Effective Methods for Environmental Justice Assessment

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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Effective Methods for Environmental Justice Assessment

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FOREWORD

By Martine A. Micozzi
Staff Officer
Transportation Research Board

This guidebook is designed to enhance understanding and to facilitate consideration and incorporation of environmental justice into all elements of the transportation planning process, from long-range transportation systems planning through priority programming, project development, and policy decisions. It offers practitioners an analytical framework to facilitate comprehensive assessments of a proposed transportation project's impacts on affected populations and communities.

This step-by-step and practical guide provides technical assistance, from selecting appropriate methods of analysis to calculating effects on air and water quality, drainage, and safety. It also addresses impacts of hazardous materials on affected persons residing in a given locale. The conclusion of each chapter provides valuable resources and references to supplement the reader's knowledge.

This guidebook should be of particular interest to planning practitioners in state departments of transportation (DOTs), metropolitan planning organizations (MPOs), and local transportation planners, as well as other practitioners concerned with planning, programming, and implementing transportation projects. The guidebook will also be beneficial as an educational resource on the concepts, tools, and procedures currently employed for assessing environmental justice issues in the context of transportation planning decisions.

Environmental justice embraces the fundamental human desire for fairness and equity. Because development and implementation of transportation projects can create potentially beneficial and adverse impacts on the communities and people they affect, they require careful consideration and incorporation of environmental justice from the onset.

With the passage of Executive Order 12898 in 1994, environmental justice has taken on greater significance in the scope of transportation planning. The U.S. DOT and state and local agencies have worked to identify appropriate processes, techniques, and effective practices for making sound environmental justice assessments and for considering their results in transportation decisions.

The objective of this research was to identify and develop processes, procedures, and techniques for integrating environmental justice considerations into transportation systems planning, priority programming, project development, and decision making at the statewide, metropolitan, and local levels. Presented as a guidebook, the research results will improve the analytical capabilities of states, MPOs, and their planning partners. The guidance builds on existing impact assessment methods and presents new techniques that improve on current practice. These methods are organized and presented to guide practitioners in assessing environmental justice issues within specific application categories (e.g., air quality, safety, transportation user effects, and economic development). It is intended to advance current knowledge, provide practical guidance and qualitative and quantitative assessment tools, and share state-of-the-art methods for addressing environmental justice in transportation.

CONTENTS

CHAPTER 1. GUIDEBOOK OVERVIEW

INTRODUCTION

Environmental justice is a complex subject that speaks to fundamental human desires for fairness, equity, and social and economic justice. Sadly, the basic objectives of environmental justice are often misunderstood. This guidebook was prepared to help those in the field of transportation planning and policy development better understand how to incorporate environmental justice assessment into planning processes for developing transportation projects, policies, and programs.

The key regulations and policy drivers behind environmental justice assessment requirements are Title VI of the Civil Rights Act of 1964 (Title VI) and Executive Order 12898 issued by President Clinton in 1994. Although environmental justice assessment is required by Executive Order, we make the case throughout the guidebook that practitioners should evaluate environmental justice because it is part of good transportation planning. Although current policy directs practitioners as to *when* environmental justice assessment should be performed, there is no standard national policy or guidance on *how* it should be performed.

Therefore, there is no "one size fits all" approach to environmental justice assessment. This is both a blessing and a curse. On one hand, it allows a practitioner the flexibility to select the most appropriate assessment technique for the problem at hand. The drawback, of course, is that the practitioner must spend time, and sometimes a considerable amount of time, determining which method or methods are most appropriate. This guidebook is intended to simplify that process.

One key purpose of the guidebook is to advance the state of the practice by presenting a broad range of effective environmental justice assessment techniques. To achieve this purpose, the guidebook must be easy to use and of value to practitioners. Each guidebook chapter therefore presents a mixture of commonly used techniques and new or little-used techniques that improve upon common practice.

Throughout the guidebook, we stress the importance of having the flexibility to select the method or methods that are most appropriate for the issue at hand. In general, the complexity of analysis and level of detail required will be greater for project planning and corridor studies than for long-range transportation plans and investment plans. In addition, the greatest level of public concern usually is expressed at the project planning level because the effects of the decision are tangible and will be experienced in the short term. Because of these realities, most of the methods in this guidebook are presented with project-level planning in mind, although this is not to say that policy, program, and longer-range planning efforts are any less important to environmental justice.

As a result of this focus, practitioners with Departments of Transportation (DOTs) may see more opportunities to directly apply these methods than will practitioners with metropolitan planning organizations (MPOs). However, many methods that function at the project level can also be used to evaluate long-range regional planning efforts. We therefore expect that this guidebook will be a valuable resource for practitioners in both DOTs and MPOs.

Environmental justice is concerned with myriad social, cultural, and environmental issues and how those issues affect particular social groups. This guidebook is organized into 13 chapters that address each of the most common issues of concern as environmental justice is related to transportation planning and policy development.

We also selected this organization because a common body of knowledge and techniques exists for many of the issues, and many of these techniques can be extended to allow for environmental justice assessment. The methods included in this guidebook, whether simple or complex, commonly or rarely used, produce results that can be readily communicated to decision-makers and to community residents.

As the title of this guidebook conveys, the focus here is on explaining approaches, techniques, and methods that will help transportation planning practitioners perform informative environmental justice assessments. As you read this guidebook, however, keep in mind that environmental justice assessment is one of many components necessary to fully integrate environmental justice into the transportation planning process. Equally if not more important are components such as developing comprehensive, agency-wide environmental justice programs and policies and implementing processes that make community participation a cornerstone of the planning process.

This introductory chapter provides the background information you need to use the remaining chapters of the guidebook effectively. We begin by providing a definition of environmental justice. This is followed by a discussion of the positive role environmental justice can play in transportation planning and policy development. The types of effects addressed in the guidebook are listed and briefly described, followed by a discussion of the philosophy applied to developing the guidebook. The chapter ends with a discussion of how to use the guidebook and how it is related to other recent publications that address environmental justice.

ENVIRONMENTAL JUSTICE DEFINED

To some, environmental justice is a social cause that promotes fairness and equity for all people. To others, it is a set of federal and state policies that must be followed to ensure agency compliance with federal civil rights laws, especially Title VI. Still others may view environmental justice as a possible roadblock to transportation planning and project development that must be overcome in situations when local activist groups use the planning process to promote a specific agenda. In reality, environmental justice involves each of these perspectives to a certain degree. Some common definitions of environmental justice are discussed in the box titled “Perspectives on environmental justice.”

In this guidebook, environmental justice is defined as “the fair treatment of all people in terms of the distribution of benefits and costs arising from transportation projects, programs, and policies.” The term “fair” means that a disproportionate share of adverse effects will not fall upon low-income or minority (protected) populations. A disproportionate share of adverse effects in turn implies that the distribution of benefits to a protected population is not commensurate with the costs that this particular population would bear. It is important to keep in mind that the value of a benefit or the adversity of a cost may vary among population groups.

Therefore, it is necessary to present the expected effects of a transportation change to these populations as accurately and clearly as possible and then to fully consider the perspectives of protected populations when planning, constructing, and operating transportation facilities.

Perspectives on environmental justice

Environmental justice as a policy. The United States Environmental Protection Agency's definition of environmental justice stresses the concepts of fairness and equity in a regulatory framework:

Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies – http://www.epa.gov/compliance/environmentaljustice.

Environmental justice as a social movement combining concerns of social justice and environmentalism. A definition used by many environmental justice proponents stresses the comprehensive array of environmental justice concerns involving both physical and human environments:

Environmental justice is the right to a safe, healthy, productive, and sustainable environment for all, where *"environment" is considered in its totality to include the ecological (biological), physical (natural and built), social, political, aesthetic, and economic environments. Environmental justice refers to the conditions in which such a right can be freely exercised, whereby individual and group identities, needs, and dignities are preserved, fulfilled, and respected in a way that provides for self-actualization and personal and community empowerment* — http://coweb.cc.gatech.edu/lcc3308/150.

Environmental justice as a call for equal access to the decision making process. Another commonly used definition focuses more on environmental laws and environmental protection, calling for equal justice, equal protection, and equal access to the decision making process:

Environmental justice has been defined as the pursuit of equal justice and equal protection under the law for all environmental statutes and regulations without discrimination based on race, ethnicity, and/or socioeconomic status. This concept applies to governmental actions at all levels—local, state and federal—as well as private industry activities — http://coweb.cc.gatech.edu/lcc3308/190.

Common environmental justice concerns

Environmental justice can be viewed as a coming together of the social justice movement and the environmental movement to focus on societal issues where there is overlap between the two. Thus, environmental justice is concerned with issues that originally came to national attention through the social justice movement, issues such as fairness and equity, healthy living environments and workplaces, human health and safety, and economic development. In addition, environmental justice is also concerned with issues that the environmental movement originally brought to national attention, such as visual aesthetics, sustainable environmental practices, and environmental quality.

Transportation system changes have the potential to affect all of the above listed issues, for better or for worse. Because of this, environmental justice concerns often will be raised as the public evaluates the results of transportation policies, programs, and projects.

While it is beyond the scope of this discussion to list all of the important concerns that may raise issues of environmental justice, the range of concerns pertinent to transportation planning can be categorized as follows:

- **Human health and safety.** Paramount in environmental justice is concern about protecting human health and safety. This concern is central to many of the most important environmental justice issues such as air quality and lead-based paint, among others. Safety-related transportation concerns fall in this category.
- **Economic development.** Environmental justice proponents believe that all persons should have equal access to economic opportunities. It is important to evaluate how transportation system changes affect economic development opportunities. The effects can be either beneficial or adverse.
- **Society and culture.** Environmental justice proponents argue that it is important to understand the many differing values and priorities of diverse social groups. Environmental justice is therefore concerned with issues such as sacred lands and community cohesion. Transportation construction projects can have considerable adverse impact on these issues.
- **Natural environment.** Environmental justice emphasizes effects to the natural environment that have a direct social consequence. So, for example, degradation of surface water quality becomes an important environmental justice issue in situations where protected populations use impaired water bodies for sustenance or recreation.

THE ROLE OF ENVIRONMENTAL JUSTICE IN TRANSPORTATION PLANNING AND POLICY DEVELOPMENT

Beginning in 1994, environmental justice was elevated to greater importance in transportation planning when President Clinton issued Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* (President, Proclamation 1994). Since that time, The United States Department of Transportation (U.S. DOT), the Federal Highway Administration (FHWA), and state and local agencies have worked to identify processes, techniques, and effective practices for making environmental justice an integral part of the planning process. Both the U.S. DOT (1997) and FHWA (1998) have issued orders and guidance on environmental justice. These policy statements are important, but they are not the only reasons to include full consideration of environmental justice in the transportation planning process.

Transportation planning is concerned with setting in place transportation projects and programs that advance specified policy goals and objectives. These goals and objectives can be quite broad in scope, such as fostering a vibrant local economy, or narrower, such as ensuring that persons without autos have access to employment opportunities. Environmental justice fits into transportation planning by introducing consideration of distributive effects—how the benefits and costs of a proposed project would be experienced by different populations. Good transportation planning has both a technical component and a participatory component. Competent analyses of possible courses of action should be blended with interaction with the affected public. This guidebook is designed to assist planners in analyzing the distributive effects of possible projects so that these effects can be discussed with members of various population groups.

It is important to stress that, depending on the analysis context, some effects are more likely to warrant extensive examination, perhaps using relatively advanced methods. It stands to reason that the effects that residents of a community feel are important should be addressed with special thoroughness and vigor. Effects that are likely to be consequential but not of paramount importance often can be examined using 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.

Incorporating environmental justice analysis into the transportation planning process is complex for at least four reasons:

- A balance has to be drawn between benefits to users of the facility and effects on other community residents.
- Even among community residents, numerous effects (some positive, some negative) interact and must be balanced.
- Various population groups within the community may be affected differently in terms of mixes of effects.
- People vary in their preferences and opinions, so that what is acceptable or even desirable to some may be unacceptable to others.

The best way to think of environmental justice as a component of transportation planning is that it can help make transportation projects as beneficial as possible to populations that historically have not had an adequate voice in the planning process. As such, it is a way of strengthening transportation planning by making a wider array of effects understood. The fact that federal policy mandates consideration of environmental justice should not be the only driving force behind considering it; a more compelling argument is that it makes for good transportation planning.

Actually, much of the underlying regulatory basis for including environmental justice in transportation planning and policy development stems from requirements of the National Environmental Policy Act of 1969 (NEPA) and other long-standing provisions such as the 1970 Federal-Aid Highway Act and the Civil Rights Act of 1964 (as amended). 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). In essence, environmental justice adds a distributive focus to many of the impact analyses already required for transportation projects.

ENVIRONMENTAL JUSTICE AND DISTRIBUTIVE EFFECTS

All methods presented in this guidebook have at least one common feature: the ability to estimate distributive effects. Distributive effects are measurable adverse and beneficial outcomes of a transportation plan, program, or project that do not affect all members of a population equally. To evaluate environmental justice, it is necessary to determine distributive effects to protected population groups. The remainder of this section describes how distributive effects can be evaluated and incorporated into a comprehensive environmental justice program.

Environmental justice requires fair and equitable processes and outcomes. Most definitions of environmental justice stress the importance of fairness and equity for all persons. This means that the *processes* used to plan, select, and implement transportation system changes must be inclusive. In an equitable process, protected populations will have equal opportunity to become involved in the planning process, and the needs, values, and concerns of these populations will be fully considered.

In a perfect world, fair and equitable processes would be expected to result in fair and equitable *outcomes*. Outcome equity is therefore an appropriate way to evaluate the environmental justice of distributive effects. In situations where, for example, members of protected populations would receive more of the adverse effects of a transportation planning decision, or a lesser proportion of benefits than other groups, the outcomes of the transportation planning decisions are not equitable and are not environmentally just.

Distributive effects assessment methods are a test of outcome equity. The test for outcome equity, then, is to determine how beneficial and adverse effects are distributed among population groups and to determine if those effects are fair and equitable. Performing this test requires three basic steps:

1. **Identify the affected population.** The affected population is that which would experience the beneficial and adverse effects of a transportation system change. The size of the population and its demographic characteristics need to be determined. Important demographic characteristics for identifying protected populations include race, national origin, age, sex, disability, English-speaking ability, and income.
2. **Estimate the nature and extent of the effects.** Beneficial and adverse effects should be identified and measured. The measure could simply consider whether effects would or would not result from the transportation system change. A more informative approach would be to measure the magnitude of effect. An example would be developing estimates of ground-level airborne pollutant concentrations from zero parts per billion to 1,000 parts per billion, and how the levels vary across a study area, rather than merely

determining whether concentrations within the study area are above or below a standard of 100 parts per billion.

3. **Assess whether the effects are equitable.** This requires combining the demographic assessment with the effects assessment to determine how effects are distributed among social groups.

Effects can be distributed across space, across social groups, and across time. Examples of spatially distributed effects include air quality, noise, and water quality. Such effects are most often assessed using models or other techniques based on natural and physical properties of the effect. Other types of effects may have a geographic component, but fundamentally they are distributed across social groups. One of the best examples is transportation user effects. For example, lower-income persons often rely more on bus transit whereas middle-income persons often rely more on transportation by personal vehicle. The adverse effects of limiting transit service on weekends can therefore be expected to fall more heavily upon lower-income persons.

Any type of effect can be distributed across time. For example, the noise and air quality effects of a new roadway will become greater as traffic volumes increase over time. To assess the temporal distribution of effects, one must develop measures of (a) changes in population characteristics through time and (b) the nature and extent of effects through time, thus making it possible to determine if equity changes over time.

There are numerous principles of outcome equity. It is important to note that equitable distributions of adverse and beneficial effects can be defined in many different ways that are appropriate based upon the specifics of the situation. *Environmental Justice and Transportation: A Citizen's Handbook* (ITS 2003) includes a discussion of commonly applied definitions of outcome equity that are summarized in the box titled "Principles of outcome equity."

Principles of outcome equity

Equality. Everyone receives an equal share of the net benefits (benefits minus burdens).

Ability to pay. Persons are entitled to receive all the benefits they can pay for, assuming they compensate for any burdens incurred by others.

Maximum benefit. The greatest benefit for the most people.

Serve the least advantaged first. Remedy existing inequalities by focusing on the needs of the disadvantaged.

Most of the assessment methods and examples presented in this guidebook apply the equality principle to determine if a transportation policy, program, or project is environmentally just. In most situations, however, it is possible to use the outcome of the equality test to consider if the other forms of outcome equity are being met. The brief hypothetical situation, "Applying outcome equity principles in practice," on the next page provides an example.

Environmental justice assessments can provide objective information in an open dialog with stakeholders. As described in the example below, application of these various equity principles can yield vastly different outcomes when applied to real-world situations. The question of equity must therefore be determined through open dialog among planners and the various stakeholder groups. Distributive effects assessment methods, such as those presented in this guidebook, can be used effectively to prepare the objective information needed to evaluate equity.

The results can be presented to stakeholders to obtain feedback on the relative importance placed on the various equity principles. However, because values and needs often vary considerably among social groups, practitioners should not expect technical distributive effects assessments to be the final word as to whether a proposed transportation system change is equitable. That decision ultimately is reached through a political process that includes members of affected communities, planners, agencies, and decision-makers.

Applying outcome equity principles in practice

Equality. A small minority community has little demand for a nearby light rail station being constructed to reduce traffic and parking congestion at a professional sports stadium. Because the minority community will receive many of the burdens and few of the benefits from the new station, the equality principle will not be met.

Ability to pay. In this situation, the "ability to pay" principle can be used to achieve environmental justice. Project planners can ensure that a special event surcharge will adequately fund the project, which would include enhancing visual quality and obtaining new housing for any displaced persons. Under this principle, equity would be achieved by compensating the community near the station for the burdens being placed upon it.

Serve the least advantaged first. Similarly, the principle of serving the least advantaged first could be used to achieve environmental justice. In this scenario, the project would be expanded to include improved bus service in the community. A priority would be placed on the bus service, and any budget limitations would be met by reducing the amenities originally planned for the light rail station. In this scenario, the needs of the disadvantaged community would be given priority.

TYPES OF EFFECTS ADDRESSED

The common environmental justice concerns that are often raised in regard to transportation were used to develop the basic structure of the guidebook. The various effects of a transportation project are organized on the basis of whether they are related to human health and safety or whether they affect social, economic, or cultural elements of the human environment. It should be noted that certain effects might have impacts in both areas. In these cases, we focus on the most common type of effect and organize that topic accordingly.

For example, noise can have both health and nuisance effects. Long-term exposure to loud noises can permanently impair hearing. In transportation planning, however, nuisance issues related to noise are much more common. Also, because noise becomes a nuisance at decibel levels much lower than those needed to cause hearing impairment, minimizing nuisance issues will also ensure that noise will not affect human health. Noise is therefore treated as a social effect. The box titled "Transportation effects addressed in the guidebook" provides more detail.

UNDERSTANDING THE GUIDEBOOK

This guidebook provides a broader set of environmental justice assessment methods than is commonly in use today. The first objective of the guidebook is to provide a resource to practitioners that can be used to identify effective methods for evaluating environmental justice in most real-world situations. The methods, tools, and techniques presented in this guidebook are therefore practical and can be readily implemented.

Many of the environmental justice assessment techniques are extensions of methods commonly used to assess impacts from effects such as air quality, visual quality, transportation safety, and others. In this way, practitioners with little background in environmental justice assessment should still have adequate working knowledge of many of the necessary processes.

The second objective of this guidebook is to advance the state of practice in environmental justice assessment. The guidebook therefore contains numerous methods that are new or have seen little application in practice. Wherever possible the guidebook provides methods that have seen real-world application. This ensures the practicality of the techniques, in keeping with the first objective of the guidebook. Some of the methods that have not yet been applied in the transportation field, but have been used in other areas, can be applied either directly or with slight modification.

The methods presented in the chapters to follow were selected because they meet the following criteria.

- They can be used to evaluate distributive effects to protected populations.
- They are predictive.
- They can be integrated into a participation-focused planning process.
- They meet regulatory and legal requirements and will stand up to scientific review.
- They are flexible and can be modified to address many types of issues.
- As a whole, the methods provide a range of assessment options that streamline and simplify method selection and implementation for the practitioner.

Key considerations used to select the methods are described briefly below.

The guidebook includes methods for evaluating beneficial, adverse, and, by extension, net distributive effects. This approach allows practitioners to develop a more holistic sense of the potential environmental justice ramifications of a proposed policy, program, or project. It allows practitioners and the public to evaluate the inevitable tradeoffs that arise when a transportation investment is made.

The methods also are well suited for evaluating effects on many social groups. This is a key to good transportation planning because it provides the ability to evaluate benefits and costs to particular groups rather than to society at large. Regulations exist that offer legal protections to numerous social groups. These protected populations include social groups defined by age, disability, gender, limited English proficiency, and religion in addition to the categories of class, race, and low-income commonly considered in the context of environmental justice. The methods in this guidebook can be used to evaluate distributive effects on these protected populations and to other social groups.

Integrating community participation and predictive assessment. An effective assessment method must provide insights into the intended and unintended consequences of a transportation system change. In other words, the method must be predictive. Ultimately, however, it is just as important that results of the assessment can be clearly communicated. This is especially true in environmental justice assessment because community participation is such an important factor. When selecting analysis methods, the practitioner must carefully consider how the results will be communicated to, and used by, the general public and decision-makers. Practitioners should strive to present the methods used, and the results should be discussed openly in public forums.

Meeting legal, policy, and scientific requirements. When evaluating environmental justice, analysts must be reasonably certain that the selected approach meets basic regulatory requirements, meets tests of legal sufficiency, and will stand up to scientific review and critique. This is not the goal of performing environmental justice assessment, but legal, regulatory, and scientific requirements do set the minimum standard of practice.

Making the tool fit the problem. It is important that a range of evaluation methods exist so that they can be matched to the problem at hand. Problems will vary based on the specific issues being addressed, their complexity, the level of public concern, and the broad range of project scales that can be anticipated in practice. In some cases, a simple screening assessment may suffice to evaluate a low-level environmental justice concern. In other cases, it may be necessary to conduct in-depth public surveys and focus groups or to use complex simulation models to evaluate distributive effects.

Simplifying the assessment process. Ultimately, this guidebook is intended to inform and educate practitioners about methods available for performing environmental justice assessment. It is intended to make the methods more available, to simplify the process of selecting appropriate techniques, and to guide the reader in carrying out the assessment. The guidebook is not a detailed, step by step “user’s manual” for methods, although it does guide you to sources for further information where possible. The guidebook provides for flexibility in choosing tools and techniques, while at the same time maintaining a consistent framework for defining environmental justice goals and objectives; presenting results and conclusions; and facilitating collaboration, community understanding, and decision making.

Transportation effects addressed in the guidebook

Human health and safety

Air quality (Chapter 3) – Air quality is important to human health, the vitality of the natural environment, and the quality of life in general.

Hazardous materials (Chapter 4) – Hazardous materials are used in the construction, maintenance, and operation activities of transportation facilities. There is also concern over spills when hazardous cargo is transported through populated areas or sensitive environmental areas.

Water quality and drainage (Chapter 5) – Impaired water quality may have environmental justice implications if it affects public or private water supplies or resources more highly valued by protected populations. Drainage issues are commonly social or economic, but are discussed here because they are related to water quality.

Transportation safety (Chapter 6) – Changes in public safety resulting from a transportation project or program can be classified into three groups: (1) traveler safety, particularly for road users; (2) safety of pedestrians and users of non-motorized transportation; and (3) safety of the general public, especially children, the elderly, and the disabled.

Social, economic, and cultural effects

Transportation user effects (Chapter 7) – Transportation user effects can be classified into five groups: (1) changes in travel time, (2) changes in safety, (3) changes in vehicle operating costs, (4) changes in transportation choice, and (5) changes in accessibility.

Community cohesion (Chapter 8) – This topic is often raised as an environmental justice concern, commonly related to displacement of persons or severing of transportation linkages that connect community members.

Economic development (Chapter 9) – One of the most positive effects of transportation projects is that reduced transportation costs can make businesses more competitive. Transportation changes can have beneficial and adverse economic development effects.

Noise (Chapter 10) – Traffic noise and the noise associated with rail and air transportation can have harmful health effects, but nuisance effects are much more common.

Visual quality (Chapter 11) – Transportation system changes can have a significant visual effect when they require new structures to be built, older structures to be torn down, or the view of pleasant settings or landscapes to be obscured.

Land prices and property values (Chapter 12) – Land use and property values are discussed together because changes in the demand for land is a key driving force behind changes in property values.

Cultural resources (Chapter 13) – Resources that may be of cultural value to protected populations can be adversely affected by transportation system changes.

USING THE GUIDEBOOK

The guidebook is organized by general types of effects. We selected this structure because it is the most logical way to present methods for issues such as visual quality, transportation safety, and noise that have their own specific techniques. Whether you are evaluating a regional investment plan, a statewide transportation policy, or a specific transportation corridor or project alternatives, you should structure the environmental justice assessment around the following questions:

- What types of effects should be analyzed?
- What are the appropriate methods for each effect given the problem at hand?
- What is the appropriate time horizon?

Once you have general answers to the first question, you can refer to the chapters that address the effects you've selected and evaluate the available methods. Each chapter includes sections that discuss these general topics:

- **Overview.** An introduction to the chapter discussing the effect or effects being addressed and why those effects could have environmental justice implications.
- **State of the practice.** The state of practice for evaluating the effects and for evaluating environmental justice.
- **Selecting an appropriate method of analysis.** Guidance on situations in which the various methods are appropriate to use. For more information, see the discussion on "Identifying Appropriate Methods" below.
- **Methods.** Each method or technique is discussed in detail. For more information, see our discussion on "Identifying appropriate methods" below.
- **Resources.** We cite articles, books, and Internet sources that are especially helpful if further information is desired. Many of the resources also are cited as references within the chapter.
- **References.** A list of additional articles, books, and Internet sources cited in the chapter.

This guidebook also contains four appendices and a glossary. Appendix A contains a summary of important environmental justice statutes and regulations. Appendix B presents a summary of important environmental justice case law. Appendix C provides information on geographic information systems (GIS) that is mentioned in various guidebook chapters but not discussed in detail. Finally, Appendix D provides information on use of current U.S. Census data products.

Choosing effects to consider for analysis. The types of effects to evaluate for environmental justice will vary depending on the specific circumstances of the policy, program, or project at hand; the level of local sensitivity to environmental justice issues; and the planning context within which the problem is being addressed. As part of the community planning process, techniques can be used to identify effects of greatest concern to local residents and to inform residents about the effects identified from engineering, environmental, and planning studies.

If the analysis is performed as part of a statewide or regional planning process, federal and local agency policy will dictate the types of effects that should be addressed. In this context, most issues will be related to questions of resource distribution and determining whether plans meet the long-term needs of all populations within the planning area. If the environmental justice evaluation is performed as part of an environmental assessment (EA) or environmental impact statement (EIS), the type of project and applicable state and federal regulations will dictate the types of effects to be assessed.

In all situations, it is important to prioritize effects. Prioritization can be based on factors such as level of public concern and potential consequences. More advanced methods should be used to evaluate effects in cases where public concern is high or the consequences could be substantial. More basic methods can be used to evaluate effects where less substantial consequences can be expected or public concern is not as great.

Identifying appropriate methods. Each chapter of this guidebook includes a table that summarizes criteria to use in selecting an appropriate method of analysis. The table can be used as a concise list of the methods discussed in the chapter and can be quickly reviewed to identify specific methods to read about in more detail. Within the discussion for each method, further information is provided to help you understand appropriate uses. The criteria listed in the tables and their definitions are below:

- **Assessment level.** Screening assessment/initial review or detailed analysis.
- **Appropriate uses.** Regional plans, investment plans, system assessment, corridor studies, project level studies.
- **Use when.** Brief description of types of issues that can be evaluated.
- **Data needs.** There are three levels of data needs:
  - Low - Data are readily available and processing demands are minor.
  - Medium - Data are generally available, must budget for acquisition/processing costs.
  - High - Data may be costly to acquire, processing requirements may be extensive.
- **Expertise required.** Listing of types of expertise needed to perform the assessment.

To the fullest extent possible, we have included methods in each chapter that vary in sophistication and complexity. As a general principle, you should use the least complex method that is sufficient for the problem at hand. The most complex methods should be reserved for cases when the potential impact is likely to be relatively major and when the affected population regards the impact as particularly important.

Once you select from the table a specific method to review, you can turn to the section that discusses that method in detail. Presentation of each method is similar, and includes a discussion of the following topics:

- **When to use.** A description of the types of situations in which this method provides informative results and for which it should be considered.

- **Analysis.** A concise discussion of the various techniques that can be used to apply the method or the sequence of steps required to carry out the method.
- **Data needs, assumptions, and limitations.** As appropriate to the specific method, this discussion presents the data required to perform the analysis, the types of expertise required to perform the analysis, and limitations of the technique that must be considered.
- **Results and their presentation.** Simple examples of results obtained from the method and ways in which the results can be prepared for presentation to the general public and to decision makers.
- **Assessment.** A final overview summarizing the most important points made about the method in the previous discussion.

Selecting the proper time horizon. The planning process is organized into a series of disciplines, each with different objectives and time horizons. It is important to consider environmental justice within each planning discipline. The process begins with long-range statewide and regional transportation plans that are updated on a regular basis to reflect changing needs and priorities. At the other end of the planning process are studies to define and select specific projects. Policies and programs developed by federal, state, and metropolitan transportation agencies govern this process.

Environmental justice is achieved by ensuring that policies and programs are fair and that all citizens have access to the planning process. Policies can also have direct effects on outcomes. One example is a policy implemented in California to reduce air pollution by retrofitting diesel engines. This policy has a distributive effect in part because large diesel-operated vehicles travel predominantly on freeways and major arterials that tend to have a large proportion of protected populations nearby. Many of the methods in this guidebook are suitable to evaluating such policies.

Studies with a long time horizon should consider how population characteristics might change within the plan's time span. Population projection may also be useful to predict future demographic changes in areas affected by specific projects. Practitioners must be aware that population projection is an extremely inexact science and should expect that population trends will need to be updated regularly.

In general, the complexity of analysis and level of detail required will be greater for project planning and corridor studies than for long-range transportation plans and investment plans. This is in part because of the nature of the problem—because projects are specific, their effects can be more precisely predicted, and they generally affect smaller areas and smaller numbers of users. In contrast, long-range plans usually are less fine-grained in nature and therefore tend to rely on more generalized information. Also, the greatest level of public concern is usually expressed at the project-planning level because the effects of the decision will be experienced in the short term. That said, it must be kept in mind that long-range transportation plans can have great potential to improve or worsen the circumstances facing protected populations, so environmental justice definitely is highly relevant to these plans, as well.

Because of these realities, most of the methods in this guidebook were developed with project-level analysis in mind, although this is not to say that policy, program, and longer-range planning efforts are any less important to environmental justice. Many methods that function at the project level can be used to evaluate long-range regional planning efforts. A project in the Atlanta area jointly conducted by FHWA, FTA, the Atlanta Regional Commission, and Georgia DOT is a good example. This project is described in a recent NCHRP report (Cambridge Systematics, Inc. 2002).

Understanding common criticisms of existing methods. Many past environmental justice assessment methods have been criticized for various reasons, and the methods in this guidebook were developed with an understanding of these criticisms. Past analyses often failed to consider the severity or magnitude of consequences, the balance between beneficial and adverse effects, and how those effects were distributed among the potentially affected populations.

Similarly, many past environmental justice evaluations have tended to rely on traditional environmental and socioeconomic assessment methods to determine “significant” effects and to only consider environmental justice consequences in cases where significant effects have been identified. Although such approaches are valid in certain circumstances, they often fail to consider unique concerns of protected populations and may be theoretically or technically inappropriate. Other criticisms from environmental justice proponents include the following:

- Using incomplete data or data irrelevant to local environmental justice concerns.
- Conducting studies and presenting results without obtaining feedback from local communities.
- Presenting studies in an overly-technical format that is difficult for the layperson to interpret.
- Failing to consider the differing values and priorities of diverse communities.

The methods in this guidebook can be used to structure objective, highly informative environmental justice assessments that can be readily communicated to the general public and to decision-makers. In many cases, especially with several of the technical methods that require Census data, GIS, databases, or statistical analysis, certain criticisms cannot be overcome entirely. Discussions in Chapter 2 and discussions of method limitations throughout the guidebook describe these limitations and ways to address them.

RELATIONSHIP TO OTHER RECENT PUBLICATIONS

Both NCHRP and FHWA have recently published informative reports that provide environmental justice guidance. In addition, a recent publication has been prepared for local communities and concerned citizens to promote understanding. How this guidebook is related to these other useful documents is described below.

NCHRP 8-36(11). A 2002 report titled *Technical Methods to Support Analysis of Environmental Justice Issues*, prepared for NCHRP Project 8-36(11), provides an inventory of technical approaches that can be used to address environmental justice issues in systems-level planning, and corridor and sub-area planning (Cambridge Systematics, Inc. 2002). The emphasis of the report was on methods that have been previously applied in transportation planning studies. The *Technical Methods* report's three main topics are the legal framework for environmental justice (Chapter 3), important findings on the current state of practice and approaches to structuring environmental justice evaluations developed from interviews with numerous agencies (Chapter 4), and a summary of recently applied analytical approaches (Chapter 5).

This guidebook is a continuation of the research begun in Project 8-36(11), focusing on modifying existing methods or developing new methods as necessary to evaluate a much broader range of effects. In addition, this guidebook is intended to be a concise reference to a broad environmental justice assessment body of knowledge.

Community impact assessment (FHWA). Community impact assessment differs from many traditional impact assessment processes in that it is focused on understanding how transportation system changes affect the quality of life in communities. There are a number of valuable community impact assessment resources including *Community Impact Assessment: A Quick Reference for Transportation* published by FHWA (1996), and a community impact assessment Web site sponsored by FHWA (2003).

The purpose of community impact assessment is squarely aligned with the principles of environmental justice. The methods presented in this guidebook are specific techniques that can be used in the community impact assessment process for developing community profiles and for analyzing impacts.

Effective EJ practices (U.S. DOT). The U.S. DOT (2003) has prepared a CD-ROM with examples of effective environmental justice assessment practices. The purpose of the *Effective Practices* CD-ROM is to provide practical examples relevant to an array of practitioners on how environmental justice has been integrated into transportation programs, policies, plans, and activities. It describes effective practices taken by transportation agencies, community-based organizations, and other grassroots and advocacy organizations to advance the fundamental principles of environmental justice. The CD-ROM can be used in conjunction with the guidebook to make environmental justice a central element of the transportation planning process.

NCHRP 45-19 (Report 456). Traditionally, effects assessments have been focused on issues of human health and impacts to the natural environment. Although these issues are extremely important in the context of environmental justice, they do not make up the full spectrum of beneficial and adverse social, economic, and environmental effects that should be considered. NCHRP Report 456, titled *Guidebook for Assessing the Social and Economic Effects of Transportation Projects* (Forkenbrock and Weisbrod 2001), discusses methods that increase the capabilities of transportation professionals to predict and assess social and economic effects to both transportation system users and other members of society. Many of the methods presented in Report 456 have been extended in this guidebook to allow for environmental justice assessment.

NCHRP 20-10(2) (Report 466). This report, titled *Desk Reference for Estimating the Indirect Effects of Transportation Projects* (The Louis Berger Group, Inc. 2002), builds on NCHRP Report 403 by the same contractor and provides guidance in identifying and estimating the indirect effects of proposed transportation projects. Indirect effects are foreseeable impacts that are caused by a project but occur at a removed location or a later time. These effects can be a source of substantial impacts of a social and economic nature. They also can cause important impacts related to natural resources, cultural resources, and accessibility.

Citizen's Handbook on Environmental Justice. A recent publication from the Institute of Transportation Studies titled *Environmental Justice and Transportation: A Citizen's Handbook* (ITS 2003) is intended to introduce community members and concerned citizens to environmental justice and its role in the transportation planning process. Whereas the *Citizen's Handbook* is intended for the general public, this guidebook has been written for the practitioner. The guidebook therefore assumes a certain level of background and experience with transportation planning processes and environmental justice concepts. When more detailed introductory information is needed or in situations where this guidebook or any of its methods are to be presented to a lay audience, it would be useful to incorporate many of the ideas presented in the *Citizen's Handbook*.

RESOURCES

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CHAPTER 2. IDENTIFYING PROTECTED POPULATIONS

OVERVIEW

Environmental justice assessment traditionally has focused on identifying distributive effects to minority populations and low-income populations. This focus has evolved out of the language of Executive Order 12898 issued by President Clinton in 1994. From a technical perspective, however, the same analytical process can be used to identify distributive effects on nearly any population group. Although considerable attention has been given to minority and low-income populations in the past decade, federal and state policies and regulations offer some level of protection to many other population groups. A review of federal law and regulations shows that the universe of protected populations includes those defined by age, disability, gender, religion, class, race, low-income, limited English proficiency, and national origin.

Assessment of distributive beneficial and adverse effects is an objective, analytical part of the environmental justice assessment process. Common transportation planning practice is to evaluate the effects of transportation system changes to "the public" or "local populations," in other words to the population at large. By identifying how effects may be differentially distributed among various population groups, the methods provided in this guidebook give you the ability to evaluate transportation system changes with greater precision. This form of analysis is a vital element in performing an environmental justice assessment. Assessment of distributive effects involves combining demographic and spatial analyses with social, economic, and environmental effects analyses.

The objective of environmental justice analysis in transportation is to assess the extent to which the benefits and costs of a proposed transportation system change would be experienced differentially by protected populations and other members of society. To make such an assessment, it is essential to have a clear sense of the areas in which minority populations and low-income populations move about most frequently, that is, where they are most likely to experience positive or negative impacts.

The most common means of defining areas where impacts are likely to be concentrated is through place of residence. This is a logical approach for many types of effects. For example, noise impacts are generally most significant when they occur near a person's home, as are community cohesion and aesthetic impacts. Unless a person spends nearly all of his/her time at home, however, many other types of effects are likely to be experienced throughout the day during daily activities.

To assess the nature and magnitude of impacts that vary spatially throughout a community, it is first necessary to gain a sense of the geographic space within which protected populations tend to circulate. This geographic space is commonly referred to as "activity space." To determine the activity space of protected populations, you must examine the social, affective, and physical aspects of these communities. Specifically, we present methods that can assist in estimating:

- The location and relative importance of activity spaces.
- Accessibility to these locations.

- How the proposed changes would affect protected population groups.

The methods presented in this chapter include many effective techniques for identifying protected populations using demographic data. This information can be collected either directly or from sources such as the U.S. Census Bureau. In addition, various geographic information system (GIS) and database applications allow you to process 1990 and 2000 census data and apply a number of the methods presented in this chapter.

The methods presented generally involve the following steps:

- Collect the necessary information.
- Verify the accuracy of the information if possible.
- Calculate pertinent population statistics.
- Assess the presence or absence of protected populations.

Many of the methods are quantitative and use census data, survey data, and GIS. Other methods are more qualitative and rely heavily on local knowledge and the public participation process.

Which method is best to use depends on various factors including the probable magnitude of a particular impact, data availability and cost, and the capabilities and experience of the person performing the analysis. The most important factor is whether or not the method is appropriate for the type of transportation system change being evaluated. For example, some effects of transportation system projects are distributed geographically, whereas other effects are distributed among system users based on their demographic characteristics. The best methods and data for identifying the demographic characteristics of affected populations may differ from case to case.

One purpose of any protected population assessment is to accurately represent the demographic characteristics of the affected populations. Any assessment should include input from members of the public and individuals with comparatively high levels of knowledge of the local area. Many methods rely directly upon these sources of information. For other methods, such as those that rely on census data, local knowledge and public input can be used to validate source data and study results.

A number of special considerations must be addressed when evaluating census data to identify protected populations. Some of these considerations include identifying appropriate comparison thresholds for analysis; selecting the appropriate scale of census data; estimating population characteristics for study areas; and comparing historic census data with current (2000) census data. These special topics are addressed in this chapter and in the appendices to this guidebook.

STATE OF THE PRACTICE

Most studies conducted since the mid-1990s to conform to requirements of the National Environmental Policy Act (NEPA) include some level of demographic review that includes analysis of minority and low-income population information. Inclusion of this information in transportation planning studies is common but not universal. A review of recent NEPA-conformance studies and a survey of practitioners show that local knowledge and analysis of large-scale census data are the most commonly used techniques for identifying protected populations (Sheeley and Forkenbrock 2002). Similar types of environmental justice assessment are also becoming commonplace in planning products such as major investment studies (MISs).

Field survey and data collection techniques also are commonly used. Assessment results released to the public often are brief summaries with very little detail. The specific methods used and analytical results obtained generally are not documented in detail.

Some techniques are used more rarely because of their technical complexity. These include formalized public participation-based qualitative assessment techniques, detailed assessment of small-scale census data, and complex methods such as historical data analysis and population projection. The state of practice could clearly be enhanced, however, if these rigorous assessment methods were more accessible to practitioners. Making these methods more accessible is one of the goals of this guidebook.

The methods presented in this chapter cover the spectrum of potential approaches from simple to complex and qualitative to quantitative. A key consideration in environmental justice analyses related to potential transportation projects is how protected populations move about in time and space. Because few people spend the majority of their time at home, it often is not sufficient to determine only where minority and low-income populations live; it also is important to ascertain prevalent daily activity spaces.

Trip diaries and surveys are the most common means of identifying how people move about in time and space. These methods can be very simple in nature or quite involved. The survey data can reveal the activity space within which protected populations frequently, occasionally, or seldom travel.

Revealed preference analyses are a practical way to evaluate how people actually respond to the choices available to them, and therefore what their preferences are when trading off attributes. These analyses enable you to assess, for example, how groups of people balance lower prices against convenience when purchasing goods. With sufficient data, this approach can enable you to “make direct inferences about the trade-offs travelers make among site and distance attributes” (Pipkin 1986, p. 183). When using these analyses, you should keep in mind that people will reveal preferences only in terms of the available alternatives. In considering shopping trips, Pipkin pointed out that individuals who do not own a vehicle or are otherwise disadvantaged might be forced to forego certain kinds of trips or to restrict their travel to nearer, smaller, and perhaps more expensive alternatives.

Variables that help explain travel patterns include the following:

- Personal attributes such as age, ethnicity, income, and level of education;
- Site characteristics such as price, quality and convenience for shopping, service, or recreational destinations; and

- Tension between locations that are of significant value yet geographically dispersed—i.e., home, work, and school.

Kitamura et al. (1997) identified four fundamental elements that influence urban travel patterns. Two of these elements, time budget and activity pattern, involve the individual traveler. The other two elements, land use and transportation, relate to the urban system. These four elements interact within a framework of space and time.

Miller (2001, p. 2) attempted to synthesize time geography, activity theory, and GIS into something he called "people-oriented GIS." Method 12 builds on Miller's approach by synthesizing several global positioning system (GPS) space-time activity studies.

SELECTING AN APPROPRIATE METHOD OF ANALYSIS

Each chapter of this guidebook includes a table that summarizes considerations you can apply to select an appropriate method of analysis. You can use the table as a concise list of the methods discussed in each chapter to identify specific methods to read about in more detail. Each method discussion provides further information to help you understand appropriate uses. Table 2-1 summarizes the protected population identification methods presented in this chapter.

We present 12 methods below, which generally pertain to identifying the areas in the community where protected populations currently reside and where they may live in coming years. The last three methods apply to analyzing the activity space within which these populations typically move about. These methods vary in complexity—how complex an analysis of activity space you should undertake may be based on the following considerations:

- **Spatial nature of likely impacts.** If a proposed project is expected to affect a sizable portion of the community, it would be important to assess the extent to which the impacts would be experienced in areas where protected populations frequently carry out their activities.
- **Perceived complexity of potential impacts.** If the potential impacts of the proposed project are likely to be substantial or complex in nature, it is essential to understand how these impacts would be distributed among protected populations as opposed to other groups.
- **Perceived importance of potential impacts.** If members of a protected population viewed a particular type of effect as particularly significant, it would be wise to use a relatively powerful method to assess how greatly this effect would impact the common activity space of that population.

As these considerations make clear, a basic knowledge of the protected population and its activity space will be necessary before a method can be selected. To determine which method to use, you should have a general idea of the potential problem and the area's population and characteristics.

Table 2-1.
Summary of methods for identifying protected populations

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. Local knowledge and public input	All	Recommended in all situations	Initial evaluation of potential for distributive effects and to assure quality of findings of other methods	Low	Local area/ community involvement
2. Threshold analysis	Screening/ detailed	Regional plans, STIP/TIP, system assessment	Demographic patterns must be evaluated for large areas	Low	GIS, Census data
3. Spatial interpolation	Screening/ detailed	Corridor/ project	Demographic patterns must be evaluated for small areas or population patterns must be evaluated for finite areas of effect	Medium	GIS, Census data
4. Field survey	Detailed	Corridor/ project	Detailed residence, business, and public space location information is required	Low/ medium	GPS & photo interpretation can be useful
5. Customer survey	Detailed	All	System users could experience distributive effects	Medium/ high	Survey design
6. Population surfaces	Detailed	Regional plans/ corridor/ project	Scenario modeling or integration with grid-based modeling packages is required	High	GIS, Census data
7. Historic data review	Detailed	All	Past projects or investment plans are at issue, or when population trends are needed	Medium/ high	GIS, Census data
8. Population projection	Detailed	Regional plans, STIP/TIP	Planning horizon is five years or more	High	Census data, statistical modeling
9. Environmental justice index	Screening/ detailed	All	Combined analysis of multiple demographic factors is needed	Medium/ high	Census data, GIS
10. Personal interviews	Screening/ detailed	Regional plans/ corridor/ project	Analysis of a relatively well-defined impact area	Low/ medium	Interview techniques
11. Abbreviated diary	Detailed	Corridor/ project	Analysis of movement along a corridor is needed	Medium	Sampling, surveys
12. Space-time activity analyses	Detailed	Corridor/ project	Analysis of movement along a corridor is needed	High	Sampling, surveys, GIS, GPS

METHODS

As highlighted in Table 2-1, the following methods can be applied to identify the locations and activity space of protected populations.

Method 1. Local knowledge and public input

Practitioners and stakeholders involved with the planning process usually are able to provide considerable insight into the population within a designated study area. Public input can be obtained as part of the community involvement process through interviews, surveys, focus groups, and feedback from public meetings.

When to use. Using local knowledge and public input is among the most commonly applied methods for identifying protected populations. This method is well suited for identifying effects that are distributed spatially, as well as those that are distributed among transportation system users. It can be used in all environmental justice assessments performed for transportation system changes at the project, corridor, and systems level.

Even if other methods are used to identify protected populations, local knowledge and public input should be used to verify results (see box titled “Using local knowledge and public input to validate census data,” p. 25). This method is also effective as an initial screening technique to determine if other, more data-intensive methods for identifying protected populations are needed.

Analysis. The following techniques should be considered for identifying protected populations through application of local knowledge and public input.

Interviews – In-person one-on-one interviews can be conducted with individuals identified as community leaders (people who work with or represent other people, e.g., neighborhood activists, elected officials, clergy, and representatives of local interest groups). These individuals are likely to have knowledge of, and insight into, local issues that cannot be found elsewhere. Interviews should be conducted early in the process so that the information gained can be taken into consideration as soon as possible during project development.

Surveys – Surveys may be carried out using samples that are broad-based (general population-based) or more narrowly focused (neighborhood-based). Some are scientific and produce statistically valid quantitative data; others are more informal and produce a mixture of qualitative and quantitative information. Surveys should be designed on the basis of the information that is needed. For example, if quantitative data are required for a particular district or area of the community, a formal survey should be designed to be statistically representative of individuals in the entire district. On the other hand, if information is needed from a group of people who have a particular interest in an issue, an informal survey should suffice.

Focus groups – A focus group is a small group discussion run by a facilitator. The group is carefully selected, either randomly or nonrandomly (to secure representation of particular groups). A random group will ensure representation of all segments of a population, whereas the nonrandom group will be helpful in eliciting a particular viewpoint or position. A focus group generally has the following elements and objectives: a scripted agenda (including five or six major questions); an emphasis on gathering many different points of view rather than on presenting information; identification of major points of agreement and disagreement; and approximately 8 to 12 participants.

Feedback from public meetings – A public meeting (or open house or hearing) is a forum for receiving comments from the public. These meetings generally have ground rules regarding listening and speaking (e.g., a time limit for speakers). Participants also have an opportunity to submit written comments at the time of the meeting or afterward. An advertising strategy is always necessary to ensure good participation in the public meeting by as large a segment of the local population as possible.

Using local knowledge and public input to validate census data

The case of Louisiana Energy Services (LES) is a good example of why local knowledge and public input must be used to identify protected populations and issues that can arise if census data are not augmented by additional information sources.

In 1994 the Nuclear Regulatory Commission (NRC) heard a complaint filed by the group Citizens Against Nuclear Trash (CANT) against proposed construction of a uranium enrichment plant. LES was planning to build the plant in Claiborn Parish near Homer, Louisiana.

CANT represented the small communities of Center Springs and Forest Grove in the complaint. Among other things, the complaint alleged that the environmental impact statement (EIS) did not sufficiently address all adverse environmental, social, and economic effects, and that there was racial bias in the choice of the plant's location.

LES planned to reroute a road and greatly increase the travel distance between the two small communities. These communities, populated by individuals in protected population groups, were not discussed in the Draft EIS and were not identified on a map that showed local communities. They were overlooked because the Draft EIS analysis relied solely on census data and map sources with a coarse level of resolution that did not show the two communities.

The NRC agreed that the EIS did not adequately address impacts to the two communities and, ultimately, LES was required to resubmit sections of the EIS. The map was changed in the final EIS. In addition, LES had to revisit the entire siting process and show that racial bias did not play a part in the choice of the site. At this point, LES withdrew its application.

Data needs, assumptions, and limitations. Information should be collected on locations and names of communities on maps, and important community centers should be identified, along with public spaces where protected populations may congregate. Assume that a representative cross-section of the communities in the study area are involved in the process. This process may be time consuming and does not produce estimated population sizes or demographic characteristics. Also, these data cannot be readily incorporated with quantitative assessment.

Results and their presentation. Map census data indicating neighborhoods and important community centers identified in a survey or set of interviews. This will produce a tabulation of protected population groups, their residential and activity spaces, and important modes of transportation.

Assessment. Techniques for obtaining input on protected populations from individuals with local knowledge should be applied to assessment of most transportation policies, programs, and projects. Techniques such as interviews, surveys, focus groups, and feedback from public meetings are often the best way to identify where protected populations live, their activity spaces, and modes of transportation. Both qualitative and quantitative information can be collected, depending on need.

Method 2. Threshold analysis using large-area census data

Census data from 1990 and 2000 are reported at many levels of analysis and are available from numerous sources, including the U.S. Census Bureau, the Internet, and federal repository libraries. Large-area census data can be obtained for states, counties, census tracts, and census-designated places. Small-area reporting units available in census data include traffic analysis zones (TAZs), block groups, and blocks. Evaluation of small-area census data is discussed as a separate method. It should be noted, however, that the large-area evaluation methods discussed below can be used with small-area data when needed.

When to use. Large-area census data are useful for evaluating the distributive effects of state and regional transportation plans and other systems-level planning efforts. These data also may be applied to initial assessment-of-corridor studies, depending upon the size of the corridor and the nature of the transportation system change that is being evaluated. Additionally, this type of data can be used when spatial demographic patterns must be evaluated or to estimate transportation user demographics at the systems level. In general, protected populations are identified from large-area census data using some form of threshold analysis.

Analysis. Threshold analyses are carried out in five steps:

Step 1 – Define the study area. Consider the scope of the proposed transportation system change and select a study area that encompasses all affected areas and populations. For a transportation investment plan, the study area may even be statewide. A regional long-range transportation plan may require a multicounty study area.

Step 2 – Select analysis units to be used. The selected analysis unit (e.g., county, tract, TAZ) must balance the amount of data to be evaluated with the level of precision required to identify the distribution of effects. For example, county units of analysis may be appropriate to evaluate distributive effects of a statewide multimodal transportation investment plan. County-level data are not sufficient, however, to evaluate whether protected populations have equitable access to a regional transit system. In this case, census tracts or TAZs may be a more appropriate choice to address the distances that members of protected population groups must travel to reach regional transit nodes.

Step 3 – Acquire data and compute demographic statistics. Information on where to obtain large-area census data is presented in "Data needs, assumptions, and limitations." Depending on the data source, it may be necessary to compute the demographic statistics needed to identify protected populations; the Census Bureau does not always precalculate these statistics. Some data sources, however, provide precalculated variables that can be used when appropriate. Guidance on techniques for calculating demographic statistics from standard census data files can be found in Appendix D.

Step 4 – Determine threshold levels. When using a data-driven technique, it is often necessary to define "protected populations" on the basis of threshold values for various demographic variables. The thresholds are used as comparison values to determine if protected populations exist in a study area. For example, if an area's percent minority population is not equal to or greater than the established threshold value, the level of environmental justice concern can be assumed to be lower than in areas where the statistic is greater than the threshold.

Two basic approaches are used to define thresholds. The first approach commonly used by agencies is to establish a working group to evaluate and determine appropriate threshold levels. Recently in New York, the state environmental agency's environmental justice working group set statewide thresholds that were approved after being submitted to the public for comment. A second commonly used approach is to set thresholds to equal either state- or county-level averages, depending upon the size and geography of the study area (see box titled "Limitations of using comparison thresholds in environmental justice assessment," p. 28).

Step 5 – Identify protected populations. When using large-area census data, all evaluation units generally include members of protected populations. It is thus more appropriate to consider this technique as an approach for categorizing evaluation units based on the proportion of protected populations that they contain. Evaluation units with protected population levels greater than the established threshold values are considered to have substantial protected populations and higher potential for distributive effects than other evaluation units. An example is shown in Table 2-2. The results were obtained from a review of county-level 2000 census data for the Texas Department of Transportation, Houston District.

**Table 2-2.
Relative level of environmental justice
concern in the Houston district**

Area	Percent minority	Percent low income	Relative level of concern
Threshold value (State of Texas)	47.6	17.0	—
Brazoria County	34.6	12.5	Lower
Fort Bend County	53.8	7.3	Higher
Galveston County	36.9	16.8	Lower
Montgomery County	18.6	11.9	Lower
Harris County	57.9	14.9	Higher
Waller County	50.1	20.0	Higher

Limitations of using comparison thresholds in environmental justice assessment

Background. Thresholds often are a necessary component of data-driven evaluation techniques. They serve as a useful way to define "level of environmental justice concern" (a commonly used term in environmental justice assessments) based on demographic characteristics. It is important, however, to use threshold comparisons wisely, as part of a thorough evaluation process. Although they can serve to categorize and prioritize areas based on level of concern, the problem with thresholds is that they are arbitrary.

Example. Consider as an example an environmental justice assessment of a proposed airport expansion. Environmental review indicates that most adverse noise and air quality effects on surrounding populations will occur within 1 mile of the airport boundary, so a 1-mile buffer of the airport is selected as the study area. Because the study area is completely contained within a single county, the county's average demographics are selected as the comparison threshold.

A review of small-area census data (described later in this chapter) shows that the percent of study area population living below the poverty level is 14.5 percent, which is below the county average threshold of 16.5 percent. Similar results were obtained in a review of minority population data. Based on this information, it could be concluded that there is limited concern about adverse distributive effects to protected populations.

Discussion. The above approach is common practice. The assessment process is relatively easy to perform, and the findings and conclusions are easily presented. It is often advisable, however, to perform a more thorough analysis in many situations.

Figure 2-1 continues with the airport expansion example and presents the results of a thorough demographic evaluation performed at each quarter-mile increment from the airport boundary out to 8 miles. The figure supports the conclusion that the low-income percentage within the 1-mile area is less than the county average threshold. A more interesting observation is that the highest percent of people living below the poverty level is from 1.25 to 2.5 miles from the airport.

Conclusion. Instead of establishing an arbitrary threshold for analysis, it may be more appropriate to perform a thorough review of the demographic data; identify areas where substantial minority populations and low-income populations live or work; and then evaluate effects to determine the beneficial and adverse distributive effects that would result in those areas.

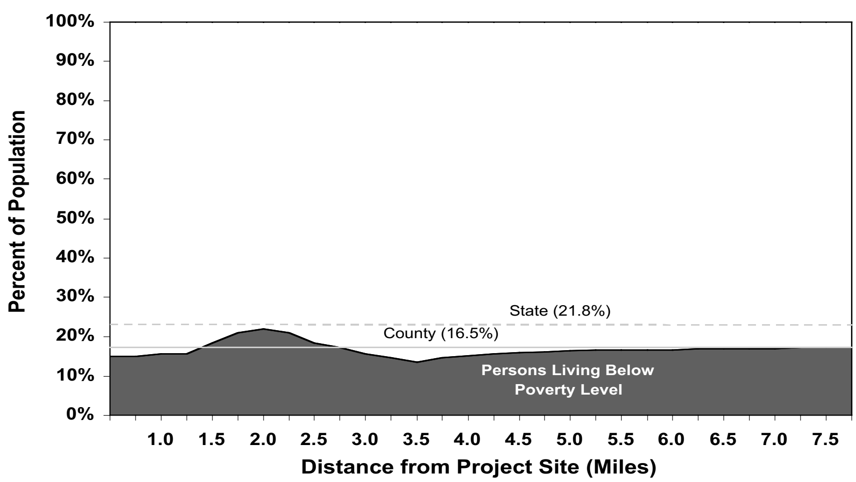


Figure 2-1. Percent of population below poverty level

Data needs, assumptions, and limitations. The single best sources of data are Summary File 3 of the 2000 Census for geographically distributed effects and the Census Transportation Planning Package (CTPP) for effects experienced by system users. Still, useful demographic data are also available in other census summary files. For comparison with previous census data, use Summary Tape File 3 from the 1990 Census. Online resources for these data are included in the resources at the end of this chapter. These data can be combined with census TIGER (Topologically Integrated Geographic Encoding and Referencing) files in GIS if maps are needed to analyze spatial distributions.

This method contains several important assumptions that serve to limit its effectiveness. The most important limitations include the following:

- **Populations are not distributed uniformly.** Most techniques that use census data assume that populations and population characteristics are uniformly distributed within census units. This assumption can be especially problematic when working with large-area census data. Census geography is hierarchical. So, for example, counties are composed of tracts; tracts are composed of block groups; and block groups are composed of blocks. In general, population characteristics will be most uniformly distributed in blocks and variability will increase with the size of the census unit. It has long been known that statistical studies will yield different results depending upon the level of census data that are analyzed. This is in part because the data violate the assumption of uniform distribution to differing degrees (Fotheringham and Wong 1991; Amrhein 1995). An example of the variability in results is provided in the discussion of "GIS-based techniques to estimate demographic characteristics," where block and block group-level data provide different results for the same study area.
- **The level of demographic resolution should match the scale of effects.** Resolution, or scale, is another limitation of large-area census data and is related to the uniform distribution assumption. Data for large-area census units are totals of the small-area census units contained within them. Large-area census units thus have less resolution than small-area census units. Therefore, it is important that large-area census data not be used in instances where a high degree of demographic resolution is needed. An example would be assessing the effects of noise on nearby residences, which is a highly localized effect. In such instances, it is more appropriate to use small-area census data, even if the study area is very large. In other instances, large-area census data are appropriate. An example would be an analysis of transportation policy changes on regional air quality.
- **The Census may undercount protected populations.** Survey and enumeration techniques used in census data collection rely heavily on address lists. It has long been argued that low-income, minority, and other protected populations are consistently undercounted and that the census is not an entirely accurate representation of these populations. Elaborate statistical techniques are available to correct for population undercounting, but these techniques rely on assumptions that are often difficult to validate. It is probably more appropriate when working with census data to understand that protected populations may be undercounted and to apply conservative threshold levels and use local knowledge as a means of verification.

GIS-based techniques to estimate demographic characteristics

Study area boundaries often do not coincide with the boundaries of census reporting units. When performing environmental justice assessments, it is important to understand the relationship between study area geography and census unit geography. It is also important to understand that use of different census reporting units, such as block groups or blocks, may yield different results.

Three common GIS-based methods for estimating study area population characteristics are known as polygon containment, polygon intersection, and areal interpolation. Each involves a different approach for identifying the census reporting units that overlay a study area. Areal interpolation is the most accurate but is more data intensive than the other methods. The polygon-intersection technique tends to over-predict population, whereas the polygon-containment technique tends to under-predict population. Census blocks offer the most detailed census geography and will yield the most precise estimates, but only limited demographic information is reported at the block level. Figure 2-2 shows the census block and census block group geographies used to derive population estimates for a 1-mile study area surrounding a proposed bridge location. The shaded census units show the area from which the 1-mile area estimates are determined. Note that the same 1-mile buffer is shown in each diagram. The population estimates obtained from the various methods and census units vary by as much as 12,092 persons, or 4.7 percent.

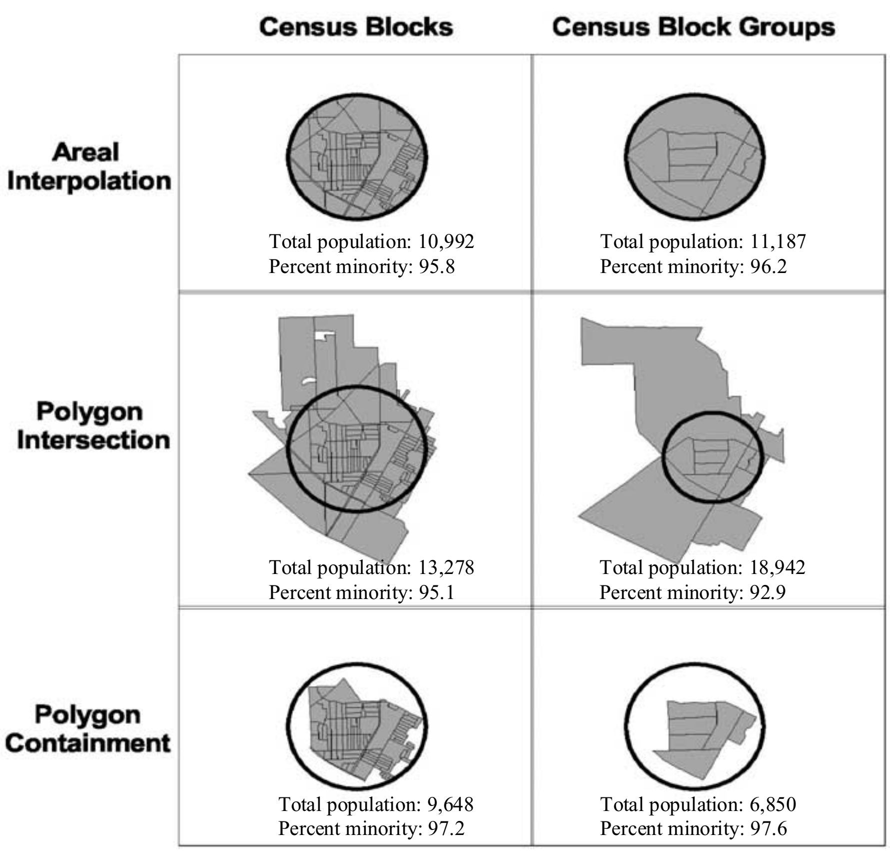


Figure 2-2. Census reporting units and study area geography

Results and their presentation. Results of large-scale census data analysis are often presented in narrative format. Using the data presented in Table 2-2, results could be expressed in the following manner:

> In the Houston District, Fort Bend, Harris, and Waller Counties have a higher proportion of individuals in protected population groups than other counties in the District.

Tables can be used to convey large amounts of information in technical reports, but the amount of information should be kept to a minimum if tables are to be used in public forums. Maps can be used to convey spatial patterns, but maps are often more appropriate for presenting small-scale census data.

Assessment. Large-scale census data are suitable for identifying protected populations if the patterns of effects are uniform over large areas. Much useful information is available for large-scale census units, such as tracts and counties. This information can be used to assess both the spatial distribution of protected populations and the demographics of transportation system users. Large-scale census data are best suited for assessing state and regional policies and programs, and for transportation system changes that would generate system-wide effects. Such census data are generally not suited for project-level analysis and should be used cautiously for corridor-level assessment.

Method 3. Spatial interpolation using small-area census data

Small-area census data at the block, block group, and TAZ level offer the most detailed nationally available demographic information useful for identifying protected populations. Database, spreadsheet, and GIS software are often necessary for this type of analysis because even relatively small study areas commonly encompass a large number of small-area census units.

When to use. Small-area census data should be used in situations where the scale of effects to be analyzed requires a high degree of demographic resolution, such as when project effects are limited to relatively small, localized areas. Small-area census data can also be used if results of studies using large-area census data are questioned, making it necessary to obtain the "best available" or most accurate census data. The small-area census data and the techniques described below are most applicable to project- and corridor-level analysis. Blocks and block groups can be used to assess spatial demographic patterns, whereas traffic analysis zones should be used in situations where transportation user demographic characteristics are required.

Analysis. Spatial interpolation using small-area census data is conducted in five steps:

Step 1 – Define the study area. Because small-area census data are best suited for identifying protected populations in situations where effects are localized, it is often possible to define a study area based on detailed geographic patterns of effects. For example, contours or receptors developed from noise and air quality analyses could be used to define areas of effects. Viewsheds may be selected as the area of effects to address visual quality impacts. A more simplified approach is to select a buffer distance that encompasses the geographic extent of effects. GIS can be a useful tool for defining study areas. Contours generated from modeling programs can be brought into GIS for overlay with census data, and buffering tools can be used to develop study areas from site locations or project corridors.

Step 2 – Compute statistics for protected populations. If patterns of effects are distributed spatially, block groups and blocks should be selected as the census units for analysis. A combination of block groups and blocks is recommended because, while blocks offer the highest level of resolution, all potentially necessary data are not reported at the block level. If patterns of effects are distributed among transportation system users, traffic analysis zones should be used where possible. Data for traffic analysis zones are available in the 1990 and 2000 CTPP. Table 2-3 lists the protected population demographic data that are available at the various census reporting levels. Statistics can be calculated using various spreadsheet, database, or GIS applications. Formulas for computing useful demographic statistics can also be found in Appendix D.

Table 2-3.
Availability of protected population data by 2000 census reporting unit

Census reporting unit	Total population	Minority	Income	Age	Gender	Disability	English speaking
Block	✓	✓		✓	✓		
Traffic analysis zone	✓	✓	✓	✓	✓	✓	
Block groups, tracts, and larger	✓	✓	✓	✓	✓	✓	✓

Step 3 – Overlay demographic data with area of effects. The purpose of this step is to identify the census-reporting units that fall within the area of effects. The three overlay methods for selecting census-reporting units are known as polygon intersection, polygon containment, and areal interpolation. Each approach can provide a different estimate because areas of effects do not commonly coincide with census unit boundaries. For more information, see the discussion on "GIS-based techniques to estimate demographic characteristics."

Step 4 – Estimate demographic characteristics of the study area population. The demographic characteristics of the study area population can be tabulated once the census units within the area of effects have been identified. Values can be reported for the individual census units within the study area, which is useful for assessing the population distribution and characteristics. It can also be useful to generate an estimate of the population characteristics for the area as a whole. An areal interpolation technique is best suited for developing this estimate. The most common and easily performed method is called area-weighted interpolation, which assumes that populations within the census units are uniformly distributed (Goodchild and Lam 1980). Many interpolation routines do not rely on the uniform distribution assumption. One of the more promising techniques, especially useful in sparsely populated areas, uses an overlay of road networks with census units under the assumption that most residences are near a roadway (Mrozinski and Cromley 1999). Another method uses ancillary data as an input mask to identify areas within census units where there are no residences (Bloom, Pedlar, and Wragg 1996). In this way, nonresidential areas such as parks and areas zoned for commercial or industrial use are assigned zero population.

Step 5 – Compare to thresholds for analysis. The final step is to compare demographic estimates to analysis thresholds in order to identify the presence of protected populations. This step is the same as that for the analysis using large-area census data.

Data needs, assumptions, and limitations. The following data sources will be necessary, depending on the census-reporting units selected for analysis:

- Summary File 1, to compute block-level statistics;
- Summary File 3, to compute statistics for block groups, tracts, and larger reporting units; and
- The Census Transportation Planning Package to compute statistics for TAZs.

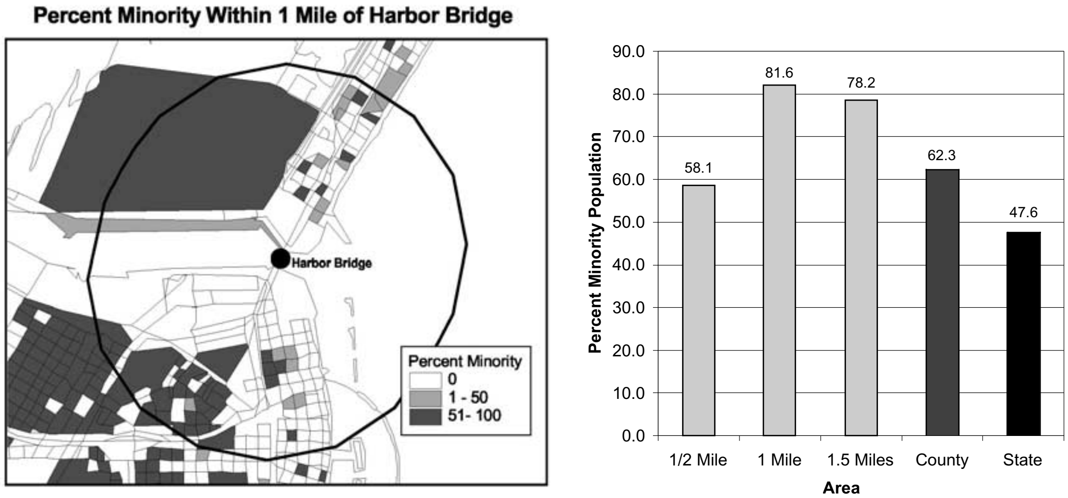
Information about acquiring and using these data sources is provided in Appendix D. Analysis of small-area census information can be quite data intensive and requires some combination of spreadsheet, database, and GIS software. GIS software is needed to perform the interpolation methods discussed above.

The assumptions and limitations discussed for large-area census data (see Method 2) generally apply to the evaluation of small-area census data. In addition, the complexity of many analytical processes and the amount of data required often limit the use of small-area census evaluation methods to situations where other less intensive techniques have not provided adequate results or results have been contested.

Results and their presentation. Results can be presented as maps, graphs, and tables (as shown in Figure 2-3) depending on the purpose and the intended audience. Maps are the best means of presenting geographic patterns and are often essential for conveying the proximity of protected populations to sources of beneficial and adverse effects. Maps should be relatively simple, showing only the census data theme, such as percent minority by census block, and enough other features to orient the reader.

Graphs, on the other hand, can be used very effectively to provide a comparison of study area demographics to comparison areas or threshold levels. Tables should be used primarily in technical reports; only tables with five to seven data values or fewer should be used for communication with the public. Tables do, however, offer a very useful way of organizing and summarizing the results of small-area census data evaluations.

Assessment. Compared to other techniques, analysis of small-area census data is more complex and more data intensive. However, this method offers the finest demographic resolution available with census data and should be selected over other methods in situations where the effects from a proposed transportation system change will be localized to specific areas.



Distance	Total population	Total minority	Percent minority
1/2 mile	124	72	58.1
1 mile	1,249	1,019	81.6
1-1/2 miles	4,717	3,690	78.2
2 miles	9,195	7,497	81.5
County	313,645	195,467	62.3
State	20,851,820	9,918,507	47.6

Figure 2-3. Techniques for presenting study area demographics

Method 4. Field survey

A field survey, also known as a dashboard or windshield survey, involves obtaining local knowledge by actually traveling about the area and taking notes.

When to use. A field survey generally is recommended as part of project-level environmental justice assessments; they are less practical for corridor and system-wide assessments. Field surveys are especially important in situations where project effects such as noise and air quality will be highly localized and census data do not provide a fine enough level of resolution.

A field survey is also a good technique for verifying the accuracy of small-area census data. Field surveys can be comprehensive in small, manageable study areas. If projects cover large areas or field surveys are conducted at the corridor level, it may be more appropriate to identify specific locations for a field study. Field surveys can be used to collect the following information that is not obtainable from a review of census data alone:

- Mapping the location of residences in a study area.

- Delineating specific neighborhoods by identifying visible changes in neighborhood characteristics.
- Identifying nonresidential locations, such as churches and community centers, that are used and valued by members of protected population groups.
- Identifying small areas of extremely high population density, such as apartment houses, and commercial and industrial areas with no population.

Analysis. The four steps in carrying out a field survey are:

Step 1 – Obtain location maps. Location maps are necessary for planning the field survey and for documenting your findings. Topographic maps, maps produced in GIS from readily available data, and maps from Internet service providers such as MapQuest and Yahoo will serve the intended purpose. City maps, county maps, and maps sold by companies such as Delorme and Thomas Brothers will also work well. To verify census information, it is also necessary to prepare small-area census maps before conducting the survey.

Step 2 – Plan your route. It is important to plan your route before conducting the survey for safety reasons, to save time, and, most essentially, to ensure that you visit all important locations and inspect a representative cross-section of the study area. This is especially important in situations where the study area is too large to be surveyed in its entirety.

Step 3 – Perform field survey, collect field notes. During the field survey, it is important to take notes to ensure that all relevant findings are documented. Be on the lookout for "sensitive receptors" such as schools, hospitals, and nursing homes, as well as locations that visually do not appear to corroborate census information. This could include large areas with no population that are depicted as having high population on the census map or affluent neighborhoods marked as low income. Because the census is only conducted every 10 years, be alert for newly developed areas that do not yet appear in the census data. In sparsely populated areas or when certain types of impacts are being evaluated, it can be worthwhile to map the location of individual residences as part of the field survey. This effort can be supported by the use of GPS technology or aerial photography. Photographs are an especially useful method of documenting detailed information about appearance and relative location for future reference.

Step 4 – Conduct follow-up activities. It is often necessary to conduct follow-up activities. Questions may arise after the survey based on information that was collected during the initial trip. When in doubt, conduct a follow-up survey, talk with community members, or speak with someone knowledgeable about the local area to answer any questions that you may have.

Data needs, assumptions, and limitations. Field maps and possibly census maps are required to conduct a meaningful field survey. Although this technique is an effective way of obtaining information about a study area, there are notable limitations. The technique relies heavily on visual cues, which are not always accurate. Unlike door-to-door surveys or telephone surveys, the dashboard survey is limited to observations obtained in the field from a visual inspection of the study area. Also, although this technique aids in identifying areas of concern, it is only of limited use in estimating population counts (such as in sparsely populated areas). Other demographic information, such as income level, age, and disability, are virtually impossible to obtain through a field survey.

Results and their presentation. Results are often printed in narrative form as references to specific locations or features of the study area. Photographs are often used to depict examples of locations of concern. Another useful method of presentation is to include specific information gathered during field surveys as annotation on project site maps. The map in Figure 2-4 includes information from a field survey. The information has been added to the census map for the area near Harbor Bridge, originally shown in Figure 2-3.

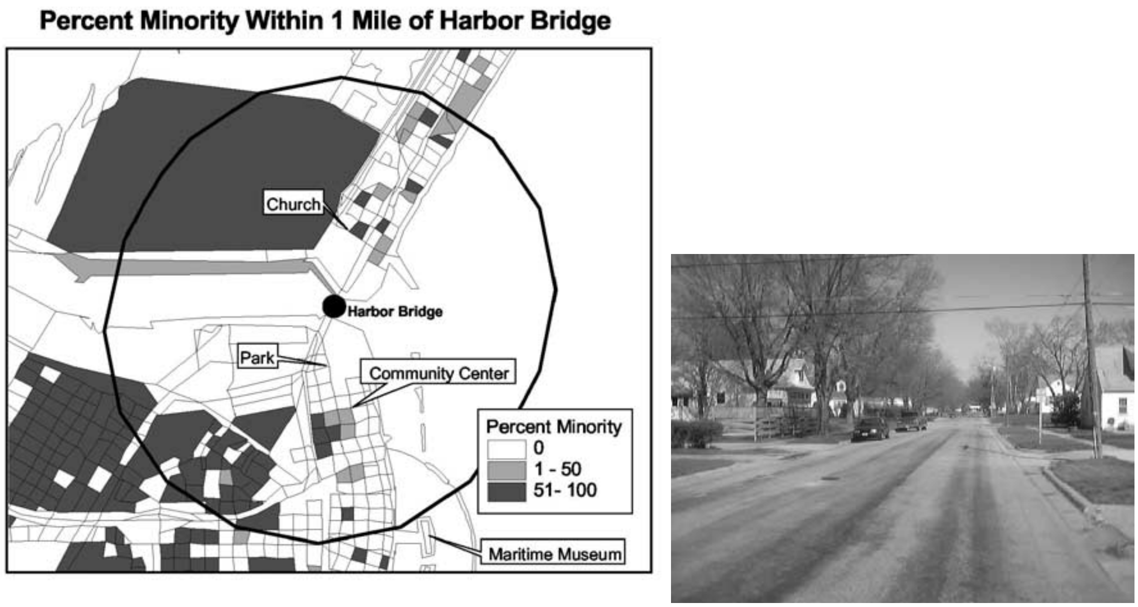


Figure 2-4. Techniques for presenting field survey results

Assessment. A field survey is an effective technique for gaining local knowledge of areas potentially affected by transportation system changes. The method is well suited to use in combination with techniques for evaluating small-area census data. Information from field surveys can be enhanced by performing door-to-door surveys to collect information from local citizens.

Method 5. Customer survey

Customer surveys are among the most effective methods for evaluating user demand and user perception of transportation system quality.

When to use. Customer surveys should be considered to identify protected populations when evaluating effects experienced by transportation system users. These include issues such as transportation safety and transportation choice. Note that the survey should be constructed to evaluate both protected populations and the effects of the transportation system change being studied.

Analysis. In general, a customer survey is conducted in two steps:

Step 1 – Construct the survey. The transportation survey should be designed to collect information on both demographic characteristics and demand/perceived quality. In many areas, it will be important to prepare the survey in multiple languages. Figure 2-5 includes a series of questions suitable for identifying important social group characteristics of transportation system users. The questions were designed to coincide with attributes available in the 2000 census.

Sex	Male ____	Female ____	
Age	Under 18 ____	18 to 29 _____	30 to 49 ____
	50 to 64 ____	65 and older ____	
Race	African American ____	Asian _____	
	Hispanic/Latino _____	Native American _______	
	Caucasian ______	Other _____	
Family income	Less that $15,000 ___	$15,000 to $25,000 ___	
	$26,000 to $50,000 ___	$51,000 to $75,000 ___	
	$76,000 to $100,000 ___	More than $100,000 ___	
English proficiency	Can you speak English?		
	Very well _____	Well _____	
	Somewhat _____	Not at all _____	
Disability	Do you have a disability that affects your mobility or preferred method of transportation?		
	Yes _____	No _____	

Figure 2-5. Survey questions to identify protected populations

Step 2 – Administer the survey. User surveys can be administered at the point-of-use for many forms of transportation including pedestrian, bicycling, and bus and light rail transit. It is more difficult to conduct point-of-use surveys for vehicle transportation. However, for any mode of transportation it is possible to distribute the surveys through organizations (such as Area Agencies on Aging), businesses, or through the mail. Another promising technique is to administer surveys online via the Internet as more and more people are obtaining access either at home, through work, or at local libraries. It is important, however, to consider whether the population to be surveyed (e.g., low-income and other disadvantaged persons) has Internet access before using an online survey.

Data needs, assumptions, and limitations. Surveys reflect the views and opinions of the people who complete them. It is critically important to ensure that a survey adequately captures the characteristics and views of the user population. Survey design and sample size are the two most important elements to ensure adequate results. A simple rule of thumb is that a larger sample provides more precise results. Larger samples, however, often cost more money, so in practice it is necessary to balance tradeoffs between statistical precision and cost. Similarly, good survey design is necessary to develop questions that are unambiguous, easily understood, and provide informative results. NCHRP Report 456 (Forkenbrock and Weisbrod 2001) provides a concise discussion of survey design and sample size. As with any user survey, results will reflect the demographic characteristics of current and past users. People who have not used or are not willing to use the method of transportation will not be represented.

Results and their presentation. Results can be summarized in narrative form to present key findings. Statistical analysis can be used to evaluate the accuracy of survey results. Results can be tabulated and presented numerically to support a statistical analysis. Key findings can also be presented graphically. Results can be presented by social group (such as low-income versus middle-high income, or minority versus nonminority) to identify if preference or levels of impacts vary by social group. Thus, if a proposed transportation change will have a greater effect on transit service than on vehicle commuting, it would be possible to determine whether there is a greater preference for transit ridership among low-income individuals.

Assessment. Surveys are an effective method of assessing transportation user demands, preferences, and perceived quality of service. To allow for environmental justice assessment, it is important to include in the survey design questions that identify whether respondents belong to any protected population groups. These questions need not be detailed or personally invasive. With a little planning, it is a simple task to administer a survey that identifies the respondents' pertinent demographic characteristics.

Method 6. Population surfaces

When to use. This is a special technique for evaluating small-area census data. It is a method for processing census data in situations where it is either necessary or beneficial to estimate population characteristics for grid-based model cells. Population surfaces can be used to evaluate distributive effects using modeling results commonly generated for air quality and noise.

Analysis. The four steps in developing a population surface are as follows:

Step 1 – Acquire input data. The input data requirements and set-up steps are the same as for traditional GIS-based analysis of small-area census data.

Step 2 – Develop analysis grid. This is commonly done in conjunction with a model-based analysis of transportation system effects. For example, the analysis grid developed for a regional air quality model could be used as the population surface grid in GIS. With most GIS software packages, it is best for the grid to be uniform (i.e., all cells have same length and width, such as 100 feet by 100 feet) although it is possible to establish a population surface using nonuniform grids.

Step 3 – Perform zonal-to-surface population conversion. The zonal (census polygon) to surface (grid) conversion can be performed using GIS. Numerous methods exist for converting zonal population surfaces to grids. Martin (1996) describes a commonly used technique.

Step 4 – Compute population statistics. It is most appropriate to generate a surface (grid) from population counts such as total persons, total minority, or total low-income. It is therefore necessary to compute population percentages from the various population surfaces using map algebra after the surfaces have been created. For example, dividing a grid of total minority population by a grid of total persons can generate a grid showing percent minority. Map algebra can be performed in any GIS software package that supports grids.

Data needs, assumptions, and limitations. Census data and census geography are used as inputs in constructing population surfaces. GIS is required to convert the polygon-based population map to a grid-based population map. This function can be performed in most commercial GIS applications.

Because this technique uses small-area census data, it is subject to the same assumptions and limitations discussed Methods 2 and 3. Also, it is virtually impossible to perform the polygon-to-surface data conversion without introducing some error into the data. Population surfaces therefore include errors contained in the original census data as well as errors introduced during the conversion.

There are two conversion error components: data omission and spatial shifting. Data omission occurs when the population for a census unit is not included in the grid-based population surface. Spatial shifting occurs because grid cells cannot represent census unit boundaries as precisely as zonal polygons. If done properly, however, the conversion can be performed with negligible error.

Results and their presentation. Results and presentation of protected population information can rely on maps, tables, charts, or graphs, similar to any other GIS-based census data technique. The difference in results and presentation with this method is that the demographic information can be combined with model-derived effects information. Further examples of this technique are given in guidebook chapters that follow.

Assessment. Use of population surfaces is a promising and powerful environmental justice assessment technique that has seen little use in the transportation field. One notable system, the System for Planning and Research in Towns and Cities for Urban Sustainability (SPARTACUS) (see pages 331-332) constructs population surfaces for integration with a raster transportation and land use model. This application is described in an NCHRP report (Cambridge Systematics, Inc. 2002). Defining population surfaces is both data intensive and computationally intensive, and it requires a considerable amount of GIS expertise. The method is best suited for analyzing distributive effects of phenomena that are most effectively modeled as a surface, such as air quality or noise.

Method 7. Analysis of historical data

When to use. Historical information is useful when issues related to environmental justice have occurred over a long period of time or have a historical context. Historical data are also useful to establish population baselines for comparisons to current or more recent data, and they can be useful for identifying population trends. Review of historical data can be especially important as part of various methods for performing population projections, which are discussed later.

Analysis. There are generally two basic steps in completing an analysis of historical data:

Step 1 – Acquire data. There are many sources of historical data. Data from U.S. censuses beginning in 1990 are readily available nationwide. Many electronic and paper products from the 1980 and previous censuses are available for most of the U.S. In addition to census information, numerous regional and local data sources are available, such as property ownership records, maps, zoning and planning records, aerial photographs, old newspapers, knowledgeable citizens, government reports, and the like.

Step 2 – Perform analysis. Many of the techniques discussed in this chapter can be performed using historical data. In cases where historical data will be used as baseline information, it will be important to format the data to overlay or match with the current data sets that are being used.

Data needs, assumptions, and limitations. Historical data often are used for a purpose that was not originally planned for or anticipated. As with any data source, it is important to understand why the data were collected and what are their limitations. Ask questions such as "What was the sample size? Were the data collection methods susceptible to either under counting or over counting protected populations? What were the quality control procedures? Are there other data sources available to corroborate this information?" In addition to these issues related to use of historical data, the assumptions and limitations of the specific analytical method also apply.

Results and their presentation. One use of historical data is to analyze population trends within a study area. The example in Figure 2-6 is based on a comparison of 1990 and 2000 census data for the Baton Rouge metropolitan area. Minority population percentages for census tracts were compared for the two census years. These data were overlaid with the interstate highway system to identify segments where there was a greater than 10 percentage point increase in minority population from 1990 to 2000. This statistic indicates areas where it may be especially important to address how transportation system changes affect protected populations.

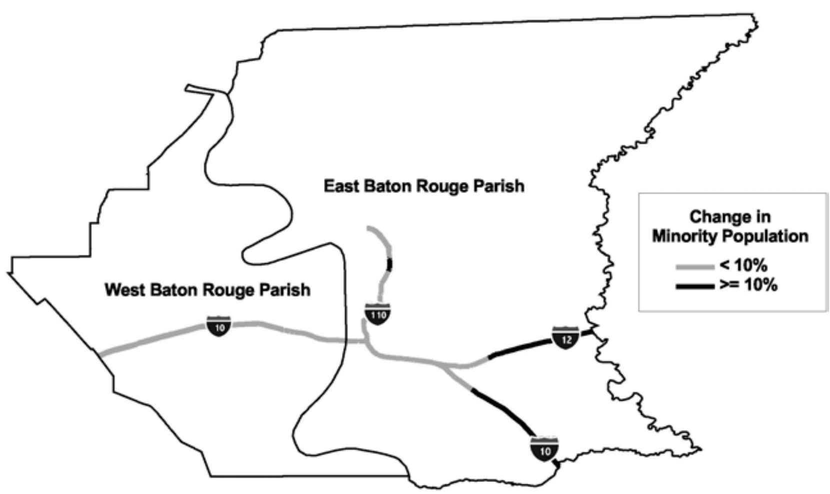


Figure 2-6. Interstate highway corridors with a significant increase in minority population from 1990 to 2000

Assessment. Historical data can be used to evaluate long-term population trends and distributive effects of transportation system changes that have occurred in the past. There are numerous data sources available regionally and locally. At a national level, data from the 1980, 1990, and 2000 censuses are readily available sources that can be used to establish population trends. In addition, trend data can be used to project future population characteristics, our next topic.

Method 8. Population projections

Population projections are as much art as they are science, and the field of demography has for decades endeavored to develop accurate population projection techniques. Worldwide population projections are *relatively* accurate, because the future population to be estimated is large and population change at the global scale is driven by the relative size of age cohorts and trends in birth rates and death rates that have been predictable for at least the past couple decades. At smaller scales of states and counties, population projections further involve finer-scale cultural issues and emigration/immigration as confounding factors. Of course, the further into the future you project a population, the less accurate the projection is likely to be.

Most transportation system changes, especially projects, require use of small-scale demographic data such as tracts, TAZs, and block groups. At this scale, general population growth trends are much more difficult to evaluate and projections are more likely to be thrown off by cultural changes. Examples such as gentrification, local economic changes, and rapid growth in various industry sectors can render useless even the most scientifically rigorous projections.

Add to the above issues the fact that for environmental justice assessment the problem is not merely one of identifying the future population in a small area. Rather, you must add to that the need to predict population change for numerous subgroups of the population.

In summary, effective population projection for environmental justice assessment of transportation system changes must utilize techniques for (a) estimating small-area populations and (b) predicting population change for multiple population groups. Such techniques are inherently imprecise, so projections of specific populations in small areas can be highly inaccurate, and they should be reevaluated regularly to determine if they remain valid.

When to use. Population projections are best used to evaluate transportation planning projects with a time horizon greater than 5 years in circumstances where the size and composition of affected populations is expected to change quite substantially. Examples would be transportation investment plans, long-range plans for cities and counties, and alternatives studies where project development is expected to begin more than 5 years from the time of analysis. Transportation systems are long-term infrastructure investments that will impact the surrounding environment for years or even decades. As such, it is advisable to evaluate all transportation policies, programs, and projects using both current population data and population data projected for some reasonable, informative future-year scenario. However, the complexity and questionable validity of population projections must be weighed against the additional insight they would provide into identifying future effects to protected populations. Because of their limited precision and the considerable effort involved, small-area population projections of specific groups are not likely to be widely applied.

Analysis. In its simplest formulation, population projection for any area can be computed using the following equation:

$$P_f = P_c + (B - D) + (I - E),$$

where

P_f = future population

P_c = current population

B = births

D = deaths

I = immigration

E = emigration

B, D, I, and *E* are computed for the future time period minus the current time period (i.e., $T_2 - T_1$). This equation can be cast in terms of the total population or for subpopulations such that the sum of P_f over all subpopulations is the total future population. In application, however, accurate measures of births, deaths, immigration, and emigration are difficult to predict and are data intensive. Most methods rely on a combination of census data and symptomatic variables. Symptomatic variables change over time according to a predictable and logical relationship with population. These variables are often collected from administrative records systems. Some examples of symptomatic variables include housing permits, new utility hookups, birth and death records, vehicle registrations, and school enrollment figures.

There are various techniques available for developing population projections, and many metropolitan planning organizations (MPOs) develop projections using standard methodologies. These projections are commonly adopted and used for transportation master planning purposes. Growth forecasts are commonly developed every 2 to 3 years for housing, population, and employment. The time horizon for these projections is generally 20 to 25 years. In general terms, there are four projection approaches commonly in use. These approaches are summarized below. See NCRHP (1999) for further discussion.

- **Demographic models.** These models are based on characteristics of the current population and net migration. Required population characteristics include fertility rates, mortality rates, age cohorts, and gender cohorts. Race and ethnicity are often evaluated for large-scale areas such as states and counties. It can be difficult to generate accurate small-area estimates using this technique, as fertility and mortality information are not readily available, so values for larger areas such as counties must be used.
- **Trend-based models.** As mentioned above, these models work by extrapolating historical trends. They are problematic for small-area projection because they do not account for land use change, such as housing developments, that occur during the historical period.
- **Land use models.** Automated models such as MEPLAN, TRANUS, and UPLAN are based on information characterizing vacant land that can be developed and therefore has the potential for greater population capacity, developed land that has a fixed or only slightly variable population capacity, and service information indicating housing unit

density and relative attractiveness of different areas. The Projective Land Use Model (PLUM) utilizes census data, place of work, trip lengths, and population capacity information to derive population projection estimates. For more information on the PLUM model, see Tayman (1996).

- **General plan models.** General plan models are based on information available in community master plans and specific development plans, such as for housing subdivisions and planned annexations. They use information from comprehensive plans, zoning codes, and other land use regulations to develop a future picture of population patterns. One benefit of general plan models is that population projections are built from the ground up, meaning that the land use characteristics and planned changes for specific locations are used as the basis of projection. This approach is beneficial for environmental justice assessment because it can be used to derive estimates for small areas, such as tracts and TAZs, as well as information for larger municipalities, counties, and regions. A drawback, however, is that the technique is extremely data intensive, requiring information on changes in land use policies, zoning, general plan updates, residential densities, city limit boundaries, the status of current development proposals, economic trends, job inventories, estimates of population per housing unit, and housing unit vacancy rates.

The basic steps of the general plan method are discussed below. The Sacramento Area Council of Governments (SACOG) approach is used as a model for descriptive purposes (SACOG 2001). This method involves two stages. The first stage is to develop total population projections for counties, cities, tracts, and traffic analysis zones. The second stage is to decompose the total population estimate into the subpopulations of interest, such as minority and nonminority.

Stage 1 – Develop county and subarea population projections

Step 1a. Define analysis zones. It is best to develop the projections for relatively small analysis units, census tracts at a minimum. For transportation planning purposes, it is also advisable to develop projection for TAZs. Larger reporting zones should be aggregations of the base analysis unit. Reporting zones should include counties, cities, and regional analysis districts (RADs). RADs are smaller than cities or counties and can be developed to mirror local community planning areas or census county divisions.

Step 1b. Establish base numbers. Develop estimates of the population, housing stock, job inventory, and school facilities and enrollment for the base year. The housing inventory should provide an annual count of residential housing units. These figures can be obtained from permit completions maintained by the building departments of each jurisdiction in the study area. Data must be collected, categorized by building unit type, and allocated to analysis units based on address. Information on demolished housing units and annexed housing units must also be acquired. Group quarters (e.g., military barracks, penal institutions, or college dormitories) should be included in this information.

The current population count can be developed by combining information from the most recent census, the housing inventory, and any current population estimates developed by state or federal agencies. In some states it is mandated that locally developed population estimates must correspond to estimates produced by the state demographic agency. In California, for example, population projections for jurisdictions can be no greater than the estimates produced by the state's Demographic Research Unit.

The housing inventory is used to estimate population by analysis unit. This is done by combining housing unit information with base-year census population data and correlations of population by dwelling type, average household size, and housing unit vacancy rates. These factors are combined to generate a base-year household population estimate. Populations for group quarters (available from local agencies) and homeless individuals (available in the census) are added to household population estimates to generate the base-year total population estimate for each analysis zone. For purposes of environmental justice assessment, it is important to identify the protected population characteristics of the base-year population.

The employment inventory is established through surveys of the study area. Employment is considered because it is a significant factor in drawing new residents to an area and in retaining current residents. School facilities and enrollment information is collected in order to (a) better plan for educational infrastructure needs and (b) refine age-cohort information.

Step 1c. Evaluate holding capacities. Determine the maximum number of jobs and housing units that can be accommodated by each analysis zone. This is the zone's holding capacity. For housing, compute densities for each type of residential land use from general plan and zoning information. The average housing density can then be applied to the total acreage of each land use type in the analysis zone. These holding capacities are not fixed; they vary as land use changes and must be updated on a regular basis, at least every few years.

For jobs, develop an employment yield matrix. The SACOG approach is to develop estimates of number of employees per acre for five employment types: retail, office, medical, manufacturing, and other. Each employment type can be correlated with land use maps and acreages computed for each analysis zone. Multiplying acreage by number of employees per acre for each employment type yields the employment holding capacity for each analysis zone. Estimates for education-related employment can be gathered from surveys of local educational institutions, and the number of education employees in each analysis zone assigned by address.

Step 1d. Determine phasing. Phasing is the process of developing growth curves, using current population and employment as the starting point for the base year and holding capacity as the end point for the horizon year. Individual growth profiles should be developed for each unique type of development pattern that exists in the study area. SACOG uses the following four development patterns:

Limited room for growth – applied to areas already at or near their holding capacities;

Growth occurring currently – steady growth beginning in the base year and continuing through a future build-out date determined from general plan information;

Current development static; growth occurring later – areas expected to begin growing at a later date and to continue growing through a build-out date based on general plan information; and

Redevelopment – when land use changes alter the housing and employment composition of an analysis zone. In this case, you should base projections on the expected year of redevelopment and the extent of redevelopment.

Step 1e. Compute jobs-housing ratio. The jobs-housing ratio is calculated by dividing an analysis zone's total number of jobs by its total housing units. The ratio is a measure of the mix of employment and housing in a given area.

Step 1f. Derive population. Compute the number of households by household type for each analysis zone and for each year and then multiply by the estimated number of persons per household by each household type to calculate the total household population. Add the population living in group quarters. Adjust the population per household and vacancy rates based on the growth profile of the area. Adjustments are related to changes in housing type from single family to multifamily and changes in age of development.

Step 1g. Conduct jurisdictional review. As described earlier, plan-based population projection is an iterative process that relies heavily on the knowledge and understanding of planners and decision-makers as to how proposed and expected land use changes will affect population over time. Jurisdictional review is therefore an opportunity for experts to validate results and, if necessary, provide the further information necessary to alter projections.

Stage 2 – Estimate populations of protected groups

The commonly used small-area projection techniques do not consider protected population characteristics. This stage of the population projection method is a technique for estimating future protected population characteristics based on the results of *Step 1f* above and trend information.

Step 2a. Collect and prepare data. Use census data for the base year to generate predictor variables for the response variables percent low-income population and percent minority population. The following variables utilized in Stage 1 should be considered as candidate predictor variables for both percent low-income and percent minority: housing costs (housing unit values and rental costs), housing unit density, housing unit vacancy rates, single family to multi-family housing ratio, average household size, jobs-housing ratio, unemployment rate, and housing density to housing capacity ratio. For minority population, also consider low-income as a predictor variable and vice versa. Housing cost and unemployment information are both potential predictors of protected populations. These variables must be added to the Stage 1 data collection efforts and future-year estimation efforts in order to be used as predictor variables.

Step 2b. Conduct exploratory study. The result of a multivariate analysis is a best-fit curve allowing estimates of the response variable to be derived from known values of predictor variables. A benefit of this approach is that prediction error estimates can be reported. Note that prediction error rates can be high for exploratory observational studies such as that described here. The purpose of the exploratory study is to reduce the set of candidate predictor variables listed in *Step 2a* to the set to be used in the regression model. Highly intercorrelated predictor variables should be eliminated, as should other variables found to have low correlation with the response variable. A variable reduction procedure should be used to develop correlation matrices and identify candidate predictors that should be retained in the final model. Although it is beyond the scope of this guidebook to provide an in-depth discussion of variable reduction, there are numerous books on applied regression analysis that can be read for further information, such as Neter, Kutner, Nachtsheim, and Wasserman (1996).

Step 2c. Refine and select model. The result of *Step 2b* is a small subset of candidate regression models with a limited number of explanatory variables that provide good predictive ability. *Step 2c* results in selection of the final model, based on review of residual plots and analyses to identify lack of fit, outliers, and influential observations.

Step 2d. Validate model. Model validity is determined based on the ability to make generalized inferences. Validation should be performed in two stages. First, evaluate the ability of the model to predict known values for percent minority and percent low-income from base year analysis zones. Ascertain if the model provides a suitable fit across all ranges of land use types. Next, evaluate the predictions made for the projection years.

Alternative step – generate trends. It may be necessary to compute protected population projections from generalized trends if an acceptable regression model cannot be developed. This alternative step is technically less complex than the regression model steps, but it is otherwise less desirable because it does not provide the ability to report prediction errors. Estimates for changes in percent minority and percent low-income are categorical, more representative of trends than of actual population numbers. This may not be a severe drawback, however, because effects being evaluated over a long time horizon tend to be nonspecific in the case of policies and programs. In addition, for projects it is valuable insight to know, for example, that there is no present day concern about distributive effects but that the project area is expected to experience an increase in low-income population during the ensuing 15 years. The approach is similar to *Step 1d* (*Determine phasing*). The trends are developed based on general plan information and can be used to estimate percent low-income and percent minority population for each year in the projection. The following trends are provided as examples, but the actual trends must be developed to reflect the characteristics of the study area.

Stable community – the area is near housing capacity; and jobs-housing ratio and housing costs are stable. In this situation it could be expected that percent minority and low income would be stable through time.

Growing community – new housing is being developed and new jobs are being created in the area. Percent low-income would be expected to remain stable or even fall. Growth in the low-income population would be related to the availability of affordable housing. Changes in percent minority could be based on the racial composition of the expanding workforce.

Declining community – upper and middle-income residents are moving out of the area, housing vacancies are increasing, housing costs are stable or declining, jobs-housing ratio is declining. In this situation, percent low income could be expected to increase because affordable housing is important to low-income individuals. Changes in percent minority could be tied to the correlation between race and income in the study area.

Redeveloping community – land use changes alter the housing and employment composition of an analysis zone. These changes in turn affect the relative desirability of housing and could affect percent minority and percent low income. In this case you should base projections on the expected year of redevelopment and the nature of redevelopment.

Step 2e. Compute protected population statistics. Using the regression model approach, percent minority and percent low income for each analysis zone can be calculated directly from the model. Reporting the confidence intervals allows for further assessment of the certainty as to whether the minority and income composition of the population will change as predicted. Using the trend-based approach, percent minority and percent low income can be adjusted for each projection year based on knowledge of general demographic trends (i.e., general trend of increasing minority population throughout the study area), knowledge of housing unit turnover rates (to understand phasing), and findings from other areas that have experienced similar land use changes. Calculate number of low-income persons and number of minority persons by multiplying by the total population estimate.

Step 2f. Conduct jurisdictional review. As with Stage 1, jurisdictional review is necessary to validate findings and to refine the assessment if the findings are deemed to be invalid.

Data needs, assumptions, and limitations. Many of the data needs, assumptions, and limitations have been described above. In general, the technique for projecting changes in minority and low-income population groups is data intensive and time consuming. Trend-based or regression-model techniques can be used to derive protected population projections from base-year and future-year data. General population projection techniques such as trending and extrapolation assume that current population patterns will continue through time and are not well suited to small-area assessment. Land use and plan-based techniques work to overcome this limitation by incorporating information on how the study area is planned to change through time. Common projection methods used in practice estimate future year changes in total population but do not predict changes to subpopulations such as protected groups. The method described above is exploratory at best, and considerable effort must be given to fit the method to the characteristics of the study area it is being applied to.

Results and their presentation. Results of this method are estimates of future year populations, including percentages and derived counts for minority populations and low-income populations. Present results as you would results for current year estimates.

Assessment. Population projections are a difficult, complex, and time-consuming effort, but in certain instances they are a useful means for assessing the environmental justice of transportation policies, programs, and projects with long time horizons. Population projection techniques useful for transportation environmental justice purposes must provide estimates for small areas such as tracts and TAZs, and they should include predictions for protected population groups. The planning-based method presented in this guidebook must be carefully calibrated to the study area in which it is being applied. As with any small-area projection approach, it is important to refine projections so that they are current with planned land use changes, population trends, and economic fluctuations.

Method 9. Environmental justice index

The environmental justice index (EJI) is a method of scoring the relative level of environmental justice concern for census-reporting units based on population density, minority population, and low-income population factors. Because the EJI uses multiple factors, it is a good method for combining information to show the distribution of protected populations on a single map.

When to use. The EJI is particularly effective for showing relative concentrations of minority or low-income populations. It also is suitable as a screening technique to identify areas where detailed assessment and outreach should be conducted. Finally, the EJI can be used as a demographic variable in combination with indicators of the level or presence/absence of environmental effects in statistical evaluations to determine if effects are disproportionately high and adverse (U.S. DOT 2000).

Analysis. There are three steps in constructing an environmental justice index:

Step 1 – Gather census data and compute demographic variables. Census data should be collected for the study area, and the level of analysis (tracts or block groups) must be selected. Demographic variables should be computed for population density, percent minority population, and percent low-income population. These variables need to be computed for the selected unit of analysis and at the state level for comparison purposes.

Step 2 – Calculate EJI factors. The standard EJI is represented by the following formula:

$$EJI = DVPOP \times DVMAV \times DVECO$$

where

DVPOP = degree of vulnerability based on population density

DVMAV = degree of vulnerability based on presence of minority population

DVECO = degree of vulnerability based on presence of low-income populations

These factors are computed as follows.

DVPOP

Population per square mile	Score
0	0
> 0 and ≤ 200	1
> 200 and ≤ 1,000	2
> 1,000 and ≤ 5,000	3
> 5,000	4

DVMAV and DVECO

Percent minority or percent low income	Score
≤ State average	1
> State average and ≤ 1.33 times the state average	2
> 1.33 times and ≤ 1.66 times the state average	3
> 1.66 times and ≤ 2.0 times the state average	4
> 2.0 times state average	5

In the standard formulation, the EJI thus ranges from 0 to 100. High EJI values indicate that a large population density is present and that a large proportion of that population is minority and/or low-income. It is also possible to modify the EJI to include additional protected population factors for disability, age, and other characteristics.

Step 3 – Review maps and identify presence of protected populations. Once the EJI factors and the EJI are computed for each census unit, GIS can be used to produce maps of the study area. The maps will depict areas of high population density and large proportions of minority or low-income population. In many cases, specific neighborhoods can be identified and labeled on the maps.

Data needs, assumptions, and limitations. The EJI is best suited for relatively large study areas and in situations where evaluation of small-area census data is desired. Block-group-level data are the most commonly used evaluation unit. Census data from 1990 or 2000 are required for the evaluation units (block groups, tracts, or TAZ), as are state data. For mapping in GIS, the 1990 or 2000 TIGER files for the study area also are needed. Appendix D contains instructions as to how these data can be obtained. The census data can be formatted and variables calculated using spreadsheet software such as Microsoft Excel or database software such as Microsoft Access.

The EJI has the limitations endemic to any mathematical index. Indexes are useful for depicting combinations of variables as a single value, which makes them valuable for screening assessments and for mapping. The underlying factors must be used, however, if more detailed analysis is required. For example, an area with an EJI score of 40 to 45 indicates that there is potential for effects to protected populations. The EJI score by itself cannot be used, though, to determine if the area is densely populated (high DVPOP), has a high proportion of minority individuals (high DVMAV), or has a high proportion of low-income individuals (high DVECO). Furthermore, the EJI does not provide meaningful results in areas with relatively uniform population density and protected population characteristics.

Results and their presentation. Figure 2-7 is a map of the EJI for block groups in a 1-mile study area surrounding a project corridor. The map clearly depicts areas of minority population and low-income population concentrations, based on EJI score. These areas are often well-defined neighborhoods and can be labeled for illustrative purposes.

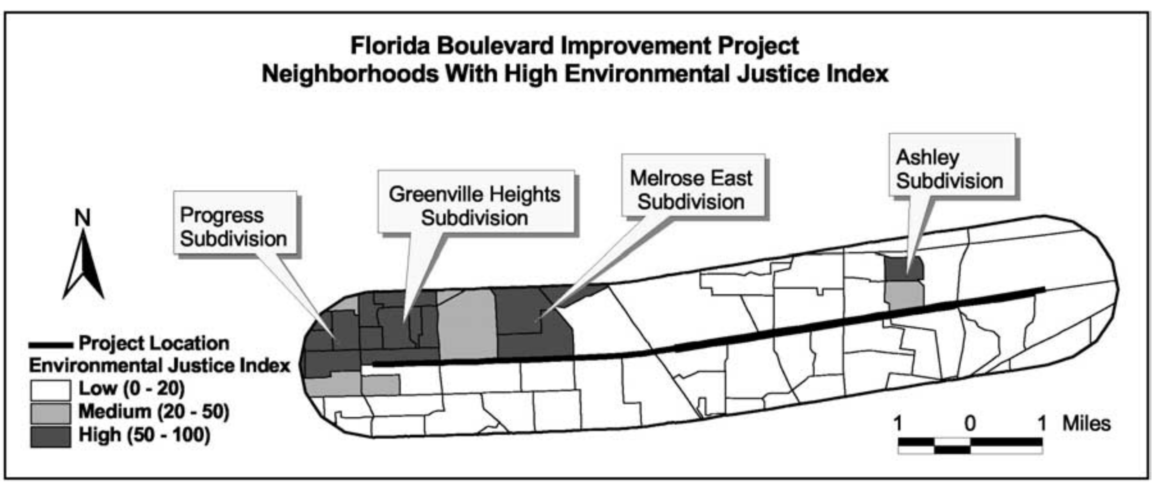


Figure 2-7. Example presentation of EJI results

Assessment. Identifying protected populations through use of the EJI relies upon census data and is best suited to block, block-group, and TAZ levels of analysis. The EJI can be used effectively to identify areas where further environmental justice assessment should be targeted based on demographic characteristics. Results of EJI evaluation are readily presented in simple maps that are easy to interpret. The EJI can also be used in statistical evaluations to identify disproportionate adverse and beneficial effects. Examples of this use of the EJI are given in other sections of the guidebook. As with any census-based evaluation method, local knowledge and public participation efforts should be used to verify that protected populations have been accurately identified within the area of concern.

Method 10. Activity space analysis using personal interviews

This simple approach can be an effective tool to provide a general idea of the areas that comprise the individual and communal activity spaces of the populations of interest. Such information supplements (it does not replace) insights derived from the foregoing methods that are largely based on the place of residence.

When to use. This method is most appropriate for projects that are likely to be low impact and whose effects are expected to occur within a reasonably well-defined communal activity space. In such cases, a sample of residents is likely to provide useful insights on local activity spaces of the residents represented by the sample.

Analysis. Space-time activity survey data should be able to help answer the following questions:

- What are the important daily activity centers (i.e., relatively frequent destinations) and what routes do individuals take to and from them?
- How frequently do members of the community typically access these centers? Are there numerous centers for different subgroups or do a few dominant?
- How do the important activity spaces relate to the impact area of the proposed project?

Data needs, assumptions, and limitations. The key to any survey-based analysis, of course, is to draw a representative sample that is large enough to provide a clear picture of the population. In this case, the sample should be of members of protected populations in the general area of the community likely to be affected by a proposed transportation project. You should have a general idea of where protected populations move about before carrying out a survey to learn more about this activity space. The most important assumption is that the activity space defined by the survey sample will enable you to assess, with a fair degree of accuracy, the nature and magnitude of probable impacts. A limitation of survey-based analyses of activity spaces is that they afford only a general indication of each respondent's daily activity space. Thus, in the aggregate, a survey can be expected to provide a general sense of the activity space of a population of interest.

Results and their presentation. The survey will enable you to derive a distribution of origin-destination pairs that depict the relative concentration of activity on the part of protected populations. This distribution can be presented graphically using GIS methods. Cells or zones that have a relatively high concentration of activity should be given special attention when analyzing the several types of effects addressed in the chapters to follow.

Assessment. It is widely understood that surveys are only as good as the sampling strategy used to select respondents and the questionnaire developed to address the issues. A statistically significant sample size and a well-conceived questionnaire can provide considerable insight into the areas of the community frequently visited by minority and low-income populations.

Method 11. Activity space analysis using an abbreviated diary

Measuring habitual travel behavior—determining what places a given population consistently travels to and the routes that they use—can be an effective way of measuring communal activity space. Because time and space constraints limit the number of activities that a person can perform on any given day, it is logical to assume that people try to maximize their utility in their choice of daily activities.

A variety of research indicates a great degree of stability in weekday daily activities. Schonfelder and Axhausen (2003) found that two to four locations could account for up to 70 percent of all destinations visited in a 6-week period. Their study also indicated that eight locations represent fully 90 percent of the total trips made. Kitamura and van der Horn (1987) also characterized daily participation in different activities—work, leisure, shopping—as very stable.

From an environmental justice perspective, the questions of interest are:

- What locations do protected populations access on a relatively frequent basis?
- How and by what mode do they access these locations?
- How much travel variability is there within the population of interest?

Habitual behavior studies typically involve a simplified version of a travel diary that asks the time and place of locations visited throughout a specified period.

When to use. This option is most appropriate for use when the understanding of a community's activity space is less certain than is needed for Method 10 but where potential impacts of the project or the data collection needs are not great enough to warrant a more time-consuming and expensive process. Because of the sensitive and personal nature of the data collected, anonymity is a prerequisite to gain the confidence of subjects. This approach requires both sufficient sample size and adequate administration of the equipment.

Analysis. While the overall approach to designing the database and extracting the necessary data will vary, space-time activity data for a given study area should at the very least enable you to answer the following questions:

- What are the principal daily activity centers?
- What are the most common routes to and from these activity centers?
- How frequently do members of the community typically access these centers?

Data needs, assumptions, and limitations. The habitual travel survey should have the following qualities:

1) **An adequate sample size and representation.** As noted earlier, a carefully selected sample of sufficient size to mirror the population being represented is critically important. Recruiting the sample and adequately briefing participants is a substantial undertaking.

2) **Clear and brief design.** The user should be able to complete the diary in a relatively short amount of time.

3) **Prompts that do not lead.** Questions should strike a balance between stimulating participants' thoughts and pointing to a certain response. Sample questions could include the following:

   - Where are the locations to which you travel daily or almost daily (i.e., work, school, day care, and any others you can think of)? How do you typically travel to these locations? Are these locations commonly visited by your neighbors?
   - What other locations do you regularly (at least once a week) travel to (i.e., stores, restaurants, church, public park, and any others you can think of)? How do you typically travel to these locations? Are these locations also visited by your neighbors?
   - What other locations do you travel to less than once a week and yet consider an important part of your life outside the home? How do you typically travel to these locations?

4) **An adequate time frame.** Participants will often vary their activities over a period of days (e.g., one may grocery shop every Thursday). It is thus helpful to give them a few days to complete their diaries to gain an accurate picture of these activities.

Results and their presentation. Habitual travel behavior surveys can provide a fairly accurate picture of where protected populations travel within a community. They allow you to distinguish between frequently versus occasionally or rarely visited locations. Once you have an understanding of the general areas where respondents live and the destinations they travel to, it becomes possible to gain considerable insight into activity spaces. As with Method 10, GIS can be used to develop maps and other graphic depictions of relatively common activity spaces and the routes connecting people's homes to them.

Assessment. This method relies on a diary format to define representative destinations and routes to and from them. As with Method 10, it is critical that the selected sample is sufficiently large and representative of the protected populations whose activity space you are interested in defining. It also is essential that the respondents understand exactly what information you are seeking. Because the data needed are quite simple, the questions should be simple and very clear.

Method 12. Space-time activity analysis using GIS

A more advanced method for exploring how the activity space of protected populations is configured within a given community is a form of daily trip diary. Miller (2001, p. 11) identifies four traditional forms for collecting spatial activity data using diaries:

1) **Recall methods** require subjects to recall and report activities during some previous time period.
2) **Stylized recall methods** require subjects to report "normal" activities that occur during some typical time period.
3) **Diary methods** require subjects to record activities in a diary, either in a free-format manner or at predetermined time periods. "Beeper studies" complement this approach by prompting subjects via a pager at selected time intervals to record their current activities.
4) **Prospective methods**, typically game-based, are employed in conjunction with other methods to investigate the effect of potential changes in the activity environment.

Miller has sought ways to combine these traditional forms with GIS to create a robust, sophisticated model for analyzing activity space. Although he acknowledges some inherent flaws, the method combines space-time activity data with new GIS technology to analyze people's movements.

When to use. With a sufficient sample size and appropriate sample selection design, this method can provide a fairly accurate picture of the activity space of the sample frame (i.e., the protected population within a particular area of a community or across a community). As this is a relatively advanced method, it should typically be used under two conditions: (1) when the nature of the project is large enough to warrant the time and expense and (2) when the data collected will help meet the data needs for multiple objectives. Robust data such as this may be necessary to reveal how people—especially low-income and/or minority populations—move and interact in their community differently than the broader population.

Analysis. Typical travel diary analysis utilizes a *point-based approach* to mark the characteristics of points A and B. A *path-based approach*, however, is likely to better represent the type of disaggregate activity data required for a full environmental justice analysis. Although a more complex data-gathering task, path-based assignment meets the dually important objectives of identifying communal activity spaces and providing a reasonable estimate of the paths linking homes with these spaces.

Path-based approaches can encompass a variety of methods for gathering data on personal activity space. A modern approach is to provide the respondent with a GPS receiver combined with recording devices [e.g., personal digital assistants (PDAs) or cellular transmitters tied to location-based services (LBS)]. The data stored by a recording device typically is entered into a GIS file to first calculate the shortest path between two points and then assign the trip along that path. Shaw and Wang's study (2000, pp. 167-168) separated the data for each trip into four components:

- Spatial—trip ends and path;
- Temporal—date, start and end times;
- Individual—person(s) making the trip; and
- Event attributes—trip purpose, travel mode.

There are numerous potential benefits of this approach, including the ability to support space-time queries. A complicating factor is that the respondent must enter the trip purpose into the recording device as there is no way to identify this information from the trip geography.

Data needs, assumptions, and limitations. A critically important component of this analysis is sample selection. It is essential that you select, recruit, and fully brief a representative sample of the low-income population and minority population that potentially would be affected by the proposed project. Special attention may be required to prepare illiterate or non-English speaking participants.

There are several steps involved in applying this method. Using a path-based approach, the GIS database should include addresses (or dummy equivalents) and an interactive address-matching process to identify common locations and expedite the coding process. A GPS receiver should be tied into the database, and a data-recording device is needed to develop a record of respondents' activity space. Using this basic approach, Shaw and Wang (2000) successfully matched 85 percent of more than 6,000 trip ends to the GIS streets database.

An alternative approach is to use a cellular data transmitter to forward data obtained using a GPS receiver to a central data management facility. With this approach, it is possible to gather path-based data that give a very clear indication of respondents' travel patterns in time and space.

As with the preceding methods, the assumption must be made that participants' activity patterns are representative of the population of interest. Another assumption is that participants will not alter their activity patterns as a result of taking part in the study.

A limitation of this type of analysis is that it is static in nature. The travel patterns identified using this approach may not reflect the activity spaces that would develop if, over time, new employment centers, shopping centers, and other facilities were to emerge. Thus, it may not accurately predict the future state of things if the proposed transportation project were to move forward.

Results and their presentation. While the database design may vary, space-time activity data should at the very least be able to answer three questions for a given study area:

- What are the vital individual daily activity centers?
- Where are frequently visited communal centers?
- How and when do members of the community access these centers?

Because this method utilizes such sophisticated data collection and processing needs, it has considerable potential for providing you with a rich data repository able to satisfy a variety of analysis needs across a range of environmental justice-related issues.

Assessment. Due to the sensitive and personal nature of the data collected, assurance of absolute anonymity is a prerequisite in order to gain the confidence of subjects. To ensure this, sample size must be sufficient and administration of the equipment adequate. If the data are collected heeding the points raised in this discussion, a very good sense of the activity space of the sampled population can be obtained. The insights provided can be extremely useful in assessing the extent to which positive and negative impacts of a proposed project would be experienced disproportionately by low-income and minority populations.

RESOURCES

1) Carlstein, T. (Editor). 1978. *Timing, Space and Spacing Time Volume 2: Human Activity and Time Geography*. London: Edward Arnold.

   Of particular interest are Chapter One, "Human Time Allocation in the City" by F. Stuart Chapin, and Chapter Four, "Rhythms of Urban Activity" by Mary Shapcott and Phillip Steadman. Chapin uses a conditional response model of human behavior, noting the relationship between the necessity of activities and how they are prioritized in terms of choice and timing. Shapcott and Steadman discuss the interconnectivity, coordination, and routine of daily activity patterns.

2) Census 1990 and Census 2000 TIGER files for use in GIS-based analysis are available free for download at http://www.esri.com/data/download/census2000_tigerline/index.html. These files include useful demographic information for some census reporting units.

3) Census 2000 Summary File 1 and Summary File 3 data sets are available from the census bureau at http://www2.census.gov/census_2000/datasets/Summary_File_1/ and http://www2.census.gov/census_2000/datasets/Summary_File_3/. These files can be downloaded and used with spreadsheet, database, and GIS programs to calculate demographic variables useful in identifying protected populations.

4) Census 1990 Summary File 3 data sets are available from the census bureau at http://www2.census.gov/census_1990. The files are online copies of the Census Bureau's Summary Tape File 3 CDs.

5) Kitamura, Ryuichi, Patricia L. Mokhtarian, and Laura Laidet. 1997. "A Micro-analysis of Land Use and Travel in Five Neighborhoods in the San Francisco Bay Area." *Transportation*, Vol. 24, No. 2 (May), pp. 125-158.

   This article examines the effects of land uses, socio-demographic characteristics, and attitudinal characteristics on travel behavior for five diverse San Francisco Bay Area neighborhoods. It employs models for numerous measures of travel behavior and confirms that neighborhood characteristics add significant explanatory power when socio-economic differences are controlled for.

6) Kitamura, Ryuichi, Takamasa Akiyama, Toshiyuki Yamamoto, and Thomas F. Golob. 2001. "Accessibility in a Metropolis - Toward a Better Understanding of Land Use and Travel." *Transportation Research Record 1780*. Washington, DC: Transportation Research Board, National Research Council, pp. 64-75.

   This article uses several accessibility indices to determine how accessibility affects aspects of long-term and short-term travel behavior in an urban area. It uses data from the Kyoto-

Osaka-Kobe area and southern California to examine a variety of conjectures regarding time availability, accessibility, and engagement in activities.

7) Kitamura, Ryuichi, and Toon van der Hoorn. 1987. "Regularity and Irreversibility of Weekly Travel Behaviour." *Transportation,* Vol. 14, No. 2 (May), pp. 227-251.

   Kitamura and van der Hoorn use weekly travel diaries to analyze the regularity and persistence of daily activities (work, shopping, and recreation). Their study examines the "behavioral lag" between routine in activity participation and changes in socioeconomic and other factors.

8) Kuhn, Walter. 2001. "Ontologies in Support of Activities in Geographical Space." *International Journal of Geographic Information Science*, Vol. 15, No. 7, pp. 613-631.

   This paper seeks to represent human activities and the objects to which activities are directed as the basic units of analysis.

9) Schlich, Rober, and Kay Axhausen. 2003. "Habitual Travel Behaviour: Evidence From a Six-week Travel Diary." *Transportation,* Vol. 30, No. 1 (February), pp. 13-36.

   Schlich and Axhausen have synthesized several methods that measure habitual travel behavior. They discuss data types and methods of calculating similarity.

10) Shaw, Shih-Lung, and Dongmei Wang. 2000. "Handling Disaggregate Spatiotemporal Travel Data in GIS." *GeoInformatica*, Vol. 4, No. 2 (June), pp. 161-178.

   Frequently referred to throughout Method 3, Shaw and Wang's article provides more detail regarding data representation issues, reducing data redundancy, query types, and other relevant information.

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CHAPTER 3. AIR QUALITY

OVERVIEW

Air quality is important to human health, the vitality of the natural environment, and the quality of life in general. Poor air is of special concern for sensitive populations with potential health issues, such as asthmatics, people with other pulmonary health problems, children, and the elderly. From an environmental justice perspective, there is some evidence that certain ailments exacerbated by poor air quality have a higher incidence rate in minority and low-income populations than in the general population. Poor air quality can also degrade the natural environment by decreasing visibility and damaging animals, crops, vegetation, and buildings. Although quality of life is subjective, poor visibility, dust, odors, and the emotional impacts of exhaust smells have a negative impact on nearly everyone.

In this chapter, we focus on air quality issues related to human activity, but natural sources of pollutants also can worsen an area's air quality problems. The important point is that the worse the general air quality in an area is due to whatever sources, the greater the harm that additional emissions are likely to bring about.

Transportation projects can affect ground-level air quality (microscale or "hot-spot") due to increased concentrations of carbon monoxide caused by idling vehicles and congestion or to particulate matter caused by diesel engine emissions and stirred dust and dirt that become airborne due to disturbance by vehicles. Environmental justice assessment of micro-scale air quality impacts is a straightforward process of combining information about micro-scale effects and demographics for affected areas.

While greenhouse gases and particulate emissions may affect regional air quality, their distribution is generally assumed to be uniform across large areas. The typical regional air quality assessment methods do not provide geographic distinctions. Therefore, environmental justice assessment of regional air quality is less informative than assessment of micro-scale issues unless experimental, resource-intensive methods are used.

In cases where protected populations are very concerned about air quality, it may not be enough to assess the impact from transportation system changes. Because it is the cumulative exposure to all air pollutants that affect human health and quality of life, many environmental justice proponents have recommended evaluating the distribution of pollutants from all sources. This form of assessment can be time consuming and resource intensive due to the large amounts of monitoring equipment and data required to develop an understanding of cumulative ground-level concentrations.

STATE OF THE PRACTICE

The most common techniques being used to assess air quality are described in this section along with examples of successful environmental justice assessments. We discuss air quality regulation, regional air quality assessment, micro-scale air quality assessment, and mitigation strategies.

Air quality has been regulated for many years, and transportation policies, programs, and projects must meet comprehensive federal and state standards. The current state of the practice is to identify both specific sites (i.e., hot spots) and regions (usually large metropolitan or multi-county areas) where these standards may be exceeded and to determine strategies for meeting the standards.

Environmental justice assessments most often are performed when air quality standards are not met or would potentially not be met if a proposed project were built. The basic assumption is that, unless the standards are violated, there is no adverse effect to be evaluated for distributive effects to protected populations. Given this assumption, some argue that transportation air quality is not an important environmental justice issue because policies, projects, and programs cannot be implemented if they violate the standards.

Many practitioners and community representatives do not accept this argument, however. Proponents of environmental justice argue that protected populations experience a disproportionate level of adverse health effects due to differing levels of exposure and differences in lifestyle, among other factors. There is also a considerable body of evidence indicating that protected population groups tend to live and work closer to sources of air pollution than does the general population (Bullard 1996; Bryant and Mohai 1992). It is beyond the scope of this guidebook to explore this argument fully or to propose alternative air quality standards that would be more protective of protected populations. Instead, the methods presented in this chapter are designed to be used independently of established air quality standards. In this way, practitioners can be responsive to air quality concerns raised by communities that argue they are experiencing adverse effects even when all air quality standards are being met.

Air quality regulation

Procedures for evaluating air quality primarily are guided by regional pollution control agencies, departments of health, and metropolitan planning organizations (MPOs). These agencies are responsible for monitoring air quality, which includes six common criteria pollutants: ozone (O_3), particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). A brief summary of the adverse effects of each pollutant is provided in Table 3-1.

State and local agencies monitor air quality to determine if it complies with the National Ambient Air Quality Standards (NAAQS). As directed by the 1970 Clean Air Act, the U.S. Environmental Protection Agency (U.S. EPA) created the NAAQS to protect human health and the public welfare. Primary standards are designed to protect human health, whereas secondary standards protect public welfare. The current primary and secondary standards are provided in Table 3-2.

When monitoring indicates that the concentration of one of the five criteria pollutants violates the NAAQS, the air quality status of the region may be changed from "attainment" to "non-attainment." If an area previously in the nonattainment category achieves attainment, it is

Table 3-1.
Effects of criteria pollutants

Pollutant	Description
Ozone (O_3)	Ozone can irritate lung airways and cause wheezing, coughing, and pain when taking deep breaths. It also aggravates asthma and increases susceptibility to diseases such as pneumonia and bronchitis (U.S. EPA 2003a).
Particulate matter (PM)	Of all measured pollutants, PM may be the most detrimental to human health. PM has been linked to increased mortality rates (Lave and Seskin 1977). Children and seniors with respiratory problems such as asthma are at greatest risk (Schwartz and Dockery 1992). Asthma rates are higher in low-income populations and mortality rates are highest among African Americans (U.S. EPA 1996).
Carbon monoxide (CO)	Exposure reduces the amount of oxygen in the bloodstream (U.S. EPA 1995). People with heart disease are at greatest risk. Seniors are at risk. Heart disease rates are higher for most African American age groups compared to Caucasians (National Center for Health Statistics 1995).
Nitrogen oxides (NO_X)	NO_X reacts with sunlight to create ozone. NO_X has been linked to acute respiratory problems (U.S. EPA 1996).
Sulfur Dioxide dioxide (SO_2)	Primarily emitted by diesel engines, SO_2 is a serious irritant to asthmatics, and contributes to particulate formation and to acid rain (U.S. EPA 1994a).

Table 3-2.
National ambient air quality standards

Pollutant	Statistic	Standard value*	Standard type
Ozone (O_3)	1-hour average	0.12 ppm (235 µg/m^3)	Primary & secondary
	8-hour average	0.08 ppm (157 µg/m^3)	Primary & secondary
Particulate (PM_{10})**	Annual arithmetic mean	50 µg/m^3	Primary & secondary
	24-hour average	150 µg/m^3	Primary & secondary
Particulate ($PM_{2.5}$)***	Annual arithmetic mean	15 µg/m^3	Primary & secondary
	24-hour average	65 µg/m^3	Primary & secondary
Carbon monoxide (CO)	8-hour average	9 ppm (10 mg/m^3)	Primary
	1-hour average	35 ppm (40 mg/m^3)	Primary
Nitrogen dioxide (NO_2)	Annual arithmetic mean	0.053 ppm (100 µg/m^3)	Primary & secondary
Sulfur dioxide (SO_2)	Annual arithmetic mean	0.030 ppm (80 µg/m^3)	Primary
	24-hour average	0.14 ppm (365 µg/m^3)	Primary
	3-hour average	0.50 ppm (1300 µg/m^3)	Secondary

* Parenthetical value is an approximately equivalent concentration.
** Particles with aerodynamic diameters of 10 micrometers or less
*** Particles with aerodynamic diameters of 2.5 micrometers or less
Source: U.S. EPA 2003.

designated as having "maintenance" status for that particular pollutant. For regions designated as nonattainment areas, state implementation plans (SIP) must be prepared by the responsible agencies.

The SIP ensures that no transportation project or policy will result in an increase in regional emissions nor cause a pollutant violation (FHWA 2001). Transportation conformity refers to the coordination of the transportation planning and air quality planning processes. To achieve transportation conformity, Transportation Improvement Programs (TIPs) must be consistent with SIPs. Transportation conformity with the NAAQS only applies to O_3, CO, PM, and NO_2 non-attainment and maintenance areas. Note that an exceedance of a pollutant does not automatically constitute a violation. For example, CO must exceed the criteria two times in a year to be considered a violation. Nonattainment or maintenance status often results in rules stating that transportation projects must not cause an increase in a specified pollutant or that more stringent analysis procedures must be followed. State and local agencies then must enforce these rules and procedures (FHWA 2001).

The models used to determine whether a transportation project or TIP would result in an air quality impact include EPA's MOBILE5 and the new MOBILE6. MOBILE6 was being phased into use nationwide at the time this document was created. These models are used to estimate emission factors for vehicles. Emission factors are the rate at which an average vehicle emits pollutants, usually expressed in grams/mile (moving vehicles) or grams/hour (idling vehicles). Emission factors determined by the MOBILE6 model often are stratified by speed and year.

MPOs or state pollution control agencies usually determine the parameters used in the MOBILE6 model for application to a given location. These parameters can include vehicle age, mileage by vehicle type, inspection and maintenance programs, and specific fuel makeup characteristics.

The MOBILE6 model output emission factors are incorporated into either or both microscale (hot-spot) and regional analyses. The microscale and regional analyses provide more meaningful results for use in quantifying project impacts.

Regional air quality assessments

Based on ISTEA and TEA-21 requirements, MPOs develop 20-year plans and 3 to 5-year TIPs. The TIP is a prioritized list of projects for which the MPO will seek FHWA or DOT approval. A regional air quality assessment is conducted to ensure that the TIP is in conformance with the SIP. This evaluation assesses the regional impacts that transportation investments will have on emissions in nonattainment or maintenance areas.

Information required to perform a regional air quality assessment includes the following:

- Estimates of current and future population and employment;
- Estimates of current and future travel and congestion;
- Assumptions about current and future background pollutant concentrations;

- Transit operating policies and transit ridership and expected future changes in fares and level of service; and
- Effectiveness of SIP measures that have already been implemented.

Regional air quality analyses incorporate travel demand information and emission factors to calculate total regional emissions. Depending on the attainment status for various pollutants and the population in the region, network-based travel demand models, local vehicle miles traveled (VMT) forecasts from the Highway Performance Monitoring System (HPMS), traffic speed and delay estimates, and/or local counts of all traffic in a region are used to evaluate regional air quality. The emission factors must be approved by the U.S. EPA.

Currently, MOBILE6 is used to generate emission factors outside California, and the current version of EMFAC (short for emissions factor) is used within California. Regional travel demand models can project VMT and average speed on each roadway link of a road network. Multiplying the link VMT by the emission factor for a given link speed results in the total emissions for the link. The sum of emissions for all links gives a value for total regional emissions. Figure 3-1 provides an overview of the regional conformity assessment process (FHWA 2001).

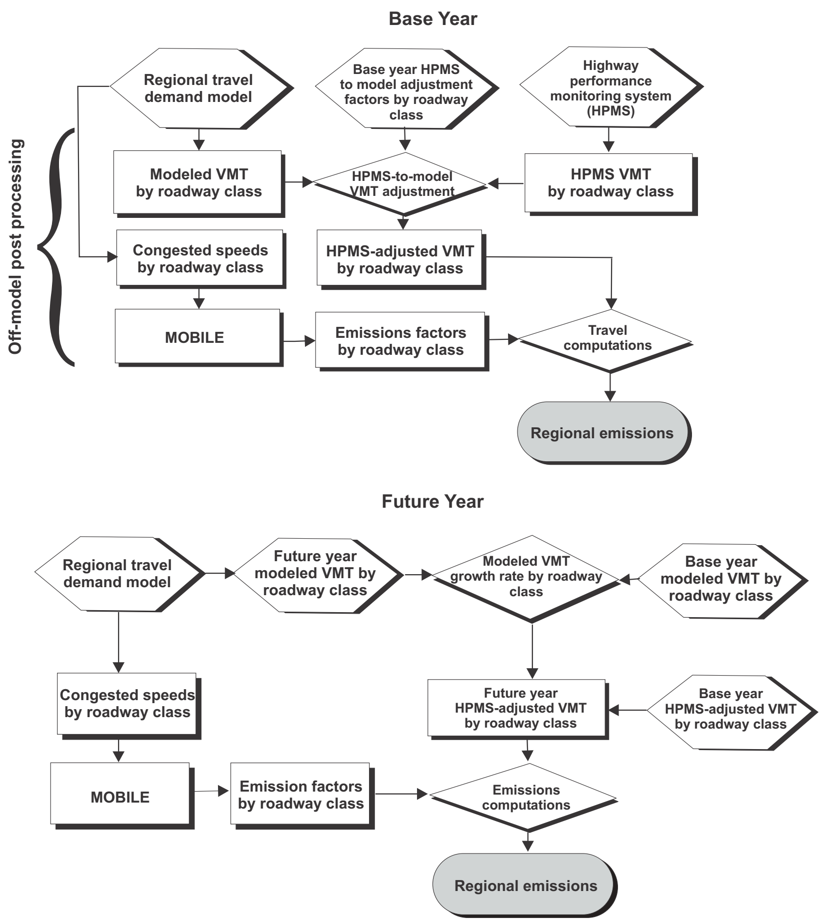

Figure 3-1. Regional conformity assessment process

Source: FHWA 2001.

Regional analyses focus on estimating emissions of transportation-related pollutants, which include CO, NO_2, and volatile organic compounds (VOC). When VOCs interact with NO_2, heat, and sunlight, they form ground-level ozone (O_3). Any increase in these pollutants is detrimental to the environment and, depending on the attainment status of the area, an increase could prevent a transportation project from moving forward.

Micro-scale air quality assessment

Motor vehicles are among the major contributors to criteria pollutant levels. They are the number one source of CO and NO_2, the number two source of VOC, the number three source of PM, and the number four source of SO_2. In total, highway vehicles and off-highway vehicles generate an estimated 77 percent of all CO emissions in the United States (U.S. EPA 1994b). Because CO is the most prevalent criteria pollutant, microscale analyses often screen for air quality violations by evaluating CO levels.

Figure 3-2 provides an overview of the microscale air quality assessment process. This example is based on an approved process for meeting microscale transportation conformity regulations. This is just one example, however, and the process can vary from jurisdiction to jurisdiction.

The most frequently used air dispersion models for localized analyses are CAL3QHC or one of the CALINE series models. The model results provide estimated carbon monoxide concentrations at discrete receptors near worst-case intersections. Analyses are performed at intersections because vehicles produce greater emissions when they are idling or traveling at slow speeds. The assumption is that if worst-case intersections do not exceed CO limits, there will be no exceedances for any of the criteria pollutants. The model incorporates the emission factors from the MOBILE6 model, along with intersection operating characteristics such as signal timing, traffic volume, and intersection geometry.

Two scenarios must be evaluated to determine transportation conformity:

- If there are no projected exceedances or violations in the area affected by the project, the project's future effect is compared to the standard because the test is whether the project causes an exceedance of the standard.
- If there is a projected violation or exceedance in the area affected by the project, the project cannot worsen an existing violation, so a no-build/build comparison is required (FHWA 2001, Section F).

For phased projects, it may be necessary to perform a microscale analysis for each significant project phase. This is done to ensure that interim phases do not cause NAAQS violations that might be eliminated once a project is fully implemented.

The intent of the microscale analysis is to ensure that transportation system changes, in combination with existing or foreseeable future background concentrations, do not result in NAAQS violations. Although the results of these analyses generally are considered to be reasonably accurate, the highly localized nature of the assessment makes it difficult to directly relate any violation to disparate effects on protected populations. If an air quality impact were predicted to result from a planned project, the impact would be at discrete receptor locations, usually near a congested intersection. The discrete receptors used for the microscale assessments typically are on sidewalks or beside buildings very near to intersections.

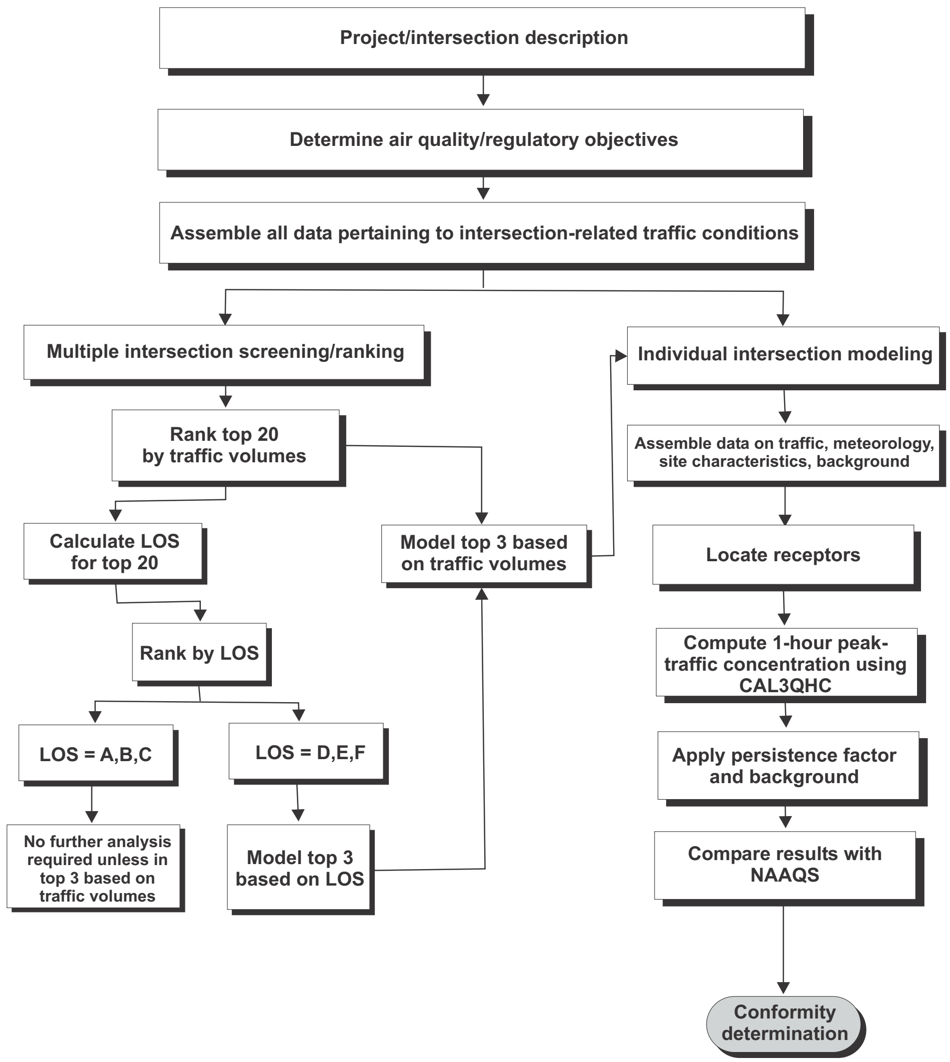

Figure 3-2. Example of a local conformity assessment process
Source: FHWA 2001.

Mitigation measures

Local air quality mitigation measures. If violations of local standards or the NAAQS are predicted to result from a proposed transportation project, mitigation measures would be required. Mitigation measures could include increasing intersection capacity by adding traffic lanes, optimizing signal timing for air quality purposes, or diverting traffic to other locations. It is possible that these mitigation measures could cause impacts themselves. Such impacts could include right-of-way acquisition for additional lanes or an increase in pedestrian conflict areas due to greater crossing distances. Diverting traffic may cause impacts at other intersections that may not be equipped to handle greater traffic volumes.

Regional air quality mitigation measures. Regional measures may be considered to address nonattainment of pollutants. Regional air quality mitigation measures may include roadway or transit projects to reduce congestion or inspection and maintenance programs to reduce vehicle emissions.

SELECTING AN APPROPRIATE METHOD OF ANALYSIS

Most of the air quality and environmental justice assessment methods presented in this chapter examine each of the major categories of vehicle-generated air pollution individually. Although these techniques are the ones most readily combined with standard air quality models and assessment processes, they do not allow practitioners to consider additive or synergistic effects of pollutants or cumulative effects from all sources. One method, however, does allow for evaluation of cumulative pollutant levels from all sources. This method can be implemented as an extension of the most commonly used air quality assessment models. Examples are provided showing how results for estimated pollutant levels can be evaluated independently of current criteria pollutant standards.

The methods presented here do not directly address questions about the causal connection between vehicle-generated pollutants and observed health effects such as asthma or increased cancer rates. Understanding this connection between environmental air quality (outdoor and indoor) and health effects is an emerging field of research, although most studies have not focused solely on transportation sources. This type of research is very time consuming and requires considerable expertise in health and epidemiology. Because the cost of health effects-based methods would be beyond the scope of all but a very few, extreme transportation situations, they are not included in this guidebook. See Carlin and Xia (1996), Hockman and Morris (1998), and Waller, Louis, and Carlin (1999) for examples of exposure-based environmental justice research on the health effects of air quality.

METHODS

Table 3-3 provides a summary of the four methods presented in this chapter.

The methods used to analyze air quality impacts from transportation projects range from simple to complex, and from well understood to experimental and not yet prescribed by regulatory authority. Micro-scale analyses for transportation-related projects nearly always focus on CO and possibly PM, whereas regional analyses generally address CO, NO_2, PM, and VOC.

Method 1. General air quality review

When projects do not warrant an air quality analysis, the assessment may extend only to a general discussion about air quality rules and the existing air quality environment. For purposes of environmental justice assessment, concentrations should be evaluated in terms of potential NAAQS violations to identify situations where alteration of the planned policy, program, or project *must* be considered. In addition, the net change in concentrations, independent of NAAQS thresholds, can be determined to identify situations where there would be either beneficial or adverse effects to protected populations.

Table 3-3.
Summary of methods for analyzing air quality

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. General air quality review	Screening	Project/corridor/system	Initial analysis and when air quality effects are expected to be minimal	Low	Spreadsheet
2. Detailed microscale analysis	Detailed	Project/corridor	Project is controversial or there are potential environmental justice concerns and more detail of microscale effects is required by local guidance	Medium	Modeling (CAL3QHC)
3. Detailed regional analysis	Detailed	Large projects/systems	Transportation conformity analysis is required and there is potential for environmental justice concern	Medium	Modeling (MOBILE6)
4. Analysis using pollution surfaces	Detailed	Project/corridor/system	Air quality is a major issue with protected population groups and previous methods have not addressed all issues	High	Modeling, database, geographic information systems (GIS), statistical analysis

When to use. This approach is advised in situations where detailed analysis is not warranted. It is intended to document both local and regional air quality in an area, as well as the presence of protected populations. The level of concern that there could potentially be distributive effects to protected populations is based on review of demographic patterns. Information gathered for this assessment can be used to perform detailed microscale analysis and detailed regional air quality analysis if findings indicate the potential for adverse effects to protected populations.

Detailed microscale or regional air quality analyses may not be necessary if the project does not trigger the requirements for a conformity determination or if the project is within an attainment area or a maintenance area with specific guidance that does not require a detailed microscale analysis. A detailed air quality analysis may not be necessary within a nonattainment or maintenance area if a project is not regionally significant and if the project does not affect any transportation control measures.

Even within maintenance or nonattainment areas, programs may be in place that provide thresholds indicating whether a microscale air quality analysis is needed. An example guidance would require evaluation of the 10 highest volume intersections in a region. The local guidance may state that a microscale air quality analysis is required if the highest volume intersection within the project area is less than the 10th highest intersection volume in the region. Similar guidance may specify that intersections operating at a particular level of service (LOS) or better may not require micro-scale air quality analysis.

Analysis. This analysis is a process of documenting regional and local air quality issues, and then documenting the presence of protected populations in the study area to determine (on a qualitative basis) whether the proposed transportation system change could potentially cause distributive effects. Based on local guidance, this analysis may include evaluating the highest traffic volume intersections within the project area, and/or evaluating the worst intersection LOS.

Step 1 – Document regional air quality. The first step is to document regulations and regional air quality in the study area. Much of the information needed for this step can be obtained from state and local agencies. At a national level, the EPA provides detailed information on regional air quality throughout the United States. Available information includes lists of regions that are in violation of the NAAQS, air pollution data and maps for ozone, PM, NO_2, SO_2, and air quality index (AQI) reports.

The AQI is an index for reporting air quality to the public. The AQI is calculated daily for each criteria pollutant using standard formulas approved by the EPA and is tied to relative levels of acute health concern. For example, an AQI of 101 to 150 is unhealthy for sensitive groups or individuals, such as those with asthma. AQI values greater than 150 are considered unhealthy (151-200), very unhealthy (201-300), or hazardous (301-500) to all persons.

The AQI is calculated on the basis of measurements taken at more than a thousand locations across the country each day. In large metropolitan areas, state and local agencies must report the AQI to the public daily. When the AQI is above 100, they must also report which groups, such as children, people with asthma, or people with heart disease, may be sensitive to the specific pollutant. Although it is not required, many smaller communities also report the AQI as a public health service (U.S. EPA 2003a).

To complete Step 1, describe the regional pollutants of highest concern in the study area, common sources of those pollutants, and provide an indication of the general level of regional air quality based on state and local information and on information available from the U.S. EPA. The data developed for this step could include the region's attainment/nonattainment status and number of days above the NAAQS for the various pollutants.

Step 2 – Document local air quality. The second step is to document local air quality rules and potential locations with relatively higher pollutant levels in the study area. Discuss the regulations and guides that are used to evaluate local transportation air quality and transportation conformity. Describe how the attainment status in the area determines the level of air quality assessment that is necessary. Next, identify locations in the study area where air quality from mobile and point sources may be of greater concern. At a minimum, you should document areas where air pollution levels could be higher because of proximity to transportation facilities. These locations could be areas near large concentrations of mobile sources, such as freeways, arterials, and congested intersections. If time and resources allow, it would be advisable to also identify other significant sources of air pollution that may affect the project area, such as electrical generation facilities and other point sources.

Step 3 – Document protected populations in the project area. Use any of a number of qualitative or quantitative methods for identifying protected populations in the project area. Many suitable techniques are discussed in Chapter 2. The best technique to use depends on the size of the project being evaluated. For policies, programs, and large projects with a sizeable area of potential effects, it is appropriate to use census data and any of the evaluation techniques that use census data, such as the Environmental Justice Index (EJI) or threshold analysis. For projects with smaller study areas, it is more appropriate to use data gathering techniques to characterize protected populations. Suggested techniques include local knowledge, field surveys, and public participation-based techniques such as focus groups.

Step 4 – Evaluate potential for unequal distributive effects. A map is probably the best way to evaluate the distribution of air pollution sources in the vicinity of protected populations. Either desktop methods or GIS can be used to map the location of significant point and mobile sources depending on available resources, the size of the study area, and the number of sources and demographic analysis units. Then, overlay the source information on maps showing the location of protected population groups. Because this is a screening test, the objective is not to identify statistically significant unequal location patterns. Rather, the intent is to identify areas where there is spatial clustering of air pollution sources and where protected populations are in very close proximity to air pollution sources. Document these sites as locations where local air quality and its effects on protected populations could be of greater concern than in other portions of the study area.

Commonly used regional air quality assessment methods assume that pollutants at this scale are distributed relatively uniformly across large areas. Therefore, it will not usually be worthwhile to evaluate unequal geographic distributions unless the study area includes multiple regions. Rather, you will need to discuss regional air quality as mentioned above and describe the adverse effects that may be experienced by various population groups.

Data needs, assumptions, and limitations. This type of analysis requires the following basic information on the project and the geographic area or region of the project:

- Project traffic study results, including traffic volumes and LOS;
- Maps showing transportation system intersections and links;
- Information on the location of point sources that emit air pollution;
- Regional attainment status, and local project analysis guidance; and
- Information on the location of protected populations.

Information on point sources that emit air pollution can be found in numerous sources. Many states publish an annual database of permitted facilities. Some of these databases include information on the level of emissions, making it possible to map not only the locations of facilities but also to categorize facilities based on the volume and types of pollutants they emit.

At the national level, the EPA annually releases this type of information in the Toxics Release Inventory (TRI) (U.S. EPA 2003b).

This technique assumes that proximity to air pollution sources is an indication of possibly higher local air pollution levels. This may not be a valid assumption in all situations because of factors such as wind speed and direction, topography, and pollutant dispersion characteristics, among others. Without further analysis, this technique merely documents local and regional air quality issues in the study area and identifies locations where air quality may be of greater concern to protected populations.

Using this method, one approach to evaluating the distributive air quality effects of a project would be to assess whether the project would affect local air quality in the areas of greater concern. If so, a more detailed analysis in those areas should be considered. However, if the project would not have an effect in these areas and air quality is not a major issue to protected populations in the study area, it should generally be safe to conclude that the project would have no distributive air quality effects.

Obviously, this method has major limitations. It relies on very basic data to assess the potential for localized air quality effects, and it assumes that the distribution of regional air quality is uniform. For areas where the potential for unequal effects is identified, the actual level of effect cannot be quantified. Because of these limitations, it is safe to assume that any results from this method of assessment would be challenged if a project were controversial. This technique is therefore best used as a screening technique only, and further assessment using more robust techniques should be performed unless no potential for unequal effects is found and the project is not controversial.

Results and their presentation. The results of this analysis could include a table showing intersection volumes or LOS, where higher volumes indicate a greater potential for localized air quality effects. A second table showing total stack and fugitive emissions from point sources could be used to display sites with high emissions levels. A general discussion of the regional attainment status and guidance for air quality should be included. Probably the most useful presentation aid would be a map showing locations of protected populations and nearby mobile and point sources of air pollution.

Assessment. A general air quality review is intended to disclose local and regional air quality concerns and regulations. For environmental justice assessment, comparison of mobile and stationary air quality sources and their proximity to protected populations is included. Due to the many limitations of this approach, further detailed analysis should be performed in any situation where protected populations could be affected by the policy, program, or project or where the transportation system change is controversial. Because no quantitative air quality analysis is conducted, this technique provides qualitative results and any conclusions are subjective.

Method 2. Detailed microscale analysis

The detailed microscale analysis is an extension of the hot spot analysis used to determine NAAQS conformance. The additional information and modeling needed to perform environmental justice assessment are reasonable and should be within the resources of most agencies that must currently perform local air quality analysis under Clean Air Act and transportation conformity guidelines.

When to use. A detailed analysis should be conducted for any regionally significant transportation project within a nonattainment or maintenance area. Because the additional data requirements necessary to perform environmental justice assessment are relatively minor, this method can be used to evaluate both projects and plans, such as TIPs or major investment studies. This analysis should also be conducted if a state agency requires it on the basis of its SIP, guidance, or rules. The analysis also is needed if the project is controversial and will be subjected to substantial public scrutiny due to perceived potential air quality impacts. Such an analysis is especially useful in situations where a general air quality review (Method 1) indicates the potential for air quality effects to protected populations.

This type of analysis should be conducted (a) to determine that no established criteria pollutant standards are violated and (b) to evaluate effects to protected populations. Although this form of detailed assessment is only required in specific circumstances according to the Clean Air Act and transportation conformity requirements, the method is broadly applicable to all transportation plans and projects that would benefit from microscale air quality assessment. The microscale analysis is typically performed at selected worst case, or "hot spot" intersections. Environmental justice assessment involves evaluating the pattern of where these intersections are located in relation to the activity spaces of protected population groups and then, at an even finer level, the effects of hot spot intersections on specific sensitive receptors.

Analysis. The following steps are specific to the environmental justice component of the local air quality assessment. For an overview of a standard procedure for performing the hot-spot analysis, see "Microscale air quality assessment," above. FHWA (2001) also provides a detailed discussion of the requirements for performing hot-spot analysis. Figure 3-3 provides an example of how a microscale analysis process can be used to evaluate environmental justice.

Step 1 – Describe the transportation system change and gather necessary data. The detailed microscale assessment can be performed for policies, plans, and projects down to the level of a specific intersection. You must define the nature of the transportation system change and the air quality objectives by which the change should be evaluated. For general NAAQS conformance with an environmental justice component, the objective could be stated as "document NAAQS compliance ensuring that the proposed projects cause no violations at worst case intersections and in areas where there is possible environmental justice concern." In situations where air quality is highly controversial and there is a history of concern over impacts to protected populations, the objective could be to obtain emissions reductions. In this case, the goal would be to "evaluate project performance and ensure that the transportation facility yields a net emissions reductions once it is fully implemented."

Once the transportation system change and objectives are described, you must assemble all the data necessary to describe intersection-related traffic conditions and demographic characteristics of the intersections. The specific data needed are described later under "Data needs, assumptions, and limitations."

Step 2 – Review demographics for all intersections. Once each intersection has been assigned a score characterizing its level of environmental justice concern, rank the intersections either categorically or numerically. If an environmental justice concern was quantified using a measure such as the EJI, select a threshold value denoting areas of relatively higher concern based on expert opinion and knowledge of both system user demographics and activity space demographics near the intersections. Tabulate the number of intersections with a high level of environmental justice (EJ) concern.

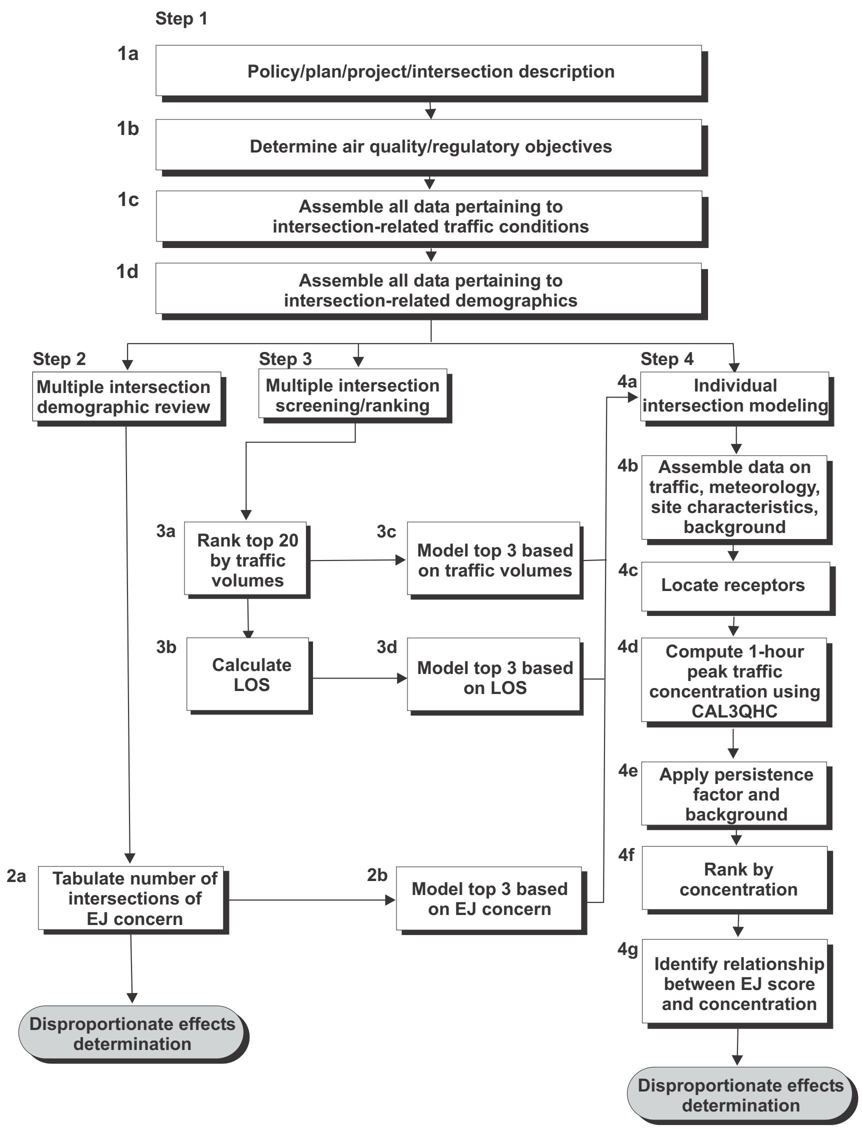

Figure 3-3. Example of a microscale environmental justice assessment process
Source: FHWA 2001.

The results of this step would lead to a finding of distributive effects to protected populations in two cases:

- Fifty percent or more of the affected intersections in the study area are in areas with high environmental justice concern.
- The proportion of intersections in the study area with high environmental justice concern is larger than would be expected for the comparison region.

The expected proportion of intersections with high environmental justice concern can be estimated from reviewing the demographic characteristics of a large sample of similar intersections in the comparison area. The comparison area should be a jurisdiction large enough to encompass the entire study area, such as a county, metropolitan area, or state.

Step 3 – Screen and rank multiple intersections. As suggested in the FHWA guide, rank the intersections by traffic volumes and select the top 20 intersections. Then calculate the level of service for those intersections. Select for individual intersection modeling, at a minimum, the top three intersections based on traffic volume ranking, the top three intersections based on LOS ranking, and the top three intersections based on EJ concern ranking. The purpose of adding at least three intersections of environmental justice concern is to allow comparison of results for worst case intersections obtained in Step 4.

Step 4 – Model individual intersection. The purpose of this step is to compute 1-hour peak traffic-related concentrations at sensitive receptors through application of a hot-spot model such as CAL3QHC with the addition of any persistence or background air quality factors. The screening and ranking step (Step 3) is recommended because the level of modeling effort increases linearly with the number of intersections being evaluated. By applying the screening process, you can be reasonably certain that the worst case intersections are being evaluated.

Once you have calculated emissions scores for each modeled intersection, rank the intersections in order of concentration. Interpretation of the results can be relatively simple, although various statistical techniques also can be used to compute rank-order correlations and determine significance of the findings. Initial findings, however, can be made simply by identifying where the “high-EJ concern” intersections fall in relation to the worst case intersections. In general, a finding of adverse distributive effects to protected populations would be warranted based on the following results:

- Fifty percent or more of the worst case intersections are in areas of high environmental justice concern.
- The proportion of worst case intersections with high environmental justice concern is larger than would be expected for the comparison region.
- A violation or exceedance is indicated at any intersection of high environmental justice concern.
- Projected pollutant concentration increases will be measurable between baseline and future-year scenarios, and the areas with the greatest increases are characterized as having high environmental justice concern.

In contrast, results indicating that concentrations are lower at intersections characterized as having high environmental justice concern when compared to the worst case intersections may support a finding that protected populations are not adversely or disproportionately affected. A finding of beneficial distributive effects would be supported by a result indicating that concentrations at the modeled intersections with high environmental justice concern will be measurably lower for future-year scenarios than for the baseline condition.

Data needs, assumptions, and limitations. This analysis requires the following types of information:

- Background concentration levels (although this can often be estimated);
- Traffic impact study, including traffic volume, intersection geometry, signal timing, traffic speeds, location of sensitive receivers;
- Regional vehicle parameters and fuel information, including:
  - Vehicle classification and mileage data,
  - Vehicle age distribution, and
  - Vehicle inspection/maintenance program details;
- Specific fuel characteristics (oxygenated fuel, or ethanol); and
- Geometric layout of intersections and locations of sidewalks and nearby sensitive receptors.

In addition, information is needed to characterize the level of environmental justice concern of each intersection being analyzed. Any number of methods presented in Chapter 2 can be used to identify the relative level of environmental justice concern. As an initial screening step, or for large projects or system-wide analyses to review policies or programs, it would be useful and possibly necessary to use a census-data-based approach such as the Environmental Justice Index. However, due to the localized nature of effects being addressed by the microscale analysis, it is more appropriate to use demographic data collected for specific receptors using field survey, local knowledge, public input, and other detailed data-gathering techniques.

A microscale intersection analysis is limited by the fact that only discrete receptors are analyzed. These locations are on such a small scale that the approach does not allow any means of generalizing or characterizing the overall air quality in an area. Thus, the approach can only be used to identify if any microscale distributive effects would result from the proposed transportation system change. It cannot be extended to address the general air quality of the local study area. It should be noted, however, that this approach does evaluate the maximum impact at intersections affected by a proposed project. So if the maximum impact is below the NAAQS, you can be reasonably confident that the project's impacts elsewhere also will be lower than the NAAQS.

Pollutant concentrations typically decrease very rapidly at greater distances from a roadway, but it would be difficult to precisely extrapolate results beyond the specific receptors being evaluated. It could also be possible that a roadway is to be moved closer to a receptor. Under these conditions, a slight shift in roadway alignment closer to a receptor could result in an increased concentration, even if an overall air quality benefit is achieved. For these reasons, occasions may arise where an increase from no-build occurs, but a build analysis verifies that concentrations do not violate the NAAQS.

Results and their presentation. Microscale intersection analyses predict the pollutant concentrations at discrete receptors near worst case intersections and intersections of high environmental justice concern. The number of receptors can vary significantly (e.g., 1 to 20). The location of these receptors is usually close (within 200 ft) to the roadway. Most analyses of this type include a figure showing the receptor locations, along with a table detailing the concentrations at each receptor. The results will always include the project alternative results and sometimes existing and no-build scenarios.

Assessment. Policy, program, and project microscale results are most often compared to the NAAQS. However, results are occasionally compared to a no-build scenario. This microscale environmental justice assessment method is based on FHWA microscale or “hot spot” NAAQS conformity analysis, and shows expected concentrations at discreet receptors in parts per million (ppm). Environmental justice is evaluated by comparing and ranking expected concentrations and level of environmental justice concern at the worst case intersections as defined by traffic volumes, LOS, and level of environmental justice concern. If an exceedance of the NAAQS is predicted or if it is found that areas with relatively greater environmental justice concern experience relatively higher emissions, mitigation measures should be included to prevent the exceedances and unequal emissions levels. Mitigation could be required depending on attainment status and local rules.

Mitigation may include adding intersection capacity with additional traffic lanes, optimizing signal timing for air quality purposes, or diverting traffic to other locations. Potential impacts associated with these measures could include right-of-way acquisition, increased pedestrian conflict areas, or increased traffic volumes at other locations. Mitigation measures often must be completed before a project is finished and sometimes may be a result of a nearby site development. Each of these mitigation measures could have environmental justice-related issues other than air quality that would need to be evaluated using appropriate methods.

Method 3. Detailed regional analysis

When to use. A regional air quality analysis is conducted for regionally significant projects and when required by local guidance. This type of analysis might be conducted for a major transit project, for a new freeway connection, or even for adding capacity to a major regional connection in an urban area. Because this technique provides only regional estimates and does not provide geographic distinction below the regional level, environmental justice assessment of regional air quality merely involves documenting the protected populations in the region and the air quality concerns that have been raised by those populations. Many of the analysis steps and issues discussed as part of the general air quality review (Method 1) apply to this technique as well.

Analysis. A detailed regional analysis is carried out in two steps:

Step 1 – Perform regional air quality analysis. Regional air quality analyses use regional travel demand models and MOBILE6 emission modeling. Regional travel demand models provide traffic volumes and speed on a link level. The MOBILE6 model provides emission rates that vary by speed and incorporates vehicle age, vehicle classifications, and other operating characteristics. By applying these emission rates to each link of the regional travel demand model, total regional emissions can be determined. Generally, if capacity is added to a transportation system, delay decreases. While this may result in more trips or longer trips, the reduced delay results in an overall decrease in emissions because vehicles operate least efficiently when idling or in congested environments.

Step 2 – Document air quality concerns of protected populations. Once the regional air quality analysis is completed, present the findings to protected population groups and address any questions or concerns. Except in cases where the geographic scope of the policy, program, or project covers more than one air quality region, it is very difficult to assess unequal distributive effects using this method. That does not mean, however, that regional air quality has no environmental justice implications. Because unequal effects cannot be determined in most cases and regional air quality is similar across broad areas, the environmental justice assessment effort should focus on sharing information with protected population groups and understanding any air quality concerns that these groups may have. To understand how protected populations perceive regional air quality and its health effects, consider either conducting a survey or focus groups. You must be sure to obtain the demographic characteristics of each participant that are relevant to characterizing protected populations. Recommended survey questions are presented in Chapter 2.

Data needs, assumptions, and limitations. This type of analysis requires the following information:

- Results of applying a regional travel demand model,
- MOBILE6 modeling variables and regional characteristics, and
- Information on protected populations.

The models that must be used (according to regulation) assume a uniform distribution of the vehicle fleet across a region. The greatest limitation of this type of analysis for environmental justice assessment is that it provides no geographic distinction for results. As a result, extension of the technique to evaluate environmental justice is merely a matter of disclosure. You can do little more than share the results with protected population groups and understand their most important air quality concerns and how those concerns may be different (e.g., lesser, greater, or focused on specific health effects such as asthma) from the general population. Suggestions for understanding locations in a study area where there may be relatively higher pollution concentrations are explained under Method 1, but can be applied here as well.

Results and their presentation. A regional air quality analysis generally includes a description of the air quality status of the region, a description of the guidance, and a tabular presentation of total pollutant emissions. The pollutants include CO, NO_2, PM, and VOC. The results of the analysis would include a no-build and build comparison of annual tons of pollutant. Again, transportation projects usually represent an increase in capacity, which usually results in reduced pollutant emissions because free flowing traffic pollutes less than stop-and-go traffic.

Assessment. This method can provide regional estimates of air quality impacts that would result from a proposed major transportation project, but it cannot give an indication of how protected populations living or moving about in particular areas of the community would be affected differently than people in other parts of the community. Its principal use would be to estimate whether the build scenario's emissions are higher than those of the no-build scenario.

Method 4. Analysis using pollution surfaces

The previous methods presented in this chapter each have relatively severe limitations when it comes to performing environmental justice assessment. The general air quality review is suitable as a screening technique, but it only provides information as to whether a transportation policy, program, or project *may* have effects to protected populations, in which case a more detailed assessment technique must be used to characterize the effects. The detailed microscale analysis provides an indication as to how protected populations would be affected at worst case sites, commonly intersections, within a study area. Its greatest limitation is that results cannot be extrapolated beyond the worst case sites that are evaluated. In other words, it does not provide results that can be used to assess the variability in pollutant levels across a study area to which all protected populations and the general population are exposed.

The regional air quality review, on the other hand, is used to characterize air quality that is assumed to be relatively uniform over large areas, and it does not yield results that are geographically variable within the region of interest. Although regional impacts to protected populations can be described in general terms, this technique is limited by the fact that its results cannot be disaggregated to evaluate variable air quality patterns within the region. With all of the previous methods discussed, it is difficult to develop estimates of the overall, or cumulative, air quality picture because the techniques are focused on assessing only transportation air quality. What is needed is a method that can be used to assess the geographic variability of air quality within a region. The method would allow air quality assessment at a subregional or local scale larger than the microscale sites within a few hundred feet of hot-spot intersections but smaller than the large air quality regions that commonly cover multiple counties or large metropolitan areas. In addition, the method needs to be able to evaluate how transportation system changes affect subregional air quality from mobile sources, as well as the cumulative subregional air quality picture.

When to use. This method is more data intensive than the previous methods discussed and is based on techniques that are less commonly used in current practice. It should therefore be used in situations where policies, programs, or projects are controversial and where the common methods for assessing local and regional transportation conformity do not address all of the concerns expressed by protected population groups.

Analysis. Commonly used air quality assessment methods rely on travel demand models (discussed in Chapter 7), mobile source emission rate models (such as MOBILE6), microscale air quality dispersion models (such as CAL3QHC), and photochemical models for calculating regional air quality. Photochemical models use emissions estimates from all human and biological mobile and point sources, combined with meteorological data, to predict regional ambient pollution levels and to determine NAAQS conformance. These commonly used techniques can be combined with ancillary data sources to develop a map showing the variation in pollutant concentrations across space and time. Such maps are called pollution surfaces because they provide a ground-level concentration estimate for each grid cell in a study area.

It has been argued that traditional transportation air quality assessment methods have three important limitations:

- The estimates of vehicle activity (vehicle-miles traveled and average speed) lack the accuracy and spatial resolution needed to evaluate control measures.
- The mobile source emission rate modeling process uses highly aggregated fleet estimates and biased emission rates.
- The modeling process is not oriented to the needs of transportation planners and engineers who design and implement emissions control strategies. These users require more feedback from typical transportation system improvement strategies than is provided in current methods (Bachman et al. 2000, p. 207).

For these and other reasons described earlier, the commonly used assessment methods also severely limit the ability to perform an environmental justice assessment. Probably the most significant reason is the third limitation cited by Bachman: namely that transportation planners cannot obtain from the existing methods the level of feedback necessary to evaluate spatial variability and to design effective control measures. Both of these factors—the ability to evaluate spatial variability and the ability to determine the effectiveness of control measures—are key to environmental justice assessment of transportation-related air quality.

Two basic approaches are used to overcome the limitations of the most commonly used air quality assessment methods. These include model-based methods and statistical methods. Model-based methods extend existing models to account for the spatial and temporal variability in vehicle emissions. They are based on more detailed information than is currently used. Statistical methods are techniques that use a combination of regression analysis and known concentrations from monitoring sites to predict pollutant concentrations across the entire study area. Recent examples of model-based research and statistical method research are described below.

One prototype model-based method is known as the Mobile Emission Assessment System for Urban and Regional Evaluation (MEASURE). The details of the MEASURE model design and architecture can be found in U.S. EPA (1998a). This method for developing pollution surfaces improves upon regulatory emissions models such as MOBILE6 in two ways. First, MEASURE is modal in that emissions rates are specific to particular modes of vehicle operation, such as engine starts, normal operation, and rapid acceleration. Second, for each grid cell, the model computes the characteristics of the vehicle fleet and the proportion of the time that the fleet is in each of the vehicle operation modes. MEASURE therefore inherently captures the spatial variability in transportation air quality. In practice, emissions estimates are calculated for each vehicle mode, and then total emissions estimates are calculated by summing across modes. Once the total emissions estimates are computed for each cell, the output can be used in photochemical models (Bachman et al. 2000). The MEASURE emissions modeling process is depicted in Figure 3-4.

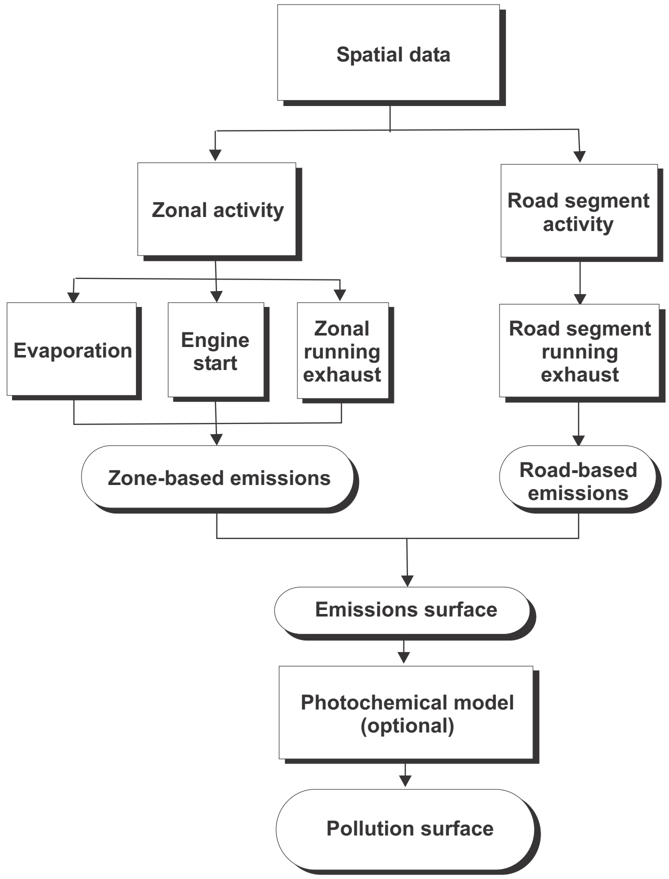

Figure 3-4. The MEASURE emissions modeling process
Source: Bachman et al. 2000. See Table 6.2.

Statistical methods to predict pollutant levels most commonly use least squares regression analysis to develop predictive models based on monitored pollution data and information such as land use, population, and vehicle miles traveled. This form of prediction is preferred over global and local interpolation techniques. This is because monitoring networks generally are sparse and thus do not accurately depict pollutant distributions that are affected by complex topography, complex meteorology, and rapid distance decay functions.

Many approaches are used to develop regression models for estimating pollution surfaces. A project known as Small Area Variations in Air Quality and Health (SAVIAH), funded by the European Union, is used as an example. Details of the SAVIAH study can be found in Briggs et al. (1997). The SAVIAH approach used in Huddersfield, United Kingdom, is depicted in Figure 3-5. The study used standard air quality monitoring devices (i.e., samplers) to record pollutant levels at a number of locations within the cities that were studied.
The following is a procedure for implementing the Method 4 analysis.

Step 1 – Develop pollution surface. Generate a pollution surface using either model-based or statistical techniques. One important benefit of the model-based technique is that it can be used very effectively to evaluate transportation-related emissions and proposed control measures. The greatest benefit of the statistical technique, on the other hand, is that it is better for evaluating cumulative pollutant concentrations from all sources. Both techniques result in a geographically variable pollution surface that can be evaluated for distributive effects to protected populations. Suggested steps for performing the model-based technique are presented as *Steps 1a-1f*. Suggested steps for performing the statistical technique are presented as *Steps 1g-1j*.

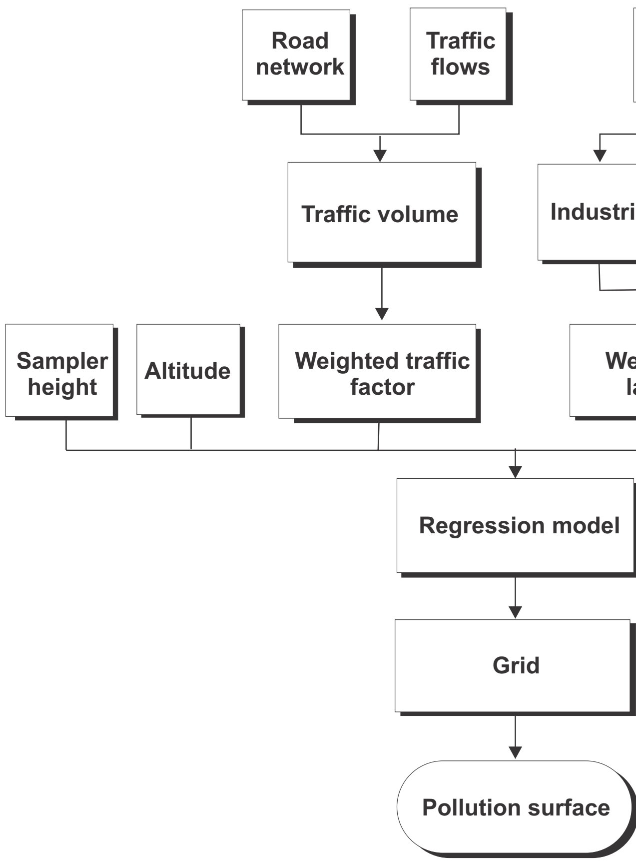

Figure 3-5. The SAVIAH statistical pollution surface development process
Source: Briggs, et al. 1997. See Table 6.2.

Step 1a (MEASURE example). Organize the spatial environment. Determine analysis units for each of the necessary input variables. For example, TAZs could be the unit of analysis for estimating trip origins and engine starts. Alternatively, it would be possible to disaggregate trip origins to a smaller analysis unit using land use information to identify residential areas and census block information to identify household densities. Travel demand model network links need to be related to an accurate GIS road layer. It is also necessary to select the output grid cell size. Cell size selection should be based on resolution of the input data, data processing requirements such as file size limitations, desired resolution of the outputs, and computational efficiency.

Step 1b. Estimate vehicle fleet characteristics. This step involves determining the characteristics of the vehicle fleet and its spatial variability. Thus, the fleet characteristics could be different for each output grid cell in the model. In MEASURE, a "technology group" distribution is calculated for each zip code in the study area. Technology groups are combinations of vehicle characteristics and operating characteristics that have been identified through empirical research as being highly predictive. For engine start and engine off modes, vehicle fleet characteristics are estimated for zonal analysis units such as TAZs and/or zip codes. Estimates for operating vehicles (i.e., vehicles in motion) associated with road segments are based on analysis of travel demand model links. In MEASURE, the mix of vehicles on various roadways is identified by developing estimates of local and regional fleet characteristics based on zip-code-level vehicle registration data.

Step 1c. Estimate vehicle activity. Use the travel demand model to predict regional travel, including the number and location of peak hour or daily trip origins, road segment volumes, and average speeds based on volume-to-capacity ratios. Use this information to estimate distributions of speed and acceleration, and vehicle mode operations.

Step 1d. Predict facility-level emissions. Transportation "facilities" include major roads, minor roads, and trip origin zones. Engine start emissions are linked to the zone (i.e., TAZ, census block group, or census block) of origin. Minor roads not usually included in travel demand models are assigned running exhaust emissions as zonal averages based on travel time, local road speeds, fleet composition estimates, and vehicle miles traveled. Major roads included in the travel demand model are assigned running exhaust emissions as linear (i.e., road segment) averages based on speed and acceleration characteristics and fleet composition estimates.

Step 1e. Generate the mobile emissions inventory. This step involves converting the facility-based emissions estimates generated in *Step 1d* to grid-cell-based emissions estimates. Convert estimates for each polygon facility (origin zone or minor road zone) to a rate expressed as grams/square kilometer, and convert major road facilities to a rate expressed as grams per kilometer. The polygon and line facilities are overlaid on the output grid cells and the rates are allocated to the grid cells based on the proportion of a facility that falls into each cell. Compute emissions per grid cell by multiplying the rates by the areas and lengths of the facility/grid cell portions.

Step 1f. Apply photochemical model (Optional). Use an appropriate photochemical model to generate estimates of ground-level pollutant concentrations across the study area. The ground-level pollutant concentrations are based on meteorological conditions and the emissions estimates obtained for each grid cell. The physical properties of the pollutant and distance decay functions are also accounted for in the model. Perform this step if you wish to evaluate the distribution of ground-level pollutant concentrations rather than transportation-related emissions (the output of S*tep 1e*). By incorporating emissions information for point sources into the photochemical model, you can evaluate cumulative ground-level concentrations in addition to ground-level concentrations from transportation-related sources. However, application of photochemical modeling requires collection and processing of far more input data (including regional speciated emission inventories and three-dimensional fields and boundary conditions of all meteorological and air quality parameters) than any of the other methods described here. Therefore, this step generally would be impractical for evaluating individual transportation projects.

Step 1g (SAVIAH example). Data collection and preparation. Unlike a model-based method that estimates emissions based on roadway geometry, traffic volumes, and vehicle fleet emissions characteristics, statistical methods predict population surfaces by fitting regression models to observations at monitoring sites based on known values for predictor variables. Because existing monitoring sites (such as stations used to evaluate regional air quality and to develop AQI scores) are relatively sparse in most areas, you may want to consider additional monitoring over a prolonged period of time (i.e., many weeks or months). A larger monitoring network and a larger number of samples will yield a more accurate regression model. In addition, you will need to collect the necessary information to compute predictor variables. Commonly used information is listed in "data needs, assumptions, and limitations."

Step 1h. Conduct exploratory study. The result of a multivariate analysis is a best-fit curve allowing estimates of the response variable to be derived from known values of predictor variables. The purpose of the exploratory study is to reduce the set of candidate predictor variables described in *Step 1g* to the set to be used in the regression model. Highly intercorrelated predictor variables should be eliminated, as should other variables found to have low correlation with the response variable. Use a variable reduction procedure to develop correlation matrices and identify candidate predictors that should be retained in the final model. Comrie and Diem (2001), for example, used principal component analysis to evaluate an initial set of candidate predictor variables. Although it is beyond the scope of this guidebook to provide an in-depth discussion of variable reduction, numerous books on applied regression analysis are available, such as Neter et al. (1996).

Although this approach is not always applied, it may be worthwhile to consider developing multiple regression models, one for each commonly observed set of meteorological conditions. Comrie and Diem (2001), for example, developed independent regression models for four distinct clusters of CO monitoring data, where observed concentrations, temperature ranges, wind speeds, and atmospheric pressure were relatively constant within each cluster.

Step 1i. Refine and select model. The result of *Step 1h* is a small subset of candidate regression models with a limited number of explanatory variables that provide good predictive ability. *Step 1i* results in selection of the final model, based on review of residual plots and analyses to identify lack of fit, outliers, and influential observations.

The SAVIAH study (Briggs et al. 1997), for example, developed regression models to predict NO_2 concentrations in Huddersfield, the United Kingdom; Amsterdam, the Netherlands; and Prague, the Czech Republic. In each city, the regression models were based on local predictors that provided results with the most predictive power. However, two constraints were placed on the regression models developed for each city. First, the models had to include terms for traffic volume, land cover, and topography because each of these is known to affect pollutant dispersion. Second, a common GIS-based buffering approach was used to compute predictor variables that had a spatial component, such as total traffic volume within 300 meters of a monitoring site. The resulting regression equation for average annual NO_2 concentration in Huddersfield included traffic volume within 300 meters, high-density housing, and industrial land use proportions within 300 meters, altitude, and sampler height.

Step 1j. Apply the model. Based on computed predictor variable values for each grid cell, use the selected regression equation to compute predicted pollutant concentrations. This yields a pollution surface for the entire study area.

The output of either the model-based or statistical approach is a pollution surface that provides estimates of either emissions or pollutant concentrations for each cell in the study area grid. This output is then combined with a population surface to perform an environmental justice assessment.

Step 2 – Develop population surface. A population surface is a raster, or grid-cell-based, representation of a population. Population surfaces are produced in GIS using any of various algorithms to convert census polygon-based, or zonal, population data to a grid cell-based format. A population surface is the best form of demographic data to use with model-based and statistical air quality prediction techniques because their results are also grid-based. By using the same set of grid cells to produce pollution surfaces and population surfaces, you create an information-rich dataset that can be evaluated to assess unequal distributive effects to protected populations. More detail on the process for developing population surfaces is provided in Chapter 2.

The output of this step is a set of GIS grids depicting the distribution of protected populations, nonprotected or other populations, and total population. Protected populations can include race, income, age, sex, or any other protected population group. It is also possible to produce a "protected population surface" that is merely the sum of all population groups of interest. From these datasets, standard map algebra routines can be used to compute estimates of affected populations and population percentages for the entire study area or for smaller areas within a larger region.

Step 3 – Overlay pollution surface and population surface. The next step is to overlay the pollution surface created in Step 1 with the various population surfaces created in Step 2. You can do this using GIS and relational database software. Both tabular and map-based results are needed. Figure 3-6 depicts the process of combining population surfaces and pollution surfaces and the resulting outputs.

Step 4 – Visualize results. The power of this technique is the rich dataset it produces for evaluating geographically distributed effects. With additional processing of time-series data, such as prebuild, build, and future-year scenarios, temporal environmental justice aspects can also be assessed. Because of the richness of the dataset, it is both unwise and unnecessary to base conclusions about distributive effects on a single statistical test or data visualization approach. Rather, it is important to analyze and visualize the data in many different ways. This will lead to a detailed understanding of distributive effects patterns and effective control measures for altering present or future distributive patterns.

The following assessment and data visualization routines are described below:

- Relative emissions burden calculation,
- Relative pollution burden graphs,
- Regional effects mapping and analysis, and
- Local effects analysis.

Relative emissions burden calculation. Relative emissions burden is defined as the ratio between (a) the average ground-level pollutant concentration (or emissions level) available to members of protected population groups and (b) the concentration available to members of non-protected population groups. Note that this is a measure of pollutant "availability," not exposure. "Burden" therefore means that pollutants are present and available for persons to be exposed to. The relative emissions burden evaluation was first used in 1998 by the U.S. EPA to determine if pollutant distributions in the Louisiana Industrial Corridor disproportionately affected minority populations (U.S. EPA 1998b).

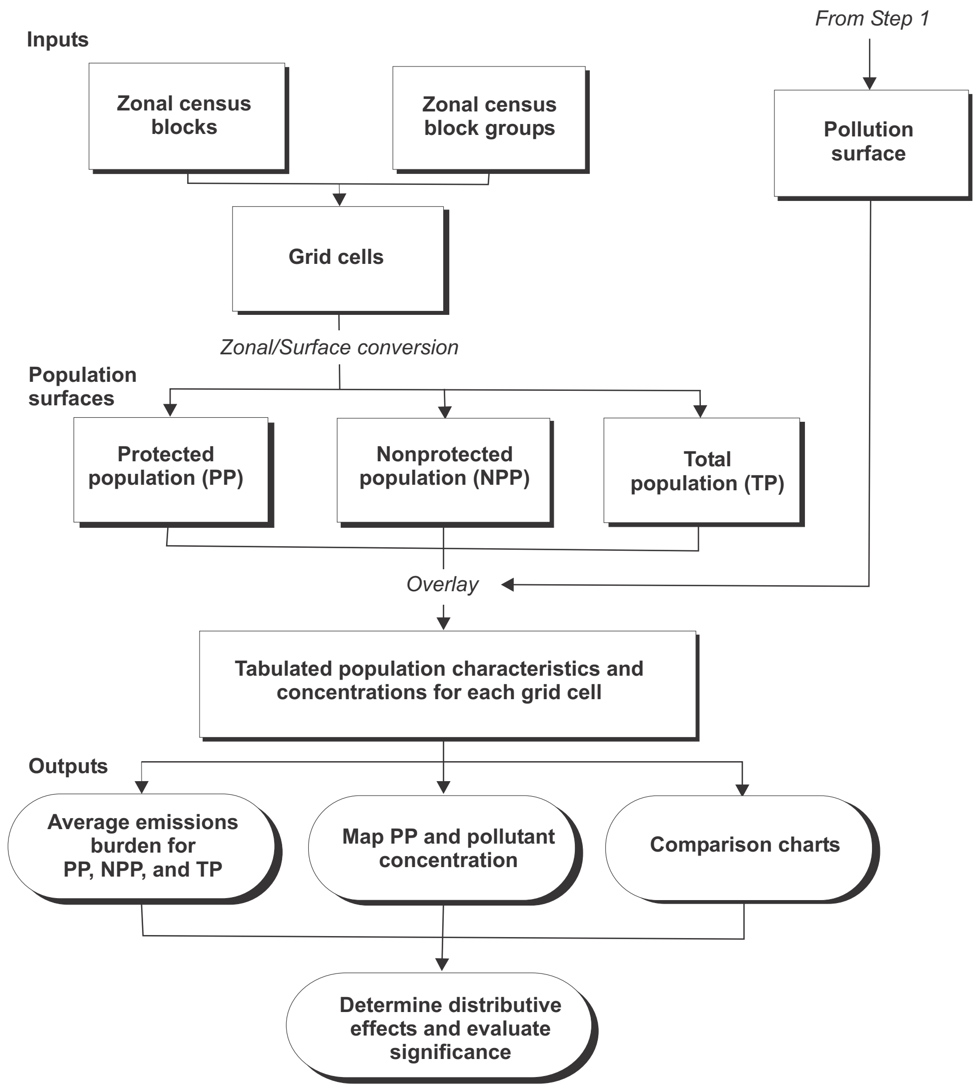

Figure 3-6. GIS process for combining pollution surfaces and population surfaces

The EPA approach based estimates of emissions burden on proximity to pollution sources and on estimates of pollutant emissions in pounds. The approach did not account for pollutant dispersion based on meteorological and chemical properties, nor did it develop estimates of ground-level pollutant concentrations. Unlike the approach presented here, the U.S. EPA study used zonal census data, buffers of pollutant-emitting facilities, and information on emissions volumes to evaluate distributive emissions patterns. One benefit of working with population surfaces is that calculation of relative emissions burden is relatively simple and straightforward when compared to working with vector GIS datasets.

Relative emissions burden is computed using the following equation:

$$R = \frac{\left(\sum_{i=1}^{N} PC_i \times NPP_i\right) / (NPP)}{\left(\sum_{i=1}^{N} PC_i \times NNP_i\right) / (NNP)}$$

where

R = relative emissions burden

N = number of cells in grid

PC = pollutant concentration

NPP = number of persons in protected population group

NNP = number of persons in non-protected population group

Evaluation of results is also straightforward. If R is greater than 1.0, the average level of emissions experienced by members of protected population groups is greater than the average level experienced by members of other population groups. If, for example, R is computed to be 1.25, this means that the average emissions burden to members of protected populations is 25 percent greater than the average emissions burden to members of other population groups. Although it is worthwhile to evaluate relative emissions burden, comparison of average burden levels across a study area is only of limited value in determining to what extent there may be unequal distributive patterns and where those patterns are evident. This more detailed evaluation is better performed by evaluating the distributions in charts and maps. Examples are provided below.

Relative pollution burden graphs. When evaluating the codistribution of air quality effects and protected populations, visualizing the information patterns in graphs and maps is often the most insightful form of analysis. To produce graphs, the pollution surface must be combined with a population surface, which yields an estimate of pollutant concentration and protected population characteristics for each grid cell. This dataset can be used to identify any areas where standards may be violated and to identify locations where strategies to reduce pollutant concentrations are required.

For purposes of environmental justice assessment, it is also important to understand that many communities may have concern over pollutant concentrations that meet regulatory air quality standards. This could be because a community feels that the NAAQS are not protective enough of sensitive individuals or of individuals that receive greater exposure due to lifestyle. Or, it could be that a community is concerned about the additive and synergistic effects of exposure to multiple pollutants.

Evaluating distributive effects at concentration levels below the NAAQS is also a useful approach for dealing with concerns about measurement error. It is often practical to evaluate effects above the NAAQS, as well as to identify a “threshold of concern” for values that approach the NAAQS. The threshold of concern can be based on policy, expert information, or even community input.

Figure 3-7 depicts results of an analysis to estimate annual average PM_{10} concentrations (see page 61) in a five-county metropolitan region. The annual average NAAQS for PM_{10} is 50 micrograms per cubic meter ($\mu g/m^3$). A decision was made, based on public input, that areas with concentrations above a 40 $\mu g/m^3$ threshold of concern should also be evaluated for distributive effects. The graphs show the regional pattern of concentrations available to protected population groups compared to other individuals. The top chart shows that a greater *proportion* of protected population groups reside in areas with concentrations between 31 and 60 $\mu g/m^3$meter. The bottom chart shows that a greater *number* of persons in protected populations also reside within areas with concentrations in this range.

It is important when using this technique to compare to the rest of the population both (a) the percent of the protected population and (b) the total number of individuals in the protected population group that would experience adverse effects. This can be done by preparing one set of graphs with percent of population as the vertical axis and another set of graphs with the number of persons as the vertical axis (as in Figure 3-7). Both evaluations are necessary to determine distributive effects because in certain study areas a majority of the affected population may belong to protected groups. In the case of this particular dataset, evaluations by number of persons and population proportions both show patterns of unequal distribution. For other study areas, however, this may not be the case. This topic is addressed again in Chapter 10.

Regional effects mapping and analysis. The graphic visualization of pollution and population surface results presented in Figure 3-7 is a very useful assessment technique for characterizing the distribution of pollutant levels among population groups. The graphs are even more useful, however, when combined with maps showing the pollution surface overlaid on the population surface. Figure 3-8 provides an example for the same five-county area discussed above. The top map depicts areas where there is a high *proportion* of protected population. The bottom map depicts areas where a large total *number* of members of protected population groups reside. As with the graphs, it is necessary to evaluate the population distribution patterns in both ways. The benefit of using both maps and graphs is that one form of visualization overcomes the limitations of the other: maps are very good at depicting geographic patterns, but all detail is lost when you try to quantify the geographic patterns. On the other hand, by viewing the graphs it is easy to speak in quantitative terms about the disproportionate pattern that seems evident in the map. If you rely on just the graphs, however, it is easy enough to understand that a disproportionate pattern exists but impossible, without the map, to determine *where* the patterns are located.

Regional analysis is thus a combination of determining relative emissions burden and visualizing any potential disparities using graphs and maps. In the examples provided above, it could be concluded that areas where annual average PM_{10} concentrations exceed 40 $\mu g/m^3$ are of concern and that strategies must be implemented to reduce these concentration levels. It could also be concluded that there is an environmental justice issue because those concentration levels burden a greater proportion of the protected population and a greater number of individuals in protected population groups. This form of analysis is useful for policies, programs, long-range planning, and regionally significant projects.

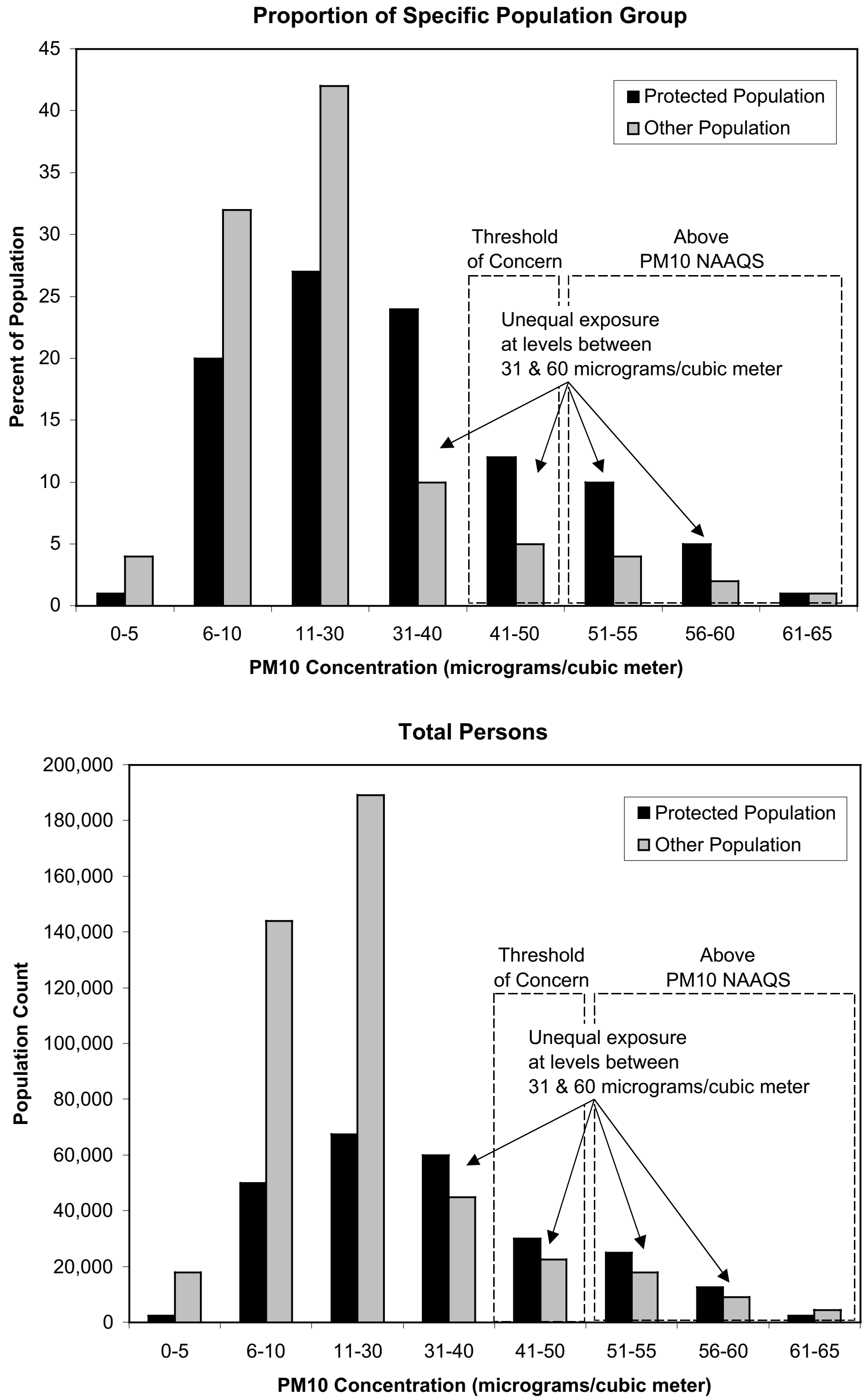

Figure 3-7. Distribution of annual average PM_{10} concentrations in a regional study area

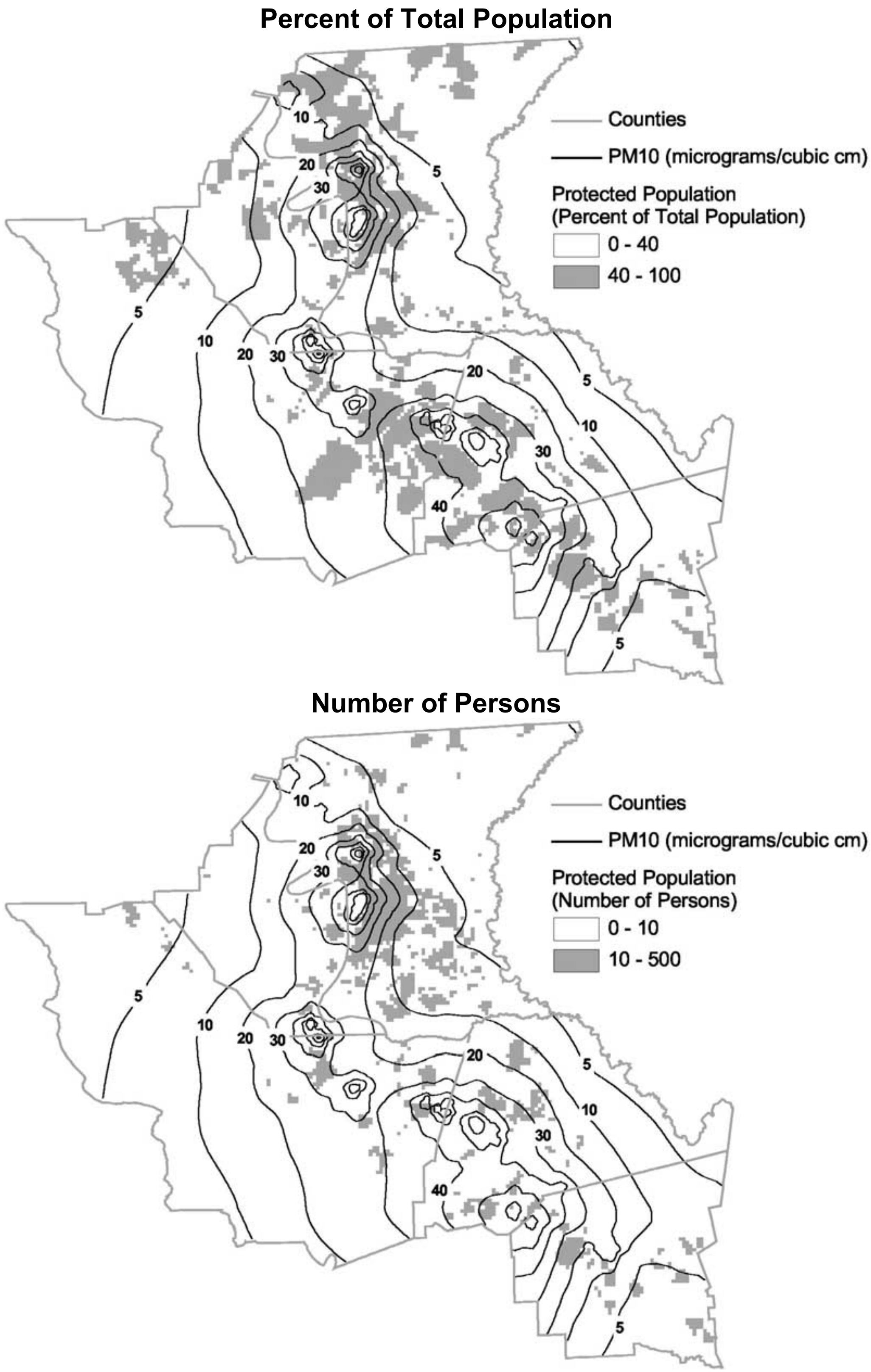

Figure 3-8. PM_{10} concentration and protected population patterns in a regional study area

By performing prebuild and postbuild modeling runs, this method also allows you to evaluate policy, program, and project impacts. With some change in current regulation, the geographic variability of pollutant concentrations that results from this method would also give transportation planners a much broader set of control measures to consider for achieving transportation conformity.

Local effects analysis. The pollution surface technique can be used to evaluate regionally significant projects and transportation corridors. However, for smaller projects with the potential only for localized effects, it is more appropriate to combine regional analysis of the pollution surface with microscale analysis (Method 2). Regional pollution surface analysis is useful to help understand whether the area of effects is in a location where pollutant concentrations are predicted to be relatively high. Microscale analysis can then be used to evaluate the localized effects of small projects.

To evaluate localized effects of regionally significant projects and transportation corridors, the project area of effects must be identified. Using the pollution surface technique, a reasonable approach is to apply a dispersion model to identify the area within which the project would have a measurable (or meaningful) effect on concentrations. This level would depend on the pollutant being evaluated as well as on the sensitivity of the model. For CO, the area potentially affected by the project would be highly localized, whereas for PM the area of effects could be far-reaching.

Figure 3-9 shows the distribution of predicted postimplementation annual average PM_{10} concentrations. The regional pollution surface described above was used to tabulate results within the project area of effects defined for two alternative alignments. Alternative 1 is depicted in the top two graphs and Alternative 2 in the bottom two graphs. For each alternative, percent of population is depicted in the left-hand chart, and population count in the right-hand chart.

A review of these graphs indicates that Alternative 1 may be preferable from an environmental justice perspective because there would be no unequal impact to protected population groups above 40 $\mu g/m^3$. In contrast, Alternative 2 would result in a greater proportion of protected population groups being exposed at these levels. Both the total number of persons and the total number of persons in protected population groups in areas with concentrations above 40 $\mu g/m^3$ would be similar under both alternatives.

The biggest drawback of the pollution surface approach is that it requires a great deal of time and effort to produce the necessary data. That is why, although limited in their predictive power, the previous three methods are likely to be used in all but the most controversial situations. Both statistical and model-based methods for estimating the regional and local variability in air quality are highly experimental. Unlike the micro-scale analysis and regional air quality assessment methods, this method has not yet been mandated, or even widely accepted, as part of the regulatory process.

The assessment of relative emissions burden is not the same as determining if people in the study area are exposed or if the level of exposure varies by person. To measure exposure, you must consider factors such as the amount of time persons spend outdoors and the ventilation properties of buildings. Tests to evaluate the statistical significance of the relative emissions burden statistic (*R*) are available, but their application is problematic. This is because in most situations the sample set, in this case grid cells, will be large and even slight differences in average emissions burden would be deemed significant. It is also uncertain whether you can assume that the sample population is normally distributed about the mean, which is a requirement of most parametric tests. Because of these concerns, it is better to merely evaluate the value of *R* to determine the direction of the difference in average burden levels.

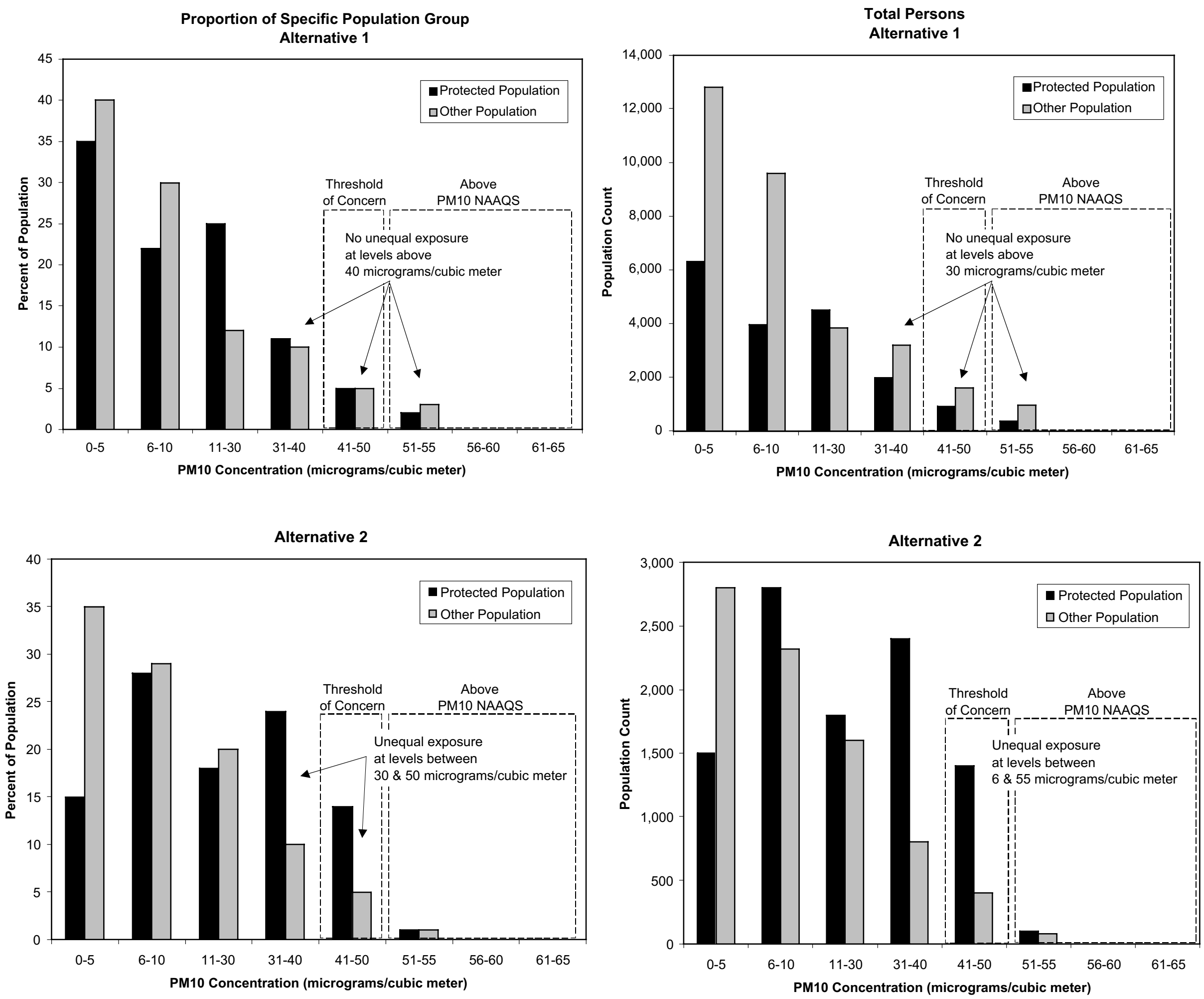

Figure 3-9. Comparison of alternative project alignments

Data needs, assumptions, and limitations of population surfaces are discussed in Chapter 2.

Results and their presentation. The graphics included in the discussion of Step 4, above, provide examples of results and how they may be presented. Depending on the audience, it may be necessary to simplify the presentation of the graphs and maps.

Data needs, assumptions, and limitations. Application of a dispersion model such as MEASURE would require the following data to be collected (Bachman et al. 2000):

- Spatial character information
  - —Land use boundaries
  - —Census blocks
  - —TAZs
  - —Roads
  - —Travel demand model network
  - —Output grid cells
- Temporal character information
  - —Hour of the day
- Vehicle technology information
  - —Model year
  - —Engine displacement
  - —Transmission type
  - —Fuel delivery technology
  - —Supplemental air injection system
  - —Catalyst configuration
  - —Exhaust gas recirculation
- Vehicle mode activity information
  - —Idle
  - —Cruise
  - —Acceleration
  - —Deceleration
  - —Starts
  - —Engine off
- Trip generation information
  - —Land use
  - —Housing units
  - —Socioeconomic characteristics
  - —Home-based work trips
  - —Home-based shopping trips
  - —Home-based school trips
  - —Home-based other trips
  - —Nonhome-based trips

Application of a regression model such as the one implemented in the SAVIAH project would generate the following data needs (Briggs et al. 1997):

- Road network
- Road type
- Distance-to-road
- Traffic volume
- Land use/land cover
- Topography
- Concentrations from monitoring sites
- Sample height
- Site exposure
- Topographical exposure

Assessment. Analysis of local and regional air quality using pollution surfaces and population surfaces is a very useful technique for evaluating distributive air quality effects to protected populations. Pollution surfaces can be developed using models that extend commonly used regulatory models to account for geographic variability in pollutant concentrations. Data visualization techniques using graphs and maps and findings based on expert opinion and public input generally are recommended over statistical tests that reduce the information-rich dataset to a single test for statistical significance. Although these methods are not widely used in current practice, considerable research has been performed. The drawback of this method is that it is extremely data intensive and has not yet received the level of regulatory approval that has been given to traditional microscale and regional air quality assessment methods. Given that techniques for understanding the geographic variability of air quality are important both for implementing more effective transportation control measures and for thoroughly evaluating environmental justice, it is expected that use of these techniques will increase in the future.

RESOURCES

1) Federal Highway Administration (FHWA). 2001. Transportation Conformity Reference Guide. Available at http://www.fhwa.dot.gov/environment/conformity/ref_guid.

   The transportation conformity reference guide provides a thorough review of the transportation conformity process. It includes information on NAAQS, approved models for evaluating transportation conformity, a discussion on how to perform a regional air quality analysis, and information on how to perform a microscale analysis.

2) U.S. Environmental Protection Agency (U.S. EPA). 2003b. *Toxics Release Inventory Program*. Available at http://www.epa.gov/tri/.

   This resource provides detailed information on the TRI program and discusses common uses of TRI reports. Detailed TRI data files are also available by state.

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CHAPTER 4. HAZARDOUS MATERIALS

OVERVIEW

The effects of hazardous materials exposure and transportation should be considered in nearly all aspects of transportation planning, construction, and operation. In the planning phase, environmental property assessments should be completed to identify properties potentially contaminated with hazardous materials. During construction, hazardous materials may be used in many aspects of the project, including equipment fueling, asphalt batching, and concrete mixing. Transportation operations involve use of hazardous materials in road maintenance and in various capacities at maintenance facilities. Also during transportation operations, system users and persons living or working near transportation facilities may be exposed to hazardous materials being transported across the system. In each case, regulations governing the identification, use, and disposal/recycling of hazardous materials are applied at the federal, state, and/or local level.

Environmental justice assessment for hazardous materials involves defining the pattern of known or potential contamination and then correlating that pattern with the underlying demographic pattern. Methods for assessing hazardous waste sites are well established. Several methods also are available for assessing hazardous materials transport issues, but in general integration of hazardous materials data with demographic data for environmental justice assessment is currently limited in the transportation field.

Hazardous materials considerations should be fully integrated within the environmental justice assessment process. Most state DOTs and metropolitan planning organizations (MPOs) collect enough data to assess environmental justice under existing federal, state, and local hazardous materials programs. The key to effectively integrating hazardous materials considerations into environmental justice assessment is to identify the existing hazardous materials data to be used and to integrate that data with demographic information to evaluate distributive effects to protected populations.

STATE OF THE PRACTICE

Management and transportation of hazardous materials is governed by environmental regulation and authority. Hazardous materials applications within the transportation industry include corridor and project assessments, transportation facility construction and operation, and transportation spills and releases.

Environmental regulation and authority

The U.S. Environmental Protection Agency (EPA) is the lead federal agency for protecting human health and safeguarding the natural environment—air, water, and land. Within the EPA, the Office of Solid Waste and Emergency Response (OSWER) oversees the implementation of most hazardous waste regulations. In response to Executive Order 12898 (President, Proclamation 1994), OSWER has had a policy on environmental justice since 1994 (U.S. EPA 1994).

Through its Brownfields Economic Redevelopment Initiative and other EPA cleanup programs, OSWER has directed that special efforts be taken for remedy selection purposes when identifying the future uses of land at sites where environmental justice concerns may exist. In August 2001, EPA Administrator Christine Todd Whitman expressed the Agency's commitment to environmental justice and its integration into all EPA programs to ensure that environmental justice is achieved for all communities and persons across the nation.

Most states have either been delegated authority or have joint authority with EPA for hazardous waste regulation. As a matter of regulation and practice, most DOTs and MPOs primarily work with state agencies on hazardous materials issues, although most state environmental justice programs are not as developed as EPA programs.

Application within the transportation industry

In the field of transportation, integration of hazardous materials data with demographic data for environmental justice assessment is limited. In general, the transportation industry's response to environmental justice is driven by the National Environmental Policy Act (NEPA). Although assessment of hazardous waste and hazardous material sites is a component of NEPA, it is not a primary focus of the NEPA documentation process. For this reason, hazardous waste issues often are not addressed within the environmental justice assessment process.

To address hazardous materials within the context of environmental justice, the following discussion is divided into three segments common to the transportation field:

- Corridor and project assessments,
- Construction and operation of transportation corridors and facilities, and
- Transportation spills and releases.

For each of these segments, we summarize current standard practices along with hazardous materials information currently collected by the transportation industry. While it is not an exhaustive list, the intent is to communicate the overall volume of data already being collected by DOTs and MPOs under current hazardous materials programs. From this information, we can identify the readily available hazardous materials information that can be used to perform environmental justice assessment.

Corridor and project assessments

Before beginning a transportation construction project, the current practice is to evaluate the transportation corridor for the existence of contaminated sites. Historically, this evaluation has been conducted to address potential impacts to corridor construction costs, schedule, routing, potential construction worker exposure, and associated environmental liability. The initial evaluation typically is a Phase 1 Environmental Site Assessment (referred to as a Phase 1 ESA or a Phase 1 Assessment) conducted in accordance with the American Society for Testing Methods (ASTM) guidelines for environmental due diligence (ASTM 2003). The Phase 1 ESA may be undertaken as a portion of the NEPA environmental review, in preparation for property acquisition, or before construction takes place within a right-of-way.

The Phase 1 ESA has become a common tool for assessing the potential environmental liability associated with the acquisition of a property. The federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), otherwise known as "Superfund," established "joint and several" liability for purchasers of contaminated property. Through this liability, a buyer of contaminated property may be held responsible for cleanup costs even though the buyer did not contaminate the property. The intent of the Phase 1 ESA is to satisfy one of the requirements to qualify for the "innocent landowner defense" to CERCLA liability, making "all appropriate inquiry into the previous ownership and use of the property consistent with good commercial or customary practice" (ASTM 2003).

For purposes of environmental justice assessment, the Phase 1 ESA provides information for evaluating the potential effects of hazardous materials sites to protected populations.

The Phase 1 ESA typically consists of the following:

- Site/corridor reconnaissance,
- Environmental records and regulatory database review, and
- Interviews with persons knowledgeable about property history and use.

During the Phase 1 ESA, environmental regulatory databases are searched for known hazardous materials sites within some defined distance from the right-of-way or construction site. Table 4-1 is an excerpt from a hazardous materials database search. The report describes the types of facilities found and their name, map location, and address. Figure 4-1 is an example of a Phase 1 ESA hazardous waste site locator map. The map was developed in LandView™ III, showing CERCLA sites, hazardous waste facilities, and Toxic Release Inventory (TRI) facilities (U.S. EPA 2003). Note that LandView ™ 5 soon will replace LandView™ III.

Information collected during a Phase 1 ESA can be categorized as:

- Sites with reported environmental releases and spills,
- Sites with permits to use and temporarily store hazardous materials/wastes,
- Sites with permits to treat, store, and dispose of hazardous materials/waste,
- Sites with permits to operate underground storage tanks and aboveground storage tanks, and
- Sites with permits to dispose/landfill solid waste (landfills).

Using the information collected in the Phase 1 ESA, the DOT or MPO may choose to pursue additional soil investigations, groundwater investigations, or both. These investigations typically are undertaken if a site within a corridor is judged to have "recognized environmental conditions." Recognized environmental conditions include, but are not limited to, underground storage tanks (USTs); above-ground storage tanks (ASTs); reports of previous hazardous materials releases; and suspected dumps, landfills, or prior or current land use consistent with sites typically associated with hazardous materials releases. Such sites would include dry cleaning operations, salvage yards, and railroad roundhouses, for example.

Table 4-1. Example excerpt of hazardous materials database search

CERC-NFRAP Search Results
1 CERC-NFRAP site within the searched area.

Page Map ID Address Site _____ _____ ________ ________
38 14 3605 HWY 52N IBM INTL BUS MCHS CORP

CORRACTS Search Results
CORRACTS: CORRACTS is a list of handlers with RCRA Corrective Action Activity. This report shows which nationally defined corrective action core events have occurred for every handler that has had corrective action activity.
A review of the CORRACTS list, as provided by EDR, and dated 05/02/2002 has revealed that there is 1 CORRACTS site within the searched area.

Page Map ID Address Site _____ _____ ________ ________
38 14 3605 HWY 52N IBM INTL BUS MCHS CORP

RCRIS Search Results
RCRIS: The Resource Conservation and Recovery Act database includes selected information on sites that generate, store, treat, or dispose of hazardous waste as defined by the Act. The source of this database is the U.S. EPA.

A review of the RCRIS-TSD list, as provided by EDR, and dated 09/09/2002 has revealed that there is 1RCRIS-TSD site within the searched area.

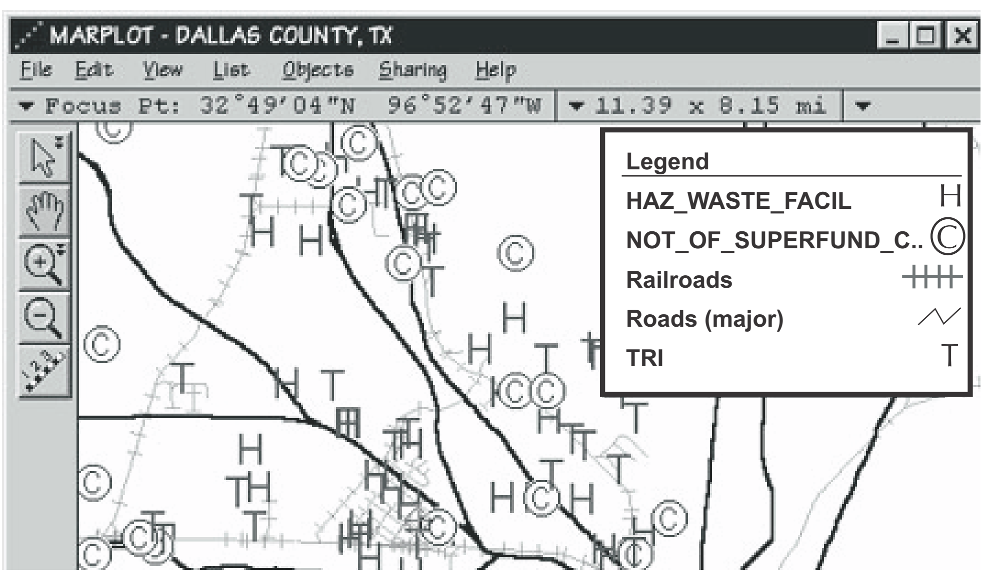

Figure 4-1. Phase 1 ESA hazardous waste site locator map
Source: EPA 1998

Standards for soil and groundwater investigations typically are based on state environmental protection agency guidelines. Results of the soil and groundwater investigation are reviewed with respect to EPA and state regulatory agency standards for environmental contamination and cleanup.

If a site within or adjacent to the transportation facility's right-of-way displays evidence of contamination above regulatory limits, the DOT or MPO may pursue a number of cleanup options. These options include, but are not limited to, negotiating with the environmental agency to perform the cleanup of the site before acquisition or construction; negotiating with private property owner(s) for site cleanup as a condition of property transfer; or realigning the transportation corridor or segment.

In practice, most transportation project cleanups address soil contamination. In general, remediation consists of contaminated soil removal and is typically associated with petroleum contamination. However, for larger corridor realignments or construction involving dewatering, more complex groundwater remediation may be warranted.

Current trends in environmental remediation include establishing risk-based cleanup criteria that allow for managing hazardous waste "in place," and establishing institutional controls (such as deed restrictions). The EPA and most state environmental protection agencies have established specific risk-based cleanup programs for soil and groundwater affected by hazardous waste. In general, the criteria for risk-based cleanups address the following points:

- Intended property use (such as industrial versus residential);
- Potential effects to human "receptors" via ingestion, inhalation, and dermal contact; and
- Potential effects to ecological "receptors."

Opportunities for offsetting environmental justice *benefits* as a result of environmental remediation may be a future area of consideration. As an example, the realignment of a road may require that in-place contaminated soil be removed. An environmental justice benefit could result if the road is within a protected population area and the removal of contaminated soil mitigated potential contaminant exposure to the nearby population. In essence, transportation projects can be a catalyst for environmental remediation that may not have otherwise occurred.

Data collected during Phase 1 ESAs have the greatest potential for use in hazardous materials environmental justice planning. In particular, environmental database information from federal and state environmental regulatory authorities can be used to assess locations of known environmental contamination sites, large quantity hazardous waste generators, and disposal facilities. These data can then be cross-referenced to demographic information. Assessing environmental justice with respect to hazardous materials should include activities such as corridor realignment as a function of environmental contamination, environmental exposure as a function of site remediation, and positive mitigation and offsetting benefits as a result of site cleanups.

Construction and operation

Construction and operation of transportation facilities, including roads, highways, bridges, railways, and maintenance facilities, inherently involves the use of hazardous materials and also generates some level of hazardous waste. Use and control of hazardous materials is regulated by various federal regulations including the Resource Conservation and Recovery Act (RCRA) Toxic Substances Control Act (TSCA), and the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA).

Standard practice for state DOTs and MPOs is to maintain regulatory compliance for construction materials and waste. In maintaining compliance, these agencies apply for and maintain environmental permits, including hazardous materials permits, waste manifests for disposal, and spill prevention plans. Hazardous materials permit information is kept by individual DOTs and MPOs and typically is available from federal, state, and local environmental agency regulatory databases. Like the Phase 1 ESA process, this information may be easily accessed for review and integration into environmental justice assessment.

Environmental justice assessment should include a review of the use and control of hazardous materials during project construction; siting and establishing construction and demolition debris landfills; siting and establishing DOT or MPO transportation facilities (e.g., maintenance facility); and, potentially, construction staging areas.

Transportation spills and releases

Accidental spills and releases of hazardous materials are relatively commonplace within transportation corridors. Federal and state DOTs, in concert with the EPA and state environmental protection agencies, regulate transportation of hazardous and radioactive materials. In addition, emergency response guidelines for mitigation and cleanup are regulated at the federal and state levels.

Large amounts of accidental release data are available from federal, state, and local agencies. The Emergency Response and Notification System (ERNS) is the primary national database used to report and track hazardous materials spills. This information can be used to determine if past accidental release patterns may disproportionately affect protected populations. For an example of this type of analysis, see Margai (2001), which contains an analysis of the impact zones of spills in two New York counties over a 10-year period using information from ERNS. However, use of predictive modeling for hazardous materials releases is not currently well defined or used in environmental justice assessments within the transportation field.

A number of models for predicting impacts as a result of hazardous materials releases are available within the public domain. These models tend to address airborne impacts but also address impacts via liquid/solid materials and radioactive materials. For example, Chakraborty and Armstrong (1995) developed a method using the Areal Location of Hazardous Atmospheres (ALOHA) model, combined with demographic information in geographic information systems (GIS) to assess the demographic characteristics of populations most likely to be exposed to hazardous materials transport accidents in the Des Moines, IA, area. Erkut and Verter (1998) provide and summarize the most commonly used hazardous materials transport models. Zhang et al. (2000) apply hazardous materials routing that considers risks to populations from airborne contaminants. Mills and Neuhauser (2000) developed an assessment method to evaluate the distributive and disproportionate effects of accidents involving radioactive materials using the probabilistic risk RADTRAN model developed by Sandia National Laboratories. The U.S. Department of Energy (DOE) has developed a useful handbook related to assessing the risks associated with routing of radioactive waste shipments (DOE 2002).

Applying an environmental justice assessment of potential spills and releases may be the most challenging hazardous materials issue. However, this subject may also be the most quantifiable in terms of developing standardized models. A heightened public awareness and scrutiny of hazardous and radioactive materials transport has resulted from the potential completion of the Yucca Mountain National Nuclear Repository in Nevada. This repository would result in a large volume of high-level radioactive waste being transported throughout the United States. Environmental justice assessment of hazardous materials transport would include assessment of disproportionate impacts to target populations as a result of selected alignments and transportation facility locations. Practical development and application of standardized models is recommended.

SELECTING AN APPROPRIATE METHOD OF ANALYSIS

The challenge before practitioners is to better integrate hazardous materials information within the context of transportation environmental justice decision making. Traditional hazardous materials practice in the transportation field has focused on site-specific information within a corridor rather than on corridor-wide information. Layering of hazardous material data with demographic information for applications to transportation environmental justice is a relatively new and nonstandardized approach.

Desktop tools and methodologies. As previously mentioned, the information gathered during the Phase 1 ESA may have the greatest potential for use in hazardous materials environmental justice planning and evaluation. DOTs and MPOs regularly complete this form of assessment for projects that involve property acquisition or construction. As such, the data required to conduct the hazardous materials environmental justice assessment generally are readily available. In addition, public domain databases, such as the EPA's LandView™ III, can be accessed to provide standardized Phase 1 ESA data and certain demographic information like that shown in Figure 4-2. It is important to note that LandView™ III is based on 1990 Census data. The soon-to-be-released LandView™ 5 will use 2000 Census data.

Computer models. A number of computer models suitable for assessing distributive hazardous materials effects have been developed. These models can be generally categorized as follows:

- Models that assess current known or suspected hazardous materials environmental impacts.
- Models that assess potential environmental impacts as a function of potential environmental releases.

Use of these models provides the basis for developing a more standardized "quantitative" approach to environmental justice assessment of hazardous materials concerns in the transportation field. Practically speaking, these models (or adaptations of them) would generally be used for larger and more complex transportation projects.

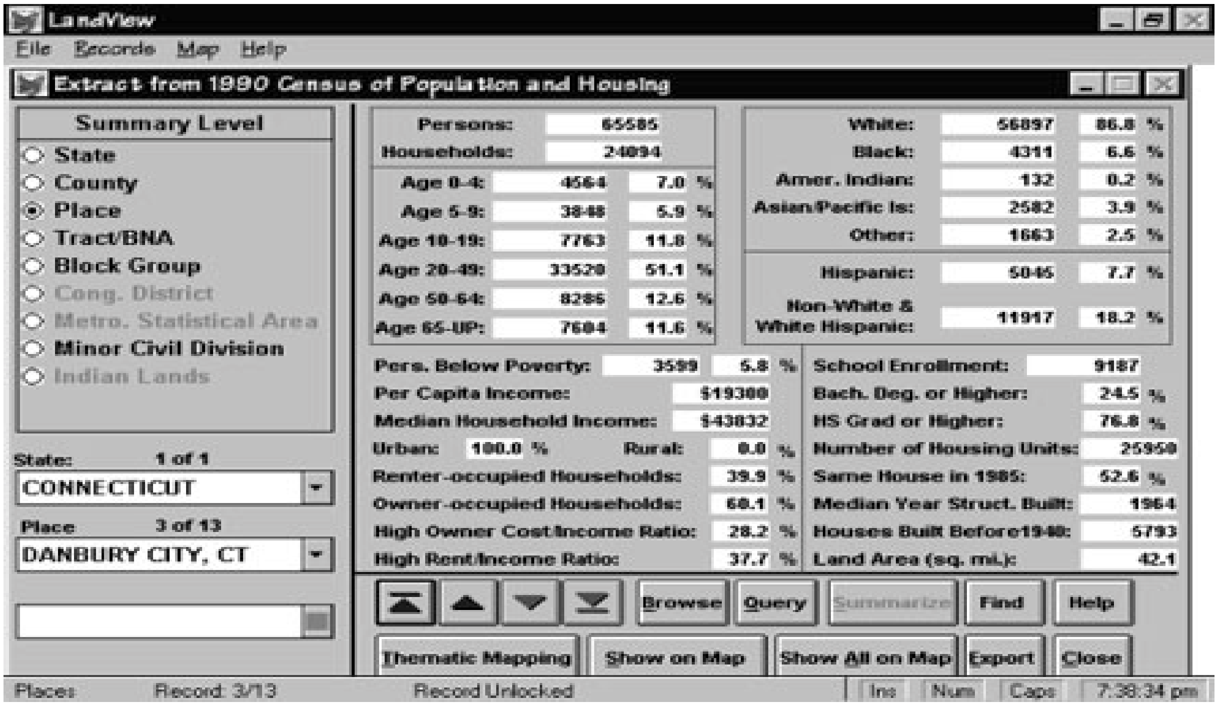

Figure 4-2. Census data from LandView III

Source: EPA 1998.

METHODS

Environmental justice assessment of transportation-related hazardous materials effects should use methods that match the overall complexity of the project or program being evaluated. Using a "tiered" process, the assessment should be initiated using practical desktop review methods and elevated to more complex analysis and computer modeling only as dictated by project requirements. By using a tiered assessment process, you can develop an efficient approach to environmental justice assessments within your agency's objectives and resource limitations.

The following methods provide examples of how hazardous material data can effectively be used to perform environmental justice assessment. The techniques presented here may be adapted or modified to meet specific project or program needs.

Table 4-2 provides a summary of four methods for evaluating environmental justice with respect to hazardous materials.

Method 1. Phase 1 desktop assessment

When to use. This approach can be used as the initial environmental justice review to evaluate distributive effects of potential hazardous materials exposure in most project or corridor studies. The examples provided below are for performing the evaluation as part of a Phase I ESA. Desktop assessment is also well suited to assessing the distribution of hazardous materials sites with respect to demographic patterns during all phases of transportation planning. Additionally, it is appropriate for evaluating environmental justice concerns related to construction staging areas, transportation maintenance facilities, transportation projects where physical property will be acquired or altered, and patterns of known hazardous materials spills.

Table 4-2. Summary of methods for analysis of hazardous materials effects

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. Phase 1 desktop assessment	Screening	Initial assessment of the presence of hazardous waste sites	During evaluation of proposed construction corridors	Low	Simple data analysis
2. Phase 1 computer-based assessment	Screening	Second-tier assessment of the presence of hazardous waste sites	When desktop assessment indicates possible problem areas	Medium	Geographic information systems (GIS), Statistical analysis
3. Hazardous materials transport screening study	Screening	Initial assessment of transport routes for hazardous materials	During evaluation of proposed construction corridors	Low	Simple data analysis
4. Hazardous materials transport—probability modeling	Detailed	Risk modeling of hazardous materials exposure or release	Screening methods indicate a significant potential for exposure to hazardous materials Cost of mitigation or remediation is high	Medium/ high	Fault-tree and other risk analysis methods, GIS

Analysis. The approach combines Phase I ESA database and map review with desktop demographic review. It involves evaluating the presence of both hazardous materials sites and protected populations in the study area. When the two are present in the same area, there is the potential for environmental justice concern and the need to perform further review. Used in this manner, the approach serves as a useful screening technique so that the resources to perform more in-depth analysis can be targeted to the areas where they are needed.

Step 1 - Conduct environmental assessment. Review national, state, and local databases to identify locations where hazardous materials and waste are likely to be produced, stored, or used. The results of a Phase I ESA presented in map form are ideal for this purpose. The Phase I ESA process is discussed above, and a list of useful databases is provided in the resources section of this chapter.

Step 2 – Perform demographic review. Collect information on the presence of protected populations using any number of the techniques described in Chapter 2. Especially useful techniques include use of local knowledge, threshold analysis using block and block-group-level census data, field survey, and the Environmental Justice Index (EJI). Whatever technique or combination of techniques is applied, the intent is to identify locations in the activity space of protected population groups.

Step 3 – Tabulate results. Results of the environmental and demographic reviews can be compiled in numerous ways. Probably the simplest approach is to mark up a Phase I ESA map to show minority or low-income neighborhoods and work places and activity centers that are predominantly used by members of protected population groups. Then it is relatively straightforward to list the sites where further environmental justice review, such as a thorough field survey, should be performed.

Data needs, assumptions, and limitations. The environmental review should include the following information sources:

- EPA National Priorities List (Superfund) sites,
- Sites on the state Priority List,
- Leaking underground storage tanks (LUST),
- Solid waste landfills, incinerators, and transfer stations,
- Registered underground storage tanks (UST),
- Sites with previous hazardous materials spills, and
- Sites that generate hazardous waste.

The demographic review should be based on readily available information according to the method used to identify the protected population. More information on data sources is provided in Chapter 2.

The desktop assessment technique is limited to identifying hazardous materials sites near areas used by protected populations. A more thorough review should be performed in situations where such locations are identified. This semi-quantitative approach does not use statistical analysis. Application of this technique alone is not recommended for controversial projects where more thorough analysis would be required. The technique is not useful in situations where hazardous materials transport and release should be evaluated.

Results and their presentation. The best form of presentation is maps showing hazardous materials sites, small-area demographic data, neighborhoods, and sites of interest to protected populations. Figure 4-3 provides an example.

Assessment. For most project and corridor environmental justice assessments, this is the logical hazardous materials screening evaluation to perform. In many cases, further study will not be necessary. In cases where there is a need for further analysis, consider using GIS to perform the environmental and demographic reviews as this would make it easier to use the results in further studies. This method can also be used as a way to evaluate benefits to protected populations by identifying areas where environmental cleanup activities are planned.

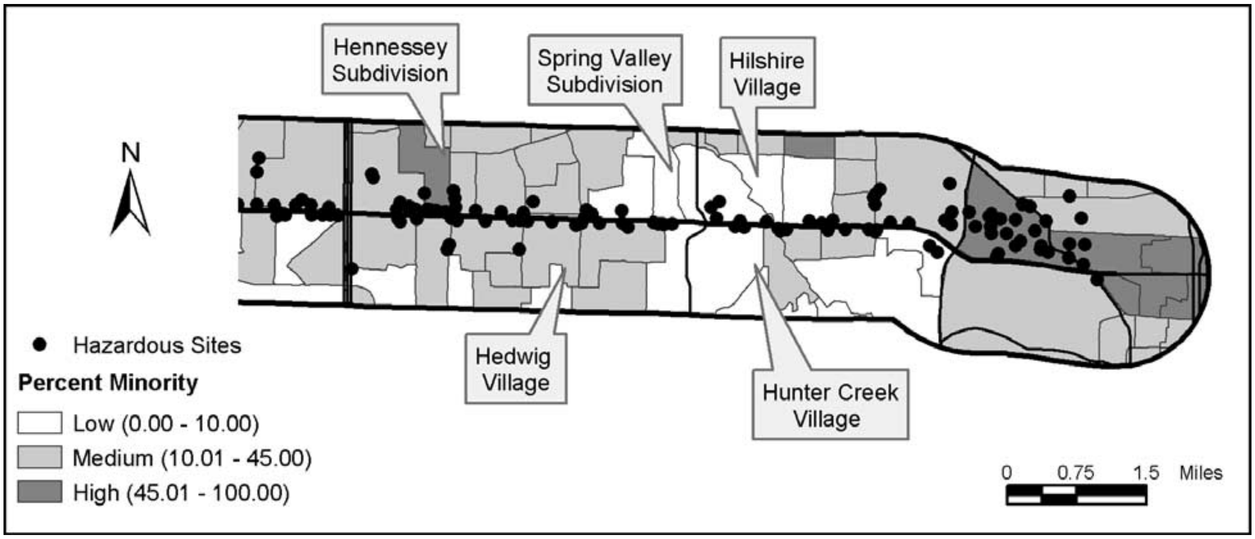

Figure 4-3. Results of a Phase I desktop assessment

Method 2. Phase 1 computer-based assessment

When to use. This approach is a modification of the Phase I desktop assessment that uses GIS and includes a statistical test. Consider using this technique when projects are controversial or large or if the desktop assessment indicates the potential for environmental justice concern. This approach, although somewhat data intensive, is also suitable for reviewing regional or even statewide hazardous materials programs.

Analysis. Steps 1 and 2 are the same as those in Method 1, Phase 1 desktop assessment, although the information should be stored electronically in GIS.

Step 3 – Statistical test. Various statistical tests are available to determine if hazardous material sites are located predominantly in protected population areas. The specific test that should be applied depends in large part on the amount of data being evaluated and on the experience and qualifications of the person performing the analysis. Often it is appropriate to use simple techniques that are easily performed manually or with the aid of spreadsheet software.

The following example illustrates the application of a chi-square test for independence. This test can be used to determine if hazardous material sites in the study area occur more frequently in areas with protected populations than would be expected if they were randomly distributed.

To perform the chi-square test, first divide the study area into sub-areas. In general, it is best to use a high level of resolution, because the chi-square test is more robust with larger numbers of observations. For a typical transportation project, an analysis based on census block or block-group subareas provides adequate resolution. Once you have determined the subareas, characterize each in terms of their relative density of protected population using one of the techniques described in Chapter 2. Using the EJI, for example, you could define subareas of higher environmental justice concern as census block groups with an EJI greater than 40 (or another value that is appropriate for the study area in question).

Next, characterize each subarea in terms of presence or density of hazardous materials, based on the Phase 1 ESA. The characterization could be based on, for example, the number of hazardous materials sites within 1 mile of the subarea. If subareas vary greatly in size, it may be necessary to convert the score to an area-weighted measure, such as the number of hazardous facilities per square mile. Convert the quantitative risk estimates to a two- or three-point scale (e.g., high, medium, and low availability). Table 4-3 is an example of results of a hypothetical analysis.

Table 4-3.
Example analysis results

Sub-area	EJI		Risk of exposure		
	> 40	≤ 40	Low	Medium	High
1	✓			✓	
2		✓		✓	
3		✓	✓		
4	✓				✓
5		✓	✓		
6		✓	✓		
7	✓				✓
8	✓		✓		
9	✓				✓
10		✓		✓	
11	✓			✓	
12	✓				✓
13		✓	✓		
14		✓		✓	
15	✓				✓

Table 4-4 shows the same data cast into a 2 by 3 contingency table. The values in italics are the expected frequencies for each cell if the EJI did not vary with the presence of hazardous materials. The chi-square test compares the actual distribution of values within the table with the expected frequencies and determines the probability that the discrepancies between the two could have occurred from sampling error alone (in other words, that there is not a statistically significant difference between the two distributions).

Simply reading the table, it appears from visual inspection of this table that the environmental impacts of this hypothetical project are not equally distributed. Only 20 percent of the sub-areas with low hazardous materials availability have EJI ratings greater than 40, whereas 100 percent of the sub-areas with high hazardous materials availability have EJI ratings greater than 40. This is only an impression, however, which can be confirmed (or not) using the chi-square test. This test can be conducted using virtually any standard statistical software package.

Table 4-4.
Contingency table for example data

		Hazardous materials presence			
		Low	**Medium**	**High**	**Total**
EJI	**> 40**	1 *2.67*	2 *2.67*	5 *2.67*	8
	≤ 40	4 *2.33*	3 *2.33*	0 *2.33*	7
	Total	5	5	5	15

Note: Expected values for the chi-square computation are in italic.

In this example, the computed value of chi-square (X^2) is 6.97. The statistical significance of the value of X^2 is determined by a table look-up (e.g., Siegal and Castellan 1988, Table C), with 2 degrees of freedom (*df*). (Statistical software programs provide this information.) The degrees of freedom are based on the number of rows and columns in the contingency table:

$$df = (\# \text{ of rows} - 1) \times (\# \text{ of columns} - 1) = 1 \times 2 = 2$$

In this example, the value of X^2 (6.97, $df = 2$) is significant at the 5 percent error level. That is, there is a 5 percent or less probability that the observed discrepancy between observed and expected frequencies would occur by chance alone. Thus, the subjective impression that the availability of hazardous materials is not equitably distributed between protected and non-protected populations is confirmed statistically.

Data needs, assumptions, and limitations. The following data are required for the calculation of X^2:

- Phase 1 Environmental Assessment results by census blocks or block groups and
- Demographic data detailing the density of protected and nonprotected populations in each census block or block group.

When the expected frequencies are very small, the X^2 test should not be used. Siegal and Castellan (1988) list several criteria that should be met, including the following:

- When the degrees of freedom is 1 (i.e., rows = 2 and columns = 2) and the total number of observations (census blocks, in the example given) is less than or equal to 20, X^2 should not be used. In these cases, the Fisher exact test may be used.

- When the degrees of freedom are greater than 1, the X^2 test should not be used if more than 20 percent of the cells have an expected frequency of less than 5 or if any cell has an expected frequency of less than 1. (Note that the example given does not meet this criterion. It has been simplified for purposes of description.)

The chi-square test is widely used and has the benefit of simplicity. However, it is limited in that it does not take into account order effects. In the example presented, the value of the chi-square statistic would be the same regardless of the order in which the columns (or rows) of the contingency table were placed. This means information is available that is not used in the analysis. Siegal and Castellan (1988) describe several nonparametric statistical tests for two independent samples that make use of order information, although they are computationally more complicated than the chi-square test. These tests (e.g., Wilcoxon-Mann-Whitney test, Rank Order test, and Kolmogorov-Smirnov Two Sample test) are more powerful than the chi-square test for ordinal-scale data. That is, they are more likely to indicate whether a statistically significant effect is present than is the chi-square test when applied to the same data.

Results and their presentation. Use maps or a GIS to plot hazardous materials and socio-demographic overlay information. The value of chi-square, degrees of freedom, and the level of significance should be presented along with the contingency table. Text should be provided documenting the methodology used, data collected, assumptions made, and interpretations derived.

Assessment. This method makes use of quantitative data similar to that gathered in Method 1 for the desktop assessment of hazardous materials distribution. It has the benefit of using an inferential statistic to validate or reject any subjective impressions that may have arisen from the desktop assessment. The proposed statistic, chi-square, is easy to use and to interpret, although it may not be as powerful as alternative, more complicated statistical tests that make use of order information in the data.

Method 3. Hazardous materials transport screening study

When to use. Assessing environmental justice aspects of accidental hazardous materials releases in transportation corridors is based on the risk to protected populations compared to that of the rest of the population. In this context, the term *risk* implies a combination of two factors—the *probability* of an accidental release and the *impact* of the release on the populations. This method and Method 4 are suitable for assessing risk of exposure to accidental releases of hazardous materials in transportation corridors.

This screening method is used to obtain a rough estimate of the possible risk of a hazardous materials release in different segments along a route or set of routes and to determine whether the risk is disproportionate in areas with protected populations. Use this method as a screening step to determine whether a more detailed risk assessment needs to be done (Method 4, below).

Transport screening studies rely on existing sources of information to determine the following:

- Routes in the study area that are available for hazardous materials transport,

- Sources and destinations of hazardous materials transport in the study area, and
- Distribution of protected and nonprotected populations in close proximity to the routes under study.

This method does not include a detailed analysis of the probability that an accidental release might occur. However, if results indicate that protected populations would be more likely to be impacted *if* a release were to occur, a more detailed analysis of exposure risks should be conducted. By the same token, if a preliminary study indicates that there is not a distributive effect, the more detailed and costly risk analysis method is probably unnecessary.

Analysis. To apply this method, you must first make a rough determination of the likely routes for hazardous materials transport within the study area. The second step is to determine the number of people protected and nonprotected populations living near enough to the roadway to suffer the consequences of a spill. The third and final step is to apply a statistical test to determine whether the protected populations would be disproportionately impacted if a spill were to occur.

Step 1 – Identify hazardous materials routes. The objective of this step is to identify roadways on which there is reason to expect that hazardous materials will be transported. Review national, state, and local databases to identify locations where hazardous materials and waste are likely to be produced, stored, or used. The results of a Phase I ESA, presented in map form or a similar presentation, are ideal for this purpose. The Phase I assessment process is discussed above, and a list of useful databases is provided in the resources section of this chapter. Use these data to identify possible sources and destinations of hazardous materials.

Next, contact the national, state, and local agencies that issue permits for hazardous material transport. Use the information previously gathered regarding sites where hazardous materials are produced, stored, or used to identify transport permit holders. In some states (e.g., Georgia), holders of hazardous materials transport permits are required to file annual reports detailing the type and amount of hazardous materials transported and the origins and destinations of transport. If available, this information can help to determine the routes of hazardous material transport within the study area.

In some areas (states, counties, or cities), the transport of hazardous materials is restricted by statute to certain routes. For example, routing information for the state of Texas may be found online (TXDOT 2003). If this information is available, it should be analyzed to determine whether the designation of preferred, prohibited, or alternate routes impacts the transport of hazardous materials in the project area.

For the purposes of this method, a hazardous materials transport route is any section of roadway that is designated by state or local statute to be a hazardous materials route or that is a preferred route to or from a location identified as the destination or source of hazardous materials. GIS-based routing analysis can be used to identify preferred routes if that information is not directly available from other sources.

Step 2 – Perform demographic review. Mills and Neuhauser (2000) describe a method for determining the density of protected and nonprotected populations living in proximity to a roadway—in this case, a roadway used for transport of hazardous materials. Their method consists of analyzing census data for the blocks in proximity to the roadway. This is straightforward, except for the issue of how to define "proximity."

The Argonne National Laboratory conducted a study (Brown et al. 2000) to determine the Initial Isolation Zone (IIZ) and Protective Action Distance (PAD) for accidental releases of various classes of chemicals that are toxic by inhalation (TIH) or that produce TIH gases when they react with water (TIHWR). They define the IIZ as the radius of a zone around a release from which all people not directly involved in emergency response are to be kept away. The PAD is the downwind distance from a release that defines a zone in which persons should be either evacuated or sheltered-in-place.

The authors computed the IIZ and PAD for small and large spills of various materials. IIZs and PADs are given for both daytime and nighttime spills. Nighttime IIZs and PADs are greater than daytime values. It may be reasoned that the IIZ represents the zone of immediate and significant impact. The largest IIZ for any of the materials in this study was 3,000 feet (e.g., the nighttime IIZ for a spill of over 55 gallons of liquefied toxic gas). Thus, for the purpose of this analysis, the figure of 3,000 feet can be used as a conservative definition of proximity to a release.

If the nature of the hazardous materials being transported in the study area is known or if it is known that only small quantities (55 gallons or less) of the most dangerous materials will be transported within the area, it may be appropriate to use a smaller value than 3,000 feet, based on the worst case IIZ for the known conditions. Indeed, the definition of proximity may differ from one section of the roadway to another, depending on local conditions.

For example, if you determine in Step 1 that a plant producing anhydrous ammonia is located on a road segment that is not designated as a hazardous material route, it may be assumed that anhydrous ammonia is the only hazardous material likely to be shipped on that road segment. In this case, it would be appropriate to use the worst case IIZ for anhydrous ammonia (200 feet) as the definition of proximity for the purpose of this analysis. Once proximities have been defined, you can use buffer techniques in GIS and perform small-area interpolation as described in Chapter 2 to characterize the demographics of the population in the proximate zone or zones.

Step 3 – Analyze the findings. In Step 1, roadways on which hazardous materials may be transported are identified. In Step 2, a buffer zone around the roadways is defined and the census data for the blocks or block groups falling within the buffer zone or zones is compiled. To analyze these findings, compare the protected population proportions and the nonprotected population proportions for the proximate zone or zones.

For example, if the study area has a total of 10,000 low-income persons (or members of any protected population group) and through small-area interpolation it is estimated that 2,000 live in a zone near hazardous materials transport routes, then an estimated 20 percent of the protected population lives in the proximate zone. This calculation is then repeated for the nonprotected population.

If the proportion of the total study area protected population living in proximate zones is greater than the total study area non-protected population living in those zones, the protected population group *may* be differentially affected by hazardous materials spills *if* they are expected to occur randomly along hazardous material route segments.

Step 4 – Optional statistical test. A discrepancy is defined as a difference in the proportion of the protected population and the proportion of nonprotected population in proximity. A statistically significant difference exists if the observed difference could not be explained by chance alone. If a discrepancy is observed that is very unlikely to occur under random and independent assignment, then the discrepancy is statistically significant.

Note that a significant discrepancy is a necessary but not sufficient condition to show a disparate impact. It is insufficient because the statistically significant result could be due to the fact that the premise of random and independent assignment of individuals to locations is not appropriate. Nonetheless, this kind of evaluation serves as a useful starting point for evaluating a potential disparate impact.

To compute the test statistic, you must calculate the proportion of the total protected population that is in proximity (this is defined as *p1*) and the proportion of the total nonprotected population that is in proximity (this is defined as *p2*). If *p1* and *p2* are different from one another, this is evidence of a discrepancy.

The test statistic is figured as the difference *p1 - p2* divided by the standard error of the difference, where the standard error is computed under the assumption that the two true proportions, *p1* and *p2*, are equal. Under this assumption, the expected value of *p1 - p2* is zero. The standard error is interpreted as the amount by which the observed difference *p1 - p2* might differ from zero just due to chance variability. Thus, taking the observed difference relative to the standard error indicates whether the observed difference is "far" away from zero. A general rule of thumb is that if the ratio *p1-p2* divided by the standard error is greater than 2 or 3, then one can conclude that *p1* is statistically significantly greater than zero. The formula for the test statistic (*P*) is thus:

$$P = \frac{(p1 - p2)}{\left(\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}\right)}$$

where

$p1$ = the proportion of the total protected population that is in proximity

$p2$ = the proportion of the total nonprotected population that is in proximity

$\hat{p}$ = the overall proportion of the *total* population that is in proximity

n_1 = the total number of individuals in the protected population group in the population

n_2 = the total number of individuals in the nonprotected population group in the population (see for example Bain and Engelhardt 1989)

The confidence interval for the ratio *p1/p2* is computed as:

$$\exp\left(\log\left(\frac{p_1}{p_2}\right) \pm 1.96\left[\left(n_{11}+\tfrac{1}{2}\right)^{-1}+\left(n_1+\tfrac{1}{2}\right)^{-1}+\left(n_{21}+\tfrac{1}{2}\right)^{-1}+\left(n_2+\tfrac{1}{2}\right)^{-1}\right]\right)$$

where

n_1 = the total number of protected persons in the population[1]

n_2 = the total number of nonprotected persons in the population

n_{11} = the number of protected persons in the population in proximity

n_{21} = the number of nonprotected persons in proximity
(see, for example, Agresti 1990)

Data needs, assumptions, and limitations. This method relies on the availability of information about which roadways are designated by state or local statute as hazardous materials transport routes. If no such statutes are in place, you must assume that all roadways in the study area are available for hazardous material transport. Additional information from the Phase 1 ESA may also be used to designate roadways as hazardous materials transport routes by virtue of being preferred access or egress routes for facilities that produce or use hazardous materials. Because no hard information is used regarding the type or volume of hazardous materials actually transported, the method relies on very conservative assumptions about what materials are being transported on what roadways.

Results and their presentation. Considering the preliminary nature of this method, elaborate statistical tests are not required, although one has been included to aid in interpreting results. The objective of the method is merely to give an impression of whether the proximate buffer zone has a higher proportion of members of protected populations compared to the proportion of members of nonprotected populations.

To quantify the possible distributive effect, simply compute the ratio ($p1/p2$) of the protected population proportion living in the proximate zone ($p1$) to the nonprotected population proportion living in the proximate zone ($p2$). A ratio greater than 1.0 indicates that there is a possible disproportionate pattern.

Assessment. This is a semi-quantitative screening method to assess the impact of hazardous materials transport within the environmental justice framework. It only crudely quantifies the probability of a transport-related release by attempting to determine what routes are used for hazardous material transport. It relies on worst-case assumptions about the volume, time, and composition of possible spills. Within those limitations, however, it can provide a high-level determination as to whether there is an environmental justice issue that needs further, more careful analysis.

Method 4. Hazardous materials transport—probability modeling

When to use. This method is used to analyze the risk to protected and nonprotected populations associated with accidental release of hazardous materials in transit. Unlike Method 3, this

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[1] Protected persons are defined as individuals who belong to a protected population group.

method makes use of a hazardous material flow survey to estimate the types and volumes of materials transported over various segments of a transportation corridor. Thus, it allows a more detailed analysis of the distribution of hazardous materials exposure risk between protected and nonprotected populations.

Analysis. This method depends heavily on the performance of a material flow survey, as described in greater detail in *Guidance for Conducting Hazardous Materials Flow Surveys* (U.S. DOT 1995).

Step 1 – Conduct hazardous materials flow surveys. The objective of this step is to derive the hazardous material flow data for each segment of the project area and for any areas that will be used for comparison with the project area as a whole. A flow survey is an empirical technique that involves monitoring the hazardous material transport on a given route segment. It is accomplished by stopping all trucks that display U.S. DOT hazardous materials placards and examining their shipping papers. For comprehensive guidance on conducting hazardous material flow surveys, see U.S. DOT (1995). The following is a brief summary of the major steps described in that document:

a) **Identify the specific purpose of the study.** In the present context, the reason for performing a flow study is to develop an accurate and defensible estimate of the probability that an accidental release of hazardous material will occur in the study area. An estimate of probability in turn relies on an accurate determination of the following information:

   - Number of trips involving hazardous material transport in any week,
   - Volume of hazardous material transported in each trip,
   - Type of material transported in each trip, and
   - Type of container.

   In some cases, the scope of the analysis may be limited to certain types of material. Any decision to limit the scope of the study should be based on an initial survey of the types of materials transported in the study area. For example, if it were known that the project corridor is or will be used for transport of spent fuel from a nuclear power station, the motivation for a risk analysis might be limited to accidental release of radioactive material.

b) **Gather baseline information.** Before conducting the actual flow survey, review existing information to determine the routes within the study area over which hazardous materials will be transported, as described in Method 3, above. In addition, gather information about the condition and other attributes of the route, such as lane widths, road capacity, and shoulder conditions. The U.S. DOT Highway Performance Monitoring System (HPMS) is a good source for this information. Gather route-specific information such as total traffic volume, volume of truck traffic, and accident history. Finally, use the techniques described under Method 3 to estimate the types of hazardous materials that might be transported in the study area.

c) **Design the study.** Using the baseline information, determine what route segments are to be studied. Establish optimal locations for survey stations where trucks can be stopped for inspection with minimal disruption to the carrier and the flow of traffic. Decide over what time periods the survey will be conducted. At a minimum, continuous 24-hour surveys of truck traffic over several days during at least two distinct seasons of the year is desirable. Based on the number of survey stations and the duration of sampling, determine the personnel needs for the survey. Two surveyors and several state police are the minimum staff that will be needed for each survey station.

d) **Perform the surveys.** Inspect all trucks displaying hazardous materials placards that indicate the truck is carrying the type of material being studied. In general, it should not be necessary to physically inspect the contents. Trucks carrying hazardous materials are required to have shipping papers containing all the necessary information. A standard checklist should be developed and used to ensure that all essential information is obtained for each truck inspected.

e) **Analyze the data.** Depending on the particular objectives of the study, the survey findings should be collated according to the type of truck, the type and volume of material carried, and the type and size of any containers used. It may also be desirable to analyze the density of hazardous material transport as a function of the time of day.

Step 2 – Estimate the probability of accidental release. For each route segment, estimate the probability of an accidental release using event-tree analysis. The basic information required for this analysis—volume of traffic for each material type, volume of shipment, and container type—comes from the material flow survey performed in Step 1. The following factors may be taken into consideration:

- Type and volume of hazardous material,
- Roadway condition,
- Traffic density, and
- Type of container.

The data gathered in Step 1 supports the event-tree analysis. The method for conducting the event-tree analysis, including normative probabilities for various types of accidental release scenarios, is given in Battelle (2001). An example event-tree is shown in Figure 4-4.

An event-tree analysis involves assigning probabilities to each branch of the event-tree. The combined probability for each "leaf" of the tree (termini on the right of the event-tree) is computed by combining the probabilities for each branch leading into the leaf.

Additional data sources for computing probabilities used in the event-tree analysis include the following:

- U.S. Bureau of the Census *Commodity Flow Survey* (1997).
- U.S. DOT Hazardous Materials Information System.
- U.S. DOT Hazardous Materials Incident Data and Summary Statistics for Incident Years 1993–2002.
- U.S. DOT, Federal Motor Carrier Safety Administration Motor Carrier Management Information System (MCMIS).

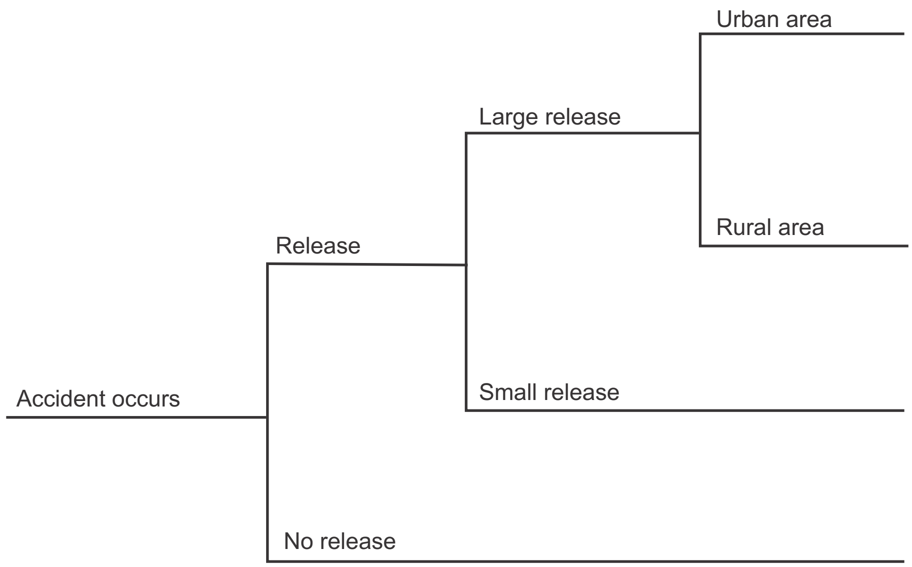

Figure 4-4. Example event-tree for release of hazardous material

The outcome of this step is a probability estimate for both small and large spills for each type of material in each segment of the study area.

Step 3 – Estimate the impact of accidental release. Whereas Step 2 consists of determining the probability that an accidental release will occur, this step involves estimating the level of impact a given type of release will have on people in the surrounding area.

Define an *impact function* for each type and volume of material transported per the materials flow survey. Use published nighttime (i.e., worst-case) PADs to estimate the maximum size of the impact area for each material type and volume of spill. A simple dispersion model can be used to weight the impact based on the distance from the roadway and the PAD; for example, an impact score of 100.0 can be assigned at the site of the release and 0.0 at the PAD distance from the roadway, with linearly decreasing scores at intermediate distances from the roadway. This relationship can be expressed as follows:

$$I_x(d) = \frac{P_x - d}{P_x}$$

where

$I_x(d)$ = the impact at distance d of a spill of type x for which the PAD is P_x

If desired, a more accurate estimate of the impact can be obtained using air dispersion modeling, taking into account such factors as the volatility of the material, the influence of terrain, prevailing wind direction, and other meteorological conditions common in the study area. In that case, the impact function would not be assumed to be uniform in all directions.

Note that the impact is in arbitrary units. The scaling of the impact is unimportant, as long as it is proportional to the relative consequence of each type of spill at a given distance from the roadway.

Step 4 – Develop a risk surface. Using the impact function and probability of each type of spill (type and volume of material), compute a *risk function* for each using the following equation:

$$R(d) = \sum_x \left(I_x(d) \times p_x\right)$$

where

$R(d)$ = the total *risk score* at distance d from the roadway for all types x of spills

$I_x(d)$ = the impact at distance d of each type of spill

p_x = the probability of each type of spill

Note that the value of d should be no greater than the PAD for each type of spill; that is, do not use negative values for any $I_x(d)$.

Use the risk function to develop a risk surface similar to the pollution surface described in Method 4 of Chapter 3. The risk surface amounts to a GIS layer that indicates for each grid cell the maximum risk of exposure to an accidental release of hazardous material.

Step 5 – Perform demographic analysis. Using GIS, develop a population surface as described in Method 4 of Chapter 3. If road use analysis indicates that a significantly disproportionate number of members of protected populations use the roadway, this should also be taken into consideration. To determine this, develop the estimated numbers of protected and nonprotected individuals traveling on the road segment over a given time interval and compare these demographics to the maximum risk scores computed for each segment. The time interval chosen should be equal to the driving time at average speed to travel a distance equal to the average PAD for the materials studied. When analyzing the road use data, you should only count individuals who are traveling through the study area, not those living in the study area, so as to avoid double counting.

Step 6 – Evaluate distributive effects. Using the techniques described in Steps 3 and 4 of Method 4 in Chapter 3, overlay the risk surface with the population surface to analyze potential distributive effects on risk of exposure to hazardous materials for protected versus nonprotected populations.

Data needs, assumptions, and limitations. This method is data intensive, relying on existing databases and reports for historical accident data, roadway conditions, and demographic information. In addition, it requires data derived from hazardous material flow surveys, which are costly and labor intensive. In both cases, the method necessarily relies on extrapolation from relatively sparse data.

Due to the high cost involved in collecting or developing truly complete information, it is necessary to assume worst case conditions. For example, because the volume of material flow data is unlikely to be great enough to allow modeling of diurnal patterns, the worst case nighttime PADS should be used to describe the area of impact of a spill. Finally, two aspects of this method—risk assessment and air dispersion modeling—require expert guidance and specialized software.

Results and their presentation. The results of this method are similar in many ways to the results of Method 4, Chapter 3. Refer to Step 4 of that method for guidance in the presentation of results.

Assessment. Risk analysis is the most quantitative and detailed form of hazardous materials environmental justice assessment. As such, it can provide the most authoritative assessment of the effects of a project on the distribution of risks associated with exposure to hazardous materials. This method requires a high level of modeling expertise and extensive data input. Due to the complexity of the method, it should only be undertaken if a screening study has indicated that the amount or frequency of hazardous material transport is not evenly distributed between protected and nonprotected populations.

RESOURCES

1) United States Environmental Protection Agency (U.S. EPA). 2003. The applicable Web site is http://www.epa.gov/brownfields/html-doc/lv3.htm.

   This Web site provides information on LandView ™ III (environmental, geographic and demographic statistics and graphics tool) as it relates to EPA environmental justice, risk-based corrective actions, hazardous materials regulations and brownfield programs. The Web site also provides links to U.S. Census Bureau and Right-to-Know Network Web sites discussing LandView™ III. The new LandView™ 5 is discussed at http://landview.census.gov/geo/landview/lv5/lv5.html. Whereas LandView™ 5 contains only information from Summary File 1, the forthcoming LandView™ 6 will also contain selected Summary File 3 data.

2) Federal and state environmental database resources for assessing hazardous materials:

   - U.S. Environmental Protection Agency (U.S. EPA), National Priorities List (NPL) (Superfund Sites), found at http://www.epa.gov/superfund/sites/npl.
   - U.S. EPA, Comprehensive Environmental Response, Compensation, and Liability Act List (CERCLIS), found at http://www.epa.gov/superfund/sites/cursites.
   - U.S. EPA List of Facilities that Treat, Store, and/or Dispose of Hazardous Waste (RCRIS), found at http://www.epa.gov/enviro/html/rcris.
   - U.S. EPA Sites with Previous Hazardous Materials Spills (ERNS), found at http://www.epa.gov/region4/r4data/erns.
   - U.S. Department of Transportation, Research and Special Programs Administration, Office of Hazardous Materials Safety, Hazardous Materials Information System (HMIS), found at http://hazmat.dot.gov/abhmis.htm.
   - U.S. Department of Transportation, Federal Motor Carrier Safety Administration, Motor Carrier Management Information System (MCMIS), found at http://www.fmcsa.dot.gov/factsfigs/mcmis/mcmiscatalog.htm.

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CHAPTER 5. WATER QUALITY AND DRAINAGE

OVERVIEW

Connections between water quality issues and environmental justice may not be apparent at first glance, but there are several possible links. Natural physical laws and topography dictate the design of water quality and drainage improvements, and the location and function of these improvements could have distributive effects. Additionally, the associated improvements typically include a number of subjective design issues that can affect the quality of the visual environment. The very essence of water quality improvements suggests a net positive result for society. You should, however, consider a wider range of interests than has typically been done in the past to ensure that protected groups are not disproportionately impacted by the proposed improvements. A brief case study presented later in this chapter provides an example of why environmental justice should be addressed when evaluating how transportation system changes affect water quality and drainage.

The state-of-practice discussion below begins with a broad look at current water quality and drainage engineering practices at the level appropriate for environmental document preparation. Common methodologies and engineering tools used to study water quality and drainage impacts are presented systematically, along with recommended approaches on how to extend these methods to allow for effective environmental justice assessment. Links to Web sites and other information are provided for those seeking more detailed information regarding the tools and processes used in the engineering analysis.

The methods discussion draws connections between environmental justice issues and the engineering analyses associated with water quality and drainage design. Strategies and checklists are presented to help practitioners seamlessly incorporate environmental justice considerations into traditional analyses. The chapter closes with the Camp Coldwater Springs case study as an example of the connections between drainage design and environmental justice.

STATE OF THE PRACTICE

The current environmental impact analysis process as it pertains to water quality and drainage is made up of five general steps.

1. Evaluate existing conditions.
2. Evaluate regulatory agency jurisdiction and requirements.
3. Evaluate impacts to groundwater quality and quantity.
4. Evaluate water quality impacts to natural water bodies.
5. Evaluate water quantity impacts to natural water bodies.

Each project will require its own unique level of emphasis for each of the general steps listed above. The following is a short summary of the components that make up the evaluations required for an environmental effects analysis.

Evaluating existing conditions

This evaluation includes identifying the overall project limits for potential build and no-build options. The evaluation must be of sufficient detail to identify surface drainage patterns. An understanding of the topography of the project area and of points "downstream" of the project limits must be developed for a successful evaluation. Typical resources used for this evaluation include the following:

- Aerial photos and contour maps (either commissioned specifically for a given project or provided by local government planning/engineering departments);
- Geographic information system (GIS)-based mapping (generally provided by local government planning/engineering departments);
- National Wetland Inventory;
- State public waters information;
- United States Geological Survey (USGS) quadrangles; and
- City and county drainage information.

Field investigation and verification of the mapping information also should be conducted as part of this evaluation. The existing conditions evaluation should include the modeling of runoff in the project area based on current surface topography and soils/pavements, as well as on improvements such as ponds, pipes, and channels. A common modeling approach is presented in the "Evaluating water quality impacts to natural water bodies" discussion on page 124.

Evaluating regulatory agency jurisdiction and requirements

This component involves developing a list of all local, regional, state, and national agencies that may have an interest in the project based on the scope of the affected area. The delineation of this area should include the project limits and downstream areas. Agencies involved may be either stakeholders or regulating agencies. Agency jurisdictions and concerns will often overlap, and open communication among agencies is necessary to ensure that project requirements are complementary, not contradictory, to each other. Tables 5-1 and 5-2 list typical agencies that might be included and their respective areas of concern.

This part of the evaluation typically requires several meetings with the stakeholder agencies to compile their specific concerns and requirements, as well as to determine which permits will be required as part of the project. A complete understanding of the cumulative agency requirements is necessary to develop the scope of the proposed improvements as they relate to water resource issues.

Evaluating impacts to groundwater quality and quantity

Typical groundwater impacts occur as a result of construction dewatering process improvements that involve permanent excavations below the existing groundwater table. Dewatering processes may result in infiltration of pollutants into the groundwater from runoff or ponding areas.

Table 5-1.
Local and regional coordinating agencies for water quality and drainage

Area of concern	Municipalities	Watershed organizations	Lake associations	Soil & water conservation districts	Coastal shoreline organizations
Water quality	✓	✓	✓	✓	✓
Water quantity	✓	✓			
System design and connections	✓				
Best management practices		✓		✓	
Groundwater quality		✓			
Shoreline erosion control			✓		✓
Habitat					✓

Table 5-2.
State and federal coordinating agencies for water quality and drainage

Area of concern	Natural resources agency	Pollution control agency	EPA[1]	FEMA[2]	Corps of Engineers	U.S. FWS[3]
Water quality	✓					
Water quantity	✓					
NPDES[4] regulations and guidelines		✓	✓			
Wetland Conservation Act					✓	
Navigable waters					✓	
Floodplains				✓	✓	
Wildlife habitat						✓
Fisheries						✓
Lakes and streams					✓	✓

1. United States Environmental Protection Agency
2. Federal Emergency Management Agency
3. United States Fish and Wildlife Service
4. National Pollutant Discharge Elimination System

Permanent excavations may ultimately alter groundwater elevations in the project area. Analysis should include estimated rates and volumes associated with groundwater infiltration from pond areas and groundwater exfiltration into sewers, ponds, and subdrainage systems.

Generally, groundwater quality is not adversely affected by infiltration from storm water detention basins collecting runoff from roadway areas. Recharge from storm water pond infiltration is often beneficial to groundwater. Special cases such as runoff from industrial sites and/or the presence of chemicals, such as deicing fluids from airport operations, in the runoff stream may cause regulating agencies to require measures to limit infiltration. Existing pollutants in the soils located between water quality ponds and groundwater tables may also cause agencies to require limitation measures.

Modeling tools commonly used for evaluating groundwater impacts include the following:

- FEFLOW (Finite Element Flow): This program provides an advanced 2-dimensional and 3-dimensional environment for performing complex groundwater flow, contaminant transport, and heat transport modeling.
- GMS 4.0 (Groundwater Modeling Software): GMS is a comprehensive program with tools for every phase of a groundwater simulation, including site characterization, model development, post-processing, calibration, and visualization.

Evaluating water quality impacts to natural water bodies

Typical water quality impacts to natural water bodies include the introduction of pollutant-laden sand and silt into runoff streams that originate from impervious or paved surfaces. Phosphorus is a commonly targeted pollutant; however, metals and salts are also found in runoff generated from roadway surfaces. Typical water quality treatment options include the construction of sedimentation ponds, infiltration areas, and hydraulic structures, such as grit chambers, to remove pollutant-laden sediments from the runoff stream. Many municipalities and watershed organizations require that water quality ponding improvements be constructed to conform to the National Urban Runoff Program (NURP) standards. However, requirements may vary depending on the area of the country and on existing conditions prior to improvement. The most common limiting factor for water quality improvements is the availability of land to construct water quality ponds. This can be especially problematic in developed corridors.

Modeling tools to evaluate water quality impacts are commonly used in conjunction with topographic maps and land use and zoning information. The most commonly used model is the P8 Urban Catchment Model. P8 is a U.S. Environmental Protection Agency (EPA) computer model for predicting the generation and transport of stormwater runoff pollutants in urban watersheds. Continuous water-balance and mass-balance calculations are performed on a user-defined system consisting of watershed, particle classes, water quality components, and storage and treatment devices.

Evaluating water quantity impacts to natural water bodies

Water quantity impacts on natural water bodies often include stream erosion and higher flood levels on streams, wetlands, and lakes. These impacts are mostly due to increased rates of runoff and, to a lesser extent, to increased volumes of runoff resulting from impervious or paved surfaces. Typical options complement existing water quality treatment options and primarily include the construction of ponds to slow down or detain runoff before it enters natural water bodies. Most regulating agencies require that the rate of runoff from a project not exceed the rate of runoff under existing conditions. This requirement may stand whether the existing condition is a natural or a built environment.

Evaluation of water quantity impacts includes an analysis of floodplain areas to ensure that the project does not ultimately reduce the available flood storage. Reduction of floodplain storage volume in one area may require the excavation of new floodplain storage volume in another area. Tools commonly used to evaluate water quantity impacts include engineering hydrologic and hydraulic formulae and computer modeling software, such as the Hydraulic Engineering Center (HEC)- River Analysis System (RAS), the HEC-2, and the Storm Water Management Module (SWMM) in conjunction with topographic maps and storm drainage infrastructure as-built information. Recommended applications of these models are summarized below.

- Corps of Engineers Hydraulic Engineering Center
  - River Analysis System – HEC-RAS is a water surface profile model for steady and unsteady one-dimensional, gradually varied flow in both natural and constructed river channels.
  - HEC-2 – HEC-2 is a water surface profile model for steady, gradually varied flow in natural and constructed channels.
- EPA
  - Storm Water Management Module – SWMM is a storm water and wastewater management modeling package for analyzing urban drainage systems and sanitary sewers. The model combines hydrology and hydraulics with water quality. An application known as MIKE-SWMM provides users with a complete, graphical, easy-to-use interface.

The data output provided by the models listed above are only as accurate as the quality of the input. For environmental document preparation, the level of necessary input detail is generally less than that needed for final design purposes. Input data generally is obtained from existing topographic maps, groundwater contour maps, and the preliminary plans of the proposed improvements, which illustrate changes in impervious areas, grading, and surface-water routing.

SELECTING AN APPROPRIATE METHOD OF ANALYSIS

The following is a discussion of methodologies for predicting the extent to which the water quality and drainage components of a transportation system change would differentially or severely affect protected populations. The design of water quality and drainage improvements generally is dictated by natural physical laws and topography, as well as by existing impediments in the built environment. Generally, improved water quality will equally affect all people using the resource, and mitigation improvements related to water quality and drainage will thus benefit society as a whole. Because regulations require either no net change or improvement in water quality and quantity characteristics, there will be little possibility for differential effects in most situations. However, the potential for distributive effects may result from situations such as the following:

- A protected population is the predominant user of the impacted resource.
- A protected population uses the resource differently than the population as a whole.
- Impacted areas and mitigation areas are distributed unequally among populations.
- The proposed water quality or drainage improvements will affect the visual and aesthetic quality of the project site or sites.

In the case where a protected population group is the predominant user of the impacted resource, the group would disproportionately experience any adverse or beneficial effects to the resource. Where the protected population uses the resource differently than the general population, it may be necessary to evaluate impacts based on type of use. A common example would be Native American use of fishery resources for subsistence compared to general population use of the same resources for recreation purposes only.

When impacted areas and mitigation areas are distributed unequally among population groups, the problem is similar to many other distribution problems discussed in this guidebook. An example would be reducing flood plain storage in one area and undertaking an offsetting excavation project in another area. The project could differentially affect protected populations depending on their proximity to, and use of, the construction and excavation areas. The potential for water quality and drainage mitigation projects to cause distributive visual and aesthetic effects can be evaluated using methods explained in Chapter 11.

The approach we recommend for evaluating impacts due to water quality and drainage improvements involves three steps.

Step 1 – Identify the scope of the proposed water quality and drainage improvements and alternative improvements based on engineering judgment and the applicable regulations of governing jurisdictions as outlined above.

Step 2 – Evaluate whether or not the improvements affect protected populations using the checklists outlined below.

Step 3 – Modify or alter the scope of the proposed improvements as necessary and practical to minimize or eliminate impacts to protected populations.

METHODS

The methods for assessing likely water quality impacts of a proposed transportation project are summarized in Table 5-3. The methods presented in this chapter are somewhat different in nature than those in most other chapters of this guidebook in that they consist of checklists. The five checklists are intended to raise the salient environmental justice considerations related to water quality when significant changes to the transportation system are contemplated.

The checklists are organized to ensure assessment of the following areas:

- Land acquisition,
- Visual quality,
- Accessibility,

- Groundwater, and
- Surface water quality and quantity.

These checklists can be used individually or in combination as necessary to evaluate water quality and drainage issues for the project in question.

Table 5-3. Summary of methods for analyzing water quality and drainage effects

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. Land acquisition checklist	Screening/ detailed	Project/ corridor assessment	Land acquisition could impact or displace protected populations	Low	Records review, survey/interview
2. Visual quality checklist	Screening/ detailed	Project/ corridor assessment	Visual quality effects of water quality improvements could affect protected populations	Low	Visual quality design and communication
3. Access-ibility check-list	Screening/ detailed	Project/ corridor assessment	Improvements impair access to water resources	Low	Survey/interview
4. Groundwater quality checklist	Screening/ detailed	Project/ corridor assessment	Improvements have the potential to affect groundwater quality or quantity	Medium	GMS
5. Surface water quality checklist	Screening/ detailed	Project/ corridor assessment	Improvements have the potential to affect surface water quality or quantity	Medium	HEC-RAS, HEC-2, SWMM

Checklist 1. Land acquisition

Water quality and drainage improvements often require that land be acquired to construct holding ponds, stilling basins, swales, and culverts. Although the locations of these improvements generally are determined by the topographical elevations of the land and the physics of water flow, there may be some flexibility in the siting of improvements.

Check for:

☑ **Does the affected area include protected populations?**
Suggested approach. Conduct a threshold analysis using the most recent census block and block-group information or more detailed information if it is available from local governments or metropolitan planning organizations (MPOs). Verify findings by conducting a field survey and interviewing persons with local knowledge of the area. Refer to Chapter 2 for more information.

☑ **Will any of the proposed acquisitions separate members of protected population groups from their homes or other properties?** Examples would include minority, low-income, disabled, elderly, or single female head of household homeowners, tenants or property owners. If the answer is yes, compile a list of the properties and answer the following checklist question. If the answer is no, there are no adverse effects to protected populations.

Suggested approach. Perform a records review to identify the property owners and any tenants. Determine if any are members of protected population groups by conducting personal interviews or surveys (see Chapter 2 for a suggested questionnaire).

☑ **Are there other options or mitigation measures that could be implemented in lieu of displacing persons in protected population groups?** If the answer is no for any of the listed properties, review the mitigation techniques and answer the following checklist questions.

Mitigation techniques.

- Consider locating ponds either downstream or upstream of optimal locations if it would mean less impact to affected populations and if water quality/quantity issues would not be overly compromised.
- Consider alternatives to ponds, including grit chambers, underground detention, or mechanical treatment methods that reduce or eliminate the need for large pond areas and decrease the number and size of necessary land acquisitions. Be aware, however, that the cost of these methods generally is much higher than ponding for an equivalent result.

☑ **Would the unmitigated acquisition of land owned by members of a protected population or the displacement of homeowners and tenants cause an economic or personal hardship for the affected individuals?** If so, consider the following information.

Discussion. Such a situation can be avoided in most cases. An exception might occur in highly populated built environments where topography and project design features severely restrict the available options. In such situations, every effort should be made to negotiate fair and reasonable condemnation terms to satisfy property owners. Assistance should be provided to displaced individuals. Because these situations are often very contentious, the responsible agency should take proactive steps to prepare a justification in the event that a formal complaint or lawsuit is filed.

☑ **Do the unmitigated acquisitions disproportionately impact members of protected population groups?** If so, it will be necessary to either alter the project design or justify the action.

Discussion. Any evaluation that shows no disproportionate impact may be contested. To prepare for this eventuality, the evaluation should consider the proportion of affected property owners and displaced persons in protected population groups relative to the population proportion in the study area and in comparison areas. See the method for threshold analysis described in Chapter 2 and the related discussion, “Limitations of using comparison thresholds in environmental justice assessment.”

Checklist 2. Visual quality

Many of the improvements associated with water quality and drainage systems are constructed within the public realm and are highly visible elements of the connection between public transportation infrastructure and the natural environment. Aesthetic design of water quality and drainage improvements can range from functional and utilitarian to highly attractive features that enhance the surrounding built or natural environment. Protected populations should be provided with meaningful public involvement that proactively solicits input and provides access to information concerning aesthetic design improvements. Chapter 11, Visual Quality, provides a much more in-depth analysis of this issue as well as techniques for evaluating visual quality impacts of water quality and drainage improvements. The following checklist can be used to evaluate visual quality effects of water quality and drainage elements.

Check for:

☑ **Is the affected area within the activity space where protected populations live, work, take part in recreational activities, or otherwise spend significant amounts of time?** If the answer is yes, go to the following checklist question. If the answer is no, there would be no adverse effects to protected populations.

Suggested approach. Use an appropriate combination of the techniques described in Chapter 2 to identify the presence of protected populations.

☑ **Would the proposed water quality and drainage improvements be visible to members of protected populations?** If yes, go to the following checklist question. If no, there would be no visual quality impacts.

Suggested approach. As a first step, use GIS or a desktop program to overlay the location of improvements on a map of protected populations. If improvements are located within the activity space of protected populations, consider conducting a field survey or using GIS, as appropriate, to perform a line of sight, view-shed, or some other type of visibility analysis.

☑ **Perform a visual quality assessment. Do results of the assessment indicate that visual quality would be adversely affected?** If so, go to the following checklist question.

Suggested approach. Perform an appropriate visual quality assessment. Techniques appropriate for identifying visual quality impacts to affected populations are provided in Chapter 11.

☑ **What are the most appropriate mitigation measures to alleviate adverse effects?**

Mitigation techniques.

- General aesthetic: Consider incorporating a high level of aesthetic into the visible or exposed portion of water quality and drainage improvements, thus making them an amenity to the community instead of a detriment. Consideration should be given to making the improvements blend with the natural landscape.

- Recreation opportunities: Consider incorporating trails for recreation and basic transportation around and through the improvement areas.
- Interpretation and education opportunities: Consider providing interpretation of the water quality improvements via signage (multilingual as appropriate) for educational purposes.

Checklist 3. Accessibility

Transportation improvements, including roadway widening or access control, and their associated storm water ponds, culverts, and channels may eliminate public access to natural water bodies and may adversely affect protected populations. Chapter 7, Transportation User Effects, goes into greater detail about how to evaluate accessibility. The following are some ideas specifically related to water quality and drainage.

Check for:

☑ **Is there existing recreational access and use of water bodies in the project area for activities such as fishing or swimming?** Be sure to ascertain whether specific population groups use the water bodies differently than the general population.

Suggested approach. Generate a list of the water bodies in the affected areas. Using expert knowledge, determine if any of the water bodies are used for recreational purposes. Review the list and findings with members of protected population groups through interviews, public meetings, focus groups, surveys, or some other form of feedback.

☑ **Will the proposed water quality or drainage improvements reduce accessibility to water bodies used for recreation or reduce the level of safety in traveling to or using the water bodies?** If so, consider appropriate mitigation techniques.

Mitigation techniques.

- Consider as part of the project providing alternative access for fishing, swimming, or other recreational uses. An example would be a publicly accessible pier or dock in a safe location that does not compromise the safety improvements included with the roadway or the water quality and drainage improvements.
- Dual-purpose improvements could be considered, such as designing access bridges or trails for maintenance of outlet structures to also accommodate public use.

☑ **Are there any safety issues associated with the proposed water quality or drainage improvements?** Consider issues such as whether the area is near parks, day care centers, residences, or other areas where children play. If so, consider appropriate mitigation techniques.

Mitigation techniques.

- Consider the use of fencing to protect people from potentially dangerous intake structures or other dangerous drops. Fencing may also be considered around ponds, although it may detract from the overall aesthetic of the area.

- Consider grading the site to provide gentle slopes around ponds (3:1 to 5:1) to reduce chances of children falling into water.
- Plantings and landscaping treatments such as boulders and thorny shrubs improve aesthetics and tend to keep curious children and adults a safe distance away from ponding areas.
- Rescue items such as boards for thin ice rescue or life rings and rope may be placed near the pond and marked for emergency use only.
- Structures with pipes large enough to crawl or walk in should include fencing or gates with locks to prevent the public from entering, while allowing access for maintenance personnel.

Checklist 4. Groundwater quality and quantity

Transportation improvements often involve excavating and filling areas of the natural landscape. Drainage improvements typically require underground pipes several feet below the roadway and the construction of drainage basins at or near the existing water table. The environmental analysis should consider whether or not potential impacts to groundwater—such as lowering the groundwater elevations in a localized area—will adversely impact protected populations.

Check for:

☑ **Are shallow private wells being used for domestic use?** Some protected populations are more likely to lack the economic means to construct deep wells for domestic water use, and therefore are more likely to experience the adverse effects of changes to shallow groundwater elevations in their area.

☑ **Is there an interface between groundwater and surface water in the project area, such as springs and water falls?** In areas where groundwater and surface water meet, any impacts to groundwater elevations could have significant impacts on surface water features. Such impacts could adversely affect protected populations because they may be more likely to utilize the surface water for domestic use or may value the resource more highly than other population groups.

☑ **Does the affected area encompass any historic settlements?** Many historic settlements and indigenous people's camps were built around natural springs; it is common for historic sites to be located at such locations.

If any of these situations exist in the study area, determine if there are impacts to protected populations using techniques described in Chapter 2. In the case of such impacts, consider the following mitigation techniques:

- Reconsider roadway and drainage design to minimize effects to groundwater. Strategies may include the following:
  - Raising roadway grades and pond elevations.
  - Designing ponds that are larger and flatter rather than deeper with smaller areas.

- Designing ponds to infiltrate water back into the ground, and thus assure no net loss to the groundwater balance.
- Taking measures to seal joints of deep sewer pipes to minimize infiltration of groundwater into the pipes and drainage system:
  - Pumpable grouts can be the most cost effective and
  - Trenchless lining of pipes with cured-in-place lining systems may also be considered.
- Isolate the roadbed from the groundwater table with concrete, clay, or a geotextile lining system.

- Provide potable water supplies to homes by extending the local water distribution network if feasible. If no water distribution network exists, consider drilling deeper wells for the affected properties.
- Recreate water flow for springs and waterfalls using mechanical means such as pumping or municipal water systems. This option is only feasible for low-volume flows and short water falls. The construction of a mechanical system may not be possible without causing temporary damage to the natural water feature and thus may defeat its own purpose.

Checklist 5. Surface water quality and quantity

Transportation improvements nearly always affect the surface water quality and quantity of the surrounding area. Drainage improvements are included with transportation projects to convey storm water away from the roadway and toward the natural water body. Such improvements typically involve underground pipes, ditches and the construction of drainage basins to conduct, store and treat surface water. These improvements often result in modifications to the physical shape, size, or dynamic characteristics of existing streams or ponds (i.e., water movement that is faster, slower, higher, or lower). The environmental analysis should consider whether or not the potential impacts to surface water quality caused by raising high water elevations in a localized area would adversely impact protected populations. Examples include increasing groundwater flows and subsequent erosion problems.

Check for:

☑ **Does the area include existing surface water elements such as lakes, streams, rivers, or wetlands that will be affected by the improvements?** Connections to such surface water features should automatically qualify for additional analysis. Also consider if existing surface water that currently runs to natural water bodies will be diverted elsewhere, thus reducing the natural recharge of those water bodies.

Suggested approach. If any of these situations exist in the study area, identify any impacts to protected populations using techniques described in Chapter 2. If so, consider the following mitigation techniques.

Mitigation technique.

- Reconsider roadway and drainage design to minimize effects on surface water features. Strategies may include the following:
  - Ensuring that water quality is maintained or enhanced as it enters natural water bodies through use of ponds, grit chambers, or vegetated swales. Generally, regulatory agencies will set requirements that ensure this is accomplished.
  - Alter pond design to reduce or increase the high-water level as desired. If there are homes near ponding areas, it is best to design a pond with the lowest possible high-water elevation, thus reducing the potential for flooding or property damage to the residences. Designing ponds that are larger and flatter rather than deeper and smaller will result in lower flood elevations.
  - Utilize structures within the roadway to improve water quality and quantity issues if ponding areas create adverse impacts to protected populations. Examples include grit chambers, vortex separator structures, and underground pipe chambers.

RESOURCES

1) An overview of the National Wetlands Inventory (NWI) and information on how to obtain wetlands maps and other information is available at the NWI Web site, http://www.nwi.fws.gov. The U.S. Fish and Wildlife Service also provides an online map for locating wetlands, available from http:// wetlands.fws.gov/mapper_tool.htm.

2) There are numerous online resources for downloading digital elevation models, topographic maps, and other GIS data useful for performing water quality and drainage evaluations. Many states have GIS data clearinghouses that offer a large amount of information either free of charge or for a minimal fee. The GIS Data Depot provides a large volume of GIS data for the entire U.S. Most of the data are free, although there is a charge for ordering information if they cannot be downloaded. The GIS Data Depot can be accessed at http://data.geocomm.com.

3) Additional Resources

For more information about the National Pollution Discharge Information System, visit the EPA NPDES Web site at http://cfpub.epa.gov/npdes/stormwater/menuofbmps/post.cfm.

For more information about floodplain assessment and to obtain floodplain information visit the Federal Emergency Management Agency (FEMA) Web site at http://www.fema.gov/fima.

For information about wildlife and fisheries habitat, visit the U.S. Fish and Wildlife Service Web site at http://www.fws.gov.

For more information on complying with the wetland conservation act and impacts to navigable waterways, visit the U.S. Army Corps of Engineers Web site at http://www.usace.army.mil.

Water Quality and Environmental Justice Case Study
Camp Coldwater Springs, Minneapolis, Minnesota

Introduction. This brief case study illustrates why it is important to assess environmental justice as it relates to water quality and drainage effects. Failure to identify issues in the planning stages can add significant costs during constructions and may delay, interrupt, or even stop projects completely.

Background. In the late 1990s, the Minnesota Department of Transportation began a highway improvement project to reconstruct the interchange of Trunk Highway 55 and Trunk Highway 62 in Minneapolis, Minnesota. The reconstruction of Trunk Highway 55 had been in the planning and development stages since the 1960s, and an environmental impact statement (EIS) had been conducted for the improvement during the 1980s. The project area for the interchange is located on the border between two local watershed agencies, the Minnehaha Creek Watershed District (MCWD) and the Lower Minnesota River Watershed District (LMRWD). The interchange is near Camp Coldwater Springs, a historically significant spring utilized by Native American groups and early settlers in the region.

As dewatering activities began at the construction site in December 2000, a noticeable decline in groundwater flow to the springs was noted by a MCWD scientist. The MCWD believed that the reduced flow was due to a storm water pond constructed as part of the interchange project. The issue became prominent as environmental and Native American groups began expressing their concerns. The situation culminated in a Minnesota law that prohibits any state action that "may diminish" groundwater flows to Camp Coldwater Springs. In addition, a District Court judge ordered the Minnesota DOT (MnDOT) to cease construction dewatering.

A dye test confirmed a direct connection between the interchange and the springs, and it was determined that construction dewatering resulted in a substantial flow decrease in the springs. A design solution was developed, but it was not possible to prove that it would completely eliminate impacts to the springs. In September 2001 MnDOT terminated the project, citing the potential for future lawsuits from citizen's groups.

Analysis. In the particular case of the Highway 55 improvements, an EIS was completed in 1985, prior to Executive Order 12898 that requires environmental justice to be considered before undertaking major federal actions. The fact that environmental justice was not evaluated and that public values changed between the completion of the EIS and the construction period led to the perception that the project's environmental and cultural impacts were not adequately considered.

The primary concern with the impact to Camp Coldwater Springs was not the environmental effect of reduced groundwater flow because the springs are not accessible to the public and are arguably not a critical recreational or ecological resource. Rather, the primary concern was the historical and cultural value of the springs, especially to Native Americans. Public issues with this project thus arose out of special values and beliefs held by specific population groups, some of them protected populations that placed cultural value on the natural condition of the springs.

The checklists included with this guide would have triggered evaluation of the impact to Camp Coldwater Springs. Identifying potential impacts and mitigation measures may not have guaranteed that all of the affected interest groups would have been satisfied with the proposed project. However, it might have diffused some of the animosity that arose out of the perception that the issue was not addressed at all. Furthermore, if the EIS had identified the impacts, they may have been mitigated in the original plans. It is likely that mitigation costs would have been reduced and that the courts would have allowed the project to proceed.

For more information on the p8 urban catchment model see http://www.wwwalker.net/p8/.

For more information on HEC-RAS see http://www.bossintl.com/html/hec-ras_overview.html.

For more information on HEC-2 see http://www.bossintl.com/html/hec-2_overview.html.

For more information on the SWMM and MIKE-SWMM see http://www.bossintl.com/html/mike_swmm_overview.html.

For more information on the Camp Coldwater Springs case study see http://www.minnehahacreek.org/Projects_Permits/35-Crosstown/summary.htm.

For more information on the FEFLOW model see http://bossintl.com/html/feflow_overview.html.

For more information on the GMS visit the GMS Resource Center at http://gms.watermodeling.org.

CHAPTER 6. SAFETY

OVERVIEW

Safety is a critically important aspect of quality of life. As such, it must be one of the principal considerations when planning transportation projects. In the most basic terms, two types of safety are most relevant to environmental justice—the safety of those who will travel on the transportation facility and the safety of those whose activities place them in proximity to the facility. The greater environmental justice issue may lie with the second group, although it can also be relevant to facility users. For example, a recent report by the National Center for Health Statistics (2003) indicates that automobile crashes are the leading cause of death among youngsters 1 through 14 years old (2,312 fatalities in 2001). The report further indicates that black children are three times more likely to be killed in traffic crashes than are white children. Hispanic children are twice as likely as white children to die in traffic crashes. Among the reasons cited for this disparity in death rates are lack of education, cultural factors, and poverty that keeps parents from purchasing car seats for their children.

Regarding injuries and fatalities for persons other than those using the transportation facility, the primary concern pertains to conflicts between vehicles and pedestrians and users of non-motorized transportation, such as bicycles. A study by Appleyard et al. (1981) reported that low-income children were more likely to be struck by motor vehicles because the lack of playgrounds encourages them to play in the street.

Similarly, Roberts et al. (1995) concluded that children living near high traffic volume and high-speed (greater than 40 mph) roadways are far more likely to be injured or killed by motor vehicles. Agran et al. (1996) had similar findings and estimated that children living in multi-family housing have a threefold greater likelihood of being injured by a motor vehicle. The latter two research teams noted that areas where much of the curb was occupied by parked vehicles were especially likely to be associated with higher child pedestrian injuries.

The evidence suggests that high-capacity streets and highways with rapidly moving traffic and curb parking produce significant safety hazards for children. Particularly in inner cities, many low-income families live in relatively high-density housing areas without much open space. Roadways running through these areas are often of the type associated with high injury rates for pedestrians, especially children. Increasing traffic volumes, flow speeds, or curb parking on such facilities thus can create important environmental justice concerns.

STATE OF THE PRACTICE

For transportation users, the safety benefits of facility improvements take the form of reductions in the rate of fatal, personal-injury, and property-damage-only (PDO) crashes per unit of travel, typically per 100 million vehicle miles of travel (VMT). It is unlikely that an environmental justice issue will exist among users of a given facility because it is equally safe or unsafe for all those who travel on it. The previously mentioned higher rate of child fatalities in traffic crashes due to deficient seatbelt use is more of an education and resource issue (funds to purchase child car seats) than a facility problem, per se. A more likely facility investment issue is whether safety-related upgrades are made in low-income or minority areas of a community to the same extent that they are made elsewhere.

In general terms, transportation projects can directly affect travel 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 in the condition of a roadway, such as resurfacing to remove potholes, create a safer driving environment and thereby reduce the number of crashes.

As stressed earlier, however, the principal environmental justice issue related to safety is likely to pertain to nonusers, those whose activities place them near the roadway. Thus, environmental justice assessments need to consider changes in pedestrian safety and that of bicyclists or users of other nonmotorized transportation modes. Pedestrian safety needs to focus on (1) those who must cross a roadway and thus risk potential conflict with motor vehicles and (2) children whose play and travel place them in harm's way. For bicyclists, the emphasis should be on road characteristics that affect their ability to travel safely on the facility.

It is important to note that safety improvements for road or highway users may not correlate with improvements in safety for these other groups. For example, a wider, faster highway may improve safety for vehicle travelers but reduce the safety of bicyclists and pedestrians who cross the facility.

SELECTING AN APPROPRIATE METHOD OF ANALYSIS

It is common practice to estimate the safety changes—in the form of a reduction or increase in the number of crashes—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 should not represent a major additional effort to compare the safety of collector facilities and local streets in areas that are within the daily activity space of minority populations and low-income populations. Methods for assessing the safety impacts for users of road projects are quite well established (see Forkenbrock and Weisbrod 2001, Section 3). Therefore, our focus here is on applying these methods to determine the extent to which a difference exists between the safety of road users in low-income or minority districts of the community compared to other areas.

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

Table 6-1 summarizes the methods presented in this chapter.

Table 6-1.
Summary of methods for analysis of safety effects

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. Analysis of national data	Screening	Assess safety effects on road users and pedestrians	In early stages of design or for a quick and easy survey of potential safety effects	Low	Spreadsheet
2. Comparison approach	Screening/ detailed	Assess safety effects on road users and pedestrians	In early stages of design for more focused analysis of potential safety effects in the same region	Medium	Spreadsheet
3. Regression analysis	Screening/ detailed	Assess safety effects of road improvements	Specific improvements are being considered to improve road safety	High	Statistical analysis
4. Bicycle safety index	Screening/ detailed	Assess safety effects on bicyclists	There is a significant level of bicycle traffic in the affected area	Medium/ high	Spreadsheet
5. Bicycle compatibility index	Screening/ detailed	Assess safety effects on bicyclists	There is a significant level of bicycle traffic in the affected area	Medium	Spreadsheet
6. Pedestrian street crossings	Screening	Assess safety effects on pedestrians	Project will increase the volume and/or speed of vehicular traffic in high pedestrian traffic areas	Low	Spreadsheet, Geographic information systems (GIS)
7. Pedestrian danger index	Detailed	Assess safety effects on pedestrians	Project will increase the volume and/or speed of vehicular traffic in high pedestrian traffic areas, and detailed data on pedestrian exposure and injuries is available	Medium	Spreadsheet
8. Barrier effect analysis	Detailed	Assess safety effects on pedestrian and non-motorized mobility	Project will increase the volume and/or speed of vehicular traffic in areas with high levels of pedestrian and non-motorized vehicle crossing	Medium	Spreadsheet
9. User demand and evaluation surveys	Screening	Assess road use patterns	Patterns of road use by pedestrians and non-motorized vehicles are unknown	Low	Survey design, spreadsheet

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. This method can be used to assess how road upgrades in the common activity spaces of protected populations would affect both the safety of road users and pedestrians. It also can be applied to make generalized assessments of the comparative safety of roads serving the activity spaces of protected populations and those serving other members of the community. The method is simple to apply and requires only nominal data collection once the activity spaces of minority populations have been identified (see Chapter 2).

When to use. These very general crash rates can be used to assess changes to facilities in areas of the community with a concentration of protected populations. Would safety improvements to users of the facility make the prevailing level of safety in areas with such concentrations comparable to other areas?

Analysis. To compare an existing road with a proposed upgrade using national data, 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 6-2 contains crash rates by functional class of road for 1997.

The crash data in Table 6-2 are presented in rates of crashes per 100 million VMT. Using these rates allows you to estimate safety impacts of improving the current roadway by multiplying the current annual VMT by the appropriate crash factor and then subtracting the result from the forecast VMT on the upgraded road times the correct crash factor.

For example, if a 10-mile urban principal arterial has 15.2 million VMT per year and is to be upgraded to an urban interstate with a forecast 29.1 million VMT per year, the change in fatal crashes would be 29.1 million VMT/100 million times 0.56, minus 15.2 million VMT/100 million times 1.30. The difference between the value of the upgraded road and the existing road represents the safety benefits and costs. In this example, there would be 3.5 fewer fatal crashes per year, even taking into account the increase in traffic volume.

In Chapter 2, we discussed spatial data that can be used to identify areas of the community with relative concentrations of protected populations. Once areas with such concentrations are defined, roadway upgrades within them can be compared to those elsewhere to assess the extent to which safety improvements are being distributed equitably.

Data needs, assumptions, and limitations. 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. The results of this analysis should be considered to be a general approximation.

Table 6-2.
Motor vehicle traffic fatalities and injuries by functional class, 1997
(per 100 million VMT)

Highway category	Injury crashes		Persons injured		Most serious injuries	Pedestrians injured	
	Fatal	Nonfatal	Fatal	Nonfatal		Fatal	Nonfatal
RURAL							
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							
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.

The data presented here do not include rates for estimating increases or decreases in PDO crashes because they are not available in the annual FHWA publication, *Highway Statistics*. If you choose 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.

Results and their presentation. A simple table can easily be constructed to depict the appropriate national crash rates for the current road and for the upgraded road. The table also can present the estimated number of crashes of each type per unit of time (e.g., a 1- or 5-year time frame), taking into account VMT before and following the upgrade. This summary table can give a general idea of the changes in road user and pedestrian safety that may result if the upgrade is completed.

Assessment. 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 differences in crash rates for each functional class of roadway. Overlaid on a GIS representation of income and race, this approach provides a general sense of whether the safety benefits of transportation investments are equitably distributed.

Method 2. Comparison approach

A 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. It has the advantage of allowing you to focus on facilities serving low-income populations and minority populations to assess the extent to which they are less safe than those serving other members of the community.

When to use. This approach is particularly appropriate for determining whether roadways serving areas of the community that fall within the common activity space of members of protected populations are less safe than roadways elsewhere in the community. It also enables you to evaluate the extent to which a particular improvement project would be likely to enhance the safety of those traveling on it.

Analysis. 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. Once a database is assembled, you can use it to assess many different projects.

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. Because crashes occur infrequently, it is a good idea to assemble data for a 3- to 5-year period. 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.

Data needs, assumptions, and limitations. The analysis presents estimates of expected crashes from a road improvement project 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.

This 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. You need 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 any type of roadway, so stable rates require data on numerous segments. Multiyear data files greatly improve the accuracy of crash rates because many more cases are included.

Results and their presentation. The most direct way to present the results of this analysis is a table displaying crash rates (fatal, personal injury, and PDO) for one or more road standards within the region alongside the rates for relevant roads within the activity space of protected populations. The table would thereby facilitate direct comparisons to address the issue of whether roads commonly traveled by protected populations tend to be less safe than other roads. If so, specific improvements can be identified to bring the safety performance of these roads more in line with others across the region.

Assessment. As discussed earlier in this chapter, roadways of a given standard are unlikely to be less safe in areas where members of protected populations live, work, or travel. The more likely environmental justice issue is whether particular facilities in such areas need to be upgraded because they currently have unacceptable crash rates. This approach is a reasonably effective means for making such an assessment.

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.

When to use. 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. If, for example, a road serving an area of the community frequently traveled by protected populations (see Chapter 2) has an unfavorable safety record, this method can be used to estimate the probable effects of making specific improvements to that road.

Analysis. We present an equation derived using the approach just described, as well as the procedure for estimating such an equation in a particular state. This equation 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.

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 6-3 contains the dependent and independent variables included in the regression model. The seven 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 6-3. 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 2001). 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 allows you 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, we apply a case in which a two-lane highway is a candidate for upgrading to four lanes. Table 6-4 presents the attributes of the base case and improved roadway.

Table 6-4. Application of the cost model to a typical upgrade

Variable	Base two-lane	Improved four-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 allows you to predict the change in crashes per year.

Suppose that a 30-mile stretch of the two-lane highway with the characteristics of the base case in Table 6-4 is being upgraded to a four-lane highway as in the improved case in the table. The highway has an average annual daily traffic (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 6-5 shows the breakdown of crashes by type. We can use the crash cost data from Table 6-6 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 6-5. 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 (1.9)	5,491 (28.3)	13,552 (69.8)	19,412 (100.0)
4	18 (1.0)	476 (26.3)	1,318 (72.7)	1,812 (100.0)

*The figures in this table are 3-year totals for 1989, 1990, and 1991 on two- and four-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.

Table 6-6. Estimates of crash costs by police-reported severity

Severity	Per person (2003$)	Per crash (2003$)
Fatal	3,359,212	3,820,635
Incapacitating injury	237,872	320,756
Evident injury	46,628	67,826
Possible injury	23,897	35,403
Property damage	2,433	6,299
Crash unreported to police	2,247	5,815

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

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

0.019 ($3,820,635) + 0.283 ($67,826) + 0.698 ($6,299) = $96,184.

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

0.010 ($3,820,635) + 0.263 ($67,826) + 0.727 ($6,299) = $61,980.

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 $96,184, the annual crash cost for the base case is $10.78 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 four-lane improved case of $61,980, the annual crash cost is $3.80 million. The annual savings in crash costs resulting from the improvement would be $6.98 million.

Data needs, assumptions, and limitations. To use the regression equation presented in this guidebook, you will need data on the current characteristics of each road segment to be improved. The analysis also requires information on the changes in characteristics that would result from the project. 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.

Results and their presentation. The approach just discussed can be applied at two levels. You can use actual road system and crash data for a particular state to estimate a regression equation or you 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

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

When to use. If a roadway through an area inhabited by protected populations is a candidate for upgrading, it is appropriate to evaluate the extent to which the safety of these populations would be affected as they move about. It is not unreasonable to expect that in low-income neighborhoods, especially those with relatively high densities, bicycles are a relatively common means of conveyance. There are occasions when upgrading a roadway to make it easier for traffic to flow through an area of the community will have a deleterious effect on local residents' ability to move about safely in their own activity space. In such instances, it often is users of nonmotorized transportation, particularly bicycles, whose safety is affected.

This method enables you to assess the extent to which bicyclists' safety would be reduced if a project were to go forward. The method also is useful in assessing how much bicyclists' safety would be enhanced if specific improvements were to be made to a roadway serving them.

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 = Sum of pavement factors (derived from Table 6.7)

LF = Sum of location factors (derived from Table 6.8)

Pavement factors include elements such 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 6-7. 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 6-7.
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 6-8). 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.

The appropriate factor values are plugged into the BSI function, and an index value is obtained. Table 6-9 provides a basis for interpreting the resulting index value.

Example. A roadway is upgraded in the following ways: (1) a center turn lane is added (reduction of 0.20), (2) a solid raised median is added (reduction of 0.50) and angled parking is converted to parallel parking (0.75 down to 0.25), (3) the speed limit is reduced from 50 km/hr to 40 km/hr, and (4) 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 0.00 (i.e., there would be no pavement-related problems if the road upgrade were to be completed), and some of the location factors would remain unchanged (moderate grades, frequent curves, restricted site distance, numerous drives, and industrial land use). The improvement would reduce the sum of location factor values by 1.20 (i.e., -0.20 [center lane] -0.50 [raised median] -0.50 [angled parking changed to parallel parking]).

Table 6-8.
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.

Table 6-9.
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.

Original case:

$$BSI = [5000/(4\times 3100)] + (50/48) + \{(50/48)\times[(4.25 - 3)\times 1.635]\} + 0.00 + 2.30$$

$BSI = 5.9$, in the "poor" category

Improved case:

$$BSI = [5000/(4 \times 3100)] + (40/48) + \{(40/48) \times [(4.25 - 4) \times 1.635]\} + 0.00 + 1.25$$

$BSI = 2.8$, in the "excellent" category

Data needs, assumptions, and limitations. As the list of variables indicates, to apply the BSI you 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. 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 to see whether these improvements would materially improve bicycle safety.

Results and their presentation. The simple equation at the heart of this method enables sensitivity tests to be carried out that assess the efficacy of various features that may be added to make a road safer for cyclists. An initial use of this method can be diagnostic—it can enable you to assess the extent to which a safety problem currently exists on one or more roadways in an area commonly traveled by protected populations. Simple tables can show the safety improvements that specific features are likely to provide.

Assessment. The BSI is a simple indicator that helps you gain a sense of how specific changes to a roadway may affect the safety of cyclists within a particular area. 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. It does have the advantage of pointing to specific features that can be included in a road upgrade to make a facility safer for cyclists.

Method 5. Bicycle compatibility index

As discussed in the previous method, nonmotorized transportation safety may be a significant environmental justice issue in some communities. If a community is safe for motorists but relatively unsafe for pedestrians and bicyclists, further road investments may worsen the safety differential and thus bring about an environmental justice problem. Such a problem could be at least partially ameliorated by making that roadway or others more compatible with bicycle traffic.

When to use. Various standards are available for evaluating cycling facilities, including those of American Association of State Highway Transportation Officials (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 within a particular geographic area of interest.

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

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

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 = adjustment factors, $f_t + f_{rt} + f_p$

NOTE: f_t is the truck volume adjustment factor found in Table 6-10, f_{rt} is the right turns adjustment factor shown in Table 6-11, and f_p is the parking turnover adjustment factor from Table 6-12.

Table 6-10. 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 6-11. 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.

Table 6-12. 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.

Once the BCI has been calculated, it is possible to determine the compatibility level and the level of service (LOS) using Table 6-13. 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.

Table 6-13.
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.

Example. Suppose that a current roadway has the following:

- No dedicated bicycle lane,
- A curb lane width of 3.2 m,
- 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 min, and
- 200 right turns per hour.

The improved roadway would have the same attributes except that a 1.2-m dedicated bicycle lane would be added; the curb lane width increased to 3.5 m; the parking turnover rate increased to 50 min; 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 6-8, the BCI for this facility was originally "extremely low" (LOS F), but with the improvements it would become "moderately high" (LOS C).

Data needs, assumptions, and limitations. Harkey's BCI requires data that are routinely available in planning or public works agencies. As the variable definitions 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.

Results and their 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. These maps can be overlaid on maps indicating the common activity space of protected populations. Roadway suitability ratings can also be used to identify preferred cycling routes; these routes can be compared to the same activity space. Collectively, 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 that serve protected populations.

Assessment. The BCI can be a useful technique for measuring and evaluating roadway conditions for cyclists in activity spaces frequented by protected populations. This rating system can be used to assess existing bicycle travel conditions and how a particular project or policy would affect these conditions. 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

An environmental justice issue is likely to arise when a road project increases the volume and speed of traffic through an area where pedestrians must cross the affected road. This method is a good means for assessing the ability of various types of pedestrians to safely cross a road. It uses a form of LOS rating to evaluate roadway crossing conditions for pedestrians that is 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. When changes are being considered for roadways that are frequently crossed by protected populations, environmental justice considerations dictate that every effort be made to make crossings as safe as possible. This method is a good way to assess how safe a crossing would be with and without pedestrian safety features.

Analysis. A logical method of assessing pedestrian LOS for street crossings is pedestrian delay. Wellar (1998) has suggested a rather basic rating system, shown in Table 6-14. 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.

Table 6-14. 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.

Data needs, assumptions, and limitations. 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 nonsignalized intersections, traffic speed and volume.

Results and their presentation. GIS can be used to produce maps that show 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 nonmotorized 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.

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. Pedestrian danger index

Conflicts with motor vehicles constitute one of the greatest safety hazards for pedestrians. Approximately 5,900 pedestrians are killed by automobiles annually (NSC 2003). Of all pedestrian fatalities, about 22 percent occur at intersections, as do approximately 44 percent of all pedestrian injuries (FHWA and ITE 2004). If a proposed transportation project would increase the factors that contribute to such incidents and if this would occur in an area of the community that is within the common activity space of protected populations, an environmental justice issue would need to be addressed. The pedestrian danger index is a basic method for assessing the danger that a roadway may pose to pedestrians.

When to use. This approach can be used to identify areas adjacent to a proposed project that are most sensitive to environmental justice issues with respect to pedestrian safety. Comparing pedestrian danger index values that pertain to the preproject situation with pedestrian index values based on estimates of the postproject situation will reveal areas where the project would compromise pedestrian safety the most. Postproject estimates are based on index values computed for comparable areas. Estimating the pedestrian danger index values requires pedestrian crash data, population data, and pedestrian exposure data. If reliable data for each of the three variables are available at an appropriate level (i.e., community, neighborhood), an index can be developed from data at that level and used to make relevant comparisons. The method can be especially helpful when a transportation project passes through multiple neighborhoods and there is a question as to where to focus available funds to improve pedestrian safety.

Analysis. The Surface Transportation Policy Project (STPP) that developed this method used it to measure pedestrian safety at the county level in California. The relative ranking of counties with respect to per capita pedestrian injuries was used as a method for identifying counties that are most hazardous to pedestrians. There is no conceptual reason why this method could not be applied at a much smaller scale of analysis.

The pedestrian danger index is determined by dividing the number of pedestrian injuries and fatalities in each area of analysis by the area's population and then dividing that number by a number representing the overall level of pedestrian activity in the area. The quotient is adjusted (normalized) to a scale ranging from 1 to 100, with 100 being the most dangerous (Ohland et al. 2000, p. 7). The steps in deriving the index are as follows:

1. Number of injuries/1,000 people = (pedestrian death and injury rate / population) x 1,000.
2. Pedestrian exposure rate = number of employed residents walking to work / Total number of workers.
3. Unadjusted index value = number of injuries per 1,000 people / pedestrian exposure rate.
4. Pedestrian danger index value adjusted to relative 1 to 100 scale = (unadjusted index value / maximum unadjusted index value within sample) x 100.

These values should be acquired for as many separate and comparable observational areas as possible. A proposed transportation project will usually pass through multiple areas for which corresponding pedestrian danger index values have been calculated. Index values for various areas affected by the project can be compared to determine the portions of the route that contribute most to the hazards faced by pedestrians in the vicinity. If data can be obtained for comparable areas in several different communities, a more meaningful assessment can be made of the relative pedestrian danger in the area under study.

The index values account for changes in population and pedestrian exposure; therefore, the index is a good measure of relative danger and can be used to compare areas with diverse land use and population density attributes. To determine how a project will impact pedestrian safety, it is necessary to compare current index values with index values that are calculated using projected pedestrian exposure data and projected pedestrian death and injury data. Projections are based on actual numbers collected from one area or (preferably) several areas where a similar project has been completed in the past. Note that pedestrian trip distance, area demographics, road geometry, and traffic volume should be reasonably similar; specifically, hazards created or relieved by the proposed project should be as similar as possible to those in other areas that are included in the comparative analysis.

Data needs, assumptions, and limitations. The first requirement for constructing a pedestrian danger index is collecting data from several areas for each of three variables. The first variable, as mentioned above, pertains to pedestrian injuries and fatalities. The STPP researchers, for example, procured these data from the California Highway Patrol. The second variable, area population, can be obtained from census files (e.g., block group data). The third variable, pedestrian exposure rate, is estimated using census data pertaining to the variable "journey to work." Specifically, the category of this variable that reflects the number of people walking to work divided by the total number of workers. This pedestrian exposure rate may be regarded as a reasonable surrogate for overall levels of pedestrian activity (Ohland et al. 2000, p. 7). Of course, the more observational areas that are included in the analysis, the more valid the findings will be.

Results and their presentation. The pedestrian danger index is a method that can be used to approximate changes in the level of pedestrian safety that would result from a proposed transportation project and can be couched as a way to determine which portion of the proposed project should receive the most attention with respect to pedestrian safety. The benefit of the measurement is that, once calculated, it is an intuitive and concrete measurement that people can easily understand. It is important to present demographic information identifying protected populations along with the pedestrian danger index. This can be done by overlaying census block group scores for the pedestrian danger index on appropriate demographic data (relative presence of minority populations and low-income populations). When planning the proposed transportation project, particular attention needs to be devoted to locations with relative concentrations of protected populations and especially great dangers to pedestrians.

Assessment. This method is a practical way of creating a relative measurement of hazard to pedestrians for various geographical areas. The method offers flexibility in terms of application—the index can be applied as a comparison between counties, communities, or neighborhoods, depending on the nature of the data being used. Collecting data that are consistent in scale and scope is crucial to the successful application of this method. For example, data collected on pedestrian deaths and injuries in Community A must be collected according to criteria similar to those used for Community B.

The main limitation of the method is the availability of data on pedestrian crashes and pedestrian exposure. The acquisition of quality comparison data will, in effect, determine the quality of the overall method. Also, the comparison areas used to develop the postproject pedestrian danger index projections should match the study area in two important ways. First, and most importantly, the demographics of the residents, and hence the degree to which the area provides residence to protected populations, should be similar. Second, the nature of the completed transportation project that serves as a comparison should closely resemble the proposed project being analyzed. These two conditions can be difficult to meet, which constitutes the most serious limitation of the method.

Method 8. Barrier effect analysis

The negative effect that highways and vehicle traffic can have on nonmotorized 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.

When to use. The goal of a road upgrade is generally to move increased volumes of traffic at higher speeds. A consequence of faster and heavier traffic, however, may be that pedestrians and cyclists have increased difficulty crossing the roadway. In an area that constitutes the activity space of protected populations, this reduction in mobility can constitute an environmental justice problem. In locations where substantial pedestrian and nonmotorized transportation crossings occur, this method can be applied to assess the change in crossing difficulty that would result from a proposed upgrade.

Analysis. Rintoul (1995) suggests three steps to quantify the barrier effect described in turn below:

Step 1 – Calculate barrier size. Calculate the barrier size 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 – Calculate crossing potential. Calculate the demand (i.e., crossing potential) for road and street crossing based on the number of residential, commercial, recreational, and municipal destinations within walking and bicycling distance of the road. The resulting estimate represents the maximum possible number of nonmotorized 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).

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

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 6-15

Continuing our example, let the population density be 741 persons per square kilometer and the population age distribution be as shown in Table 6-16. Then the crossing potential can be obtained from Table 6-15.

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

Table 6-15. 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.

Table 6-16 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 6-16. 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. Calculate disruption site. 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 – percent 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 use of controlled crossings is 30 percent, so the adjustment factor is 1 – 0.30 = 0.70. Using this estimate, the total disruption is displayed in the far right column of Table 6-17. 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 6-17. Total disruption per kilometer 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

Data needs, assumptions, and limitations. A barrier effect analysis requires routinely available data. 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.

Results and their presentation. The results of a 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 of 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 would result from a proposed transportation system project. Two key assumptions contained in the analysis 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 to perform sensitivity analyses 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.

Method 9. User demand and evaluation surveys

User demand and evaluation surveys are helpful in gathering 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.

When to use. This method is appropriate when you need to 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 for evaluating bicycle and pedestrian conditions.

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 nonmotorized 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?

For purposes of environmental justice assessment, it is necessary to collect information on the demographic characteristics of the survey respondents. Suggested questions are provided in Chapter 2.

Data needs, assumptions, and limitations. 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).

Results and their 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., nondrivers, 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.

In an environmental justice context, user demand and evaluation surveys can be carried out to estimate the specific effects a particular project would have on protected populations. These surveys also can be used to assess problem areas and the efficacy of possible improvements.

Assessment. User demand and 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 for facilitating 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

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 nonmotorized transportation. The ratings take into account the existence of separated facilities, conflicts, speed differential, congestion, maintenance, amenities, and traffic demand modeling (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 nonmotorized travel behavior were incorporated into the model. This article should be useful to planners and modelers who might want to incorporate nonmotorized 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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CHAPTER 7. TRANSPORTATION USER EFFECTS

OVERVIEW

Transportation system changes generally benefit users by reducing travel time, improving safety, and lowering vehicle-operating costs. A transportation system change may also improve the choices available to travelers by offering them different routes or modes of travel at different times of the day. A change can also increase the number of accessible destinations. In terms of environmental justice, the point of interest is the extent to which minority populations or low-income populations would experience these benefits.

To understand the distributive effects that would result from a potential transportation project, it is first necessary to examine the performance of the existing transportation service, including how this service varies between members of protected populations and others. Then, a reasonable comparison can be made between the existing service and the new service that would result from a system change. In general, system performance may be measured by the volume-to-capacity (V/C) ratio and by the accessibility of destinations that the affected populations consider important. Thus, the methods presented in this chapter focus on changes in accessibility and changes in transportation choice.

Geographic information systems (GIS) are capable of combining and analyzing layers of data about a location and thus are well suited for analyzing distributive effects. A detailed account of applying GIS mapping as part of an assessment is provided in Appendix C. GIS will also be the major method used to assess changes in transportation choice.

Accessibility

Accessibility is the ability to reach desired destinations. It is related to, but different from, mobility, which is the ability to move. If a population group has limited mobility (e.g., people with low incomes may be less likely to own automobiles), achieving accessibility will require a residential location that is near places where essential activities are conducted, such as work, school, shopping, worship, child care, social services, and recreation.

In general, accessibility has two main components: (1) the physical ability to reach a desired destination and (2) the degree of difficulty in reaching it. If a destination can be reached, travel time is the measure most often used to assess the difficulty or ease of reaching it. Travel time is greatly affected by the level of congestion on road segments; by how directly the road system connects trip origins and destinations; and by the standard and condition of applicable road segments.

In our analysis of accessibility, we treat vehicle operating costs as a function of travel time, even though a more engineering-oriented approach would take into account pavement surface quality and related variables when evaluating road segment performance. Our primary focus is on travel demand analysis that is specific enough to assess differential effects on protected populations versus travelers in general. We are aware, however, that the process of developing more refined and accurate measures of system performance continues. More comprehensive evaluation models are currently being developed, and some will be operational soon. Thus, we also provide a brief overview of future generation, activity-based techniques for assessing road system performance and accessibility.

Transportation choice

Closely related to accessibility is transportation choice, which refers to the quantity and quality of transportation options available to residents of an area. Most communities have transportation systems that are strongly auto oriented. Very few options are available for those who either prefer an alternative mode or are not able to travel by auto. Because public transportation planning is beyond the scope of this guidebook, we focus on pedestrian travel as well as non-motorized transportation, particularly bicycling.

It is not unusual for a road project to affect, either positively or negatively, the ability of people to use other transportation modes. More specifically, there are at least four reasons why 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 auto, and so may face barriers to mobility in auto-dependent communities.
- **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. Many 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 in the selection of modes that need to be examined. A key element in environmental justice is to ensure that protected populations have mobility that is comparable to that of other populations; this often means that transportation modes other than the auto must be available.

New or upgraded transportation facilities may affect the viability of alternate transportation modes in three major ways:

- **Upgrading roads can increase vehicular traffic.** Heavily traveled roads are more likely to be dangerous, difficult to traverse, and unpleasant for those traveling via something other than a motor vehicle. As traffic increases, so does the risk to bicyclists and pedestrians, and some who might have chosen to walk or ride a bicycle before 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 nonmotorized 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 nonmotorized 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.

STATE OF THE PRACTICE—ACCESSIBILITY

Travel demand modeling is the primary tool for assessing the ability of people living within a particular area of a community to travel to desired destinations. This mode of analysis has been dominated over the years by trip-based models that use a four-step procedure for analysis consisting of (1) trip generation, (2) trip distribution, (3) mode split, and (4) traffic assignment. These models often do a good job of replicating aggregate travel patterns. However, they are limited in their ability to account for the attitudes, values, and constraints that determine travel patterns by the general population, much less specific groups such as minorities or those with low incomes.

Activity-based approaches attempt to take into account the interdependences in trip decisions made by groups of individuals. These approaches generally are flexible enough to consider the way household members allocate and share resources and tasks among themselves, and jointly share activities that are dispersed in time and space. In other words, activity-based approaches can be more realistic for the purposes of analyses related to environmental justice (see RDC, Inc. 1995).

Nevertheless, four-step travel demand modeling is a very useful tool for gauging road system performance—an essential part of assessing transportation user effects. Thus trip-based models can serve an important role in providing a preliminary analysis of the likely impact a proposed transportation change would have on accessibility by low-income populations and minority populations.

Trip-based models

The trip-based approach is founded on several assumptions:

- The number of trips generated by a household is a function of household size (number of members) and the number of vehicles available.

- Individuals always make optimal decisions with respect to their travel arrangements; in other words, an individual can identify and pursue the travel option that would take the least time on any given occasion.
- Destinations attract trips on the basis of distance from the trip origin and attributes such as size and attractiveness.
- Changes in travel costs to the traveler, such as parking fees and effects of congestion on travel demand, are not usually taken into account. The latter means that these models are not typically sensitive to travel time analysis; literally the assumption is made that trip demand is inelastic with respect to higher costs arising from congestion.

Trip-based models present two concerns: (1) nonmotorized transport is not usually taken into account and (2) the models lack sensitivity to chained trips. Chained trips are those that involve multiple stops en route to a destination. These trips are of particular significance when considering project impacts on low-income and some minority populations who may rely on networking more than others for purposes such as child care. By treating trip segments independently, trip-based models fail to reflect that trip decisions made by individuals often are interrelated.

On the other hand, the advantages of trip-based models stem from their simplifying assumptions, which allow for the development of standard analysis packages, such as TransCAD, TRANPLAN, and the Urban Transportation Planning System (UTPS) and which make the forecasting procedure affordable to most metropolitan planning organizations (MPOs). The data requirements of trip-based models are less than for activity-based models. Indeed, the simplicity and lower data requirements of these models can be appreciated when making a preliminary assessment of the impact of a transportation project on travel time or congestion levels.

Activity-based models

In general, activity-based models are still in the developmental stage, but it is likely that they will see increased application in the near future. Testing of early versions of these models has revealed that travel demand forecasts can be developed to treat daily travel patterns in their entirety without breaking them down into individual trips. This is important because attempting to reduce travel to individual trips tends to compromise the interdependencies and continuities that exist across the series of trips made by a given traveler.

The testing to date also indicates that activity-based models will be able to predict travel behavior along a continuous time axis and to evaluate specific transportation system changes, such as the impacts of daycare facilities at work, extended transit service hours, or changes in transit lines on travel patterns and demand.

Travel Model Improvement Program (TMIP) is developing the Transportation Analysis and Simulation System (TRANSIMS), an integrated system of travel forecasting models that includes a population synthesizer, activity generator, route planner, and traffic microsimulator. The system seeks to create a virtual metropolitan region with a completely disaggregated representation of the population. TRANSIMS simulates the movement of individuals and vehicles across the transportation network using multiple modes. The system can forecast how changes in transportation policy or infrastructure might affect individual trips by time of day. In addition, the model is capable of evaluating impacts on different subpopulations, such as minorities and low-income groups, because it simulates individual travelers, taking into account their demographic characteristics.

Highway economic requirements system (HERS) model

The Highway Economic Requirements Systems (HERS) model allows you to examine the issue of accessibility from a different perspective than that afforded by the exclusive use of travel demand modeling systems. It gives you the opportunity to assess environmental justice concerns based on the actual and forecasted performance of the road segments used most frequently by protected populations. Performance can be measured in terms of average vehicle speed. The recent innovation of making an interface between HERS-ST (State) and TransCAD makes it possible to analyze the travel experience of members of protected populations as they move between traffic analysis zones (TAZs), particularly for trips to work, school, child care facilities, and other social services, and recreation. The focus here is on the use of HERS at the state level because many MPOs will be using it increasingly for routine analysis of travel behavior.

METHODS FOR STUDYING ACCESSIBILITY

Table 7-1 summarizes the methods for studying accessibility that we present in this chapter.

Before conducting an in-depth analysis of how a transportation project might affect accessibility for protected populations, it makes good sense to conduct a preliminary assessment. This assessment should be simple and should use an off-the-shelf method of analysis. The most efficient approach would be to apply the travel demand model already in use within the agency.

Method 1. Unmodified transportation demand models

As discussed earlier, transportation planning agencies commonly use four-step travel demand (TD) models, which are capable of measuring travel time between TAZs under varying traffic conditions. By comparing travel time estimates before and after modeling a project’s characteristics, changes in travel time can be assessed. This method is a useful indicator of a project’s impact on trip costs, level of accessibility, and transportation choice.

When to use. Standard TD models can be used to obtain a preliminary assessment of changes in travel time or V/C ratios affecting TAZs with relative concentrations of protected populations. This assessment allows you to determine the likelihood that a project would improve or worsen environmental justice within the community by changing the relative accessibility of areas within the activity space of protected populations.

Analysis. The starting point for determining the existence of an environmental justice problem lies in identifying those TAZs in which a high proportion of members of protected populations reside. In the analysis, these TAZs will be considered as the origin of travel. Likewise, TAZs that are the common or primary destinations for these special populations are identified, including job and shopping centers, social service agencies and providers (including daycare centers), and schools.

Table 7-1. Summary of methods for studying accessibility					
Method	**Assessment level**	**Appropriate uses**	**Use when**	**Data needs**	**Expertise required**
1. Unmodified transportation demand models	Screening	Estimate travel demand (TD) between TAZs	The project will impact travel demand patterns	Medium	Standard travel demand modeling; census data analysis
2. Adapted transportation demand models	Detailed	Estimate travel demand (TD) between census tracts	The project will impact travel demand patterns and protected population distribution is uniform within census tracts	Medium/ High	Standard travel demand modeling; census data analysis
3. Advanced adapted transportation models	Detailed	Estimate travel demand (TD) between census blocks	The project will impact travel demand patterns and protected population distribution is not uniform within census tracts	High	Standard travel demand modeling; census data analysis
4. HERS-ST model	Screening/ detailed	Estimate traffic congestion and/or travel cost	The project will impact travel cost for protected populations	Medium	HERS-ST application; TransCAD
5. Activity-based travel simulation	Detailed	Estimate traffic congestion and/or travel cost	Detailed, dynamic analysis of traffic patterns is required or for large or high-impact projects	High	Advanced modeling tools and techniques
6. Transportation analysis and simulation system (TRANSIMS)	Detailed	Estimate traffic congestion and/or travel cost	Detailed, dynamic analysis of traffic patterns is required or for large or high-impact projects	High	Advanced modeling tools and techniques

The transportation demand model is first run with the data that characterize the current transportation system. The results, either travel time or V/C ratios of road links between TAZs, are recorded. The next phase of analysis involves running the model again, but this time with the data that embody the intended transportation project. The focus, as before, is on the times or V/C ratios for travel between principal origin-destination (O-D) pairs by protected and other groups.

Data needs, assumptions, and limitations. The data requirements for analyzing differences and changes in travel time and V/C ratios consist of demographic data such as:

- Household size;
- Number of persons in household of working age;
- Household income and availability of vehicles;

- Nonresidential land use data that include number of employees, floor area, and retail sales;
- Zone data such as population density and distance from central business district or other business centers; and
- Data about designed highway capacity.

Departments of transportation collect most of these data in the course of building TD models. As mentioned previously, TD models are based on simplifying assumptions that do not accurately depict factors such as trip-chaining, and so are limited in their ability to account for the relationships at work in human travel behavior patterns. Moreover, the results may be significantly skewed by estimates of economic activity, land use, and people's propensity to travel, all of which are approximated in the model.

Results and their presentation. Whether using travel time or V/C ratios, a comparison is made of the results obtained on trips between origin and destination TAZs for protected and other populations under existing conditions of the network. If the comparison reveals that travel times or V/C ratios related to protected populations are typically greater than for other groups, it may be concluded that low-income and minority groups are most likely carrying a disproportionate burden of transportation-related costs; and therefore an environmental justice problem may exist. Of course, if there is no significant difference, there is probably no environmental justice problem. One note of caution in presenting the results: because of the aggregate level at which the analysis is conducted and the difficulty of definitively knowing which road segment(s) were used, you would only be able to say, for example, "About 95 percent of trips from zone 1 to zone 2, representing protected population groups, experienced a reduced/increased travel time or V/C ratio." This percentage is based on the proportion of the population in zone 1 who are members of protected groups.

Assessment. Caution should always be used in drawing conclusions from the results of this type of analysis because of the underlying simplifying assumptions with respect to the factors that influence the choice of mode, the impact of various public policies on people's travel patterns, and the relationship between land use and mode choice, among others. In short, the results should be viewed as crude and should be interpreted as indicating only the likelihood of an environmental justice problem even when the magnitude of the changes in travel time or V/C ratios is significant. In such a case, a more detailed analysis is required.

Method 2. Adaptation of transportation demand models

By making use of TAZs, TD models allow you to take advantage of the demographic data contained within them to enhance the analysis. TAZs typically are aggregations of census tracts and may be redefined based on the presence of protected populations within zones before the model is run.

When to use. These models are appropriate when the preliminary analysis indicates that a more accurate method of estimating changes in travel-time costs is needed. Though more costly in terms of time necessary to redefine TAZs, this remains a relatively inexpensive method because it does not require new computer software. This method is suitable for small- to medium-sized projects.

Analysis. The first step in redefining TAZs is to identify which zones contain the residences of members of protected groups. The second step is to dissect TAZs into units that are smaller groups of census tracts based on the relative presence or absence of protected and other populations. TAZs should be configured so as to be as homogenous as possible in terms of income and/or race. The third step is to identify the destination TAZs to which households of protected populations are routinely attracted, such as job and shopping centers, social service agencies and providers (including daycare centers), and schools.[1]

The transportation demand model is first run with the data that characterize the current transportation system and the travel times on road links between origin and destination TAZs. The next phase of analysis involves running the model again, but this time with the data that characterize the intended transportation project. As before, a record is made of travel times between principal origins and destinations by the respective kinds of groups.

Data needs, assumptions, and limitations. The data required for this analysis are the same as for other routine analyses using the TD model. This includes demographic, nonresidential land use, zone, and road data as mentioned in the description of the preliminary assessment method. Again, departments of transportation routinely collect most of these data in the course of building TD models. The limitations are the same as with the unmodified TD models; the simplifying assumptions that the models are based on leave out factors such as trip-chaining and so are limited in their ability to account for relationships among travel behavior patterns. As with unmodified models, results may be skewed by estimates of economic activity, land use, and people's propensity to travel, all of which influence the model.

Estimating travel-time savings is a challenge because of the significant issues involved in attaching economic value to travel time. Researchers have yet to agree on the following:

- What fraction of the wage rate should be used for work-related travel.
- What fraction of the work-related travel rate should be used for personal or nonwork-related travel.
- What fraction of a driver's hourly time value should be assigned to passengers in the vehicle.
- Whether a lower time value should be used for commuting trips that are shorter than the common travel-time budget (i.e., the amount of time people are willing to spend journeying to and from work) and a higher value for the time increments that exceed this budget.

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[1] TIGER/Line data based on the 2000 census are currently available from the U.S. Census Bureau regarding the location of employment centers (including shopping and major retail centers; industrial buildings/parks; office complexes/parks; government centers; and major amusement centers), educational and religious institutions, and transportation terminals.

- Whether the same time value should be applied for very short periods of time saved (e.g., 30 seconds) as for longer periods (e.g., over 5 minutes).
- How to take into account variation in time en route and hence unreliability of arrival time.
- How to include changes in travel time for pedestrians, cyclists, and others using nonmotorized transportation modes.

Completely overcoming these challenges is beyond the scope of this guidebook. The choice of method used to estimate travel-time savings is influenced primarily by how much detail is perceived to be necessary to make a decision about a project alternative. For many small projects, the preliminary assessment described earlier using travel demand models will prove adequate. For more extensive projects, or those where a reasonably strong likelihood exists that the benefits and costs of the project may raise questions of equity, a more accurate and detailed estimation of travel-time savings is needed.

Results and their presentation. The travel times obtained on trips between origin and destination TAZs for protected populations are compared with those for other populations under existing conditions of the network. The analysis is then repeated with the transportation improvement in place. As in the preliminary assessment, if the comparison reveals that travel times of protected populations tend to be significantly higher than those of other groups and that the project would do little to reduce the disparity or even worsen it, the conclusion may be drawn that an environmental justice problem currently exists. As in the case of the preliminary assessment, the results should be presented in terms of trips originating in each applicable TAZ in comparison with all TAZs.

Assessment. Although the results acquired using this method reflect a greater degree of accuracy than the preliminary analysis, it too is quite aggregate. As such, it can provide a general sense of the extent to which travel times to important destinations would improve or worsen for protected populations. It also can be used to compare such changes with those of travelers in general. If unfavorable results emerge relative to environmental justice, more detailed analyses will be required.

Method 3. More advanced adaptation of transportation demand models

This method is an advance on the previous one and disaggregates the applicable TAZs using census-block-group data instead of tract data. As before, the TAZs are redefined based on the presence of protected populations within zones before the model is used to determine travel times between analysis zones.

When to use. This method is appropriate when a more accurate assessment of changes in travel time is needed than that afforded by the preliminary analysis or tract-level analysis. This method will be more costly because the tract data have to be replaced by block-group data. The method is suitable for small- to large-scale projects and is particularly useful for achieving relatively high accuracy in determining the probability of an environmental justice problem using TD models.

Analysis. To redefine and prepare the TAZs for use, the four steps outlined in the previous method are followed, but with block group data as the basis. Care must be taken to ensure that the TAZ geometry matches the network geometry. As before, the TD model is first run with the data that characterize the current transportation system and the travel times on road links between origin and destination TAZs, then run again with the data that characterize the intended transportation project.

Data needs, assumptions, and limitations. The data required for this analysis are essentially the same as for other routine analyses using the TD model with the exception that the demographic and nonresidential land use data are at the census block group level instead of the census tract level. Census block group data, including those on population density, can be downloaded from the U.S. Census Bureau Web site; zone and road data are the same as mentioned in the description of the previous assessment method. Departments of transportation routinely collect data for modeling in the course of building TD models. The same limitations described previously affect the reliability of results for this approach.

Results and their presentation. The travel times obtained for the trips between origin and destination TAZs for protected populations are compared with those from other populations under the existing network conditions. As in the preliminary assessment, if the comparison reveals that travel times of protected populations are consistently significantly higher than those for other groups, then low-income and minority groups are likely carrying a disproportionate burden of travel time costs; and therefore an environmental justice problem exists.

Assessment. These results are about the most accurate that can be obtained using a traditional TD model. Nevertheless, they still represent a probability of occurrence, even though we may express it with greater confidence. This level of confidence may be adequate for most small- to medium-sized projects, but larger projects and highly sensitive projects may require the use of a of model that provides an even higher level of accuracy.

Method 4. HERS-ST model

Aggregate models, such as the HERS model, often are less expensive to use than more disaggregate models. Much of the necessary data for these models is routinely collected and updated by states and maintained by the FHWA in the Highway Performance Monitoring System (HPMS) database.[2] The HPMS database does not, however, routinely include data on urban and rural local roads, nor on rural minor collectors, as indicated in Figure 7-1.

These categories of roads are important in assessing environmental justice concerns because low-income populations and minority populations are likely to use them, and their performance would have an impact on travel costs for these protected populations. The data problem is partially resolved by HERS-ST, which treats the performance of these roads in terms of changes

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[2] The FHWA and the states, beginning in 1978, jointly developed and implemented a continuous data collection system called the Highway Performance Monitoring System (HPMS). Currently, the HPMS contains more than 110,000 sample sections, the most comprehensive nationwide data system available regarding the physical condition and usage of the nation's transportation infrastructure.

in vehicle speed or level of congestion in one of the submodels. Figure 7-2 is a graphic representation of the HERS model.

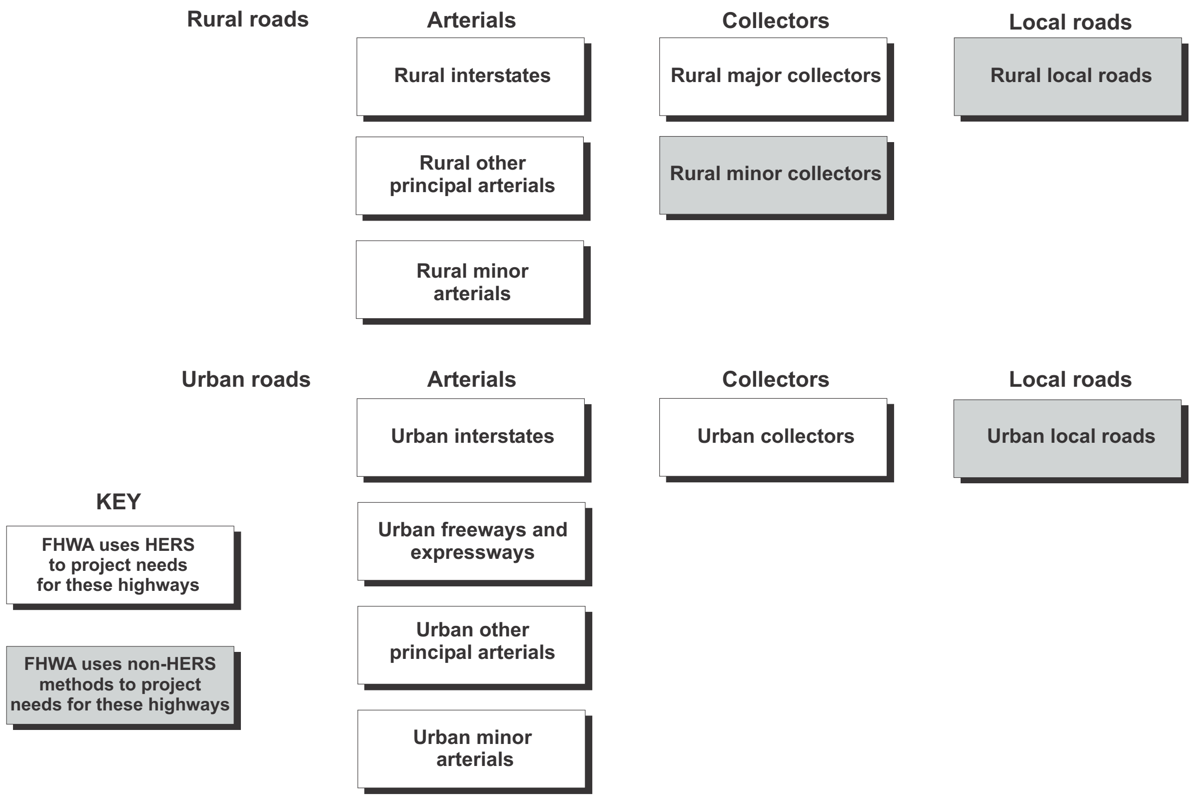

Figure 7-1. FHWA's road classification system

Source: U.S. General Accounting Office 2000.

It is important to note that an interface can be created between HERS-ST and TransCAD. This enables you to identify those segments of the road network, including the urban and rural roads that are most likely to be used by members of protected populations. These segments often represent the probable routes between the origin TAZs and destination TAZs for the most essential trips made by such populations. The TAZs may be defined using either census tract or block-group data, but using the latter provides more detailed and accurate information, as noted earlier.

When to use. The HERS-ST model is best suited to estimating changes in average vehicle speed or levels of congestion, as it takes into account factors such as traffic volume, pavement condition, and lane width. When this capability is coupled with the GIS-based TransCAD, the model becomes a reasonably accurate measure of how the existing road network affects protected populations and how the intended improvements will alter that. Of course, additional costs are incurred with this increased proficiency and must be weighed against the size, cost allocation and social and political significance of the project.

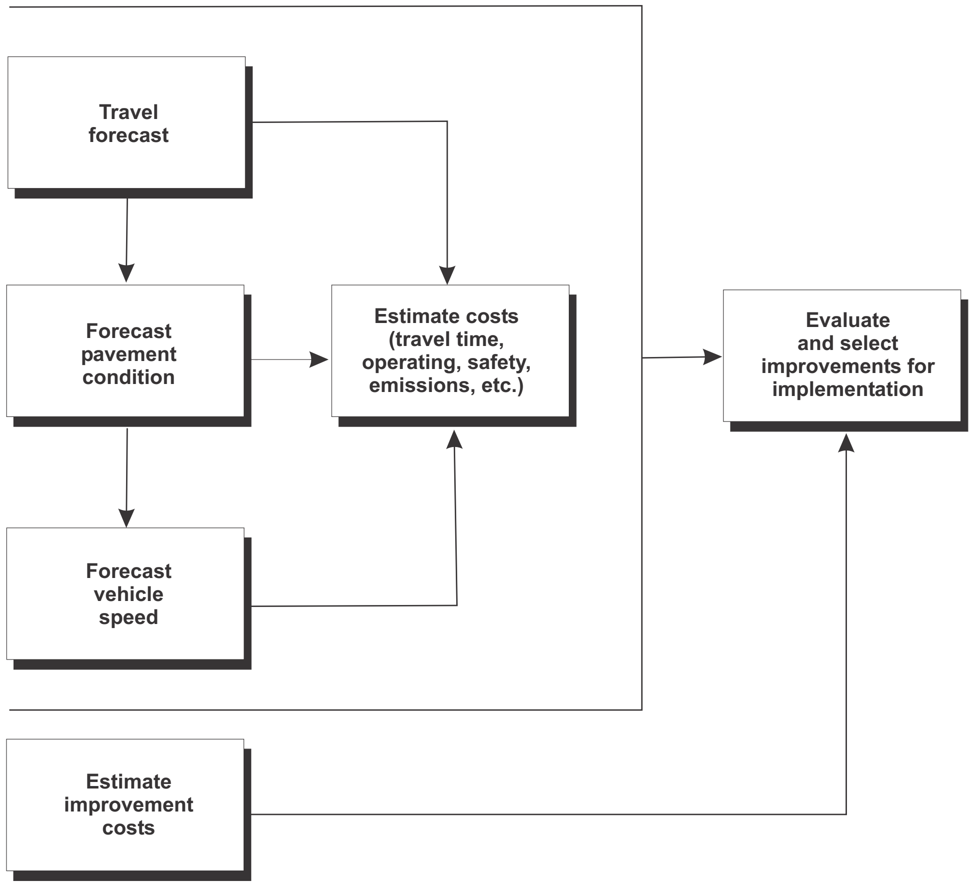

Figure 7-2. Simplified representation of the HERS model
Source: U.S. General Accounting Office 2000.

Analysis. In the data analysis of urban and rural local roads and rural minor collectors, HERS-ST clumps together lower rural classified roads with rural major collectors and lower classified urban roads with urban minor collectors. In this approach, the derived output information on these roads is separated from the rest prior to reporting. Another approach would be to analyze the lower classified roads separately from the rest of the system once the induced deficiency and cost data are appropriately adjusted prior to conducting the analysis. As in the methods using travel demand models, defining the TAZs at the block-group level is an option, but if the choice is made to redefine them, every effort must also be made to ensure that each TAZ's geometry matches that of the road network. In addition, the interface with TransCAD provides data on the volume of traffic traveling on each road segment, which it tags with a unique identifier. This identifier is what makes it possible for TransCAD to interface with HERS-ST, and the traffic volumes relayed to the HERS model via this mechanism are incorporated into its computations.

HERS-ST consists of a number of submodels with the output of one becoming the input for another (U.S. General Accounting Office 2000). The travel forecast submodel projects traffic growth, and it utilizes current traffic volume data, along with data related to the cost of travel—travel time, safety, and vehicle operating costs—and combines them with the state's projection of traffic growth and with a measure of the price elasticity of travel demand. The output of this sub-model is the input to the pavement condition submodel and, subsequently, the vehicle speed sub-model. Thus, the change in average vehicle speed is an important measure because it not only reflects changes in the volume of traffic and associated congestion, but also the quality of the road surface, which is subject to wear-and-tear effects. Furthermore, changes in average speed, which can be measured for each road segment, including those most frequently used by protected populations, are key to assessing whether an environmental justice concern exists. The model begins by assessing the current condition of the highway segments in the data sample. Average speeds under existing conditions may be first compared with those for segments used by members of other groups, followed by a similar comparison of forecasted values that reflect expected changes that would result from the intended project.

Data needs, assumptions, and limitations. HERS-ST requires data on average annual daily traffic (AADT), highway capacity, pavement condition, and lane width. Most of these data are also readily available from the HPMS database. Moreover, HERS-ST provides the option to substitute more accurate local data, where feasible. Additional effort will be needed to gather more specific data on urban and rural local roads, as well as on rural minor collectors. If the decision is made to redefine the TAZs in TransCAD using data at the block group level, the applicable data must be obtained from census files.

This model assumes that the forecast for each road segment represents the level of use that will occur if a constant level of service is maintained on the segment. There is also an implicit assumption that the model captures the net effect of all changes in the transportation network and the economy through its assumed price elasticity of travel demand. In addition, the model assumes that all roads face the same weather conditions. Some of these assumptions give rise to the model's limitations, which are stated below (U.S. General Accounting Office 2001).

- Because it analyzes each road segment independently rather than the entire network as a whole, it does not completely account for the interrelationships between all segments and different transportation modes (e.g., how traffic is redistributed as improvements are made).
- It does not fully account for the uncertainties associated with its methods, data, and assumptions. For example, the model uses the price elasticity of demand for travel to incorporate information on how changes in vehicle user costs affect travel; there is thus an implicit assumption that the model captures the net effect of all cost changes in the transportation network. The overall economy is thus assumed to remain constant because its condition affects consumer choice.
- The accuracy of estimates generated by HERS-ST is uncertain because the model uses data that vary in quality. For example, the state-supplied data on pavement roughness vary significantly in quality because different states use different devices and approaches to measure it. In addition, some data used in the model, such as pavement resurfacing costs, are usually outdated. Users may exercise the option of using more accurate, local construction data.
- The model uses information to project the future condition of the road pavement, which does not take full account of environmental conditions that affect highways. For example,

the assumption is made that all road segments experience freezing and thawing conditions, while this is not the case in the warmest parts of the country.

Results and their presentation. Changes in average speed on the various road segments are generated by the model and may be displayed in tabular form or reflected in maps generated by TransCAD, which receives the output of HERS-ST via a routing system and dynamic segmentation process. Maps can also be used to display the location of the intended improvements to in-house staff or to policymakers.

Assessment. The HERS-ST model differs from the national-level HERS model in significant ways that can be an asset to the analyst. First, it allows the user to override some or all of the improvement decisions generated by the model. For example, users can specify the type of improvement they see fit for any segment of the highway in any funding period, whether or not the specified improvement is economical. FWHA contends that this capability gives users the opportunity to apply specific knowledge of a particular condition. Second, as implied earlier, the HERS-ST can analyze more classes of roads and provide a higher level of detail in its results with respect to every segment analyzed. Third, this model permits the substitution of more relevant state data for national-level data so that local conditions may be modeled more accurately. Finally, this model provides the user with the option of analyzing a statistical sampling of highways drawn from the HPMS database or analyzing all segments of the state's road network.

Method 5. Activity-based travel simulation

A new set of travel forecasting and analysis procedures based on travelers' daily activity patterns is being encouraged under the TMIP. TMIP is an attempt to satisfy the need for more accurate and sensitive travel forecasts and to facilitate better-informed decision making on transportation matters. Activity-based simulation models of human activity and travel behavior contain several modules. These modules enable the researcher to combine stated and revealed preference data along with baseline activity patterns, network and land-use data, and socio-economic and demographic data. Not only does this type of model check the network data for logical consistency and missing information, it also assesses whether a modified travel pattern is feasible, based on a human adaptation and learning module.

Behavioral responses are captured by the statistics accumulator within the evaluation module, which provides descriptive and frequency statistics about vehicle miles traveled, number of trips by mode and time of day, number of stops by purpose, trip chains, vehicle occupancy, and travel times by trip purpose, among other classifications. Because this micro-simulation approach does not rely upon over-simplifying assumptions, it does not reduce the complexity and realism of the response and adaptation patterns of the travelers being modeled. As a result, the model is capable of providing highly accurate analysis of travel-time savings compared to most currently available models. As might be expected, this improved accuracy comes at a relatively higher cost. Further detail on this sort of model may be found in RDC, Inc. (1995).

When to use. Activity-based simulation is most appropriate when the project to be implemented is costly. It also is suitable when a relatively high level of precision is needed to determine the travel-time savings that would occur in various areas of the community if the project were implemented.

Analysis. One significant advantage of this type of model is that it permits a dynamic, longitudinal analysis of travel behavior, as opposed to the static, cross-sectional analysis afforded by the traditional four-step demand models. This means not only that behavior is examined over a continuous time frame but also that impacts originating within and outside of the transportation system can all be evaluated together. As a consequence, people's entire daily itinerary is the focus of analysis, rather than individual trips. In addition, whereas evaluation has traditionally been based on capacity and level of service, this approach evaluates the impacts of transportation policy measures and projects based on time-use utility, which is represented by the daily time-use patterns of the target population.

Data needs, assumptions, and limitations. Because this type of model focuses on the entire daily itinerary of travelers, it requires considerably more data than traditional models, a factor that contributes significantly to its running costs. In addition, it uses response data that must be gathered by means of a survey. Thus, the magnitude of potential benefits from its use should be carefully weighed against the costs. Nonetheless, many of the data requirements are similar to those of four-step models and may be obtained from most MPOs. These include data on TAZs, including network system and travel time, mode choice, trip distribution, and land use inventory. Demographic and socio-economic data by TAZ, such as household size, vehicle ownership, income, and race (white and nonwhite categories) are also needed and may be obtained from the Census Bureau. Original data needed include information from trip diaries for the revealed preference analysis.

If the project being evaluated requires a change in TDM strategies, the type and characteristics of these strategies can also be input. To do this, however, a survey must be designed to collect stated preference data in the form of potential responses to the anticipated impacts or policy changes. The same survey can also be used to gather information to complement that received from trip diaries, such as tradeoffs between parking costs and walking distance.

Activity-based simulation models are based upon the assumption that travelers engage in "satisficing" behavior (making appropriate choices with limited information), as opposed to always making optimal decisions or decisions that always maximize their utility in the purest understanding of the concept, as is typically assumed in traditional models. This satisficing assumption more appropriately reflects the reality of day-to-day living in a world where individual travelers do not have perfect information of events and concerns that affect their decision making. In other words, most travelers often make decisions with the intention of "making do" with the current circumstance, and this will be reflected in random or stochastic travel behavior because factors and constraints will affect persons differently. Moreover, the model assumes that the marginal utilities of travel vary across people, modes, and environmental conditions encountered, and that route choice preferences vary according to socio-economic characteristics and perceptions of individuals. Both of the latter assumptions impact the individual's valuation of time and allow for the differential analysis of travel-time savings across income and racial groups. The model's limitations derive from the fact that it is still in development.

Results and their presentation. Activity-based models can be configured to generate descriptive statistics, and they are also capable of carrying out statistical tests and providing statistical analyses in the form of response distributions. They can also cross-classify these response distributions against socio-economic and demographic variables, which allows a level of disaggregation that facilitates the application and assessment of environmental justice criteria. Detailed results can be presented in tabular and graphical formats that are easy to comprehend.

Assessment. This form of model has many capabilities and has the potential to provide accurate analysis of investment and demand management policies. The level of financial and technical support that the FHWA has devoted to this process reflects its commitment to fully developing activity-based simulation models and making them widely available. A major benefit of this form of model is its potential for giving relatively accurate valuations of travel time savings. A certain expertise will be required to design a survey instrument capable of eliciting the necessary information. The goal should be to make questions as simple as possible and yet clear enough to obtain the required data. One approach to such a survey design is that used in the Adaptive Stated Preference survey instrument (Richardson 2001, p. 13). Of course, all survey questions should be pilot-tested to ascertain whether the target population is able to comprehend them fully. Realistically, it is highly unlikely that an agency would develop so ambitious a model solely for assessing environmental justice implications of a project. Rather, this type of model is most likely to be developed to meet an agency's general needs for travel demand analysis. In such a case, it is feasible to enhance the modeling effort to provide a first-rate capability to evaluate the environmental justice effects of almost any significant transportation project.

Method 6. The Transportation Analysis and Simulation System

The TRANSIMS is an activity-based travel demand model that functions as six integrated modules, along with a feedback selector/iteration database. The feedback mechanism is the primary modeling tool as it functions to achieve consistency among the various computational modules (Los Alamos National Laboratory and Price Waterhouse Coopers 2002, p.3). This mechanism is critical to simulating decision/choice responses of individuals to events such as accidents, closure of a segment of highway, or interruption of transit service that occur directly within the transportation system; it is also helpful in evaluating policy alternatives that affect the use of an entire transportation system, even though the policy may be targeting a particular segment of the system. TRANSIMS simulates the movement of individuals and vehicles across the transportation network and can also forecast how changes in transportation policy or infrastructure might affect individual trips by time of day. The results of the simulation are aggregated only after the activities have been set, the trips routed, and the entire set of individual trips simulated in the presence of all other travelers. Because of this capability, TRANSIMS promises a substantially expanded scope of analysis along with improved analytical ability, particularly when evaluating the impacts of potential transportation projects on different populations.

One of the first requirements to make this model operational is the creation of a detailed network that represents the future transportation infrastructure. Infrastructure includes signs, signals, streets, highways, and transit information, along with information about where activities (e.g., residential, commercial, and recreational) will occur and where parking lots will be located. This network supplies data to all the modules. Figure 7-3 depicts the primary modules in the center row; each is dependent on external data inflows, which are shown on the top line. The data produced by each module, indicated in the bottom row, becomes the input for other modules.

The population synthesizer creates a synthetic population of households and individuals that are distributed both geographically and demographically according to the input data related to the metropolitan area under study. Vehicles are also assigned to households and individuals according to the input data. This synthetic population then interacts with the other modules. The first of these is the activity generator, where an activity list is constructed for each individual in a household by matching his or her demographics against information gathered from household travel and activity surveys. At this point, the synthetic population has places to go, and the means of going to those places are supplied by the route planner module. This module computes the fastest route to each activity by each individual based on the activity information and trip plans supplied from travel diaries and stated choices of transportation mode. Mode choice is also accomplished within the route planner module using external functions, such as logit and travel cost functions. In addition, shared rides, in which the passenger and the driver are from different households, are accounted for by this module as long as information related to the dependency is recorded with other household information in the population synthesizer module.

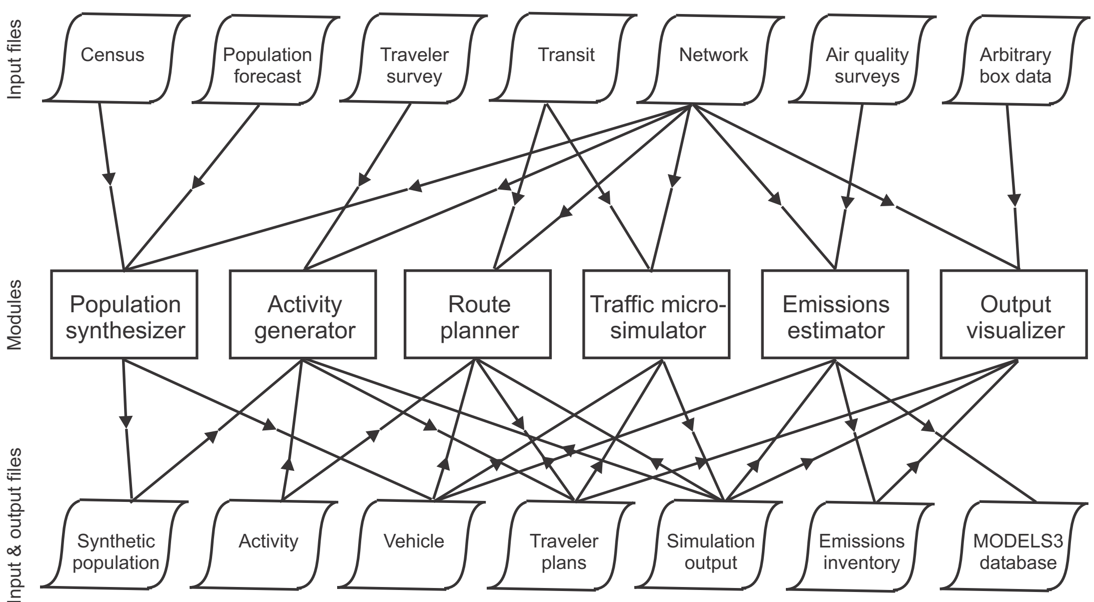

Figure 7-3. The TRANSIMS architecture from the perspective of data flow

Source: Los Alamos National Laboratory and Price Waterhouse Coopers 2002.

The traffic microsimulator module processes the output of the aforementioned modules, causing the synthetic individuals to interact with one another and realistic features of the traveling environment. This module simulates the movement of individuals throughout the network, including their use of private vehicles and public transportation, and the high level of realism in the simulation is directed by the selector/iteration database, which utilizes an iterative process and feedback mechanism. The next step in the process, calculating vehicle emissions, is not pertinent to our analysis of transportation user effects; but the one following, the creation of a visual representation of the model's output, is of particular interest.

When to use. This model is most useful when the situation requires a high degree of accurate information regarding the impact of a proposed project on protected populations. Obtaining such accuracy is relatively more expensive compared to other methods, but because this type and standard of modeling is in demand due to federal requirements for other information and decision making, the use of TRANSIMS may become widespread in the not-too-distant future.

Analysis. The special ability of this model to simulate the travel of an individual over an extended time period, beyond peak periods and for travel other than commutes to work and other basic activities, means that the potential for more thorough comparative analysis is greatly enhanced. For the purpose of assessing environmental justice, the most critical stage is gathering and inputting accurate demographic data in the population synthesizer. Such information determines how the individual is going to travel across the simulated transportation network and, hence, the quality of the model's output.

While current use of TRANSIMS does not require demographic data about race, this must be included to facilitate environmental justice assessment. Furthermore, the matter of trip-chaining, which often is an important part of low-income people's travel itinerary, is dealt with explicitly by the model within the activity generation module—a discrete choice-based model that generates trip chains along with activity locations using the data related to the synthesized householder's travel itinerary and domicile location.

The operation of the traffic microsimulator module gives this model an important advantage over traditional demand models because it is capable of simulating multiple travelers per vehicle and multiple trips per traveler, both factors that are fairly common to low-income and minority travel routines. Another key feature that facilitates determination as to whether an environmental justice problem will exist is the output visualizer module. The module allows the user to select for display any data value of interest that can be drawn on any link of any size on a given network. Because TRANSIMS is a completely disaggregate system, much care is required in calibrating and applying mode choice.

Data needs, assumptions, and limitations. Much detailed information related to individual travel is required by this model, so building the database can take considerable time. In addition, the data need to be location-specific for the model to be most useful, so considerable data have to be gathered at the local and regional level. The bulk of the data is keyed into the population synthesizer and consists of geographic and demographic information at both census tract and block-group levels. TIGER/Line layouts of census tracts and block groups make up the geographic data, while summary tables (STF-3A), and public use microdata area (PUMA) samples are obtained from the U.S. Census Bureau. TIGER/Line data are used to build the transportation network, which must be able to reflect the location of workplaces, shops, stores, schools, daycare and recreation centers, hospitals, and other areas identified from household activity surveys, along with parking lots. Other network data include number of lanes, streets, freeways, highways, ramps, turn pocket lanes, and intersections (with and without traffic signals). It is important to stress that in order for the model to provide a predictive output, a forecast marginal demographic file consisting of race, household size, income and age data based on census tract and block-group data must first be generated before it is keyed into the synthesizer.

The master area block level equivalency/geographic correspondence engine (MABLE/Geocorr)[3] is also utilized to generate a link between the PUMA samples and census blocks. Because the population synthesizer assigns individuals to activity locations, household travel and activity surveys (including travel diaries) are important sources of information about the types of activities individuals engage in (e.g., work, school, and shopping) as well as the start, stop, and travel times associated with them. Trip-chaining activities, including stop and start times, must also be included for origin-destination travel because the traffic microsimulator chains together several legs to form a trip. In fact, data on network travel times and activity locations are essential elements that allow the model to select a likely location for each activity, and each location's relative attractiveness is computed using criteria such as the number of retail employees or the amount of retail-store floor space.

Unlike conventional travel demand models, TRANSIMS is not merely concerned about peak-hour activity, so travel diaries should cover an extended period of about a month to ensure that a reliable trend can be established. Information on whether individuals walk, use private vehicles or transit, or use any other mode of transportation is also gathered from the surveys. Transit data, such as route paths, terminals, and schedule of stops, are part of the required network data.

This model assumes that the traveler always makes rational choices and so takes the route and uses the mode of transportation, including walking, that yields the shortest time between two points, while taking into account any situation or obstacle that may cause delay on any of the possible routes. For example, if the input information is that the traveler walks to and from work, the model will subsequently compute all work-related activity as accomplished by walking unless programmed otherwise. In other words, the travel cost function of the synthetic traveler is based on a predetermined, user-defined cost structure obtained from the survey data. On the other hand, if the information reflects that the individual drives his own vehicle and sometimes walks part of the distance, or takes transit, the model assumes that if the delay using motorized transportation would cause the time traveled between two points to be longer than it would take to walk, then that individual would, in fact, decide to walk.

Though the model structure may not reflect all decisions made in reality, this should not be regarded as a serious limitation because it is applied without bias. Like other methods of forecasting, the assumption is made that once the characteristics of the surrounding infrastructure are recorded and there is no subsequent change, the forecast year behavior of the traveler is the same as that captured in the base year. Any change in infrastructure, such as changes to a roadway or to the level of transit service, and the area's population are assumed to be reflected in the base-year calibration function. Changes in such things as travel time, transit fares, and parking costs are assumed to affect modal choice. The intensity of the impact on an individual traveler depends on the nature of the demographic data input obtained from the Census Bureau

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[3] MABLE/Geocorr supports data maintained by the Center for International Earth Science Information Network (CIESIN) at Columbia University. See http://plue/sedac.ciesin.org/plue/geocorr.

and from the surveys. There is, therefore, an implicit assumption that the cost functions in the model reflect the thought processes of the traveler.

TRANSIMS is one of the new generation of behavioral travel models and as such is still under development. As its validation process continues, much optimism has been expressed about its capabilities. However, one of the limitations we observed is that it is not sensitive to certain geometric factors, such as lane width, and the length of both acceleration and deceleration lanes. In addition, the microsimulator has been found to be inaccurate in predicting the velocities of individual vehicles along weaving sections of highways.[4]

Results and their presentation. As long as a region is defined by a set of vertices, user-selected data can be drawn, and this capability facilitates the display of data aggregated into regional areas. Users can manipulate three-dimensional objects using the Output Visualizer's graphical user interface. Getting the Output Visualizer to generate output is facilitated by an extensive, user-friendly system of menu options. Moreover, by setting a configuration file key, this module can be run remotely to produce images that may be incorporated into reports, presentations, or motion pictures.

Assessment. According to the FHWA, TRANSIMS will enable planners and citizens to have a better understanding of the effects and implications of transportation policy choices. It provides planners with the means to evaluate proposals to enhance the serviceability of the highway system, as well as transit, bikeways, and pedestrian amenities. The FHWA further surmised that the fine level of detail afforded by the software would not only more accurately represent the impact of transportation movements on travel, driving, and air pollution emissions but would also aid in the assessment of the socio-economic impacts of proposals for improvements (*Public Roads* 2000). The latter capability underlines the importance of this model as a valuable tool in assessing environmental justice concerns in the foreseeable future. Models such as TRANSIMS, however, have large data requirements and therefore would require a major commitment of resources by an agency.

STATE OF THE PRACTICE–TRANSPORTATION CHOICE

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:

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[4] Weaving is the crossing of two streams of vehicular traffic traveling in the same direction along a significant length of highway without the aid of traffic control devices. Capacity is significantly reduced in these weaving areas because drivers from two upstream lanes compete for space to merge into a single lane and then to diverge into two different streams.

- **Nondrivers –** People who cannot drive or do not have access to a motor vehicle.
- **Low-income persons –** Drivers and nondrivers whose basic transportation needs are significantly constrained by financial limitations, especially out-of-pocket costs.
- **Disabled persons –** People who have physical disabilities that limit their ability to travel independently.
- **Automobile-dependent people –** 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 7-2 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 parent, and low-income with disabilities.

Table 7-2.
Indicators of transportation disadvantage and possible data sources

Indicator	Data sources
Households that do not own an automobile (sometimes called zero-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 7-3 suggests which modes tend to be particularly useful for various user groups.

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 nondrivers 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 7-3.
Modes that are particularly important for specific user groups

Mode	Non-drivers	Low-income persons	Disabled persons	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

Note: A = primary mode; B = potential mode.

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 nonmotorized 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 nonmotorized facilities; and
- 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.

The following four general steps are suggested for analyses of the extent to which protected populations have a choice of transportation modes and services:

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. Nonmotorized travel data may be available from existing travel surveys and traffic counts, although conventional sources such as these tend to under-record nonmotorized trips. Some data sources exclude nonmotorized trips altogether, and many undercount short trips, nonwork trips, travel by children, and recreational trips. Automatic traffic counters may not record nonmotorized 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 nonmotorized travel. Whenever possible, the data should be geocoded and incorporated into a GIS. This makes it easy to create maps that integrate various types of data (such as roadway and sidewalk conditions) with the demand for nonmotorized 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 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 FOR STUDYING TRANSPORTATION CHOICE

Table 7-4 summarizes the three methods we suggest for evaluating the extent to which transportation choice exists for protected populations.

Method 7. Modal quality assessment

Qualitative analysis is a screening tool that is especially useful during the design phase of a project. The analysis answers the question of how a transportation project will affect the number and quality of transportation choices.

Table 7-4. Summary of methods for evaluating transportation choice					
Method	**Assessment level**	**Appropriate uses**	**Use when**	**Data needs**	**Expertise required**
7. Modal quality assessment	Screening	Assess demand for various transportation modes	Design phase when project will produce significant changes in availability of certain transportation modes	Low	Survey methods; graphs, charts, maps
8. User demand and evaluation surveys	Screening	Assess current level of use of various transportation modes	Planning phase when project will produce significant changes in availability of certain transportation modes	Low	Survey methods; graphs, charts, maps
9. Improved transportation surveys and models	Screening/ detailed	Assess current use and future demand for various transportation modes	Planning phase when project will produce significant changes in availability of certain transportation modes	Medium	Survey methods; graphs, charts, maps

When to use. An assessment of modal quality provides you with a baseline condition of transportation choice in an area of the community that is likely to be affected by a proposed transportation project. If the analysis reveals significant deficiencies, they can and should be addressed in the process of planning for the proposed project. If the project would worsen the level of choice, either it should be redesigned or substantial mitigation efforts must be carried out.

Analysis. The analysis has three steps:

1. Identify the transportation modes to be considered.
2. Select suitable standards, guidelines, or indicators for each mode. This selection depends on two factors:
   – *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.
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.

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.

Data needs, assumptions, and limitations. Table 7-5 summarizes a series of simple factors that indicate whether an alternate mode would help provide mobility for nondrivers, low-income households, or people with disabilities within the affected area of the community. All of these impacts are highly relevant to an environmental justice assessment. Additionally, one is able to assess related quality-of-life factors such as whether it supports TDM objectives such as reduced traffic congestion, road and parking facility cost savings, and reduced environmental impacts.

Results and their 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 (see Chapter 6), 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. An analysis of modal quality is a potentially valuable element in an assessment of the current mobility of protected populations. It also is a relatively simple way to gain a general sense of how various options for achieving environmental justice objectives 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 7-5, 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 8. User demand and evaluation surveys

User demand and evaluation surveys can be used to gather information from travelers 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.

When to use. User demand and evaluation surveys are a practical method for assessing the capacity of an area of a community to enable localized mobility. If an area that is within the activity space of protected populations would be affected by a proposed transportation project, this method can be used to assess current capabilities and those if the project were undertaken. User surveys can be distributed to walkers and cyclists at a study site (e.g., survey forms can be

Table 7-5. Sample of factors to use in a modal quality 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 likely 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 nonmotorized travel in the area surrounding the facility?	❑ Improve ❑ Worsen ❑ Not affect

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.

Analysis. 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).

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.

Data needs, assumptions, and limitations. 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?

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.

Results and their 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 used to demonstrate mode, group, or location analysis findings. 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., nondrivers, 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. By making it easier to travel by modes other than the auto, those whose resources are severely limited are bound to enjoy greater mobility. 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 definitive for establishing the needs and preferences surrounding alternative transportation issues.

Method 9. 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 nonmotorized 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 nonmotorized 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.

When to use. In many circumstances, travel 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. This information can be of great value when assessing the extent to which a proposed transportation project would reduce or worsen such functional barriers.

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 user 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.

Data needs, assumptions, and limitations. 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 data such as the following:

- Survey data concerning the number of people who have various transportation-relevant attributes (e.g., nondrivers, 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; and
- Analysis of survey data that can evaluate how a particular change in the transportation network would affect alternative modes and their use, especially by protected populations.

Results and their 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, nondrivers, minority populations, low-income populations, 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 nondrivers; and
- 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 you 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.

RESOURCES

1) American Association of State Highway and Transportation Officials (AASHTO). 2003. *User Benefit Analysis for Highways.* Washington, DC: AASHTO.

This publication is a replacement for the 1977 AASHTO "Redbook" that provided guidance in estimating the user effects of highway and transit projects. The new book focuses on highways and provides the latest thinking on user effects. It is presented in an easy-to-access format.

2) Beinborn, Edward A. 1995. *A Transportation Modeling Primer*. Milwaukee, WI: University of Wisconsin, Milwaukee, Center for Urban Transportation Studies. Available at http://www.uwm.edu/Dept/CUTS/primer.htm.

This Web document is an excellent overview of the traditional four-step transportation modeling process. It presents technical considerations in an easy-to-understand manner.

3) 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.

4) 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 nonmotorized 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 nonmotorized roadway conditions that may be simpler to apply than other, more data-intensive methods.

5) 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 that it could evaluate pedestrian and bicycle travel. Smaller analysis zones were created, and various demographic and transportation system factors that affect nonmotorized travel behavior were incorporated into the model. This article should be useful to planners and modelers who might want to incorporate nonmotorized travel into a conventional traffic model.

6) Federal Highway Administration. 1983. *Calibrating and 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.

7) 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.

   This article shows the correlation between automobile-oriented transportation development and subsequent changes in patterns of accessibility to retail and service activity within metropolitan areas. It demonstrates how alternative land use and transportation patterns can affect trip distances, and it shows how local access and broader regional access can be affected differently.

8) 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.

9) 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 nonmotorized 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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CHAPTER 8. COMMUNITY COHESION

OVERVIEW

Community cohesion is the term that describes the social network and actions that provide satisfaction, security, camaraderie, support, and identity to members of a community or neighborhood. Of all the environmental justice issues related to implementation of transportation projects, this one may be the most difficult to address because it is hard to find a practical way of predicting the impact of projects on community cohesion. Though this issue may be viewed as primarily psychological, it is very much a part of the day-to-day experience and behavior of people. For many people, community cohesion is essential to the success of family life, contributes to feelings of satisfaction and fulfillment in community life, and provides a sense of security.

Estimating changes in community cohesion relies heavily on the researcher's experience and common sense judgment, as well as on 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. Because transportation projects have impacts on community cohesion that "may be beneficial or adverse, and may include splitting neighborhoods, isolating a portion of a neighborhood or an ethnic group…or separating residents from community facilities…" (FHWA 1987, p. 17), it is important not to dismiss or overlook these impacts. Understanding impacts starts with defining the impact area, which is not always obvious.

STATE OF THE PRACTICE

Assessing the likely effects of a proposed transportation project on community cohesion is a blend of public discussion and careful analysis. This effort commonly involves five steps.

Step 1 – Define the impact area. Defining the impact area begins with an understanding of the approximate boundaries of the affected community or neighborhood. Though each community or neighborhood needs to be defined in the context of the perceptions and everyday realities of the people living there, the impact area will assume a distinctive physical space with boundaries. Determining the impact area requires developing an intimate relationship with the affected neighborhood, in particular with community leaders, in addition to tapping the knowledge of city staff and the general public, when appropriate.

Although each impact area will have its own characteristics, four possible scenarios are anticipated:

1. The area is constrained by its geography. In such a case, the inhabited area is bounded by a wide area of undeveloped land or by a land use activity other than residential (such as industrial) or a very different kind of residential development. In such a case, the geographically defined area is the impact area.

2. There is a cluster of residences, businesses, and other social amenities that are predominantly owned, occupied, or used by low-income or minority populations. Though such a formation readily lends itself to defining the impact area, there may also be important facilities that foster a sense of community and contribute to community cohesion located outside the cluster-area. These facilities may include houses of worship, schools, and places of recreation and should be considered part of the community.
3. There are multiple clusters of low-income or minority residences and businesses located in a large geographic area that is well defined. In such a case, it is important to ascertain the level of cohesion that exists between clusters. It is reasonable to assume that the clusters nearest to each other are most connected and those farthest apart are less connected, but such may not always be the case.
4. The low-income or minority households are dispersed in a broad geographic area among households of a higher income level or some other larger ethnic group. In this case, defining the impact area could be difficult. However, determining the level of interaction that takes place between persons living within the geographic area can greatly contribute to identifying alternatives that preserve the overall cohesion and stability of the community.

Understanding the dynamics of community cohesion among protected groups requires recognition that, even among homogeneous minority groups, the level of cohesion can vary significantly. One factor in this variability may be income. If only part of a large homogenous minority community is affected by a project, it may be more appropriate to use level of income as the basis for decision-making rather than ethnicity. Consideration of distributive effects would then be based on a comparison of project-related costs borne by low-income earners relative to high-income earners.

Research shows that the spatial sphere of social activities among low-income earners is much smaller that that of high-income earners, largely because they tend to have a greater proportion of family and/or friends residing near their places of residence (Donnelly and Majka 1996, p. 270). This often leads to strong community cohesion among low-income groups. In addition, residents with similar economic status and lifestyle patterns are more likely to interact with each other and form strong bonds (Donnelly and Majka, 1996, p. 271). Therefore, it is reasonable to also expect social networking among the wealthier even though the characteristics of this networking may differ somewhat from that which takes place among the less wealthy.

Step 2 – Collect information. Community leaders and civic groups can provide valuable information because of their 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. But experience suggests that greater, community-wide participation is needed if projects, particularly those that significantly alter the spatial composition of the impact area, are to win the approval of a majority of affected community members.

The step of collecting information is an excellent point at which to start involving community members because it gives them a sense of being part of the creative process of the project and not merely the recipients of a plan devised elsewhere. Failure to involve members of the community raises the likelihood that the project may be resisted, with possible negative effects. Discussions of the issue of resistance and strategies to gain community participation also follow.

Step 3 – Spend time in the study area. To evaluate social networks and to estimate how a transportation project might affect those networks, you must get to know the study area. Site walks and visits to special community centers and gathering spots can provide important insights for evaluating community cohesion effects. While spending time in the area, information may be collected through visual observation and informal discussion, and photographs may be taken of community facilities, shops, services, and recreation facilities. These photographs can be very useful in public meetings and workshops. Being in the study area also facilitates a more formal site analysis for evaluating relocation effects, as detailed in Forkenbrock and Weisbrod (2001, p.103-104).

Step 4 – Estimate the existing level of community cohesion. Secondary data about personal attitudes and social networking in a particular neighborhood generally do not exist. As a result, first-person interviews and workshops are necessary to gain information about community cohesion in the study area. Block-level census data that identify areas of relative demographic homogeneity can substitute (albeit, not always very well) for primary survey data or can be used to extrapolate from information collected in the field. You 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 – Predict the project's effects on areas of relative cohesiveness. Most existing 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 identify 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.

Because major transportation projects can create barriers to community cohesion, dialogue with members of the affected community is the most effective way of identifying the nature and magnitude of the hindrance to cohesion. This dialogue is also the most practical way to develop an understanding of the most effective and feasible mitigation measures. How much the project affects existing levels of accessibility and how it alters the current living environment are important factors in predicting a project's effects on community cohesion.

Suggested communication strategies

In the previous description of the five steps for estimating the probable effects of a transportation project on community cohesion, we noted the importance of effective interaction with the public.

Below are several suggested approaches and specific considerations that should be taken into account regardless of the selected approach.

Be attentive to possible resistance. It is possible that implementing any transportation project will have some impact on community cohesion. Being able to understand the nature of community cohesion, and to predict the level of impact the project will have on it provides a basis for considering the degree of resistance that can be anticipated. Accordingly, you gauge the amount of effort needed to involve community members early on in formulating alternative strategies for project implementation, including the “no-action” alternative. Awareness of the nature of the impact on cohesion also helps you consider the type and extent of mitigation and/or compensation that may be required to complete a project. In general, the greater the impact in the presence of a strongly cohesive community, the greater the mitigation and/or compensation required.

Select an appropriate communication strategy. Before looking at the methods for involving community members, it is important to consider systemic barriers to participation. Language could be a barrier for individuals whose first language is not English. Outreach and literature therefore should be prepared in the language(s) of residents of the affected community, and translators provided to assist at meetings.

Another barrier is fear of speaking before a large group. In such a case, it may be necessary to set up a spokesperson who can read the written comments of those who do not wish to speak. It is important to keep in mind that the Code of Federal Regulations (CFR) Title 28.1 Sec.35.130 requires the state or local government unit to ensure that individuals with disabilities are not “excluded from participation in or…denied the benefits of the…activities of [the] public entity.”

The time schedule of public meetings may also hinder participation, so two or more meetings at different times may be required. It may also be necessary to underwrite the cost of child care for low-income individuals who show an early interest in participating in the collaborative processes.

A good discussion of techniques for communicating with members of affected populations is presented by Barnard and Lall (1998) in their publication titled, “We’ve Got to Stop Meeting Like This: 36 Ways to Encourage Civic Participation.” We draw on their ideas in the discussion that follows. The objective of the methods outlined in this section is twofold: (1) to gain the fullest possible community participation and (2) to arrive at the best choice of alternatives for implementing public transportation projects. The methods are ranked according to the predicted level of community cohesion, the anticipated intensity of the impacts of the project on it, and the size of the community (see Table 8-1). These three factors must be weighed together when selecting a strategy.

The communication methods suggested in Table 8-1 offer flexibility and an opportunity to match scarce resources, financial and otherwise, with the goal of achieving the desired outcome—i.e., the fullest possible level of participation by affected residents—given unique circumstances.

The effectiveness of each of these communication strategies is directly related to the amount of effort exerted to organize the forum and the skill of the facilitator in guiding the discussion of the agenda items. Greater success is likely if participants receive written information about the issues before the meeting. The information packet should contain a full disclosure of the costs and benefits of each alternative for implementing the project, including the "no action" alternative. You should clearly identify the preferred choice. The possible adverse impacts associated with each alternative, along with proposed recommendations for mitigating them, should also be presented in a neutral manner and in language familiar to community members. In addition, each alternative may include a number of arguments for and against it. Because the task of the facilitator includes motivating and controlling, it is important that the person be well trained and competent.

Table 8-1.
Community participation strategies

Scale of:		Communication methods			
Cohesion	**Impacts**	**Focus group[1, 2a]**	**Fish bowl[2a]**	**Charrette[2b]**	**Nominal group workshop[2b]**
Weak	Weak	✓			
Weak	Moderate	✓	✓		
Weak	Strong		✓		
Moderate	Weak				
Moderate	Moderate		✓	✓	
Moderate	Strong		✓	✓	
Strong	Weak	✓			
Strong	Moderate	✓			✓
Strong	Strong				✓

1. A stratified random selection of participants is recommended when cohesion is dispersed.
2. Useful when there are dispersed pockets of cohesion
   a. Most appropriate for small- to medium-size communities.
   b. Most appropriate for medium- to large-size communities.

Focus groups are adequate for situations where only a few people are willing to participate or where community cohesion is so strong that the community feels that a few knowledgeable persons could represent the majority view. Because a focus group usually involves six to eight people, this method is also well suited to small communities in which cohesion is weak to moderate, and where a weak-to-moderate project impact is expected. In addition, it may be useful in medium-size communities where cohesion is strong. A random selection of participants, particularly one that is stratified, can ensure that all sectors of society are adequately represented.

Fish bowls are so named because in the initial portion of the consultation, the researcher plays a passive, observing role as the discussion takes place. Like the focus group, the fish bowl is applicable to small- and medium-size communities and in situations where a larger group of interested participants is expected to observe the discussion. These observers usually are unclear or undecided about the project and its impacts on the community, and so wish to listen to the views and ideas of others before forming their own opinion. At the end of the "formal" discussion, the facilitator should invoke a response from observers either vocally or in writing.

Charrettes (for full description, see pages 302-304) are useful when dealing with medium-large communities and are frequently used by planners. They are appropriate when the moderate-to-strong nature of anticipated impacts is expected to draw significant attention from residents nurturing a moderate level of cohesion. From 50 to 100 people can be expected to participate in the discussion. As a consequence, many charrettes are day-long events that require a facilitator who is very knowledgeable about group process and is able to motivate all attendees to participate.

Nominal group workshops are also suited for medium-to-large communities, particularly where cohesion is strong and the predicted impacts are medium to strong. This is a good strategy in communities where polarization of racial or group interests can lead to tense situations; it ensures that all interests are heard in a well-organized manner. After a briefing by the planning staff about the project and the impacts associated with each alternative, participants are asked to fill out a card (with staff assistance, as necessary) stating their major issues of concern regarding each alternative and what make the issues important to them. Participants are then assigned to small groups (four to seven persons), along with a resource person from the relevant planning authority. Each individual in the group is given a chance to voice his or her issues of concern with arguments related to each alternative. The resource person provides group members with information that enhances the discussion.

The facilitator records all of the highlighted issues and pro and con arguments on a flip chart for all group members to see. Afterward, the large group is reassembled and the flip charts displayed. A reasonable time is given for their perusal, then participants are asked to vote on the alternatives, including the no-action alternative. The chosen alternatives are ranked according to the ballot count for further discussion, which is mediated by the workshop facilitator. Persons are asked to lobby for and against each alternative, after which a final vote is taken to decide which alternative should be adopted.

Resources needed. Table 8-2 presents a summary of the comparative costs associated with the various approaches discussed above. As with many other worthwhile public exercises, time, funds, organization, and resources are required to achieve community participation. Table 8-2 provides estimates of the amount of time involved in staging a discussion forum. Time here refers to the length of the discussion period, as well as the time it takes to prepare materials, notify the participants, and complete all other organizational arrangements. Expenses include the out-of-pocket costs associated with arranging and staging the discussion forum, as well as the cost of training or hiring a facilitator. Preparing and staging any forum requires organization, but as with time, each method calls for a varying level of financial commitment, as Table 8-2 indicates. Likewise, because each communication strategy is intended to fit a community and a project with specific characteristics, resource requirements vary among methods. Resources consist of the persons involved at each stage of planning, organizing, outreach, and staging of the discussion forum, and include such things as stationery, models, vehicles, equipment, and procurement of the venue.

Table 8-2.
Requirements for community participation strategies

Communication method	Time	Expense	Organization	Resources
Focus group	Low	Low	Medium	Low
Fish bowl	Medium	Low	Low	Low-Medium
Charrette	High	Medium	Low	High
Nominal group workshop	High	Medium-High	Medium	Low-Medium

Source: Barnard and Lall 1998.

SELECTING AN APPROPRIATE METHOD OF ANALYSIS

It is not always easy to accurately assess the current level of community cohesion in an area that would be affected by a proposed transportation project, and it is even more difficult to predict the project's likely effect on cohesion. Described below are seven basic indicators that a project could adversely affect community cohesion. The predictive power of each indicator is dependent on the characteristics of the impact area, the intensity of community cohesion, and the nature of the transportation project. In general, the greater the number of predictors present, the greater the likelihood that the project will impact the community. The magnitude of each of these predictors will also determine the level of impact.

Creation of a physical barrier. Any project that divides the community constitutes a physical barrier and will be offensive to members. However, the extent of the disruption caused by the barrier is very important and may be gauged by examining the level of interdependence between members of what will be the two "newly created" neighborhoods. For example, if the project separates many residents from popular meeting places, cohesion will be negatively affected. In addition, a project may constitute a physical barrier if it makes travel in the neighborhood more stressful, especially for the elderly and disabled, thereby discouraging movement between residents' homes and to and from regular congregational centers. For example, a significant change in the gradient of a sidewalk could cause such a barrier.

Change in travel time. This is best understood by comparing the difference in time it takes to go between several points in the neighborhood. First, the planner should take timed journeys on foot, covering routes that are routinely traveled and varying the pace of travel so as to have some appreciation of travel time for both the young and elderly. Then, with the knowledge of where spatial changes to the neighborhood environment are intended, simulate the journeys between the same origins and destinations using a computer software program, such as TransCAD (see Chapter 7).

Disruption of access to neighborhood/community child care facility. Access to various parts of a neighborhood is often important for reasons other than recreation. Low-income and minority households tend to rely on each other for support in areas such as transportation, preparation of meals, and child supervision and care. Child care facilities, particularly private homes of residents, are especially important in communities where there is a large proportion of women of child-bearing age and several extended family units exist. Thus, any disruption of access, whether temporary or permanent, can result in significant stress on affected households. Gathering accurate information on how many households would be affected and the extent to which they are dependent on such a service is necessary. Households that are strongly dependent may be classified as those that rely on this service more than 4 days per week; moderately dependent if used 3 to 4 days per week; and weakly dependent if less than 3 days per week.

Increased risk of physical injury. Increased risk of injury leads to frustration, particularly for the elderly and for small children, along with their guardians or caregivers, because of the challenges involved in moving around the district. Projects that significantly change the gradient of streetscapes, widen roads, alter the elevation of the road relative to buildings, and create steep drop-offs from the roadway to the existing terrain, all increase the risk of injury. Knowing the design of the proposed project and the changes that will be made to the existing topography, particularly to the streetscape, children's play areas, entrances and exits, is essential to understanding the magnitude of the risk of injury the project will generate. This knowledge is most useful when combined with data about the number of elderly and children living in or frequenting the spatially altered area. Generally, most of the risk may be removed by careful adjustments to the design of the project.

Decreased accessibility to usual congregational centers. Decreased accessibility may reduce the frequency with which neighbors attend gatherings and thus strike at the heart of community involvement and cohesion. Furthermore, if a group leader's access to the regular meeting-place is curtailed by the project, the functioning of the entire group may be significantly hampered, possibly leading to its dissolution. Having a clear idea as to how the project design affects access to usual congregational centers is therefore important. Accessibility may be diminished by a physical barrier, by an increase in travel time to and from the center, or by an increased risk of injury, all of which are dealt with above. Altered spatial arrangement discourages participation, which is important to community cohesion. As a consequence, project design factors that inhibit participation in any form must be of concern. Steps, as outlined above, can be taken to measure such impacts.

Increased noise level. Any transportation project that increases the number of vehicles on a roadway through or adjacent to a neighborhood or increases the average speed of those vehicles will raise the level of noise in the area. A new railway line presents a similar challenge. A sudden rise in traffic noise means that members of the affected community must exert more effort to communicate by speaking more loudly. It also means that radios, television sets, and other commonly used audio devices have to be played at higher volumes for persons to derive the same level of satisfaction and understanding that they previously enjoyed. Not only is communication made more difficult, but also it is a natural response to try to avoid the additional exertion required to communicate. At the same time, the combined increase in noise from the traffic and domestic electronic devices could contribute to hearing loss over time, compromising the health of individuals and their ability to enjoy their living environment.

METHODS

Table 8-3 provides a brief summary of the methods presented in this chapter.

Table 8-3.
Summary of methods for analyzing community cohesion

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. Focus groups	Screening	Assess current level of cohesion; identify sensitive issues	Planning phase when project may impact community cohesion	Low	Group facilitation
2. Personal interviews	Screening	Assess current level of cohesion; identify sensitive issues		Low	Conduct interviews
3. Deliberative polling	Screening/ detailed	Assess current level of cohesion; identify sensitive issues		Low	Television production; polling techniques
4. Travel demand models with geographic information systems (GIS)	Detailed	Estimate travel demand (TD) between census blocks	Planning phase when project may impact community cohesion and a high level of detail required	High	Standard travel demand modeling; census data analysis; GIS
5. Stop watch and distance wheel	Screening/ detailed	Evaluate pedestrian travel times and distances	Planning phase when a project may impact community cohesion	Low	None

Method 1. Focus groups to identify interaction patterns

To adequately understand the desired spatial linkages of a particular area of the community, there is no substitute for directly communicating with members of the affected area.

When to use. Focus groups are a practical means of gaining an understanding of how cohesive an area of the community is, how dependent this cohesiveness is on specific types of interaction, and the spatial extent of common patterns of interaction. If there is a potential for spatial disruption of an area of the community, especially one occupied by minority populations and low-income populations, focus groups are a sensible means for acquiring information that can be useful in designing the project or mitigating unwanted impacts.

Analysis. When community cohesion is the concern, a one-size-fits-all approach is certainly not appropriate. Rather, a series of issues and concerns should be addressed, some of which cut across most possible types of projects and others that may or may not apply in a particular instance. First, participants of the focus group should help define the perimeters of the area of the community of concern. Then, they should be asked about frequency of trips and important destinations in the environment that could potentially be affected by the proposed transportation project. Once the spatial nature of the affected population is deduced, potential impacts can be discussed in terms of how they may affect community cohesion.

Earlier in this chapter, various types of impacts were briefly discussed. We now translate them into a series of questions that can be used in the focus group discussion:

1. Would a **physical barrier** be created between members of the community?
2. Would the **travel time** to residences of close friends living in the community increase?
3. Would access to any **neighborhood/community child care facility** be diminished?
4. Would the **risk of physical injury** increase to those accessing regular meeting places, houses of worship, community centers, recreation centers, open spaces, and other common congregation sites?
5. Would there be a **decrease in accessibility** to usual congregational centers?
6. Would any changes in the spatial arrangement of community activities **discourage participation** in these activities?
7. Would **increased noise levels** reduce residents' ability to communicate outdoors?
8. Would **changes to the visual aesthetic environment** in the community make it less desirable for community members to spend time outdoors in places where persons often congregate?
9. Would persons feel like their **community ties would be broken** if they were relocated to other nearby housing or to another neighborhood?
10. Would a **reduction in open spaces**, such as parks or undeveloped parcels cause residents to spend less time with their neighbors or other community members?
11. Would allowing mixed commercial/residential development or nearby commercial/industrial development cause residents to feel that their **community has been changed** in a significant manner?

Data needs, assumptions, and limitations. Focus groups provide opportunities for open-ended responses and discussions that are typically not possible in surveys. The groups are usually small—often not more than six or eight persons. They are thus typically used when the need for detailed information outweighs the need for statistical analysis. Focus groups are desirable when agencies are in the exploratory phase; often the information gathered can be used in later research. The most important considerations in forming focus groups are the following:

- Ensure that minority populations and low-income populations are properly represented.

- Select people whose activities would be in the area likely to be affected by the project.
- Include representatives of nearby businesses that serve the affected area.
- Include people whose responsibilities extend to members of the affected population, such as school administrators, parks and recreation staff, public safety personnel, neighborhood leaders, and human service staff.
- Enlist the services of a facilitator who is known to, and trusted by, the participants. A member of the clergy, for example, may be a possibility.

Results and their presentation. The central purpose of focus groups is to acquire a clear understanding of the general attitudes, concerns, and preferences of minority populations and low-income populations regarding a proposed transportation project. The results can be used to help assess whether the project would have a generally positive or negative effect on the well being of these populations. They can also help to identify changes in the project or measures that could be taken to mitigate undesirable effects.

Often, the analysis of data gathered in focus groups involves summarizing responses for the population. For environmental justice analyses, responses will typically be summarized by geographic area, income, or race. This requires that data be collected on locations of participants (firms or households) and on income or race for individuals or for firm owners, employees, and clientele.

Assessment. If carried out well, focus groups can provide first-hand information on the distributive impacts of transportation projects, and the results can be used to modify the project or to design mitigation measures. A delicate balance must be achieved, however, between providing the focus group sufficient information to foster a productive discussion, while being careful not to lead the group to conclusions.

Method 2. Personal interviews

Fully involving stakeholders by conducting personal interviews with them provides the basis for acquiring a sound understanding of the potential issues and perceived impacts from the community's perspective. A good place to start selecting appropriate people to interview is with identified community leaders.

When to use. Personal interviews are especially helpful early on in an effort to assess the approximate geographic area of concern and the current extent of cohesiveness in the area. Questions can then be asked regarding the common activity space of the affected populations to gain insight into how the proposed transportation project would affect community cohesion.

Analysis. A community leader can be anyone who is both knowledgeable about the community and its issues or objectives and who exercises some influence over others within the community. Ideally, the individual should have lived in the community for several years. Potential subjects include religious leaders, school principals, local business owners, recreation center organizers, executive members of community organizations or neighborhood associations, or owners of child care facilities. Those persons contacted initially may also be asked to name others who could contribute to the research. Social welfare personnel responsible for persons in the community may also provide some useful information about the community's networking system.

Predictors of level of impact that should be addressed in personal interviews include the following: (1) extent to which the completed project would act as a barrier; (2) changes in accessibility to usual congregational centers; (3) effects on the spatial arrangement of functions and probable effects on participation in community, commercial, and cultural activities; and (4) changes in travel time to residences of close friends living in the community or displaced from the community.

These interviews 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.

Data needs, assumptions, and limitations. To collect information using personal interviews, two initial steps must occur. First, you must identify interview subjects; second, a questionnaire or interview guide must be designed. With personal interviews, the information collection protocol should be loosely 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. Subjects that should be addressed in the interviews 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.

Results and their presentation. Personal interviews are a valuable means of learning about the nature of community cohesion among protected populations in the area likely to be affected by a proposed transportation project. These can interviews help the researcher identify sensitive issues that will need to be addressed fully and carefully. Well-advised design modifications and mitigation measures can then be devised.

It is very good practice to present a summary of the insights gained to local community and neighborhood leaders. These leaders can then validate the findings and offer suggestions as to how the results can most accurately be interpreted. Working with them also strengthens one's association with them and keeps the lines of communication open.

Assessment. Personal interviews offer a rich perspective as to the perceptions of members of minority and low-income populations regarding their community and how a proposed transportation project would affect it. These perceptions should be related to objective data on distances and travel time to important functions. Of course, without the personal interviews it would be difficult to know what all these functions are or where they take place. In a sense, then, it is wise to regard the personal interviews as one critical step in the process of understanding how a project would affect the daily living space of protected populations.

Method 3. Deliberative polling

This technique is designed to incorporate the best characteristics of polling and television and apply them to facilitate community engagement. Whereas town hall meetings tend to attract the most engaged citizens, who often already have well-established opinions, deliberative polls seek to bring participants of diverse backgrounds together with the objective of broadening the extent to which citizens become part of the planning process. The technique has certain features in common with a charrette.

When to use. This method is especially appropriate when there is concern that a proposed transportation project could adversely affect community cohesion. In this process, a stratified random sample of citizens is brought together for one or two days to discuss the proposed project. The stratified random sampling process ensures that women and men, minority and low-income groups are represented in numbers equal to their proportion in the affected population.

Analysis. The random sample of residents is brought together for one or two days. After completing a survey, participants are briefed on issues related to the possible impacts of the project. The briefings should contain a full disclosure of the costs and benefits of each alternative for the project, including the "no action" alternative and identifying the preferred one. Of great importance is a description of the possible adverse impacts (economic, social, cultural, and environmental) that could affect the cohesiveness of the community and the quality of life within it. Possible means for addressing and mitigating any impacts that participants determine to be significant can be presented. Each alternative may include a number of opposing opinions for and against it. The issues in the deliberative materials should be presented in a neutral and unbiased manner, with care given to the language and expression used so as to ensure that the participants, coming from all walks of life, obtain a sufficient grasp of the issues involved. After studying the materials, the group of residents is given an opportunity to ask questions of experts, including those from interest groups.

The fully briefed and informed participants then take part in a televised session for broader dissemination of the relevant issues and ways to address them. During the television session, members of the public are given contact information for each member of the group so that, within 24 hours after the session airs, they may communicate their concerns on any issue to the group member with whom they feel the greatest connection.

Later, a second televised session is convened and begins with the local planning department providing a summary of the pros and cons, costs and benefits of each alternative and any suggested modifications that arose out of the discussions and expert testimonies. The citizens involved in the process are then surveyed (polled) to determine if and how their opinions have changed as a result of the discussion process and, ultimately, their most favored alternative. This allows for ranking of the issues as well as the alternatives and provides a broader basis for decision-makers in selecting their course of action.

Data needs, assumptions, and limitations. There may be significant expenses involved in this approach including (1) television airtime, (2) transportation of participants, (3) catering for participants, (4) interpreter services (if matter concerns non-English-speaking residents), (5) possible wage/salary compensation for participants, and (6) daycare costs for children of participants. Quite possibly, the television airtime costs will be minimal because such an exercise should be viewed as a public service by the producing station. Working flexibility into the scheduling times for discussion meetings may also reduce wage or salary compensation. A better outcome probably would be achieved, however, if full compensation were given to participants so that they were able to remain focused on the issues before them and to be available to receive feedback from callers.

Results and their presentation. Deliberative polling is rooted in the concept that a representative group of local residents can become well informed about the probable impacts of a proposed transportation project. This group of people can then become a practical conduit through which information can be presented to the general public. Analysts can observe the process and learn a great deal about aspects of the project that might jeopardize community cohesion. They can also gain a clear sense of the likely support for modifications to the project or specific mitigation measures.

Assessment. Because of the expense involved, this approach to engaging residents may be best suited to implementing high-cost projects and those that are likely to generate considerable popular concern and resistance, particularly where the affected communities are large and where citizen involvement may be problematic.

Method 4. Travel demand models with GIS capability

An important issue in estimating the effect on community cohesion of a proposed transportation project is how it would affect area residents' ability to interact. To interact, these residents must be able to move conveniently between desired origin-destination pairs. Newer travel demand models such as TransCAD that have a geographic information system (GIS) interface are useful in measuring changes in distance and travel time between places of importance to affected residents. Preferably, census-block data should be used and the existing road geometry, including local streets and avenues, must be accurately input into the model and matched with the census data.

When to use. This method is most appropriate in cases where the project would be sizable and may impact a relatively large community of residents, including protected populations. While the travel demand model cannot be expected to estimate microscale impacts, it can give a general approximation of the extent to which movement to and from specific areas of concern would be affected. If such movement would be inhibited, an adverse effect on community cohesion is a potential result.

Analysis. The method here is much the same as that outlined in Chapter 7, Method 2, Adaptation of transportation demand models. In that method, traffic analysis zones (TAZs) are defined based on protected and nonprotected group criteria using census-block data. Travel times and distances traveled by those most sensitive to change—including the elderly and mothers with infants and preschool children among protected groups—should be a major concern. The focus here is on changes in distance traveled and travel time between regularly traversed points within the community or to destinations close to the community. Change is observed by first running the model and recording times and distances under existing conditions and then comparing these results with those obtained from a second running of the model that yields projected times and distances that reflect the impact of the intended transportation project. Any significant deterioration in travel time or extended distance to be traveled may be considered as a potential environmental justice problem because it makes the affected individuals worse off. However, it is only through consultation with community members that a meaningful conclusion regarding the nature and magnitude of such a problem can be ascertained. The travel demand analysis, therefore, should be regarded as an initial approximation of travel time and distance impacts. Also, it may be found that what is intolerable or offensive to one group may be acceptable to another group, and so the extent of mitigation methods required may differ considerably.

Data needs, assumptions, and limitations. The data required for this approach are quite similar to those needed for other routine travel analyses. The distinguishing assumption here is that persons in the area of interest may have to travel relatively long distances compared to those in smaller communities to access child care, shopping centers, community and recreation centers, places of worship, and schools. Consequently, they drive their own vehicles, carpool, or use public transit quite frequently. Thus, information on what percentage of the population in each TAZ has regular access to a private vehicle is important, as well as what proportion relies primarily on transit services. This method is limited in that it does not take adequate account of persons who use nonmotorized transportation. Consequently, this method may be combined with the following method, which is better suited to walkable communities.

Results and their presentation. Evaluation of the tabulated results representing before and after scenarios is made convenient by the output derived from travel demand models. The additional ability of these models to graphically portray the results using GIS capabilities is a further asset because the visual representation facilitates discussion as well as joint decision-making by professional planners and stakeholders. After identifying potential problem areas, the GIS technology further enables the focus to shift towards mitigation measures that are agreeable to various parties. In situations where changes impact a significant number of persons who walk, the results obtained from the method that follows may be combined with the tabular results generated by travel demand models to ascertain the overall magnitude of the change in travel time or distance traveled.

Assessment. This is a reasonably accurate method for determining actual changes in travel time and distances, and it could be easily adopted by many planning departments without any significant increase in costs because of the ubiquitous use of travel demand models. For those using the state version of the Highway Economic Requirements Model (HERS-ST), a unique roadway identifier may be used with the database and a beginning and ending log mile to allow the model's output to be attached to a geographic (GIS) mapping system using a routing system and dynamic segmentation. Planning departments that currently use activity-based models that can generate even more accurate results should also conduct dual scenario analyses as described above. Activity-based models also facilitate GIS mapping of results.

Method 5. Stop watch and distance wheel

After extensive discussions have taken place with minority and low-income populations in the area that would be affected by the transportation project, simple methods are appropriate to estimate the changes in accessibility that may result. Specifically, once these residents have indicated which of their important destinations would become less easy to reach, you should estimate how great the impact would be. You also should evaluate the efficacy of possible mitigation measures. This very basic method entails use of a stopwatch for measuring travel time and an engineer's distance wheel for measuring the distance traveled between origins and destinations on a small scale.

When to use. If the project impact area is relatively small and involves a clearly defined geographic area, changes in the distances that must be traveled can be assessed using this method. Greater distances and travel times between essential activities within an area can be disruptive to community cohesion.

Analysis. This method is best applied in two phases: the first dealing with existing conditions and the second forecasting project impacts. In order to become more aware of how an intended project would affect the most sensitive groups in the community, average travel times between important points—residences, schools, daycare facilities, neighborhood shopping centers, community and recreation centers, and places of worship—are recorded. As could be expected, one needs to have intimate first-hand knowledge of the community and to walk the routes regularly traversed with timer and distance wheel in hand. Estimates of changes in times and distances likely to be caused by the intended project can be computed based on plans and graphs, and a comparison made with the outcome obtained under existing conditions. Significant deviations can then be identified and used in discussions with affected residents.

Data needs, assumptions, and limitations. Information on the location of important places relative to residences may be obtained directly from residents or through an analysis of GIS maps of the area configured at the census-block-group level; a combination of both may be even more helpful. Times and distances under existing conditions are recorded using the abovementioned pieces of equipment. The primary assumption is that the facilities that contribute significantly to community cohesion and connectivity are within walking distance of residents. One advantage of this method is that it can be adapted to take into account shortcuts that may have been created by pedestrians over time and any associated impacts of the intended project. The most obvious limitation of this method is its reliance upon computed estimates of changes in travel time that may be somewhat susceptible to human error.

Results and their presentation. Results may be displayed in tabular form along with sketches and maps produced for engineering and planning purposes. Photographs may also be used in discussion sessions to aid understanding and decision-making. Because most persons are able to comprehend changes in time more easily than changes in distances, every effort should be made to convert distance changes to travel time units using the average walking speeds obtained during the first phase of this method.

Assessment. This is a relatively simple and low-cost method of assessing the impact of a proposed project on the accessibility of residents in a community that includes protected populations. This method may also be combined with the previous one to effect greater accuracy in decision-making. As stated before, accessibility is one of the key factors that affects communication and connectivity between members of such populations, factors that are central to the presence, strength, and level of community cohesion.

RESOURCES

The following documents are guides that provide readers with further information regarding the methods and techniques recommended in this chapter. A short description follows each title; it draws its text from the summary or introduction provided.

1) Babbie, Earl. 2000. *The Practice of Social Research*. Belmont, CA: Wadsworth Publishing Company.

   This textbook provides insights into the measurement and interpretation of aspects of social reality. Specifically, it provides guidance on the construction of questionnaires and the evaluation and analysis of survey results.

2) Barnard, Kara, and Samita Lall. 1998. "We've Got To Stop Meeting Like This: 36 Ways To Encourage Civic Participation." Toronto Health City Office, Toronto, Ontario, Canada. Available at http://www.unchs.org/cdrom/governance/html/yellop31.htm>http://www.unchs.org/cdrom/governance/html/yellop31.htm.

   This report is a reference for governments, organizations and agencies to assist them in gaining greater public participation in decision-making. It provides a variety of methods for engaging the public and discusses barriers to participation, both physical and perceived.

3) U.S. Architectural and Transportation Barriers Compliance Board. 1998. "Accessible Elements and Spaces: Scope and Technical Requirements." *Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities*. Washington, DC. Section 4. Available at http://www2.bc.cc.ca.us/supportiveservices/ada_text.htm.

   This link provides technical information on standards for constructing transportation facilities as required under the American for Disabilities Act (ADA). The focus is on aspects related to accessibility.

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Forkenbrock, David J., and Glen E. Weisbrod. 2001. *Guidebook for Assessing the Social and Economic Effects of Transportation Projects*. NCHRP Report 456. Transportation Research Board, National Research Council. Washington, DC: National Academy Press. Also available at http://trb.org/trb/publications/nchrp/nchrp_rpt_456-a.pdf.

CHAPTER 9. ECONOMIC DEVELOPMENT

OVERVIEW

Transportation projects have long been identified with economic development. By changing the pattern of accessibility, highway projects can facilitate trade between locations, allow consumers to more easily shop or sell wares at particular places, and even change commuting patterns in ways that might facilitate the growth of employment centers.

These economic impacts often are distributive in nature. The shopping malls locating along a beltway might represent commercial activity that to some extent comes at the expense of stores in a downtown area. Similarly, a highway bypass can facilitate the growth of employment centers, but at the expense of other employment locations. Inner city mayors and downtown business interests have often expressed concern that outlying highway projects can draw jobs and economic development away from central areas, but the distributive effects of highway projects are much more general. Many highway and road projects can generate differential economic impacts across places, and if those differential impacts correlate with the spatial pattern of low-income or minority populations, this can require an environmental justice analysis.

STATE OF THE PRACTICE

The idea that the economic impacts of highways are distributed across the landscape has a long basis in theory. Mohring and Harwitz (1962) argued that many of the economic development impacts observed near highways come at the expense of slower growth in other areas. Forkenbrock and Foster (1990) suggested that a proposed new highway from St. Louis to St. Paul would provide employment growth near the corridor in large part by shifting jobs and economic activity from areas more distant from it. Boarnet (1998a) analyzed data for highway capital stock, employment, private capital, and economic output in California counties from 1969 through 1988. The results suggested that increases in highway capital stock were associated both with higher levels of economic output in the county receiving the additional capital and with lower levels of economic output in other counties. Boarnet concluded that this evidence confirmed the idea that highways redistribute economic activity across the landscape. While some theory suggests that such redistributions need not be zero sum, Boarnet interpreted the magnitudes of the statistical associations as suggesting that the redistributive impacts of highway infrastructure can be at least as important as any aggregate increase in economic growth associated with highways.

Many authors have argued that transportation planners should avoid double counting highway project benefits. Economic benefits flow from changes in accessibility; and, partly for that reason, counting both economic benefits and the underlying changes in accessibility will double-count (and hence inflate) true project benefits. An example of double counting is as follows: suppose a highway improvement reduces the cost of shipping tomatoes to market. Also suppose that, because of these savings, tomatoes are sold at a lower price that exactly reflects the lower shipping costs. The lower market price simply reflects the reduced shipping cost and thus is not a unique benefit. Transportation analysts could count either the reduced shipping costs or the lower market price of tomatoes as a benefit, but not both, because the one flows directly from the other.

For this reason, highway project benefit-cost analysis has often focused strictly on user benefits—reduced travel times, lower vehicle operating costs, and a reduction in the number of accidents—and broader economic impacts have at times been ignored (see AASHTO 2003 for a discussion of this approach). The matter is even more complicated for economic impacts that are in part shifts in activity. Here analysts often argued that ignoring economic impacts altogether was more practical than having to evaluate the gains in one location and the losses in another.

The old maxims do not apply when examining environmental justice concerns. To continue with the tomato analogy, lower shipping costs that result in lower market prices benefit consumers. Lower shipping prices that do not result in lower market prices benefit shippers or tomato growers. Understanding the distributive impacts of the various economic benefits illuminates who gains from a transportation project. The same holds true for business development and economic growth. Environmental justice requires a shift in focus from aggregate benefit-cost comparisons to an understanding of which groups benefit and which groups do not.

While traditional highway project analysis has not focused on the distributive impacts of economic benefits, there are many methods and techniques that can be easily adapted to the task. Because local officials often understand and care about the spatial distribution of economic impacts of highway projects, there is research and practice to provide a foundation for environmental justice analysis in this area. The techniques range from plotting businesses in a corridor, to survey and focus group techniques, to more complex analytical methods. Most have their roots in existing transportation analysis and so will be familiar to transportation planners. In evaluating the environmental justice implications of highway economic impacts, the primary task will be to adapt existing tools to a spatial and distributive framework. This can often be done easily and without substantial additional commitments of agency resources.

SELECTING AN APPROPRIATE METHOD OF ANALYSIS

There are generally two types of economic effects: direct and indirect. The nature and extent of these effects can be quite different during and after construction. Each of these aspects is discussed below. Be sure to adequately address each of these issues as part of an economic assessment.

Steps in the assessment. In general, an environmental justice assessment for the economic development impacts of highways involves two steps—assessing the spatial extent of the positive and negative effects and then overlaying this information on data (often in the form of maps) about minority and low-income communities to assess whether the distributional impact raises environmental justice concerns. In this chapter, we discuss methods for assessing the spatial extent of positive or negative economic impacts from highway projects. Methods for analyzing the locations of low-income or minority populations and for overlaying spatial impacts with demographic characteristics are described in Chapter 2.

Direct and indirect effects. In the rest of this chapter, we refer to direct and indirect economic impacts of highway projects. Direct effects impact businesses immediately within the project area, while indirect effects are experienced by businesses outside of the project area. For example, if a store is adjacent to a widened highway, a direct effect of the project could be increased business due to greater vehicle traffic past the store location. If that increased business represents a shift of business from a competitor a few miles away, the loss in business at the competing store would be an indirect effect.

During and after construction. The distributive impacts of highway projects can be divided into two phases—the construction disruption and the postconstruction period. During construction, access to businesses in the vicinity of the project can be disrupted. Sometimes businesses fear that they will lose customers because of poor access, loss of parking spaces, noise, or other disamenities associated with nearby road or highway construction. The disruption to business activity can be temporary, if the lost customers return after construction is complete, or permanent, if customers form loyalties with substitute stores or suppliers during the construction period. Importantly, there is some disagreement about how much businesses are harmed during a road construction project. Often, transportation agencies take measures to minimize or mitigate the effects of the loss of access, parking, or noise. Also, the negative effects on nearby firms will be influenced by the loyalty of their customers and the nature of their competition. Hence different firms in a construction zone could be affected differently by the project.

After construction, a completed road or highway project can change the pattern of accessibility and thus influence the competitiveness of different businesses. One might imagine that the spatial influence of a road project after construction will be roughly the reverse of the impact during construction. The businesses near the road improvement will benefit from improved access, and might be able to lure customers from more distant competitors. Yet while this example helps illustrate the different distributive impacts of the construction and post-construction time periods, there are many reasons why the impacts during and after construction will not be mirror images. Environmental justice analysis should consider the spatial pattern of the positive and negative impacts of highway projects before and after construction, and how those patterns affect minority and low-income communities.

METHODS

Table 9-1 summarizes the methods we present in this chapter.

Method 1. Map and GIS assessment

The simplest method for assessing the environmental justice impacts of highways related to economic development is to map businesses around the project. This could be as straightforward as walking or driving the corridor (i.e., a so-called "windshield survey") to assess which businesses might be affected by a construction project. More involved analyses can be carried out by looking at business locations that are depicted on a map. Typically, such a map would be developed using geographic information systems (GIS). A similar technique could be used for the after-construction period to identify which firms might benefit from improved access and which might be negatively affected by the loss of business to those firms.

Table 9-1.
Summary of methods for analyzing economic development

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. Map and GIS assessment	Screening	Project/corridor	Effects are expected to be low and more resource-intensive techniques are not available	Low	Geographic information system (GIS)
2. Surveys or focus groups	Screening/ detailed	Project/corridor/ system	Project or policy is controversial and high level of interaction with affected individuals is required	Medium	Group interaction and facilitation
3. Gravity models	Detailed	Project	Changes are expected in accessibility in many directions and over a wide area	High	Accessibility modeling

When to use. This technique is among the least resource intensive and simplest to apply. It is appropriate either where more resource-intensive techniques are not available to an agency or for projects with relatively small impacts for which more rigorous (and hence expensive) analyses would not be commensurate with the scope of the project.

Analysis. For each business identified in the project, you can assess whether the impact of construction will result in a loss of customers using rules of thumb (e.g., reasonable walking or driving distances) or expert judgment (see the description of focus groups in Method 2). This direct effect cannot be cleanly separated from indirect effects because to some extent the loss of customers will depend on available substitute business locations in the same market area. Hence, for each business in the construction zone, you may also want to use data in a GIS format to assess possible competing businesses. This could be a simple listing of such firms, or one could assess the relative characteristics of the competing businesses and the businesses in the construction zone to assess the likelihood of shifts in a customer base.

Data needs, assumptions, and limitations. The key element of this method is to document firms that are likely to be affected either during or after construction because of their proximity to the project. These firms will experience the direct effects of the project. For indirect effects, one could catalogue firms in surrounding market areas. The area of interest might be established based on rules of thumb, as noted earlier, or on more detailed assessments of market areas and the locations for nearby competitors of particular firms near the project.

Results and their presentation. One example of this technique would be to walk or drive the project corridor and catalogue each business by location, type of business, and assessment of the expected impact during and after construction. A hypothetical example of the survey results is shown in Table 9-2.

Table 9-2.
Example of local access assessment

Location	Business	Expected impact during construction	Expected impact after project completion
22 Main	Gas station	One entrance lane obstructed	No change in access
26 Main	Grocery	Loss of 20 parking spaces	New right turn lane into parking lot
30 Main	Hair salon	Entrance lane narrowed	Five new parking spaces
34 Main	Drugstore	Increase in traffic in opposing lane at parking lot entrance	New dedicated left turn lane into parking lot

The same type of analysis could be used to understand impacts after construction. For each business in an area of improved accessibility, you can assess whether that business will likely draw business away from competitors. This can again be based on rules of thumb or expert judgment.

Assessment. This method is the simplest and least resource intensive of those described. As such, it is appropriate in several circumstances. Agencies with limited capabilities can conduct a GIS-based analysis quite easily. This method is also suited to small projects and particularly to those where the agency expects few or no environmental justice issues. Agencies can use this technique as a screening method to verify hunches that projects will have limited environmental justice implications or to illuminate possible issues that will require further analysis. The disadvantage of a GIS-based assessment is that the results can be subjective if, for example, agencies do not carefully articulate the criteria that led to particular conclusions regarding choosing competing businesses or project impact areas. Agencies should take care to apply systematic criteria when making such judgments so that the outcome of the assessment can be clearly linked to the assumptions and methods used.

Method 2. Surveys or focus groups

Understanding attitudes and reactions of parties affected by transportation projects is important in assessing environmental justice. Surveys or focus groups are a useful tool to acquire information about the characteristics of the affected parties, as well as their expectations regarding the project. These can include expected business losses due to construction disruption, expected benefits due to improved accessibility after the project is complete, and perceived changes in competitiveness due to the altered pattern of accessibility. The quality and appropriateness of surveys and focus groups can vary in different contexts. Occasionally, analysts have been suspicious of these methods, fearing that they allow users to overstate negative impacts. Yet agencies have sometimes under-appreciated the value of surveys or focus groups both as a means of outreach and as an analytical tool. In some instances, the perceptions of persons and businesses affected by a project might be more accurate than analytical methods, and surveys and focus groups are an excellent way to get information that otherwise might not be available.

When to use. Survey or focus groups are especially useful (1) when input from affected parties is vital for understanding the distributive character of economic impacts, (2) when impacts are confined to small geographic areas and analytical techniques based on data for larger geographic regions will not capture the spatial character of the impacts, (3) when data on impacts are not readily available from other means, and (4) when agencies will benefit from direct interaction with the public, as in the case of controversial projects where perceptions are important or when an agency wishes to facilitate communication with parties affected by the project.

Analysis. Surveys can be used to capture the general attitudes of a wide range of parties. The results can be analyzed to match groups that benefit from, or are disadvantaged by, transportation projects to geographic locations. Survey sample sizes should be large enough that summaries by geographic areas, income, or race will have sufficient within-category sample sizes. That will often require over-sampling within specific geographic areas, income groups, or minority or ethnic groups.

Data needs, assumptions, and limitations. Surveys can be designed to elicit two kinds of information. The first includes general characteristics of the parties in question, such as type of business, number of employees, logistical and other inventory arrangements, and mode of travel of a firm's suppliers, clientele, and employees. The second includes the expectations of the affected parties regarding losses and gains during and after construction of the project. Firms can be asked to estimate how much business will be lost due to construction disruptions, such as closed lanes, noise, and lack of parking space. The gains are mainly in the form of expected increases in business volume once the project is completed. After completion the project may also adversely affect some firms because of shifts in economic activity to locations better served by the new transportation infrastructure. Hence, some firms might be asked to estimate these negative impacts.

Surveys are typically conducted either by mail or phone. Various books give detailed advice on how to conduct a survey using either method. One popular reference book is *Mail and Internet Surveys: The Tailored Design Method* (Dillman 1999). These books offer suggestions on matters such as phrasing questions in a neutral manner, techniques to increase response rates, and follow-up methods for subjects who do not initially respond to the survey. This literature is useful whether an agency develops its own survey or contracts with an outside firm to create it. There are many firms that provide survey research services. Some have a national client base, while others specialize in particular regions or metropolitan areas.

Internet-based surveys have recently been used in some settings and are also described in Dillman (1999). A common risk in Internet-based surveys, however, is that the sample of respondents will not be representative of an underlying population of interest. This can occur both because persons or firms with Internet access do not represent a random sample of all persons or firms and because those parties who are particularly interested in a topic are the most likely to respond to a survey. While response bias is a potential issue in any survey, it is often regarded as more problematic in settings, like some crude Internet-based surveys, where nonrespondents are not contacted to prompt a response. For environmental justice studies, the fact that low-income populations might not have good Internet access could limit the scope for Internet-based surveys. For this reason, we cannot recommend them.

Note that, when assessing the economic impacts of transportation projects, the survey population is likely to be firms. This raises additional complications beyond those in household surveys. Before the survey is sent, the appropriate officer within the firm must be identified. This should be an individual who has the needed data readily available. For surveys about economic impacts, this individual will likely be someone high in the management structure of the firm. Thus a pre-survey contact to explain the importance of the study is important. Response rates will increase if firms clearly understand how the survey study will benefit them. Even with the best efforts, response rates for surveys of firms are often lower than response rates for surveys of households. For firms, response rates of 20 to 30 percent are not unusual. See, for example, the discussion in Boarnet (1998b) or Kalafatis and Tsogas (1994).

Focus groups provide opportunities for open-ended responses and discussions that are typically not possible in surveys. The groups are usually small—often not more than six or eight persons. They are thus typically used when the need for detailed information outweighs the need for statistical analysis. Focus groups are desirable when agencies are in the exploratory phase; often the information gathered can be used in later research. For example, it is common to use focus groups in the preliminary phase when designing a survey.

Results and their presentation. The central purpose of surveys and focus groups is to acquire a clear understanding of the general attitudes, concerns, and preferences of minority populations and low-income populations regarding a proposed transportation project. Results of these methods of interacting with protected populations can be used to help assess whether the project would have a generally positive or negative effect on the economic well-being of these populations. The results also can be used to identify changes in the project or measures that could be taken to mitigate undesirable effects.

Often, the analysis of survey data involves summarizing responses for the population. For environmental justice analyses, survey responses will typically be summarized by geographic area, income, or race. This requires that data be collected on locations of survey respondents (firms or households) and on income or race for individuals or for firm owners, employees, and clientele.

Assessment. Surveys and focus groups provide detailed information due to the first-hand knowledge of the persons surveyed or interviewed. Hence, these techniques can improve the understanding of the distributive impacts of transportation projects, and the results can be used to design mitigative measures. One must be careful when using survey data, however. Survey respondents who oppose a project, for example, may exaggerate its negative impacts. In addition, the gains and losses predicted by respondents will be based on their perceptions, which may be inaccurate. Care should thus be taken when interpreting the results. Surveys are most reliable when respondents are better able to judge impacts than any other group and when they have little incentive to exaggerate or misstate impacts.

Method 3. Gravity models

In addition to being used as a trip distribution model in the traditional four-step transportation planning process, gravity models are also widely used for market analysis. These models can be used to determine such things as the spatial extent of retail market areas, optimal store or public facility sizes, and optimal store or facility locations. The ability of gravity models to give estimates of the size of market areas is of particular interest when assessing the economic impacts of highway projects. Gravity models can be used to understand how changes in accessibility will change market areas, and hence sales, at particular store locations or in particular geographic areas. They can give both qualitative assessments of locations that will likely experience changes in business activity after a transportation improvement and quantitative estimates of those changes. Good references on gravity models for this sort of application include Hayes and Fotheringham (1984), Bendavid-Val (1991), and Filipovitch (1996).

Gravity models have two basic elements, scale and distance, which are the determinants of the interaction between any pair of geographical areas. For example, densely populated cities (large scale) tend to generate and attract more trips than sparsely populated cities. Moreover, trips are more likely to occur between cities that are located closer together (short distance) than between distant cities. Gravity models can be adapted to assess environmental justice impacts of highways by analyzing how changes in accessibility (distance impacts) affect the relative attractiveness of communities or neighborhoods.

When to use. Gravity models are most appropriate for a highway project that creates significant changes of accessibility in many directions and over a wide area. They can help answer questions about how a proposed transportation project would affect the ability of businesses operated by or serving minority populations to be competitive. Agencies with an operational transportation planning model can make some adjustments to the model to analyze environmental justice impacts. Also, gravity models can be used as a stand-alone tool. Some technical skills are required, however, and so this method may not be suitable for agencies with limited resources.

Analysis. With traffic analysis zones (TAZs), census tracts, or census block groups as the units of observation, gravity models can predict how a highway project will affect the attractiveness of an area through changes in its relative accessibility. Consider the hypothetical example in Table 9-3. In the table, origin TAZs are shown in each column, and destination TAZs in the rows. For example, initially, average time for trips that start and end in TAZ A is 5 minutes. Average time for trips that start in TAZ A and end in TAZ B is 15 minutes.

The impact of the project is depicted in Figures 9-1 and 9-2. Before a new highway is built, traffic from TAZ A to C must go through B. The construction of the highway causes disruption in TAZs A and C, thereby increasing travel time both within the TAZs and between them. However, after the highway is opened, travel time between A and C (bypassing B) is reduced by more than half. Because less traffic needs to go through TAZ B, the travel time between A and B also decreases. However, the travel time between A and C becomes less than between A and B. The question is then, how does the new highway affect the relative attractiveness of each zone?

The *production-constrained* gravity model can be written as:

$$T_{ij} = \frac{O_i w_j^a d_{ij}^b}{\sum_j w_j^a d_{ij}^b}$$

where

Tij = the shopping spending of zone i residents in zone j

Oi = total shopping spending of zone i residents

wj = the number of retail stores (or total retail square footage) in zone j

dij = the distance between zone i and j

The total amount of retail sales in zone *j*, R_j is given by

$$R_j = \sum_i T_{ij}$$

Table 9-3.
Travel times between TAZs

Initial travel times (minutes)			
	Origin TAZ		
Destination TAZ	**A**	**B**	**C**
A	5	15	25
B	15	5	10
C	25	10	5
Travel times during the construction (minutes)			
	Origin TAZ		
Destination TAZ	**A**	**B**	**C**
A	10	15	30
B	15	5	10
C	30	10	10
Travel times after the opening of the highway (minutes)			
	Origin TAZ		
Destination TAZ	**A**	**B**	**C**
A	5	12	10
B	12	5	8
C	10	8	5

The parameter *a* is expected to be positive, as the larger the number of stores in a zone, the more attractive it will be to shoppers. In contrast, *b* is expected to be negative because the more distant the zone, the less likely shoppers will travel to shop there. The above model can be estimated with survey data on shopping travel patterns. In past studies, the ranges of *a* and *b* were found to be between 0.5 and 2.0, and -0.5 and -2.0, respectively.

Although how the values of the parameters are determined is beyond the scope of this guidebook, some insights into their relative values may be provided here. For example, the values of the parameters may reflect characteristics of trip makers and road networks. Inaccessible locations, such as those within congested areas, may be associated with larger d_{ij} because even short distances can provide disincentives for making a trip. Also, destination characteristics and trip purpose can be reflected by the parameter w_j. For instance, grocery stores attract trips with higher frequency than furniture stores. In this case, zones with stores that attract trips with lower frequency may be associated with a smaller w_j.

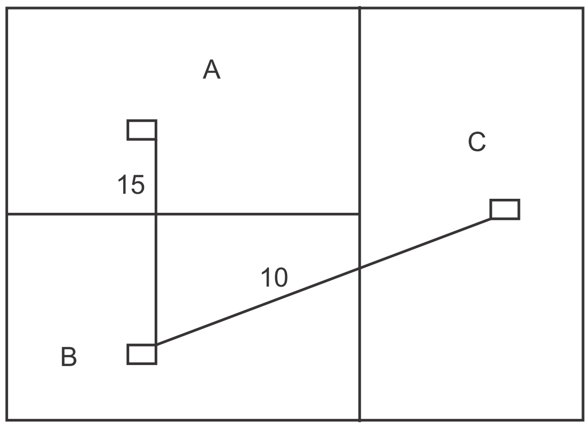

Figure 9-1. Initial network travel times between TAZs

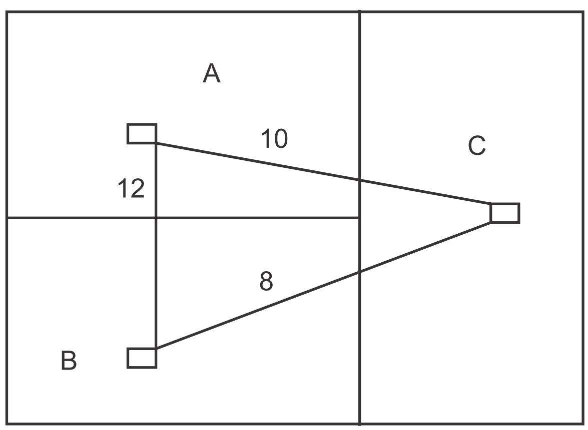

Figure 9-2. Network travel times between TAZs after the opening of the highway

The forecasted link travel times during and after construction can be input into the gravity model. The results will be a new pattern of trip distribution between zones. If we assume that each zone generates the same amount of traffic, the travel time between zones will determine the amount of traffic between them. The initial distribution will therefore be such that TAZ B will be the most attractive because it is most accessible to both A and C. During the construction, the distribution pattern will not change much because even though travel times in TAZs A and C increase, the relative travel times do not change overall. However, after the highway is opened, travel times from both TAZs A and B to C will decrease, thereby improving the overall attractiveness of TAZ C. TAZ B, on the other hand, will become less attractive relative to C. With this pattern of changes in trip distribution, we can assume that businesses in TAZ C will benefit from the highway opening, but those in TAZ B will likely suffer. According to these results, we can create a map that reflects the distribution of benefits as shown in Figure 9-3.

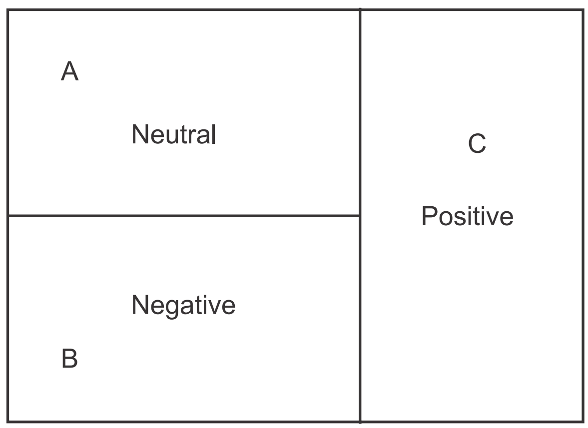

Figure 9-3. Distribution of economic impacts after construction

This map can then be overlaid on a map that represents ethnic and income groups to analyze the environmental justice impacts of the new highway. It is also possible to quantify the gain and loss at different locations in monetary terms. A gravity model can be used to allocate retail-shopping spending to various neighborhoods based on existing residential locations and accessibility changes due to the new highway project. For example, if the population and average income in the three TAZs above are known, they can be used to estimate retail-shopping spending by residents of each TAZ using the gravity model described below.

To quantify the impact of a highway project on retail sales, you can compute the retail sales in each TAZ based on current network travel times. This is used as a basis for comparison. The new network travel times can then be used to predict retail sales after the project is completed. The change in retail sales reflects gains and losses in each TAZ. This information can be used to construct a map of distributive impacts. The overlaying technique, as discussed earlier, can then be used for further analysis to determine how distribution impacts may differentially affect protected populations.

Data needs, assumptions, and limitations. The key information for this method is how a highway project affects accessibility. This information will be used to determine changes in link travel times in the network, which will in turn become inputs for the gravity model. For the construction phase, changes in accessibility can include delays that can be estimated by the number of lanes lost. The construction delay can also be estimated through expert judgment based on past experience with similar projects. For the postconstruction period, changes in accessibility will likely be available from other elements of the project analysis. The information on changes in accessibility can then be used to forecast the change in link travel times in the overall network. Forecasted link travel time changes, for both the construction and post-construction time periods, can be used to obtain a gravity model assessment of the spatial distribution of the economic impacts of a highway project.

Results and their presentation. The primary results obtained from applying gravity models is an assessment of how businesses in a particular area of the community would fare if a major transportation project were undertaken. The analysis can be carried out to estimate competitive effects during the construction phase, as well as when the project is completed. As indicated in Figure 9-3, it is possible to superimpose a spatial depiction of changes in competitiveness on socioeconomic data. This facilitates an assessment of the economic development effects on low-income or minority activity spaces of the community.

Assessment. In agencies with readily available transportation planning models, the method for assessing environmental justice impacts using the gravity model is quite simple and straightforward to implement. Agencies with limited resources, however, may not be able to utilize this method. The method works well with large transportation projects to identify which areas of a community would experience gains or losses but is sometimes not sensitive enough for smaller ones. This is due to the aggregate nature of the analysis, with data typically aggregated to TAZs or similarly sized geographic observations. Of course, if small-scale geographic impacts are important, one could collect data for smaller areas. In assessing distributive impacts, the unit of analysis should be internally homogenous in racial, ethnic, or income distribution. If this is not the case, variations within a geographic area will possibly have environmental justice implications that would not be illuminated by the analysis. If the geographic observations are not internally homogenous, additional studies on microlevel distributive effects within areas of special concern can be used as a supplement to further clarify environmental justice issues.

Another important problem that cannot be addressed explicitly by the gravity model is the impact of new development. New highways can attract new development, which could in turn affect the distribution of sales. The gravity model, however, treats retail businesses as exogenous and therefore cannot capture this aspect of the distributive impacts of transportation projects. The problem can be alleviated if new development can be forecast. The forecast future retail floor space can then be input into a gravity model. This will yield results whose reliability will depend on the quality of the forecast of changes in the location of business activity.

RESOURCES

1) 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.

2) 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.

3) 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 postinvestment effects of businesses that benefited by specific road projects.

4) Hagler Bailly Services, Inc. 2000. “Guidance on Using Economic Analysis Tools for Evaluating Transport Investments.” National Cooperative Highway Research Program, Project 2-19(2) Contractor Final Report. Washington, DC: Transportation Research Board, National Research Council.

This 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.

4) 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.

5) 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.

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CHAPTER 10. NOISE

OVERVIEW

Any undesirable sound can be considered noise. Vehicle engine, vehicle exhaust, tire-pavement interaction, locomotive engine and exhaust, locomotive horn, train wheel-track interaction, and jet engine noises all result from everyday transportation activities. These noises also are among those most often cited as causing the highest levels of annoyance. Various transportation modes can generate sound levels great enough to cause hearing loss and tinnitus (i.e., ringing in the ears). It is unlikely, however, that very many people will be exposed long enough to experience actual hearing loss or damage, except in the workplace environment. Health effects are therefore not the most common transportation noise issue. A much more common concern is the annoyance that persistent noise causes for individuals living, working, or participating in other daily activities near transportation facilities.

The FHWA and the FTA have developed methods to determine project noise levels and whether these levels are significant enough to be defined as an impact. The results of these standard methods can readily be used to perform environmental justice assessment. Impacts can occur either as a result of noise level increases or of threshold exceedance. The impact criteria adopted by FHWA and FTA have been developed over time and are based on surveys and research on annoyance and aggravation.

Both the FHWA and FTA use impact level as an indication that noise mitigation should be considered. The FTA has stratified impact levels into three classifications: no impact, impact and severe impact. In general, environmental justice assessments of distributive noise effects should use these standard impact classifications and threshold levels only as a starting point. Evaluating the level of effects against standard thresholds is not acceptable as a final determination of “adverse effect” as the term is used in this guidebook. Perceptions of what constitutes an adverse noise effect can vary considerably from individual to individual and from community to community. For transportation projects, the noise impact criteria are therefore not designed to be absolute. Rather, the criteria may be used as a guide to determine whether levels of an effect *must* be mitigated according to regulation.

Various methods are used to evaluate project noise level increases and net project noise levels. The FHWA and FTA have slightly different methods, and each can be used to evaluate distributive effects to protected populations. Results of both FHWA and FTA noise assessments commonly indicate the number of sensitive receptors (locations at which noise is measured) that would experience an impact (e.g., 57 residences). Thus, analyses usually are performed at discreet locations within the study area. In some instances, noise level contours are used to determine the number of receptors. Both contour-based and receptor-based results can be used to evaluate distributive effects to protected populations.

It can generally be expected that receptors near a project will incur the greatest noise level increase and sustain the greatest net noise level. Noise impacts of road and rail construction and operation are localized, and normally are experienced at the first row of houses or properties adjacent to transportation projects. Properties further from the project often are protected from noise by the first row of properties.

Due to the localized nature of noise impacts, it is often acceptable to evaluate the potential for effects to protected populations by assuming a maximum distance at which impacts could occur. This assumed distance can be used to perform a quick buffer analysis in a geographic information system (GIS). If sensitive receptors are located within the area of potential effects, more sophisticated noise receptor or contouring techniques can then be used to characterize the level of effects and the sensitive receptors that would experience them. Regardless of the approach selected, noise analysis results can be overlaid with demographic information in GIS to evaluate effects to protected populations.

STATE OF THE PRACTICE

Noise modeling analyses frequently are conducted using models developed by the FHWA and the FTA, and transportation projects are evaluated according to the criteria established by each agency. This section describes how noise is evaluated and presents the FHWA and FTA criteria.

Table 10-1 lists common transportation factors that affect neighborhood noise levels. See FHWA (1992), FHWA (1995), and FTA (1995) for further information. Reviewing transportation projects with these factors in mind will help to identify projects in which noise should be assessed.

Table 10-1.
Transportation factors affecting neighborhood noise levels

Factor	Description
Traffic volume	Traffic noise increases with traffic volume. Two thousand vehicles per hour sound twice as loud as 200 vehicles per hour.
Traffic speed	Traffic noise increases with traffic speed. Traffic at 65 miles per hour sounds twice as loud as traffic at 30 miles per hour.
Vehicle types	Trucks are especially noisy. A single truck sounds as loud as 28 automobiles at 55 miles per hour.
Traffic flow	Free-flow traffic and stop-and-go traffic create different noise problems.
Distance from roadway	Sound levels decrease in proportion with the square of distance from the source. Traffic noise is not usually a serious problem more than 150 meters from a heavily traveled road or more than 30 to 60 meters from lightly traveled roads.
Barriers	Barriers such as buildings and walls are highly effective ways to deflect noise from residential areas or other sensitive receptors.
Land use	The level of acceptable noise intensity varies by land use. Even moderate noise levels may be unacceptable near churches, hospitals, schools, and other sensitive receptors.
Construction	Noise from transportation construction projects, although temporary, can cause serious disruptions and should be evaluated as part of noise studies.

Source: Derived from Forkenbrock and Weisbrod 2001, p. 130.

Sound level and the noise pattern (continuous, random, or repeated) all are important in characterizing nuisance levels. Absolute noise levels, or the net change in noise levels due to a transportation system change, are thus only part of what must be considered in an effort to understand how a community may respond to altered noise patterns.

FHWA. The highway traffic noise prediction requirements, noise analyses, noise abatement criteria, and requirements for informing local officials comprise the noise standards mandated by 23 U.S.C. 109(i). See FHWA (1995) for further information. All highway projects developed in conformance with this noise regulation are considered to be in conformance with the FHWA noise standards.

Table 10-2 shows the current FHWA Noise Abatement Criteria (NAC). The NAC are defined in hourly A-weighted decibels expressed as L_{eq}(h) or L_{10}(h). A decibel (dB) is the most common unit of noise measurement. Because the human ear has differing levels of sensitivity to high-pitched and low-pitched sounds, highway traffic noise measurements are adjusted to approximate human hearing. These adjusted measurements are known as A-weighted decibels (dBA).

Table 10-2.
Noise abatement criteria hourly A-weighted sound level in decibels

Activity category	L_{eq}(h)	L_{10}(h)	Description of activity category
A	57 (Exterior)	60 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to fulfill its intended purpose
B	67 (Exterior)	70 (Exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals
C	72 (Exterior)	75 (Exterior)	Developed lands, properties, or activities not included in Categories A or B above
D	None	None	Undeveloped lands.
E	52 (Interior)	55 (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums

Source: FHWA 1995, p. 7.

Although the A-weighted sound level may adequately indicate the level of environmental noise at any instant in time, community noise levels vary continuously. Most environmental noise includes a conglomeration of noise from distant sources that creates a relatively steady background noise in which no particular source is identifiable. A single descriptor called the equivalent sound level (L_{eq}) is used. L_{eq} is the mean A-weighted sound level during a measured time interval. It is the "equivalent" constant sound level that would have to be produced by a given source to equal the measured fluctuating level. The Day-Night Average Sound Level (L_{dn}) is defined as the A-weighted equivalent sound level for a 24-hour day with a 10 dBA penalty applied to nighttime levels (10 p.m. to 7 a.m.) to compensate for the increased sensitivity to noise during the quieter nighttime hours.

L_{eq}(h) is most commonly used to evaluate project noise impacts. These NAC levels are only to be used to determine impact, and by definition are the absolute levels at which abatement *must* be considered. Depending on the circumstances of the project being analyzed, it may be necessary to mitigate noise levels that fall either below the NAC or below state-designated criteria. When noise abatement is required, it should be designed to achieve a substantial noise reduction. It is generally not acceptable to merely reduce noise levels to just below the NAC.

Figure 10-1 provides an A-weighted decibel scale showing commonly experienced noises for comparison with the FHWA NAC in L_{10}(h). Zero dBA is defined as the faintest sound that can be heard by the human ear. To most people, 60 dBA is perceived as twice as loud as 50 dBA, and 70 dBA is perceived as four times as loud as 50 dBA.

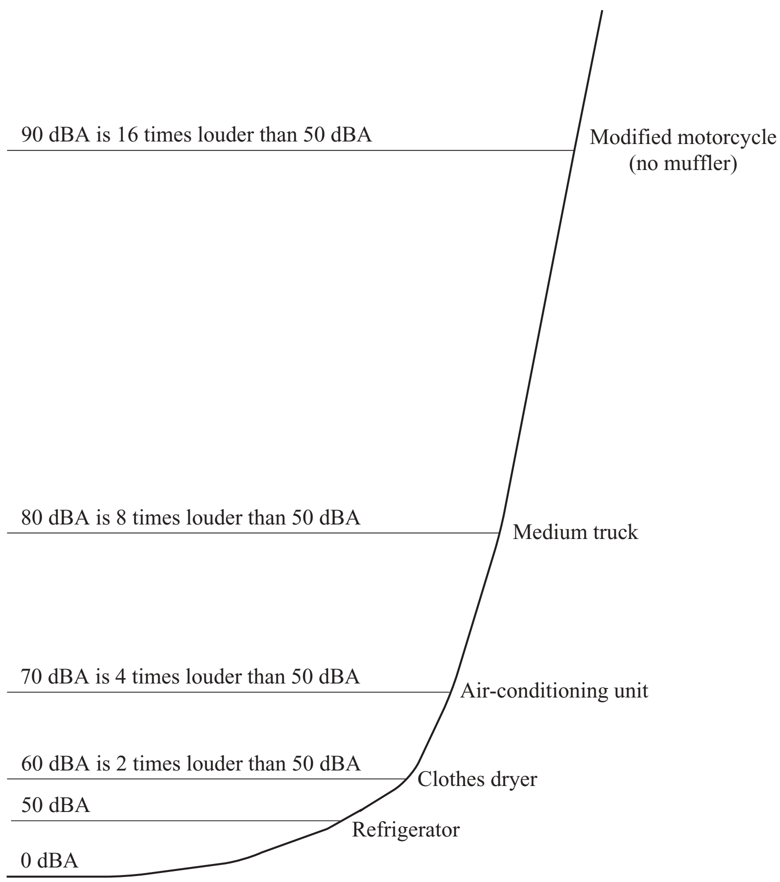

Figure 10-1. Commonly experienced noise levels

Source*:* FHWA 1992, p. 3, reproduced from Forkenbrock and Weisbrod 2001.

State highway authorities have the power to determine how to implement the NAC. States can thus develop criteria for abatement levels that approach or exceed the NAC. For example, a state could establish abatement criteria for noise levels that are within 1 to 2 decibels of the NAC, or it could set abatement requirements for noise levels that exceed the NAC. States also have the authority to establish impact criteria for decibel level increases. Under such criteria, the absolute noise level is not at issue. Rather, the criteria recognize that significant increases in noise levels may have adverse effects in and of themselves.

The FHWA model was redeveloped in 2002 and is called the Traffic Noise Model (TNM). This model provides noise levels at discrete receptor locations and also can be used to create noise level contours (Forkenbrock and Weisbrod 2001).

FTA. The FTA Transit Noise and Vibration Impact Assessment criteria are shown in Figure 10-2 and Table 10-3. Similar to the FHWA criteria, FTA criteria provide a threshold at which noise abatement *must* be considered. The FTA criteria are a set of complex curves that incorporate a comparison of existing noise levels with predicted project-generated noise levels.

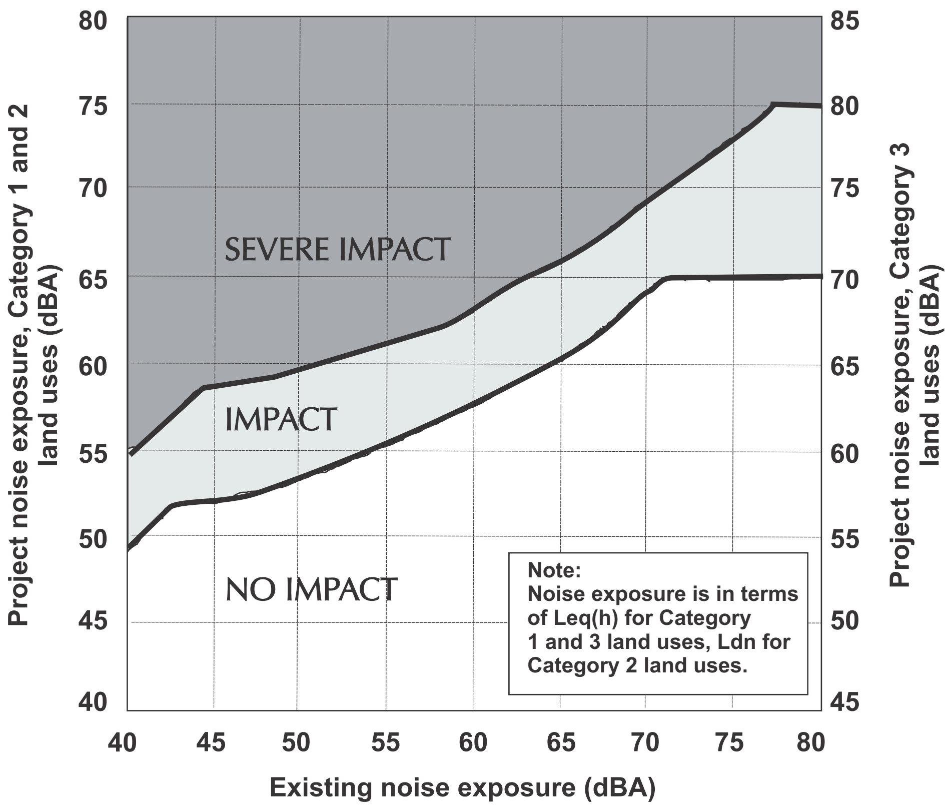

Figure 10-2. FTA transit noise and vibration impact
Source: FTA 1995.

The FTA analysis procedure uses a spreadsheet to determine project-generated noise levels, which are then compared to existing noise levels. The results of these analyses are not net noise levels at discrete receptors but impact levels (no impact, impact, or severe impact) at discrete receptors. This information is sometimes used to create impact level contours. These contours can be used along with GIS to determine whether disparate impacts occur based on net noise levels (FTA 1995).

Table 10-3.
Land use categories and metrics for transit noise impact criteria

Land use category	Noise metric (dBA)	Description of land use category
1	L_{eq}(h)* (outdoor)	Tracts of land where quiet is an essential element of their intended purpose. This category includes lands set aside for serenity and quiet and for such land uses as outdoor amphitheaters and concert pavilions, as well as for National Historic Landmarks with significant outdoor use.
2	L_{dn}(h) (outdoor)	Residences and buildings where people normally sleep. This category includes homes, hospitals, and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
3	L_{eq}(h)* (outdoor)	Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, and churches where it is important to avoid interference with such activities as speech, meditation, and concentration on reading material. Buildings with interior spaces where quiet is important, such as medical offices, conference rooms, recording studios, and concert halls fall into this category, as do places for meditation or study associated with cemeteries, monuments, museums. Certain historical sites, parks, and recreational facilities are also included.

* L_{eq} for the noisiest hour of transit-related activity during hours of noise sensitivity.

Mitigation. Noise mitigation is often considered as a part of a transportation project study if a noise impact is expected. Results of noise analyses may include the mitigated noise levels, and could still result in project noise impacts even though all reasonable and feasible measures were included. Noise mitigation measures include barriers such as noise walls or earthen berms; other measures include reducing speeds, limiting truck usage, or moving roadway alignments further from a receptor.

Consideration also should be given to possible side effects of noise mitigation, such as aesthetics, safety, and visibility. These effects can be evaluated using techniques provided in other chapters of this guidebook. Examples of impacts include blocked views of features considered valuable by property owners, such as sunlight, wetlands, parks, and other aesthetic views. Communication with residents is an important element in determining whether any planned mitigation is desirable.

SELECTING AN APPROPRIATE METHOD OF ANALYSIS

Table 10-4 provides a summary of the methods presented in this chapter. Because noise is one of the most common community concerns with transportation projects, noise evaluation methods for highway, transit, and rail projects are well developed and commonly used.

Both the FHWA and the FTA have developed standards and guidance for evaluating noise impacts. Integrating standard noise-effect information with demographic information therefore is the best way to perform an environmental justice assessment of noise effects. The demographic information must adequately characterize the activity spaces within which protected populations may be subject to increased noise levels. Because noise impacts are highly localized, detailed information that identifies demographic characteristics of persons associated with specific properties (i.e., living, working, or otherwise spending significant amounts of time at a site) is preferred over census data. Census data can be used to evaluate distributive effects in cases where the affected area is relatively large or where only screening-level results are needed.

Table 10-4.
Summary of methods for analyzing noise effects

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. Initial evaluation	Screening	Project, corridor and system initial review to identify potential for noise effects	In early planning stages and for initial environmental review or for evaluating projects with limited noise effects or with few nearby noise receptors	Low	Spreadsheet, knowledge of census data, GIS helpful
2. Highway project noise analysis	Detailed	Assess noise exposure levels from transportation projects	Highway construction and operation noise effects must be evaluated in detail and there is potential for effects to protected populations	High	FHWA Transportation noise model, knowledge of demographic data, GIS helpful
3. Transit project noise analysis	Screening/ detailed	Assess noise exposure levels from transit projects	Transit construction and operation noise effects must be evaluated in detail and there is potential for effects to protected populations	Medium/ high	FTA noise/vibration evaluation methods, know-ledge of demo-graphic data, spreadsheet, GIS helpful

Three general methods are described in the next section of this chapter. The first method, initial evaluation, can be used in most situations (highway, transit, rail, and multiple modes) to determine if there is potential for noise effects and if protected population groups could experience those effects. It does not, however, provide information on the level of noise effects or if protected populations would be disproportionately affected. The method is best suited for identifying projects that require more thorough evaluation and for targeting specific sites within an affected area that may require environmental justice outreach and detailed assessment. The second and third methods are based on FHWA and FTA noise assessment standards and can be used to perform detailed environmental justice assessment relative to noise effects of highway projects and transit projects, respectively.

METHODS

Method 1. Initial evaluation

When to use. The initial evaluation consists of a data review to identify the presence of protected populations in a study area and to determine the level of potential noise impact. The objective of this method is to determine whether a detailed noise analysis is needed and if there is potential for noise impacts to be experienced by protected populations. The results will be important in planning for the time and resources needed to conduct a thorough noise assessment and, if necessary, for enhanced public outreach and detailed environmental justice assessment to characterize distributive effects. The initial evaluation should be performed early on in project planning or during the scoping phase of environmental review. The information needed and required tools are straightforward and easy to use.

Analysis. There are three main steps to this analysis, each described below.

Step 1 - Define the impact area. Use the geometry of the project (such as the roadway or rail centerline) and any larger construction areas (such as interchanges or rail terminals) to define the area of potential noise effects. For roadways, determine if the segment is highly traveled, such as a freeway or arterial, or lightly traveled. As a guide, consider defining the area of potential effects as being within 150 meters of either side of the centerline for highly traveled segments and within 60 meters of the centerline for lightly traveled segments (Forkenbrock and Weisbrod 2001, p. 130).

For initial assessment of transit noise, the area of potential effects can be determined using the FTA guidelines for transit noise assessment (FTA 1995, Chapter 4, Table 4-1). In general, a distance of 750 ft (230 m) will capture all likely noise effects from common linear transit system features. For larger transit system features, such as yards and storage and maintenance facilities, a distance of 2,000 ft (610 m) should be used from the center point of facilities. This distance is also reasonable for evaluating temporary noise effects of highway and transit construction.

For relatively small projects, this step can be performed efficiently using desktop information, such as hardcopy maps. For larger projects, it will be more efficient to use buffer analysis in GIS to define the area of potential effects.

Step 2 – Identify protected populations, affected land uses, and activities. Overlay the area of potential noise effects with demographic information and, if available, information on the location of sensitive receptors. Depending on whether you are evaluating a roadway or rail project, assign land uses in the area of potential effects to the corresponding FHWA or FTA categories. Use as input a combination of small-scale census data (blocks and block groups), land use information, and sensitive receptor information collected through a field study and/or through interviewing neighborhood residents.

Step 3 – Perform noise impact screening analysis. If the results of Step 2 indicate that residences, work places, or other activity centers used by protected populations are likely to be affected, perform the noise impact screening analysis. This is the final step in determining if noise can be expected to be enough of a concern to justify a more detailed analysis. For highway projects, the TNM provides lookup tables that can be used to perform the screening analysis (FHWA 2004). In some states, models other than TNM are used to evaluate noise impacts. If the TNM is not available, procedures specific to the model in use should be used to conduct the screening analysis. For transit projects, the FTA noise screening procedure can be used (FTA 1995).

Data needs, assumptions, and limitations. Protected population information needed for an initial assessment includes census maps showing minority and low-income populations and information on receptors that neighborhood residents feel should be protected. For highway projects, the following information is needed to use the TNM lookup tables:

- Volume and speed information for automobiles, medium trucks, heavy trucks, motorcycles, and buses;
- Terrain information (i.e., pavement, lawns, etc.);
- Distances from centerline to receptors; and
- Noise barrier information including distance from centerline and height (optional).

For transit projects, the following information is needed to perform the FTA noise screening procedure:

- List of transit project features (e.g., commuter rail stations and mainlines, bus ways, maintenance facilities) and
- Distances from noise source to receptors.

As screening procedures, the FHWA and FTA make numerous simplifying assumptions. The TNM lookup tables assume free-flow traffic at a single speed on a straight roadway. Multiple barriers cannot be evaluated. The receptor height is assumed to be constant, always 1.5 meters. The FTA noise screening procedure is based on considerable research into the maximum distance of effects that can be expected in most transit project configurations. The distances are based on the formulas used in the FTA's detailed assessment, with a factor added to ensure conservative results. For either screening technique, the detailed assessment is required if project noise levels are found to approach levels that require abatement.

Results and their presentation. Figure 10-3 shows a summary table and map excerpt for a hypothetical initial assessment of a proposed light rail transit (LRT) expansion project. The map shows the rail centerline and major cross streets. The area of potential impact was defined based on such FTA criteria as census-block-group areas within 230 meters of the rail centerline. The block-group areas are categorized based on relative level of environmental justice concern, computed using the environmental justice index (EJI) (See Chapter 2). For each block-group area, the table lists the estimated number of receptors and estimated number of potentially affected minority individuals.

Based on the results in this example, a detailed transit project noise analysis would be required. In addition, a detailed environmental justice evaluation should be conducted for the areas of medium and high concern. These are the areas where targeted environmental justice evaluation work should be performed. Possible evaluation activities could include public outreach; interviews to identify receptors that the minority communities would like to have protected; and detailed assessment to determine if noise mitigation measures adequately protect minority individuals.

Block group	Relative level of EJ concern (EJI)	Potentially affected minority individuals	Receptors in area of effects
5005	Medium	0	0
9001	High	163	58
6023	Medium	32	20
6021	Low	63	84
7021	Medium	63	35
5064	Low	19	61

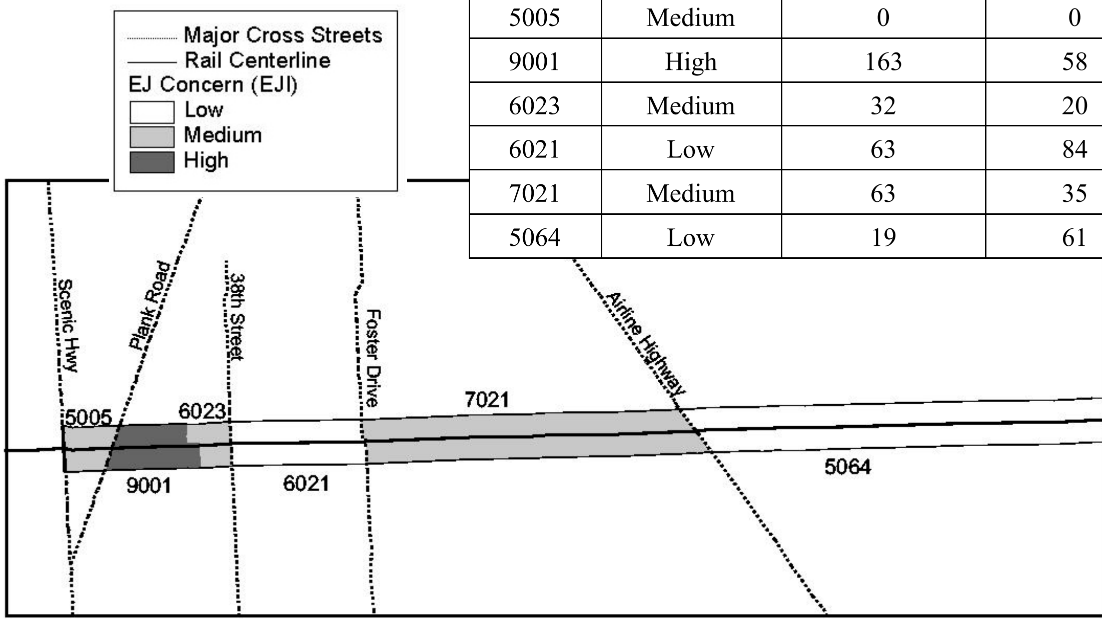

Figure 10-3. Initial noise evaluation results for LRT corridor expansion

Assessment. The highway and transit initial evaluations are effective techniques for quickly identifying whether a project or project alternatives would have noise impacts. The objective of these evaluations is to determine if more detailed and costly noise assessment is warranted. Desktop techniques or GIS buffer analysis can then easily be used to identify the potential for noise effects to protected populations. Use of these techniques should be limited to early project planning stages or to the beginning stages of an environmental review. Data needs are relatively low, and little expertise in either noise modeling or GIS is needed to perform the evaluation. As a result, this technique can readily be used to evaluate distributive noise effects at the system and corridor level.

Method 2. Highway project noise analysis

When to use. A detailed highway project noise analysis should be conducted in the following situations:

- Along a newly constructed segment of roadway,
- Where significant horizontal or vertical alignment shifts will occur,

- When significant traffic volume increases are expected as a result of the project, and
- When an initial evaluation indicates the potential for adverse noise effects to protected populations.

If an alignment shift or traffic volume increases are substantial enough to cause a noise impact, a detailed analysis should be considered. Any capacity increase will generally cause alignment shifts or involve new roadway connections and traffic volume changes that require a detailed noise analysis. In addition to roadway characteristic changes, proximity to sensitive noise receptors should also be considered. If there are no sensitive receptors within several hundred feet of a roadway project, a detailed analysis may not be needed.

Analysis. The four steps in the analysis are described below.

Step 1– Run detailed highway noise model. Detailed highway noise analyses usually incorporate the FHWA noise model (described previously) to determine noise levels at discrete receptor locations. After impact areas are determined, a detailed noise mitigation analysis is conducted. This analysis will generally include the introduction of a barrier, such as a noise wall or an earthen berm, between the roadway and the receiver. The noise-level results of the mitigation analysis are used to determine whether noise mitigation is reasonable and feasible. A reasonable noise wall would meet cost-effectiveness criteria, which are typically determined by the state highway agency. A feasible noise wall is one that could be constructed without causing another unwanted impact, such as a safety problem from loss of line of sight or another environmental impact.

Cost effectiveness can be determined by analyzing noise levels with and without noise barriers, counting the number of houses that will experience a noise-level reduction, and calculating the cost of the barrier that produces the noise-level reduction. State highway agencies will often have a dollar value that is considered cost-effective, typically $3,000-4,000 per decibel reduction per household.

The publication, *Highway Traffic Noise Analysis and Abatement Policy and Guidance* (FHWA 1995), assists state highway agencies in setting local policies.

Step 2 – Overlay with demographic information and tabulate results. This step is similar to the process described under Method 1. The only differences are the level of detail provided by the noise impact model and the more thorough review of the demographic data used, including data collection from surveys and/or interviews.

Step 3 – Evaluate distribution. To evaluate distributive effects, you must estimate the number of affected persons in each population cohort. You must also assign an estimated level of effect to each individual, such as an estimated decibel level or a category of high-, medium-, or low-impact.

A basic technique for estimating the number of individuals and their demographic characteristics is to assign population percentages to receptors based on the census blocks and block groups that they fall in. Thus, if the receptors are housing units, you multiply the number of housing units by the average persons per household and the minority and low-income population percentages reported for the block group in which they fall. Adding estimates of the number and demographic characteristics of persons using nonresidential receptors completes the tabulation. A more precise approach would be to tabulate the number of individuals linked to receptors and their demographic characteristics based on results of surveys and interviews of neighborhood residents, even to the level of property-by-property information if possible.

Step 4 – Compare against alternative scenarios. A common need is to compare existing conditions with future-year build/no-build scenarios, both with and without mitigation options. This will demonstrate if the project is likely to generate noticeable increases in noise levels to protected populations and will also indicate the locations in which those increases may be expected. If premitigation distributive effects are identified, it is especially important to evaluate whether or not the mitigation options adequately reduce noise levels in areas of concern. When performing this analysis, it is not advisable to apply the NAC, FTA, or state-derived criteria. Rather, once a potential for unequal distributive effects has been identified, the net increase or decrease in noise levels should be evaluated without respect to threshold criteria.

When evaluating the co-distribution of effects and protected populations, it is often helpful to visualize the information. Throughout the guidebook we present many examples of maps serving this function. Figure 10-3 is one example. Figure 10-4 shows a graphical visualization of results. Both premitigation and postmitigation future-year noise level estimates for 30 housing unit receptors with an estimated exposed population of 100 persons are displayed. The performing agency set the noise abatement threshold at 50 dBA L_{eq}(h), which is two dBA below the FHWA NAC of 52 dBA (interior) for residences. Thus, by the performing agency's definition, 50 dBA is the level at which noise abatement must be performed. Further, the agency established a threshold of concern at 45 dBA, indicating that concern over noise could be expressed by community members at levels from 45 to 50 dBA and that mitigation measures might be required within this range.

The top chart shows the premitigation dBA exposure for members of protected population groups compared to other exposed individuals. This chart shows that a higher proportion of individuals in protected population groups were likely to experience noise exposure levels above 47 dBA when compared to the rest of the population in the impact area. The chart also shows that there are individuals who would experience noise levels above the 50 dBA mitigation threshold (if no individuals were exposed above 50 dBA, the "percent of population" beyond that number would be zero).

The bottom chart gives the postmitigation dBA exposure comparison. This chart shows that (a) no individuals are exposed to noise levels above the noise abatement threshold of 50 dBA, and (b) the proportion of individuals in protected population groups exposed to 45 to 50 dBA is equal to that of the population as a whole.

It is important when using this technique to compare the rest of the population to both (a) the percent of the protected population and (b) the total number of individuals in the protected population group that would experience adverse noise effects. This can be done by preparing one set of graphs with percent of population as the vertical axis (as in Figure 10-4), and another set of graphs with the number of persons as the vertical axis.

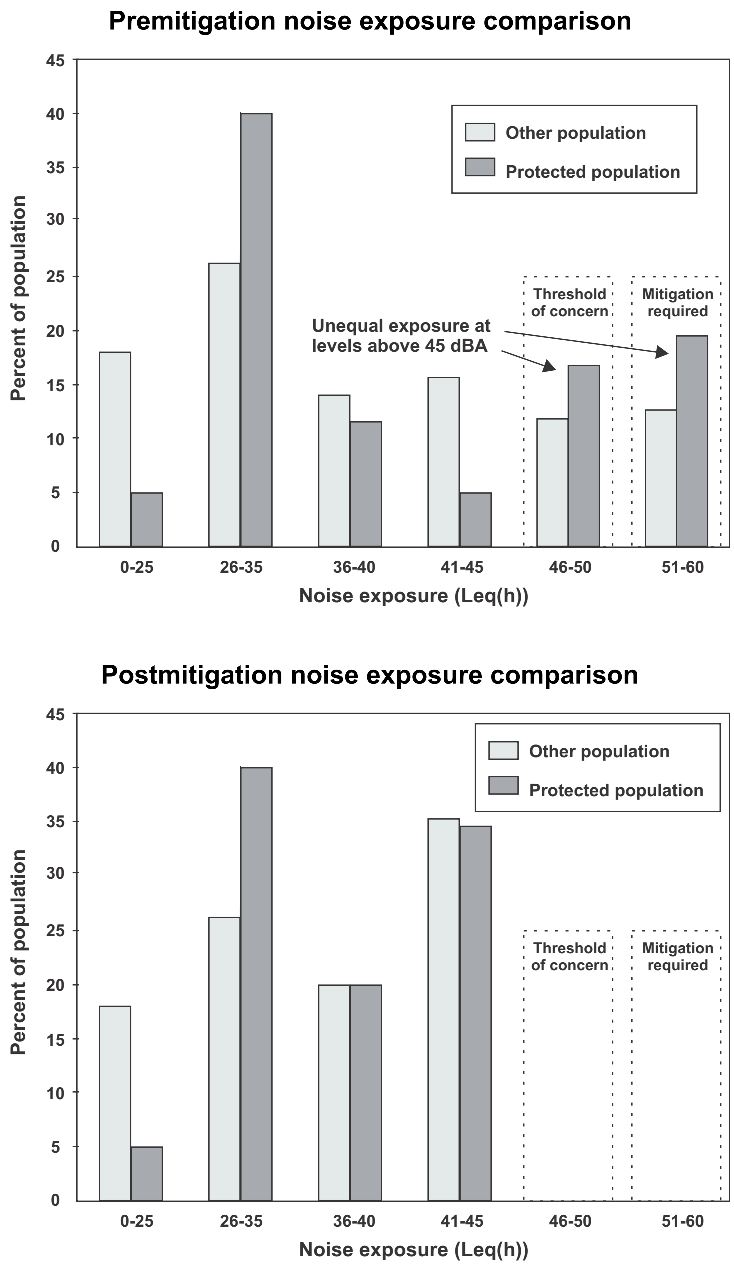

Figure 10-4. Evaluation of pre- and postmitigation noise assessment results by percent of population

Both evaluations are necessary to determine distributive effects because in certain study areas a majority of the affected population may belong to protected groups. Figure 10-5 displays results of the same dataset evaluated in Figure 10-4, but here the vertical axis measures number of persons. In the case of this particular dataset, evaluation by number of persons does not show any disproportionate effects to protected populations. For other study areas, however, the reverse could be true.

Data needs, assumptions, and limitations. Data needs for a detailed highway noise analysis include the following:

- Traffic volumes:
  - Traffic speeds and
  - Vehicle classification information (autos, trucks, etc.);
- Roadway geometry, both horizontal and vertical;
- Topography;
- Land use information; and
- Some common assumptions (be certain they hold for the project in question):
  - That the roadway is dry,
  - Vehicle speeds are generally consistent, and
  - Vehicle platooning is average.

This approach of estimating the affected population and its demographic characteristics using receptors and census data will give you a general sense of the distribution of noise impacts among population groups. There are, however, extreme limitations to this technique due to the relatively coarse level of detail in the census compared to the localized nature of noise impacts.

Although survey, interview, and property-by-property data collection techniques will provide more accurate and defensible results, the cost and time needed to collect the necessary information is a drawback. This limitation means that collecting data through survey and interview techniques is more cost effective for relatively small projects with few receptors in the area of effects. As the impact area and number of potential receptors increases, it may become necessary to rely on information such as census data to perform a study-area-wide evaluation, with follow-up data-gathering activities focused in areas where greater densities of protected populations are found.

Results and their presentation. Detailed highway noise analyses usually include a description of any local noise rules or guidelines, diagrams showing noise receptor locations and potential noise mitigation locations, and tables showing noise levels at each sensitive receptor location. The noise levels provided often include existing noise monitoring, existing conditions modeling, future-year no-build modeling, future-year build modeling, and future-year build modeling with noise mitigation. Any noise level approaching or exceeding the federal noise abatement criteria or a state standard generally will generate a requirement for further mitigation and additional modeling. The results of the noise mitigation analysis will show the noise level reduction that could be achieved by the proposed mitigation and the cost per unit of decibel reduction per household.

For purposes of evaluation, data presented in the form of graphs and maps may need to be relatively complex. In actuality, the number of categories displayed in Figures 10-4 and 10-5 has been simplified for presentation purposes. When presenting results to the public, it is also important that maps, charts, and other graphics be kept simple so that they convey very specific messages to the viewer. Figure 10-6 provides an example of how the graphs presented in Figures 10-4 and 10-5 could be simplified even further to present results to the public.

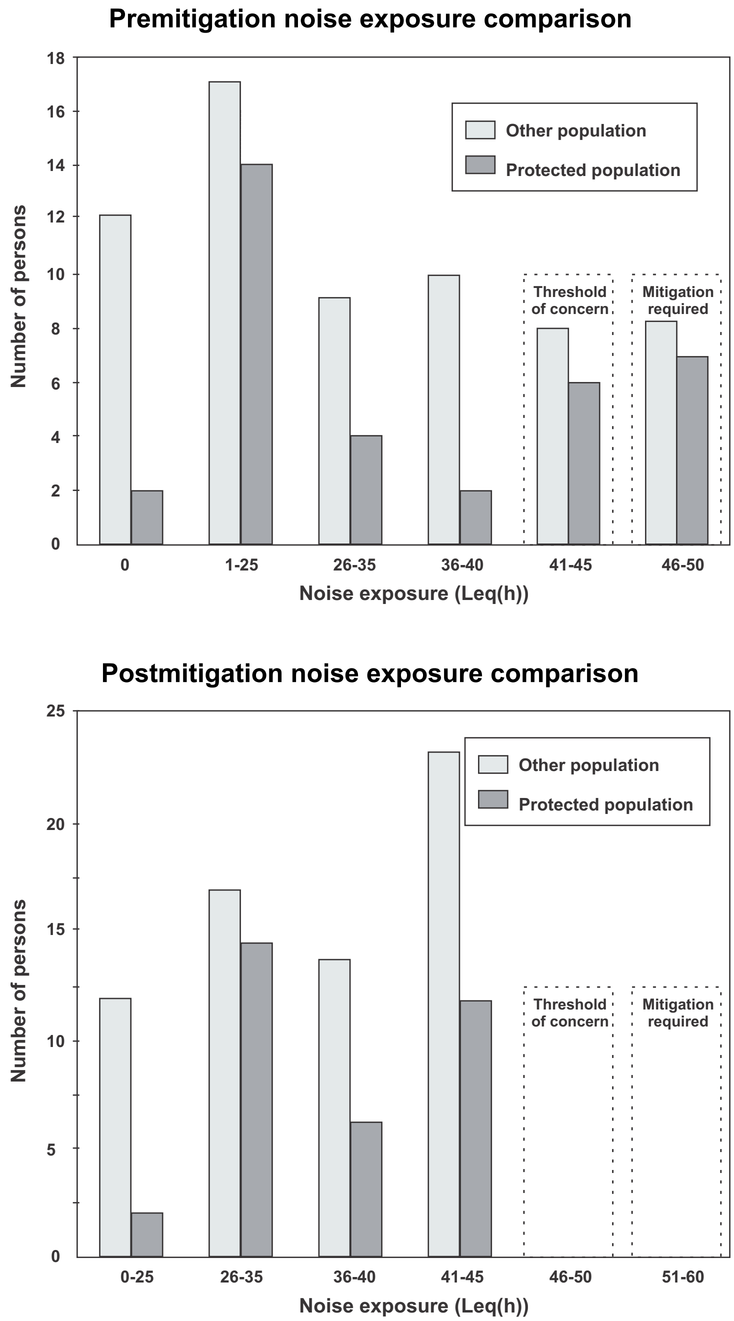

Figure 10-5. Evaluation of pre- and postmitigation noise assessment results by number of persons

Assessment. The goal of a detailed noise analysis is to completely characterize noise levels before and after a project. If noise mitigation is included as part of the project, details about the location and cost-effectiveness of the mitigation should be clearly defined:

- Ensure that adequate public outreach is performed in locations where members of protected population groups may be affected.

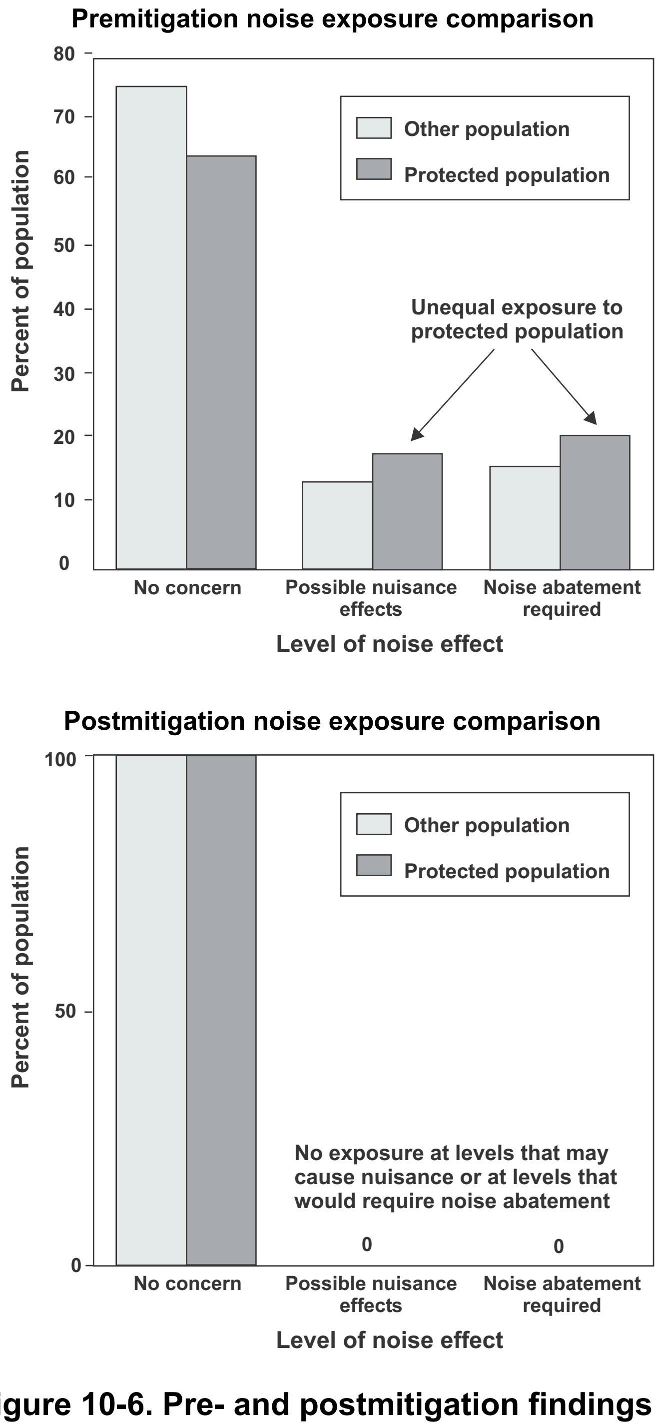

Figure 10-6. Pre- and postmitigation findings of environmental justice assessment

- Identify the level of effects to protected populations.
- Evaluate whether effects are equitable.

- Ensure that postmitigation exposure levels are no higher to members of protected population groups than to other individuals. Because noise usually only impacts receptors immediately adjacent to a roadway project, specific property information is preferred over use of census or other zonal demographic data to identify locations where protected populations may be exposed.

Method 3. Transit project noise analysis

When to use. Considering that transit projects must be located amidst or close to concentrations of people, noise and vibration impacts can be a concern throughout the planning and project development phases. This method offers transportation planners flexibility in addressing noise and vibration at different stages in the development of a project and at different levels of detail, depending on the types of decisions that need to be made.

Analysis. Three levels of analysis may be used, depending on the type and scale of the project, the stage of project development, and the environmental setting. The technical content of each level is summarized below:

Screening procedure. Identifies noise-sensitive land uses in the vicinity of a project and whether there is likely to be an impact. It also serves to determine the study area for further analysis when sensitive locations are present. The screening process may be all that is required for many of the smaller transit projects that qualify for categorical exclusion (CE). This procedure is performed as part of the initial evaluation (Method 1) described above. When noise-sensitive receptors are present, two levels of quantitative analysis are available to predict impact and assess the need for mitigation measures.

General assessment. Identifies the location and estimated severity of noise and vibration impacts in the areas identified in the screening procedure. For major capital investments, the general assessment provides the appropriate level of detail to compare alternative modes and alignments. It can be used in conjunction with established highway noise prediction procedures to compare and contrast highway, transit, and multimodal alternatives. For other types of transit projects, this level is used to more closely examine projects that show possible impacts as a result of screening. For many smaller projects, this level may be sufficient to define impacts and prepare mitigation as necessary.

Detailed analysis. Quantifies impacts through an in-depth analysis usually only performed for a single alternative. The detailed analysis delineates site-specific impacts and mitigation measures for the preferred alternative in major investment projects during preliminary engineering. For smaller projects, detailed analysis may be warranted as part of the initial environmental assessment if there are potentially severe impacts due to close proximity of sensitive land uses.

Results of the FTA analysis can be used to evaluate distributive effects using the same steps as described for the detailed FHWA analysis (Method 2) described above.

Data needs, assumptions, and limitations. This type of analysis requires the following data:

- Project alignment, both horizontal and vertical;
- Topography;
- System operation plan;
- Vehicle technology (e.g., light rail transit [LRT], diesel multiple unit [DMU]);
- Land use characteristics and location; and
- Demographic information (same as for Method 2).

Results and their presentation. Results of transit noise projects are sometimes presented as tables listing neighborhoods with impacted sites, including number of residences. This information may be obtained by specifically analyzing each neighborhood individually or by drawing project impact contours on maps. The primary result is to document the number of impacted properties. Results of the distributive effects assessment can be presented using the techniques described in Method 2.

Assessment. Graphical presentations of noise impacts usually include maps with boundaries showing where impacts occur. It is relatively simple to combine results with protected population information to assess environmental justice for transit projects, although data collection may be time consuming in areas where environmental justice concern is high.

If the project evaluation identifies an impact or severe impact, noise mitigation will need to be considered. Noise mitigation for transit projects includes more options than are available for a highway project. One key difference is that the source (i.e., train) can have mitigation measures applied directly to it. These may include wheel skirts, wheel damping to prevent squealing, and a special configuration of the vehicle to hide mechanical devices, such as air conditioners, under the vehicle. Mitigation measures may also include greasing tracks at curves to prevent squealing or building barriers in the form of walls or earthen berms to block the line of sight. The impacts of any mitigation measures would need to be considered, including the detrimental effect of applying grease to tracks and the potential security and loss of visibility due to barriers.

RESOURCES

1) Federal Highway Administration (FHWA). 1995. *Highway Traffic Noise and Abatement Policy and Guidance*. Washington, DC: United States Department of Transportation.

   The Federal Highway Administration's site on highway traffic noise provides links to numerous resources, including the highway traffic noise guide for 1995. The information can be found at http://www.fhwa.dot.gov/environment/noise. In addition, the FHWA procedures for traffic noise analysis and abatement are described in 23 CFR 772, available at http://www.fhwa.dot.gov/legsregs/directives/fapg/cfr0772.html.

2) Federal Transit Administration (FTA). 1995. *Transit Noise and Vibration Impact Assessment*. Washington, DC: U.S. Department of Transportation.

   Much of the information used to describe the Transit Project Noise Analysis method is from the FTA's Transit Noise and Vibration Impact Assessment guide. The entire document is available at http://www.hmmh.com. To access the report, follow the links to rail and transit noise, FTA guidance manual. Information is also available from the FTA at http://www.fta.dot.gov/office/planning/ep/subjarea/noisevibration.html, which includes a direct link to the spreadsheets to be used for the detailed analyses.

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Forkenbrock, David J., and Glen E. Weisbrod. 2001. *Guidebook for Assessing the Social and Economic Effects of Transportation Projects*. NCHRP Report 456, Section 9, “Traffic Noise,” pp. 129-142. Transportation Research Board, National Research Council. Washington, DC: National Academy Press. Also available at http://trb.org/trb/publications/nchrp/nchrp_rpt_456-a.pdf.

CHAPTER 11. VISUAL QUALITY

OVERVIEW

Visual quality is a very important component of human existence. Because we are continuously exposed to visual stimuli in the environment, visual quality helps shape our perceptions, attitudes, and general views of life. Our visual physical environments can range from the grand and inspirational, such as a mountain vista or a pristine lake in the woods, to the utilitarian and dreary, such as views of a refuse dump or a barren, surface parking lot. A positive visual environment can stimulate feelings of well being, whereas a negative one can diminish enjoyment and quality of life. One key component of improving quality of life is thus to improve and enhance the visual quality of our environments.

Visual quality is one of the most tangible areas affected by physical improvement projects. Almost all transportation projects will in some way alter the physical landscape and thus the perceived visual quality of the community. Many people will accept basic alterations in their physical environment as the price of progress, and so these changes may not be controversial. Some alterations, such as adding landscaping to screen a transportation corridor from a residential area, may even be perceived as beneficial and a positive impact. Other types of changes, however, such as adding a screen wall that blocks views of adjacent businesses in a transportation corridor, may be perceived as having a negative impact and may be highly controversial.

It is important to remember that visual quality is highly subjective. “Beauty is in the eye of the beholder,” as the saying goes, and perceptions and interpretations of visual quality can vary widely. This is especially true among populations with different backgrounds, ethnic origins, or cultural traditions. In developing improvement projects, it is imperative that you first gain a clear understanding of the standards and values of the affected population group or groups. It is equally important to clearly and accurately communicate to the affected populations the likely visual impacts of the various project improvements and their rationale. Care needs to be taken that negative visual effects do not disproportionately impact protected populations.

Assessments of visual quality play a key role in the project development process. These assessments help not only to communicate and explain the visual quality impacts of projects but also to illustrate the nature and appearance of the improvement project as a whole.

Visual quality design and assessment should not be delayed until the end of the design stage when most design decisions for a project have already been made; rather it should be viewed as an integral component of the total design and project development program. This is especially true where environmental justice issues are concerned. It is much more efficient and effective to identify and avoid negative impacts early than to try to offset or mitigate them at the end.

STATE OF THE PRACTICE

This section is presented in two parts. The first part addresses the current state of visual quality assessment. The second part discusses contemporary techniques for designing and communicating visual quality effects, with particular focus on communicating with protected population groups.

Visual quality assessment process

Transportation projects can cause significant visual impacts in the surrounding built environment. These projects may alter topography, require the removal of existing structures or landscaping or add new structures or landscaping, cast shadows on sensitive uses, introduce new streetscape urban design elements, or alter or obscure views and vistas of the existing landscape or of unique or historic community features.

Visual quality assessments for transportation projects need to address three major components: affected visual environment, visual impacts, and visual impact mitigation. Each of these components is discussed below.

Affected visual environment. It is first necessary to identify and describe the existing visual environment in the project area. In his book *Image of the City,* Kevin Lynch (1960) identifies five major components that make environments legible and imageable: edges, paths, districts, nodes, and landmarks. These components provide a potential structure for grouping and identifying existing visual characteristics in the project area.

Visual impacts. The second component involves identifying and describing the potential visual impacts of the proposed project. Visual impacts need to be addressed from two different points of view: that of the population that will have to look at the project (i.e., people living or working in the project vicinity), and that of the population that will use the project (i.e., people driving on the roadway or riding on the train or bus). In instances where protected population groups will be affected, it is important to understand the community's perception of the visual impact and to balance that against the perceived benefit of the project. In addition, the visual effects should be assessed in terms of their distribution in the project area to ensure that negative effects do not disproportionately impact protected populations. Visual effects that typically need to be considered for transportation improvement projects include one or more of the following:

- **Removal of buildings** where existing development needs to be cleared;
- **New buildings,** such as new maintenance buildings or stations for transit projects;
- **New, removed, or changed structures,** such as bridges or elevated roadway or track segments;
- **New or changed urban design elements,** such as equipment at transit stations, street furniture along roadways, entry monuments, or signs;
- **New or changed landscaping,** such as installation of new street trees or removal of existing landscaping;

- **New or changed lighting,** such as new lighting in a transit maintenance yard that may impact adjacent residential developments;
- **New screens,** such as noise abatement or visual screen walls;
- **New or changed pavements,** such as special pavement treatments in downtown areas;
- **New public art,** such as free-standing sculptures;
- **Natural features,** such as water bodies, streams, or natural areas;
- **Adjustments to topography,** such as large-scale excavation or filling;
- **Shadows** where shadows from buildings or structures may impact adjacent sensitive developments;
- **Views** where improvements may block existing views or open up new ones; and
- **Visual relationships** where improvements may not affect existing facilities directly, but, because of close proximity or critical view-sheds, may indirectly impact the visual environment around special uses or features, such as historical districts, historical buildings or structures, or community landmarks.

Visual impact mitigation. This component involves identifying mitigation measures for ameliorating potential negative visual effects. Mitigation measures might include modifications to the basic infrastructure, embellishment of the proposed improvements, or enhancement of the visual environment of the project area. Where various population groups are affected, the mitigation measures might vary to provide the most appropriate solution for each affected group.

Although visual quality issues are highly significant for maintaining or improving quality of life, assessments of visual quality frequently are not given the same attention or weight as other evaluation criteria, such as transportation safety, air quality, or noise impacts. One reason for this might be that visual quality issues are much more subjective and cannot be as easily quantified as other effects. Another reason might be that effects such as air quality and noise are much more direct and physical, whereas visual quality effects are more subtle and visceral. In addition, visual quality assessments are very rarely conducted to evaluate environmental justice issues. To ensure a high-quality visual environment, more attention needs to be paid to the overall visual quality of projects, as well as to how visual quality relates to environmental justice.

Visual quality design and communication techniques

The techniques described below can be used in all phases of project design to identify the most appropriate design solutions, to communicate potential visual quality impacts to affected populations, and to mitigate negative impacts.

Characterizing the potential visual quality effects of a project and communicating those effects to the affected population are important design and planning components in their own right. They are also important parts of the process of evaluating the environmental justice aspects of a project. These techniques can be used to evaluate project design decisions, to communicate ideas to protected population groups and to obtain feedback from those groups. They can be used in combination with the environmental justice assessment methods described later in the Methods section of this chapter to assess distributive effects.

Following is a discussion of some of the more commonly used evaluation methods, ranging from the relatively simple to the complex, for illustrating various types of visual quality impacts and for responding to various public concerns. Table 11-1 summarizes the visual quality design and assessment techniques.

Table 11-1.
Summary of techniques for visual quality design and assessment

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. Existing condition photographs	Screening/ detailed	Document existing environment, illustrate special features	Always	Low	Photography
2a. Illustrative plans or diagrams	Screening	Communicate size, location, and basic intent of elements	In early stages of design, when design resources are limited, when realistic background material is not available, when photo-realism is not essential, or when there are technical issues that are best represented in plan view	Medium	Drafting and/or computer-aided design and drafting (CADD)
2b. Illustrative sections	Screening/ detailed	Illustrate vertical, horizontal scale			
2c. Perspective or axonometric sketches	Screening	Convey massing, scale, image, and character of a project			
3. GIS view-shed analysis	Screening/ detailed	Identify view-sheds and lines of sight	Appropriate GIS terrain data are available or there are significant view-shed or line-of-sight issues	High	Geographic information systems (GIS)
4. Photo simulation or montage	Screening	Visualize proposed designs	Existing condition photographs are available, the design is fairly advanced, or the audience is skeptical or poorly informed	Medium	Manual paste-up or digital photo editing (e.g., Photoshop)
5. Computer imaging	Detailed	Visualize proposed designs	Existing condition photographs are not available, the design is fairly advanced, the project will radically alter existing environment, or the audience is skeptical or poorly informed	High	3-D CADD
6. Computer animation or virtual-reality modeling	Detailed	Visualize proposed designs	Changing views over time are required or the view as seen from, for example, a train window is required	High	3-D CADD, Computer Animation
7. Three-dimensional, physical models	Detailed	Visualize proposed designs	Inadequate budget for computer animation and/or virtual reality	Medium	Model-building
8. Videos	Detailed	Illustrate similar existing designs	Whenever comparable, completed projects exist	Low	Video production and editing

It is important to illustrate visual quality impacts, whether they are positive or negative, in a realistic and accessible fashion. The illustration and analysis technique(s) selected for the communication process should be appropriate for the target audience and for the level of design that is being represented. Too much abstraction or introduction of stylistic design elements can distort the potential visual quality impacts and confuse the viewing audience.

Technique 1. Existing-condition photographs. The most common illustration technique used in visual quality assessments is existing-condition photographs. These photographs are used to supplement text describing the current conditions in the project area. In most assessments, photographs are used in conjunction with one or more of the design and assessment methodologies that illustrate the proposed project improvements. Although they can be used by themselves, existing condition photographs are much more effective if they are referenced on a base map or aerial photo of the project area. Such referencing provides accurate information regarding where the photographs were taken and which areas of the project they illustrate. Figure 11-1 represents typical panoramic photographic images and a key base photo used for illustrating existing conditions in a project area.

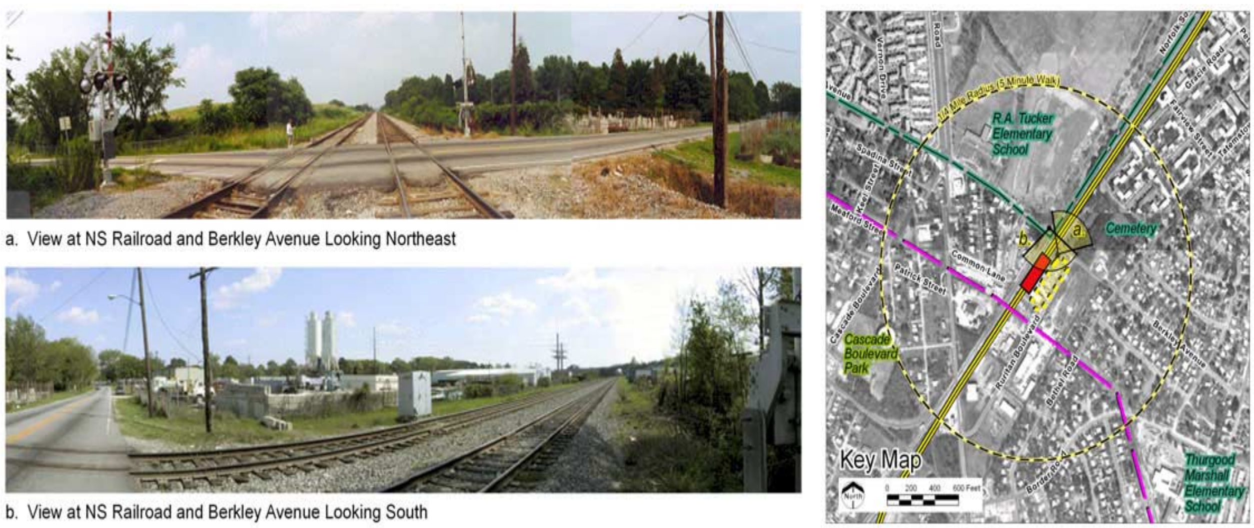

Figure 11-1. Example of panoramic photographic images and key map

Existing-condition photographs are an essential component of virtually all visual quality assessments. The following data and equipment would be required:

- Information regarding where the project is to be located,
- Film or digital photo camera, and
- Methods for copying or reproducing the images.

Computer equipment and software provide a quick and easy method of taking, splicing, and reproducing the required photographic images. Existing-conditions photographs can be presented at meetings using printed copies or electronically, for example in PowerPoint presentations. Care should be taken that these photographs represent all of the typical conditions in the project area. This is especially important on projects where protected populations have been identified.

Technique 2. (a) Illustrative plans or diagrams, (b) illustrative sections, and (c) perspective or axonometric sketches. Illustrative plans, sections, and image sketches represent design and illustration techniques that can be used on most projects. This type of material is relatively easy to generate because the information needed is readily available for most projects and the tools used can be as simple as a sketchpad or conventional drafting equipment. This does not mean, however, that these techniques will always involve the least effort or be the least costly. Some image sketches may require a considerable amount of preparation, layout, and rendering time.

Figures 11-2, 11-3, and 11-4 represent examples of typical illustrative plans, sections, and image sketches, respectively.

Figure 11-2. Typical illustrative site plan

Although illustrative plans, sections, and image sketches can be used for the design and assessment of most projects, they are especially appropriate in situations such as the following where:

- Detailed designs have not yet been developed, such as in the early stages of the design process;
- Design resources do not permit the use of more elaborate presentation techniques;
- Realistic background material is not available, such as for aerial perspectives where aerial photographs have not been taken;

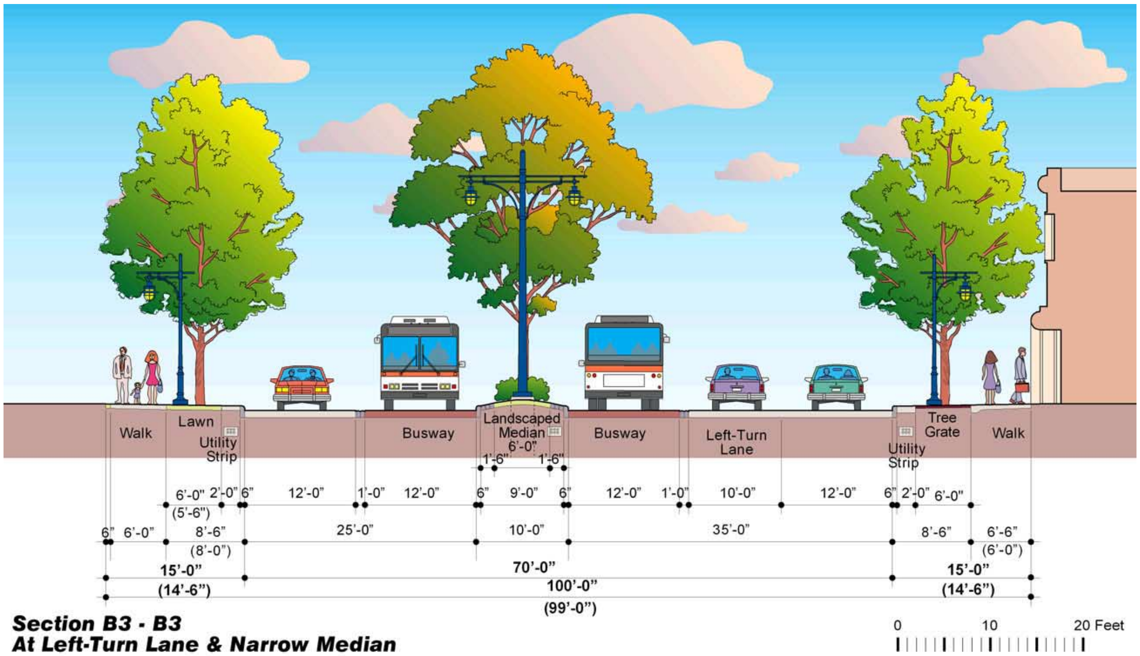

Figure 11-3. Typical illustrative section

Figure 11-4. Typical illustrative perspective

- Photo-realism is not essential; and
- The visual quality impacts evaluation involves technical issues, such as viewsheds that are best represented in plan view rather than as photographs or computer imaging.

The data and equipment requirements can be quite simple for preparation of illustrative plans, sections, and image sketches. Illustrative images can be created using sketch pads or conventional manual drafting equipment. However, with the current advances in computer technology, most of these illustrations are just as easily, and sometimes more conveniently, prepared using computer programs. As a minimum, the following data and equipment would be required:

- Base maps;
- Existing conditions information;
- Design information regarding the proposed improvements, such as location and siting, massing, dimensions, materials, textures, and color schemes; and
- Manual drafting equipment or computer programs, such as AutoCAD, Freehand, or CorelDRAW, for drafting and rendering the drawings.

This method produces schematic and illustrative drawings that represent the general intent and appearance of the proposed improvements and their visual quality impacts. Because this material is more technical and schematic than photographic images, it should be tailored to the target audience. The material should not be so technical and detailed that the general public will have a hard time understanding the intent of the design. Written or verbal explanations can help make the material accessible to the public.

Technique 3. GIS view-shed analysis. Topographic base information can be used to identify view-sheds and lines of sight in the project area. These in turn can be used to establish which parts of the project would have visual quality impacts on which populations. GIS view-shed analysis is most appropriate at the macroscale level or for very large and/or tall projects where long vistas are important.

Technique 4. Photo simulation or montage. The photo simulation or montage technique has evolved into one of the most widely used methods for illustrating visual quality impacts. This technique consists of superimposing images of the proposed improvements on photographs of the existing environment. Because the results of this technique are very realistic images, the design of the proposed improvements has to be advanced enough to permit realistic interpretation and representation.

The primary benefit of this technique is that it illustrates proposed improvements in the context of existing conditions. The viewing public has a much easier time relating to images of known conditions than to more abstract drawn or computer-generated scenes. This technique is especially effective when the material is presented using “before” and “after” images, which allows for easy comparison between the two. An even better comparison can be made when the “before” and “after” images are presented in an interactive mode, such as on a Web page, where a viewer can instantly click between them. Figure 11-5 represents typical "before" and "after" photo simulation images for a project.

Before

After

Figure 11-5. "Before" and "after" photo simulation images

Photo simulation or montage techniques should be used in the following situations:

- Existing condition photographic backgrounds are available and applicable;
- Designs have been advanced far enough to clearly define the proposed improvements; and
- Photorealism is very important to illustrate the visual quality impacts—especially to highly skeptical audiences or where the impacts may be dramatically different from what the audience is expecting.

One drawback of the photo simulation or montage illustration technique is that each image is "frozen," which means that it represents only a single viewpoint. If another viewpoint is desired, a totally new photo simulation image needs to be created.

Technique 5. Computer imaging. Computer imaging is similar to photo simulation or montage in that it can be used to create realistic images and scenes of proposed improvements. The major difference between the two is that in computer imaging everything is artificially created, whereas photo simulation or montage uses actual photographs of project components and backgrounds. Another important difference between the two is that in computer imaging, a 3-D model is created of the project. This model provides much more versatility and flexibility than the still images that are created with photo simulation or montage. With computer-generated 3-D images, different views of the proposed project can be very easily generated and presented. Many examples of such images, including videos, are available on one of the URS Corporation's Web sites (www.ursimaging.com/2002onlineportfolio/). Figure 11-6 represents a typical example of a computer-generated 3-D image.

Although tremendous advances have been made in the development and refinement of computer imaging techniques, the technology has not yet reached a level where computer-generated images are indistinguishable from actual photographs. Therefore, this method is mostly used where photo simulation or montage techniques are not feasible.

Computer imaging typically is used in cases such as the following:

- Existing-condition photo backgrounds and/or images of comparable proposed improvements are not available;
- Designs have advanced far enough to clearly define the proposed improvements;
- The proposed improvements would alter the existing environment to such a degree that very little of the existing conditions would remain; and
- Reasonably realistic images are important to illustrate the visual quality impacts—especially to highly skeptical audiences or where the impacts may be dramatically different from what the audience is expecting.

This type of imaging product requires computer equipment and 3-D rendering programs. At a minimum, the following would be required:

- Data about the existing conditions, such as AutoCAD plans, massing of existing buildings and structures, materials, textures, and color schemes;
- Design information regarding the proposed improvements, such as location, massing, dimensions, materials, textures, and color schemes; and
- 3-D computer drafting and rendering programs, such as AutoCAD, 3-D Viz, or Photoshop.

Figure 11-6. Computer-generated 3-D image

This approach produces highly realistic images of the proposed improvements and their visual quality impacts. However, because everything is artificially created, there may be less credibility with this technique than with photo simulation or montage. This technique can also be more expensive and time consuming than the previous methodologies, although it does have the major advantage of built-in flexibility and versatility. Once a model has been created in 3-D, it can easily be rotated to illustrate various viewpoints or perspectives, as illustrated by the examples on the Web site listed under Resources. This ability to manipulate or vary viewpoints can be set up as an interactive process and can be very effectively used in meetings to respond to various questions or requests from the viewing audience. Computer images can also be made available on a Web site for easy access.

Technique 6. Computer animation or virtual reality modeling. Computer animation is one of the most advanced methodologies for designing and illustrating visual quality impacts. It is also the most involved and expensive. Some computer animation can be relatively simple. By building upon the 3-D models produced with computer imaging, simple "drive-by" or "fly-through" sequences can be created for the proposed project. In these simple scenes, everything appears static. More advanced and complex computer animation, such as the animation of a proposed highway project, involves adding cars, people, and other objects and carefully choreographing their movement and timing in the 3-D animation sequences. Computer animation techniques can also be used to illustrate project staging and the impact of the proposed improvements upon the existing landscape. Examples of computer animation are presented on the URS Corporation Web site at www.ursimaging.com/2002onlineportfolio/.

Computer animation should be used when it is important to illustrate the visual quality impacts of a proposed project in three dimensions, as well as in time. For example, animation may be the best way to illustrate the changing views of a corridor from a moving vehicle, the movement of a train through a neighborhood, or the impact of a project on existing uses and facilities.

For computer animation, the following are required:

- Data about the existing conditions, such as AutoCAD plans, massing of existing buildings and structures, materials, textures, and color schemes;
- Design information regarding the proposed improvements, such as location, massing, dimensions, materials, textures, and color schemes; and
- 3-D computer drafting and rendering programs, such as AutoCAD, 3-D Viz, and Photoshop, and computer animation equipment and programs.

This method produces highly realistic animated sequences of the proposed improvements and their visual quality impacts. It is the most expensive and time consuming of all the techniques available. However, the cost may be justified due to the large amount of information that can be conveyed in a very short time and the dramatic impact it can have. Computer animation may be viewed as part of a PowerPoint presentation or on a Web site. In this sense, it does require special equipment (e.g., a projection system or computer) and thus is slightly more difficult to access than computer imaging or other visual presentations.

Technique 7. Three-dimensional, physical models. Where issues of massing or spatial relationships need to be addressed, three-dimensional physical models can be useful in conveying a large amount of information in a very concise and direct way. Physical models are especially useful in illustrating conditions of extremely complex urban conditions.

Technique 8. Videos. A technique that is sometimes used to convey information regarding the visual appearance of a proposed project, and to address issues such as noise impacts is to take a video of a comparable situation in a similar project. Videos are frequently taken of Light Rail Transit (LRT) systems to allow impacted populations to experience, as realistically as possible, how a proposed LRT system will work, look, and sound.

Review. There are two primary components for assessing visual quality and environmental justice. The first comprises techniques for designing and communicating the visual effects, described above. The second component involves determining how different population groups may perceive the effects differently and how effects are distributed among population groups. That is the topic of the remaining sections in this chapter.

SELECTING AN APPROPRIATE METHOD OF ANALYSIS

Proper design and communication of visual effects is an important part of environmental justice assessment, and the methods described above can be used for that purpose. However, that alone is not enough. The overriding objective of an environmental justice analysis is to ensure that protected populations are not subjected to a disproportionate share of the negative impacts of a project—or that negative impacts are counterbalanced by equivalently disproportionate benefits. In the case of visual quality impacts, this analysis is problematic due to the fact that it is difficult to quantify negative impacts on a population. The problem is made even more difficult when you consider that different subpopulations (e.g., ethnic groups or age cohorts) may vary in how they value the numerous aspects of visual quality.

One approach to this problem is to survey the affected populations to determine how attractive or aversive the visual quality impacts of the project are perceived to be. Nelessen (1994) describes a well-developed methodology for rating visual quality aspects of public projects. This method is variously known as *Visual Preference Survey*™ (VPS), *Image Preference Survey*, and *Community Preference Survey*. In a VPS, respondents are asked to rate each of a set of photographs on a 21-point hedonic scale ranging from -10 (most aversive) to +10 (most appealing). The results can be used to estimate how a population values various aspects of visual quality or how effective particular mitigation measures would be.

Another approach is to estimate the economic "value" of visual quality effects for each protected population impacted by the project and for the total affected population. In this context, the estimation of economic value is not meant to imply that monetary compensation might be made for negative visual quality impacts; the estimations are for comparative purposes only. For example, if it could be determined that individuals in the protected population place half again as much economic value on visual quality as the population as a whole (i.e., 150 percent), that estimate could be factored in to the analysis of distributive effects.

The question of how to assign economic value to things such as visual quality has received considerable attention from economists. Visual quality is one example of what are called "nonmarket goods"—that is, goods (things of value) that are not traded in open market systems. Economists use two broad classes of methods to establish the value of nonmarket goods: revealed preference and stated preference methods.

Revealed preference (RP) methods rely on the analysis of quantifiable behaviors that, while not involving direct monetary payment for goods, can be used to infer willingness to pay for the goods in question. The *travel cost* method uses the amount of time someone is willing to spend traveling to see a visually appealing feature as a measure of its value. Similarly, the amount of time a person is willing to spend traveling to avoid a visually unappealing feature is a measure of its aversiveness. The *hedonic pricing* method is based on analysis of the effect of a nonmarket good on the actual value of market goods. For example, if you compared the values of homes that were close to a visually aversive feature with those of similar homes that were not close to the feature, you could derive an estimate of how much the visual feature would reduce the market value of the particular home.

Stated preference (SP) methods rely on surveys to estimate how much value individuals ascribe to a non-market good. Two variants of SP have been widely used – contingent valuation and contingent choice.

The **contingent valuation** (CV) method makes use of survey questions that directly address the respondent's willingness to pay for a non-market good—for example, "How much would you be willing to pay in extra taxes to beautify the roadway?" Alternative survey formats for CV are closed-ended questions (e.g., "Would you be willing to pay $50/year in extra taxes to beautify the roadway?") and multiple-choice questions (e.g., "I would be willing to pay $10 / $25 / $50 / $75 / $100 per year in extra taxes to beautify the roadway").

Contingent valuation is the most commonly used method for establishing a value for nonmarket goods. In recent years, however, CV has been criticized for several reasons, including the fact that it generally overestimates the true value of goods (Diamond and Hausman 1994; Hanemann 1994).

The **contingent choice** (CC) method—also known as the "method of choice experiments"—is similar to CV in that it asks people to make choices based on a hypothetical scenario. It differs from CV in that it does not directly ask people to state values in dollars. Instead, values are inferred from the hypothetical choices or tradeoffs that people make.

The CC method asks respondents to state preferences between a scenario with one group of attributes or characteristics and other scenarios with different sets of attributes. Usually, each item on the survey is binary; in other words, there is a discrete choice between two scenarios. If one of the attributes in each scenario is a dollar amount, CC can be used to estimate dollar values. However, the method may also be used to simply rank options, without focusing on dollar values. Because it focuses on tradeoffs among scenarios with different characteristics, CC is especially suited to situations where a proposed project might result in multiple types of impacts or a proposed policy may have tradeoffs that need to be evaluated. For example, a highway project might result in improved access to work places and shopping venues but at the same time reduce the visual quality of the corridor.

Economists have used RP and SP methods extensively to estimate the dollar value of nonmarket goods such as visual quality. In the present context, however, the intent is to characterize the standards and values of impacted populations, not to estimate the dollar value ascribed to visual quality. A dollar value estimate is only of interest to the extent that it can reveal the underlying standards and values of a population.

RP and SP methods can be used to analyze the standards and values of a population as long as the results are cast in relative terms. For example, if an analysis reveals that a given population places twice as much dollar value on the benefit of cutting travel time to their workplace as on the visual quality of a traffic corridor, that ratio can be factored into the analysis of the overall impact of a project on that population. Using relative valuation in this way obviates the problem caused by the fact that different populations may have different ideas about the value of a dollar, as might be anticipated when comparing, say, a low-income population with a high-income population. It also reduces any possible concern about the absolute accuracy of the estimates.

The following sections contain detailed descriptions of the visual preference survey and contingent choice methods. Much of the material describing CC is derived from uncopyrighted material found on the Ecosystem Valuation Web site (King, et al. undated; see www.ecosystemvaluation.org). In addition, a method is described for analyzing distributive effects of visual quality using either objectively or subjectively weighted visual quality information.

METHODS

Table 11-2 summarizes the methods for analyzing visual effects described in the remainder of this chapter.

Table 11-2. Summary of methods for analyzing visual effects

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. Visual preference survey	Screening/ detailed	Select among design choices or compare standards and values of populations	Visual quality impacts are to be analyzed apart from other impacts	Low	Survey methods, statistical methods
2. Contingent choice experiments	Detailed	Compare standards and values of populations	Visual quality impacts are to be analyzed vis-à-vis other factors or when a dollar estimate of visual quality impact is desired	Medium	Survey methods, statistical methods, economic analysis
3. Distributive effect analysis	Screening/ detailed	Analyze distributive effects	Differences in population standards and values are deemed important	Medium/ high	Statistical methods, GIS

Environmental justice assessment of visual quality effects consists of four major steps:

1. Identification of protected populations (covered in Chapter 2).
2. Identification of standards and values of the impacted populations.
3. Design and communication of the visual impacts to the affected populations (covered in “Visual quality design and communication techniques,” earlier in this chapter).
4. Analysis of distributive effects.

This sequence is recommended because in most situations the key to environmental justice will be making design and visual aesthetic decisions that meet the approval of the populations that will have to look at the project and of the populations that will use the project. Identifying whether or not these populations include protected population groups (Step 1) and, if so, identifying the unique standards and values of those groups (Step 2) is crucial to making the best design decisions (Step 3). Distributive effects assessment (Step 4) can then be used to evaluate various design alternatives and the distribution of adverse and beneficial visual quality effects. Our discussion of "Selecting an appropriate method for analysis" provides an overview of techniques for identifying standards and values of protected populations and a method for evaluating distributive visual quality effects. Three of these methods are described in more detail below.

Method 1. Visual preference survey (VPS)

When to use. The VPS method can be used to determine which of a set of possible design choices is most appealing from a visual quality perspective. It may also be used to estimate the value placed on particular aspects of visual quality or on changes in visual quality resulting from a transportation project. By conducting equivalent surveys on groups of respondents representing different protected and nonprotected populations, the standards and values of impacted populations can be characterized and integrated into subsequent analyses of distributive effects and environmental justice. Population standards and values may be expressed in terms of the relative appeal or aversiveness of a particular visual feature or design option.

Analysis. This method consists of the following five steps.

Step 1 – Define the valuation problem. Determine the visual quality impacts to be assessed, and the relevant protected and nonprotected populations. Use interviews or focus groups to broadly identify which aspects of visual quality are of concern to the affected populations. For these preliminary inquiries, images of similar projects or computer simulations of the proposed project may be used to elicit comments.

Step 2 – Make preliminary survey decisions. Make preliminary decisions about the survey itself, including how images will be presented (slides, computer projector, video), how many respondents will be surveyed in each session, and whether photographs of similar, completed projects or computer simulations will be used for the actual survey. If any of the protected populations to be studied include a significant number of members for whom English is not their first language, conduct the survey in the preferred language of the population.

Step 3 – Survey design. Select scenes or images that illustrate the visual quality issues of concern to the impacted populations. Furthermore, select a range of levels of impact for each aspect of visual quality. For example, if foliage was identified as an important aspect of visual quality, use multiple images showing different types and amounts of foliage. Generally speaking, no more than 80 images should be used.

Step 4 – Survey implementation. The first implementation task is to select the survey sample. Ideally, the sample should be a randomly selected group of participants from each relevant population, gathered using standard statistical sampling methods.

Because it is reasonable to anticipate that there may be wide variation in survey results within each subpopulation, a minimum of 50 respondents from each should be surveyed. It is best to divide the sample of respondents from each population into multiple small groups that are surveyed in separate sessions. The order in which the images are presented should be varied randomly across sessions to minimize order effects in the analysis.

Respondents should be asked to rank each image on a 21-point (-10 to +10) scale, where the highest negative score indicates extreme aversion and the highest positive score indicates extreme appeal. Respondents should be given a score sheet on which to enter their responses. The score sheet should include a thumbnail of each image to ensure that the responses are properly matched with the images. If the order in which images are presented to each group is random, arrange the score sheets for each group in the same order as the images presented. Respondents should be instructed not to make comments or otherwise indicate their reaction to each image during the survey so that peer pressure does not bias scores.

Step 5 – Compile, analyze, and report the results. VPS findings can be used for several different purposes, and different methods of analysis are used depending on the intended goal of the survey. For example, VPS findings could be used to determine the most attractive (or least aversive) design for noise abatement or visual screen walls for a particular population. VPS findings could also be used to establish relative attractiveness of, or degree of aversion to, a visual feature across two or more populations. Finally, VPS could be used to estimate differences in standards and values between protected and nonprotected populations—for example, to establish how highly each population values foliage as a visual quality asset.

To determine the most appealing design for a visual feature, simply compute the mean score for each alternative design within each population. The design with the highest mean score is preferred by that population. If the objective is to establish a relative value for attractiveness or aversiveness of a particular visual feature, simply use each population's mean score for that feature. However, you should take note if there is a low level of agreement among respondents within a population. Any major disagreements should be resolved through the use of focus groups or other methods for consensus gathering.

Differences in standards and values between the various populations regarding broad aspects of visual quality may be analyzed as follows:

- For each aspect of visual quality studied, group the images showing different levels of the aspect. Perform the subsequent analysis steps for each grouping of images.
- Compute the *range* of each respondent's scores for the group of images. This value reflects that respondent's *sensitivity* to that aspect of visual quality.
- Combining all respondents from all populations, rank order the sensitivity scores.
- Divide the ranked sensitivity scores into three groupings—high, medium, and low, such that each grouping contains approximately 1/3 of the respondents.
- For each population studied, compute the number of respondents exhibiting high, medium, and low sensitivity.
- Cast these numbers into a 3 x *n* table (*n* is the number of population groups studied).

- Use the chi-square test to determine whether the distribution of high, medium and low sensitivities differs among populations.

Chi-square is the preferred statistical method because it does not rely on an assumption of the normality of the underlying distributions (see pages 105-108).

Data needs, assumptions, and limitations. VPS has relatively low requirements for external data because the majority of data are generated from the survey. Demographic data are required to determine if there are protected populations within the area of concern. Keep in mind the possible pitfalls associated with using VPS for estimating the relative appeal of a particular visual feature or for comparing the standards and values of populations:

- There may be differences between populations in terms of the degree to which they express extreme likes or dislikes. If one population is relatively more stoic or more strongly opinionated overall, this will influence the outcome.
- There may be a confounding of visual quality factors with other aspects of an image. For example, if you present images illustrating various levels of truck traffic, the respondents' scores may reflect their attitudes toward noise or congestion in addition to their attitudes toward visual quality.
- By using ranges within groupings of images as an indication of respondents' sensitivity to different aspects of visual quality, any differences between individuals or populations in the average response to those groupings are lost. For example, one population may react more negatively to *all* images of a particular scene regardless of differences among the images in, say, the number of trees.

Results and their presentation. Results are presented in tabular form or using bar charts to illustrate population differences. Parametric statistics such as the mean and standard deviation may be used for descriptive purposes, but nonparametric statistics such as chi-square should be used for inferential purposes.

Assessment. Visual preference surveys involve asking a group of respondents to rate each of a set of images according to their perceived attractiveness or aversiveness. Ratings consist of scores for each image on a 21-point hedonic scale. Results may be used to select among design choices; to establish an absolute measure of attractiveness or aversiveness of a particular visual feature; or to evaluate population differences in standards and values regarding broad aspects of visual quality.

Method 2. Stated preference/contingent choice (SP/CC)

The CC method is a hypothetical method—it asks people to make choices based on a hypothetical scenario. It differs from the CV method in that it does not directly ask people to state their values in dollars. Instead, values are inferred from the hypothetical choices or tradeoffs that people make.

There are a variety of formats for applying contingent choice methods, including:

- **Contingent ranking** – Contingent ranking surveys ask individuals to compare and rank alternate project impacts with various characteristics, including costs. For instance, people might be asked to compare and rank several mutually exclusive roadway beautification projects under consideration for a travel corridor, each of which has different outcomes and different costs. Respondents are asked to rank the alternatives in order of preference.
- **Discrete choice** – In the discrete choice approach, respondents are simultaneously shown two or more different alternatives and their characteristics and asked to identify the preferred alternative.
- **Paired rating** – This is a variation on the discrete choice format, where respondents are asked to compare two alternate situations and to rate them in terms of strength of preference. For instance, people might be asked to compare two roadway beautification projects and their outcomes, to state which is preferred, and to indicate whether it is strongly, moderately, or slightly preferred to the other program.

Whatever format is selected, respondents' choices are statistically analyzed using discrete choice statistical techniques to determine the relative values for the different characteristics or attributes. If one of the characteristics is a monetary price, then it is possible to compute the respondent's willingness to pay for the other characteristics.

When to use. The contingent choice method asks the respondent to state a preference between one group of environmental services or characteristics (a *scenario*) and another. A typical CC survey might comprise 50 to 100 such choices. If an estimate of the dollar value of each characteristic is desired, a monetary characteristic is included in the set for each scenario. Because it focuses on tradeoffs among scenarios with different characteristics, contingent choice is especially suited to situations where a project or policy might result in multiple different impacts on a population. For example, a highway project might impact accessibility to the workplace, noise levels, and safety, in addition to visual quality. While contingent choice can be used to estimate dollar values, the results may also be used simply to rank impacts, without focusing on dollar values.

Analysis. This method consists of the following five steps.

Step 1 – Define the valuation problem. Determine the visual quality and other impacts to be assessed and the relevant protected populations. Note that the size and complexity of the CC survey increases at roughly the square of the number of different impacts analyzed. For this reason, it is best to limit the number of impacts analyzed to five or fewer.

Step 2 – Make preliminary survey decisions. The second step is to make preliminary decisions about the survey itself, including whether it will be conducted by mail, phone or in person, how large the sample size will be, who will be surveyed, and other related questions. The answers will depend, among other things, on the importance of the valuation issue, the complexity of the question(s) being asked, and the size of the budget.

In-person interviews are generally the most effective for complex questions, because it is often easier to explain the required background information to respondents in person and people are more likely to complete a long survey when they are interviewed in person. In some cases, visual aids such as videos or color photographs may be presented to help respondents understand the conditions of the scenario(s) that they are being asked to rate.

While in-person interviews are generally the most expensive type of survey, mail surveys that follow procedures aimed at obtaining high response rates can also be quite expensive. Mail and telephone surveys must be kept fairly short, or response rates are likely to drop dramatically. Telephone surveys are generally not appropriate for CC surveys because of the difficulty of conveying the tradeoff questions to people over the telephone.

If any of the protected populations to be studied include a significant number of members for whom English is not their first language, consider communicating (interviews, focus groups, questionnaires) in the preferred language of the population.

Step 3 – Survey design. This is the most important and difficult part of the process and may take 6 months or more to complete. It is accomplished in several steps. The survey design process usually starts with initial interviews and/or focus groups with the types of people who will be receiving the final survey, in this case members of each subpopulation to be studied. In the initial focus groups, the researchers would ask general questions, including questions about peoples' understanding of the issues related to the project, their familiarity with the area of impact (e.g., the travel corridor), and the value they place on the area and its attributes.

In later focus groups, the questions would get more detailed and specific, to help develop specific questions for the survey, as well as to decide what kind of background information is needed and how to present it. For example, people might need information on the location and characteristics of the project and what impacts it will have on various environmental, social, and economic aspects of their lives.

At this stage, the researchers would test different approaches to the choice question. Usually a CC survey will ask each respondent a series of choice questions, each presenting different combinations and levels of the relevant impacts, possibly including the cost to the respondent associated with each scenario. Each scenario might be described in terms of impact on travel time between two particular points, visual quality (e.g., billboards, trees, and beautification measures), tax burden, etc. The visual quality impact for each scenario should be illustrated using an image. Images may be presented as hard copies or projections.

After a number of focus groups have been conducted and researchers have an idea of how to provide background information, describe the hypothetical scenarios, and ask the choice questions, they will start pretesting the survey. People would be asked to fill out the survey. Then the researchers would ask respondents about how they filled it out and let respondents ask questions about anything they found confusing. The researchers would continue this process until they had developed a survey that people seemed able to understand and answer in a way that made sense and revealed their values for the visual quality features being addressed.

Step 4 – Survey implementation. The first task here is to select the survey sample. Ideally, the sample should be a randomly selected group of participants from each relevant population, selected using standard statistical sampling methods. Although CC surveys are sometimes conducted via mail or phone interview, CC surveys that include visual quality factors should be conducted in a controlled setting. In-person surveys may be conducted with random samples of respondents or may use "convenience" samples—asking people in public places to fill out the survey.

Step 5 – Compile, analyze, and report results. The final step is to compile, analyze, and report the results. The statistical analysis for CC is often more complicated than that for CV, requiring the use of discrete choice analysis methods to infer valuation or willingness to pay from the tradeoffs made by respondents. A full description of the analysis method is beyond the scope of this document; see Louviere et al. (2000) for a thorough discussion of the method.

From the analysis, you can estimate the average value for each of the impacts of the project for an individual or household in the sample. This can be extrapolated to the relevant population to calculate the total benefits from the site under different scenarios. The average value for a specific action and its outcomes can also be estimated, or the different policy options can simply be ranked in terms of peoples' preferences.

Data needs, assumptions, and limitations. CC methods have relatively minimal requirements for external data because most of the data are generated from the interviews and surveys that comprise the study itself.

To collect useful data and provide meaningful results, the CC survey must be properly designed, pretested, and implemented. However, because responses are focused on tradeoffs, rather than direct expressions of dollar values, contingent choice may minimize some of the problems associated with contingent valuation. Often, relative values are easier and more natural for people to express than absolute values.

While CC generally is an excellent method for studying a population's values, the following limitations should be addressed when designing a study:

- Respondents may find some tradeoffs difficult to evaluate because they are unfamiliar.
- The respondents' behavior underlying the results of a CC study is not well understood. Respondents may resort to simplified decision rules if the choices are too complicated, which can bias the results of the statistical analysis.
- If the number of attributes or levels of attributes is increased, the sample size and/or number of comparisons each respondent makes must be increased.
- When presented with a large number of tradeoff questions, respondents may lose interest or become frustrated.
- By providing only a limited number of options, respondents may be forced to make choices that they would not voluntarily make.
- Contingent ranking requires sophisticated statistical techniques to estimate willingness to pay.

Results and their presentation. The discrete choice analysis methods used to analyze the results of a CC study yield weights that represent the value placed on each factor studied relative to the other factors. For this reason, it is desirable to select one factor, such as dollar cost, that can be used as a standard for comparisons among the other factors. Results may be presented in tabular form or bar charts that describe the differences among populations in relative valuation of the factors studied.

Assessment. The CC method can be used to establish how populations value a project as a whole, as well as the various visual quality attributes or visual quality effects of the project. The method allows respondents to think in terms of tradeoffs, which may be easier than directly expressing dollar values. In addition, respondents may be able to give more meaningful answers to questions about their behavior (i.e., they prefer one alternative over another), than to questions that ask them directly about the dollar value of a social or economic impact or the value of changes in environmental quality. Thus, an advantage of this method over the CV method is that it does not ask the respondent to make a tradeoff *directly* between environmental quality and money.

Method 3. Distributive effects analysis

When to use. Use distributive effects analysis when screening data indicate that there may be a disproportionate distribution of visual effects with respect to protected populations in the project impact area.

Analysis. This method consists of the following three steps.

Step 1 – Quantify the distribution of protected populations. Before proceeding with any more detailed analysis, determine whether any protected populations are disproportionately represented in the project area as a whole or whether they are unevenly distributed within the project area. Because visual quality impacts people in their homes as well as when they travel, both population distribution analysis and use analysis should be performed. Population distribution analysis may be performed using the Environmental Justice Index or one of the other methods described in Chapter 2. Use analysis may be performed using one of the transportation demand methods described in Chapter 7.

If protected populations are proportionally represented in the project impact area as a whole and are uniformly distributed within the project area, no further analysis need be performed. If protected populations are not proportionally represented or are unevenly distributed within the project area, the maldistribution should be quantified. The project impact area should be divided into analysis areas that can be characterized with respect to the number of members of each protected and nonprotected population group that live in or use each area.

Step 2 – Quantify the level of visual quality impact on each affected population. The level of visual quality impact on each affected population can be quantified using objective or subjective measures of impact.

Objective measures can be based on counts of visual features, such as number of trees planted or number of billboards in each analysis area. An economic measure might also be used, such as the amount spent on beautification or visual screens in each analysis area. In either case, the estimate of visual quality impact is based simply on objective information and does not differ between protected and nonprotected populations.

Subjective measures make use of information gathered using VPS, CC, or some other measure of the value placed on particular visual quality features by the various affected populations. The level of subjective impact may not be the same for all populations. For example, suppose that a VPS revealed that a protected population rated a particular visual feature (such as a screening wall) as –3 on a 21-point hedonic scale, whereas the nonprotected population rated the same feature as +2. Those values could be used as direct measures of visual impact.

It is also possible to combine subjective measures with objective measures. For example, if VPS or CC revealed that a protected population was 25 percent more sensitive than the nonprotected population to a particular type of visual quality effect (e.g., in their aversion to billboards), that could be used as a factor to estimate total aversiveness for each population. In this example, the impact of billboards on visual quality for the nonprotected population could be quantified simply as the number of billboards anticipated, whereas the impact on the protected population could be quantified as 1.25 times the anticipated billboard count.

Step 3 – Combine the visual quality impact metrics with the population distribution data. This step involves computing the visual quality impacts—either objectively or subjectively measured—for each protected and nonprotected population within each analysis area. That is, for each area, the following calculations are performed:

$$T_{pa} = I_p \times N_{pa}$$

where

T_{pa} = total visual quality impact on population *p* in analysis area *a*

I_p = level of visual quality impact on population *p* as calculated in Step 2

N_{pa} = number of members of population *p* in analysis area *a*

Values of T_{pa} for each population and area are cast into an $n \times m$ table, where *n* is the number of populations and *m* is the number of areas. A Friedman two-way analysis of variance or similar nonparametric test may then be used to determine whether there is a significant interaction effect between populations and areas in total visual quality impact. A significant interaction effect would indicate that the visual quality impacts were not proportionately distributed among protected and nonprotected populations.

Data needs, assumptions, and limitations. These considerations depend on the methods selected to estimate the impact of visual quality factors on different populations. One limitation of this method is that it does not account for any additive effects, such as disproportionate distribution of counterbalancing benefits.

Results and their presentation. Results and presentation of protected population information can rely on maps, tables, charts, or graphs similar to any other GIS-based census data technique. Many examples of results and their presentation are included in Chapter 2.

Assessment. This method allows you to combine objective or subjective measures of visual quality impact with information about the demographics of protected populations.

RESOURCES

1) *Guidelines for Landscape and Visual Impact Assessment*. 2002. The Landscape Institute with the Institute of Environmental Management and Assessment. London, UK: Spon Press.

   Although this book is geared towards European projects, many of the ideas and concepts presented in it would also apply to United States projects.

2) The following Web site provides numerous examples of visual quality design and communication techniques for transportation system changes. Animation and video techniques that cannot be presented in this hardcopy guidebook, as well as photomontage and other techniques, are available for review at http://www.ursimaging.com/2002onlineportfolio/.

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CHAPTER 12. LAND PRICES AND PROPERTY VALUES

OVERVIEW

Scholars and practitioners have long recognized that highway projects influence land and property values. Importantly, the influence of a highway project on land or property values is based on many of the other impacts that are discussed earlier in this guidebook. Highways can influence the accessibility of various parcels and may produce disamenities such as noise, air quality, and visual impacts. Construction disruption can also influence property prices near a transportation facility. The net effect of these and all other impacts can be reflected in changes in the value of the property. Thus changes in property value are not distinct from the other impacts that have been discussed in this guidebook. Instead, property values reflect the broad range of impacts from highway projects, and so provide another window into understanding both the effects of transportation system change and the implications for environmental justice.

Property prices reflect the full range of positive and negative impacts of transportation system changes. More generally, property prices reflect all location-specific characteristics of a parcel, including characteristics that are not related to transportation, such as desirable views, proximity to good schools, crime rates in the area, and noxious nearby land uses, such as toxic waste dumps.

The fact that property prices reflect all impacts, both positive and negative, has both advantages and disadvantages. On the plus side, once the impact of a highway project on property prices has been determined, one has a good summary measure of the net impact of all of the possible effects of the highway. In some cases, rather than assessing each of the various effects discussed in this guidebook individually, an environmental justice analysis might focus on the total impact of the highway by examining impacts on property values. On the negative side, like many summary measures, a property value analysis can obscure information on specific effects of the highway. If the property value analysis does not distinguish between the various effects of the highway, one might be unable to comment on how the influence of a highway can be disaggregated into impacts based on accessibility, noise, air quality, and other effects of the highway.[1]

STATE OF THE PRACTICE

The link between property values and transportation has long been recognized. Models of urban development often incorporate the influence of transportation on land values. See, for example, descriptions of classic models of urban form in Alonso (1964; 1972) and Fujita (1989). Empirical studies of highways and property values date to the early years of the Interstate Highway System (Adkins 1959; Mohring 1961).

[1] This is not necessarily the case. A property value analysis can be designed to illuminate the independent effects of, for example, changes in accessibility, noise, air quality, and other impacts of the highway. In that case, the result of a property value analysis is not a summary measure but, rather, an analysis of the influence of several types of impacts on property values.

The methods for assessing the link between property values and highways are similarly well established. The methods described below are based largely on appraisal techniques and hedonic analyses that have been applied for decades. Every metropolitan area and small town has property appraisers, and their expertise and methods can be adapted to understand the impact of highway projects on land and property values. Hedonic analysis of property prices was pioneered in the 1970s and is now the subject of a large literature. While both appraisal techniques and hedonic (or regression) studies of property values can be applied to many phenomena other than transportation projects, both can and have been adapted many times to highways in ways that provide a strong foundation for incorporating land and property value impacts into an assessment of environmental justice.

The state of the practice in this area is evolving rapidly. Until recently, property value data were difficult to obtain and hard to apply to geographically oriented studies of the sort required by an environmental justice analysis. For that reason, despite a wealth of theory, applied property value studies were rare until a decade ago. Both technology and data availability have changed that.

There is a wealth of data sources for property values. In most states, local tax assessor offices collect data on property sales. Those data are increasingly available, either at no charge from the assessor's office or (more commonly) for a fee from real estate data companies such as those described in Method 3 of this chapter. Local newspapers typically track the health of local real estate markets, and universities now often have units devoted to collecting and disseminating real estate market data. These data can be supplemented, as needed, with information on property values from tax appraisals or other sources, such as the U.S. Census public use micro sample. The rich availability of data combined with modern geographic information system (GIS) technology creates a powerful tool. Property sales data can be matched to specific parcels; and, with GIS, precise estimates of distance from a highway project or distance from other sources of impacts can be developed.

The net effect is that the use of property values to understand the impact of public projects is poised to grow rapidly. Public agencies will increasingly be able to use information about property values or real estate markets to understand the impacts of their projects, highway projects included.

SELECTING AN APPROPRIATE METHOD OF ANALYSIS

Certain special issues must be considered when performing any environmental justice assessment of property values. These topics are described below.

Retrospective versus predictive analyses. Most property value analyses of highways have so far been retrospective in nature. Typically, a researcher examines how access to an existing or newly built highway influences property values nearby. While that adds to our knowledge about the link between highways and property prices, a retrospective study is often not sufficient for environmental justice questions that arise as part of the project analysis phase. For many environmental justice questions, a predictive analysis is needed. The question is often, "if this highway project goes forward, what will be the environmental justice implications?" For property value-based environmental justice assessments, the objective often is predicting the future impact of highway projects not yet built and then assessing how those property value impacts affect minority, low-income, or other protected populations.

Fortunately, predictive analyses can often be an easy adaptation from retrospective analyses, and as land price and property value analyses become increasingly common, that adaptation will become even more feasible. Briefly stated, the retrospective analyses are the knowledge base for moving to predictive analyses. Future impacts of highway projects can be understood by applying what is known about past impacts of similar highway projects on similar properties. The methods described below can be used to predict how a highway project will impact property values. Often past studies will provide coefficients, slopes, or average effects that can be applied to similar projects to infer how future projects will influence property values.

Owners and renters. Property value impacts affect both owners and renters. Economic theory suggests that the purchase price of a structure is directly linked to the rental value. For that reason, studies of property value impacts can and should be applied to both owner-occupied and rental property.

For housing markets, most data sources report either the appraised value or the sale value of the property and as such apply most directly to the market for owner-occupied housing. If a property is rented, one can infer the magnitude of the impact on rental property by relating the rental price to the overall purchase price of the structure. What will likely be more important for an environmental justice analysis is to distinguish between benefits and costs that are borne differentially by landlords and tenants.

In a simple situation, negative property value impacts on owners (landlords) will result in lower rents because the demand for the rental property will drop. In such situations, landlords will be harmed, because they will lose property value. Renters will both pay lower rents and experience disamenities, and so the perceived effects to renters are based on their individual values and perception. Thus, counterintuitively, the landlords might be more adversely affected by a negative highway impact than renters, depending on the renters' values. To clarify this, consider the following example.

A house near a new highway is subject to increases in highway noise. This disamenity reduces the number of persons willing to rent the house, and that drop in demand results in a lower rental price. The renter, living near the highway, experiences a noise disamenity, but if the rental market is competitive, the lower rental price will compensate the renter for the noise disamenity. The renter, on net, might be no worse off depending on his or her values and needs. The owner of the house, on the other hand, sees rental income (and the sale value of the house) drop, and so the landlord is adversely affected.

The converse situation could also hold. Suppose that, for the same house near the same new highway, the renter has signed a long-term lease. The rent will not drop to reflect the noise disamenity until, at the earliest, the lease is up for renewal. Even then, if the rental market is not perfectly competitive, or if renters have imperfect information about the nature of the noise disamenity, rents might not drop to fully reflect the noise disamenity. Then the renter would be, on net, disadvantaged by the impact of the highway, while the landlord could, if rental income does not drop at all, see no impact.

The crucial question is whether and how quickly property prices adjust to reflect the impact of the highway, be that impact positive or negative. While understanding that is important in interpreting any property value analysis, it is especially important in understanding how land value impacts may be experienced by renters and landlords.

Residential property and commercial property. Most property value studies, and most property value data sets, look at either residential or commercial properties. Combining the two in the same analysis is rare. Because environmental justice studies will sometimes need to understand the impact of highways on both residential and commercial properties, we recommend looking at both markets when that is appropriate. The analyses of the residential and the commercial markets will likely use different data and might yield different findings.

For example, the literature has shown that being very close to a highway (typically less than a quarter mile) can be, on net, a disamenity that will depress the value of residential property (e.g., Langley 1981). The noise and (possibly) air quality impacts of the highway apparently outweigh accessibility advantages for residential properties at those distances. Yet the evidence does not as strongly suggest that commercial properties will experience the same disamenities. Apparently firms either benefit more from being very close to highways or the negative impacts (such as noise) matter less for commercial or office uses.

The double counting critique. The impacts on property values should not be added to other impacts that are also influencing property values. Consider the following example. Suppose one found that persons near a highway would be bothered by increased traffic noise, and suppose surveys of those residents yielded a dollar value estimate of the noise impact. Suppose a transportation agency also conducted an assessment of how the highway would affect property values in the area adversely impacted by increased highway noise, and suppose that study showed that property values near the new highway would drop. One should not add both the estimated value of the noise impact from the survey and the lost property value together. To do so would count the impact of noise twice, since the lower property values are due in part (likely in large part) to the increased noise. An agency should choose one way to measure the impact of increased highway noise—the survey method or the property value assessment. Or the agency could consider both methods as alternative measures, and choose some way to average or otherwise use information from both methods. But adding the dollar value impact from both methods together will overstate the noise impact from the highway, because that impact would be counted twice—once by asking residents in a survey how they perceive they are impacted and a second time by assessing how home buyers pay less for homes in the noise contour of the new highway.

Property value analysis can illuminate and verify analyses from other methods. Often times that will be good practice. Yet agencies should be aware not to double count impacts by adding the estimated impact from property value analysis to assessments of specific impacts that are driving the property value analysis. Remembering that property values are a summary measure and that changes in property values are derivative of the full range of effects of a highway project should clarify this cautionary note. With that caution in mind, property analysis is one of the most powerful tools available in understanding the influence of highway projects on nearby residents and businesses, and the applicability of this tool, which already is high, will increase in the future as new data and GIS tools become available.

Importance of impacts. In some cases, the collection of sufficient data to carry out an analysis of the probable effects of a transportation project on nearby property values may be quite costly. It may be prudent to begin with a simpler approach, like the first method listed below, to gain insight into the approximate magnitude of these effects. If the effects are unlikely to be sizable, it generally is not necessary to collect the data necessary to apply the more rigorous Method 3.

METHODS

Table 12-1 provides a summary of the methods presented in this chapter.

Table 12-1.
Summary of methods for analyzing land prices and property values

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. Market studies and expert opinion	Screening/ detailed	Project/ corridor	Small project or where a more resource-intensive analysis is either not feasible or not necessary	Low	Data collection and interview
2. Property comparisons and appraiser opinion	Detailed	Project/ corridor	Projects and alternatives assessments where sophisticated models are not available	Medium	Property appraisal
3. Hedonic regression	Detailed	Project/ corridor/ system	Large projects or policies where changes in land and property values are expected	High	Statistical methods

Method 1. Market studies and expert opinion

This method can be the simplest and least data intensive of the methods described in this chapter. The application of this method can be as simple as having a real estate expert advise on the likely property value impacts of a highway project and then incorporating that assessment into an environmental justice analysis. Yet, as with almost any method, agencies can use variations that are more systematic and hence can provide more reliable inferences.

There are, broadly speaking, two types of expert judgment that can be obtained. In the first case, one can consult real estate experts, usually local professionals who are knowledgeable about local property markets. In the second case, an agency can contract with a firm or expert to conduct a market study. The two cases are likely to be distinguished by the rigor and amount of systematic analysis employed, even though both will rely heavily on expert understanding of the property markets.

In some cases, a market study might combine expert analysis with the techniques from Method 2 (property appraisals) and Method 3 (hedonic regression). Experts might form their opinion, in part, based on appraisals or hedonic studies. So there can be cases where it is difficult to cleanly separate which of the three methods described in this chapter is being used, and the boundaries between the methods can blur at times. Yet having said that, the three methods described in this chapter—expert opinion, appraisals, and hedonic regression—each involve increasing levels of sophistication and are each appropriate in different circumstances, and so it is sensible to describe each separately.

When to use. The method of expert opinion is most appropriate in cases where a more resource-intensive analysis is either not feasible or not necessary. For small projects, with likely small environmental justice implications, an expert analysis might be sufficient. Similarly, smaller agencies with limited technical capabilities will find that careful use of expert opinion can go a long way toward illuminating the potential environmental justice impacts of a project.

This method can be used as a preliminary stage in the analysis, to identify the location of possible positive or negative impacts. If, for example, the use of expert opinion suggests that the property value impacts might lead to importantly large environmental justice concerns, the other two methods (appraisals or hedonic regression) can be used to understand the magnitude of the property value impacts and how those positive or negative impacts will be incident on different groups.

Analysis. The data collection should yield information about where property values will be expected to increase and where they will be expected to decrease as a result of the highway project. In some cases, agencies might even have estimates of magnitudes of property value increases or decreases at particular locations. The analysis involves comparing that information to the spatial distribution of low-income or minority tenants (owners and renters of residences and also possibly business space) to understand if those groups are disproportionately affected by the highway project.

Data needs, assumptions, and limitations. The data collection involves canvassing real estate experts to assess the likely impact of a highway project on nearby properties. This can include focus groups or systematic surveys of experts. Less systematically, an agency might simply discuss the impact with a few experts and carefully document the results. In some cases, such less systematic assessments might be sufficient.

It is also necessary to obtain data on minority, low-income, and other protected populations' characteristics, such as is available from the census. Information on housing unit occupancy and owner/renter tenancy are also available from the census. This method provides general information on the potential for a project to affect property values. While expert opinion might not be able to precisely quantify the magnitude of land price or property value impacts, expert opinion can be quite useful in assessing where property values might be positively or negatively influenced by a highway project. Typically, this method will be regarded as less systematic than the other two methods described below. Certainly, agencies should carefully document how experts arrived at their opinion, so that the agency can defend the analysis, if necessary, in the future.

Results and their presentation. Generally, the results of this method will be contained in a report summarizing the insights of the experts contacted. Two levels of analysis are possible. In the simplest case, the experts may provide an indication of the properties that would be affected if the highway project were to be carried out. A more extensive analysis may reveal the experts' opinions as to the approximate magnitude of effects on property values.

Assessment. The reliability of this method depends crucially on the knowledge of the experts and the care taken to interpret their opinions. Agencies should seek to understand not only the experts' opinions, but also how reliable (or precise) they believe their analysis to be. Overall, this method is best used either when the scope of the project or the expected environmental justice implications are of a small enough magnitude that large resource investments are not justified or when the agency does not have the means to conduct a study using the other methods described below.

Method 2. Property comparisons/appraiser opinion

The method of property comparisons is widely used by property appraisers to determine values of houses and commercial properties. To conduct the analysis, an appraiser finds recently sold properties within the same vicinity and with characteristics similar to the property being appraised. The properties comparable to the property to be appraised are known as "comps." Their sale prices are adjusted to yield the appraised value of the property in question. In practice, the comparison criteria include dwelling age, various physical characteristics, and a broad range of location characteristics.

When to use. Since this method is based largely on appraisers' judgment, property value impacts of transportation projects of any size can be evaluated in this way. Appraisers' judgment may well be the best estimates of property values when sophisticated models are not readily available. The agency should give special attention to finding comparison properties near transportation projects that are similar to the project being analyzed.

Analysis. To use this method for assessing environmental justice impacts of transportation projects, appraisers must include a precise measure of how transportation accessibility is capitalized into property value. If there are numerous recent property sales, it may be easy to find comps with similar accessibility characteristics. Otherwise, a gradient must be developed, such that it can explain variation in property value by variations in accessibility. For instance, past empirical studies of the relationship between house values and distances to highways revealed a gradient of approximately \$1 to \$4 per foot, which implies that each foot of distance away from a highway will reduce house values by \$1 to \$4 (Boarnet and Chalermpong 2001). In this way, even when comps with similar accessibility characteristics cannot be found, other comps can be used, and the values of those comps can be adjusted using an accessibility gradient.

Data needs, assumptions, and limitations. Data to be collected include physical characteristics (such as number of rooms, floor area, quality of construction, piping condition), transportation accessibility, amenities (such as school quality), and disamenities (such as crime and noise). More importantly, location characteristics that involve transportation accessibility must be evaluated and recorded. These include, for example, distance to the transportation facility of interest, such as highway ramps or transit stations. Other neighborhoods in the region with similar transportation accessibility characteristics must then be identified. Appraisers can then search for comps using the information about properties to be appraised. Market rents and sale prices of these comps are then used to estimate the values of properties in question.

Special care must be given to identify good comps. Since human judgments can vary widely, this method may not be suitable if similar properties are difficult to find. Without good comps, this method, which relies solely on appraisers' judgment, may not yield an accurate forecast of changes in property values.

Results and their presentation. For the potentially affected properties, each appraiser provides a report on the likely change in value, based on comparable properties. If two or more appraisers are used, the analyst can compile a brief report providing a range in impacts on the values of affected properties.

Assessment. Difficulties in finding similar properties or land with similar accessibility and other characteristics may limit the use of this method. Some location characteristics that may affect property values, such as air and noise pollution, may be difficult to compare, and thus cannot be assessed. Yet the advantages of this method are that all metropolitan areas have a large number of property appraisers and property appraisal techniques have become highly standardized. By using a panel of several appraisers, a transportation agency can obtain a range of estimates that will help the agency cope with differences in interpretation that are inherent in this method.

Method 3. Hedonic regression

Hedonic regression is a statistical method for evaluating impacts of various kinds on house and residential property prices. These factors range from basic attributes of houses, such as size, number of rooms, and age, to location attributes, such as accessibility to highways and other amenities and disamenities, including the quality of public services, local tax burdens, and public safety. The method utilizes a wide range of data to estimate how a change in a given factor increases or decreases house prices.

Environmental justice analyses of new highway projects can be carried out by applying this method to forecast the highway-induced changes in prices of houses that are owned or rented by people in protected population groups. For example, increased levels of traffic noise caused by a new highway can reduce the desirability of houses nearby and therefore reduce sales prices of these houses. If the owners or tenants belong to protected population groups, actions may need to be taken to compensate them for the losses or disamenities. The losses can often be quantified using the output of the regression model.

When to use. The regression method is appropriate when the project in question is of significant scale. A new grade-separated highway, for example, will not only change transportation accessibility for residents in the area, but also may have major environmental impacts. These changes will be translated into changes in house prices in the surrounding areas, which can be evaluated using the hedonic method. However, smaller projects, such as a road widening in a commercial district, will likely have minor impacts on house prices, and the method may not be able to detect any significant changes in house prices.[2] Also, this method requires extensive data as well as technical skills, both of which may not be available in smaller agencies.

Analysis. A multiple regression technique is used to isolate effects that various factors have on house prices. These factors are called explanatory (independent) variables because they are used to explain the variation in house and property prices (the dependent variable). The influence of each factor (independent variable) on property values is reflected by its coefficient; that is, if the coefficient of an independent variable, such as floor area, is positive, an increase in that variable (larger floor area) will increase the property value, all else being equal. Statistical knowledge and judgment are required for hedonic modeling to make decisions such as which factors should be used as explanatory variables.

The estimation of different specifications of hedonic regressions is carried out by commercial software, such as SPSS, SAS, STATA, or GAUSS. The performance of each estimated model is reflected by two measures – the R^2 (goodness of fit of the overall equation) and t-statistics of the coefficients. The R^2 ranges from 0 to 1 and shows how well the independent variables together explain the variation in the dependent variable (property prices). The t-statistics show how precisely each coefficient is estimated.

Environmental justice analyses for highway projects can be carried out as follows. First, identify and quantify changes in independent variables that result from the project. For example, a new highway may reduce the distance from a house to the nearest highway.[3] The highway project might also increase the noise levels and create visual blight. Changes in property values can be determined from the coefficients of a hedonic model. For example, if the coefficient on distance to the nearest freeway is -$1 per foot, and the highway project will reduce the distance from a particular house to the nearest freeway by 2,000 feet, then that house would gain value equal to (-$1) x (-2,000) = $2,000. If noise levels at the house rise by 5 decibels (dB) due to the highway project and if the coefficient on noise in a hedonic regression indicates that property prices are reduced by $100 per dB, then the noise impact due to the highway project will reduce the house's value by (-$5) x (100) = -$500. Thus, ignoring visual effects, the net effect of the changes in accessibility and noise caused by the completion of the highway project increases the house's value by $1,500.

[2] Note that a road widening in a commercial district might have larger effects on the prices of commercial property.

[3] The straight-line distance to the nearest highway is one measure of accessibility. Others include street-network distance to the nearest highway and distance to the nearest mass transit station.

The hedonic regression method is used to explain the variation in property prices by their characteristics. For example, a house that is 500 feet away from a rail transit station is more expensive than the one that is 5 miles away partially because of its better accessibility to transit. Similarly, a house near the beach is more expensive than the one farther inland, and a house in a good school district is more expensive than the one in an under-performing school district. Each of the proceeding characteristics—access to transit, proximity to a beach, and school quality—are location-specific. GIS software, such as ArcView, is a useful tool that can help quantify the value of these variables.[4] Agencies can use GIS software to generate many of the location-specific variables, which in turn can be used for regression analysis of property prices.

The most obvious variables needed for transportation analysis are accessibility measures, often approximated by distance from a property to a transportation facility (straight-line and street-network distance have both been used). You can use GIS software to measure the distance from each house to the nearest transportation facility. Other location-related variables are available based on local jurisdictions. For example, average SAT scores, which can be used as a measure of school quality, are often available from school districts. GIS software can be used to match house locations to school district boundaries. Similarly, GIS software can match house locations to other jurisdictional boundaries, so that data available from various jurisdictions can be used, often as control variables, in an environmental justice analysis of highway projects. For example, you could assign a city's average crime rate (which reflects the city's public safety) to a house according to where the house is located.

The procedures for creating independent variables using GIS are summarized below.

Step 1 – Geocode the street addresses of houses. You can match (geocode) each house's street address, obtained from a source such as tax assessor's records, to the GIS street-network map. The geocoding process can be automated to match many addresses at the same time, and GIS software packages typically include routines for address matching and geocoding.

Step 2 – Verify match accuracy. You can examine the accuracy of the address match by either using diagnostics from the GIS software or by comparing a small number of computerized matches to printed maps. For example, one can randomly draw 100 houses and compare the GIS match with published street maps. If relatively few of the GIS matches are inconsistent with the paper map, then the automated address matching can be judged to be relatively accurate.

Step 3 – Create independent variables. The spatial join feature of ArcView can be used to determine the distance (straight-line or street-network) from a property (from Step 2) to a transportation facility. The same feature can also be used to assign amenity/disamenity characteristics that follow jurisdictional boundaries. This requires GIS maps for jurisdictions on which the data are based, such as school districts or municipalities.

Some other aspects of data preparation are listed below:

- The accuracy of the raw data should be verified. Data quality can vary across different sources and even across time periods for the same source.

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[4] ESRI's ArcView for desktop computers can be obtained from http://www.esri.com/.

- Home sales prices should be adjusted for inflation, using, for example, the consumer price index for housing in the region or metropolitan area. This index can be obtained from the U.S. Bureau of Labor Statistics' Web site, http://stats.bls.gov/.
- Non-arms-length transactions should be excluded from the analysis to ensure that sales prices reflect market transactions. For example, transactions, in which buyers and sellers share the same last name should be dropped, or at least scrutinized closely, as those sales might reflect non-arms-length transfers of property from, for example, parents to children. The sales price in such cases might not reflect the market value of the home if, for example, the seller is willing to sell the house below market rate to a relative.

Data needs, assumptions, and limitations. Due to the nature of the statistical method, the hedonic regression technique requires input data that cover a reasonably wide range of properties. House and property sales records are the main source of data for hedonic analysis. These data generally include property sale prices, rents, physical characteristics of property, street address, sellers and buyers, loan amount, etc. Such records can be obtained from local government agencies, such as tax assessor and collector's offices or appraisal data support companies that compile such data from these agencies. Measures of accessibility can be generated from street addresses, using GIS software. In addition to these sources, information about amenities and disamenities can be gathered from local authorities, such as local police departments and state departments of justice for crime, and school districts for school quality. Finally, information about environmental impacts is available in environmental quality reports, which are commonly required in large highway projects.

Visual effects, being unique to each project and location, might be difficult to assess in a generalizable way using a hedonic regression approach. Also, there may be variation in different types of effects across places. For example, some neighborhoods may value quietness more than others. As a result, the model estimated from data in one neighborhood may not be transferable for use in other places.

Results and their presentation. This method produces regression equations that show the additive effects of various attributes on residential property values. If the appropriate data are available and included in the analysis, it is possible to estimate the effects of a change in a transportation facility on residential properties located at varying distances from the facility. These results can be easily presented to a nontechnical person in a way that gives him or her considerable insight.

Assessment. The hedonic method is more objective and more firmly grounded in theory than the other methods described in this chapter. Changes in property values can be attributed directly to each different effect from a transportation project. However, there are substantial technical and data requirements associated with this method. Moreover, some effects, such as visual quality, cannot be easily quantified, and thus are difficult to analyze using hedonic regressions.[5]

[5] Rough measures, such as dummy variables for visually blighted areas, can be used as independent variables. For example, a dummy variable for visual blight can be specified, such that it takes a value of 1 if a highway can be seen from a house and 0 otherwise. In this way, the effect of visual intrusion from highways on house prices can be isolated.

ADDITIONAL INFORMATION

The following four tables provide information useful in performing the methods presented in this chapter. Table 12-2 provides a summary of findings from recent studies on house prices and local amenities and disamenities. In general, these studies found that good access to major highways has a positive effect on house prices, but when the house is very near to the facility, noise, dust, and other disamenities may counter the value of accessibility to some extent.

Table 12-2.
Selected recent studies of house prices and local amenities or disamenties

Study	Findings
Studies of highways or other transportation infrastructure	
Boarnet and Chalermpong (2001)	Impact of new toll roads on house prices in Orange County, CA; techniques used include hedonic estimation and repeat sales
Langley (1981)	Impact of the Washington, DC Beltway on house prices; found that house prices increase with the distance from the highway out to a distance of 1,125 feet, and then decrease beyond that distance
Gatzlaff and Smith (1993)	Effect of Miami rail transit on house prices; used repeat sales technique to construct house price index
Huang (1994)	Surveyed the literature on the impacts of transportation infrastructure, specifically transit stations and highways, on property value
Kockelman and ten Siethoff (2002)	Property values and highway expansion: an investigation of timing, size, location, and use effects
Studies of other (nontransportation) environmental amenities or disamenities	
Gayer (2000)	Effect of Superfund hazardous waste sites on house prices in the greater Grand Rapids, MI, area
Gayer et al. (2000)	Effect of Superfund hazardous waste sites on house prices in the greater Grand Rapids, MI, area
Kiel (1995)	Effect of Superfund hazardous waste sites on house prices in Woburn, MA
Leggett and Bockstael (2000)	Effect of fecal coliform bacteria in Chesapeake Bay on the price of waterfront property
Palmquist and Danielson (1989)	Soil quality and farmland value in North Carolina
Smith and Huang (1993)	Air quality (metaanalysis of 26 studies)
Smith and Huang (1995)	Air quality (metaanalysis of 37 studies)
Zabel and Kiel (2000)	Air quality and house prices in Chicago, Denver, Philadelphia, and Washington, DC, metropolitan areas

Table 12-3.
Residential gradients from recent studies

Author(s)	Year	Data	Metro area	Rent gradient[1]
Highway studies				
Boarnet and Chalermpong (2001)	1988-2000	House sale price and distance to nearest highway ramp	Orange County, CA	-\$0.88 to -\$4.49/ft. (1982 dollars)
Voith (1993)	1970-1988	House sale price and auto commute time	Montgomery County, PA	-\$955 to -\$1,168 (1990 dollars) per minute
Langley (1981)	1962-1978	House sale price index from sale-resale pairs, comparing houses within and outside of 1,125 foot buffer from highway	Washington, DC, Metro Area	-\$3,000 to -\$3,500 per house for properties within 1,125 feet of highway
Li and Brown (1980)	1971	House sale price and distance to expressway interchange	Boston, MA	-\$1,642 to -\$1,815 per house for each doubling of distance
Transit studies				
Haider and Miller (2000)	2000	Prices of houses in and out of 1.5 km distance from subway line	Greater Toronto area, Canada	C\$4,000/house[2]
Sedway Group (1999)	1999	House price and distance from transit station	San Francisco Bay Area, CA (Alameda and Contra Costa Counties)	-\$3,200 to -\$3,700/mile
Cambridge Systematics (1998)	1997	House price and distance from transit station	San Francisco Bay Area, CA (Urban/CBD properties)	-\$2.88 to -\$69.12/ft [3]
Voith (1993)	1970-1988	House sale price and accessibility to train station	Montgomery County, PA	\$7,279 to \$9,605/house

[1] Unless otherwise indicated, this is the drop in value for each unit distance from a transportation facility.

[2] In this study, the authors separate housing stock into two groups: one includes houses within a 1.5km distance of a subway line and the other includes the rest of the housing stock. All else equal, the authors found that a house within the 1.5 km distance of a subway line sells for C\$4,000 (4,000 Canadian dollars) more, on average.

[3] The gradients are for single-family housing units in urban areas. The gradient is steep closer to the BART station (within 1,000 ft.) and flat farther from the station (more than 2,000 ft.). In other words, house values drop quickly near station but slowly far away from station. Note, also, that the data used in this study were gathered from properties that are located in urban areas (not suburban locations) and within 2,500 feet of stations only. The magnitude of gradient is much higher than in the Sedway study, where the data are from suburban counties.

House price gradients that were obtained from various studies on transportation and residential property values are listed in Table 12-3. We note that some of these studies are quite dated. The various price gradients estimated in these studies corroborate the less specific findings presented in Table 12-2 in that the Orange County and Boston studies indicate a considerable negative price effect of distance from a major highway. The trade-off between the positive influence of shorter commute times versus the negative effect of direct proximity to such a facility is evident in the two studies of the Washington, DC, area.

Similar information for commercial property is presented in Table 12-4. In the case of commercial properties, access to major highways and thus customers has a strong positive impact on property values. In some cases, these studies found a greater than linear decline in values with greater distance from an access point.

Table 12-5 lists a series of gradients obtained from a recent TCRP report. That study found that direct proximity to a rail transit station within the city has a major positive effect on both single- and multiple-family residential property values. Within the city, impact on per-square-foot rental prices for offices space is nearly twice that on retail space. In suburban areas, retail space benefits much more due to direct proximity to a station.

Table 12-4.
Gradients for commercial property

Author(s)	Year	Data	Metro area	Rent gradient
Highway studies				
Kockelman and ten Siethoff (2002)	1982-1999	Property and land value (10 types of use) and distance to frontage road network	Austin, TX	-$510,000/ acre/sq.mi.[1]
Transit				
Cambridge Systematics (1998)	1998	Rent per sq ft per month of retail and office properties	San Francisco Bay Area, CA	-$.05/1000 sq ft/mo/mi
Sedway Group (1999)	1999	Land price per sq ft for office properties	San Francisco Bay Area, CA	-$117/sq ft/ mi

[1] The gradient in this case is quadratic (dollar value per distance squared), rather than linear (dollar value per distance). In the case of a quadratic gradient, the negative effect of being away from a frontage road increases more rapidly with distance than in the case of a linear gradient. For example, for the gradient of $510,000/acre/sq mi, being 0.1 mile away from the road network will reduce property value by $5,100 per acre. If we double the distance to 0.2 mile, the effect on land value will be quadrupled, to -$20,400 per acre. In the linear case, however, doubling the distance will only double the negative effect on land value.

Table 12-5.
Property value increases near BART stations
(1997 dollars)

Land use type	Distance from BART station (ft)	Central business district/Urban	Suburban
Single family		**Per Unit**	**Per Unit**
	0-500	$48,960	$9,140
	500-1,000	$14,400	$7,930
	1,000-1,500	$8,640	$3,040
	2,000-2,500	$5,760	$5,500
Multifamily		**Per unit/month**	**Per unit/month**
	0-1,300	$50,00	$42.30
	1,300-2,500	$0.00	$0.00
Offices		**Per sq ft/month**	**Per sq ft/month**
	0-1,300	$0.13	$0.00
	1,300-2,000	$0.07	$0.28
	2,000-2,500	$0.00	$0.00
Retail		**Per sq ft/month**	**Per sq ft/month**
	0-500	$0.07	$0.24
	500-1,000	$0.00	$0.24
	1,000-2,500	$0.00	$0.00

Note: This table summarizes how property values change with proximity to Bay Area Rapid Transit (BART) stations.

Source: Cambridge Systematics 1998.

RESOURCES

1) Cambridge Systematics, Inc. 1998. *Economic Impact Analysis of Transit Investments: Guidebook for Practitioners*. Transit Cooperative Research Program Report 35, Transportation Research Board, National Research Council. Available at http://www4.trb.org/trb/crp.nsf/.

   This comprehensive guidebook describes various technical methods for measuring the economic impacts of transit investments, including changes in adjacent property values. It also includes a summary of research on the increases in property values found near BART stations in the San Francisco Bay Area.

2) Sources of property value information:

   - DataQuick, Inc. is a provider of real estate and land data. The Web site is http://www.dataquick.com/.
   - Domain is a look-up Web site that provides sales information by location. Available at http://www.domania.com/.

- Web sites in many states provide summaries of home sales data. For example, the Texas A&M Real Estate Center provides data for Texas metropolitan areas from 1979 to present. The Web site is http://recenter.tamu.edu/data/.
- Regional consumer price indexes can be obtained from the U.S. Bureau of Labor Statistic's Web site. Available at http://stats.bls.gov/.

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CHAPTER 13. CULTURAL RESOURCES

OVERVIEW

Although the term "cultural resources" is not explicitly defined in the National Environmental Policy Act (NEPA), NEPA does require consideration of "Federal actions significantly affecting the quality of the human environment." (Section 102 [42 USC 4332]). The Council for Environmental Quality (CEQ) regulations implementing NEPA state that the "'human environment' shall be interpreted comprehensively to include the natural and physical environment and the relationship of people with that environment" (40 CFR 1508.14). The CEQ regulations specifically address actions that "may adversely affect districts, sites, highways, structures, or objects listed in, or eligible for, listing in the National Register of Historic Places (NRHP) or may cause loss or destruction of significant scientific, cultural, or historic resources" (40 CFR 1508.27). Culturally valued aspects of the environment generally include historic properties, other culturally valued pieces of real property that are often referred to as "traditional cultural properties" (TCP, see King 2003), and cultural use of the biophysical environment.

In some contexts, the term "cultural resources" is narrowly defined to mean a place that is eligible for listing in the NRHP. In other contexts, the term is used broadly to refer to "all elements of the physical and social environment that are thought by anybody—a community, a tribe, an interest group—to have cultural value" (King 2003, p. 11). The broad meaning of the term is used in this guidebook.

Other laws and directives that are applied in concert with NEPA include the following:

- The National Historic Preservation Act (NHPA),
- The Native American Graves Protection and Repatriation Act (NAGPRA),
- The American Indian Religious Freedom Act (AIRFA),
- The Archeological Resources Protection Act (ARPA),
- The Archeological Data Preservation Act (ADPA)[1], and
- Executive Orders 13006 and 13007.

Source materials for each of these directives is described in the reference section at the end of this chapter.

In this chapter, we present a context for identifying resources that may be of cultural value to protected populations. We also suggest methods for assessing the likely effect of a proposed transportation project on these cultural resources.

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[1] The Archeological Data Preservation Act of 1974 (ADPA) is an unofficial term commonly confused with the actual name of the 1974 act, which is the Archaeological and Historic Preservation Act of 1974 (Moss-Bennett Act). Public Law 93-291, 16 U.S. Code 469-469c.

There are generally three types of culturally valued aspects of an environment:

- Historic properties that include objects, buildings, sites, structures, and districts where some historically significant event occurred, are associated with important people, are architecturally distinctive, or have produce important information concerning history.
- Anthropological sites, including cultural use of the biophysical environment (e.g., burial grounds).
- Intangible sociocultural attributes such as social institutions, religious practices, and other cultural institutions.

Unlike most of the other aspects of environmental justice addressed in this guidebook, impacts of many types of transportation projects on cultural resources cannot be measured quantitatively. Rather, the value and sensitivity of most cultural resources can be deduced only through contact with the affected populations. To facilitate assessment of project effects on various types of cultural resources, we have included methods in this chapter that are as intuitive, practical, and as useful as possible.

STATE OF THE PRACTICE

Many cultural resources are identified and protected as a result of either grassroots community efforts or through surveys mandated by federal law or executive order (including Section 106 of the NHPA) as projects are developed. Either path can result in a building, structure, district, object, or site being surveyed for inclusion in the NRHP (administered by the National Park Service). Most surveys include a study of the nature and scope of historical significance for each resource.

However, as described above, there are differing perceptions of how cultural resources should be identified, with implications reaching far beyond the identification of old buildings and archeological artifacts. A broader and more inclusive definition of cultural resources is being suggested in an effort to include concepts like cultural use of the environment, social cohesion and institutions, and religious activities. It is with this new definition and the connection between cultural resources and social impacts that we are addressing environmental justice.

Today, the practice of cultural resource identification and management involves a diverse group of fields and individuals. Some of the major contributors to the field include the following:

- Archeologists
- Ethnographers
- City/regional/state/tribal governments
- Sociologists
- Arts organizations
- Historic preservationists

Collaboration with some or all of these contributors will produce the most thorough survey and comprehensive results.

SELECTING AN APPROPRIATE METHOD OF ANALYSIS

There are three general steps to any cultural resource evaluation. These steps are described in order.

Step 1 – Determine the study area. The first and most important step in the analysis is to identify the area that will need to be surveyed, or the area of potential effects (APE). It is important to remember that this may not be a single area, that it may not have hard and fast boundaries, and that its limits are not based on land ownership. It is often necessary to define different APEs for the different types of cultural resources. For example, the APE for archaeological sites would nomally be restricted to the area of direct impact from ground disturbing activities, while the APE for TCPs would cover a larger area to anticipate indirect impacts from such issues as the introduction of new, visually intrusive elements to the landscape. The study area should include the following:

- Alternative locations for the project;
- Locations where ground may be disturbed;
- Locations from which elements of the undertaking (structures or land disturbance) may be visible; and
- Locations where the activity may result in changes in traffic patterns, land use, or public access.

Step 2 – Inventory the cultural resources within the impact area. Fortunately, this can be a resource inventory very similar to that which must generally be carried out to conform with Section 106 of the NHPA. This act requires that all buildings, sites, structures, districts, and objects within the study area be surveyed for eligibility for inclusion in the NRHP. This survey will provide much of the information needed to identify resources for the analysis.

Most state DOTs have ongoing contracts or relationships with state archeologists or other licensed individuals or groups that conduct research and fieldwork and present their findings and recommendations. In the event that an ongoing relationship does not exist, referrals to qualified individuals can be obtained from the State Historic Preservation Officer (SHPO) or state archeologist office, or in cases on Indian Reservations or other tribal lands, the Tribal Historic Preservation Officer (THPO) or tribal archaeologist if such offices have been established.

Information provided by the NHPA survey that is needed for presentation to the public includes, but is not limited to, the following (as appropriate):

- Name and location of resource,
- Property owner,
- Category of property,
- Number of resources within property,
- Previously listed related resources,
- Resource function or use (historic and current),

- Architectural classification and materials used,
- Brief narrative description of current condition,
- Brief narrative description of resource significance,
- Period of significance (i.e., dates and related people),
- Cultural affiliation, and
- Maps and photographs of each resource (both historic and current).

Describing the entire investigation conducted by survey professionals is well beyond the scope of this guidebook, but the following is a brief summary of the categories of investigation and types of resources about which information will be needed.

Historic Properties. Included are buildings, sites, structures, districts, and objects that have already been listed or deemed eligible for listing in the NRHP. The NRHP lists all properties that have been so designated or are currently being evaluated for inclusion in the register. A list of properties for the study area and documentation on their significance can be obtained from either the National Park Service, an SHPO, or THPO.

Anthropological and archeological considerations. It is often very difficult to recognize the important anthropological and archeological features of an area. Artifacts and their locations can be complicated and fragile. Information concerning Native American sacred sites and other types of TCPs is often confidential and not readily shared with outsiders. This complexity requires that the evaluation be conducted by qualified investigators and that it include the following:

- Background research:
  - Existing anthropological reports;
  - State or tribal historic preservation plans and data;
  - Tribal records, histories, documents, and agreements;
  - Contact with additional local/state/tribal anthropological and archeological experts; and
  - Consultation with local/state/tribal historic preservation and cultural commissions.
- Field investigation and reconnaissance:
  - Site visit and visual inspection of area of potential impact;
  - Subsurface or interior investigation as warranted;
  - Intensive site investigation as necessary; and
  - Recovery work.
- Consultation with Indian tribes for undertakings on, or affecting, tribal lands or in areas where there was historical usage by Native Americans.

While contact with local tribal governments can provide most, if not all, of the pertinent research and documentation you may need on the cultural resources of Native Americans, your responsibility does not end there. It is also necessary to make a good-faith effort to identify tribes that may attach cultural significance to a site and to establish whether or not that tribe still inhabits the area in question. The U.S. Department of the Interior, Bureau of Indian Affairs (BIA) maintains a list of federally recognized Indian tribes and is required to publish an updated list every 3 years in the Federal Register. The most recent list was published in 2002 and is available at 67 FR 46328 (BIA 2002). There also are BIA regional offices throughout the country. These offices can be found in the blue pages of the local telephone directory under U.S. Department of Interior, Bureau of Indian Affairs.

Ongoing dialogue and negotiations between federal agencies and states with tribal governments can help ensure fair and equitable treatment of cultural resources. It should be noted that many archeological findings and locations of Native American artifacts (specifically burial grounds) are confidential and, as such, not part of the public record or the public notification process that you will undertake in keeping with these environmental justice guidelines. Nonetheless, good-faith efforts must be made to inform, discuss, and (when necessary) mitigate impacts on these cultural resources with the same vigor as with more public findings.

To facilitate the good faith efforts of federal agencies and state governments, the Advisory Council on Historic Preservation (ACHP), with support from the FHWA, has developed a geographic information system (GIS)-based system to help identify Indian tribes with whom an agency should consult, provide initial contact information, and define areas of tribal historic interest by individual counties. However, the database should not be the sole basis for the good faith effort since participation on the part of the Indian tribes is voluntary and not all tribes have responded to the request for information. At this time, the initiative, which has been named "Project Vision," is in the pilot stage and the interactive map can be viewed at http://216.87.89.238/ACHP/startMap.asp.

Historical aspects of the community. While some historical aspects of a community surveyed as part of the NHPA may not be eligible for inclusion in it, they still may qualify as cultural resources for the purposes of a survey related to environmental justice. The best way to become familiar with the relevant historical events and their sites is to contact leaders within the communities of interest, both generally and within protected populations. Among the cultural resources that may warrant special attention are those such as the following:

- Sites of cultural significance, regardless of age;
- Sites of current cultural events or activities;
- Travel corridors to and from cultural resources; and
- Sites that have significant social impact on a group or neighborhood.

Based on insights compiled through background research and site visits, follow-up research may be necessary. Local historical societies and state or tribal cultural organizations can often refer you to experts on specific time periods, cultures, or histories, as needed. Use of the standardized forms that are part of the NRHP application process can help to ensure uniformity of documentation and provide a template for the type of data that need to be collected.

Step 3 – Determine impacts of project on identified resources. The disturbance of cultural resources can have an influence far beyond the physical. To be appropriately comprehensive, impacts can be categorized into one of three areas:

- ***Environmental*** **–** changes in the physical structure or environment;
- ***Economic*** **–** loss, movement, or change in the economy of the population; and
- ***Social*** **–** loss or adverse alteration in the social capital of a community.

METHODS

Table 13-1 provides a summary of the methods presented in this chapter.

Table 13-1.
Summary of methods for analyzing cultural resources

Method	Assessment level	Appropriate uses	Use when	Data needs	Expertise required
1. Multilevel impact valuation	Screening	Project	Initial assessment or when a project has several alternative locations	Low	Survey and interview
2. Site visit and survey with a community leader	Screening/ detailed	Project	Area of effect is small or for confidential or sensitive sites	Medium	Interview
3. Stakeholder and expert charrette	Detailed	Project/corridor/ system	For large complex projects, when relationships must be rebuilt, or when ongoing dialogue is required	Medium	Group process and facilitation

Method 1. Multilevel impact valuations

This approach is intended to produce a summary perspective of how a transportation project would affect the cultural resources of an area. It takes into account the fact that changes in cultural resources can have social, economic, and environmental consequences.

When to use. If a project has several alternative locations, this method will provide the quantitative data for comparison purposes. This method is recommended as an initial assessment technique for most projects where cultural-resource effects may be anticipated. For many projects, this method will yield sufficient results to characterize effects to cultural resources that are important to protected populations.

Analysis. Categorization of the impacts (both immediate and projected) fall into three areas: economic, environmental, and social. For each of these areas, a questionnaire is used to obtain input from local cultural resource experts, community representatives, and community members.

Data needs, assumptions, and limitations. Social, economic, and environmental data needed for this approach are presented below as interview questions. This method, as an interview technique, requires you to survey a representative cross section of individuals that represent the views of the population in general and protected populations in particular. Many of the local knowledge, public input, and survey techniques presented in Chapter 2 are useful in understanding the protected population groups that should be interviewed within the study area.

Social data. Social impacts related to changes in cultural resources that would result from a project have the potential to be the most difficult to measure. The key is to increase the understanding of the contributions of cultural resources to a community and the role they play within it. The answers to the questions in Table 13-2, organized by categories of social capital, will provide information about the use and importance of the resources to the norms and networks within the survey area. These questions are only guides and can be tailored to meet the function of each resource. A brief site visit to the resource to interview patrons and employees will help you locate appropriate interview subjects. Most questions merely require either a yes or no answer; others ask the respondent to make a mark on a map.

Economic data. These data largely pertain to changes in the number of visitors to culturally significant sites and facilities. They are derived from interviews with persons who are very familiar with the resources that would be affected. Among the performance measures that might be gathered are the following:

- Total operating dollars
- Number of employees and salary paid
- Capital assets
- Total annual budgets
- Number and types of events held
- Attendance (paid and free)
- Ticket revenue generated
- Number of volunteers
- Volunteer hours
- Visitor spending (direct and indirect)
- Audience demographic profile

Environmental data. Data on most adverse effects can be determined by a brief site survey. The demolition of a structure is not the only effect of concern. Following are some basic considerations that can shed light on how and to what extent the cultural resource would be enhanced or damaged in an environmental sense if a potential transportation project were to move forward:

- Nature and extent of destruction or alteration of resource;
- Destruction or alteration of access to the site;
- Introduction of intrusive elements (e.g., visual, audible, or atmospheric);
- Transfer, lease, or sale of property;
- Potential for neglect or deterioration;
- Duration of any disruption or damage; and
- Likelihood of unexpected discoveries or impacts.

Table 13-2.
Interview questions for evaluating social cultural resource effects

Travel data
1) What is your travel route when you visit this resource? (marks on map)
2) What is your most common mode of transportation when visiting this resource?
3) Where do you live? (marks on map)
Social trust
1) Have you had contact with this resource in the last 12 months?
2) Has this resource impacted social activity in your neighborhood?
3) Has the impact been positive?
4) Do you feel safe when you have contact with this resource?
5) Do you feel safe traveling to and from this resource?
6) Do you see this resource on a regular basis (while traveling to and from work, school, and other activities)?
Multiracial trust and organizing
1) Are you aware of any diversity activities related to this resource?
2) Have you met or interacted with other cultures in connection with this resource?
Diversity of friendships
1) Have you met and made friends with people you would not have otherwise met?
Civic leadership and engagement
1) Have you or has anyone you know attended public meetings or activities at this location or related to this resource?
Associational involvement
1) Do any groups, clubs, or associations regularly use this resource?
2) Are you part of any of these groups?
3) Do you know anyone who is part of any of these groups?
Educational value
1) Do you have children in school?
2) Has this resource been a part of their curriculum?
3) Have you visited this resource as part of an education-related activity (e.g., a field trip)?
Informal socializing
1) Does this resource encourage informal socializing?
2) Do groups gather to chat or "hang out" near or at this resource?
3) Is this a meeting place for people you know?
Giving and volunteering
1) Have you or has anyone you know given money or time (volunteering) to this resource?
Faith-based engagement
1) Have you or has anyone you know participated in religious activities related to this resource?

Results and their presentation. This general method is a rather wide-ranging approach to identifying ways in which an area's cultural resources may be impacted by a proposed project.

Economic impacts. Presenting the alternative project impacts in a table or spreadsheet comparison will allow you to assess how specific elements would be affected and to estimate the bottom-line economic impacts.

Environmental impacts. These impacts can be presented via spatial or visual data using GIS or other mapping program output (in either two- or three-dimensional formats) combined with artists' renderings or photography as needed. Such presentations can display separately and in overlay form the physical impacts of the project. Color-coding map points based on impact type (as discussed in the data section of this method) provide clear visual evidence of impacts.

Social impacts. Two types of information result from the questions shown in Table 13-2 on the elements of social capital. The first is a map with respondent residential locations and travel patterns to the resource site, and the second is survey data that can be presented in table or summary form.

Assessment. This method relies on quantitative and visual data for the purpose of gaining an initial perspective of project impacts of various sorts that are related to cultural resources. This method does not attempt to produce a form of relative valuation of different impacts. Rather, the goal is to gather clear, easy-to-interpret data to help with an evaluation of trade-offs and distributive effects.

Method 2. Site visit and survey with a community leader

This method involves the participation of a community leader who is a recognized and respected member of a protected population. He or she must be well informed about both the cultural resource(s) in question and the social mores and values of the population being represented.

When to use. When the area of potential effect is relatively small, contains only one (or very few) impacted resources, and the protected population is small and concentrated, the use of a site visit and informal surveys has merit. This method may also be advisable when dealing with confidential or sensitive Native American sites.

Analysis. Collection of impact data from protected populations occasionally can be difficult. The use of a community leader can be useful in bridging gaps in comfort and communication between residents and planners. It is vital that you establish a strong working relationship with this person, a relationship based on trust and open communication. This person can facilitate introductions and broker informal discussions centered on the proposed project and potential impacts. This individual or group of individuals should have an established rapport with the protected groups. In many communities, these representatives can be found in local businesses or religious organizations. Visual data, informal interviews, and survey questions collected during the site visit can be used.

Data needs, assumptions, and limitations. Advance preparation of a series of questions incorporating both your organization's own expertise regarding the project and the community leader's knowledge of the community are used during the site visit. Methods for recording answers and discussions can include audiotaping (always with prior consent of the respondent) or a more general note-taking approach. A subject who declines to be taped can still provide vital information as to community perceptions of cultural resources. Having an extra planning representative along for the express purpose of documenting conversations is valuable whenever possible. Interview subjects might include (but are not limited to) neighborhood residents, merchants and business owners, and visitors to the site at the time of the visit (e.g., shoppers and diners). A physical record of the community or site area (e.g., photographs, videotapes, or drawings) should also be collected.

This process requires a great deal of trust in the community leader and a willingness to do much more listening than talking. The method of selecting interview subjects is not scientific, and it should be a collaborative effort between the analyst and the community leader. The emphasis of this method is in gathering both relevant data and anecdotal information regarding cultural resources and their value to the community. The quantitative analysis will reveal what aspects of the cultural community are most important to the respondents and qualitative data should reveal cultural values and perceived impacts within the area of potential effect. More than one site visit may be required depending on the number of protected groups and physical structures involved.

Results and their presentation. Comments and responses can be organized by theme and presented either by video or as written text supported by visual data regarding the neighborhood and the resources it contains.

Assessment. While this method provides a great deal of transcript information, the assessment is fairly straightforward. The themes, comments, ideas, and concerns that appear in multiple interviews are those that require the most attention. An impact that is articulated by several interview subjects (either within a small group or by those with diverse backgrounds) should be flagged as potentially adverse. Special attention should also be paid to any statements that indicate prior adverse impacts and their effect within the community.

Method 3. Stakeholder and expert charrette

A charrette is a meeting of people with varied perspectives and dissimilar interests. The objective is to come as close as possible to a consensus as to what cultural resources exist in the study area, their importance, and what should be done to balance the proposed project and these resources.

When to use. A charrette can be used for any type of project where there is a need to derive a community consensus on an issue usually involving large a complex project with multiple alternatives. In situations where past projects have strained the relationship between agencies of change and the public, this method can be used to rebuild relationships and empower members of the community by including them in your assessment process. This method can also encourage ongoing dialogue and provide you with individuals to consult throughout the project's duration.

Analysis. As mentioned earlier, impacts can be divided into three main categories: economic, environmental, and social. Convening small discussion groups under each of these categories and inviting stakeholders and experts for each of these areas will not only provide specific local knowledge and insights but also forge new collaborative bonds for future projects.

Data needs, assumptions, and limitations. The data gathered with this method will be qualitative in nature and will generally consist of comments by attendees and a statement-of-findings document from each group. Groups can be either quite small (five to eight participants) or larger. Larger groups can initially be divided into smaller working groups and then brought together. One week prior to the scheduled meeting, each group member should be provided with the following:

- A clear map delineating the boundaries of the area under investigation;
- A list of the resources identified within the area;
- A description of the proposed transportation project;
- A graphic, photo, or video documentation of the site;
- An introduction to the category of concern; and
- A clear outline of why the research is being done, its goals and objectives.

When defining groups, consider including the following individuals and organizations:

- Archeologists and anthropologists
- Ethnographers and local historians
- Indian tribe representatives
- Government officials
- Engineers
- Neighborhood or tenant representatives
- Comprehensive plan makers
- Environmental organizations and agencies
- Business people
- Minority businesses/trade groups
- Health care providers
- Protected community representatives
- Social service agencies representatives
- County historical societies
- Media representatives
- Religious leaders
- Grassroots/community-based social service organizations
- Labor unions and organizations
- Libraries, vocational and other schools, colleges and universities
- Legal aid providers
- Civil rights organizations
- Senior citizen’s groups

Results and their presentation. After a brief introduction and review of the documentation provided prior to the meeting, assigned groups form and (in a brainstorming fashion) list *all* answers provided to each of these questions:

1) Why are these resources important to the community?

2) What are their direct impacts on the immediate area?
3) What are their direct impacts on the community at large?
4) What are their indirect impacts on the immediate area?
5) What are their indirect impacts on the community at large?
6) What attributes of the immediate area would be affected or lost as a result of this project?
7) What attributes of the community at large would be affected or lost as a result of this project?

After gathering the responses to each of these questions, the participants rank the comments in order of importance or effect. This can be done (depending on the group dynamic) either as a group or individually with the group's final list being a consensus of individual lists.

Respondents, having been provided with a list of protected populations and demographic or neighborhood maps of a demographic nature, would then be encouraged to comment on questions as to how their findings might impact specific demographic groups or communities. Findings that, according to the group, would have a disproportionate effect on a protected population would be highlighted.

Finally, the group would prepare a statement of findings. This narrative document would highlight their ideas and responses in each area. This document, along with the lists generated, can be used to present the group's findings at public meetings. Data from the group can be synthesized into a single table that can accompany the statement of findings. It may be useful to highlight those ranked items that each group identified as having disproportionate effects on protected populations. One can then make a qualitative assessment of overall impacts by viewing the chart and taking note of how many cells are highlighted.

Assessment. The key to an effective charrette is including an appropriate mix of participants. Among the considerations that should be taken into account in designing a charrette are ensuring that protected populations are represented and that people are included who have a good working knowledge of the area's cultural resources. With the right participants involved, a charrette can be an effective method of fostering dialogue that can point to the cultural resources that are valuable and would be affected by a proposed transportation project.

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APPENDIX A – ENVIRONMENTAL JUSTICE REGULATIONS AND GUIDANCE

OVERVIEW

This appendix summarizes the statutes and regulations that govern and, to some extent, motivate environmental justice assessments for transportation projects. The information is organized into four topics:

1) A description of the statutes, regulations, orders, and policies that form the legal framework for environmental justice in general and transportation projects in particular;
2) A summary of the legal issues addressed by those statutes, regulations, orders, and policies;
3) A summary of the minimum requirements for a legally sufficient environmental justice assessment; and
4) A discussion of best practices for environmental justice, as distinct from the question of legal sufficiency.

Most of the material for this appendix is drawn from other summaries to which you should refer for a more detailed presentation. In particular, see the following:

- The National Cooperative Highway Research Program (NCHRP) report, *Technical Methods to Support Analysis of Environmental Justice Issues*, a thorough and comprehensive review of the legal framework for environmental justice issues in transportation, including a review of recent case law (Cambridge Systematics, Inc. 2002).
- Appendix D of NCHRP Report 456, *Guidebook for Assessing the Social and Economic Effects of Transportation Projects,* an overview of the major federal statutes relating to environmental justice, including Executive Order 12898 (Forkenbrock and Weisbrod 2001).

THE LEGAL FRAMEWORK FOR ENVIRONMENTAL JUSTICE

This section reviews the federal statutes and regulations that provide the primary legal basis for applying environmental justice policies to transportation plans, programs, and projects.

Statutes and implementing regulations

Title VI of the Civil Rights Act of 1964. The Civil Rights Act is the foundation for most federal rules, regulations, and mandates concerning nondiscrimination in federal activities. Title VI of the Civil Rights Act of 1964[1] requires that any program or activity receiving federal financial assistance be free of discriminatory effect with regard to race, color, or national origin.

[1] 42 USC §§2000d-2000d-4.

The key section states:

> No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance.

Later, the Civil Rights Restoration Act of 1987 clarified Title VI to cover all programs and activities of federal-aid recipients, subrecipients, and contractors, whether or not such programs and activities were federally funded.

Both the United States Department of Transportation (U.S. DOT)[2] and the Federal Highway Administration (FWHA)[3] have issued regulations governing the implementation of Title VI.

National Environmental Policy Act of 1969. The National Environmental Policy Act[4] (NEPA) requires federal agencies to consider environmental impacts before taking major actions that have the potential to significantly affect the human environment. In contrast to Title VI, which prohibits certain activities, NEPA is purely procedural. In other words, NEPA defines procedures that must be followed before making a decision but does not restrict the decisions that can be made once the required procedures have been completed.

As interpreted in the Council on Environmental Quality (CEQ) regulations[5], NEPA establishes two types of procedural requirements. These are evaluating effects and providing opportunities for public involvement.

NEPA requirements – evaluating effects. As interpreted by the CEQ, NEPA requires that "reasonably foreseeable" direct, indirect, and cumulative effects of a proposed action be considered in the decision making process. The term "effects" has been defined by the CEQ to include "aesthetic, historic, cultural, economic, social, or health" effects.

According to the CEQ regulation, FHWA policy (FHWA 1987) requires consideration in an environmental impact study (EIS) of impacts on "general social groups" affected by the action, including "minority and ethnic" populations, the elderly, the handicapped, and the transit-dependent. The same policy also states that the EIS should address whether any social group is disproportionally impacted and identify possible mitigation measures to avoid or minimize adverse impacts.

Thus, the FHWA's implementing policies for NEPA require at the least an analysis in the form of an EIS of the potential for disproportionate effects on protected population groups. While the

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[2] 49 CFR §21.5(b).

[3] 23 CFR §200.

[4] 42 USC §§4321-4347.

[5] 40 CFR Part 1500 –1508.

policies do not specifically mention low-income groups, the reference to "general social groups" could be interpreted to signify low-income populations in addition to those groups specifically mentioned in the policy.

NEPA requirements – public involvement. NEPA also requires public involvement in the environmental review process. Both the CEQ and FHWA implementing regulations are very flexible in terms of how one determines the appropriate public involvement procedures in each case.

The CEQ regulations require agencies to make diligent efforts to involve the public in preparing and implementing their NEPA procedures, and require agencies to provide public notice of NEPA-related hearings, public meetings, and the availability of environmental documents.

The FHWA regulations establish similarly broad requirements. They require each state to adopt a public involvement/public hearing program for use in the NEPA process. This program must include, among other things, early and continuing opportunities during project development for the public to be involved in the identification of social, economic, and environmental impacts, as well as impacts associated with relocation of individuals, groups, or institutions.

Title 23 of the Federal-Aid Highway Act of 1970. A year after NEPA was passed, the Federal-Aid Highway Act (FAHA) of 1970[6] further clarified the role of community and environmental impact assessment in evaluating potential transportation investments. The law requires that:

> [P]ossible adverse economic, social, and environmental effects relating to any proposed project on any Federal-aid system have been fully considered in developing such project, and that the final decisions on the project are made in the best overall public interest, taking into consideration the need for fast, safe and efficient transportation, public services, and the costs of eliminating or minimizing such adverse effects [as] the following:
>
> 1. air, noise, and water pollution;
> 2. destruction or disruption of man-made and natural resources, aesthetic values, community cohesion and the availability of public facilities and services;
> 3. adverse employment effects, and tax and property values losses;
> 4. injurious displacement of people, businesses and farms; and
> 5. disruption of desirable community and regional growth.

Thus, the FAHA requires the consideration, in some form, of socioeconomic effects when making decisions on transportation projects. However, two important caveats should be kept in mind in evaluating the legal relationship between the FAHA and environmental justice.

[6] 23 USC §109(h).

- The FAHA does not prohibit actions that have disproportionate impacts on a particular resource or social group. On the contrary, it requires decisions to be made in the "best overall public interest." By mandating that decisions be based on the good of the public as a whole, the FAHA implicitly allows for decisions that, in some cases, may disproportionately impact a particular resource or group.
- The FAHA applies to "all proposed projects with respect to which plans, specifications, and estimates are approved by the Secretary [i.e., the U.S. Secretary of Transportation] after the issuance of such guidelines." Over time, the role of the U.S. DOT in approving plans, specifications, and estimates (PS&E) has been greatly reduced as PS&E approval authority has been delegated to individual states. Today, PS&E approval authority has been, or can be, delegated to state DOTs for all noninterstate projects.[7] Thus, in any state that has received full delegation of PS&E approval authority, the only projects that are still subject to the FAHA are those on the interstate system.

Other civil rights statutes. While Title VI, NEPA, and the FAHA provide the primary statutory basis for environmental justice in transportation projects, several other statutes are deserving of mention:

- The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970[8] provides that all groups should be treated uniformly and fairly in the case of residential relocations resulting from eminent domain.
- Title VIII of the Civil Rights Act of 1968[9] (Fair Housing Act) designates protected populations, taking into account "race, color, religion, sex, handicap, familial status, or national origin" in relocation decisions.
- The Age Discrimination Act of 1975[10], prohibits age discrimination in federally assisted programs.
- The Americans with Disabilities Act of 1990[11] protects persons with disabilities.
- Chapter 21 of the Civil Rights Act of 1964[12] provides the legal basis allowing private plaintiffs to bring disparate impact claims.

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[7] 23 USC §106(c).

[8] 42 USC §§4601-4655.

[9] 42 CFR §§3601-3619.

[10] 42 USC §§1601-1607.

[11] 42 USC §§12101-12213.

[12] 42 USC §1983.

Executive orders and implementing regulations

In addition to the statutes described above, several executive orders have addressed environmental justice and related issues. Executive orders are policy statements issued by the executive branch of government. Their purpose is to set forth operational guidelines for federal departments and agencies. As such, they exert considerable influence on the activities of those departments and agencies, although they do not carry the force of law, as do the statutes described in the previous section.

Executive Order 12898. On February 11, 1994, President Clinton issued Executive Order (EO) 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations." The order requires each federal agency to make environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations. Thus, EO 12898 addresses both the requirements for equal justice embodied in Title VI and the requirements for environmental protection embodied in NEPA. As such, it is the seminal policy for environmental justice.

As directed by EO 12898, representatives from 17 federal departments and agencies were convened to form the Interagency Working Group on Environmental Justice. The Interagency Working Group issued guidance interpreting key terms in the EO. Later, individual agencies, including the U.S. DOT, issued their own environmental justice policies, which govern the activities of those agencies. The key policy documents governing FHWA are as follows:

- U.S. DOT Order 5610.2, "Department of Transportation Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" (February 3, 1997.
- FHWA Order 6640.23, "FHWA Actions to Address Environmental Justice in Minority populations and Low-Income Populations" (December 2, 1998).

In addition to these policies, FHWA issued a number of memoranda from headquarters to field offices on the topic of environmental justice in 1999 and 2000 (Wykle and Linton 1999; Burbank and Adams 2000). FHWA also maintains statements of its environmental justice policies on its Web site. These memoranda and Web site materials provide additional guidance on FHWA's interpretation of the requirements of EO 12898.

Other pertinent executive orders. In addition to EO 12898, which directly addresses environmental justice policy, two other Executive Orders are somewhat pertinent:

- EO 13166 mandates all federal agencies to improve access to their federally conducted programs and activities by eligible persons with limited English proficiency. This order has particular relevance with regard to the NEPA mandate to foster public involvement in the environmental review process. It stipulates that accommodations must be made for persons with limited English proficiency who wish to participate in public environmental reviews.

- EO 13045 mandates all federal agencies to identify and assess environmental health risks and safety risks that may disproportionately affect children. This has the effect of making children a protected population with regard to environmental justice issues.

LEGAL ISSUES

Whereas the previous section of this appendix summarizes the major statutory and federal policy guidelines that are the basis for environmental justice, this section describes how those statutes and guidelines address particular issues, such as which population groups are considered "protected" and how to define a "disproportionate" impact.

Population groups to be considered. EO 12898 protects both minority populations and low-income populations. Title VI protects minorities against discrimination, but does not apply to low-income groups. Other statutes protect the elderly, the disabled, and women against discrimination, but these groups are not protected under EO 12898. Table A-1 summarizes the sources of protection for each of these groups.

Table A-1. Groups Protected

Protected by specific statute and by EO 12898	**Protected by specific statute but not by EO 12898**
Minorities (Title VI)	Elderly (Age Discrimination Act) Disabled (ADA, Rehabilitation Act) Women (Federal Highway Act)
Not protected by specific statute but protected by EO 12898	**Not protected by specific statute and not protected by EO 12898**
Low-income persons	Other socioeconomic groups

Types of adverse effects to be considered. Under EO 12898, the U.S. DOT requires consideration of all reasonably foreseeable social, economic, and environmental effects on minority populations and low-income populations. Thus, essentially every impact category considered as part of the NEPA process—including secondary and cumulative impacts—needs to be considered in an environmental justice analysis.

Measuring "proportionate." There are no established legal standards or guidance for deciding how to measure the proportionality of the distribution of benefits and burdens for a plan or project. Measuring the proportionality of benefits and burdens raises numerous conceptual and practical problems. How is a *benefit* or a *burden* defined? Over what time period should benefits and burdens be evaluated? How should the sum total of benefits and burdens be measured? Is it even possible to calculate such a total? These questions must be answered to develop legally sound methods for assessing compliance with EO 12898. However, at present, there are no established legal standards or federal guidelines for practitioners to follow in answering these questions.

Extent to which benefits should be considered. The U.S. DOT requires that benefits be considered in three distinct ways. First, a denial, reduction, or significant delay in the receipt of benefits constitutes an *adverse effect* for purposes of EO 12898 and therefore should be taken into account in determining adverse impacts. Second, off-setting benefits should be considered when evaluating the adverse effects on a protected population. Finally, the overall distribution of benefits also must be considered.

Standards for approving actions with disproportionate effects. In early 2000, FHWA and the Federal Transit Administration (FTA) issued guidance stating that one of the three basic principles of environmental justice was to ensure that low-income and minority groups receive a proportionate share of the benefits of transportation investments. Current FHWA guidance, however, focuses on enhanced public involvement and an analysis of the distribution of benefits and impacts. The guidance goes on to state that there is no presumed distribution of resources to sustain compliance with the environmental justice provisions. This more recent guidance confirms that there may be circumstances in which actions with disproportionate benefits or disproportionate burdens can be approved.

The U.S. DOT and FHWA orders do establish standards for approving actions that are found to have a disproportionate impact on minority populations or low-income populations. These orders establish two distinct standards: one for groups that are protected only under EO 12898 and one for groups that are protected both under EO 12898 and under Title VI. (The orders do not address the elderly, the disabled, or women.) The standards set forth in the U.S. DOT and FHWA orders are summarized in Table A-2.

ELEMENTS OF A LEGALLY SUFFICIENT ENVIRONMENTAL JUSTICE ASSESSMENT

The previous sections of this appendix present pertinent environmental justice regulations and guidance. Based on the language and intent of these regulations and guidance, it is important to address the following question: *From a regulatory and policy perspective, what is the standard of legal sufficiency for environmental justice assessment of transportation policies, programs, and projects?* Although this question cannot be fully answered, some guidance is provided below.

The legal and regulatory basis for environmental justice is, at best, not fully tested. As could be expected, statutes, regulations, and case law speak more to the *process* of environmental justice assessment than to the *content* of assessments. The following basic process is suggested by environmental justice statutes, regulations, and guidance:

- Transportation planning organizations must carry out their policies, programs, and projects in a manner that is free of intentional discrimination and highly sensitive to the possibility of discriminatory outcomes. Legal requirements against intentional discrimination are clear, whereas the limitation against discriminatory effects is not as clearly defined.

- In addressing potential discriminatory effects, practitioners must involve the public freely and openly in the decision making process and make certain that the views of protected populations are adequately represented.
- Under the disparate impact standard, a plaintiff must identify specific discriminatory actions of permitting agencies, show disproportionate inclusion or exclusion of a protected population, and provide causal connection between the alleged discriminatory action and the disproportionate effect. The defendant bears the burden of rebutting the claim or providing justification. It is in the permitting agency's best interest to identify such potential claims early in the planning process and involve the public in resolving the issues. Then, if litigation results, the permitting agency will be prepared with rebuttal or justification information.

Table A-2.
Standards for approving actions with disproportionate effects

Disproportionate effects on groups protected only by Title VI **(Minority populations)**	**Disproportionate effects on groups protected by EO 12898** **(Low-income and minority populations)**
May be approved if: 1) A substantial overall need for the program, policy, or activity exists, based on the overall public interest; and 2) Alternatives that would have less adverse effects on protected populations (and that still satisfy the need identified in 1) above), either: a) Would have other adverse social, economic, environmental or human health impacts that are more severe or b) Would involve increased costs of extraordinary magnitude.	May be approved if: 1) Avoidance alternatives are not practicable; and 2) Additional mitigation measures also are not practicable. Practicability assessment will take into account social, economic (including costs) and environmental effects of avoiding or mitigating the adverse effects.

As part of that process, an environmental justice assessment should satisfy *at least* the following minimum content requirements:

- Most statutes, such as the Civil Rights Act of 1964, protect against discrimination based on race, class, or national origin. Executive Order 12898 extends many of these same protections to low-income populations. The EO also focuses on disproportionately high and adverse environmental and human health effects. One could thus argue that greater weight should be given to identifying potential adverse effects to minority populations because such issues have the greatest legal protections. It may be in the best interest of transportation planning agencies, however, to address both beneficial and adverse effects to all protected populations.

- Federal law requires that the economic, social, and environmental effects of a proposed project be fully considered in the development of that project. An environmental justice assessment therefore should address the adverse economic, social, and environmental effects on protected populations. Department of Transportation and FHWA guidance extend this adverse-effects-assessment requirement to include beneficial effects.
- Environmental justice assessments should be grounded in agency-wide strategies and programs to address Title VI and related concerns, and they should work to reach the goals of these programs.
- An environmental justice assessment should include a demographic profile of the populations potentially affected by the program, policy, or project in question.
- The environmental justice assessment should seek to identify the needs of the minority and low-income populations potentially affected by the program, policy, or project in question.
- The assessment should use public involvement both to identify potentially affected protected populations and to obtain input on the perceived effects of the program, policy, or project.
- The environmental justice assessment should be an analytical tool for identifying the benefits and burdens of the proposed program, policy, or project to protected populations. If undue burdens are identified, the assessment should take these into account and seek to minimize or eliminate them through planning modifications, design changes, or implementation of mitigation measures.

This is not to say that an environmental justice assessment conducted according to these requirements meets the standard of best practice. Rather, an assessment that meets these technical criteria and has been conducted as part of the process outlined above, could be expected to meet legal sufficiency tests if based on suitable information and methods.

BEST PRACTICE VERSUS LEGAL SUFFICIENCY

The ultimate objective of any transportation project is to promote the public good. Highways, secondary roads, bridges, and intersections are designed to provide social and economic benefits to the communities they serve. To whatever extent a transportation project disrupts a community or decreases the quality of life, those purposes are defeated.

The standard of best practice is whether or not an environmental justice assessment is an integral part of the planning process and whether or not it provides insight to decision-makers, protected populations, and the general public as to how best to apply limited transportation resources while balancing social, economic, and environmental goals.

RESOURCES

1) http://www.epa.gov/fedsite/eo12898.htm. This Web site contains the full text of the Executive Order 12898 on Environmental Justice. It is the executive order signed by President Clinton on February 11, 1994.

2) http://www.fhwa.dot.gov/environment/ej2.htm. This Web site contains the Federal Highway Administration's comprehensive listing of environmental justice and transportation resources, rules, policies, publications, and training opportunities.

3) http://www.fhwa.dot.gov/environment/ejustice/facts/index.htm. This Web site provides an overview of the legal aspects of environmental justice legislation.

4) http://www.epa.gov/compliance/. U.S. Environmental Protection Agency. "Environmental Justice." U.S. Environmental Protection Agency.

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APPENDIX B – IMPLICATIONS OF RECENT ENVIRONMENTAL JUSTICE CASE LAW

OVERVIEW

This appendix provides a general sense of the case law that has recently developed regarding environmental justice, with emphasis on transportation-related situations and the implications for performing environmental justice assessments. This brief survey describes what the courts have deemed acceptable when considering environmental justice and mitigating adverse effects. Much of the material in this appendix is drawn from other summaries, to which you should refer for a more detailed presentation. In particular, see the NCHRP report, *Technical Methods to Support Analysis of Environmental Justice Issues* (Cambridge Systematics, Inc. 2002). The report provides a thorough and comprehensive review of the legal framework for environmental justice issues in transportation, including a review of recent case law.

With some exceptions, relevant case law shows that plaintiffs have been more successful in attacking the procedures that planning organizations use than in attacking the distributive effects of their activities.[1] This has been largely due to the difficulty of plaintiffs' burden of proof requirements in disparate impact cases. Under the disparate impact standard, a plaintiff must identify specific discriminatory actions of permitting agencies; show disproportionate inclusion or exclusion of a protected population; and provide a causal connection between the alleged discriminatory action and the disproportionate effect.[2]

While the plaintiff bears the burden of proof of disparate impact, the defendant bears the burden of rebutting the claim or providing justification for its actions.[3] Therefore, it is in the permitting agency's best interest to identify such potential claims early in the planning process and to involve the public in resolving the issues. Then, if litigation results, the permitting agency will be prepared with a rebuttal or information justifying its actions.

RECENT CASES BASED ON EQUAL PROTECTION STATUTES AND REGULATIONS

Title VI of the Civil Rights Act of 1964, as amended, only prohibits intentional discrimination, which is extremely difficult to prove. The U.S. DOT Title VI regulations, however, go a step further by prohibiting actions that have a disparate effect on protected populations. The

[1] See *Tolbert versus Ohio DOT* 992 F. Supp. 951 (N.D. Ohio 1998); 172 F.3d 934 (6th Cir. 1999).

[2] Under Title VI, courts have also frequently inferred causation based on statistical comparisons between minority host sites and the racial demographics of neighborhoods that would have been suitable for the facility. See *Elston versus Talladega County Bd. of Educ.*, 997 F.2d 1394, 1407 (11 Cir. 1993); *Georgia State Conference of Branches of NAACP versus Georgia*, 775 F. 2d 1403, 1417 (11th Cir. 1985); *Larry P. versus Riles*, 793 F. 2d 969, 982-983 (9th Cir. 1984); *Coalition of Concerned Citizens Against I-670 versus Damian*, 608 F. Supp. 110 (DC Ohio 1984); *Bryan versus Koch*, 627 F.2d 612 (1980).

[3] See New York Urban League, 71 F.3d at 1036.

"disparate effect" standard in the Title VI regulations is similar, at least in concept, to the standard embodied in Executive Order (EO) 12898, which addresses "disproportionately high and adverse effects" on minority populations and low-income populations. As a result, plaintiffs seeking to bring environmental justice lawsuits have frequently based their legal claims on the U.S. DOT Title VI regulations, not on Title VI itself.

In *Alexander versus Sandoval*, issued on April 24, 2001, the U.S. Supreme Court held that private plaintiffs can no longer bring lawsuits under the U.S. DOT Title VI regulations.[4] As a result, private plaintiffs no longer can bring claims in federal court alleging a "disparate impact" on the basis of race, ethnicity, or national origin. The only avenues still open to private plaintiffs under Title VI are: (1) filing a lawsuit in federal court based on an allegation of intentional discrimination, which cannot be proven based solely on evidence of disproportionate effects and (2) filing an administrative complaint with the US. DOT, which can include a disparate-impact claim, but does not involve a private lawsuit in federal court.

In the *Sandoval* case, the Supreme Court did not resolve the issue of whether private plaintiffs may be able to bring the equivalent of a Title VI disparate-impact claim under another federal statute, 42 U.S.C. Section 1983. Just a few weeks after *Sandoval* was decided, a U.S. District Court in New Jersey issued a decision in another high-profile case, *South Camden Citizens for Action versus New Jersey Department of Environmental Protection*. In that decision, the District Court held that Section 1983 does allow private plaintiffs to bring disparate-impact claims.[5]

The District Court's decision, however, was overturned by the U.S. Court of Appeals for the Third Circuit in December 2001.[6] In its decision, the Third Circuit held that Section 1983 does not allow private parties to bring the type of disparate-impact lawsuits that the Supreme Court barred in *Sandoval*.

RECENT CASES BASED ON ENVIRONMENTAL STATUTES AND REGULATIONS

Unlike Title VI, the National Environmental Policy Act (NEPA) is purely procedural. It requires an analysis of environmental impacts and opportunities for public involvement, but it does not restrict the types of decisions that can be made once the necessary process has been completed. As a result, environmental justice claims based on NEPA are quite different from those based on Title VI. In NEPA cases, plaintiffs generally allege that a NEPA document did not sufficiently consider impacts on minority and low-income groups; the relief requested in such a lawsuit is usually an order requiring that further study be done.

The ability of private plaintiffs to raise environmental justice issues in NEPA lawsuits remains unresolved. On one hand, there are several reported cases in which courts have rejected efforts to

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[4] See *Alexander versus Sandoval*, 532 U.S. 275, 121 5. Ct. 1511 (2001).

[5] *South Camden Citizens in Action versus New Jersey Department of Environmental Protection*, 145 F. Supp. 2d 505 (D.N.J. 2001).

[6] *South Camden Citizens in Action versus New Jersey Department of Environmental Protection*, 274 F. 3d 771 (3d Cir. 2001).

raise environmental justice issues in a NEPA lawsuit; those courts have held, in essence, that raising environmental justice claims under NEPA would be tantamount to circumventing EO 12898, which specifically states that it does not create any enforceable legal rights.[7] On the other hand, in a few reported cases the courts appear to have assumed—without explanation—that a court can review the adequacy of an agency's environmental justice analysis as part of its review of an environmental impact statement (EIS) under NEPA.[8]

Thus, at this point, there remains some uncertainty about whether plaintiffs can challenge an EIS (or other NEPA document) based on alleged inadequacies in the review of impacts on low-income populations or minority populations. This issue may be resolved in the future through additional NEPA litigation.

PROPORTIONALITY IN DISTRIBUTION OF BENEFITS AND BURDENS

There has been relatively little case law that directly addresses the core issues presented in EO 12898—namely, how to determine whether a particular population group is disproportionately affected by a project and, if so, how to determine whether such disproportionate impacts are justified. However, in one relatively recent case, *Jersey Heights Neighborhood Association versus Glendening*, the U.S. Court of Appeals for the Fourth Circuit directly addressed some of these issues. In that case, the plaintiffs alleged that the location of a highway in a minority neighborhood violated the nondiscrimination requirements of the federal Fair Housing Act.[9] One of the plaintiffs' arguments was that "similarly situated residents" are entitled to an "equal distribution" of benefits and burdens of the project. The Fourth Circuit rejected this line of reasoning as follows:

> This proportional burden theory is an unmanageable proposition. Under the [plaintiff's] standard, how is a multicultural society ever to locate a highway? Suppose a roadway runs by a neighborhood that is 35 percent Anglo, 45 percent Latino, and 20 percent African American. Does the predominant ethnic group have a disparate impact claim? What if 35 percent of a route runs proximate to a predominately Asian American neighborhood and 25 percent next to a predominately Hispanic American neighborhood? Will planners have to relocate the corridor to ensure that it affects each ethnicity proportionally? Simply to pose these questions is to demonstrate the absurdity of the result—a twisting, turning

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[7] See *Acorn versus U.S. Army Corps of Engineers*, 2000 U.S. Dist. LEXIS, * 24 (E.D. La. April 20, 2000) (holding that environmental justice claim could not be based on NEPA, even though CEQ regulations required agencies to integrate NEPA analyses with analyses "required by…other environmental laws and executive orders"); *Citizens Concerned About Jet Noise, Inc. versus Dalton*, 48 F. Supp.2d 582 (E.D. Va. 1999) (holding that "NEPA does not require an environmental justice analysis" and, as a result, "the court does not have jurisdiction to review this portion of the FEIS [i.e., the environmental justice analysis]"); *New River Valley Greens versus U.S. Department of Transportation*, 1996 U.S. Dist LEXIS 16547, *16 (W.D. Va. October 1, 1996) (holding that plaintiffs cannot "do indirectly under NEPA what cannot be done directly under the Order [i.e., bring an environmental justice claim]").

[8] See *Donald Young versus General Services Administration*, 99 F. Supp. 2d 59, 84-85 (D.D.C. 2000) (holding that an ElS for a federal agency office building adequately considered environmental justice impacts); *American Bus Association, Inc. versus Slater*, 1999 U.S. Dist. LEXIS 20936 (D.D.C. September 10, 1999) (holding that U.S. DOT adequately considered environmental justice issues when deciding not to prepare an EIS for proposed regulations).

[9] See *Jersey Heights Neighborhood Association versus Glendening*, 174 F.3d 180 (4~ Cir. 1999).

> roadway that zigs and zags only to capture equally every subset. Such a standard would lead to race-based decision making of the worst sort. We do not think the drafters of the Fair Housing Act ever contemplated such a reading.[10]

As a matter of legal precedent, the Jersey Heights decision only applies to cases under the Fair Housing Act. However, this case is noteworthy because it signals that courts may be skeptical of lawsuits based on the claim that the benefits and burdens of a transportation project have been distributed disproportionately.

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[10] See *Jersey Heights Neighborhood Association versus Glendening*, 174 F.3d 180, 193 (4th Cir. 1999).

APPENDIX C – USING GEOGRAPHIC INFORMATION SYSTEMS TO EVALUATE ENVIRONMENTAL JUSTICE

INTRODUCTION

This appendix provides an overview of how geographic information systems (GIS) can be used to evaluate environmental justice as it relates to proposed transportation system changes. The appendix discusses in more detail a number of GIS-related topics introduced in the guidebook chapters. In addition, this appendix briefly describes certain GIS-based methods for evaluating environmental justice that have not been discussed elsewhere in the guidebook.

Two recent NCHRP research reports have discussed GIS and its use in environmental justice and social economic impact assessment (Forkenbrock and Weisbrod 2001; Cambridge Systematics 2002). Much of the content in this appendix was borrowed from the above referenced research reports. They are valuable information sources if you desire more information on these topics.

BACKGROUND

GIS allows you to analyze and present the spatial nature of predicted social and economic effects to protected populations. Using various types and scales of maps, it is possible to compare effects between one location and another to determine how various population groups may be differentially affected by a proposed transportation system change. Thus, GIS can be used to display the patterns of distributive effects at varying scales.

In this appendix, we assume that you have a least a basic working knowledge of GIS. Our intent is not to teach GIS basics, but rather to discuss the particular data, techniques, and software issues that may arise during GIS-based analysis of the social, economic, and environmental effects of a transportation project.

GIS products are designed to combine and analyze layers of information about a place or location. Most, if not all, of the variables considered in an environmental justice assessment have a spatial component. Because of this, GIS is extremely well suited for analysis of the distribution of benefits and burdens. GIS technologies are now being used throughout the world by a diverse group of technicians from all different disciplines. Historically, demographers and planners have used GIS as a tool to store, manipulate, and display data. However, GIS can be implemented as a modeling, decision making, and general spatial statistical analysis tool as well. GIS is unique among computer-based analysis tools for several reasons:

1) GIS allows geo-referenced variables and data from diverse sources and scales to be overlaid and viewed so a more complete picture can be developed of a geographic area.
2) GIS allows aggregation and disaggregation of data to different scales so analysis can be done at an appropriate scale or at multiple scales allowing more robust results.
3) GIS facilities mapping and visualization of information.

Most commonly, GIS is used for querying spatial databases to find locations that fit criteria for mapping demographics, displaying trends or historical data, displaying assets like transportation infrastructure, and visualizing areas and points of capital investment; as well as processing points, polygons, and lines to find numeric descriptors of data that can then be used in spatial-statistical analysis. Spatial statistical analysis is the description of patterns in space with mathematics and statistics. This type of analysis allows geographic patterns and trends to be numerically described.

Geographic and demographic data

The U.S. Census Bureau has a Web site with numerous demographic data available for downloading. Other basic data needed for GIS analysis can be accessed or developed from existing public records, such as tax and real estate databases. Table C-1 lists the data and possible data sources commonly used when mapping transportation-related effects. Not every analysis requires all the types of data listed, but the table provides a sense of where to search for location-specific data.

Table C-1.
Data and data sources for GIS analysis

Data type	Source
Demographic	U.S. Census Bureau, local planning departments (for updates and detailed forecasts)
Topographic	U.S. Geological Survey (USGS), metropolitan planning organizations, state departments of natural resources, local planning departments
Street network	TIGER/Line Census files (available from the U.S. Census Bureau) local planning/engineering departments, commercial GIS data vendors
Land use	Local planning departments, city public works departments
Accessibility points of interest (local landmarks/activity centers)	Local planning departments, neighborhood organizations, geocoded addresses
Activity centers (major employers, schools, houses or worship, shopping, and public services)	Geocoded addresses, local or regional economic development or planning departments

Source: Forkenbrock and Weisbrod 2001.

Topographic data usually must be collected on a local-to-regional level. The United States Environmental Protection Agency (U.S. EPA) mandates reporting on some environmental factors; thus, the U.S. EPA may have relevant data available. Otherwise, good sources for obtaining environmental features include the United States Geological Survey (USGS), state departments of natural resources, and metropolitan planning organizations. Data on road networks are usually available from the U.S. Census Bureau in the form of Topologically Integrated Encoding and Referencing (TIGER/) Line files. If greater detail or accuracy is desired, local planning and engineering departments and state departments of transportation may have files depicting road networks, or such files usually can be purchased from commercial GIS data vendors.

Data issues

Conversion. Once data for measuring the effects of a transportation project have been obtained, several issues may arise. Data are available in different formats for use with GIS software packages, including several different types of coordinate systems and projects. Projections relate to how spherical data from the surface of the earth are transformed to the flat surface of a map. Some distortion is inevitable. Fortunately, most GIS software packages now include data and file translators that automate the conversion of data to the projection currently being used for the impact analysis. It still is important to remain aware of the projection used for each data file. Although conversions from one projection to another are not generally likely to be a problem, travel demand or other impact models may only be able to use one specific projection.

Another data incompatibility issue arises when data have been created using different software packages than the one being used for the impact analysis. Because most GIS software is capable of converting incompatible file types to data that are recognizable by the software, this form of incompatibility is rarely a serious problem.

Privacy and data suppression. Obtaining detailed household data raises privacy issues. The U.S. Census Bureau publishes income and other sensitive data (such as welfare status) only at the block-group level—not at the census-block level that is desirable for many project impact analyses. Typically, there are about 30 blocks in a block group.

Often, however, local city or regional city planning departments may have done their own estimates or personal income and poverty at the block level; those data can be useful for transportation-related analyses. If no other estimates exist, it is possible to estimate block levels from data at higher levels of aggregation.

Example. Being careful to use explanatory variables available at both the block and the block group, you can fit a regression model that predicts the percentage of persons living in poverty at the block level (see Forkenbrock and Schweitzer 1999). Once the coefficients of the regression have been estimated at the block-group level, it is possible to apply these coefficients to explanatory variables at the block level to predict the number of persons living in poverty at the block level.

Forkenbrock and Schweitzer (1999) built such a model for a metropolitan area using three variables (median home value, percent of homes that are owner-occupied, and percent of population over 65 years of age) at the block-group level to predict the percentage of persons at the block level.

Software requirements

Several GIS software packages are suitable for analyzing the distributive effects of transportation projects. Choosing which specific software package to use can be difficult, however, because of the wide variety of functions and tools available in the different packages. It is necessary to assess which tools and techniques will be needed to complete the analysis as well as what data type and format is being used. Almost any analysis of social and economic effects will require basic GIS tools such as the following:

- Database query capability,
- Geocoding and address matching, and
- Data projection and translation.

Very few GIS packages consist of only these tools; most contain a comprehensive array of capabilities for spatial analysis.

For more complicated functions—such as barrier or buffer analysis—a GIS software package needs additional tools. Most GIS packages include scaled-down tools for statistical analysis, but often it is necessary to use a more powerful, separate statistical analysis package. When this is the case, data must be exported out of the GIS software and into the statistical package. The tabular data in the GIS software must be compatible with the data format that the statistical package uses and vice versa. Usually, this presents only minor problems.

The most complex analyses of the environmental justice-related effects of transportation projects require GIS tools that are often not included with basic GIS software packages. These tools normally are available in groupings with other complex analysis tools as extensions or add-ons to the software. Three examples of complex tools that may only be available in this way are grid processing, irregular polygon information aggregation, and triangulated irregular network (TIN) creation and analysis. TIN creation and analysis is important for impact analysis because of its ability to depict areas of equal effects at various distances from a roadway (e.g., to generate noise level contours from sample sound receptor locations). Irregular polygon information aggregation allows identification and counting of households and their associated demographic characteristics within selected contours (see Chapter 2, Method 3). Grid processing and analysis allows you to perform surface analysis and certain forms of spatial disaggregation (see Chapter 2, Method 6, and Chapter 3, Method 3).

Common types of GIS-based analyses

Many different types of GIS-based analysis can be used to evaluate environmental justice. Most require the use of network analysis for transportation impacts. Network analysis can include travel demand analysis and traffic simulation studies. Such analyses can be extremely complex and may require the use of large data sets and powerful computers to predict effects on a road network.

Estimating the social and economic effects of transportation projects may require the use of any or all of the following analysis techniques, which are briefly discussed in turn:

- Mapping and visualization,
- Buffer analysis,
- Barrier analysis, and
- Overlay analysis.

Mapping and visualization. Maps almost always are an important first step in an analysis. Sometimes they reveal patterns that would not be obvious in numeric or statistical charts. They allow hypotheses to be made and then provide visual backup of any results and statistical testing that is done on the hypotheses. Much can be learned about a problem or situation simply by viewing the variable(s) over space. Simple choropleth, or graduated color, maps of Census 2000 demographic characteristics by block group compared to Census 1990 demographic characteristics can be an important initial analysis tool, for example, for understanding how population characteristics of a particular area have changed (see Chapter 2, Method 7). It is easy for the human eye to pick up differences in spatial patterns when they are displayed on a map. This method is a good way of demonstrating how environmental justice status can change over time. Transportation networks and infrastructure may remain relatively unchanged through time, while settlement patterns of various demographic groups may change considerably.

Slightly more complex maps can be developed that combine different types or dimensions of information into a single visual display. The environmental justice index (EJI) described in Chapter 2 is an example. For the Atlanta Benefits and Burdens project (Cambridge Systematics 2002), information from the Census Transportation Planning Package (CTPP) journey-to-work data were extracted, formatted for use in GIS, and processed to find the most common journey-to-work flows in the study area. The largest flows were displayed on maps as lines with graduated line widths to represent the magnitude of commuter flows. In addition to the line maps, a pie chart was displayed on the origin district of each major flow depicting the distribution of mode split for the journey to work. These maps thus communicate three important dimensions of travel patterns—origin/destination, volume, and means of travel—in a single visual display.

Buffer analysis. A buffer is an area of specified width that surrounds one or more map features. Buffer analysis is used when examining areas affected by activities or events that take place at or near these map features (Caliper Corp. 1996). It is most often used in environmental justice assessment as a screening tool to determine if effects actually would exist in the predicted impact area before proceeding with a more in-depth analysis. To perform buffer analysis, it is necessary to know the specific width (i.e., distance) from a map feature within which an effect may occur. Most GIS software packages include an analysis tool dedicated to creating buffers. Performing the analysis simply involves selecting the map feature to be buffered and then selecting the buffer tool. GIS packages include dialogue boxes designed to guide users through the buffering process. The program will ask for a specified distance at which to buffer the map feature or features. Many software packages offer different options for buffering, such as creating buffers of different specified sizes, creating evenly spaced buffers, or creating buffers of variable sizes using a database field as a reference.

Carrying out a buffer analysis typically involves four steps:

1. Select the map feature(s) to be buffered. Map features may include specific locations (i.e., points), road network segments (i.e., lines), or established areas and districts (i.e., polygons).
2. Determine the distance(s) necessary to buffer the selected map feature. This distance should reflect the expected spatial extent of the social or economic effect under consideration (e.g., the area within a quarter-mile of bus stops, as an indication of transit service availability).
3. Using a GIS buffer tool, create the buffer and overlay it on appropriate demographic or economic data, generally displayed at the census-block level.
4. Observe the resultant map and determine whether potential social or economic issues exist. If potential issues are observed, then proceed further with a more in-depth analysis.

When evaluating a transportation project, it is often important to be able to summarize what will be impacted within a certain distance of the project. For example, as part of the Boston area's Silverline project, the Metropolitan Boston Transit Authority (MBTA) project team analyzed the economic level of the residential population and the number of jobs within half-mile radius buffers around the proposed Silverline boarding points. First, the locations of the boarding points were mapped as a layer in the GIS. Then, half-mile radius buffers were constructed around each boarding point. Next, the demographic data were collected at the smallest scale possible and joined to geographic boundary layers in the GIS. Specifically, an extract of the Census of Population and Housing 1990 Summary Tape File 3A (see Appendix D) was used that included variables about poverty and household income at the block-group level and data on number of workers at the Transportation Analysis Zone (TAZ) level that was created by Boston's Central Transportation Planning Staff (CTPS). Since neither TAZ boundaries nor block group boundaries nest neatly in the circular buffer rings, a script was applied to each boundary that returned what proportion of the boundary fell within the buffers. Then, the proportions were applied to the demographic data and summed for each buffer. The results could be reported to the MBTA and FTA as approximate numbers of low-income people living or working within a half-mile of the boarding points.

Barrier analysis. Barrier analysis involves the creation of a barrier such as a road construction zone or a road that prohibits nonmotorized travel across it. The analysis estimates the change in level of access that has occurred due to the creation of the barrier. A GIS-based analysis can provide useful insights into changes in the accessibility of important destinations. To assess the relative change in access to common and important destinations on the part of protected versus other populations, four general steps can be followed:

1. Determine the general locations of households using a GIS-based geocoding function. Census-block data are the most geographically specific data available, so the coordinates of the block's centroid may be used as a proxy for the locations of households in the block. It is from these centroids that distances and travel times are computed.
2. Geocode the locations of important destinations. Locational data are readily available for businesses, agencies, and most households in the United States. Analyses related to

schools, houses of worship, shopping sites, human service agencies, and major employment centers are likely to be among the most common.

3. Compute the shortest paths between origins and destinations. The shortest path is that which minimizes the distance between two locations over a street network. The network capabilities of GIS and related software enables shortest paths to be computed from all block centroids.
4. Estimate the changes in access. The analysis can be carried out using the existing transportation system, both before and after the barrier is in place on the network. Results can be expressed in terms of units distance, time en route, or number of persons crossing a street corridor.

Overlay analysis. Overlay analysis involves the integration of several discreet data layers. Analytic operations in estimating most types of effects require two or more data layers to be joined. Overlays, or spatial joins, can integrate spatial data on concentrations of different population groups with the incidence of one or more types of effect. To perform an overlay analysis, it is necessary to have data layers already created. For example, to estimate the number of persons who would be affected by noise pollution resulting from a proposed transportation project, layers containing data on (1) population characteristics, and (2) the estimated air or noise pollution extent (represented by contours) must already exist. In most GIS packages, it is possible to choose the overlay tool and then follow the instructions in the dialogue boxes for inputting the desired layers. Generally, four steps are required:

1. Using transportation noise modeling software (such as the Minnesota Department of Transportation's MNNOISE model; see Minnesota Department of Transportation [Mn/DOT]1991), generate noise levels and point distances from the transportation project. Distances can be specified by the user with an x,y coordinate plane and standard units of measure (e.g., feet or meters), or distances can be calculated using geocoded locations.
2. Create TIN structures by triangulating the values between points using extrapolation. Equal value noise contours will be created with this process. This can be done using the TIN creation and analysis tool within the GIS software.
3. Overlay the noise contours on the street network or transportation project area and demographic data layer.
4. Use a GIS spatial analysis feature to count the number or calculate the percentage of persons within the noise contour considered likely to experience an effect.

Spatial linear models. Simple spatial econometric and regression models can be used to test for environmental justice. For example, a regression model could be developed to relate the amount of transportation benefit from a project (expressed as a change in accessibility or travel time savings) to the percentage of minority population in a census tract, TAZ, or other spatial unit of analysis. A model could be constructed to predict transportation access as a function of different demographic characteristics. The error in the model also can be examined geographically. Every linear model is expected to have error, but in a good spatial regression model, that error would be evenly distributed through space. If the error from the model results in a spatial pattern, there is likely some additional spatial variable that explains the variation in the dependent variable.

GIS is not required to construct a spatial linear model, but it can facilitate the analysis. GIS can be used to aggregate data to the scale at which the model is operating, to map the results of the model, to map the error or residuals of the model, and to group or cluster the geographic entities that behave similarly in the model. For example, a spatial linear model was built in Atlanta to examine the geographic distribution of vehicle ownership. It was found that several variables—percent black, percent low-income, and average household size—have a statistically significant explanatory relationship with the dependent variable, average vehicles per household. Results showed that with the other variables (income and average household size) held constant, as the percent of the population that is black increases, vehicles per household decreases. Similarly, as percent low-income population increases, vehicles per household decreases, holding percent black constant. Conversely, as average household size increases so too does vehicles per household. This analysis was done at the census-block-group level but could be done at any scale.

Spatial autocorrelation tests for phenomena. Spatial phenomena can be tested for spatial autocorrelation. Spatial autocorrelation means that like values are clustered geographically. Typically, if spatial autocorrelation exists, inequity also exists. For example, if transit stops are spatially autocorrelated, that means that they are clustered and that the areas where there is not a cluster of transit stops are not receiving the same level of transit service. Tests to see if positive outcomes of the transportation plan or project are spatially autocorrelated can be done in a GIS setting to help determine the proportionality in the distribution of benefits and burdens.

Spatial indices - index of dissimilarity. For comparability purposes, it is important to be able to describe patterns or distributions with numbers. The field of spatial statistics seeks to do just this. There are many simple statistics that can be calculated to describe the location, centrality, and dispersion of a spatially distributed variable. The most simple of these is probably a *population weighted centroid.* Population weighted centroids were computed to describe how the distribution of the black population in Atlanta has changed since 1980. As expected, the population weighted centroid of the black population has been moving away from the central city since 1980.

Another set of statistics is used to describe the dispersion of a variable. The *nearest neighbor statistic* can be used to calculate how clustered or spread out a population is. The numeric nearest neighbor statistic allows description of a pattern that is clustered, random, or regularly spaced. This statistic is useful when calculated for many sets of data across time so the results can show historical trends.

There also are many statistical indices that measure or compare the spatial patterns between variables. One that is very useful in environmental justice is the *index of dissimilarity.* This index is also sometimes referred to as the *segregation index.* This index measures the degree to which two spatial variables are distributed differently within a specified area. The index of dissimilarity can be used to calculate whether the spatial distribution of nonminorities and the spatial distribution of minorities are similar or dissimilar, and thus help to assess the degree to which transportation needs are being met by existing and proposed services. Data on the number of nonminorities and the number of minorities would need to be gathered at a geographic scale smaller than a county (preferably a scale that allows a significant number of entities within the county so statistical significance can be determined).

For example, if there are at least 20 TAZs in a county, the TAZ level would be an appropriate scale at which to collect data on number of nonminority populations and number of minority residential populations. This index was calculated for each county in Georgia. It was known that the percentage of population that is black in one particular county increased substantially between 1990 and 2000. However, that does not indicate that at a smaller scale, the population within the county necessarily is becoming less segregated. The index of dissimilarity compared the percentage of the black population in each block group to the percentage of the white population in each block group. The results of the analysis showed that, although a larger percentage of the county's population is black, the county is not more integrated. In fact, segregation at the block-group scale has increased since 1990.

This kind of analysis should be calculated at different scales. For example, data could be collected at the county level and the index could be calculated for the state, or data could be collected at the census-block level and calculated for the TAZ. GIS could be used to automate the calculation of indices like these at multiple scales.

The index of dissimilarity formula is applied as follows:

$$I = 100(0.5 \sum(|x-y|))$$

where

I = index of dissimilarity

x = the percentage of the county’s non-minority population in a TAZ

y = the percentage of the county’s minority population in a TAZ

Sum for all TAZs, divide by two, and multiply by 100. The index can vary from 0 to 100. An index of zero reflects a perfect similarity between the distributions of minorities and the distribution of nonminorities. Conversely, an index approaching 100 reflects a large dissimilarity between the two populations and means that within the county, the minority population is clustered (segregated) and not spread evenly across space.

Spatial disaggregation and population surfaces. GIS-based spatial disaggregation techniques can be used to disaggregate population and impact data in order to better estimate the distribution of impacts by population group. For example, a GIS raster module can be used to disaggregate zone-based population data and network-based impact data to grid cells. This allows impacts calculated for different types of spatial units to be more precisely overlaid on population data. For example, emissions from a transportation network can be assigned to the grid cells corresponding to the network, and then overlaid with population data that is assigned from census tracts to the corresponding grid cells.

This approach was demonstrated in the System for Planning and Research in Towns and Cities for Urban Sustainability (SPARTACUS) project undertaken in three European cities: Helsinki, Naples, and Bilbao (Commission of the European Communities 1998). Raster-based data disaggregation also has been applied in the Salt Lake City, Utah, metropolitan area, although impacts were not analyzed by socioeconomic group. SPARTACUS is based on an underlying “engine” that combines the integrated transportation-land use model, MEPLAN, with a GIS raster module to calculate and display 100-meter grid cell micro-scale indicators. For example, emissions and noise dispersion models were used within SPARTACUS to calculate the impacts resulting from the transportation network. In the Helsinki analysis, it was found that about 29 percent of the metropolitan population would feel disturbed by traffic noise in the peak hour under the baseline transportation scenario. This percentage does not vary significantly by population group.

While the SPARTACUS project admittedly was a large-scale modeling project with substantial data and resource requirements, it does indicate that large amounts of data can be aggregated down to a small number of indicator values. The project illustrates approaches for quantifying the equity and social justice implications of alternative scenarios. While MEPLAN, in particular, may require some data that may not be readily available in all U.S. urban areas, the GIS-based analysis of emission and noise exposure can be applied independently of the land use model (see Chapter 3, Method 3).

RESOURCES

1) Environmental System Research Institute (ESRI). 1999. *GIS for Everyone.* Redlands, CA: ESRI Press.

   This book is a basic beginner's guide to GIS. It includes detailed GIS data, a full working version of GIS software, and tutorial exercises. No previous experience with GIS is necessary, but experience with computers is very helpful in understanding the tutorials.

2) Mitchell, Andy. 1999. *The ESRI Guide to GIS Analysis, Volume 1: Geographic Patterns and Relationships.* Redlands, CA: Environmental System Research Institute (ESRI) Press.

   This book offers a review of basic GIS concepts and provides an easy-to-understand guide to GIS analyses. Many real-world examples are used to illustrate the GIS analyses presented. This is not an introductory text; it assumes some prior knowledge of GIS concepts.

3) DeMers, Michael. 1996. *Fundamentals of Geographic Information Systems.* New York, NY: John Wiley and Sons.

   This book is a comprehensive text that presents information on GIS without excessive detail. It covers all basic GIS concepts and most advanced concepts. This text may be too advanced for persons with no GIS background.

Internet sites

4) http://www.gis.com/jumpstation/

   GIS.com is ESRI's Web site providing beginner-level discussion of GIS. The jump-station is a searchable index that provides links to other GIS Web sites including federal, state, and local government agencies; commercial; noncommercial; and universities.

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APPENDIX D – THE DECENNIAL CENSUS AS A SOURCE OF DATA FOR THE ANALYSIS OF ENVIRONMENTAL JUSTICE

A recent NCHRP research project includes a detailed discussion of census data products and their usefulness as a source of data for the analysis of environmental justice (Cambridge Systematices, Inc. 2002). The contents of this appendix was borrowed from that research project.

INTRODUCTION

The Census of Population and Housing (decennial census) is one of the most important sources of demographic and socioeconomic data to support an analysis of environmental justice.[1] Once a decade, during the first week in April, personnel from the Census Bureau count all the housing units and people across the United States. The information collected from the census is disseminated in a variety of ways depending on purpose, geographic unit of reporting, the questionnaire used to collect the information (short form or long form), avoidance of individual disclosure, and end-user requirements.

Because of the scope of the census, the wide area of coverage, and large sample size, the decennial census is a very important source of demographic data that can advantageously be used to identify emerging transportation planning concerns, especially those related to environmental justice. This appendix addresses products of the year 2000 decennial census and their application to the analysis of environmental justice.

The appendix is divided into three sections. To use the information collected from the census, the user needs to understand basic census concepts. Accordingly, the first section defines data collection approaches, units of geography, data concepts, availability, and mapping issues. The section is designed to provide an introductory tour of the census, along with notes on how and what data to use for analysis of environmental justice. The second section provides detailed information on some key Census Bureau reporting products. The final section then provides an introductory exploration of data sources other than the decennial census that can provide supplemental information.

CENSUS CONCEPTS

This section provides an overview of census concepts relative to environmental justice analysis. To use the information from the census effectively, the user needs to determine the following:

1) Are the data (or package) based on data from the short form or the long form?
2) What is the geographic detail at which the data are reported?

[1] The information contained in this appendix is based on material contained on various Census Bureau Web sites.

3) When will the data be available?
4) How can these data be supplemented with other sources of data?

Short form versus long form data

Five out of six people across the country receive the census short form. This form contains basic information on individuals and housing. For example, the 2000 short form included only seven subjects: name, sex, age, relationship, ethnic origin, race, and housing tenure (whether home is owned or rented). One out of six people (17 percent of households) receive the census long form. This questionnaire includes 52 questions covering topics such as educational level, income, ancestry, housing conditions, commuting patterns, disability, veteran status, and employment.

In general, if the desire is to look for complete counts of all people or housing units at the block level, the smallest unit of census geography, releases that are packaged from the short form should be used. Examples where information from the short form may be needed include neighborhood-planning analysis to find relative distributions of minority population groups or to find relative population distributions in a rural location. Important releases that use short form data include the Census Bureau redistricting file (PL-94-171 file) and the Summary Files 1, 2, and 4 (SF 1, SF 2, and SF 4).

At a somewhat higher geographic level (block groups and census tracts), information from the long form can be used. For example, if the desire is to investigate specific travel-related issues or ascertain telephone availability by race to conduct a telephone survey, only the Census Bureau released long form data can be used. The important packages containing long form data include Summary File 3 (SF 3) and the Census Transportation Planning Package (CTPP).

Geographic detail

The Census Bureau uses a hierarchy of “geography” to report data. Key geography delineations include (in the increasing order of size) census blocks, census block groups, census tracts, traffic analysis zones (comparable in size to block groups in urban areas and tracts in rural areas), voting districts, places, counties, states, and the nation.

Census blocks are the smallest area of census geography, normally bounded by streets or other prominent features. They may be as small as a city block bounded by four streets or as large as 100 square miles in rural areas. Blocks are basic units and building blocks of the Census Bureau geographic hierarchy. Blocks are used to report only selected population counts obtained from the census short form.

Block groups consist of a set of census blocks identified by the same census first digit as the next higher hierarchy, the tract.

Census tracts are areas containing, on average, roughly 4,000 people. Counties and equivalent areas are subdivided into census tracts. Most of the information collected from the long form is reported at the block-group or tract level.

Traffic analysis zones (TAZs) are a new unit of geography in the 2000 census. They are included as part of the Census Transportation Planning Package. TAZs have been defined collaboratively by metropolitan planning organizations (MPOs) working with the Census Bureau through the TAZ-UP program. While TAZs have been defined for over 1,400 counties, not all areas of the country have defined TAZs as a separate unit of geography for census reporting.

Voting districts are areas such as election districts, wards, or precincts identified by states.

Places are typically cities (in urban areas) or minor civil divisions (such as townships) in rural areas.

The Census Bureau periodically releases digital files called “TIGER/Line.” The TIGER/Line files are a digital database of geographic features, such as roads, railroads, rivers, lakes, political boundaries, and census statistical boundaries covering the entire United States. For 2000, the Census Bureau released a version of TIGER/Line 2000 in early 2001 to accompany the PL-94-171 redistricting data. This file contains the final TAZ layer for all organizations that participated in the TAZ-UP program. However, this initial file did not contain zip code tabulation areas (polygon areas derived from post office zip codes) and did not include the new address ranges obtained in 2000. A second version of census 2000 TIGER/ Line files containing this updated information was released in April 2001.

Mapping and GIS overlays

TIGER/Line can be used along with the other census packages to develop complete GIS databases for every area in the United States. TIGER/Line files are easy to convert to GIS files in almost all commercially available software.

Most of the key census tables useful for an environmental justice analysis are available at the tract, block-group, and TAZ level. Each area, therefore, can be examined in a GIS environment. For example, key household information, such as income, race, presence of elderly population, vehicle ownership, and physically handicapped status, can be overlaid with travel-related information (such as travel time) to analyze the benefits and impacts to minority tracts or block groups.

If an agency has other sources of information, new data layers can easily be brought into the GIS environment, and overlaid on top of the census information. For example, transit availability can be mapped over area characteristics obtained from the census and, by using several thematic maps, a visual inspection of population groups benefiting from transit can be obtained. More complex analyses, such as creating buffers and examining corridor characteristics can also be performed with standard GIS software packages. A significant advantage of using census data is that they allow for precise spatial analysis at small levels of geographic detail.

Mapping specific area characteristics can be used as a powerful visual communication tool to convey planning concepts to neighborhood advisory committees, a key requirement for environmental justice.

Data availability

When will data be available? The Census Bureau processes short form data first and then the long form data. Packages containing the short form data are released first, followed by the long form data. Table D-1, shows the relative dates of release, along with the lowest level of geography for key packages containing the short and the long form data. Table D-5, located at the end of this appendix, provides a detailed listing of all standard census products.

Table D-1
Key census 2000 products

Short form data products (Contents = race, basic housing counts)			**Long form data products** (Contents = age, income, occupation, mobility, industry, commute, and vehicle ownership)		
Release date	**File**	**Lowest level geography**	**Release date**	**File**	**Lowest level geography**
Data available as of April 2001	Census 2000 Redistricting Data File (PL-94-171)	Blocks	Data available as of September 2002	Summary File 3 (SF 3)	Block Groups
Data available as of September 2001	Summary File 1 (SF 1)	Blocks	Data available as of Spring 2003	Census Transportation Planning Pkg.	Transportation analysis zones (TAZ)

Source: U.S. Census Bureau, Population Division, Decennial Programs Coordination Branch.

How to look for specific tables in a census package. The Census Bureau divides tables broadly into person tables and household tables. Person tables can be defined for all workers, all persons, and persons over 18 (called a "universe" in the census packages). Once the package and table type are identified, it is relatively easy to go through the data dictionaries to locate the exact table. For example, if a planner is looking for a table containing household counts by poverty status and mode used for work, the likely package would be the Census Transportation Planning Package (CTPP). The likely table would be a residence end table containing household counts.

What release to use and when? If an agency desires to do some early analysis with basic racial and ethnicity data, the redistricting file provides this capability. If basic data (one-way, two-way, or three-way tables) containing detailed income, physically handicapped status, or elderly status are the variables needed, the Summary File 3 (SF 3) or the CTPP are required. If detailed journey-to-work flow information or travel-related information by place of work are required, then the CTPP is the only choice. More detailed information on package content is provided in the following section.

In addition to the standard tabulations, the Census Bureau also allows users to make custom tables through the Internet via a portal called the American FactFinder (AFF). Using the AFF, specific tables can be defined for an area without depending on any standard package.[2]

[2] The Internet site is http://factfinder.Census.gov/

DECENNIAL CENSUS PRODUCTS

The Census Bureau disseminates information collected from the decennial census through several packages. Each package, or release, is meant for a specific purpose. For example, the redistricting file (PL-94-171) is released primarily for the purposes of election redistricting, and it is required by law that the Census Bureau should release 100 percent counts of the population within 1 year following the date of collection. In 1990, there were five packages that contained information at lower levels of geography:[3]

- PL-94-171 Redistricting data,
- Summary Tape File 1,
- Summary Sample Tape File 3,
- Subject Summary Tape Files, and
- Census Transportation Planning Package (CTPP).

PL-94-171 Redistricting data. Congress passed Public Law (PL) 94-171 in 1975, offering states the opportunity to receive population totals for election precincts and similar areas. From 1990 onwards, states have been receiving population data by race at the block level to support redistricting. The PL-94-171 file is based on a 100 percent sample (the census short form) and contains the most detailed information on the location of the total population by race and ethnic origin and on population over the age of 18 (voting population) by race and ethnic origin.[4]

The PL-94-171 file is important because it is one of the first products released after the decennial census. The data for 2000 were released by April 2001 and accompanied by software to access the data. The file contains various tabulations:

1) Six “single race” tabulations, namely African Americans, American Indian/Alaska Native, Native Hawaiian and other Pacific Islander, Asian, White, and some other race.
2) Fifty-seven combinations for those that marked “more than one” of the six race categories.

Implications of “more than one race.” Environmental justice requires “all impacted minority groups” to be identified as a first step in the analysis. A memorandum issued by the Office of Management and Budget (OMB Bulletin No. 00-02) requires that for those that marked more

[3] Summary File 2 and 4 also represent major census reporting packages. Summary File 2 (SF 2) contains 47 detailed tables focusing on age, sex, households, families, and occupied housing units for the total population. These tables are repeated for 249 detailed population groups. Summary File 4 (SF 4) contains population and housing characteristics iterated for many detailed race and Hispanic or Latino categories, American Indian and Alaska Native tribes, and ancestry groups. While SF 2 and SF 4 contain more detailed race and ancestry information, the higher-level reporting contained in SF 1 and SF 3 is expected to be sufficient for most analyses of environmental justice.

[4] Agencies can get a copy of the software and the data via the Internet or their local state data center contact. For more information on the redistricting program, visit the Census Bureau Web site at http://www.Census.gov/clo/www/redistricting.html. Instructions for transferring the redistricting data to a GIS are provided at http://www.fhwa.dot.gov/planning/census/pl2gis.htm.

than one race, if one of the categories is a minority category, then that person should be included as a minority. For people that marked more than two races, the most adversely impacted community among the three should be treated as their race. However, analyses conducted by the Census Bureau show the numbers of people that marked more than two races to be a very small proportion of the total population.

For those organizations that defined TAZs for TIGER 2000, a TAZ field is included in the redistricting file so that users can aggregate blocks into TAZ summaries. This is an improvement over the 1990 package because it allows locally developed TAZ-level information to be easily overlaid with the PL-94-171 data.

The PL-94-171 data constitute an important source of information that can be immediately used in transportation planning to support an environmental justice analysis. Although the Census Bureau provides far less data at lower geography levels (such as block groups), the PL-94-171 file contains extensive data on race and ethnicity. The data can be used to analyze the concentrations of minority population groups. Since the data are released at the block level, precise spatial disaggregation can be performed, which in turn can help with analyzing the impacts of transportation related projects on different groups.

Strengths of PL-94-171 file. There are three main strengths:

1) It is the first file released (April 1, 2001, is the legal deadline for the Census Bureau).

2) A great amount of geographic detail is retained.

3) It contains the greatest detail on race and ethnic origin.

Weaknesses of PL-94-171 file. The file does not contain information on households or other characteristics such as income, physical mobility status, and age, which are desirable in fully defining minority groups for environmental justice purposes.

Summary File 1 (Summary Tape File 1 in 1990)

The Summary File 1 (SF 1) contains data from the short form and includes population counts by age, race, sex, marital status, ethnic origin, household type, and household relationship.[5] In the 1990 file, population items were cross-tabulated by age, race, ethnic origin, or sex. Housing items included occupancy/vacancy status, tenure, units in structure, contract rent, meals included in rent, value, and number of rooms in housing unit. For 2000, the state-by-state release of SF 1 was completed by the Census Bureau between June and September 2001.

SF 1 contains the 100 percent data, which is the information compiled from the questions asked of all people and about every housing unit. Population items reported include sex, age, race,

[5] The FHWA portal on census issues contains information on SF 1 data. Procedures to convert the data to a GIS and to aggregate the block data to traffic analysis zones are also provided. For further information see http://www.fhwa.dot.gov/planning/Census/sf1.htm.

ethnicity, household relationship, and group quarters. Housing items include occupancy status, vacancy status, and tenure (owner occupied or renter occupied).

There are 171 population tables (identified with a "P") and 56 housing tables (identified with an "H") available at the geographic detail of census blocks. In addition there are 59 population tables with detailed race and ethnic origin available at the geographic detail of census tracts (identified with a "PCT") for a total of 286 data tables. For major race and Hispanic or Latino groups, there are 14 population tables and 4 housing tables shown down to the block level and 4 population tables shown down to the census-tract level.

Strengths of SF 1. The three primary strengths are as follows:

1) The data are released between June and September 2001, a year earlier than long-form data.
2) The data contain at least basic information on housing units as opposed to the PL-94-171 file.
3) The data are available at the block level.

Weaknesses of SF 1. Important information for environmental justice such as income, physically handicapped status, and commute characteristics (essentially long-form characteristics) are not available.

Sample Summary File 3 (Summary Tape File 3 in 1990)

The Summary File 3 (SF 3) contains long-form sample data weighted to represent the total population. In addition, the file contains 100 percent counts and unweighted sample counts for total persons and total housing units. Most of the tabulations in the 1990 STF3 were two-way tables. For example, some of the race tabulations in the 1990 STF3 included the following:

- **Table P86.** Age of householder (7 categories) by household income in 1989 (9 categories) – Universe: Households.
- **Table P87A.** Race of householder (1 category) by age of householder (7 categories) by household income in 1989(9 categories) – Universe: White households.
- **Table P87B.** Race of householder (1 category) by age of householder (7 categories) by household income in 1989(9 categories) – Universe: Black households.
- **Table P87C.** Race of householder (1 category) by age of householder (7 categories) by household income in 1989(9 categories) – Universe: American Indian, Eskimo, or Aleut households.
- **Table P87D.** Race of householder (1 category) by age of householder (7 categories) by household income in 1989(9 categories) – Universe: Asian and Pacific Islander household.

- **Table P87E.** Race of householder (1 category) by age of householder (7 categories) by household income in 1989(9 categories) – Universe: Other race households.
- **Table P88.** Age of householder (7 categories) by household income in 1989 (9 categories) – Universe: Households with householder of ethnic origin.

Population items covered by the 1990 STF3 relevant to environmental justice analysis include age, mobility limitation status, ancestry, occupation, citizenship, place of birth, class of worker, place of work, educational attainment, poverty status, ethnic origin, sex, household type and relations, travel time to work, income in 1989, urban and rural population, industry, veteran/military status, language spoken at home, work disability status, marital status, work status in 1989, means of transportation to work, and workers in the family in 1989.

Relevant housing items in the 1990 STF3 include age of householder, race of householder, ethnic origin of householder, telephone availability, vehicles available, selected monthly owner costs, condominium status, tenure, units in structure, housing units, value of housing unit, mortgage status, occupancy status, and rent.

A draft of the SF 3 specifications for 2000 are available at the Census Bureau State Data Center (SDC) Web site (http://www.sdcbidc.iupui.edu/Census_2000/census_2000.html). SF 3 is expected to be released from June to September of 2002. The residence information for the Census Transportation Planning Package is being released in 2004. This package contains most of the important long form information useful for transportation planning applications.

Strengths of SF 3. There are three main strengths:

1) The SF 3 contains additional information to support an analysis of environmental justice.
2) Cross tabulations such as race and income can help in developing more complete definitions of environmental justice populations.
3) In association with SF 1, the SF 3 package can be used to effectively support all types of microarea analysis.

Weaknesses of SF 3. The three principal weaknesses are as follows:

1) The data are released 2 years after collection.
2) The lowest level of geographic detail is at the block group. This is inherently true of all packages derived from the sample, or long-form, questionnaire.
3) The SF 3 contains few three-way tabulations.

Subject summary tape files

Additional subject summary tabulations (SSTF*)* were provided by the Census Bureau in 1990. For the 2000 Census, the user will be allowed to make custom tables by using the American Fact Finder portal. The 1990 tabulations of interest include the following:

- The foreign-born population in the United States (SSTF01);

- Persons of ethnic origin in the United States (SSTF03);
- Characteristics of adults with work disabilities, mobility limitations, or self-care limitations (SSTF04);
- The Asian and Pacific Islander population in the United States (SSTF05);
- Education in the United States (SSTF06) and employment status, work experience, and veteran status (SSTF12);
- Metropolitan housing characteristics (SSTF07);
- Housing of the elderly (SSTF08);
- Housing characteristics of new units (SSTF09);
- Mobile homes (SSTF10);
- Employment status, work experience, and veteran status (SSTF12);
- Characteristics of American Indians by tribe and language (SSTF13);
- Occupation by industry: 1990 (SSTF14);
- Geographic mobility in the United States (SSTF15);
- Poverty areas in the United States (SSTF17);
- The older population of the United States (SSTF19);
- Journey to work (SSTF20);
- Characteristics of the black population (SSTF21); and
- Earnings by occupation and education (SSTF22).

Census Transportation Planning Package

The CTPP is a set of special tabulations derived from the decennial census designed specifically for transportation planning. CTPP contains tabulations by place of residence (Part 1), by place of work (Part 2), and for flows between home and work (Part 3). The level of aggregation used is the TAZ for those counties that have a TAZ layer defined in TIGER/Line. For other metropolitan areas, the lowest level of geography is the tract or block group, depending on the choice of the local MPO. The CTPP is part of the third tier of data products released by the Census Bureau.

The 1990 CTPP contained several tabulations useful for an environmental justice analysis. Tables D-2 and D-3 are extracts from the data dictionary of the 1990 CTPP.

The CTPP 2000 standard tabulations contain roughly 30 tables useful for an environmental justice analysis. A significant addition is the introduction of a flow table in Part 3 consisting of minority population flows by origin and destination. Another important feature of the CTPP is that it contains tabulations both by work and home end. Moreover, the tabulations at the work end are “mirrored” by tabulations at the home end. “Mirrored” tables enable CTPP users to estimate the flow of workers from their place of residence to their place of work by household and worker characteristics. With techniques such as the Fratar method (a method for applying growth factors to traffic within origin-destination tables) or iterative proportional fitting (IPF), users can estimate worker flow tables that will not be included in the CTPP 2000 standard tabulations.

Table D-2
Residence end (Part 1)

Table	Tabulation
1-5	Universe: Persons; Ethnic Origin (3 categories) by Race (4 categories)
1-9	Mobility limitation status (3 categories) by age (11 categories) Universe: Persons 16 years and over
1-10	Mobility limitation status (3 categories) by employment status (6 categories) Universe: Persons 16 years and over
1-24	Ethnic origin (3 categories) by race (4 categories) by means of transportation to work (11 categories). Universe: Workers 16 years and over
1-44	Mobility limitation status (3 categories) by means of transportation to work (11 categories) Universe: Workers 16 years and over

Table D-3.
Work end (Part 2)

Table	Tabulation
2-1	Ethnic origin (3 categories) by race (4 categories) by means of transportation to work (11 categories) Universe: Workers 16 years and over

The CTPP, combined with SF 3 and SF 1, is a powerful tool to develop significant data capabilities needed for an environmental justice analysis. Worker flows between residence and workplace and the workers' household characteristics and travel behavior are reported in the 10 tables in this group and provide information on household income, vehicle availability, and mode of travel to work. The CTPP also contains many tables (at both the residence and the work end) with poverty, elderly, and disability status; and race and ethnic origin combined with income. In addition, there are many three-way tables specifically designed with the analysis of environmental justice as an objective. A few small four-way tables also are included.

The cross-tabulations of race by income, race by occupation, and race by industry are very powerful tools to derive indices and develop estimates of most significantly impacted population groups. These cross-tabulations, in turn, can assist in classifying households based on characteristics such as poverty tracts or delineating areas needing transit access. For example, geographic areas dependent on transit can be defined using a table in CTPP with household counts of the following four cross-tabulated characteristics:

- Poverty status (income less than 100 percent, between 100 and 150 percent, or greater than 150 percent of poverty threshold);[6]
- Race (white, black, other);
- Ethnic origin; and
- Mode (single-occupancy vehicle, carpool, transit, etc.).

Strengths of the CTPP. There are five primary strengths:

1) Tabulations at the work end are provided.
2) Minority status population group worker flows are tabulated by origin and destination.
3) Along with SF 1 and SF 3, CTPP completes the information that can be derived from the census standard products.
4) The new CTPP design specifically considers environmental justice analysis requirements.
5) The CTPP can be used for tract-level, place-level, county-level, or even for statewide analyses.

Weakness of the CTPP. The most important weakness is the following:

1) The tabulations contain fewer categories (e.g., race is divided into only four categories for Parts 1 and 2). This was done to increase the number of cross-tabulated variables. The package needs to be used in conjunction with SF 1 and SF 3 to draw the maximum benefits. For the Part 3 origin and destination flow reporting, all minority population groups are combined into a single category because of the potentially small sample sizes associated with many of the individual cells.

Other sources of demographic data

Although the decennial census is the most important source of information for reliable data on race, ethnicity, income, age, and physically handicapped status, it only provides a snapshot in time. To obtain data on a noncensus year, it is necessary to rely on a combination of estimation techniques based on the use of census data and information from other survey and data sources. This subsection provides an introduction to five potential supplementary data sources:

- American Community Survey,
- American Housing Survey,
- Current Population Survey,
- Nationwide Personal Transportation Survey, and

[6] A listing of poverty tracts is contained at the Census Bureau Web site, http://www.census.gov/hhes/www/poverty.html

- Other commercial sources.

American Community Survey

The American Community Survey (ACS) is a continuous survey performed by the Census Bureau. The ACS data constitute a paradigm shift from a "snapshot" approach to one of continuous collection across time.[7] When implemented fully, it will provide information on demographic, economic, and housing profiles of America's communities every year. The ACS has the same questionnaire content as the decennial long form and is expected to replace the long form in 2010. Between 1999 and 2001, the ACS was conducted in 31 sites to compare ACS results with those from the census 2000 long form. Full implementation of the ACS is planned to begin in 2003 for every county in the country and will achieve the same one-in-six sample size as the census long form.

Table D-4 lists data availability for different areas. The ACS data from the test sites are available as of the middle of July 2001. The earliest data from the fully implemented ACS are expected to be available in 2004 for areas having a population greater than 65,000.

Table D-4
Availability of American Community Survey data

Area characteristics	Expected release date of ACS data	What will be released
Population greater than or equal to 65,000	2004	Yearly data
Population between 20,000 and 65,000	2006	Three-year average
Population below 20,000 (e.g., census tracts or block groups)	2008	Five-year average

The Bureau of Transportation Statistics (BTS) has produced a report entitled *Implications of Continuous Measurement for the Uses of Census Data in Transportation Planning* (BTS 1996).[8] This report presents the findings of an expert panel on the utility of data obtained from continuous measurement for transportation planning. The report found that a change from the traditional long form to continuous measurement can significantly affect how state and metropolitan transportation planners use decennial census data. The continuous measurement process, however, is a new process, and the results need to be compared and evaluated against those from the conventional census.

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[7] Additional information on the American Community Survey is available at the Census Bureau Web site, http://www.Census.gov/acs/www.

[8] A copy of this report and a discussion on the American Community Survey from a transportation perspective can be accessed at http://www.trbcensus.com/acs/.

American Housing Survey

The American Housing Survey (AHS) collects data on the nation's housing.[9] The AHS consists of a national sample of 55,000 households, collected every year. The AHS also samples 47 selected metropolitan areas once every 4 years. The sample size for each area is 4,800 households. Though the AHS is primarily designed to collect data on the nation's housing stock, the survey also contains several questions relating to race, income, household size, vehicle ownership, and journey to work. The survey is conducted by the Census Bureau for the U.S. Department of Housing and Urban Development (HUD). The AHS returns to the same housing units each time to gather data. While the sample size for the AHS is relatively small, the data can be used to develop inter-censal estimates at a county level. Moreover, data from two or three surveys can be combined and weighted with population estimates to obtain estimates at a tract level.

Current Population Survey

The Current Population Survey (CPS) is a joint venture of the Census Bureau and the Bureau of Labor Statistics (BLS). The survey has been conducted for more than 50 years. The sample size for the survey is expected to increase to 99,000 households nationwide in the near future.[10] The sample is scientifically selected to represent the civilian noninstitutional population.

Respondents are interviewed to obtain information about the employment status of each member of the household 15 years of age and older. Published data, however, focus on those ages 16 and over. Although the CPS is designed primarily to collect up-to-date information for states, it can be used in conjunction with other census-related products to develop estimates at lower level geographies.

Estimates obtained from the CPS include employment, unemployment, earnings, hours of work, and other indicators. These are available by a variety of demographic characteristics including age, sex, race, marital status, and educational attainment. They also are available by occupation, industry, and class of worker. Supplemental questions often are added to the regular CPS questionnaire to produce estimates on a variety of topics including school enrollment, income, previous work experience, health, employee benefits, and work schedules.

Because the sample size for both the CPS and AHS are very small, the data from these surveys need to be combined and weighted with the decennial census data to obtain estimates of various characteristics not collected in the decennial census. Several methods can be used to weight the census data. Methods commonly used to iterate the data include IPF and Bayesian techniques.

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[9] The Census Bureau Web site provides comprehensive information on the American Housing Survey at http://www.Census.gov/hhes/www/ahs.html.

[10] More information on the Current Population Survey is available at http://www.bls.Census.gov/cps/cpsmain.htm.

Nationwide Personal Transportation Survey

The Nationwide Personal Transportation Survey (NPTS), now renamed as the National Household Transportation Survey (NHTS), provides a periodic snapshot of daily travel from a sample of 25,000 U.S. households. The data provided by the NHTS cover all trips made by all household members, by all modes and trip purposes, in a single travel day. First collected in 1969, subsequent rounds of data were collected in 1977, 1983, 1990, and 1995. A new round of NHTS data collection became available in 2003.

The survey includes questions similar to those in the decennial census about the respondent's "usual" journey to work. This permits comparison of how people interpret the question about their "usual" mode to work with how they actually travel to work on a specific survey day. A few organizations and states purchase add-on samples of the NHTS to use in place of a local household travel survey for regional travel forecasting purposes. Because the NHTS contains information on nonwork modes, the data can be weighted with the CTPP data and used to analyze all types of travel characteristics of all special population groups. A summary of relevant census products and approximate release dates are presented in Table D-5.

Other commercial sources

Data from the decennial census provides information for a specific day once every 10 years. More current data, however, are often desirable for an environmental justice analysis. Several other Census Bureau surveys and other federal government surveys can be combined to produce updated estimates at small areas of geography, as indicated in the previous subsections. The ACS is expected to be particularly helpful in this regard when it becomes fully operational. In addition, Claritas Corporation continuously updates the census data at the block-group level and releases an updated dataset every year.

Table D-5.
Timeline for standard census products

Release date	100-percent data products	Lowest level	Media
March 2001	**Census 2000 Redistricting Data Summary File** State population counts for race and Hispanic or Latino	Census blocks	Internet CD-ROM DVD
May-June 2001	**Demographic Profile** Selected population and housing characteristics in a single table.	Places	Internet CD-ROM/DVD Paper
May 2001	**Census 2000 housing unit counts**	Places	Internet
May-June 2001	**Congressional District Demographic Profile** Same as the demographic profile but for Congressional districts	Congressional districts of the 106th Congress	Internet CD-ROM/DVD Paper
June 2001	**Race and Hispanic or Latino Summary File**	Places	Internet (FTP) CD-ROM

Table D-5.
Timeline for standard census products (continued)

Release date	100-percent data products	Lowest level	Media
States: June-Sept. 2001 *Advanced national:* Nov.-Dec. 2001 *Final national:* May-June 2002	**Summary File 1 (SF 1)** – Population counts for 63 race categories and Hispanic or Latino – Population counts for many detailed race and Hispanic or Latino categories and American Indian and Alaska Native tribes – Selected population and housing characteristics	Census blocks Census tracts Census blocks/ census tracts	Internet CD-ROM DVD
States: Sept.-Dec. 2001 *Advanced national:* Mar.-Apr. 2002 *Final national:* June-July 2002	**Summary File 2 (SF 2)** Population and housing characteristics iterated for many detailed race and Hispanic or Latino categories and American Indian and Alaska Native tribes	Census tracts	Internet CD-ROM DVD
States: Mar.-Dec. 2001 *National:* Nov. 2001-Apr. 2002	**Quick Tables** Table shells with population and housing characteristics where the user can specify a geographic area and a population group	Census tracts	Internet CD-ROM/DVD
States: Mar. 2001-Jan. 2002 *National:* Nov. 2001-Aug. 2002	**Geographic Comparison Tables** Population and housing characteristics for a list of geographic areas (e.g., all counties in a state)	Places	Internet CD-ROM/DVD
Apr. 2002	**Advanced Query Function** – User specifies contents of tabulations from full microdata file – Includes safeguards against disclosure of identifying information about individuals and housing units	User defined down to census block groups	Internet
Jan.-Nov. 2002	**Summary Population and Housing Characteristics (PHC-1)**	Places	Internet Paper
2003	**Population and Housing Unit Totals (PHC-3)**	Places	Internet Paper
Mar.-May 2002	**Demographic Profile** Demographic, social, economic, and housing characteristics presented in three separate tables	Places	Internet CD-ROM/DVD Paper
Mar.-May 2002	**Congressional District Demographic Profile** Demographic, social, economic, and housing characteristics presented in three separate tables for Congressional districts only	Congressional districts of the 106^{th} Congress	Internet CD-ROM/DVD Paper

Table D-5.
Timeline for standard census products (continued)

Release date	100-percent data products	Lowest level	Media
June-Sept. 2002	**Summary File 3 (SF 3)** – Population counts for ancestry groups – Selected population and housing characteristics	Census tracts Block groups/ Census tracts	Internet CD-ROM DVD
Oct. 2002-Feb. 2003	**Summary File 4 (SF 4)** Population and housing characteristics iterated for many detailed race and Hispanic or Latino categories, American Indian and Alaska Native tribes, and ancestry groups	Census tracts	Internet CD-ROM DVD
June 2002-Feb. 2003	**Quick Tables** Table shells with population and housing characteristics where the user can specify a geographic area and a population group	Census tracts	Internet CD-ROM/DVD
July 2002-Mar.2003	**Geographic Comparison Tables** Population and housing characteristics for a list of geographic areas (e.g., all counties in a state)	Places	Internet CD-ROM/DVD
For 1-percent sample: 2002	**Public Use Microdata Sample (PUMS) file** – 1-percent sample (information for the nation and states, as well as substate areas where appropriate) – 5-percent sample (information for state and substate areas)	Super public use microdata areas (PUMAs) of 4,000,000+ PUMAs of 1,000,000+	CD-ROM DVD
Oct. 2002	**Advanced Query Function** – User specifies contents of tabulations from full microdata file – Includes safeguards against disclosure of identifying information about individuals and housing units	User defined down to census tracts	Internet
2003	**Summary Social, Economic, and Housing Characteristics (PHC-2)**	Places	Internet Paper
2003	**Congressional District Data Summary File** 100-percent and sample data for the redistricted 108th Congress	Census tracts within Congressional districts	Internet CD-ROM DVD

Source: U.S. Census. Population Division, Decennial Programs Coordination Branch, July 13, 2001.

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GLOSSARY

Accessibility	Accessibility measures the relative ease with which one can reach desired destinations. See mobility.
Activity space	Geographic space within which a population tends to circulate.
Affected population	Population that would experience the beneficial and adverse effects of a transportation system change.
Air quality index (AQI)	An index for reporting daily air quality. It focuses on health effects due to breathing polluted air and includes five major pollutants: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide.
American Association of State Highway Transportation Officials (AASHTO)	AASHTO is a nonprofit, nonpartisan association representing highway and transportation departments in the 50 states, the District of Columbia, and Puerto Rico.
American Society for Testing Methods (ASTM) International	Founded in 1898, ASTM International is a not-for-profit organization that provides a global forum for development and publication of voluntary consensus standards for materials, products, systems, and services.
ALOHA model	Areal Location of Hazardous Atmospheres (ALOHA) model.
Artist's sketches	A method of presenting alternative proposals for a transportation facility whereby respondents can react to renderings of aesthetic features.
Average annual daily traffic (AADT)	The average number of vehicles passing a point on a roadway per day based on an annual average of daily traffic rates. Actual daily traffic rates may vary somewhat from the AADT because of seasonal variations, special events, and other phenomena.
Barrier effect	The reduction in mobility and safety of nonmotorized travel caused by the construction of new transportation projects such as those that increase traffic volumes and speeds on existing roads.

Benefit-cost analysis	An analysis that compares the potential benefits of a project with the estimated costs of the project. If the potential benefits outweigh the expected costs, the analysis suggests that the project will benefit society in general.
Bicycle Compatibility Index (BCI)	A composite level-of-service measure for bicycle condition evaluation. Standard BCI values represent abilities and preferences of average adult cyclists.
Bicycle Safety Index (BSI)	An index that enables one to estimate the safety of bicyclists riding on a roadway that has certain characteristics. These characteristics include traffic levels, speed limit, and a series of physical attributes.
Categorical exclusion (CE)	A component of the NEPA process. A CE can result from a determination that a project would have no significant environmental impacts and therefore that an expedited permitting process can be followed. See environmental assessment and environmental impact assessment.
Census Transportation Planning Package (CTPP)	A data package available from the U.S. Census Bureau for most major metropolitan areas that contains demographic data and self-reported journey-to-work travel times. The data are available by jurisdiction within the metro area.
Charrette	A meeting to resolve a problem or issue. Within a specified time limit, participants work together intensely to reach a resolution. The sponsoring agency usually sets the goals and time limit and announces them in advance.
Chi-square test	A statistical test that can be used to determine if a particular type of impact would be experienced differently by protected populations.
Community cohesion	The amount and quality of social networking among members of a community.
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)	The federal law otherwise known as "Superfund" under which hazardous waste remediation is conducted.
Computer-aided design and drafting (CADD) software	Computer graphics software that is commonly used to make architectural and engineering drawings and for making technical illustrations of any kind. It also

	enables you to revise drawings quickly and with minimal effort.
Consolidated Federal Regulations (CFR)	A compilation of proposed, new, and amended federal regulations that have been published in the Federal Register.
Cost-effectiveness analysis	Several alternatives are compared to determine which would achieve the desired outcome at the lowest cost.
Council on Environmental Quality (CEQ)	Coordinates federal environmental efforts and works closely with agencies in the development of environmental policies and initiatives. The CEQ has oversight of the federal compliance with Executive Order 12898 and NEPA.
Descriptive statistics	The branch of statistics concerned with (1) summarizing the distribution of a single variable or (2) measuring the relationship between two or more variables.
Distributive effects	Measurable adverse and beneficial outcomes of a transportation plan, program, or project that do not affect all people within an area equally.
Distributive effects analysis	An analysis that compares potential effects, positive and negative, of publicly funded projects or services on various population groups and (in some instances) on individuals or subgroups within groups.
Double-counting	Counting a particular effect twice, either explicitly or implicitly. For example, adding transportation cost savings to the economic effects brought about by these savings may result in an overestimation of the economic effect of a project.
Economic development	The process of expanding economic activity in an area to provide more jobs and income to that area's residents.
Emergency Response and Notification System (ERNS)	The primary national database used to report and track hazardous material spills.
Emissions factor (EMFAC)	The relationship between the amount of pollution produced and the amount of raw material processed.
Environmental assessment (EA)	A component of the process mandated by the National Environmental Policy Act of 1970, as amended. An

	EA is a concise public document that includes a brief discussion of the rationale behind the proposed project, alternatives to the proposed action, the probable environmental impacts of the proposed action and its alternatives, and a listing of agencies and persons consulted. The EA must show why the impacts are not significant or how they can be mitigated to become nonsignificant.
Environmental impact statement (EIS)	Also a component of the NEPA process. An EIS is an analytic document that informs decision-makers and the public of the potential environmental effects of the proposed project, as well as those of any reasonable alternatives. It must be completed when impacts would likely be significant, and it must show how they would be mitigated.
Environmental justice	Environmental justice is concerned with a variety of public policy efforts to ensure that adverse human health or environmental effects of governmental activities do not fall disproportionately upon minority populations and low-income populations.
Environmental Justice Index (EJI)	An index describing level of environmental justice concerns based on minority population, low-income population, and population density factors.
Executive Order (EO) 12898	An executive order on environmental justice signed by President Clinton on February 11, 1994. The order obligates each federal agency to identify and address disparate effects of policies, programs, and activities on low-income populations and minority populations.
Equity	An often-elusive concept that pertains to fairness of distribution of the benefits and costs of a transportation project among population groups. There are several measures of equity but, in the end, what is equitable depends on personal, individual definitions of fairness.
Federal Highway Administration (FHWA)	The administrative unit within the U.S. Department of Transportation charged with improving and maintaining designated roadways across the nation. It also is responsible for carrying out various federal policies that apply to surface transportation.

Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)	The primary focus of FIFRA is to provide federal control of pesticide sale, distribution, and use.
Federal Transit Administration (FTA)	The FTA assists in developing improved mass transportation system for cities and communities nationwide. Through its grant programs, FTA helps plan, build, and operate transit systems with convenience, cost, and accessibility in mind.
Finite element flow (FEFLOW)	A model that provides an advanced two-dimensional and three-dimensional environment for performing complex groundwater flow, contaminant transport, and heat transport modeling.
Fixed-guideway transit	Any public transit service that uses exclusive or controlled rights-of-way or rails. This includes heavy rail, commuter rail, light rail, trolleybus, aerial tramway, inclined-plane cable car, automated guideway transit, ferryboats, and the portion of motor bus service that operates on exclusive or controlled rights-of-way and high-occupancy or toll (HOT) lanes.
Focus group	A small group discussion with professional leadership. A carefully selected group of individuals convenes to discuss and give opinions on a single topic. Participants are selected in two ways: (1)random selection is used to ensure representation of all segments of society or (2) nonrandom selection can help clarify a particular position or point of view.
Geographical information system (GIS)	A computer system capable of assembling, storing, manipulating, and displaying geographically referenced information. GIS enables spatial data files to be layered for purposes of analysis or presentation.
Global positioning system (GPS)	A worldwide radio-navigation system involving a constellation of 24 satellites and their ground stations. GPS receivers use signals from these satellites to accurately compute positions relative to the face of the earth.
GMS 4.0 (Groundwater Modeling System)	A comprehensive program with tools for every phase of a groundwater simulation, including site characterization, model development, postprocessing, calibration, and visualization.
Gravity model	A method of analysis that generally assumes the number of trip ends at a destination location to be

	proportional to the size or attractiveness of the destination and inversely proportional to a measure of separation between this location and various origin zones. Gravity models are routinely used in travel demand models to forecast how many trips will be made to each destination from a given origin.
Ground-level air quality (microscale, or hot spot)	Air quality in the lower atmosphere very near the source of emissions, such as around an intersection.
Corps of Engineers Hydraulic Engineering Center River Analysis System (HEC-RAS)	A water surface profile model for steady and unsteady one-dimensional, gradually varied flow in both natural and constructed river channels.
HEC-2	A water surface profile model for steady, gradually varied flow in natural and constructed channels.
Highway Economic Requirements Model (HERS) and HERS-ST	A computer model developed for FHWA to assist state and local governments in programming their highway resources. HERS contains routines to estimate the economic benefits of potential transportation projects.
Highway Performance Monitoring System (HPMS)	A national highway information system that includes data on the extent, condition, performance, use, and operating characteristics of highways.
Horizontal equity	Horizontal equity refers to the equitable distribution of benefits and costs *within* a group.
Incident	An event that reduces the performance level of a roadway, including crashes, vehicle breakdowns, and debris on the road. Incidents are random events, but the likelihood of their occurrence is affected by the design and condition of the roadway, as well as by the congestion level on the roadway.
Initial Isolation Zone (IIZ)	The radius of a zone around an accidental release of toxic chemicals from which all people not directly involved in emergency response are to be kept away.
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991.
Leaking underground storage tank (LUST)	Underground storage tanks (e.g., gasoline) that have uncontained leaks.

Level of service (LOS)	A concept that describes traffic conditions and associated traffic flow rates. Six levels of service are typically recognized: A (free flow) through F (stop-and-go waves). The concept of LOS also is applied to gauge the performance of nonmotorized transportation (e.g., the ability of pedestrians to cross a major urban street).
Likert scale	A composite measure that attempts to improve levels of measurement through the use of standardized response categories in survey questionnaires. Response categories may include strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree.
Major investment studies (MIS)	Federally mandated studies in which MPOs examine which alternative transportation strategy, or mix of strategies, would best solve transportation problems within particular corridors.
Metropolitan Planning Organization (MPO)	A transportation policy-making organization made up of representatives from local government and transportation authorities. They are required for any urbanized area with a population greater than 50,000. Federal funding frequently is channeled through MPOs.
Mobile Emission Assessment System for Urban and Regional Evaluation (MEASURE)	Model-based method used for developing pollution surfaces.
Mobility	The ability of people to move about and make use of various transportation modes. See accessibility.
Mode	The method of transportation by which people travel or goods are shipped.
Motor Carrier Management Information System (MCMIS)	The Federal Motor Carrier Safety Administration (FMCSA) operates and maintains the MCMIS. MCMIS contains information on the safety fitness of commercial motor carriers and hazardous material (HM) shippers subject to the Federal Motor Carrier Safety Regulations (FMCSRs) and the Hazardous Materials Regulations (HMRs).
National Ambient Air Quality Standards (NAAQS)	Directed by the 1990 Clean Air Act and created by the U.S. EPA, these standards are designed to protect human health and the public welfare. Primary

	standards protect human health; secondary standards protect public welfare.
National Environmental Policy Act of 1969 (NEPA)	A federal law enacted January 1, 1970, to ensure that federal agency decision-making takes environmental factors into consideration. State and local entities must comply with NEPA when they are involved in federal actions (e.g., using federal funding for a project).
National Personal Transportation Survey (NPTS)	A survey conducted periodically by FHWA to measure travel of American households, focusing primarily on local, repetitive travel. NPTS data are intended to provide insights on travel by trip purpose and mode, social and economic characteristics of the trip makers, changes in vehicle ownership, vehicle and fuel usage, the changing travel patterns of women and minorities, and changes in the mobility of the older driver population.
National wetlands inventory (NWI)	An inventory of wetlands maintained by the U.S. Fish and Wildlife Service. Databases are available in digital (computer readable) format and are compatible with GIS software.
Network	An integrated series of road segments that behave as a system. Thus, a change in one road segment often will affect the performance of others.
Noise abatement criteria (NAC)	Noise levels established by FHWA for a series of activity categories (i.e., land uses). If a proposed project would result in noise levels higher than the NAC, noise abatement measures must be taken.
Origin-destination (O-D) pair	The passage of traffic originating at one node on the network and traveling to another along a unique path.
Office of Solid Waste and Emergency Response (OSWER)	The office within U.S. EPA that oversees implementation of most hazardous waste regulations. In response to Executive Order 12898, OSWER has had a policy on environmental justice since 1994.
Protective action distance (PAD)	The downwind distance from a release that defines a zone in which persons should be either evacuated or sheltered-in-place.
Paratransit	The use of small buses or vans to provide transit services for transportation-disadvantaged groups, such as people with significant physical disabilities, and

	nondrivers who require medical or social services. Paratransit may also include flexible route, door-to-door transit service to the general public.
Pass-by traffic	Traffic that both originates in, and is destined for, locations outside of the local area in which it is traveling.
Pedestrian danger index	The number of pedestrian injuries and fatalities in an area of analysis divided by the area's population. This number is then divided by a number representing the overall level of pedestrian activity in the area.
Phase 1 environmental site assessment (ESA)	Initial evaluation of a transportation corridor for the existence of contaminated sites. The ESA may be undertaken as a portion of the NEPA environmental review, in preparation for property acquisition, or before construction in a right-of-way zone.
Photomontage	A photo-realism technique in which images of various alternatives are superimposed on an image of the existing environment. It allows respondents to evaluate the positive or negative effects of each project alternative in relation to the existing environment.
Price elasticity of demand	A measure of consumer response to a change in price calculated by dividing the percentage change in quantity by the percentage change in price.
Privacy	An issue in sociodemographic data, privacy generally is understood to mean that the information conveyed is not specific (i.e., disaggregate) enough for the attributes of a single household, person, or business to be revealed. To ensure the privacy of individuals, the US. Census Bureau may suppress data when only very small numbers of observations are present.
Progressive	A project or financing approach in which the cost burden is disproportionately higher for persons with larger incomes or the benefits accrue primarily to persons with lower incomes. See regressive.
Property damage only (PDO) crashes	Motor vehicle crashes in which there are no fatalities or personal injuries but property is damaged. This property may be the involved vehicle(s) or other property that is struck by a vehicle.

	property that is struck by a vehicle.
Protected population	Groups of people defined by age, disability, gender, religion, class, race, low-income, limited English proficiency, and national origin.
Qualitative analysis	An approach that involves considering qualities or attributes that do not lend themselves to quantification. It can be applied to assess people's general feelings toward alternatives by evaluating the way they respond to a series of nonmetric indicators, such as aesthetic quality.
Quality of life	A general way of expressing the presumed ultimate objective of any form of public action. There are numerous dimensions to quality of life, which are valued differently by different people. Among the normally included dimensions are safety, access to opportunity, clean air and water, and social tolerance.
Raster	A method of coding and storing a graphic image as a pattern of dots. Also known as a bitmap.
Regional air quality	Air quality in a region or large area.
Regression analysis	A statistical technique used to assess the extent to which one or more measures are related to a criterion measure. For example, household rent may be affected by a series of attributes of a property. How much each of these attributes affects rent, given the presence of the other attributes, can be assessed using regression analysis.
Regressive	A project or financing method that results in persons with lower incomes paying a larger share of their income for a project or a project whose benefits largely accrue to those with higher incomes. See progressive.
Rent theory	A concept that explains how increased access to a location tends to encourage more intensive use of land at that location.
Resource Conservation and Recovery Act (RCRA)	The primary goals of the Resource Conservation and Recovery Act (RCRA) are to protect human health and the environment from the potential hazards of waste disposal, to conserve energy and natural resources, to reduce the amount of waste generated,

	and to ensure that wastes are managed in an environmentally sound manner.
Road segment	A short portion of a roadway, often a half-mile or so in length, that is the unit of analysis in safety evaluations and in road network models.
Roadway geometry	Specific design elements of roadways, including number of lanes, lane width, median type and width, length of acceleration and deceleration lanes for on- and off-ramps, curve radii, and roadway alignment.
SARA	Superfund Amendments and Reauthorization Act of 1986.
SAVIAH	Small Area Variations in Air Quality and Health.
Scale economies	Reductions in average costs that come about through increases in the output (i.e., scale) of plants and equipment.
Sensitive noise receptor	A person or activity that is particularly vulnerable to traffic noise (e.g., hospitals, rest homes, schools, or houses of worship).
Sensitivity analysis	The process of analyzing how changes in one factor (e.g., population growth assumptions) influence a key outcome such as traffic volume. Often the factor to be varied is the basis for several scenarios. For example, one might construct several scenarios based on different population growth projections.
State Implementation Plan (SIP)	EPA-approved state plans for the establishment, regulation, and enforcement of air pollution standards.
State Transportation Investment Program (STIP)	A fiscally constrained and prioritized program of projects to which state and local transportation agencies have committed over a three-year period. A STIP is required to receive federal funding. Projects within metropolitan areas are contained in the relevant TIP and are referenced in the STIP.
Stated preference surveys	A citizen survey in which respondents are asked to state their preference for one of two attributes at a time. A series of such pair-wise comparisons are made to estimate how people's preferences are ordered.
Storm Water Management Module	EPA's storm water and wastewater management

(SWMM)	modeling package for analyzing urban drainage systems and sanitary sewers. The MIKE-SWMM application provides users with a complete, graphical, easy-to-use interface.
TEA-21	Transportation Equity Act for the 21st century, enacted in 1998.
Topographically integrated geographic encoding and referencing (TIGER) files	Digital files that contain line and polygon information representing boundaries of census tracts, block groups, and blocks, as well as the locations of streets and roads.
Toxic by inhalation (TIH)	Classes of chemicals that are toxic by inhalation or that produce TIH gases when they react with water (referred to as TIHWA).
Toxic Substances Control Act (TSCA)	The Toxic Substances Control Act (TSCA) of 1976 was enacted by Congress to give EPA the ability to track the 75,000 industrial chemicals currently produced in, or imported into, the United States.
Toxics Release Inventory (TRI)	Database of toxic releases in the U.S. compiled from the Superfund Amendments and Reauthorization Act of 1986 (SARA) Title III Section 313 reports.
Traffic analysis zone (TAZ)	Small geographic areas that represent urban areas in travel simulation models. TAZs are characterized by population, employment, and other factors and are the places where trips begin (i.e., trip producers) or end (i.e., trip attractors).
Traffic calming	A combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior, and improve conditions for nonmotorized street users. Expected consequences include safer roadways for pedestrians, bicyclists, and neighborhoods in general. Specific road design characteristics include speed bumps and traffic circles.
Traffic demand models	Models used to calculate changes in travel time between specified origins and destinations that might be the result of transportation projects, such as changes in road capacity. A limitation of these models is that they rarely take into account non-motorized transportation modes. Same as travel demand models.

Traffic noise	Any unwanted noise generated from four major sources: tire/pavement interaction, engine noise, exhaust noise, and brakes.
Traffic Noise Model (TNM)	Noise-prediction software. Developed by FHWA, TNM is the successor to STAMINA and offers clear improvements over it, including modeling for free-flow and stop-and-go traffic conditions.
TRANPLAN	A set of integrated computer programs that encompass a four-step travel demand model. It operates within a GIS environment.
Transportation Analysis and Simulation System (TRANSIMS)	An integrated system of travel forecasting models that includes a population synthesizer, activity generator, route planner, and traffic microsimulator.
TransCAD	A GIS-based computer model that stores, displays, manages, and analyzes transportation data. It has modules for routing and travel demand forecasting.
Transportation choice	The quantity and quality of transportation options available in a geographic area. Choice is an especially complex issue for those who are economically or physically challenged.
Transportation conformity	Process of coordinating the transportation planning and air quality planning processes. This conformity is achieved when the TIPs are consistent with SIPs.
Transportation demand management (TDM)	Programs designed to maximize the people-moving capability of the transportation system by increasing the number of persons in a vehicle or by influencing the time of (or need to) travel. TDM programs must rely on incentives or disincentives to make those shifts in behavior attractive.
Transportation disadvantaged	People who face significant unmet transportation needs.
Transportation Improvement Plan (TIP)	A federally mandated regional transportation improvement plan developed by a metropolitan planning organization (MPO). The TIP outlines the staged development of the area's fiscally constrained long-range transportation plan with priority projects identified.

Travel demand (TD) models	A series of mathematical equations used to represent how choices are made when people travel. Such models require a series of assumptions, and the parameters in the equations are calibrated to match existing data. The models are used to forecast future travel. Generally, these models have four steps: trip generation, trip distribution, mode split, and traffic assignment.
Travel Model Improvement Program (TMIP)	A continuing research program to help planning agencies improve their travel analysis techniques. A major product of this program has been the TRansportation ANalysis SIMulation System (TRANSIMS), a new form of travel modeling technology.
Travel time variability	Uncertainty as to the amount of time a trip will take or the time at which one will arrive. For just-in-time industries or commuters, travel time variability often is as important as average travel time.
Triangular irregular network (TIN)	A surface representation derived from irregularly spaced sample points and break-line features. Each sample point has an x,y coordinate and a surface, or z-value. These points are connected by edges to form a set of nonoverlapping triangles used to represent the surface.
Trip purpose	The reason why a trip is made. The purpose of a trip influences the mode used, the time at which the trip is made, the length of the trip, and other trip attributes. Common trip purposes include work and work-related business, shopping, and social/recreational interaction.
Underground storage tank (UST)	A storage tank designed to contain chemical compounds such as hydrocarbons that is located below ground level. USTs and above-ground storage tanks (ASTs) can be sources of toxic releases.
Universal access	Transportation facility design that accommodates people with a range of needs, including wheelchair users, people who walk with difficulty or are vulnerable to falls, people who have visual disabilities, and pedestrians who are pushing strollers or handcarts.
Urban form	The array of land uses and their densities within an urban area. Urban form is influenced by transportation

	facilities that affect the relative accessibility of different locations.
Urban Transportation Planning System (UTPS)	A system of analytic tools and methods developed by the U.S. Department of Transportation in the 1970s to facilitate the four-step travel demand modeling process. See travel demand models.
U.S. Environmental Protection Agency (U.S. EPA)	EPA's mission is to protect human health and to safeguard the natural environment—air, water, and land.
Vehicle hours traveled (VHT)	The number of hours spent on a specific road segment or within a road network by the vehicles operating on it per unit of time, generally a day. For a given volume of traffic, higher flow speed (e.g., less congestion) will lead to a reduction in VHT.
Vehicle miles traveled (VMT)	The number of miles driven by the vehicles using a specific road segment per unit of time, usually a day. VMT is equal to the traffic volume multiplied by the length of the roadway. See AADT.
Vehicle operating cost (VOC)	The variable cost to vehicle owners of operating these vehicles on roadways per mile of travel. Included in VOC are fuel and oil consumption, wear and tear, depreciation, and insurance. Flow speed, as well as road geometry and other physical attributes, can influence VOC.
Vertical equity	Equitable distribution of benefits and costs *among* groups. Groups are usually distinguished by wealth or income.
Viewshed	An area that can be viewed from a particular site or roadway. Communities may adopt ordinances to reduce the impact of man-made structures and grading on views of existing landscapes and open spaces as seen from public roads.
Virtual metropolitan model	A model that combines several visual computer models to create a comprehensive virtual model of an entire metropolitan area. Virtual metropolitan models are constructed by combining aerial photographs with street-level imagery and 3-D geometry to produce realistic simulations of large urban environments.

Visual acuity	The ability of the eyes to resolve detail.
Visual preference survey (VPS)	A form of resident survey that allows respondents to express their preferences for certain types of development rather than for specific proposals. Through a series of slides, respondents rate their attitudes regarding images, which are later analyzed to produce a consensus of resident preferences.
Volume-to-capacity (V/C) ratio	The ratio of the number of vehicles traveling on a roadway to the number that would result in a slowing of traffic to a specified speed. This level of traffic is defined as the effective capacity of the roadway. In general, congestion begins to set in at a V/C ratio of about 0.8.
Weighted decibels (dBA)	Units of sound that include an adjustment whereby high- and low-pitched sounds are given higher scores. The objective is to approximate the way humans hear sounds.
Windshield survey	An inventory of land uses and an observation of natural and human environments collected visually, generally by driving through a corridor in which changes are proposed.
Wire-frame model	A type of visual computer modeling commonly used for proposed transportation projects. Wire-frame models are derived from a continuous series of roadway cross sections that are linked together to form a 3-D model of the proposed roadway design.

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation