Many people enjoy using alternative modes such as walking and bicycling, or riding the bus, and they value living in or visiting a community where these activities are safe, pleasant, and readily available.

Some alternative modes are more prevalent than others, and not every analysis need consider every alternative mode. Public participation and dialogue with local officials can help one select the modes that need to be examined.

Transportation factors affecting alternative transport modes

There are three major ways in which new or upgraded transportation facilities may affect the viability of alternate transportation modes:

- **Upgrading roads can increase vehicular traffic.** Heavily traveled roads are more likely to be dangerous, difficult to traverse, and unpleasant for those traveling outside of motor vehicles. As traffic increases, so does the risk to bicyclists and pedestrians, and some who might have chosen to walk or ride a bicycle prior to the increase in traffic may no longer be willing to do so.

- **Street widening can create barriers.** Several aspects of road design can affect the quality of non-motorized transportation choices. Widening road facilities may be a boon to motorists, but for bicyclists and pedestrians (especially for those with disabilities), wider roads can be difficult and dangerous to traverse.

- **Transportation projects can displace or disrupt facilities.** Bicycle trails, sidewalks, and transit stops may have to be moved to make way for other facilities. If so, it is likely that the non-motorized facilities will be less accessible to at least part of the neighboring community. Even though relocating facilities to areas accessible to more people in total may be a wise thing to do, it can create accessibility problems for people who purposefully chose to live near the original location of the facility.

Special issues

Equity concerns. Equity is perhaps the most important goal served by increasing transportation choice. Some members of a community may not be well-served by the automobile-oriented transportation systems prevalent in most U.S. cities. Lower-income populations, children, and people with disabilities are often particularly sensitive to restricted transportation choice because they tend to walk and cycle more than average and are more vulnerable to barriers and risks. Transportation disadvantage refers to people who face significant, unmet transportation needs. The four attributes below are key determinants of whether an individual or group is transportation disadvantaged:

- **Non-driver.** People who cannot drive or do not have access to a motor vehicle.

- **Low income.** Drivers and non-drivers whose basic transportation needs are significantly constrained by financial limitations, especially out-of-pocket costs.

- **Disabled.** People who have physical disabilities that limit their ability to travel independently.

- **Automobile dependent.** People who live in a community with automobile-dependent transportation and land use patterns.

A person with any one or two of these attributes is not necessarily transportation disadvantaged. For example, individuals who use a wheelchair are not transportation disadvantaged if they can afford an automobile and chauffeur or can drive and live in a community with good universal access (i.e., one designed to accommodate people with a range of needs, including wheelchair users, people with visual disabilities, and pedestrians pushing strollers or handcarts). On the other hand, the greater the number of these attributes a person has, the more likely he or she is to be transportation disadvantaged.

Obtaining information on the number of people with attributes associated with being transportation disadvantaged may be difficult. Table 5.1 describes some indicators that may be used when more specific data are unavailable. There is considerable overlap among these categories. One should try to identify the number of residents who have multiple attributes, such as lower-income, employed, single parents, and low-income people with disabilities.

Table 5.1. Indicators of transportation disadvantage and possible data sources

Indicator	Data sources
Households that do not own an automobile (sometimes called 0-vehicle households)	Census, NPTS, consumer surveys, and local transportation surveys
People with significant physical disabilities	Social service agencies and special surveys
Low-income households	Census, household, and labor surveys
Low-income single parents	Census, social service agencies, and special surveys
People who are too young or old to drive	Census and other demographic surveys
Adults who are unemployed or looking for work	Census and labor statistics
Recent immigrants who cannot drive	Census, social service agencies, and special surveys

Note: NPTS is the National Personal Transportation Survey, available at http://www.bts.gov.

Although not everybody in these groups is transportation disadvantaged—and not everybody outside of them has their mobility needs satisfied—these populations may be used as surrogates if better data are unavailable. Table 5.2 suggests which modes tend to be particularly useful for various user groups.

Barriers to non-motorized travel may have particularly adverse effects on local businesses in low-income and minority communities where most customers arrive on foot; access to local institutions, such as houses of worship and civic organizations, may also be significantly impaired, weakening community cohesion.

Because their transport options are constrained, people who are transportation disadvantaged can be seriously affected by even relatively small changes in transportation systems. For example, low-income non-drivers may be highly dependent on a particular walking path or transit route. Changing that route may have major repercussions on their access to destinations important to them. To the greatest possible extent, it is important to use data collection and analysis methods that can identify such effects. Occasionally, this may require different analysis techniques than are used in conventional transportation planning.

Table 5.2. Modes that are particularly important for specific user groups
(A = primary mode; B = potential mode)

Mode	Non-Drivers	Low-Income Person	Disabled Person	Commuters
Walking	A	A	B	B
Bicycle	A	A	—	B
Taxi	A	B	B	—
Fixed-route transit	A	A	B	A
Paratransit	B	A	A	B
Automobile	—	B	B	A
Ridesharing	B	A	B	A

Network analysis. Any analysis of transportation choice must treat each transportation system as a comprehensive, integrated network. Transit accessibility, for example, depends not only on the quality of bus or rail services, but also on the ease of accessing stops, stations, and destinations—usually by walking. Accessibility in this case is affected by pedestrian conditions, by land use patterns (such as the density and mix of development), and by whether popular activity centers (such as schools, shops, and work sites) are near transit stops. Travel choice analysis therefore requires a comprehensive approach that can take into account the many transportation and land use factors that affect the effectiveness of alternative modes.{xe "Equity concerns:in analysis of nonmotorized and alternate transport" \r "Nonmotorizedequity"}

Facility safety and security. Safety issues for alternative modes of transportation involve more than reducing the risk of crashes. With most alternatives to the automobile, travelers are exposed to both weather and the possibility of assault as they walk, ride, or wait for the bus. Facility design and security can be an important determinant of an individual's willingness to use an alternative mode, and thus, of the number of transportation choices available.

Children use non-motorized transportation, and ensuring their safety draws on the equity issues discussed earlier. Every child's safety is important, and research has shown that children in low-income and minority communities may be especially at risk as pedestrians and bicyclists. In these communities, parks, lawns, and backyard areas may be nonexistent or unsafe play areas, and, as a result, children may play on or near the street, increasing their risk of injury.

WHEN TO DO THE ANALYSIS

A preliminary, qualitative analysis of a project's effects on transportation choice should be conducted for all projects. Relatively detailed analyses are useful whenever a project:

- Widens an existing road;
- Is expected to increase traffic volumes;
- Eliminates or moves a transit stop, trail, sidewalk, or other non-motorized facility;
- Reduces the shoulder width of the road or adds shoulder rumble strips;
- Increases the length of city blocks;
- Increases the number of driveways that intersect non-motorized facilities; or
- Increases the incline of pedestrian or bicycle facilities.

In most cases, an understanding of the transportation choices available within a community provides vital information for cities and regions trying to enrich the opportunities for non-motorized transportation as part of their demand management goals.

STEPS IN THE ANALYSIS

Step 1. Define the study area.

As with the other analyses presented in this guidebook, it is important to take a critical look at the neighborhoods and infrastructure surrounding the proposed project and to determine which, if any, are likely to be affected by it. A geometric change in a roadway, for example, may affect transit routes well beyond the location of the change.

Step 2. Perform a preliminary inventory of the modes (both motorized and non-motorized) and facilities available in the study area.

Site visits, combined with reviews of sidewalk, trail, and transit maps, can be used to inventory modes and facilities that the proposed project may affect—either positively or negatively. Some non-motorized travel data may be available from existing travel surveys and traffic counts, although conventional sources such as these tend to under-record non-motorized trips. Some exclude non-motorized trips altogether, and many undercount short trips, non-work trips, travel by children, and recreational trips. Automatic traffic counters may not record non-motorized travelers, and manual counters are usually located on arterial streets that may be less used by cyclists than are adjacent streets with lower traffic.

For these reasons, special efforts are usually required to obtain the information needed to evaluate non-motorized travel. Whenever possible, the data should be geocoded and incorporated into a geographic information system (GIS; see Appendix A). This makes it easy to create maps that integrate various types of data (such as roadway and sidewalk conditions) with the demand for non-motorized travel to identify areas where effects might be greatest.

Step 3. Examine the demand for alternative modes.

This step involves estimating how many people use (or want to use) alternative modes of transportation. Applying one (or a combination of) the methods presented in this section, one assesses how many people are likely to be directly affected by changes to the availability and usability of modes other than the automobile. If surveys are used, it may be possible to estimate how people value transportation choice as part of the community, even if some residents currently do not use alternative modes.

Step 4. Evaluate how mobility and safety would be affected by a project.

Depending on the scope of the assessment, an analysis of the use and safety of alternative modes of transportation may range from a qualitative assessment of the project's impacts on transportation choice to an actual calculation of the total number of trips or people likely to be affected. Either way, the analysis results will be enriched by feedback from local planners, officials, and transportation users.

METHODS

Method 1. Case studies

Project impacts can be evaluated based on before-and-after studies or on comparisons with similar areas, facilities, or projects. Before constructing a pedestrian overpass, for example, it may be helpful to identify an existing overpass in a similar situation as an indicator of its likely use. It is especially beneficial to obtain before-and-after data from the analogous project when possible.

Information collection. Comparison studies require identifying similar situations, either nearby examples suitable for evaluation or published case studies. If traffic counts and travel surveys are being performed in the case-study area, it may be possible to collect information on non-motorized travel by including categories for pedestrians and cyclists in manual counts. Mechanical counters can be modified to count cyclists on a path or road shoulder by replacing the standard heavy rubber tube with lighter surgical tubing. Photoelectric counters can be installed on paths. Volunteers from pedestrian and cycling organizations may also be willing to perform manual counts on non-motorized travel.

Analysis. When evaluating and comparing study sites, it is important to consider any differences that may affect non-motorized travel. For example, if an existing pedestrian overpass is similar except for the number of nearby residents, projected demand should be adjusted to account for this difference. Judgment is required to determine which factors are likely to have significant effects.

Measurement and presentation. To the degree that conditions are comparable, the case study method can be used to predict likely effects in the study area. Information should be presented in ways that highlight differences and similarities between the case study and the study site. For a relatively simple analysis, comparisons can be descriptive. More complex comparisons can include a more detailed statistical analysis.

Assessment. Case studies can be a useful indicator of the effects a project or policy may have on non-motorized travel. The key is to find comparable situations in which before-and-after comparisons were made. It is important to take into account any differences between a case study and the study site when making predictions.

Method 2. Qualitative analysis

Qualitative analysis is a screening tool that is designed for use during the design phase of a project. The analysis answers the following question: will a transportation project affect the number and quality of transportation choices?

Information collection. Information collection involves three steps:

Step 1: Identify the transportation modes to be considered.

Step 2: Select suitable standards, guidelines, or indicators for each mode. This selection depends on:

- *Overall goals and objectives.* For example, an analysis focusing on equity effects would probably use different indicators of transportation choice than would an analysis focusing on TDM objectives such as congestion and emission reduction.
- *Community preferences*. Some communities may place greater weight on a particular choice or indicator. Consultation with elected officials and public advisory committees or a public forum may be useful to gauge community preferences.

Step 3: Consolidate material from Step 2 into a small number of indicators that reflect the nature of the project being designed and the preferences and concerns of affected residents.

Analysis. Although a qualitative analysis certainly can involve the development of numeric measures, its principal objective is to give a general idea of who is likely to be affected by a transportation project and how. Using GIS, it is possible to categorize residential areas according to the number of transportation-disadvantaged residents and other attributes that may affect the need for alternative modes. Incorporated into a transportation model that has been modified to include alternative modes and transportation-disadvantaged groups, spatial data can indicate how the project would change transport choice and trip affordability for residents and visitors to the affected area.

Table 5.3 summarizes a series of sample factors that indicate whether an alternate mode helps provide mobility for non-drivers, low-income households, or people with disabilities and whether it supports TDM objectives such as reduced traffic congestion, road and parking facility cost savings, and reduced environmental impacts.

Table 5.3. Sample of factors to use in qualitative analysis

Issue	Likely result
As a result of this transportation project, traffic volumes are likely to:	❑ Increase ❑ Decrease ❑ Stay the same
As a result of this transportation project, the *number* of pedestrian facilities surrounding the facility is likely to:	❑ Increase ❑ Decrease ❑ Not change
As a result of this transportation project, the *quality* of pedestrian facilities (e.g., number of cracks or potholes) surrounding the facility is likely to:	❑ Increase ❑ Decrease ❑ Not change
Will the number of pedestrian barriers (e.g., steep inclines or lengthy road crossings) increase, decrease, or not change as a result of this project?	❑ Increase ❑ Decrease ❑ Not change
As a result of this project, will residents surrounding the facility have increased, decreased, or the same access to transit stops?	❑ Increased access ❑ Decreased access ❑ No change
Are transit service coverage (i.e., the number of routes *within a quarter mile*), reliability, and frequency likely to increase, decrease, or stay the same as a result of this project?	❑ Increase ❑ Decrease ❑ Stay the same
The quality of service associated with paratransit services to residential areas surrounding the new facility is like to:	❑ Increase ❑ Decrease ❑ Stay the same
Are availability and response times for taxi services likely to increase, decrease, or not change as a result of this transportation project?	❑ Increase ❑ Decrease ❑ Not change
Will the number of mobility barriers identified by people with physical disabilities increase, decrease, or not change as a result of this project?	❑ Increase ❑ Decrease ❑ Not change
The portion of the pedestrian network surrounding the project that meets barrier-free design standards is likely to:	❑ Increase ❑ Decrease ❑ Stay the same
As a result of this transportation project, the number of bicycle facilities (e.g., lanes or trails) will:	❑ Increase ❑ Decrease ❑ Stay the same
As a result of this transportation project, accessibility of bicycle facilities (e.g., lanes or trails) is likely to:	❑ Increase ❑ Decrease ❑ Stay the same
In general, will the proposed transportation project improve, worsen, or not affect the environmental conditions for non-motorized travel in the area surrounding the facility?	❑ Improve ❑ Worsen ❑ Not affect

Measurement and presentation. The results of a qualitative analysis can be presented using graphs or maps and incorporated into a transportation model. For example, analysis of a highway-widening project could include graphs showing how pedestrian and cycling level of service (LOS) would change under various design options, along with maps showing the location of major activity centers (e.g., schools, shops, transit stops, parks, and recreation centers) and residential areas relative to the project.

Assessment. Qualitative analysis is a relatively simple way to gain a general sense of how various options for achieving a transportation system objective might affect the transportation choices available to residents of a geographic area. Its advantage is that it can be done quickly for several design options, and it can provide important insights. Using a rather basic checklist such as that in Table 5.3, one can evaluate the probable effects of each alternative on the transportation choices of area residents and visitors. Such an analysis can hardly be regarded as rigorous or definitive, but it can be a useful tool for providing an early warning at a critical juncture in the development of a transportation project.

Method 3. User demand and evaluation surveys

User demand and evaluation surveys can be used to gather information from consumers who may be inclined to use a particular transportation alternative. These surveys can also be used to obtain feedback on the specific barriers and problems facing people who currently walk or cycle on a particular facility or in a specific area. Such surveys are useful in that they help identify specific attributes of roadways and their environs that make them especially conducive to travel by means other than the automobile. The National Highway Institute (1996, Chapter XVI.B) provides information on user surveys to evaluate bicycle and pedestrian conditions.

See:

- Appendix B: Survey Methods, p. 211.

Information collection. User surveys can be distributed to walkers and cyclists at a study site (e.g., survey forms can be passed out along a sidewalk or trail), distributed through organizations (e.g., hiking and cycling clubs) and businesses (e.g., bicycle shops), or mailed to area residents. Note that in some circumstances results may be skewed by the fact that club members, people who frequent bicycle shops, and people most inclined to return surveys may not be representative of the entire user population.

Pedestrian and bicycle travel surveys should attempt to gather the following information:

- Origin and destination of trips, including links by other modes (such as transit);
- Time, day of the week, day of the year, and conditions (such as weather, road, and traffic conditions); and
- Factors that influence travel choice (such as whether a person would have chosen another route or a particular mode if road conditions or facilities were different).

Analysis. A crucial part of this analysis involves identifying specific problems that travelers encounter when walking and cycling, such as streets with inadequate sidewalks, roads with inadequate curb lane widths or shoulders, and dangerous railroad crossings. These problems can then be addressed during the design phase of transportation projects in the area.

The following questions might be included in non-motorized travel surveys:

- How much do you rely on walking and cycling for transportation and recreation?
- How do you rate walking and cycling conditions in the study area?
- What barriers, problems, and concerns do you have related to walking and cycling in the study area?
- What improvements or programs might improve walking and cycling conditions?

Measurement and presentation. User survey results should be summarized to highlight key findings. The results can then be used to identify how transportation choice should be evaluated and how a particular policy or project is likely to affect transportation options. Standard statistical analysis techniques can be used to evaluate the accuracy of survey results. Geographic information can be presented on maps, and time series data can be graphed to illustrate trends.

Results from user surveys can be presented by mode, group, or location to meet analysis requirements. For example, to analyze the effects a highway project will have on the travel choices of transportation-disadvantaged people, it may be appropriate to present survey data indicating the number of people in various groups near the project site (e.g., non-drivers, low-income persons, and persons with disabilities), their current travel patterns (e.g., how many currently walk and bicycle along the proposed route), and how these travel modes are likely to be affected.

Assessment. User evaluation surveys are a commonly applied tool for determining the current circumstances facing pedestrians and cyclists. Problem areas identified in these surveys can then be addressed as a transportation project is designed. More specifically, this gives planners a better understanding of features to avoid or include to facilitate travel by alternative modes when designing upgraded or reconfigured facilities. As is true of any user survey, however, the results will reflect only the views and experiences of current or past users. Those who have not been able or willing to use the various forms of alternative transportation will not be represented. Thus, it must be recognized that these surveys are only one useful source of information; they cannot be regarded as completely definitive for establishing the needs and preferences surrounding alternative transportation issues.

Method 4. Improved transportation surveys and models

Various conventional travel surveys can be improved to more accurately assess demand for alternative modes and how this demand would be affected by particular policies and projects. Most current surveys tend to undercount non-motorized modes because the walking and cycling links of motorized trips are ignored (e.g., a walk-bus-walk trip is coded only as a transit trip).

One study found that the actual number of non-motorized trips is six times greater than what conventional surveys indicate (Rietveld 2000).

Other limitations of most current surveys include not being sensitive to many factors that affect public transit demand. For example, most surveys are not sensitive to convenience and comfort features or to the quality of the pedestrian environment around transit stops. Furthermore, most current surveys do not consider certain alternative modes at all; they generally exclude ridesharing, taxi trips, automobile sharing, and delivery services. Most are not very accurate in predicting the effects of TDM strategies. Finally, many surveys and models are unable to specifically address travel by transportation-disadvantaged persons.

Fortunately, some surveys can be improved to provide better information on travel demand for alternative modes, on travel requirements of transportation-disadvantaged groups, and on functional barriers to the use of alternative transportation.

Information collection. The first step in improving standard travel surveys is to determine what questions the analysis is to answer. For example, the question might be, "How will widening this highway affect the travel choices within the study area?" Answering this question may require:

- Survey data concerning the number of people who have various transportation-relevant attributes (e.g., non-drivers, low-income persons, persons with physical disabilities, commuters, and tourists) in the area.

- Survey data concerning the demand for transportation alternatives by the different groups (i.e., the types of modal attributes they find desirable and within their reach).

- Survey data on the current quality of alternative modes and on the barriers that different user groups encounter, such as poor pedestrian conditions or inconvenient transit access.

- Analysis of survey data that can evaluate how a particular change in the transportation network would affect alternative modes and their use by different groups.

Analysis. Surveys that are sensitive to alternative modes can be analyzed using fairly standard methods to answer such questions as how basic mobility for transportation-disadvantaged persons or travel choice by commuters is likely to be affected by a particular policy or project.

In addition to examining direct, short-term effects, the analysis should consider to what degree the project is likely to contribute to long-term changes that increase automobile dependency and how this is likely to affect alternative modes. For example, the issues emerging from users surveys can become a checklist for identifying specific effects of the project that need to be assessed in the design phase. They also should be factored into go, no-go decisions.

Measurement and presentation. Information can be presented in much the same way that current transportation survey data are presented: using tables, graphs, and maps, with results disaggragated by mode and demographic group as appropriate. Below are some examples of ways in which the survey results might be presented:

- Graphs showing the number and quality of travel options currently available to different groups (e.g., motorists, non-drivers, low-income persons, and those with disabilities) and how these options are likely to be affected by a particular policy or project.

- Maps showing the location of barriers to walking and cycling identified in a survey and their relationship to public transit stops, shops, and employment and education centers.

- Maps showing the location of transit access points and retail shops that provide delivery services and their proximity to residential areas with a sizable population of non-drivers.

- Graphs comparing average door-to-door commute times and financial costs between various residential areas and common workplace sites for travel by automobile and by alternative modes.

Assessment. Travel surveys have long been an important tool for transportation planners. Such surveys have been almost entirely directed at the automobile, but it is certainly possible to adapt them for inquiries into the performance and needs of alternative transportation modes. Knowing as much as possible about people's concerns regarding current facilities and their desires for travel by alternative modes will help one assess the extent to which a proposed project would support these other modes. The surveys also can provide insights into how a proposed design could be modified to better support travel by alternative modes.

Method 5. Bicycle compatibility index

Various standards are available for evaluating cycling facilities, including those of AASHTO (1999). Consistent with these standards, the Bicycle Compatibility Index (BCI) (Harkey et al. 1998), developed for the FHWA, can be used to evaluate cycling conditions on road links. It also can be used to estimate the effects of transportation projects on bicycle travel.

Information collection. Harkey's BCI requires data that are routinely available in planning or public works agencies. As the variable definitions below indicate, many of the data are geometric: they define roadway and curb features. Other data pertain to traffic flow and roadside land patterns. All of these data are likely to be easily acquired.

Analysis. The BCI consists of an equation into which the salient values are inserted:

$$BCI = 3.67 - 0.966\,BL - 0.41\,BLW - 0.498\,CLW + 0.002\,CLV + 0.0004\,OLV + 0.022\,SPD + 0.506\,PKG - 0.264\,AREA + AF$$

where:

BL= presence of bicycle lane or paved shoulder (≥ 0.9 m. No = 0; Yes = 1)
BLW = bicycle lane or paved shoulder width (to nearest tenth meter)
CLW = curb lane width (to nearest tenth meter)
CLV = curb lane volume (vehicles per hour [VPH] in one direction)
OLV = other lane volume(s) (same direction VPH)
SPD = 85th percentile speed of traffic (kilometers per hour)
PKG = presence of parking lane with more than 30 percent occupancy (no = 0; yes = 1)

AREA = type of roadside development (residential = 1; other = 0)
AF = $f_t + f_p + f_{rt}$

NOTE: f_t is the truck volume adjustment factor found in Table 5.4, f_p is the parking turnover adjustment factor from Table 5.5, and f_{rt} is the right turns adjustment factor shown in Table 5.6.

Table 5.4. Truck volume factor (f_t)

Truck* volume (per lane hourly)	f_t
≥ 120	0.5
60-119	0.4
30-59	0.3
20-29	0.2
10-19	0.1
< 10	0.0

*Trucks are defined as all vehicles with six or more tires.
SOURCE: Harkey et al. 1998, Table 1.

Table 5.5. Parking turnover factor (f_p)

Parking time limit (minutes)	f_p
≥ 15	0.6
16-30	0.5
31-60	0.4
61-120	0.3
121-240	0.2
241-480	0.1
>480	0.0

SOURCE: Harkey et al. 1998, Table 1.

Table 5.6. Right turns factor* (f_{rt})

Right turn volume (hourly)	f_{rt}
≥ 270	0.1
<270	0.0

*Includes total number of right turns into driveways or minor intersections along a roadway segment.
SOURCE: Harkey et al. 1998, Table 1.

Once the BCI has been calculated, it is possible to determine the compatibility level and the LOS using Table 5.7.

Table 5.7. Average adult cyclist compatibility level and LOS of roadways by BCI

BCI Range	Compatibility level	LOS
≤ 1.50	Extremely high	A
1.51-2.30	Very high	B
2.31-3.40	Moderately high	C
3.41-4.40	Moderately low	D
4.41-5.30	Very low	E
>5.30	Extremely low	F

SOURCE: Harkey et al. 1998, Table 2.

The standard BCI values are intended to represent the abilities and preferences of average adult cyclists. The authors of this method therefore suggest that only LOS C or better be considered suitable for casual cyclists.

Example. Suppose that a current roadway has no dedicated bicycle lane, a curb lane width of 3.2 meters, a traffic volume of 600 VPH in both lanes in the same direction, an 85th percentile speed of 40 km/hr, a parking lane with more than 30 percent occupancy, residential development along the roadway, a truck volume per lane of 35 VPH, a parking turnover rate of 30 minutes, and 200 right turns per hour. The improved roadway would have the same attributes except that a 1.2 meter dedicated bicycle lane would be added, the curb lane width increased to 3.5 meters, the parking turnover rate increased to 50 minutes, and the parking lane alongside the road decreased to less than a 30-percent occupancy. The change in bicycle LOS can be easily calculated.

The original condition is:

$$BCI = 3.67 - 0.966(0) - 0.41(0) - 0.498(3.2) + 0.002(600) + 0.0004(600) + 0.022(40)$$
$$+ 0.506(1) - 0.264(1) + (0.3 + 0.5 + 0.1) = 5.538$$

The improved condition is:

$$BCI = 3.67 - 0.966(1) - 0.41(1.2) - 0.498(3.5) + 0.002(600) + 0.0004(600) + 0.022(40)$$
$$+0.506(0) - 0.264(1) + (0.3 + 0.4 + 0.1) = 3.325$$

Referring to Table 5.7, the BCI for this facility was originally “extremely low” (LOS F), but with the improvements it would become “moderately high” (LOS C).

Measurement and presentation. GIS can be used to produce maps that show existing cycling conditions, identify problems and barriers, assess the effects of a proposed project or policy, and suggest how these correlate with indicators of cycle demand. Roadway suitability ratings can also be used to identify preferred cycling routes. This information can be used to prioritize cycling facility improvements by identifying problems in the road and path network on corridors with relatively high cycling demand. For example, problem areas around major cycling attractions (e.g., college campuses, schools, and recreation facilities) can be given higher priority than areas with less cycling demand.

Assessment. The BCI can be a useful technique for measuring and evaluating roadway conditions for cyclists. This rating system can be used to assess existing bicycle travel conditions and how these would be affected by a particular project or policy. A low LOS implies poor safety and convenience, both of which are bound to discourage travel by this mode. The technique is simple and easy to apply, and it gives approximations that should be adequate for most applications.

Method 6. Pedestrian street crossings

Pedestrian LOS ratings have been developed to evaluate roadway crossing conditions for pedestrians that are similar to LOS ratings used by transportation engineers to evaluate roadway performance for motorized traffic. The most important consideration in terms of pedestrian service and safety is intersection performance. It is there that pedestrian–motor vehicle conflicts are the most likely to occur. Accordingly, we focus on pedestrian street crossings.

Information collection. The current performance of an intersection and its expected performance after a transportation project in terms of pedestrian crossings are the key to LOS for foot traffic. It is not difficult to compare the actual time available for crossings with the generally accepted time requirements: crosswalk walking speeds are 1.2 meters per second (m/s) for most areas and 1.0 m/s for crosswalks serving large numbers of older pedestrians. Time available is affected by signal cycles and, in the case of non-signalized intersections, traffic speed and volume.

Analysis. A logical method of assessing pedestrian LOS for street crossings is pedestrian delay. Weller (1998) has suggested a rather basic rating system, shown in Table 5.8. The table implies that when delays become relatively long, the likelihood increases that pedestrians will not always comply with signals or yield to traffic. In short, they will occasionally place themselves in harm's way. The implication is that by reducing average pedestrian delays at intersections, two positive effects are possible: encouragement for more short trips to be taken on foot and greater safety for those walking across intersections.

Measurement and presentation. GIS can be used to produce maps showing existing pedestrian conditions, the effects of a proposed project or policy, and how these effects correlate with indicators of pedestrian demand. For example, the city of Portland, Oregon, used GIS mapping to prioritize pedestrian improvements. Planners performed a survey of existing pedestrian facilities, such as sidewalks, and identified barriers and missing links in the network. They also identified areas with a relatively high demand for walking, taking into account factors such as population density, attractions such as schools and commercial districts, and current non-motorized travel. With this information incorporated into a GIS system, it was relatively easy to identify barriers and links in areas with high pedestrian demand, which were assigned the highest priority for improvement.

Table 5.8. Pedestrian road crossing LOS
(Values are average delays in seconds per pedestrian crossing)

LOS	Signalized intersection	Unsignalized intersection	Pedestrian noncompliance likelihood
A	<10	< 5	Low
B	10-20	5-10	Low to moderate
C	20-30	10-20	Moderate
D	30-40	20-30	Moderate to high
E	40-60	30-45	High
F	≥ 60	≥ 45	Very high

SOURCE: Derived from Milazzo et al. 1999, Tables 5 and 7.

Assessment. Pedestrian conditions can be evaluated based on sidewalk, path, and roadway crossing conditions. It is possible to estimate the likelihood that pedestrians will venture into dangerous conditions by examining the probable delays at a point of crossing. In hazardous situations, measures such as pedestrian signals can be installed to improve convenience and safety. Other indicators of pedestrian convenience, such as circuitous routes between common origin-destination pairs, can best be examined in the field.

Method 7. Barrier effect analysis

The negative effect that highways and vehicle traffic can have on non-motorized mobility is sometimes called the "barrier effect." Swedish and Danish highway agencies have developed methods for quantifying the barrier effect in terms of additional travel delay experienced by pedestrians and cyclists, similar to the way traffic congestion delays to motor vehicles are quantified. Rintoul (1995) has suggested a reasonably direct method for estimating the barrier effect.-

See:

- Appendix A: Geographic Information Systems, p. 201.

Information collection. To carry out a barrier effect analysis, routinely available data are used. These data pertain to road systems (e.g., number of pedestrian crossings, AADT, average traffic flow speed, and vehicle mix), demographic characteristics of the served population, and land use patterns.

Analysis. There are three steps to quantifying the barrier effect, as suggested by Rintoul.

Step 1: The barrier size is calculated based on traffic volumes, average speed, share of trucks, number of pedestrian crossings, and length of roadway under study.

$$B = q \times k_l \times k_h$$

where:

B = barrier size
q = average annual daily traffic

k_l = correction factor for trucks, 0.667 + 3.33 x percentage of trucks
k_h = $(v/50)^4$ where v = average traffic flow speed (km/h)

For example, let q = 13,600 AADT, the percentage of trucks = 8.1%, and the average traffic flow speed = 60km/hr:

Barrier size = (13,600) x (0.667 + [3.33 x .081]) x ($[60/50]^4$) = 26,417

Step 2: The demand (i.e., crossing potential) for road and street crossing is calculated based on residential, commercial, recreational, and municipal destinations within walking and bicycling distance of the road. The resulting estimate represents the maximum possible number of non-motorized trips, assuming that there is no traffic barrier to walking and cycling. For a small study area, this can be done using maps to mark major origins (e.g., housing) and pedestrian destinations (e.g., schools, parks, transit stops, and commercial areas).

$$CP = d \times \sum (p \times cpf)$$

where:

CP = crossing potential
d= population density (persons per km^2)
p= portion of total population for each age range
cpf = crossing potential factor for each age range, indicated in Table 5.9 below

Table 5.9. Crossing potential factor (cpf)

Age range	cpf
Infant/Toddler (0-4 yrs)	0.42
Elementary (5-12 yrs)	5.0
Secondary (13-17 yrs)	7.0
Adult (18-65 yrs)	2.6
Senior (more than 65 yrs)	0.74

SOURCE: Rintoul 1995, p. 9. Values are based on experimental data.

Continuing our example, let the population density be 741 persons per square kilometer and the population age distribution be as shown in Table 5.9.

$$CP = 741 \times \sum (.07 \times .042) + (.12 \times 5.0) + (.07 \times 7.0) + (.82 \times 2.6) + (.12 \times .74) = 2,089$$

Table 5.10 shows in tabular form this example calculation of total crossing potential for an area with a population density of 741 persons per square kilometer. The values for "crossing potential" represent the expected number of crossings per day, in this case, 2,089.

Table 5.10. Crossing potential factor example

Age range	Portion of total population*	Crossing potential factor	Population density	Crossing potential
Infant/Toddler (0-4 yrs)	0.07	0.42	741	22
Elementary (5-12 yrs)	0.12	5.0	741	444
Secondary (13-17 yrs)	0.07	7.0	741	363
Adult (18-65 yrs)	0.62	2.6	741	1,194
Senior (more than 65 yrs)	0.12	0.74	741	66
Total	1.00			2,089

*These are example values. They may not be representative of a given community.

Step 3: The barrier size and the potential daily crossings are combined to yield a measure of total disruption per kilometer of barrier. The total disruption represents the amount of exposure of pedestrians and cyclists to vehicular traffic.

$$TD = A \times CP \times R \times B$$

where:

TD = total disruption per kilometer of barrier
A = adjustment for controlled crossing (A= 1–% utilization of the crossing)
CP = crossing potential, as previously discussed
R = relative disruption factor, an approximate weighting by age (infant = 24, elementary age child = 16, secondary education child = 4, adult = 1, and senior citizen = 4)
B = barrier size, as previously discussed

The relative disruption factor takes into account the fact that street crossing causes different levels of disruption for various age groups. This difference is due to such factors as ability to correctly assess risk, mobility, and ability to use other transportation modes. Although somewhat arbitrary, it provides a greater degree of realism.

Suppose that observation leads to an estimate that the utilization of controlled crossings is 30 percent, so the adjustment factor is 1–.30 = .70. Using this estimate, the total disruption is displayed in the far right column of Table 5.11. A total of 32,602,280 units of disruption results in our example. This value can be compared with the total for the base case or various alternatives.

Table 5.11. Total disruption per km of barrier

Age range	Portion of total population	Crossing utilization	Crossing potential	Disturbance factor	Barrier size	Total disruption (1,000s)
Infant/Toddler (0-4 yrs)	0.07	0.70	22	24	26,417	683.41
Elementary (5-12 yrs)	0.12	0.70	444	16	26,417	15,764.08
Secondary (13-17 yrs)	0.07	0.70	363	4	26,417	1,879.57
Adult (18-65 yrs)	0.62	0.70	1,194	1	26,417	13,689.29
Senior (more than 65 yrs)	0.12	0.70	66	4	26,417	585.93
Total						32,602.28

Measurement and presentation. The results of barrier effect analysis are presented in terms of total units of disruption. The best use of this numerical result is to compare it with a parallel analysis of an upgraded roadway (or pedestrian facility) to see in fractional terms how much the amount of disruption per kilometer would change.

Assessment. Barrier effect analysis was developed in Europe as a means for gauging the impediment to pedestrian and bicycle travel posed by an intervening roadway. It is especially useful in estimating how great a change in barrier effects a proposed transportation system project would bring about. There are two key assumptions contained in the analysis that influence the outcome: the crossing potential factor (i.e., the relative likelihood of risk-taking by age group) and the utilization rate of signalized crossings. The latter factor, of course, can be varied by age group to reflect actual behavior. Best estimates of the two key assumed values by age group can be arrived at through observation, preferably at the actual site where a change in the transportation environment is being contemplated.

It would not be difficult to construct a spreadsheet that would enable sensitivity analyses to be done regarding the importance of assumed values on the actual estimates. This technique, coupled with user surveys, generally will allow good insight into the effects of a project on pedestrian and bicycle crossing behavior. The implications are considerable, in terms of both modal choice and safety.

RESOURCES

1) Dixon, Linda. 1996. "Bicycle and Pedestrian Level-of-Service Performance Measures and Standards for Congestion Management Systems." *Transportation Research Record 1538*. Washington, DC: Transportation Research Board, National Research Council, pp. 1–9.

This article describes LOS ratings for walking and cycling conditions to help identify ways to improve and encourage non-motorized transportation. The ratings take into account the existence of separated facilities, conflicts, speed differential, congestion, maintenance,

amenities, and TDM. These are relatively easy-to-use methods for evaluating non-motorized roadway conditions that may be simpler to apply than other, more data-intensive methods.

2) Eash, Ronald. 1999. "Destination and Mode Choice Models for Nonmotorized Travel," *Transportation Research Record 1674*. Washington, DC: Transportation Research Board, National Research Council, pp. 1–8.

   This article describes the techniques used to modify the Chicago Area Transportation model, so it could evaluate pedestrian and bicycle travel. Smaller analysis zones were created, and various demographic and transportation system factors that affect non-motorized travel behavior were incorporated into the model. This article should be useful to planners and modelers who might want to incorporate non-motorized travel into a conventional traffic model.

3) Landis, Bruce. 1996. "Bicycle System Performance Measure." *ITE Journal*, Vol. 66, No. 2 (February), pp. 18–26.

   This article describes relatively easy-to-use techniques for estimating potential bicycle travel demand (the Latent Demand Score) and evaluating roadway conditions for cycling in a particular area (the Interaction Hazard Score). These approaches are similar to other models used by traffic engineers that require demographic, geographic, and road condition information.

4) Schwartz, W.L., C.D. Porter, G.C. Payne, J.H. Suhrbier, P.C. Moe, and W.L. Wilkinson III. 1999. *Guidebook on Methods to Estimate Non-motorized Travel: Overview of Methods.* Turner-Fairbanks Highway Research Center. FHWA-RD-98-166. Washington, DC: Federal Highway Administration.

   This guidebook describes and compares various techniques that can be used to forecast non-motorized travel demand and to evaluate and prioritize non-motorized projects. It provides an overview of each method, including pros and cons, ease of use, data requirements, sensitivity to design factors, typical applications, and whether it is widely used.

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SECTION 6: ACCESSIBILITY

OVERVIEW

Steps in the analysis	Methods
• Identify key origins and destinations • Measure current accessibility between key origin-destination pairs • Estimate accessibility between key origin-destination pairs for each alternative • Estimate accessibility effects in terms of cost	• Interviews, focus groups, and surveys • Site analysis • Maps and aerial photographs • Spreadsheet analysis • Gravity models • Traffic demand models

Definition

In general, accessibility measures the relative ease with which desired destinations can be reached. A transportation project may substantially improve the accessibility of some locations while actually reducing the accessibility of others. For example, converting an expressway with at-grade intersections to a freeway with limited access will diminish the ease with which businesses and households located between the interchanges can be accessed. The level of accessibility of a location depends on two major components:

1) **Areawide accessibility.** Accessibility in an areawide context is dependent upon the availability of transportation service from other points to the given destination and on the associated LOS. The available services may include roads, sidewalks, bicycle paths, and bus or passenger rail lines. LOS may refer to the average travel time, reliability, and schedule frequency (if applicable) available to travelers. For instance, a direct highway route with high-speed traffic movement and no congestion delay could provide a high degree of areawide accessibility, as could an express transit service operating with a high schedule frequency.

2) **Local accessibility.** In a very local context, accessibility pertains to the ease with which travelers may get to a specific destination. Accessibility depends on the degree of directness for getting to the destination, the simplicity of finding it, the availability of parking facilities, and the ease of walking to its entrance. For example, a direct road with clearly marked store driveways and convenient parking could provide a high degree of local vehicular access. On the other hand, the presence of one-way streets, traffic signals that are not coordinated between intersections, left-turn restrictions, and limited parking can all serve to substantially reduce the level of local access to a home or business. Lack of sidewalks can also reduce local accessibility for walking trips.

Transportation factors affecting accessibility

Transportation projects can directly affect the accessibility of households and businesses in a given location in the following ways:

- Improvements to public transport systems can expand travel options and opportunities for residents and sometimes reduce traffic congestion. The direct result is enhanced job options and quality of life.

- Improvements to road system capacity and traffic control can reduce travel times to and from affected areas for those with vehicles. Reduced travel times can expand markets for commercial businesses and improve productivity and competitiveness for production businesses. Some of the benefits of reduced travel time may decrease over time as people react to changes in accessibility by making more trips.

- Any type of transportation infrastructure (including highways, rail lines and other fixed guideways, terminals, stations, and parking lots) can represent a physical barrier to pedestrian or vehicular movement, thereby reducing accessibility to preferred destinations. Similarly, changes in traffic controls (such as one-way streets, restricted turning, or entry and exit limitations) can represent an effective access barrier. These barriers can usually be overcome, but only by means of a circuitous route involving extra travel time and cost.

- During construction of transportation projects, there can be considerable disruption of travel, and access to numerous destinations can be adversely affected. Although such disruptions normally are of limited duration, certain destinations, such as small businesses, may not be able to weather the loss of customers during this period.

Special issues

Effects on land markets and urban form. Among the most important concepts in urban land economics is "rent theory," first advanced by Alonzo (1964). Rent theory postulates that the value of land is directly related to its relative accessibility within an urban area. Because locations that have the best accessibility have comparatively high land values, such land tends to be intensely developed. The idea is to derive as much economic activity as possible out of a parcel of expensive land. Tall skyscrapers in the center of a city, which is a highly accessible location, are an example of intensive land use.

When transportation projects are undertaken that substantially improve the accessibility of a location (e.g., a new interchange connecting two major urban highways), changes in land use are a frequent consequence. Likewise, upgraded radial highways increase the accessibility of undeveloped land on the urban fringe, making it attractive for residential, commercial, and industrial uses. In short, certain transportation projects are likely to change the relative accessibility of numerous land parcels and lead to changes in land use patterns and urban form.

Definition of the impact area. The methods and measures selected to estimate the effects on accessibility will depend on the type of transportation project under consideration, and thus on the geographic impact area. Some projects, such as pedestrian improvements in a neighborhood retail area, may affect a relatively small geographic area (primarily defined by walking distances). Projects such as new fixed-guideway transit systems may require analysis at more than one geographic level. Pedestrian accessibility might be of major concern at some station locations, while a regional assessment of accessibility effects related to improved access to a central city employment center from suburban locations would also be of interest. Major new highway projects through rural areas might focus more on regional accessibility effects related to businesses' access to labor, suppliers, and markets.

System performance and accessibility. In some cases, it may be inappropriate to equate the speed and traffic-carrying capacity of a roadway with accessibility to facilities along the route. For example, an upgraded urban arterial may move traffic very well, but the upgrade could make it more difficult to exit the roadway, park one's vehicle (or arrive by transit), and walk to a business. Likewise, walking from that business to another in the same general area may also be inhibited by the major arterial. In this case, the road upgrade may enhance access to more distant locations within the urban area, but actually reduce access to certain areas along the arterial. In assessing changes in accessibility resulting from a proposed transportation project, one should examine both (1) systemwide changes in accessibility to major employment, entertainment, cultural, religious, and shopping facilities, and (2) the implications for other sites that depend on easy access to customers or visitors.

Equity concerns. The lesser degree of mobility typical of low-income populations restricts access to economic and social opportunities. Most data used in regional travel models are too aggregated to reveal detailed information on small-scale travel patterns such as trip purposes and reasons for modal choices. Targeted surveys can identify differences in travel patterns and in the motivations of residents of affected low-income and minority communities; these surveys should also identify desired destinations and perceived barriers to access.

Some common assumptions about accessibility may *not* hold for disadvantaged populations. Simply because transit service is available between a low-income or minority neighborhood and employment centers does not mean that the centers are accessible or that the service is used; assuming that the existence of a transit service equals access may lead to erroneous conclusions. For low-income working parents, for example, the ability to use transit for commuting may be severely limited by the lack of childcare facilities near home, employment, or transit stops. Detours for childcare purposes make transit commutes costly and time-consuming, and thus a modal choice of last resort for many. A survey of transit riders will not measure the accessibility problems of those who cannot use transit.

An evaluation of access to important destinations should consider not only those who can reach desired destinations by particular modes, but also those who cannot. Evaluation of access to jobs requires information on job availability (e.g., skills and education-appropriate job openings by location) and on modal access. Data on the number of working parents who must make detours to childcare can be collected using surveys or travel diaries, along with information on locations of childcare facilities. GIS mapping can be a valuable tool for examining the spatial relationships between destinations and transit and road networks.

Selecting a method. The method selected to evaluate access is dependent on three factors: (1) the specific type of access being studied, (2) the measure of accessibility desired, and (3) how the findings will be presented and used.

In most cases, one of four types of access will be of interest:

- **Access to basic services.** Access to basic services is a fundamental need of the population served by a transportation investment. This category includes access to necessities such as health care, education, and public safety facilities. Generally, access to basic services is measured from place of residence and is limited in geography to the local or community level.

- **Access to quality-of-life destinations.** Such destinations include shopping and recreation centers, places of worship, and other cultural opportunities. An evaluation of access to quality-of-life destinations may require analysis at more than one geographic level.

- **Access to markets.** {xe "Market access" \t "*See* Accessibility, types of access"}Market access is a broad category that can include access to employees by major employment centers, access to jobs by potential workers, and access to both suppliers and customers by businesses. An individual's access to employment centers and businesses' access to labor may or may not have identical geographic study areas for any given project.

- **Local access.** The ability to travel to and from specific sites is a concern for both households and businesses. Fences, lack of sidewalks, difficult street crossings, absence of parking, complicated one-way street systems, and vehicle-turn restrictions can affect local access to affected homes and businesses.

In general, one can use a combination of four different measures to quantify the effects on accessibility of a transportation investment. These measures are:

- **Change in travel time.** This is a measure of the time it takes to access specific destinations before and after the proposed transportation project. There are two approaches to evaluating changes in travel time. The affected population might be interested in travel-time changes to destinations to which it *already* travels. Conversely, the affected population might be interested in what new destinations could be reached within a given travel time.

- **Change in travel costs.** Travel costs encompass several components, including VOC (generally fuel costs and vehicle wear and tear), parking costs, and transit fares. For businesses, an area is made more accessible if a transportation project decreases the cost of receiving supplies or shipping output. For individuals, changes in travel costs can affect access in a number of ways. For example, a transit investment may make suburban jobs accessible to newly served populations by cutting VOC and high parking costs. Conversely, increased parking costs at down-town parking facilities may decrease accessibility to shopping and services for populations unable to pay them.

See:

- Section 2: Changes in Travel Time, p. 13.
- Section 4: Changes in Vehicle Operating Costs, p. 43.

- **Change in number of choices.** As mentioned above, a transportation investment might increase (or decrease) the number of destinations reachable within a given travel-time distance for an affected population. Travel time is one measure of this effect; the actual number of shopping centers, medical facilities, recreational facilities, or other destinations within the target travel time represents another measure of access.

- **Change in market reach.** Change in market reach is a measure of how access affects business competitiveness and economic development. For businesses, the issue is whether the transportation investment increases or decreases the number of potential suppliers or customers to which they have access. Market reach might be presented in terms of a specified time or operating cost constraint.

See:

- Section 8: Economic Development, p. 107.

WHEN TO DO THE ANALYSIS

Accessibility analyses are best carried out when alternative transportation projects are being designed. How accessibility effects are examined will depend on the intended use of and audience for the information. There are three general levels of analysis:

1) **Binary (yes/no).** In some instances, it might be sufficient to answer questions of accessibility with either a "yes" or a "no." For example, residents of a community affected by a transportation project may simply want to know if a grocery store is or is not within a reasonable walking distance of their neighborhood. An analysis of access that can be presented in a binary format is generally simple to conduct, and the results are easily understood by a broad audience. Such an analysis, however, does not lend itself to ranking among alternatives, as there is no distinction between choices that both report a finding of either yes or no. Generally, yes/no answers are not sufficient for an environmental impact statement, in which decision-makers are comparing accessibility among several alternatives. A matrix that includes yes/no information for a variety of different access issues can provide a good tool for screening alternatives.

2) **Maximum impact option (continuous measure).** When it is important to be able to compare access characteristics across alternatives, actual numerical values of travel time savings and operating costs related to the access provided by each alternative are important. In such cases, the accessibility effects are best reported as the actual change in travel time, operating costs, number of options, or market reach (measured in miles or in the number of suppliers or customers within a given travel time). For residential populations, information presented in this form is used to answer questions regarding changes in travel time and travel cost to the nearest shopping center, hospital, school, or other community service. To assess business accessibility, the data might be presented to indicate travel time to the nearest Interstate for interstate shipments. Presentation of accessibility effects in these terms is common for the environmental review process, as well as for inclusion in benefit-cost analysis. One drawback of this presentation technique is that it relies on information from a traffic impact model, which may not be available.

3) **Weighted values (utility score from gravity model).** Alternative transportation investments might increase (or decrease) access to a number of destinations. For example, one option for a new transit investment may connect several residential neighborhoods with a number of employment centers; alternative options would provide different services to these neighborhoods and employment centers. Furthermore, the project would increase the accessibility of some employment centers more than others. In this situation,

one may be interested in more than the travel time to a center and the number of employers made accessible. One may also need to know the relative importance of access to different kinds of centers such as educational or childcare facilities. The issue of relative importance can be addressed by assessing alternatives using weighted values for access. To estimate weighted values, a gravity model is used. A gravity model sums up all available destination options within a reasonable distance from a given location and weights each by its size (an increasingly positive weight as size increases) and distance squared (an increasingly negative weight as distance increases). It is noteworthy that this approach is routinely used in travel demand models to forecast how many trips will be made to each destination from a given origin. It is thus feasible to apply this approach when a transportation model has been developed. What is relevant for measuring accessibility is that the sum of the scores for all available destinations provides a composite rating of a transportation investment, based on the level of access it provides to a variety of destinations. Transportation improvements that reduce travel times or costs to one or more of the destination alternatives will improve the composite rating (depending on the number and size of destinations with improved access, and the time savings involved).

See:

- Method 5, pp. 91–94.

Each project is unique in terms of the type of access, the measure of interest, and the appropriate presentation technique. Any or all of the above may be relevant to the evaluation. One needs to decide which elements are pertinent prior to selecting a research method and proceeding with the analysis.

STEPS IN THE ANALYSIS

Following are the basic steps of an accessibility analysis. Although the steps may vary slightly depending on the chosen method, in general they form the foundation of any estimation of accessibility.

Step 1. Identify key origins and destinations.

It is first necessary to specify key origin-destination (O-D) pairs for which accessibility improvements are of interest (e.g., home-work, home-school, home-recreation, home-shopping, place of employment-shopping/services, business-customers, or business–suppliers).

The type and scale of the transportation system change, the reason for the change, and the motivation for the study will each influence the choice of linkages to be evaluated. The geographic impact area of the project will also influence the choice of origins and destinations. For example, a project that restricts left turns along an arterial roadway generally will affect a localized market area. This type of transportation change would usually affect access to shopping, work sites, and services. Restrictions of left turns in a limited area would not be likely to affect shipping over long distances. Conversely, if the project under study is regional or super-regional in nature (such as a major new highway between two distant cities), key origins and destinations might include localized access issues related to the effects on businesses along a community bypass, as well as effects related to business access to suppliers and customers. Projects might also create barriers that inhibit neighborhood access to schools, shopping, and houses of worship. Such effects are discussed in more detail in the section on community cohesion.

See:

- Appendix C: Travel Demand Modeling, p. 217.
- Section 7: Community Cohesion, p. 97.

A variety of techniques are available for identifying key origins and destinations. Community stakeholders, neighborhood groups, businesses, and other affected parties can be asked to identify travel patterns, origins, and destinations. Alternatively, aerial photographs and maps may provide relevant information. More detailed and information can be collected through travel diaries.

Step 2. Measure current level of accessibility between origin-destination pairs.

To measure the *change* in travel time, cost, or reliability between two key activity nodes, it is first necessary to measure the current level of accessibility. To identify current levels of accessibility, one must first define the boundaries of the affected (or study) area. Once the impact area is defined, the location and number of origins and destinations (by trip purpose) within this area can be calculated. Using (1) simple mapping techniques; (2) information on roadway geometry from local, regional, or state transportation agencies; or (3) a travel demand model, the travel time and travel costs for these O-D pairs can be calculated for the no-build or base case alternative.

Step 3. Estimate the accessibility between key origin-destination pairs for each alternative.

Paralleling Step 2, one must estimate the level of accessibility between key points that would be provided by each alternative. This again entails defining the boundaries of the affected area. Note that if the measure of interest is the number of destinations reachable within a specified travel time, the geographic boundary of interest may change for each alternative. After origins and destinations are identified, the techniques listed in Step 2 can be used to estimate the travel time and travel costs for the O-D pairs for each alternative. Note that Steps 2 and 3 can (and should) be calculated separately for temporary construction effects and longer-term effects.

Step 4. Estimate accessibility effects in terms of cost.

To calculate this effect, the accessibility measures for the base case are subtracted from accessibility measures calculated for each alternative. This can be done using averages or totals by geographic area, specific population, business segment, or other defining characteristic. The difference is the actual change in accessibility by alternative. The results can be presented in matrix form to allow easy comparison among alternatives.

The measures of accessibility closely parallel and, in many cases, overlap with measures of community cohesion, traffic effects, business competitiveness, neighborhood disruption, and economic development. To avoid double-counting, one must be careful not to add together results from these various categories of effects.

METHODS

There are several methods currently available to gauge the accessibility effects of a transportation investment. A representative sampling of methods is presented in order from the most basic methods that require few resources and limited expertise to the most advanced methods that involve somewhat complex modeling techniques.

Method 1. Interviews, focus groups, and surveys

Information collection. Interviews, focus groups, and surveys are used to ask affected groups about:

- Their existing transportation needs;
- Trip origins and destinations by trip purpose;
- Acceptable travel times and costs for various trip purposes;
- Choices for various trip purpose destinations that fall within acceptable time and cost limits; and
- Attitudes regarding how alternative transportation improvements will affect travel times, costs, reliability, and choices.

The questions asked in the interviews and surveys are bound to differ based on the trip purpose for which accessibility effects are being measured.

Analysis. The information collected through the interviews, focus groups, and surveys must be analyzed to identify common travel needs, destinations, expectations in terms of travel times and costs, and the expected effects of alternatives. One can group similar responses to quantify needs and expectations. Alternatively, surveys and interviews can be designed for computer entry to allow cross tabulation of results.

See:

- Appendix B: Survey Methods, p. 211.

Measurement and presentation. The effects most often measured using interviews and surveys include (1) changes in travel times, (2) changes in travel costs, (3) changes in reliability of travel, and (4) changes in geographic area of accessibility and thus in the number of accessible destinations. Provided that a range of potential types of users of the transportation system are interviewed or surveyed, effects can be measured for a variety of trip purposes, origins, and destinations.

Assessment. Surveys, interviews, and focus groups best measure current behavior, rather than hypothetical responses. These approaches are a good way to learn about trip origins and destinations by trip purpose and about current means of transportation. Information on where or how people may wish to travel is, of course, useful, but cannot be regarded as quite as definitive as factual or behavioral data. It is only natural for people to want more choices in terms of destinations or travel modes, but it may be hard for respondents to accurately estimate what their actual behavior would be if a wider choice set were to materialize. That said, patterns in responses regarding desired destinations and transportation modes can occasionally be good general predictors of what behavior would be if a new transportation option were to become available.

Method 2. Site analysis

Direct observation through site analysis requires one to go into the field and walk or drive the study area.

Information collection. Site analysis provides one with first-hand knowledge of the study area. It is possible to directly measure distances and travel times, identify barriers, and document origins and destinations. Data can be recorded using aerial photographs and maps; photographs of the site provide a permanent record of the study area for later analysis and review.

Analysis. A site analysis provides hard data for the base case or existing conditions. Travel times and costs for access by most modes can be measured (or estimated) and recorded. The number of destinations—and the character of these destinations—within a specific travel distance from specific origins can be identified. For projects that need to analyze several potential alternatives, it is necessary to supplement site analysis data with data on changes in travel speeds, expected barriers, and changes in geographic areas of access. This information might come from transportation agencies or might require the use of rules of thumb regarding speeds associated with alternative design standards and roadway geometry.

Measurement and presentation. Site analysis provides a foundation for measuring accessibility effects including (1) changes in travel time, (2) changes in number of destinations accessible within a given travel time, and (3) changes in travel costs and reliability.

Assessment. First-hand data collection can provide a useful perspective on measures of accessibility. Particularly in studies of small geographic areas, it is possible to acquire a clear understanding of how a transportation project would affect local accessibility. On the other hand, this type of analysis will not necessarily provide a clear perspective regarding social and political factors that might influence travel patterns and choices of destinations.

Site analysis can supplement interviews and surveys; combining the two techniques will provide both an understanding of local perspectives and an unbiased assessment of conditions, opportunities, and barriers. This type of analysis is especially useful for estimating the probable effects of construction disruptions on accessibility. In combination with interviews of residents and operators of businesses, it is possible to gain a clear idea of who would be affected and how.

Method 3. Maps and aerial photographs

Maps and aerial photographs provide an important, low-cost, efficient tool for assessing effects on access (see Weisbrod et al. 2000). They allow identification of specific origins and destinations, and, used with care, they can pinpoint barriers and potential bottlenecks. Topographical maps and aerial photos can be used to identify geological and other natural and man-made barriers (e.g., utility lines).

Information collection. Supplemental information regarding the number of signalized interchanges and other impediments to uninterrupted travel will need to be collected from local, regional, or state transportation agencies so that travel times can be accurately estimated. Published sources such as the Census Transportation Planning Package (CTPP) and the Census of Population can provide data on the number of households and number of employees within a given geographic area.

Analysis. For the base case, the distance between origins and destinations can be estimated using a ruler and the scale of miles. For proposed alternatives that do not follow existing routes, one may need to measure distances using string and the scale of miles. To estimate travel times, information from local transportation agencies or published sources (e.g., AASHTO 1977 or TRB 2000) can provide rules of thumb for speeds for alternative classes of roadway improvements. Two examples follow of how maps can be used to analyze features of an area's accessibility.

Example 1: Access to a new facility. In this first example, the objective was to determine whether a particular highway alignment would optimize local access to the highway. The selected measure of access is the number of persons who can reach the proposed highway facility within a 5-minute drive.

> **Step 1. Obtain data: population and transportation.** Figure 6.1 shows a map depicting a highway facility and population displayed as dots. The map was generated from data obtained from the Census Bureau. The CTPP enables users to produce a dot-point map showing population, households, and employment stratified by income and other attributes.
>
> **Step 2. Perform travel time analysis.** Each dot in the map represents 250 persons. Our objective was to identify the number of households within a 5-minute drive of a particular interchange. In the illustration below, 1 inch equals roughly 2.5 miles.
>
> Assuming an access speed of 15 mph, 1 mile is traveled every 4 minutes. In 5 minutes, then, 1.25 miles can be traveled. To calculate the number of persons within 5 minutes of the interchange, we can draw a circle of radius 1.25/2.5 inches (or 1/2 inch) wide. The number of persons within that boundary, as represented by the dots, would then simply be counted—in this case the total equals 41 dots or 10,250 persons. These people will have 5-minute access to an Interstate facility that will provide high-speed access to major cities and employment opportunities.

Figure 6.1. Accessibility analysis, Example 1

Note: 1 inch = 2.5 miles; each dot = 250 persons

Example 2: Access of households to an employment center. Figure 6.2 is a map of the major transportation facilities in a city. The figures on the map represent the number of households in municipalities, districts, and other jurisdictions in the area. The map is generated by the CTPP package, available free of charge from the U.S. Census Bureau. As an example, suppose that we need to find out how many households are within 20 minutes of the city. Even if one does not have access to a transportation model and a GIS, there are several ways to obtain this information. The destination (our city) and the travel times are fixed, and we wish to know how many households are within the 20-minute travel distance. Let us suppose that the purpose of the analysis is to estimate the local population's access to an employment center.

Step 1. Obtain data: households by zone. Household data for municipalities around our city are displayed on a map obtained from the U.S. Census Bureau. The map includes major transportation facilities.

Step 2. Perform travel time analysis. A simple approach to estimating travel times is to determine points on the compass and to draw a box whose width and height correspond to estimated speeds along each of the compass points. According to the map, points in the northwest and northeast quadrants have very good access; the southeast and southwest have poorer access; the south has the least access to high-speed facilities.

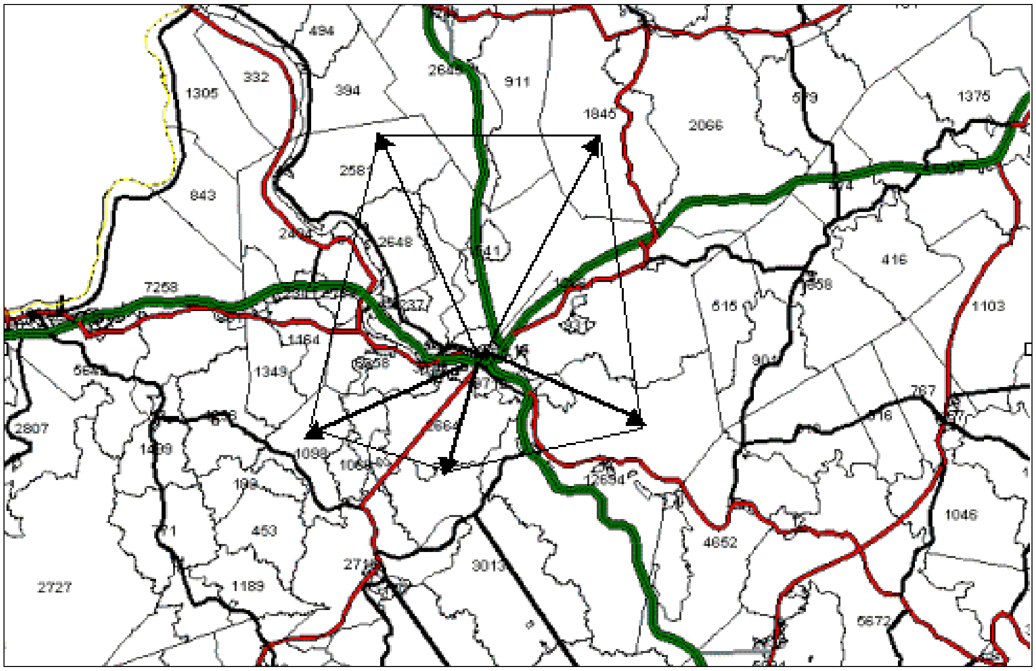

Figure 6.2. Accessibility analysis, Example 2

Note: 1 inch = 10.7 miles

Suppose we determine that the average speed from the city center to the northwest and northeast is 40 mph; to the southeast and southwest, it is 35 mph; and to the south, it is 30 mph. Using the map scale to determine the distance traveled as recorded on the map, we would make the following calculation for the northwest and northeast:

$$\frac{40 \ \text{miles}}{\text{hour}} \times \frac{1 \ \text{hour}}{60 \ \text{min.}} \times 20 \ \ \text{min.} \times \frac{1 \ \text{inch}}{10.7 \ \text{miles}} = 1.25 \ \text{inches}$$

We could then draw an arrow 1.25 inches in length from the center of the map to the northeast and northwest to depict the ability to travel to it within 20 minutes. After making similar calculations for the remaining directions, we could draw a line connecting each of the arrows at their end points. The area inside the figure we have drawn corresponds to the area within 20-minute access from the city center.

Step 3. Count the households. We then count the number of households inside the area defined by the line we drew. In most cases, the defining line will cut through polygons containing household counts. If the area has been geocoded, a GIS can be readily applied to determine the portion of the polygon that is included within the area defined by our line. Failing that, one can use a small grid overlay to estimate the portion within the line. One then multiplies the included portions of each polygon by its number of households and sums the results for all polygons.

Measurement and presentation. The use of maps and published sources for rules of thumb can provide simple estimates of the same effects on accessibility as primary data collection and analysis: travel times, travel costs, reliability, and number of destinations by trip purpose.

Assessment. The use of maps provides a low-cost, efficient method for estimating the accessibility effects of transportation projects. We should stress, however, that without direct input from the affected populations and a good working knowledge of the site, this technique is susceptible to error. For example, this technique does not allow one to evaluate the characteristics of specific destinations, so it is possible to over- or underestimate the importance of a particular activity center as a destination. Furthermore, destinations such as medical clinics may not be discernable from the maps. This approach is best used for measuring accessibility between major jurisdictions. It is much less appropriate for use at the microlevel.

Method 4. Spreadsheet analysis

The capabilities of computer spreadsheets enable one to organize data on distances between various origins and destinations, as well as specific information about the routes linking them, including signalization, traffic flow speeds, intersection delays, and other characteristics (see Weisbrod et al. 2000). As a result, it is possible to carry out efficient analyses of how the project would affect various aspects of accessibility. Spreadsheet tables also represent an alternative to map-based calculations and presentation methods.

Information collection. As was discussed in Sections 2 through 4 of this guidebook, it is not especially difficult to assemble data that approximate the value of travel time, typical flow speeds for various roadway designs, and crash rates and costs. These data are largely available from published sources and transportation agencies. To estimate the effects of a proposed transportation project on accessibility, one must assemble such data on both the base (i.e., unimproved) case and the facility as if the project were to be undertaken.

Analysis. The data collected for the base case are entered into a spreadsheet, and existing travel times between origins and destinations are calculated. Using appropriate time values, travel times can be easily converted into monetary values. VOC and crash costs can similarly be estimated, and the three values can be combined to estimate travel costs for the base case. To estimate the value of travel time for the improved roadway, changes in design standards and thus average flow speeds are taken into account. Likewise, VOC and crash costs for the improved facility can be entered into the spreadsheet, and associated changes in costs can be calculated.

Example. An alternative approach for measuring access to an employment center near a proposed highway interchange is to develop a spreadsheet to analyze existing data on travel times and household characteristics using data from the CTPP. The CTPP is available on CD-ROM for metropolitan areas and contains demographic data such as employment and households, as well as self-reported journey-to-work travel times between fairly aggregate origins and destinations. To use this data to estimate accessibility to the employment site discussed earlier, one would take the following steps:

Step 1. Obtain household data by zone. The CTPP provides data on the number of households by jurisdiction. These data can be downloaded and printed or imported into a spreadsheet application.

Step 2. Obtain data on travel times by zone. The CTPP Part C provides data on average and median journey-to-work travel times from all jurisdictions to central cities within metropolitan statistical areas (MSAs). The CTPP software allows the user to sort these travel times by destination. These data also can be printed or imported into a spreadsheet application. Travel times between suburban communities are not yet available through the CTPP.

Step 3. Match household and travel time data. The household and travel time data are stored in separate files that, for the purposes of the analysis, must be merged. Although this can be done manually, it is tedious work, and it is therefore preferable to write a fairly simple program to accomplish the task. Alternatively, the "pivot table" feature of spreadsheets such as Microsoft Excel may be used to sort and summarize data from multiple sources. Merging the data requires a piece of data common to each source. In this case, one can use the name of the jurisdiction, or the Federal Information Processing System (FIPS) codes.

Step 4. Count total households whose travel times are within the threshold. Table 6.1 presents a list of jurisdictions within 20 minutes of a central city using data from Part C (journey to work) and Part A (place of residence) of the CTPP.

Table 6.1. Households within 20 minutes travel time from a central city

Municipality	Travel time to central city (minutes)	Total households
A	5.0	3,413
B	15.0	3,115
C	15.2	3,913
D	10.3	15,575
E	20.0	931
F	15.0	6,440
G	20.0	9,438
H	4.7	5,989
I	12.0	1,613
J	20.0	2,359

Measurement and presentation. Spreadsheet techniques are one way to systematically measure differences in accessibility among transportation alternatives. All of the typical measures (including changes in travel time, VOC, reliability of travel time, and number of destinations by trip purpose within a specified travel time) can be calculated by individual road segment and summed for the entire route under consideration. The results can be reported in matrix form to allow easy comparison across alternatives.

Assessment. Spreadsheet analysis develops quantitative measures of accessibility using computer software that is widely available. The greatest drawback to this method is that the collection of related data such as roadway geometry and number of existing signals can be time-consuming, and such data may not be readily available.

To keep the analysis as simple and easy to accomplish as possible, simplifying assumptions can be made as needed. For example, travel times can be based on speeds estimated in the field, rather than taking into account signalization and the like. A number of public agencies and consulting firms routinely use spreadsheet analyses because once the basic data are assembled, numerous analyses can be carried out quite readily, and the results can be presented graphically.

Because this method uses simplifying assumptions and approximations, it is not as accurate as more advanced methods, such as travel demand models. On the other hand, the widespread knowledge of basic spreadsheet software among transportation professionals makes this a highly usable method.

Method 5. Gravity models

Gravity models measure the accessibility effects associated with a change in market opportunities, such as residential access to workplaces or shopping centers, or business access to labor markets or customer markets. This method can be carried out using straightforward spreadsheet-based calculations.

The basic concept behind gravity models is that the proportion of trips going from any given origin to any given destination is (1) positively related to the level of attraction associated with that destination, such as the number of jobs or stores located there, and (2) negatively related to the distance (literally, the distance squared) or travel time to that destination. Gravity models are used in market studies to predict business sales effects of changes in travel times and distances to a shopping center (as discussed in Section 8 on economic development), and it is also used in traffic demand models to forecast patterns of trips (discussed later in this section). Gravity models calculate a measure of overall accessibility as the weighted average of changes in travel time for all affected O-D pairs. The weights reflect the number of trips actually expected to occur for each O-D pair.

Information collection. A series of origin and destination zones must first be defined. Depending on the nature of the project and its impact area, the zones may be very broad (e.g., individual counties, or townships, or communities), coarse subsets of a region (e.g., central city, northern suburbs, and southern suburbs), or fine zones (e.g., hundreds of traffic analysis zones in a metropolitan transportation network model). Estimates should be made of travel times between all combinations of zones for both the base case and project completion alternatives. For each area, data should be collected on population and employment. Population and employment typically are used to reflect the relative number of work trip productions (i.e., home locations) and attractions (i.e., destinations). Retail employment or retail square footage is commonly used to reflect the amount of shopping activity in a zone.

Analysis. The gravity model may be applied using a calculator or spreadsheet. Various alternative forms of the gravity model are discussed in resource documents listed at the end of this section. The most common formulation of the model estimates the number of trips going from any given origin zone (*i*) to any other destination zone (*j*) as

$$P_{ij} = \frac{A_j / T_{ij}^2}{\sum_n^{j=1} A_j / T_{ij}^2}$$

where:

P_{ij}	=	portion of trips going from zone *i* to zone *j*
A_j	=	attraction of destination zone *j* (e.g., employment or square footage of stores)
T_{ij}^2	=	square of the travel time from zone *i* to zone *j*
n	=	the total number of destinations
$\sum_n^{j=1}$	=	sum of the calculation for all possible destination zones *j* (1 to *n*)

The denominator of this formula (i.e., the summation over all zones) represents the composite measure of accessibility from zone *i* to all possible destinations. This calculation may be repeated for various situations:

- Residential accessibility to specific workplaces (where zone *i* is a place of residence, and A_j is measured as employment in zone *j*);
- Residential accessibility to shopping (where zone *i* is a place of residence, and A_j is measured as the amount of retail—either employment or square feet—in zone *j*);
- Commercial accessibility to workforce (where zone *i* is a business location, and A_j is measured as the population of workers residing in zone *j*); and
- Commercial accessibility to markets (where zone *i* is a business location, and A_j is measured as the population of consumers residing in zone *j*).

Note that by summing across all destination zones *j*, one estimates the relative accessibility of a particular destination zone *j* to an origin zone *i*, compared with the accessibility of all destination zones to the specific origin zone *i*. One could repeat this computation for all origin zones *i* to estimate how accessible the particular destination zone *j* is across the entire market area.

Example. A proposed transportation system improvement would provide faster travel to an urban retail district from the southern part of the city. The accessibility improvement to the urban retail district may be computed as shown in the two tables below:

Step 1. Obtain data on households and travel times. Obtain data concerning the potential shopper base in each major part of the urban area (i.e., the market area) and the change in travel times from those areas to the relevant shopping center, as illustrated below in Table 6.2.

Step 2. Calculate gravity model results. One must obtain data concerning the potential shopper base in each major part of the urban area and the change in travel times associated with building or not building the proposed highway. One then applies the gravity model formula to calculate an index of accessibility to each shopping center from each of the residential market areas, as well as a composite index of accessibility to each shopping center. The composite index is a weighted average of the accessibility from each market area, weighted by the number of households residing in each area. The numbers are calculated as shown below in Table 6.3.

Table 6.2. Gravity model input data on accessibility to a shopping area (j)

Market area: Place of residence (Origin i)	Total households (A_i)	Average travel time to shopping area (Gravity Model T_{ij})	
		Base case (current)	With new highway (proposed)
Central urban core	3,413	15	15
Northern suburbs	3,115	55	55
Southern suburbs	3,913	45	30
Eastern suburbs	15,575	40	38
Western suburbs	931	36	36

Table 6.3. Gravity model calculations of accessibility to a shopping location (j)

Market area: Place of residence (Origin i)	Gravity model index (A_i / T_{ij}^2)		
	Base case (current)	With new highway (proposed)	Percent change
Central urban core	15.2	15.2	0
Northern suburbs	1.0	1.0	0
Southern suburbs	1.9	4.3	+125
Eastern suburbs	9.7	10.8	+11
Western suburbs	0.7	0.7	0
TOTAL (composite effect on shopping location j)	**3.3**	**3.9**	**+19**

Measurement and presentation. The outcome of the above calculations represents the composite accessibility of residences to all available work or shopping destinations and the composite accessibility of businesses to all available consumer markets or workforce markets. For shopping centers, this calculation may also be used to estimate the portion of total retail spending going to each individual shopping center. By comparing this calculation for the base case with that for the proposed transportation project, it is possible to calculate a percentage change in accessibility. This can be interpreted as either a weighted average percentage change in travel times for residential accessibility, or as a proportional change in retail sales for shopping centers.

Assessment. For some transportation projects, it may be sufficient to define a simple set of 5 to 10 zones, and then calculate changes in accessibility between each pair (so that 5 to 10 zones would yield 25 to 100 pairs). This can be done using a calculator. Other cases, where there are complex changes in travel patterns, or larger numbers of affected zones, may be more easily handled with traffic forecasting models (discussed next).

Method 6. Traffic demand models

See:

- Appendix C: Travel Demand Modeling, p. 217.

Traffic demand models are transportation network models that forecast the effects of given travel demand (i.e., trip generation) and changing network performance (i.e., distance or speed) characteristics on overall traffic patterns (i.e., traffic volumes and times). They can be used to forecast changes in travel time and travel distance for any and all points in the transportation network, and they also provide forecasts of how proposed projects can change the performance of the transportation system in terms of systemwide changes in average speeds, travel distances, and travel times. These data can be used to assess changes in accessibility for individual zones or areas or for overall regionwide changes. A discussion of travel demand models (essentially the same thing as traffic simulation models) appears in Appendix C.

Information collection. Traffic demand models require specialized computer software. The models must be calibrated with network characteristics, including a zone system with data on population and employment, existing travel patterns, and the locations of network links and nodes. They also require measures of zone-to-zone travel times and distances by mode of travel for both the base case (i.e., no build) and project case (i.e., build) scenarios.

Analysis. Given the required data, traffic demand models provide:

- Estimates of changes in travel time for all affected O-D pairs;
- Estimates of the number of trips affected by the change in travel time between each O-D pair; and
- Forecast changes in the use of available transportation choices (i.e., mode options) and travel routes, as well as the resulting shift in each mode and the number of daily trips associated with each combination of travel mode and O-D pair.

Traffic demand models typically allocate trips to O-D pairs on the basis of CTPP data for commuting trips and gravity model estimates for shopping and other non-work trips. Given that allocation of trip patterns, the models then calculate the number of daily trips and average travel times and distances for each O-D pair.

Measurement and presentation. By aggregating zones, traffic demand models also measure the average change in travel time for work, shopping, and other trips associated with origins or destinations in any given region of the city. The output is a change in forecast systemwide traffic conditions, in terms of aggregate measures of congestion, total VMT, and total vehicle-hours of travel (VHT). These data can be used to estimate the effects of proposed projects on average travel times to and from any zone or group of zones, weighted by the number of expected daily trips.

Assessment. Traffic demand models are expensive and require technical training. As a result, they are primarily used by metropolitan planning organizations (MPOs) and state DOTs. Such organizations often have existing traffic network models and staff trained in using them. If adequate technical support is available, these models can be a valuable tool for assessing changes in accessibility of important destinations in the area affected by a proposed transportation project.

RESOURCES

The following documents provide further information regarding the methods and techniques used for measuring accessibility and assessing how a transportation project would affect it.

1) Bureau of Transportation Statistics. 1997. "Mobility, Access and Transportation." *Transportation Statistics Annual Report*. Washington, DC: U.S. Department of Transportation, Chapter 6, pp. 135–145, and Chapter 8, pp. 173–192.

   These chapters define and distinguish access and mobility in an historical context. There is little explanation of tools to measure "accessibility," but there is a discussion of factors that affect it.

2) Handy, Susan. 1993. "A Cycle of Dependence: Automobiles, Accessibility and the Evolution of Transportation and Retail Hierarchies." *Berkeley Planning Journal,* Vol. 9, pp. 21–43.

3) Handy, Susan. 1994. "Regional Versus Local Accessibility: Implications for Nonwork Travel." *Transportation Research Record 1400.* Washington, DC: Transportation Research Board, National Research Council, pp. 58–66.

   These two articles show the correlation between automobile-oriented transportation development and subsequent changes in patterns of accessibility to retail and service activity within metropolitan areas. They demonstrate how alternative land use and transportation patterns can affect trip distances, and they show how local access and broader regional access can be affected differently.

4) Federal Highway Administration. 1983. *Calibrating & Testing a Gravity Model for Any Size Urban Area*. Washington, DC: U.S. Department of Transportation. Available from the National Transportation Library at http://www.bts.gov/NTL/DOCS/CAT.html.

This document provides a technical definition of accessibility measurement, as implemented with gravity models in urban travel forecasting models. It explains how zonal accessibility measures are used with gravity models to estimate impacts of transportation projects on trip distances and the spatial distribution of trips in a metropolitan area.

5) Filipovitch, A.J. 1996. *Spatial Distribution Analysis*. Mankato, MN: University of Minnesota, Mankato, Urban and Regional Studies Institute. Available at http://krypton.mankato.msus.edu/~tony/courses/604/gravity.html.

   This document introduces basic concepts in spatial distribution analysis, focusing on the definition and application of gravity models to calculate market areas. The definition focuses mainly on the role of travel distance as an explanatory factor rather than using travel time measures that are more often affected by transportation projects. It does provide an example problem focusing on transit service impacts.

6) Weisbrod, Glen, and Roanne Neuwirth. 1998. "Economic Effects of Restricting Left Turns." *NCHRP Research Results Digest No. 231*. Washington, DC: Transportation Research Board, National Research Council.

   This document summarizes a study of how activity levels of retail and service businesses are affected by changes in local accessibility. Differential effects on various types of business are discussed, and readers are walked through a 14-step process to assess business impacts of accessibility changes. A gravity model calculation of accessibility is provided through a free spreadsheet available at http://www4.nationalacademies.org/trb/crp.nsf/All+Projects/NCHRP+25-04.

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Transportation Research Board. 2000. *Highway Capacity Manual*. Special Report 209E. Washington, DC: Transportation Research Board, National Research Council.

Weisbrod, Glen, Jinevra Howard, Margaret Collins, and Donald Vary. 2000. *Handbook for Asssessing Economic Opportunities from Newly Completed Segments of the Appalachian Development Highway System*. Washington, DC: Economic Development Research Group and Cambridge Systematics, Inc. for the Appalachian Regional Commission.

SECTION 7: COMMUNITY COHESION

OVERVIEW

Steps in the analysis	Methods
• Define the study area • Collect information from community leaders and groups active in the community • Spend time in the study area • Estimate the existing level of community cohesion • Extrapolate the project's effects on areas of relative cohesiveness	• Interviews, focus groups, and surveys • Site analysis • Maps and aerial photographs • Databases on structures

Definition

The term "community cohesion" is used to describe patterns of social networking within a community. The effects of transportation projects on community cohesion "may be beneficial or adverse, and may include splitting neighborhoods, isolating a portion of a neighborhood or an ethnic group, generating new development, changing property values, or separating residents from community facilities…" (FHWA 1987, p. 17). Displacement of businesses and residences resulting from a transportation project is an important related effect.

Estimates of the extent to which a proposed transportation project may affect community cohesion rely heavily on site analysis, self-reporting, and survey analysis. Measuring the changes in community cohesion resulting from a transportation project requires documenting existing patterns of community social networking (i.e., the base case) and then estimating the potential reduction of or increase in community interaction if the proposed project were built. Because this category of effects does not necessarily lend itself to quantitative measures and because the effects overlap with several other categories of effects (e.g., noise or distributive effects), community cohesion effects often get only limited attention. Yet, these effects can be substantial and important to those most affected by a transportation project—the residents and businesses located in the vicinity of the project.

Transportation factors affecting community cohesion

Changes in transportation systems can affect community cohesion in several ways. Transportation projects can create both physical and psychological barriers within a neighborhood or community or, conversely, may work to tie a neighborhood together (e.g., in the case of improved pedestrian facilities). The changes brought about by such projects may have the following direct and indirect effects on community cohesion.

- **Direct effects of household and business relocation.** Whether voluntary or involuntary, the relocation of households disrupts a neighborhood. The removal of residents can dismantle informal social networks upon which residents rely for ride-sharing, childcare responsibilities, or other reciprocal services—what economists might call the "social capital" within a neighborhood. Furthermore, if a large number of households are relocated outside the community, community facilities such as schools, churches, police and fire stations, and community centers may face declines in enrollment or demand that ultimately result in closure or reduced services. Business relocations may mean that residents need to look outside of their community for shopping and services, and some residents may lose their jobs or be forced to commute long distances to the site of the relocated business. Planners and decision-makers have become increasingly sensitive to the problems residential and business relocations create for a neighborhood. When relocations cannot be avoided, the associated effects on community cohesion need to be identified and mitigated to the degree possible.

See:

- Section 6: Accessibility, p. 77.

- **Direct effects of structural barriers** Wider roads, interchanges, and fixed-guideway transit facilities can create physical barriers between residents and community facilities where, prior to the transportation change, the facility could be accessed by an easy walk, bicycle ride, or short drive. In general, any transportation change that impedes pedestrian and local traffic in an area can hinder community cohesion. New or larger transportation facilities act as visual edges and boundaries: widening a facility can cut away portions of a neighborhood and isolate members of a community from their friends and neighborhoods. Conversely, transportation projects such as new pedestrian facilities or bikeways may have the opposite effect, improving connections between residents and community facilities.

See:

- Section 5: Transportation Choice, p. 55.
- Section 10: Visual Quality, p. 143.

- **Indirect effects of psychological barriers.** Increased or induced traffic resulting from a transportation project often creates serious psychological barriers that lessen the amount and quality of social interaction in a community. Traffic-related barriers to social interaction include increased noise and dust. Another serious indirect effect centers on the safety of neighborhood residents. Residents' safety decreases as traffic through their neighborhood increases, thereby decreasing their quality of life. Children are especially likely to be at risk when traffic through a neighborhood increases. As a result, transportation projects that increase traffic or widen facilities eventually may restrict children's freedom to walk to friends' homes or to play along the street within their neighborhood, as caregivers respond to the increased safety risk.

Special issues

Two major issues should be kept in mind when examining the possible effects on community cohesion of a transportation project.

Definition of impact area. To assess community cohesion effects, communities and neighborhoods must be defined spatially. Yet, an accurate spatial depiction of community or neighborhood boundaries usually presents a challenge. Neighborhood boundaries almost always feel arbitrary; anecdotes abound about the unfairness of analyses or policies that consider one feel arbitrary; anecdotes abound about the unfairness of analyses or policies that consider one side of the street but not the other. Nevertheless, such distinctions are inevitable. Working closely with city staff and neighborhood organizations can help one select the most appropriate boundaries for an analysis. As noted in other sections of this guidebook, the geographic scale of the analysis will change based on the nature and the severity of the transportation effect. When drawing boundaries, it is in general better to be inclusive and to gather as many viewpoints as possible, even if being inclusive reduces the precision of the analysis.

Equity concerns. Communities characterized by concentrations of ethnic groups may have unique value systems that differ in important ways from those of other populations in the region. For instance, some groups rely more on extended kinship structures than others. Furthermore, communities characterized by strong ethnic ties often support shops and community centers that cater to the tastes and customs of individual ethnic groups. Severing ties within *any* community is a serious concern for transportation analysts, but doing so in low-income and ethnic communities can be especially disruptive. Often, informal networks in communities exist for services (e.g., ridesharing and childcare) that neighborhood residents exchange with one another. Diminishing community ties can mean that residents will have to pay for services they had formerly traded.

Generally, the fewer personal resources an individual has, the more harmful the loss of community. Studies have shown that those who have lower incomes rely more on extended family as a source of social contact. Relocation of these households—or separation from their community or family by a transportation facility—may cause more social isolation than for those with higher incomes, especially when language presents a barrier to making new friends and forging a new social network.

WHEN TO DO THE ANALYSIS

Any time a transportation project would be likely to affect some aspect of how a neighborhood functions, an assessment of community cohesion and how it may change is called for. Generally speaking, community cohesion effects are best measured through working with neighborhood leaders and residents to identify the landmarks, facilities, and activities they value and to discuss how these might be affected by the proposed transportation project. Site review and mapping of key community facilities and activity patterns can also provide important information for estimating the community cohesion effects of a project.

Analysis of community cohesion must draw on other types of social and economic impact analyses to create a comprehensive picture of the neighborhood. Like economic development or changes in property value, neighborhood cohesiveness relies on an often-unpredictable amalgamation of neighborhood features and personalities. Noise, pedestrian safety, changes in property value, and changes in visual quality are all inexorably linked to the opportunities for—and, perhaps more importantly, the quality of—social life within a neighborhood. As with the other effects we discuss in this guidebook, transportation projects can exert both direct and indirect effects on community cohesion.

STEPS IN THE ANALYSIS

The estimation of changes in community cohesion relies quite heavily on one's experience, commonsense judgement, and the quality of public discussion and involvement. An analysis of community cohesion is inherently inexact, and a flexible, give-and-take approach to public involvement in estimating these effects is necessary. Although the following steps may vary slightly depending on the chosen method, in general they form the foundation of any estimation of cohesion.

Step 1. Define the study area.

One must work with city staff, community leaders, and, when appropriate, the general public to identify the boundaries of the study area. Census data on ethnic composition, income levels, and home ownership rates in the area may also prove helpful. Identification and mapping of community facilities, as well as geological and man-made barriers, will further help to establish the boundaries of the study area.

Step 2. Collect information from community leaders and groups active in the community.

Community leaders and civic groups have valuable, first-hand knowledge about the important social institutions in the community, important activity centers and gathering spots, and other features that bind the community together. They can identify community characteristics that are not apparent to an outsider charged with evaluating the community cohesion effects of a transportation project. Their participation also lends credibility to the analysis.

Step 3. Spend time in the study area.

To evaluate social networks and to estimate how a transportation project might affect those networks, one must get to know the study area. Site walks and visits to special community centers and gathering spots can provide important insights for the evaluation of community cohesion effects.

Step 4. Estimate the existing level of community cohesion.

Secondary data about the personal attitudes and social networking in a particular neighborhood generally do not exist, so first-person interviews and workshops are necessary to gain information about community cohesion in the study area. Sometimes, city-level neighborhood coordination or development officers may have administered a survey or conducted public outreach in a neighborhood recently enough that transportation analysts can use this existing data for their own work. When available, block-level census data that identify areas of relative demographic homogeneity can substitute (albeit, not always very well) for primary survey data. One can also map the results of the interviews and surveys to locate community facilities and to identify blocks or clusters of blocks that show relatively high levels of cohesiveness.

Step 5. Extrapolate the project's effects on areas of relative cohesiveness.

Currently used analytic methods provide little predictive information about how social networking within a community may change in response to a transportation project. With input and discussion from community stakeholders, however, it is possible to discuss ways that the project may discourage (e.g., by increasing traffic on neighborhood streets) or enhance (e.g., by providing new pedestrian access across existing facilities) opportunities for community interaction. Does the project bisect a cohesive, well-defined neighborhood? Does the project make it more difficult to walk to a neighborhood park or community center? How will other changes in the environment—such as increases in noise levels or a loss of visual quality—alter the quality of neighborhood activity?

See:

- Section 9: Traffic Noise, p. 129.
- Section 10: Visual Quality, p. 143.

METHODS

The following methods can help to ascertain the effect a transportation project may have on cohesion within a community.

Method 1. Interviews, focus groups, and surveys

Interviews, focus groups, and surveys can be used to collect first-hand information about social networking within the study area. Because community cohesion effects are very specific to each affected area, combinations of these methods are imperative in any assessment of community cohesion effects. Together, they provide a unique opportunity to gain a direct understanding about existing community facilities and important patterns of social networking, as well as about how community members feel the transportation project will affect their community. Often, information collected through these methods provides insights that could not be obtained in any other way. A brief example helps illustrate this point.

See:

- Appendix B: Survey Methods, p. 211.

Example. The Central Artery project in Boston, the largest transportation infrastructure project in this country's history, affects a wide range of residential and business communities. The project involves the removal of an elevated highway structure and its replacement with a tunneled highway under downtown Boston. The North End neighborhood in Boston is an ethnic community populated predominately by second-, third-, and fourth-generation Italian-American families. It is characterized by small, locally owned shops and eateries. This neighborhood was isolated from most of Boston by the elevated structure, and many planners assumed that removal of the elevated structure would be welcomed by the neighborhood. Yet, interviews revealed that many residents of the North End did not want the structure removed because it provided a barrier to keep out gentrification and to maintain the ethnic character of the neighborhood.

Information collection. To collect information using interviews, focus groups, and surveys, two initial steps must occur. First, one needs to identify candidates for participation in the study.

When studying community cohesion, it is often useful to include two different groups of participants. One of these groups should be made up of community and neighborhood leaders. These might include clergy, business owners, youth program staff, day care providers, community activists, and others who have access to special interest groups in the community. The other group should be composed of a broad range of residents of the affected community.

The second step in information collection is the design of a questionnaire, interview guide, or survey form. If interviews or focus groups are used to collect data, the information collection tool can be less structured, with open-ended questions that allow for follow-on discussion. Often it is through discussion, not structured questions, that real concerns regarding community cohesion effects are uncovered. If a survey is being administered to a broader audience, the questions need to be designed to allow for shorter, more structured answers. The subjects that should be covered in the questions on surveys include the following:

- Location of community-serving stores and services;
- Location of community service facilities such as houses of worship, senior centers, day care centers, and youth centers;
- Location of community recreation facilities and parks;
- Special populations served by these facilities and their location within the community;
- Identification of pedestrian pathways and commonly traveled routes; and
- Other issues specific to the community and relevant to community cohesion that might not be known until the interview process begins.

Analysis. General guidelines for the development of structured survey questionnaires can be found in Appendix B. In general, the analysis of the results of focus groups, interviews, and surveys can be accomplished in one of two ways. Interviews and focus group discussions do not lend themselves to statistical analysis or measurement, but they provide perhaps the richest source of available information related to community cohesion issues. One needs to review the information collected and develop a catalog of potential effects. This can take the form of a list or database. The database might include information on the type of activity or facility affected, the location of that facility, the location of the affected population, and the utilization of the facility. Using this database, and with help from community leaders and residents, one can then begin to identify the most critical effects, as well as potential mitigation measures.

Measurement and presentation. The most effective means of presenting the results of focus group discussions or personal interviews is a simple listing of specific concerns voiced by participants. When possible, it is a good idea to indicate which of these concerns emerged as most pressing and which were mentioned, but not emphasized. In effect, the results of these discussions and interviews become a checklist in a series of potential effects about which residents are concerned.

Assessment. Focus groups, interviews, and surveys are extremely flexible, and one can tailor questions to the neighborhoods of interest. They provide the opportunity to collect first-hand information about the neighborhood (e.g., travel patterns and employment locations). Like all of the methods that require the collection of primary data, these methods can be expensive and time-consuming. Survey design is not a trivial task: development of long, complex questionnaires is often best handled by people experienced in survey methods.

Method 2. Site analysis

To fully understand how a project will affect community cohesion, one is well advised to spend some time in the community or neighborhood, walking the common routes used to access community facilities, recreation facilities, shopping areas, and services and speaking with people about the effects of the project on the community.

Information Collection. Information is collected through visual observation and informal discussion. It is often useful to photograph community facilities, shops, services, and recreation facilities to document utilization of these important community features. Photographs also help one recall specific features after leaving the area.

Site inspection for evaluating relocation effects is somewhat more formal. Using assessors' maps with the transportation project transposed on the maps, one may need to walk the corridor to identify the structures that will be razed to build the project and the current uses of these structures. For commercial or industrial buildings, it is a good idea to record the names of the businesses using the structure, a task that is not always simple. In some cases, it may be necessary to inquire at the facility to identify all businesses located on the site. A contact should be identified to collect follow-up information about number of employees, years in operation, and other pertinent characteristics. Similarly, one might need to count the number of mailboxes at a residential building to estimate the number of residences that are located at a particular address. All data collected in this way need to be recorded by address.

Analysis. Site inspection provides first-hand knowledge of how a proposed transportation project would be integrated into a community, how it would be used by community residents, and the potential effects of the project on significant features of the community. Although site inspection is qualitative, the information collected can be paramount to understanding the results of interviews, focus groups, and surveys, and to effectively mapping information (see Method 3, below). For assessing relocation effects, site inspections can be used with assessors' data to identify the use of buildings, vacancies, and other information (see Method 4, below).

Measurement and presentation. Two types of presentation media are effective for conveying the results of a site analysis:

1) An annotated listing of buildings to be razed, along with the names and types of businesses that currently occupy them or descriptions of households that reside in them (e.g., number and ages of persons, ethnicity, and whether any residents have disabilities).

2) Photographs of the buildings and other facilities corresponding to the above listing. Emphasis should be placed on structures and facilities that the site analysis revealed are important to residents and that may be removed or in some way harmed by the project.

Assessment. No amount of data collection, interviews, or other information-collection techniques can substitute for knowledge gained through first-hand observation of the communities and neighborhoods that will be affected by a transportation project. Furthermore, the credibility of the analyst with the affected population will be boosted considerably by the demonstration of first-hand knowledge of the study area. At no time is this credibility more important than when discussing community cohesion effects.

It is worth noting that the photographs taken as part of the site analysis can be an effective tool to use in public meetings and workshops. They can be attached to maps to illustrate the facilities at specific locations, and they can be blown up to emphasize the importance of a facility to the affected community. They provide further evidence to the community that the analyst has a grasp of the community cohesion issues raised by the transportation project.

Method 3. Maps and aerial photographs

Information on community facilities, community-serving shops and services, and other community activity centers or unique populations can be mapped using topographical maps, street maps, aerial photographs, or GIS technology to provide a good visual picture of how a transportation project will affect community cohesion. A clearly depicted map can be a highly effective means of showing which facilities will be isolated from the population they serve. Conversely, mapping can be used to identify alternative ways to access facilities, thus mitigating the effects of a project.

Information collection. Maps of various sorts are available from community planning agencies, the U.S. Geological Survey, and state DOTs, among other sources. Aerial photographs may also be available from planning agencies or DOTs.

Information to record on maps and aerial photos will come from a variety of sources. Census data can be used to map the location of special populations (e.g., ethnic clusters, low-income groups, and elderly housing). Information collected through interviews, focus groups, and surveys also can be used to site community facilities and activity nodes. Assessors' records may provide additional information about the exact location of community facilities. The location of the transportation project should also be mapped to allow analysis of how the project relates to special populations, community facilities, activity centers, and recreation facilities.

Analysis. The graphic display afforded by appropriate maps and aerial photos allows for an easy visual interpretation of how the transportation project will affect community cohesion. By reviewing the information displayed in this manner, one can quickly identify where social networking would be interrupted by the transportation project, as well as potential options for mitigating effects.

Measurement and presentation. Maps and aerial photographs can be presented to residents of the affected area and to decision-makers using a variety of media. Slides and computerized images can be projected onto screens in public meetings. It can be especially effective to provide a simple map with the vantage point of the photographer indicated. Special considerations affecting community cohesion can be noted as one presents the maps and associated photographs in public meetings or workshops.

Assessment. Information presented on maps and aerial photographs can be a powerful tool for understanding the effect of a project on neighborhood and community cohesion. These media provide graphic representations for use in public outreach meetings and workshops, allowing participants to visualize how the project will affect their neighborhood and community facilities. Even though the information generally cannot be quantified, a sense of the magnitude of the effect can be realized through these visual techniques.

Method 4. Databases on structures

For relocation effects, it is important to develop a database of information about the structures to be removed, as well as options for relocation of occupants (e.g., households and businesses) within the community.

Information collection. First, the properties to be razed must be identified. This can be done either by drawing the transportation project on assessors' maps and identifying structures to be torn down (this will have to be verified in the field, as assessors' data are not always up-to-date), or by conducting a site inspection and mapping structures to be taken. Then, a database of information about each structure should be developed. The database should include the following information for each structure: current use, size, number of businesses, number of residential units, occupancy, number of employees (for businesses), value, rental rates, and ownership status (owner versus renter occupied). Sources of information include:

- Assessors' records for building size, value, and use (building footprint and number of stories can be used to estimate the size of a commercial building);

- Realtors for estimates of rental rates and property values, site analysis for information about number of units, and types of businesses; and

- Surveys or interviews (for information about number of employees, reliance of businesses on neighborhood clientele, ownership status, and rental rates).

Additional information it may be wise to collect includes community-wide vacancy rates, rental rates, property values, and characteristics of vacant or soon-to-be-available structures within the community (number of bedrooms or square feet of commercial or industrial space) to identify opportunities for relocating households and businesses within the same community.

Analysis. A database on relevant structures provides a description of each property to be removed from its current use, along with the options for relocating affected businesses and residences within the same community. The database can be used to tabulate the number of businesses, employees, and residents that will need to be relocated and the value of the properties to be taken. Additionally, the database can be used to match dislocated businesses and households with potential new locations within the community.

The extent to which matches cannot be found represents the level of permanent dislocation that will occur. It is the case, of course, that any relocation can be thought of as a permanent dislocation. In this guidebook when we use the term permanent dislocation, we are using it in the context of community cohesion; thus, we can assume that relocation within the same community would limit negative effects on community cohesion.

Measurement and presentation. Residents and decision-makers benefit from comprehensible information on how a proposed transportation project would affect the functioning and ambience of their community. An easy-to-read tabular presentation of buildings to be razed, along with a listing of businesses and the number of households occupying them, is important to community awareness of how they would be affected. A map showing the locations of these buildings and a summary of how the respective land parcels would be used if the project were to be carried out also can be valuable.

Assessment. The use of a database to collect and record information about dislocation effects provides an organized approach to assembling and reviewing information about the characteristics of businesses and households that would be forced to relocate as a result of the transportation project. Furthermore, it provides an easy-to-use format for matching dislocated businesses and households with relocation options within the community.

RESOURCE

Howard/Stein-Hudson Associates, Inc., and Parsons Brinckerhoff Quade and Douglas. 1996. "Chapter 3: Getting Feedback from Participants." *Public Involvement Techniques for Transportation Decision-making*. Publication No. FHWA-PD-96-031. Washington, DC: Federal Highway Administration and Federal Transit Administration.

This chapter provides examples of how public opinion surveys and focus groups have been used, what they are, why they are useful, and special uses for them regarding transportation projects. Brief examples of completed surveys are used to supplement descriptions. In addition, this chapter provides information on the use of focus groups for transportation projects. It describes basic features, why they are useful, special uses, and other important information about their use. Instances in which focus groups have been used are briefly detailed.

REFERENCE

Federal Highway Administration. 1987. *Guidance for Preparing and Processing Environmental and Section 4(F) Documents*. FHWA Technical Advisory T 6640.8A (October 30). Washington, DC: U.S. Department of Transportation.

SECTION 8: ECONOMIC DEVELOPMENT

OVERVIEW

Steps in the analysis	Methods
• Measure the transportation factors affecting economic development • Estimate the direct effect on business competitiveness • Estimate the direct effect on business growth or decline • Estimate indirect, induced, and dynamic effects on economic development	• Expert interviews • Market studies • Case studies • Computer models • Input-output models

Definition

Economic development is the process through which economic activity in an area is expanded to provide more jobs and income to the area's residents. The primary means of economic development are business startup, expansion, attraction, and retention. Economic development policies are generally designed to improve the quality of life in an area by increasing:

- **Income**—the economic well-being of area residents is enhanced by increased wage levels. Also, larger numbers of workers generate more income in the area.

- **Job choices**—opportunities for personal well-being and income growth in an area are improved when there is an increase in the types of jobs available there (particularly those involving higher skills, more attractive work conditions, and higher pay).

- **Activity choices**—quality of life can be improved by expanding opportunities for shopping, dining, and social and entertainment activities in (or accessible to) an area.

- **Stability**—the stability of jobs and income in an area increases as its economy becomes more diversified. Stability also reduces its vulnerability to economic downturns caused by an over-reliance on mature industries and on those subject to severe business-cycle fluctuations.

- **Amenities**—beautifying an area or adding cultural and recreational facilities can make it more attractive to workers and businesses that collectively bring additional income and jobs to the community.

Other related effects are sometimes also of interest. For instance, greater income and business growth may lead to increases in the local tax base of an area. These increases can help make it possible to improve the quality of parks, education, and other local services. Impacts on government revenues and expenditures are generally classified as "fiscal impacts" affecting the functioning of government. Such impacts are a direct consequence of changes in an area's economy.

Transportation factors affecting economic development

Economic development effects occur as the *end result* of other direct effects that a transportation project has on travelers and non-travelers. There are five specific factors or mechanisms at the root of economic development effects from transportation projects. These factors include effects on (1) business travel costs, (2) business market reach, (3) personal travel costs, (4) job access, and (5) quality of life.

Depending on the transportation project, one or more of the five classes of transportation impact factors may need to be estimated. For assessing economic development effects, one does not necessarily have to collect data and conduct analysis on all five of these factors. It is usually possible to focus just on those that are clearly the most important.

- **Business travel costs.** Transportation improvements can reduce direct costs for freight shipping, thereby reducing business costs of acquiring materials and delivering products. They can also reduce direct costs for business-related passenger travel, thereby reducing costs for client service delivery and employee compensation. All else being equal, businesses tend to locate and expand in locations where they have comparatively low costs and hence can be more productive and profitable.

Example: A new highway or rail route may reduce distances for worker travel and/or freight deliveries to and from the study area. Alternatively, improvements to existing highways or rail routes may improve travel times and improve reliability. In either case, the effect may be to reduce travel times and increase travel time reliability for work-related travel.

- **Business market reach.** Besides affecting travel costs, transportation improvements can expand the breadth of markets for business suppliers, customers, and workers. This can occur through increased choice of freight shipping or passenger travel services or through extended ranges for labor markets or delivery markets. Such changes may bring further business productivity savings through economies of scale or facilitation of just-in-time production and delivery pro- cesses, which were previously not feasible. Some types of transportation changes may also shift traffic patterns and change local access patterns in ways that reduce pass-by traffic markets for some businesses. Ultimately, any of these market changes can shift business location patterns, so that some places gain and others lose business activity.

Example: A highway project may *temporarily* add barriers to or put limitations on traffic movements or parking during construction. Alternatively, a highway project may *permanently* add median barriers or limited access interchanges. In either case, the effect may be to reduce direct traffic accessibility for local area businesses located along the highway route, although it may also increase traffic in the vicinity of interchanges.

  Regardless of whether a highway or transit project significantly changes out-of-pocket costs for shoppers, it may expand the base of potential shoppers for a local area retail district. This expansion may occur either because the distance from which shoppers may travel has been increased, or because the range of population segments (such as households without automobiles available) that have access to the area has been increased. Either way, the primary effect would be market access—in this case, access by new population segments.

- **Personal travel costs.** Transportation system improvements can reduce household out-of-pocket costs for personal travel, thereby increasing disposable personal income. The result is increased living standards and consumer spending, which can then support additional retail and consumer-service business activity.

- **Job access.** Even when transportation system improvements do not increase local business activity, they can sometimes increase the employment and incomes of local residents by increasing their access to outside business locations.

- **Quality of life.** Transportation system changes can also affect an area's visual quality, level of traffic noise, and accessibility to important destinations—all factors affecting the attractiveness of an area as a place to live or do business. These factors can ultimately affect the area's ability to attract new businesses and encourage them to stay and grow; in the process, local property values may rise.

> **Example:** A transportation project (such as an elevated rail line or highway) could also have negative localized effects on noise levels and views along its route. These effects could then reduce the attractiveness of locations along that route as a place to live and work. Although the effect is manifested directly through reduced property values, it might also be a factor affecting businesses' decisions about remaining and expanding.

Once the transportation impact factors have been identified and estimated, the actual assessment of economic development effects may be made through a model of how local area business activity would be expected to respond to those factors.

Special issues

Relocation versus growth. Just as interjurisdictional transfers of economic activity are an important consideration, so also are relocations within the same community. It is not unusual for a transportation project to improve the accessibility of certain sites relative to other locations within the same community. When this occurs, businesses seeking a competitive advantage may relocate to sites whose accessibility is better than their current location. In estimating the likely economic development effects of a proposed project, a clear distinction should be drawn between such relocations and actual net increases in local economic activity that result from business arrivals or expansions. It also is important to anticipate whether such relocations would be consistent with the community's comprehensive plan—will they contribute to desired land use patterns?

Definition of the impact area. The measurement or estimation of economic development effects is intrinsically tied to the definition of a particular spatial area, which is designated as the study area. Often, the extent of economic development effects can be radically different, depending on whether the study area is a neighborhood, city, metropolitan area, or state. For that reason, care must be taken to select the most appropriate study area and to be clear about its definition. Failure to distinguish and address the way effects vary when different scales of analysis are analyzed is a common problem and is a factor in public confusion and loss of credibility.

> **Example:** A metropolitan area uses incentives, including road construction to a site, to attract a business. If the business currently is located elsewhere in the same state, it is possible that economic development would be fostered in the gaining community, but it is unlikely that any net economic development would occur at the state level; activity merely has been transferred from one place to another. Thus, the scale of the analysis matters greatly.

Time period of the impact analysis. The magnitude of effects on business activity can be very different for (1) the short-term project construction period (2) the near-term period following project completion, and (3) the long-term period 20 or more years after project completion. For that reason, there may need to be separate consideration of effects during these various time periods.

Changes in the mix of business activity. The mix—in addition to the scale—of business activity is an important component of economic development: considering changes in the mix of activity makes it possible to examine the types of jobs likely to be created (or lost) and the associated skills and wage rates. Taking into account mix of business activity also makes it possible to assess the degree to which diversification (affecting economic stability) is improved or worsened. All of this is critical to assess how the expected economic development effects relate to the specific economic development goals or needs of the area.

Capital investment. In some cases, a transportation project is contemplated as a means for helping to attract a specific firm to the community. In addition to estimates of the number of jobs and the level of wages that would result, an important consideration should be the amount of capital investment the firm would make within the community. A firm that would only make a modest investment, such as purchasing furnishings for leased office space, is a far less certain prospect than a firm that would actually build or purchase a major facility. A sizable capital investment is a good indication that the firm is committed to long-term involvement in the community. If the magnitude of the public investment in transportation facilities far exceeds the firm's investment, one should proceed with caution.

Tax-base issues. A related consideration is the effect that businesses likely to be attracted by the proposed transportation project would have on the community's tax base. Depending on the tax concessions granted by the community, level of capital investment, and amount of payroll, these businesses may or may not help strengthen the community's fiscal position.

Analysis assumptions. It must be noted that transportation is but one of many factors affecting economic development, so forecasts of the economic development effects of a transportation project are always built upon certain assumptions regarding the overall economy and other related factors at various points of time in the future. In reality, other changes in local- or outside-area economic conditions can enhance or reduce the nature of economic development effects from a transportation project.

Double-counting. The economic development effects of a transportation project are distinct from (but related to) changes in user travel costs, accessibility, and quality of life. For that reason, it can be useful to identify the nature of these various types of effects separately, but care must be taken to avoid double-counting in calculating the magnitude of total overall effects. For example, an improved highway may reduce the travel time and operating costs of freight trucking. Because of this reduction in transportation costs, a business increases in competitiveness and employs 20 additional workers. It would be double-counting to add the new income of the workers to the transportation cost savings that brought about the additional income.

Equity concerns For low-income communities, economic development effects may magnify the effect of any change—positive or negative—in the economic vitality of an area that has little economic activity to begin with. It is important to look at both the short-term (i.e., direct and secondary effects of construction disruptions) and long-term (i.e., effects on surviving businesses and the attraction potential for new businesses). Evaluation of long-term economic development potential should consider (1) the employability prospects of the local population with the particular businesses attracted to an area and (2) the multiplier effects these businesses might have on the local community. New businesses without much employment potential for the local population and with limited multiplier effects (e.g., growth in service businesses, such as food establishments) tend to generate less of a net growth in income.

WHEN TO DO THE ANALYSIS

There may be particular interest in documenting or estimating economic development effects for any of three reasons.

1) **Economic development targeting.** Sometimes a transportation project is aimed (at least in part) at improving economic development for a particular area that has been economically disadvantaged or that has special economic development needs.

2) **Concern about adverse effects.** Sometimes a project raises concerns about unintended but likely adverse effects on existing business activities and, hence, job loss in a local area or region. In such a case, there may be particular interest in estimating the nature of potential losses of business activity and jobs.

3) **Inclusion in benefit-cost analysis.** Occasionally a project will affect business productivity and markets in ways that make its effects on income generation greater than the standard valuation of user benefits (e.g., value of savings in travel time, safety, and vehicle operating expense). In that case, there may be particular interest in examining the extent to which overall economic development benefits differ from the standard valuation of direct user cost savings.

STEPS IN THE ANALYSIS

The estimation of economic development effects typically involves four steps. Their elements and methodology options are outlined here and then discussed more fully under the specific methods.

Step 1. Measure the transportation factors affecting economic development

This analysis depends on the findings regarding other types of transportation system effects. As appropriate, the following sets of transportation impact factors should thus be estimated for the construction period and the post-project period.

Travel cost savings Any significant cost savings associated with changes in travel time, safety, and vehicle operating costs for trips to, from, and within the study area should be estimated. This should be done separately for business travel costs and personal travel costs. For purposes of economic development analysis, distinctions must be made between actual expenses, which will directly affect the flow of dollars in the economy (e.g., truck driver hourly wage costs and medical or insurance costs), and other societal valuations that do not literally affect the flow of dollars in the economy (e.g., value of personal time savings and the value of reducing fatal crashes).

See:

- Section 2: Travel Time Savings, p. 13.
- Section 3: Safety, p. 29.
- Section 4: Changes in Vehicle Operating Costs, p. 43.

Market and access effects. Any significant change in businesses' market size in term of supplies or deliveries, and any change in the available workforce in the study area should be assessed for the economic development analysis. Here again, distinctions must be made between actual expenses and other societal valuations.

Market effects are normally measured in terms of the percentage increase in potential suppliers, customers, or workers who can reliably access the study area within an appropriate travel time range. The analysis should be done separately for different types of businesses. In some cases, (particularly at the neighborhood level), a project might affect resident access to jobs outside of, as well as within, the study area. Greater access to outside jobs should be addressed in terms of the percentage change in job opportunities.

See:

- Section 6: Accessibility, p. 77.

Other quality-of-life effects. If a project is expected to have a major effect on the relative attractiveness of a location as a place to live or locate a business (due to quality-of-life enhancement or degradation), those effects should also be estimated.

See:

- Section 9: Traffic Noise, p. 129.
- Section 11: Property Values, p. 159.

Step 2. Estimate the direct effect on business competitiveness

The changes in travel cost, business markets, and quality of location for the study area estimated in Step 1 provide a basis for analyzing how the business cost competitiveness and market competitiveness of the study area would be enhanced or degraded by the transportation project.

To estimate the likely direct effect on business competitiveness of a proposed transportation project, changes in business-related transportation costs need to be allocated to the different types of businesses (e.g., retail, manufacturing, and services). This allocation is dependent upon which industries currently use the transportation facilities and which are expected to benefit most from the changes. Any additional changes in business costs related to travel time reliability or scale economies can also be added.

Those changes in business operating costs can then be turned into measures of effects on the relative cost of doing business in the study area compared with elsewhere in the state or nation and, hence, on the relative attractiveness of the location as a place for business. Other quality-of-life factors that further enhance or reduce the attractiveness of the study area as a business location can also be recognized and accounted for.

In addition, any changes in business markets should be quantified in terms of the expected effect on business sales volume and market share. These effects should also be broken down by type of business and by time period (e.g., construction period, near-term, and long-term). Depending on the detail one needs, effects can be further divided by product line (e.g., some businesses produce or sell multiple products in very different markets).

Step 3. Estimate direct effect on business growth or decline

The changes in business competitiveness from Step 2 provide a basis for analyzing how the level and mix of business activity within the study area would be expected to change. There are four methods available for such an analysis: (1) a survey of local experts, (2) market studies, (3) case studies of similar situations elsewhere, and (4) computer models. Each of these methodologies is described in detail below.

The end product of Step 3 should be an estimate of the expected growth (or decline) in business activity resulting from the change in business operating costs, markets, and other location factors. Estimates of changes in business activity should be done separately by type of business and should include measures of the change in total business sales, jobs, wages, and other measures that may be appropriate.

Step 4. Estimate indirect, induced, and dynamic effects on economic development.

The direct effects on business growth in the study area from Step 3 represent what regional economists refer to as a "first-round effect." Ultimately, however, any significant change in business activity in an area can have a domino effect, increasing or decreasing sales for the local businesses that supply materials or services to the directly affected businesses. These are commonly referred to as "indirect effects." Changes in total employment and wages paid in the study area (due to direct or indirect business changes) can also affect consumer purchases, thus increasing or decreasing sales for firms throughout the economy.

Finally, if a project has a substantial effect on a region's economy, it may also lead to changes in labor costs, to changes in land and building prices, and to the migration of population and workforce over time. These are commonly referred to as "dynamic effects," and they can lead to additional long-term changes in an area's business activity.

The end product of Step 4 should thus be an estimate of the total change in business activity levels, jobs, and income in the study area. The estimate should reflect the sum of shifts in business growth rates resulting from direct, indirect, induced, and dynamic effects. Depending on the motivation for the analysis, one may need to explicitly distinguish effects expected to occur during the construction, near-term, and longer-term periods. It may also be important to present economic development effects in terms of the types of businesses affected, the types of jobs affected, the number of households affected, and the level of income change in the study area.

METHODS

Method 1. Expert interviews

Expert interviews, focusing on local governmental officials and business leaders, can provide insights as to the likely direct economic development effects of changes in transportation services.

Information collection. The analysis begins with the development of one or more scenarios representing how travel conditions, business costs, and market access may be expected to change with the transportation project. One then asks key business representatives, developers, and planners to report on:

- Their perceptions of existing transportation needs,
- The existing constraints or threats to economic growth within the community, and
- How the project under consideration would be likely to affect economic growth prospects of existing businesses and new businesses that might be attracted to the area.

Discussion can also cover economic development transfer effects, such as long-term population gains, long-term employment gains, and long-term property value increases.

Usually, the interviews focus on specific topics, which may include locations (such as particular neighborhoods in a city or different communities in a region) and industries (which represent existing dominant sectors in the economy or special growth opportunities). The interviews can actually take the form of one-on-one conversations, written surveys, or focus group discussions.

Analysis. Once the interview or survey results are collected, one can compile them to identify the expected effects and the extent to which they represent a consensus expectation, a dominant expectation, or just an average among widely divergent expectations. Another analytic option is to utilize a delphi process, whereby experts are first surveyed individually, then informed of the initial results of the survey and given the opportunity to revise their estimates in light of their colleagues' expectations. This process can help experts to achieve a consensus expectation. A focus group discussion also can provide a means for movement towards a group consensus, although the composition of the discussion group can be critical in determining whether there is political positioning by individuals representing divergent positions.

Example: Interviews of economic development agencies. Some sample questions follow.

Effects on new business attraction and growth

- Over the past 3 years, which businesses have been attracted to the area and which have been lost?
- During this time, what factors have enhanced or inhibited business attraction and growth in the area?
- Is current highway access a limiting factor for economic development? If so, in what ways?
- Is the proposed project more likely to help existing businesses expand or to help attract new businesses?
- Are there entirely new industries that might be attracted to the area once the project is complete? How will the project affect market opportunities? For whom?

Effects on tourism

- How important is tourism to the area's economic base? What forms of existing tourism can be expanded as a result of the proposed project?
- What new forms of tourism might be attracted or created once the project is completed?

Measurement and presentation. The expected effects that are most often assessed by the expert interview method are changes in business sales, changes in land development rates and patterns, and changes in property values. Changes in employment and wages are typically assumed to be proportional to the business sales changes. Expert interviews can typically provide separate estimates of various effects by major types of business (retail, manufacturing, wholesale/distribution, and services), although usually they cannot be expected to provide insights into detailed industry effects.

Assessment. Expert interviews have an advantage over modeling approaches in that they reflect an understanding of local contexts in which social, regulatory, and political factors may influence an area's economic development. Interviews, however, can sometimes yield widely divergent expectations, so a near-consensus is necessary to have confidence in the results. There is also a widely recognized problem that expectations for change are often greater than what is subsequently observed. This disparity means that expectations concerning both adverse effects and potential beneficial effects can sometimes be subject to overestimation.

Method 2. Market studies

Overview. Market studies provide estimates of changes in business sales as a result of increases or decreases in market size and the competitive capture of market shares. There are several variations on this general approach: retail market studies and industrial market studies focus on projections of sales volumes, while real estate market studies focus on property values. They all share the common concepts of estimating total demand (i.e., sales), competing supply (i.e., land or business locations), and resulting market shares (i.e., market capture rates for alternative locations). The end product is an estimate of business sales (i.e., land and building absorption). The market study typically is able to forecast potential future growth in specific business markets and to estimate how much business growth could be captured with improved transportation services and reduced costs.

Information collection. Market studies depend on four basic types of information: (1) the over-all level of market demand, which is dependent on the surrounding area population and its associated spending or on the pass-by traffic level and its associated spending; (2) the competitive market supply, which is typically the business profile of the study area and that of competing areas; (3) current characteristics of the size, accessibility, and other attraction factors for the study area and competing areas; and (4) scenarios representing how costs and market access would be expected to change with the transportation project.

Depending on the definition of the study area, the basic characteristics of total market business sales and competing sites (elements 1, 2, and 3) can be collected at the neighborhood, city, county, or state level as appropriate. Original data collection is often necessary, however, to assess how particular business segments in the study area are sensitive to transportation changes. Specific data collection tools include the following:

- **Shopper surveys.** Surveys of shoppers can provide information that will help to define the breadth of market areas served by existing businesses in the study area, as well as to define market areas for competing businesses located elsewhere. They can also provide information on how the destination preferences of shoppers may be affected by changes in the cost, convenience, or time involved in accessing competing shopping areas.

- **Windshield surveys or GIS data.** Both of these techniques are means for counting the number of business establishments along a highway right-of-way. Windshield surveys are typically made by driving through a corridor where changes are proposed and simply observing business fronts. GIS systems contain listings and classifications of business establishments in a geocoded format. Either way, these data sources can be used to identify the number, type, and size of the businesses that would be affected by transportation improvements. Spreadsheets models can then be applied to relate the different types of businesses to levels of dependence on pass-by highway traffic levels or broader market areas.

- **Business surveys.** Surveys of businesses provide a means for identifying delivery patterns for incoming shipments from suppliers and outgoing shipments to customers. These surveys help one understand how the existing transportation network is used by businesses, the value of shipments, and the potential business cost savings associated with a proposed highway project.

Analysis. The data collected from market studies make it possible to estimate the market share of total sales occurring in the study area. There are two primary approaches used, depending on the nature of the transportation changes:

- **Spreadsheet models—**If the transportation project would affect direct access to adjacent businesses, a spreadsheet model can be used. Such a model requires information on a business' sensitivity to pass-by traffic and on the average sales per visitor, both of which will differ dramatically depending on the type of business (e.g., service station versus custom jeweler). Subsequently, for any change in the level of pass-by traffic, one can then forecast the change in sales for businesses along the route. The extent of that change, as well as the number and mix of businesses affected, can also be forecast.

- **Gravity models**—If the transportation project affects customer access from numerous directions, a form of gravity model can be used. The amount of customer attraction is actually a simple calculation that relates (1) the observed market share of businesses in the study area to (2) the relative travel time cost of accessing them from different parts of the study area, compared with the time and cost of accessing competing business areas. Once the relative attraction has been calculated, it can be used in a straightforward process to forecast the likely change in market sales due changes in access (or locational attractiveness) associated with a new transportation facility.

See:

- Section 6: Accessibility, p. 77.

Example 1: Business and shopper surveys. Some sample questions follow.

Business owners or managers may be asked the following:

- How many people work at your company? Where do they commute from? (Request approximate breakdowns by general direction or municipality.) By what transportation mode? (Ask for a general breakdown of modal usage.)
- How many visitors come to your business each day? Where do they live, or where do they travel from? By what transportation modes do they arrive to shop or visit? (Ask for a general breakdown of modal usage.)
- How many trucks enter and exit your business each day? Where do they travel from and where are they going next?
- Have you heard about the proposed new transportation project? If it were to be completed, how would you expect it to affect your access to potential employees and to your customer and delivery markets? If changes are expected, what role do you think would be played by changes in travel times, reliability of travel times, and new modal options?

Shoppers may be asked the following:

- How often do you come here to shop?
- How long did it take you to travel to this place today? From what area did you travel (general direction or municipality)?
- Where will you be going next?
- Have you heard about the proposed new transportation project? If it were to be completed, how would you expect it to affect how often you shop here?

Employees may be asked the following:

- How long did it take you to come to work here today? From what area did you commute (distance and direction)?
- Have you heard about the proposed new transportation project? If it were to be completed, how would you expect it to affect your commute?

Example 2: Spreadsheet model of pass-by traffic effects. A new highway median and intersection increase traffic throughput and total volumes passing by stores, but the upgrade also eliminates direct driveway access to some businesses. In this example, a four-step process is appropriate:

1) Compile an inventory of businesses along the affected route. This corresponds to column A in Table 8.1.

2) Use business or customer interview data to estimate the extent to which each business along the route depends on pass-by traffic. Alternatively, professional judgement based on direct observations or results from prior studies may be used to estimate the degree of business sensitivity to pass-by traffic. This corresponds to column B in Table 8.1. (In this example, it is assumed that a business' customers either are going especially to that business destination or are pass-by travelers who stop at the business when they see its sign and a driveway that is easily accessible from the road.)

3) Obtain estimates of the expected change in traffic levels along various portions of the corridor, as well as estimates of the extent to which various business locations would lose some direct access to traffic unable to turn from the other side of the road. This corresponds to columns C and D in the table below.

4) Use a spreadsheet representation of a table like Table 8.1 to calculate the resulting effect on business sales. The basic formula for estimating the overall change in retail sales is:

$$Col.\ E = \left[Col.\ B \times (1 + Col.\ C) \times (1 - Col.\ D)\right] - \left[Col.\ B\right]$$

This general approach is further explained and a spreadsheet model provided in Weisbrod and Neuwirth (1998).

Table 8.1. Spreadsheet model of pass-by traffic effect

Inventory of business (A)	% of customers from pass-by traffic (B)	Expected % change in pass-by traffic (C)	Expected % of traffic unable to turn left to store (D)	Overall % change in retail sales (E)
Gas station	95	+30	50	-33
Fast food	60	+30	0	+18
Hotel	10	+30	0	+3
Gas station	95	+30	25	-2

Example 3: Spreadsheet model of shopping center market attraction. Three shopping centers currently serve a metropolitan area. Average travel times to each of the three shopping centers from each of the five districts of the metro area are measured for both the base case and for conditions that would exist if a proposed project were completed, as shown in Table 8.2.

Table 8.2. Gravity model input data on accessibility to three shopping centers
(Base case and project-completion scenarios)

Residential market segment	Total households	Average time to Shopping Center 1		Average time to Shopping Center 2		Average time to Shopping Center 3	
		Base	Project	Base	Project	Base	Project
Central urban core	3,413	15	15	22	22	30	30
Northern suburbs	3,115	55	55	16	16	55	55
Southern suburbs	3,913	45	30	38	37	25	25
Eastern suburbs	15,575	40	38	15	15	40	40
Western suburbs	931	36	36	20	20	16	16

One then applies the gravity model formula shown in Section 6 (p. 91) for calculating an accessibility index for each of the three shopping centers. This yields an index of accessibility to each shopping center from each of the residential market areas, as well as a composite index of accessibility to each shopping center. (The composite measure of accessibility is an average of the accessibility from each market area, weighted by the number of households residing in each of those areas.) Finally, one calculates the portion of total community retail spending occurring in each of the three shopping centers, based on the simple formula mentioned above.

Table 8.3 displays the results for our three-center example. In this case, the market share increases for Shopping Center 1 and decreases for the other shopping centers.

Table 8.3. Gravity model results on market share for three shopping areas

Residential market segment	Market access index: Shopping Center 1		Market access index: Shopping Center 2		Market access index: Shopping Center 3	
	Base	Project	Base	Project	Base	Project
Central urban core	15.2	15.2	7.1	7.1	3.8	3.8
Northern suburbs	1.0	1.0	12.2	12.2	1.0	1.0
Southern suburbs	1.9	4.3	2.7	2.9	6.3	6.3
Eastern suburbs	9.7	10.8	69.2	69.2	9.7	9.7
Western suburbs	0.7	0.7	2.3	2.3	3.6	3.6
Composite index	3.3	3.9	9.6	9.9	4.2	4.2
Shopping center size (Gross leasable area in 1,000s of sq. ft.)	600	600	400	400	800	800
Market share of total community retail spending dollars	21%	24%	42%	41%	37%	35%

Measurement and presentation. Real estate market studies generally forecast the change in square footage of development likely to occur if a transportation project is completed, as well as the associated increase in property values. Business market studies typically forecast the likely change in sales volumes for new or expanded businesses resulting from a transportation project. Both types of market studies provide a basis for forecasting the associated increase in employment and wages.

Assessment. Market studies have an advantage over expert interviews in that they have some basis in empirical data, although in reality the assessment of changes in locational attractiveness and market access often has a subjective component. This approach has a fundamental limitation in that it is primarily relevant for cases in which the project causes a change in the size of the customer market. Such cases may include changing the level of pass-by traffic or changing the breadth of the market area. Thus, the effect must generally be focused on a shopping center, business district, or corridor in which there is a clearly defined and relatively limited number of competing areas.

Method 3. Case studies

Information collection. Case studies require three types of descriptive data: (1) the type of project; (2) the locational setting and context; and (3) before and after data on changes in business activity patterns—business mix, business sales levels, property values, and development rates.

Generally, case studies are readily available for projects in which the locations are clearly defined and limited in size. These include community bypasses, new interchanges, added transit stations, and new airports. At such sites, one can observe the business mix and pace of growth over time and relate them to the new transportation facility. Currently, there are relatively few detailed case studies with before and after data for major highway corridors or entire transit lines. The paucity of such case studies is largely due to the greater costs of data collection, as well as to the fact that such projects entail a much more complex characterization of the affected region.

Analysis. The applicability of findings from case studies depends on three factors: (1) establishing a strong match between the case study projects and the project being considered; (2) establishing a strong match between the community setting in the case studies and the new project setting; and (3) the existence of multiple case study examples with consistent results, to ensure a degree of confidence in their relevance and applicability to the project in question.

In some cases, there have also been statistical studies comparing locations that have had transportation system changes with locations without such changes (so-called "counterfactual" studies). Where that kind of statistical information is available, it can serve as a further measure of the validity and reliability of the observed relationships between transportation changes and business activity changes.

For example, there have been many case studies of bypass highways around small and medium-sized communities. A general finding has been that the degree of effect on a bypassed downtown business district depends largely on whether that district has served as a special destination for tourists and outside visitors or as a more general service to pass-by traffic. It follows that for a proposed bypass of a city with a large tourist base, it would be important to select two or three case studies of similarly sized cities that also had large bases of tourists.

Steps in applying analogous case studies follow.

> **Step 1. Identify case studies of similar transportation changes.** Determine whether there are write-ups of case studies corresponding to the type of transportation project or situation currently being proposed.
>
> **Step 2. Determine factors affecting the local context.** The local setting of the proposed transportation project may be a small town, a downtown area, a suburban area, or a rural region. Its economy may be focused on tourism, manufacturing, commercial districts, or agriculture. The local situation must be classified in terms of these basic categories to assess the appropriateness of available case studies.
>
> **Step 3. Assess the implications of case study findings for the proposed project.** Depending on the degree of match in terms of type of project and type of context, the case studies may be considered to be good estimates, underestimates, or overestimates of the likely magnitude of effects associated with the proposed new project.

Measurement and presentation. Case studies typically provide before and after comparisons in terms of the volume of business sales and employment occurring in the affected area. If there also are comparable data for areas surrounding the affected area or for other comparable areas, then they can be used to standardize the observed rates of change to adjust for other factors that are changing over time.

Assessment. Case studies can be useful insofar as they provide a real-life account of how development patterns can change when a transportation facility is built. This type of real-world experience is particularly useful when presenting information at public meetings because it is easier for lay people to understand case studies than more rigorous economic analyses that involve technical terms and concepts. Case studies are thus especially effective for public communications; however, their applicability is limited to situations in which case studies exist for projects and settings that match the proposed project type and setting.

Method 4. Computer models

Several widely used computer models are available to estimate the effect of reductions in transportation costs brought about by a major project on economic growth in the affected region. These economic simulation models contain a series of equations that replicate the economy (i.e., indicate the extent to which various economic sectors purchase from and sell to other sectors).

Information collection. Computer simulation models of a regional economy are based on a scenario representing the changes in business costs for labor, materials, equipment, and deliveries to customers, as well as any changes in feasible market size. To forecast future economic growth or decline in a region, the scenario must first be applied to some base-case representation of the region's current pattern of business.

Analysis. The analysis requires some form of production function or other technique to estimate how businesses and broader economies would respond to changes in their relative operating costs. We list three possible options.

1) The naïve option (which has been used in some studies but which we *do not* recommend) is to assume that the cost savings to business will translate into an equal-sized income growth for the local workforce.

2) A more difficult but accurate option, which has largely been relegated to academic research, has been to use industry studies of the price elasticity of demand for some manufactured products. The factors can be used to estimate how much a given type of business may be able to expand due to its ability to lower prices, but it is difficult to do so without further information on the current cost competitiveness of the affected industries.

3) The most widely used approach for forecasting effects of cost changes is the regional economic simulation model (such as the Regional Economic Models, Inc. [REMI] model). Such models are often applied by state DOTs and some MPOs to forecast regional business responses to business cost changes. These microcomputer software programs contain detailed data on current baseline economic characteristics, projected industry changes, the cost-competitiveness of businesses in the specific study area, and the business' sensitivity to cost changes.

More generally, regional economic simulation models can be used to represent the effects of a range of different scenarios. For highway investments, the most basic factors represented in modeling systems are changes in costs of living and costs of doing business resulting from proposed transportation improvements. In some cases, researchers have simply calculated the direct user cost savings associated with the investment and have input these savings into the model. Several studies have included not only estimates of changes in user cost savings, but also regional productivity and regional location shifts related to highway location. These include additional tourist spending due to changes in regional tourism markets and additional employment from business attraction as a result of improved accessibility and opportunities for superior freight logistics, just-in-time processing for industries, or supplier/customer market changes. To estimate tourism effects and business attraction effects, analysts have relied on market studies of specific industries likely to be affected.

For public transit, economic models factor in personal costs and business costs associated with varying levels of public transit availability, as well as ridership changes associated with differences in costs of traffic delays, crashes, and parking when transit service is changed.

Example. If a manufacturer could reduce the cost of products delivered to customers by 20 percent, how much would output and associated wages grow? If the firm were a monopoly, it would not necessarily grow at all, and it could keep the cost savings as additional profits without its workers necessarily earning any extra income. If, on the other hand, the business were employee-owned, that cost savings might be paid out entirely to the workers. More dramatically, if the business were in a highly competitive national or international market, then the cost savings might allow it to lower its prices, substantially increase its market share, and expand its size (providing more local jobs). Any of these situations might apply, depending on the nature of the business. More generally, an economic model can be used to assess the economic effects of a major urban highway project as follows.

First, determine the direct effects of the project on (1) business costs and net revenue, (2) household cost of living and net disposable income, (3) shifts in business and consumer spending patterns, and (4) tourism and industry attraction or retention. Depending on the specific project, these factors may include some or all of the factors listed below. (This example builds on input variables in the REMI model.)

Business cost and spending (by industry)

- Change in business cost of truck operation (fuel, etc.)
- Change in business cost for truck driver time (labor)
- Change in business logistics and production cost for freight time
- Change in business cost of crashes for trucks
- Value of business cost of commuter compensation for parking and work commute

Household cost and spending

- Change in cost of automobile crashes (and spending on medical care and automobile repair)
- Change in automobile operating costs (spending on fuel and automobile maintenance)
- Value of change in travel time for transit passengers

Transportation agency and other government activities

- Change in cost of transit operations, labor, and materials
- Change in transit fare collections (consumer spending)
- Change in business and household taxes associated with project financing
- Change in capital spending on transit vehicles and systems
- Change in construction and capital spending on highway facilities

Other changes in the economy

- Shift in tourism and inflow of new consumer spending
- Redistribution of existing consumer, business, and government spending
- Change in net inflow of new investment (shift and/or expansion of business activity)

Next, one runs the economic model and evaluates the results. Typical output results from an economic model are listed below. (In the example of the REMI model, this list would include separate values for each year during project development, as well as for each year following project completion.)

- Change in business output (sales volume) by industry
- Change in personal income
- Change in employment by industry
- Change in population or workforce

Measurement and presentation. The key outputs from regional economic simulation models are values for total business output (i.e., sales), gross regional product (i.e., value added), employment, and wages. These values are forecast by industry on a year-by-year basis into the future. Information is also provided on the occupational skill mix of jobs and on the relative cost of labor, capital, energy, and other production factors in the study area (compared with the U.S. national average).

Assessment. Computer models are most important in situations in which the transportation project can change the cost of production for a manufacturer or supplier of products or services. In such cases, there is a critical need to forecast how such changes would affect business growth as well as associated jobs and income.

Regional forecasting/simulation models can estimate effects of alternative highway or rail alignments when there are significant differences in user travel costs between options. Such models can be calibrated for a specific county or aggregation of counties in the United States. These models, however, are not readily available for areas smaller than a county, nor are they available for areas outside of the United States. The cost for obtaining such models, custom-calibrated for a specific study area, is not trivial. For these reasons, their applications have generally been limited to major highway and high-speed rail corridor studies.

Method 5. Input-output models

Input-output (I-O) models are essentially accounting frameworks that track inter-industry purchasing patterns. They provide a means for calculating the indirect and induced effects on business sales and spending, given a set of direct project effects on business sales, employment, or wages.

Information collection. I-O models require some estimation of a project's direct effect on local business growth. Such estimates may come from expert interviews, case studies, market studies, or a computer model. The estimates of direct effects are then applied to the multipliers in a regional I-O model. The I-O model is usually obtained from one of four commercially available vendors (IMPLAN, RIMS-II, PC I-O or REMI). These commercial models have compiled information on (1) the industry technology patterns, represented by the purchasing and spending patterns of businesses in different industries at the national level; (2) regional adjustments reflecting the extent to which business and consumer purchases go to local versus outside business suppliers; and (3) patterns of worker wages and spending in a region.

Analysis. The various I-O models show how each additional dollar of spending growth in one industry affects the sales of other industries. The effects of that growth on worker wages and consumer spending are also included in most I-O models. Nearly all of the I-O studies conducted in the United States utilize one of the four commercially available regional models listed above; these models allow analysis of any county or aggregation of counties in the country.

It should be noted that the REMI model is the only one of these four models built to function as both a means of estimating direct business effects from cost savings and the subsequent rounds of indirect and induced effects. The other three models require that cost and market effects be calculated separately.

The process of analysis requires one of two approaches:

1) With the IMPLAN, PC I-O, and REMI models, the computer software asks the user for a scenario concerning the size of direct business growth by industry. The then forecasts the magnitude of indirect and induced growth.

2) With the RIMS-II and IMPLAN models, the user is given a set of multipliers that can be applied in a user-built spreadsheet to calculate indirect and induced effects on the regional economy.

Measurement and presentation. All of the I-O models provide results in terms of total business output (i.e., sales), gross regional product (i.e., value added), employment, and wages. All of the I-O model options provide these values broken down in detail by industry.

As discussed earlier, the REMI model functions as a regional simulation and forecasting model that predicts the dynamic effects of changes over time in labor market costs, housing costs, migration of population, and workforce. Its output shows the sum total of direct, indirect, induced, and dynamic effects on business growth, jobs, and income on a year-by-year basis for up to 35 years. Information is also provided on the occupational skill and mix of jobs, as well as on the relative cost of labor, capital, energy, and other production factors in the study area compared with the U.S. national average.

Assessment. The applicability of indirect and induced economic effects depends on the study area and its economic conditions. In general, indirect (i.e., supplier) and induced (i.e., consumer spending) effects represent additional economic growth to a region only if (1) the labor and facility resources for those additional business activities are available in the region or can come into the region and (2) those additional business activities do not take away jobs or resources from other existing activities in the region. Indirect and induced effects would then represent real additional growth if the area either has some unemployment or has a continuing immigration of population and workers. These conditions generally hold for local and regional studies, but may not represent any net growth at the national level, where the total supply of labor and capital is more fixed.

The need for expensive and complex regional simulation models depends on the type of the proposed project. Projects that will affect relative business operating costs and have long-term consequences for regional growth are best represented by long-term simulation models that can account for those factors.

Regardless of the models used, additional effort must be made to ascertain the types of jobs and wage levels available in order to assess the extent to which a given project would provide the most needed or desired types of jobs in the local area.

RESOURCES

The following documents provide readers with further information regarding the methods and techniques to be used in assessing the economic development effects of transportation projects.

1) Transportation Institute of Canada. 1994. *A Primer on Transportation Investment and Economic Development*. Ottawa, Ont.: Transportation Association of Canada.

   This brief document summarizes the relationship between transportation infrastructure and the rate of economic growth. It then provides an evaluation framework in which effects of transportation investments can be assessed in terms of how they could potentially affect economic growth.

2) Burkhardt, Jon E., James L. Hedrick, and Adam T. McGavock (Ecosometrics, Inc.). 1998. *TCRP Report 34: Assessment of the Economic Impacts of Rural Public Transportation*. Washington, DC: Transportation Research Board, National Research Council.

   This report examines the economic effects of selected rural public transportation services at the local level through case studies. It provides practical examples of how to assess effects associated with the introduction or expansion of public transportation services in rural areas.

3) Cambridge Systematics, Inc., Robert Cervero, and David Aschauer. 1998. *TCRP Report 35: Economic Impact Analysis of Transit Investments: Guidebook for Practitioners*. Washington, DC: Transportation Research Board, National Research Council.

This report provides guidance on selecting methods to conduct analysis of the economic and land development effects of transit investments. It reviews the major methods and shows their application through case studies.

4) Forkenbrock, David J., Thomas F. Pogue, Norman S. J. Foster, and David J. Finnegan. 1990. *Road Investment to Foster Local Economic Development*. Iowa City: University of Iowa, Public Policy Center.

A detailed presentation of the conceptual relationship between transportation investment and economic development is contained in this monograph. The relationship is explored in an analysis of post-investment effects of businesses that benefited by specific road projects.

5) Hagler Bailly Services, Inc. 2000. "Guidance on Using Economic Analysis Tools for Evaluating Transport Investments." National Cooperative Highway Research Program, Project 2-19(2) Final Report. Washington, DC: Transportation Research Board, National Research Council.

This forthcoming NCHRP report discusses research and application of existing techniques for measuring economic development and productivity effects of transportation projects. It discusses the appropriate use of existing tools, including their usefulness, reliability, and data requirements. It is designed to help analysts select appropriate techniques given their unique needs, data constraints, and staffing expertise. Case study examples are provided.

6) Weisbrod, Glen, and Burton Weisbrod. 1997. "Assessing the Economic Impacts of Transportation Projects: How To Choose the Appropriate Technique for Your Project." *Transportation Research Circular 477.* Washington, DC: Transportation Research Board, National Research Council.

This circular, sponsored by the Transportation Research Board Committee on Transportation Economics, is a concise primer on how to best assess economic effects of transportation projects. It is designed to provide the reader with guidelines for (1) identifying the types of economic effects most relevant for decision-making, (2) defining the appropriate evaluation perspective, and (3) selecting techniques to be used for analysis and presentation of findings.

7) Wilbur Smith Associates, Benjamin J. Allen, C. Phillip Baumel, David J. Forkenbrock, and Daniel Otto. 1993. *Guide to the Economic Evaluation of Highway Projects.* Ames, IA: Iowa Department of Transportation.

This guidebook identifies methods by which economic analysis can be used to help decision-makers select highway projects and project types that would produce net economic benefits. It explains how the included methodologies work and discusses how to ensure that they are applied so as to produce results that are consistent and fair.

REFERENCE

Weisbrod, Glen, and R. Neuwirth. 1998. “Economic Effects of Restricting Left Turns.” *NCHRP Research Results Digest No. 231*. Washington, DC: Transportation Research Board, National Research Council.

A link to download the spreadsheet model contained in this publication is available from http://www4.nationalacademies.org/trb/crp.nsf/All+Projects/NCHRP+25-04.

SECTION 9: TRAFFIC NOISE

OVERVIEW

Steps in the analysis	Methods
• Define the impact area and affected land uses and activities • Do an initial screening analysis • Determine existing noise levels • Predict traffic noise levels resulting from the transportation project • Identify and evaluate noise effects • Identify construction noise effects	• Look-up tables: TNMLOOK • Traffic noise prediction models

Definition

Noise is usually defined as any unwanted sound. Traffic noise comes from three major sources: tire- pavement interaction, vehicle engines, and vehicle exhausts. At very high levels (75 to 80 A-weighted decibels [dBA]), noise can cause hearing loss and tinnitus (i.e., ringing in the ears). Although traffic can produce fairly high levels of noise, it is not likely that people will be exposed to it for long enough to cause actual hearing loss or damage. Health effects are thus not the central issue with traffic noise. What generally matters in impact analysis is the aggravation that such noise may cause neighboring residents. In general, people have varying tolerances for and perceptions of noise.

Sound level is only one factor in determining noise nuisance. Pitch is also important, as is whether a sound is continuous, random, or repeated in a regular pattern. In general, people tend to dislike traffic noise; in surveys, traffic noise often tops the list of obnoxious noises heard in outdoor areas like parks and yards. It is also consistently rated as the worst outside noise heard inside homes.

Noise analyses range from the basic screening tools that one can use to get a general understanding of whether noise is likely to be an issue for a proposed transportation project to complicated, computerized noise-modeling techniques best handled by specialists. In this section, we provide an overview of the NEPA and FHWA requirements about noise, in addition to basic information about the computer noise models available for noise-level prediction.

Changes in the absolute noise level—such as those predicted by FHWA noise models—reveal little about how communities and individuals will respond to noise. In keeping with the social and economic focus of this guidebook, we dwell on measuring the effect that noise has on a community. Our aim is not to recreate a user's guide for the FHWA models, but we do list FHWA resources at the end of this section to facilitate their use.

Transportation factors affecting neighborhood noise levels

Traffic noise varies with the volume and type of traffic as well as with the physical geography of the terrain surrounding the roadway. A transportation project can bring about a series of noise-related effects within a community.

- In general, traffic noise increases with traffic volume, speed, and the proportion of trucks in the flow of traffic; 2,000 VPH sound twice as loud as 200 VPH; traffic at 65 mph sounds twice as loud as traffic at 30 mph; and a single truck sounds as loud as 28 automobiles at 55 mph (FHWA 1992, pp. 4–5).

- Stop-and-go traffic tends to create different noise problems than does free-flow traffic.

- Sound intensity in general decreases in proportion with the square of the distance from the source; barriers—vegetation and buildings—act to deflect noise from neighborhood residents. In general, traffic noise is not usually a serious problem more than 150 meters away from a heavily traveled road or more than 30 to 60 meters from lightly traveled roads (FHWA 1995, p. 5).

- Heavy road traffic (and its subsequent noise and exhaust) disrupts street-side and front-yard activities such as socializing. Increased noise levels make streets less pleasant places for people to converse, walk, or play. Inside the home, traffic noise has been linked to sleep disturbance.

- Even if absolute noise levels are moderate to low, intermittent traffic noise may intrude on neighboring land uses that require a tranquil setting, such as houses of worship, funeral homes, nursing homes, schools, or hospitals. As a result, the FHWA has become more active in encouraging local governments to exercise care when planning for noise-sensitive land uses near highways.

- Elevated traffic noise can impede pedestrian travel in two ways. First, walking is much less pleasant near a noisy facility. Second, elevated noise levels can make street crossings more hazardous for pedestrians who need to listen for oncoming traffic.

- Although temporary, construction noise from transportation projects can seriously disrupt neighborhoods and businesses.

Special issues

Definitions. Several terms related to noise are referred to in this section. They are briefly defined for reader convenience.

- Receptor—an x,y coordinate defining a location where noise levels are measured. Usually, receptor locations are a specified perpendicular distance from the edge of a roadway.

- Weighted decibels—sound is measured in units called “decibels” (dB). Measuring highway traffic noise involves an adjustment or weighting of high- and low-pitched sounds to approximate human hearing of these sounds. Adjusted sounds are called “A-weighted levels” (dBA).

  — L_{10} – the noise level in dBA exceeded 10 percent of the time during specified hours of the day.

  — L_{eq} – a composite descriptor that takes into account the variance in noise over time. It is a scale that converts a varying noise level into a constant equivalent noise level. L_{eq} for typical traffic conditions is about 3 dBA less than L_{10} for the same conditions. Although more difficult to present than the L_{10}, the L_{eq} tends to be a better measure for the noise from low-volume roads. In addition, the calculation of the L_{eq} allows for the addition of noise from sources other than the roadway.

Existing resources and regulations. Because of its importance, traffic noise has been studied and regulated by both federal and state transportation and environmental agencies for a long time. The FHWA has developed a comprehensive set of rules, procedures, and modeling techniques to help transportation analysts with EISs, and these guidelines can be helpful in measuring and understanding the community effects of traffic noise. Because transportation system changes that create a noise effect according to FHWA standards are likely to also create a change in the social and economic environment of a community, we rely on FHWA procedures and models for this section of the guidebook.

See:

- Appendix A: Geographic Information Systems, p. 201.

Equity concerns. Low-income and minority communities close to high-traffic areas and high levels of industrial and commercial activity almost certainly have high levels of background noise already. The cumulative effects of added noise from a proposed transportation project may be adverse to community cohesion, public health, and pedestrian and bicycle safety. Thus, noise propagation studies should be particularly sensitive to potential cumulative noise effects. Besides traditional decibel measurements and wave dispersion studies, surveys should be carried out to determine community perceptions about noise, including effects on social interactions and pedestrian and bicycle safety. Noise effects on various types of community facilities should be mapped to identify particular problems (e.g., noise-sensitive populations and activities, such as nursing homes, hospitals, libraries, schools, and residences). Forkenbrock and Schweitzer (1997) describe the methodology for mapping vehicle-generated noise and relating it to such facilities.

Among low-income populations, construction noise may pose a special concern. Insofar as existing facilities are located in proximity to low-income and minority communities, those communities may be affected disproportionately by construction noise. For one thing, low-income residents may be more likely than other area residents to work during later shifts, so that construction noise during daytime shifts (when third shift workers are trying to sleep) may be especially intrusive.

WHEN TO DO THE ANALYSIS

In recent years, the FHWA has clarified its stance about what constitutes a significant noise effect in relation to its own noise abatement criteria. The following from the FHWA (1995, p. 6) provides its definition of a "noise impact":

> *"A traffic noise impact occurs when the predicted levels approach or exceed the noise abatement criteria (NAC) or when predicted traffic noise levels substantially exceed the existing noise level, even though the predicted levels many not exceed the NAC. This definition reflects the FHWA position that traffic noise impacts can occur under either of two separate conditions: (1) when noise levels are unacceptably high (absolute level); or (2) when a proposed highway project will substantially increase the existing noise environment (substantial increase). In order to adequately assess the noise impact of a proposed project, both criteria <u>must</u> be analyzed."*

The FHWA does not provide guidelines about what constitutes a substantial increase in noise, but most state DOTs consider either a 10- or 15-dBA increase to be substantial (FHWA 1995, Table 6). It follows that if a proposed transportation project will result in increased vehicular traffic, especially trucks, an analysis of noise effects should be carried out.

STEPS IN THE ANALYSIS

In general, noise analyses are completed in two phases. An initial evaluation determines whether noise is likely to be a problem. Often, initial evaluations do not account for the effects of sound-dampening barriers such as topography, buildings, or berm, although some available methods for initial evaluation do allow the user to consider terrain and barriers in a simplified way. The initial evaluation helps to define the area affected by elevated noise and to identify land uses (e.g., residences, schools, houses of worship, hospitals, and extended-care facilities) that lie within the affected area.

If the initial evaluation shows that noise is likely to be a problem with the transportation project, a more refined analysis should be done to compare existing and future (predicted) noise levels to more accurately reflect the mitigating effects of existing barriers and to correlate spatially the predicted noise levels with characteristics of neighboring land uses.

Finally, public involvement with neighborhood residents and businesses—as well as coordination with local decision-makers—is an integral part of analyzing noise effects. Neighborhood residents are a source of information about potentially sensitive noise receptors. In addition, residents can identify neighborhood resources they most want protected from noise. Local-area planners and decision-makers can provide information about existing and future development along the highway project.

Initial evaluation phase (A)

An initial evaluation phase should occur early on in project planning. It can be a quick analysis to ascertain whether a noise increase is likely to be significant enough to require a refined evaluation. The data and tools necessary for an initial evaluation are relatively straightforward and easy to use.

Step 1A. Define the impact area and affected land uses and activities.

During this step, one identifies neighboring land uses and activities likely to be affected by the noise from a proposed project. It is helpful to assign neighboring land uses to the corresponding activity categories the FHWA uses for the NAC; it is similarly helpful to map or mark particularly noise-sensitive land uses at this time. During this step, one should ask neighborhood residents for information about what parks or other gathering areas they think might be affected, as well as for help locating neighborhood features that residents feel should be protected.

Step 2A. Do an initial screening analysis.

A screening analysis early in the project development determines whether noise is likly to be enough of a concern to justify a longer, more complicated analysis. To assist in the screening analysis, the FHWA provides a screening tool called the Traffic Noise Model (TNM) Look-up Tables (called TNMLOOK), a simplified version of their highway noise prediction model, FHWA TNM (see FHWA 2000b).

Refined evaluation phase (B)

If the results of the initial evaluation show noise levels over or approaching the FHWA NAC, the project needs a more rigorous analysis. A refined noise evaluation usually occurs in later phases of project planning. Often, a refined evaluation is completed as part of an environmental impact statement. Refined evaluations require specialized equipment and knowledge. Consultants or other experts should therefore be retained for this level of analysis. Information gathered during the initial phase—such as the definition of the impact area, the nature of neighboring land uses, and the location of sensitive receptors—form the basis for the refined evaluation stage.

Step 1B. Determine existing noise levels.

The first step in the analysis is to gather field measurements (using a noise meter) of existing noise levels. In most urban situations, the noise signature in an area is the result of many sources (including transportation facilities). Baseline noise measurements help show how the predicted noise level will change the overall noise level in the area.

Measurements are usually taken at three exterior locations:

- At the highway right-of-way line;
- Near buildings in residential or commercial areas; and
- At a site of frequent activity, such as a patio or front yard, between the right-of-way line and a front-row building (FHWA 1995, p. 20).

A number of field measurements should be taken so as to represent the noise signature under varying conditions, and at least some of the measurements should indicate the worst noise level likely to occur. Noise readings should thus be recorded with information regarding peak versus non-peak and weekend versus workday traffic levels. If there is a time of day or week when the project area has more trucks moving through because of factory production schedules or business delivery, field measurements should be taken during those times as well as during off-periods. Most state DOTs have automated noise meters that will take measurements every 15 minutes, but longer time periods may be more appropriate for low-volume roads or for areas where the public or local officials have noticed a problem with traffic noise.

Step 2B. Predict traffic noise levels resulting from the transportation project.

Using one of the methods discussed later in the section, one should predict the increase in noise likely to occur as a result of the transportation project. If a project has more than several alternatives, it is advisable to model noise levels for each alternative, including the base-case (i.e., do-nothing) alternative.

Step 3B. Identify and evaluate noise effects.

Next, one should compare the predicted noise levels with the NAC, as well as estimate the change in existing noise levels to determine whether noise abatement is appropriate. Discussing the effect on noise of each alternative at this time with members of the public and local-area officials can help identify the least-intrusive alternative. The FHWA (1995, pp. 25–31) outlines abatement procedures such as vehicle type and use restrictions, modified speed limits, and noise barriers.

Step 4B. Identify construction noise effects.

Calculation of construction noise effects is not commonly performed, but methods do exist for predicting the noise level likely to result from construction activities. It is more common, however, for analysts to describe the noise likely to occur in a general way, including the types of construction activities that will occur and the noise levels typical of those activities. For any type of construction noise analysis, it is important to identify sensitive receptors—that is, people or activities particularly affected by noise.

Large-scale, long-term projects near densely populated or heavily used areas may require a more thorough treatment of construction noise, including mitigation such as portable noise barriers or special construction equipment.

METHODS

Method 1. Look-up tables: TNMLOOK

TNMLOOK is a software application for use with the TNM Look-up Tables developed by the FHWA as a screening tool. It generates precalculated FHWA TNM values for simple highway scenarios. Although other screening methods do exist, they will be phased out by the year 2002 when the FHWA's TNM model is set to become the standard.

Information collection. TNMLOOK performs noise calculations on single, straight-line highway configurations and allows for a straight-line barrier. It uses the following data:

- Automobile volume and speed
- Medium truck volume and speed
- Heavy truck volume and speed
- Bus volume and speed
- Motorcycle volume and speed (optional)
- Barrier (yes/no) (optional)
- Distance between centerline and barrier
- Barrier height (optional)
- Terrain (pavement=hard, lawn=soft)
- Distance from centerline to receptor

The receptor indicates the position of the person, house, or building where noise from the highway is likely to be heard. The distance is the perpendicular distance from the centerline to the receiver, and the height of the receiver is assumed to be 1.5 meters.

Analysis. TNMLOOK is a small, Windows-compatible program. It is written in FORTRAN, and to use it, it is helpful to be familiar with the way batch calculations are performed. After the data have been entered, the TNMLOOK program computes the hourly equivalent sound level (the L_{eq}) for the specified receptors.

Measurement and presentation. TNMLOOK, like most noise analysis methods, uses measures of acoustic energy to represent noise levels. Acoustic energy measures use a descriptive noise exceedence scale that takes into account pressure (decibels), sound duration, and the way that people perceive noise.

Many people are unfamiliar with dBAs, and noise descriptors like the L_{10} and L_{eq} often can be difficult to explain. To help, the FHWA (1992, p. 3) relates noise levels in decibels to common sounds. Figure 9.1 shows a graphical representation of how the dBA levels relate to commonly experienced noise.

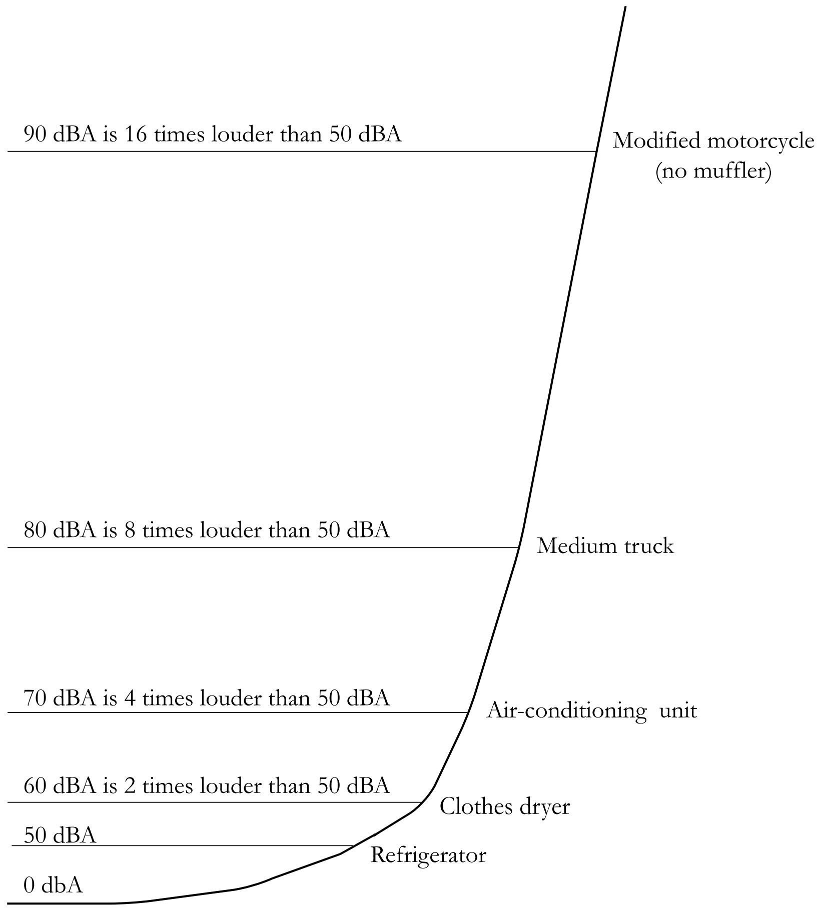

Figure 9.1. Commonly experienced noise levels

SOURCE: Adapted from FHWA (1992, p. 3)

A noise effect occurs when there is a substantial increase in noise (usually greater than 10 dbA) or when the noise level exceeds the FHWA noise abatement criteria. NAC levels are set depending on the time of day and the type of activity immediately adjacent to the roadway. This reflects the fact that maximum acceptable levels of traffic noise depend largely on the type of activity close to the roadway. Table 9.1 summarizes the FHWA noise abatement criteria based on the L_{10} and L_{eq}.

If the initial analysis shows noise levels approaching or exceeding the NAC, the project needs further analysis using more sophisticated models. This would be the time to begin planning noise mitigation measures for the project in consultation with the surrounding communities.

Assessment. TNMLOOK is a good screening tool; the program and data tables are easy to install and use. The data needed for this preliminary analysis are easily gathered. Although TNMLOOK is the simplest of the screening tools, it is quite accurate, given its limitations. Because it is based on the voluminous research the FHWA put into its TNM, TNMLOOK provides better results than certain other, more complicated screening tools.

Table 9.1. FHWA noise abatement criteria
(Hourly A-weighted sound level measured in dBA)

Activity category	L_{eq}	L_{10}	Description of activity category
A	57	60	Lands where serenity and quiet are of extraordinary significance
B	67	70	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, schools, churches, libraries, and hospitals
C	72	75	Developed lands or activities not included in categories A or B
D	—	—	Undeveloped land
E	52 (interior)	55 (interior)	Residences, motels, hotels, public meeting rooms, schools, houses of worship, libraries, and hospitals, and auditoriums

SOURCE: FHWA (1995, p. 7).

The assumptions of TNMLOOK are very limiting: the model considers only free-flow, one-speed traffic on a straight-line highway. It does not allow for multiple, staggered barriers for variance in receptor height. Because of the limitations, TNMLOOK is not a tool to be used for making abatement or compensation decisions. It is useful only to discover whether the highway project in question needs a more detailed analysis to protect neighboring communities from noise effects.

Method 2. Traffic noise prediction models

The STAMINA 2.0 highway noise prediction model and the FHWA noise barrier design program, OPTIMA, have been in widespread use for many years. Highway departments and consultants across the United States and Canada have used STAMINA as a tool for predicting the noise levels associated with major highway projects. STAMINA is a DOS-based computer program that calculates noise levels using a noise propagation algorithm that employs data on road geometry, barriers, traffic conditions, and terrain (although the model was limited to only two terrain factors).

In 1998, the FHWA released its newest prediction software, the TNM, which is a flexible, Windows-compatible program. TNM has some clear improvements over STAMINA. Although it is technically possible to model both stop-and-go traffic and noise contours with STAMINA, the procedures for doing so are time-consuming and complex. In TNM, it is possible to model both free-flow and stop-and-go traffic, as well to generate noise contours within the TNM program.

Information collection. Both TNM and STAMINA require basic data about the traffic, roadway, and surrounding terrain of the study area. Depending on the class of road, state highway departments, local area planning staff, and direct measurement at the project site can provide the data required to run either TNM or STAMINA, including the following:

- Profile, elevation, and distance data for the project and the surrounding terrain, receptors, and barriers;
- Vehicle hourly volumes by percentage of each vehicle type (both through-traffic and turning traffic, if applicable); and
- Speed(s) for each vehicle type (at each stage of acceleration and deceleration, if applicable).

Additional parameters that TNM can use to increase accuracy include the following:

- Roadway grade (to account for the effects of grade on acceleration and deceleration);
- Atmospheric absorption;
- Sound divergence;
- Acoustical characteristics;
- Type and topography of the ground between the road and the receptor;
- Rows of buildings; and
- Vegetation.

Although all of the foregoing information is not necessary to run the noise models, understanding how noise will affect a community requires that one become familiar with the location of sensitive receptors (such as schools or nursing homes) and land uses (especially residential) contiguous to the study project. If the results are to be mapped, one will need geographic base files of some form along with the geocoded locations of receptors. (Receptors can also be located by distance from the roadway using GIS software.)

Analysis. After the data are acquired and input into the model, both TNM and STAMINA use noise propagation algorithms to calculate noise levels at specified locations according to the study's parameters. The acoustical calculations ensconced in TNM are more complex—and more accurate—than those in STAMINA.

As with any model, it is useful to run sensitivity analyses to see how changing the input values alters the results of the data run.

Measurement and presentation. The FHWA noise prediction models produce noise estimates at both L_{eq} and L_{10}, the same descriptive noise measures as the TNMLOOK screening tool. Once again, a noise effect occurs when there is a substantial increase in noise (usually greater than 10 dbA) or when the noise level exceeds the FHWA NAC. If the noise levels exceed the NAC, the project will require abatement.

As FHWA and noise experts stress, the NAC are only one aspect of traffic noise measurement. Residents near the project will often dread traffic noise more than any other traffic-related effect.

Even if the model results show that the noise levels do not surpass the NAC levels, public participants generally will want to be informed of the analysis results.

Maps are perhaps the most effective presentation tool for noise prediction model results. Isarithmic mapping is particularly useful for depicting noise levels generated from STAMINA. An advanced GIS package (such as TransCAD or ArcInfo) can use a triangulation procedure to interpolate surfaces between STAMINA receptor locations to create a triangulated irregular network (TIN) than can in turn be used for contour mapping.

Generally, the GIS software used for contour mapping supports the creation of contours as both line features and area features. The noise level or pollutant concentration contours can be visually displayed in the form of isolines labeled with corresponding values or contour areas shaded in the form of a choropleth map.

Figure 9.2 is a sample map showing block-level demographic data (in this case, percent of the census block population that is nonwhite) overlain by noise contours displayed as isolines in the top map layer. Such a map can be a useful tool in examining the distributive effects of a proposed highway project.

Assessment. Computerized noise prediction models have been the focus of intensive FHWA research and improvement. Their effort has resulted in accurate (but complex) modeling tools like the TNM. Criticisms of TNM include its long run-time and cost (it is distributed by a private vendor: the Center for MicroComputing in Transportation).

It generally is common practice for state DOTs to analyze the expected changes in noise levels a proposed project would bring about. When this is the case, it may be possible to combine the analysis of community effects with the analysis being done by others.

RESOURCES

The following documents are guides that provide further information regarding the methods and techniques to be used in assessing traffic noise effects of transportation projects.

1) Center for MicroComputing in Transportation (McTrans). 2000. “Traffic Noise Model” (online). http://mctrans.ce.ufl.edu/featured/trafficNoise. Available July 25, 2000.

The Federal Highway Administration’s Traffic Noise Model (TNM) is available from the Center for MicroComputing in Transportation. This web site contains information about TNM software components, capabilities, and computer requirements to run the program.

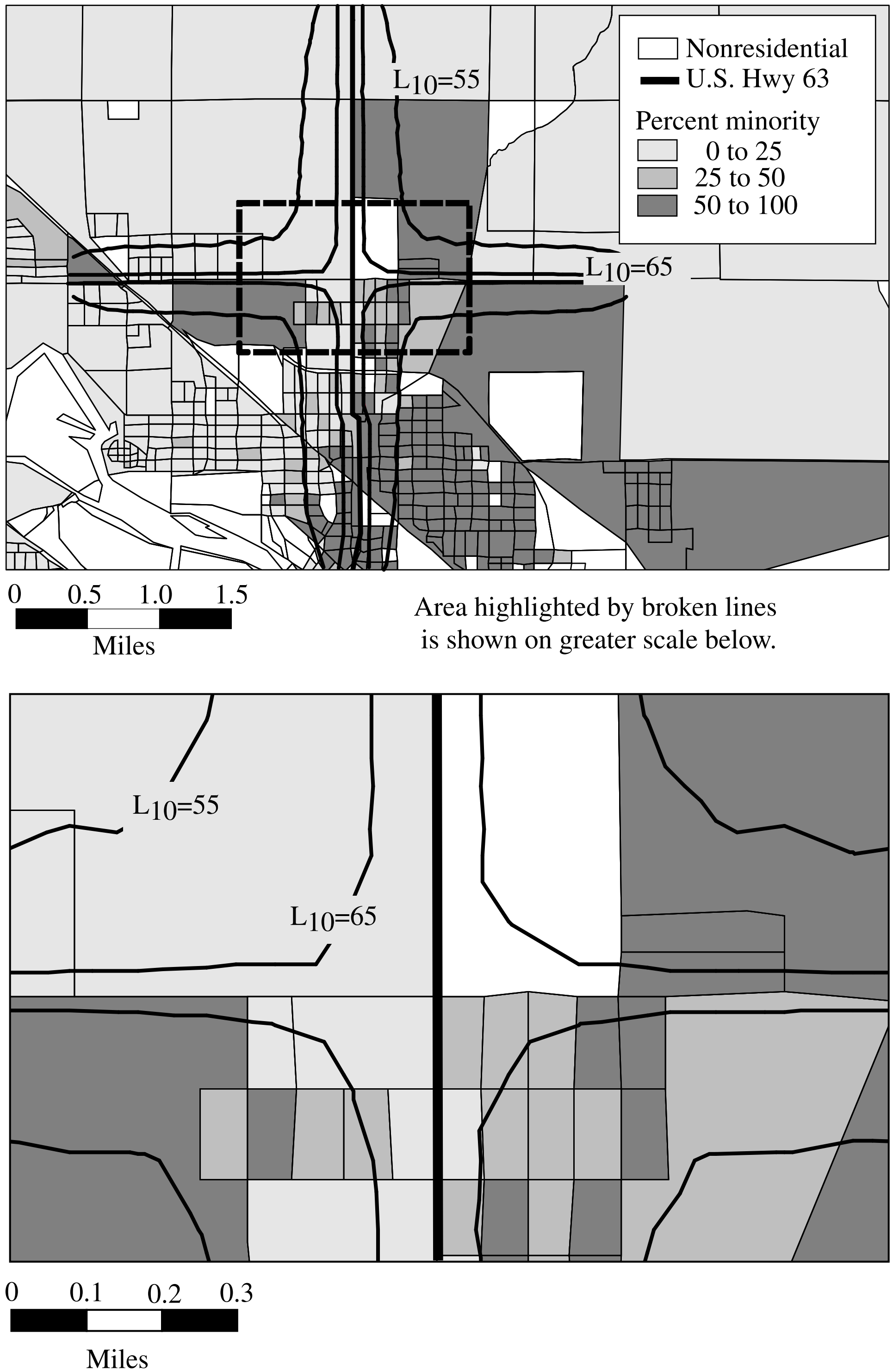

Figure 9.2. Sample contour map showing L_{10} noise levels and demographic data

2) Federal Highway Administration (FHWA). 2000a. "*FHWA Highway Traffic Noise*." Federal Highway Administration (online). http://www.fhwa.dot.gov/environment/probresp.htm. Available July 24, 2000.

This easy-to-understand paper presents a three-part approach to dealing with highway traffic noise. It summarizes the general nature of highway traffic noise and mitigation efforts and provides a review of noise abatement procedures.

3) Federal Highway Administration (FHWA). 2000b. "Highway Traffic Noise Products." Federal Highway Administration (online). http://www.fhwa.dot.gov/environment/AB_ NOISE.HTM. Available July 25, 2000.

This web site contains a comprehensive listing of the FHWA's noise-related products. Some products are downloadable from the web site, other listings provide contact information for obtaining the product.

4) Federal Highway Administration (FHWA). 1995. *Highway Traffic Noise Analysis and Abatement Policy and Guidance*. Federal Highway Administration (online). http://www.fhwa.
dot.gov/environment/polguid.pdf. Available July 24, 2000.

This online publication provides a review of the fundamentals of sound and traffic noise. Federal legislation pertaining to traffic noise abatement and regulations and methods of lessening the effects of highway traffic noise are also discussed.

5) Forkenbrock, David J., and Lisa A. Schweitzer. 1997. *Environmental Justice and Transportation Investment Policy*. Iowa City, IA: The University of Iowa, Public Policy Center.

This monograph provides a relatively complete discussion of a GIS-based approach for assessing whether minority populations or low-income populations are disproportionately affected by vehicle-generated noise. It also includes a discussion of the problem of traffic noise and its measurement.

6) Minnesota Department of Transportation. 1991. *Noise Analysis: Stop and Go Traffic Procedures*. Noise Group of Environmental Engineering, Engineering Services Section. St. Paul, MN.

This manual explains how the FHWA Stamina 2.0 noise model is used to predict stop-and-go traffic noise levels. It explains the necessary modeling procedures, discusses general data requirements of modeling stop-and-go traffic, and uses common stop-and-go traffic scenarios as examples.

REFERENCE

(Note: some cited references appear under “Resources.”)

Federal Highway Administration. 1992. *Highway Traffic Noise*. Washington, DC: Government Printing Office.