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Environmental Justice and
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PREFACE

During the past four decades, massive investments have been made in transportation facilities, enabling great progress to be made in the efficient movement of people and goods. As time has passed, however, it has become increasingly clear that not everyone has benefited from these transportation facilities. In fact, some populations, often low-income or minority, have been made worse off by the construction and operation of these facilities. Noise or air pollution levels in their neighborhoods may have increased, for example.

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. In the realm of transportation, environmental justice means that transportation system changes such as road improvements are studied carefully to determine the nature, extent, and incidence of probable impacts, both favorable and adverse.

The objective of this project has been to develop a series of practical indicators of economic, social, and environmental impacts related to transportation system changes. Comparing the spatial incidence of these impacts with the locations of low-income populations and minority populations, it is possible to assess whether the impacts would adversely and disproportionately affect these populations. Our intent is to help make it possible for everyone who is likely to be affected by a particular transportation system change to understand the expected types and magnitudes of anticipated impacts. The objective of such an understanding is to enable those who would be affected to determine which impacts would be most important to them.

Some impacts, particularly those pertaining to air pollution and noise, require computer-based quantitative modeling. To address these types of impacts, we obtained state-of-the-practice models from several government agencies and integrated them with a geographic information system (GIS). We were thus able to examine the spatial nature of relevant impacts. To field test our resulting spatial analysis methods, we used the U.S. Highway 63 corridor in Waterloo, Iowa, as a trial application. Because Waterloo is comparatively diverse in terms of race and income, it is an excellent site for applying methods related to environmental justice.

Research for this project was carried out at the University of Iowa Public Policy Center. Funding was provided by the U.S. Department of Transportation, University Transportation Centers Program, with supplemental funding contributed by the Iowa and Minnesota Departments of Transportation.

The research team has benefited greatly from its collaboration with a 16-person technical advisory committee. Members of this committee helped focus the issues to be addressed and shared their insights throughout the research process.

ACKNOWLEDGMENTS

In the preface, we mention financial support of our research by the U.S. Department of Transportation, University Transportation Centers Program; the Iowa Department of Transportation; and the Minnesota Department of Transportation. These agencies have our gratitude for their support.

Members of the technical advisory committee, listed on the next page, contributed greatly. Attendance at all the meetings was nearly 100 percent, and the enthusiasm, support, and commitment we saw was both helpful and inspiring.

Our special thanks go to Sharon Juon, Executive Director of Iowa Northland Regional Council of Governments (INRCOG) in Waterloo. Her interest in the project enabled us to use the U.S. Highway 63 corridor in our trial application of the methods of analysis developed in this study. Kevin Blanshan and Jennifer Kragt, also of INRCOG, provided us with extremely helpful insights about the city. They also provided us with extensive data.

Professor Gerard Rushton of the University of Iowa Department of Geography was a major resource. As one of the nation's most respected scholars in the area of geographic information systems (GIS), he provided excellent technical leadership during many phases of the study.

Graduate research assistants Jayne Moraski, Li Zuo, and Marilyn Hall conducted much of the literature review and synthesis. They were marvelous resources and were very thorough and professional in their work.

Special thanks are due Jay Chakraborty who conducted much of the spatial analysis for the project and developed innovative solutions to many technical problems. His creative approach to GIS applications constitutes a blueprint for future environmental justice work.

The successful completion of this project was in no small way due to the efforts of Anita Makuluni, editor at the Public Policy Center. She ensured that the text is accessible to a wide audience, while maintaining the report's technical accuracy.

With great appreciation, we acknowledge the contributions of these people. It has been a pleasure working with them.

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CHAPTER 1

INTRODUCTION

Environmental justice represents a public policy goal of ensuring that adverse human health or environmental effects of government activities do not fall disproportionately upon minority or low-income populations. To achieve this goal, decision makers must acquire a clear understanding of how programs, policies, and various activities may affect people. It is equally important to convey sound, reliable information to all populations that would be affected by a proposed action so that everyone can participate in choices that are important to them.

The purpose of this report is to provide practical insights into how to estimate the likely impacts of government actions regarding transportation system changes. In the context of this report, “transportation system changes” refer to a range of possible actions at the project level, such as the construction of a passenger transit rail line or an urban freeway. We focus on impacts that affect human health or the living environment with the objective of facilitating the development of as clear an understanding as possible of the potential effects of transportation system changes, especially those impacts that might adversely and disproportionately affect low-income or minority (protected) populations. We seek to provide practical indicators of impacts so that all who may be affected by a transportation system change will be able to understand the likely types and magnitudes of these impacts.

Knowing the positive and negative impacts of potential changes in transportation systems enables residents of the affected area to relate these impacts to their own priorities and value premises. Those affected can then determine the acceptability of the system change and identify specific impacts that would be most valuable or troublesome to them.

It is critical that all those who would be affected by a transportation system change understand the full array of economic, social, and environmental impacts that would be likely. Failing this understanding, adverse impacts that could have been avoided or at least mitigated might produce deleterious effects on the quality of life of affected persons.

NET SOCIETAL GAINS VERSUS DISTRIBUTIONAL IMPACTS

When significant changes to transportation systems are contemplated, two general considerations emerge: (1) overall effect on society (will society be better off with the change than without it?) and (2) distributional impacts. Almost any time a major change is made to a transportation system, some members of society will gain, while others become worse off. In theory, if a change produces a net gain to society, those who become better off could fully compensate those who lose and still experience net gains. Voluntary compensation rarely happens, so distributional impacts are an

important aspect of project feasibility analyses, especially as they relate to protected populations.

Economic efficiency

The chief criterion of economic feasibility analysis when transportation investments are contemplated is economic efficiency. An economically efficient project is one in which the total forecast benefits over the life of the project exceed the total forecast costs. Benefits are mostly various types of cost savings to travelers, including reductions in time en route, accidents, and vehicle operating costs (Forkenbrock and Foster 1990, pp. 307–308). If the benefits (or cost savings) of a transportation investment exceed associated costs (construction, operation, and maintenance), society becomes better off; if the costs are greater than the benefits, society becomes poorer in the aggregate. Inefficient projects should be avoided even if they predominately benefit protected populations.

Distributional impacts

If a project is deemed technically feasible from an engineering standpoint and likely to be economically efficient, another criterion warrants consideration: will it be environmentally just? One could imagine a project whose benefits would exceed its costs but the preponderance of those benefits would accrue primarily to an area's more affluent residents, while costs would mainly fall upon low-income or minority populations.

There are two ways of looking at the balance between efficiency and equity. One perspective might be that those who gain as a result of a project could fully compensate those who lose (i.e., are made worse off), and still have something of value left, given that total benefits exceed costs.¹ Institutional mechanisms such as taxation can be set in place to accomplish this compensation. Another perspective is that society should forego efficient projects altogether if they would entail substantial disproportionate and adverse impacts to specific populations.

Perhaps the best way to think about adverse impacts to specific populations is in the context of net costs. Consider a transportation system change that would produce substantial benefits along with some costs. If, for example, 80 percent of the benefits of a project will accrue to low-income or minority populations and 51 percent of the costs will as well, these populations would on balance become better off. Considering costs (including adverse impacts) alone, instead of net costs can produce results counter to the interests of the protected populations.

Environmental justice and equity

A fundamental element of environmental justice is that adverse impacts should not fall disproportionately on low-income or minority populations. Taken a step further, two conclusions can be reached: (1) a project that will impose significant costs on

¹ In the case of an efficient public investment, the so-called "Kaldor-Hicks criterion" implies that persons who have gained by virtue of the project could fully compensate those who have in some way been harmed and still gain. See Kaldor (1939) and Hicks (1939).

minority or low-income populations may be rejected, even if compensation is offered that is equal in value to the costs borne, or (2) conditions may be imposed on the project that would minimize damaging or burdensome costs and also provide compensation (something that is of particular value) in return for costs the people affected feel they can endure.

Which conclusion is reached depends in part on the nature of benefits that would result from a project. Opposition from affected populations may be considerably diminished if (1) protected populations would stand to gain substantially (e.g., greater access to jobs), (2) the most negative impacts would be averted or substantially mitigated, or (3) full compensation would be paid to those enduring negative impacts (i.e., costs).

Inefficient projects

It is difficult to turn the argument around to justify investing in inefficient projects in pursuit of distributional equity. One problem is that society as a whole would become poorer. In essence, one must ask whether other, cost-effective means could achieve the objective of assisting a target population. There is seldom only one possible means for attaining a given social objective, and embracing an inefficient project is rarely good public policy.

FEDERAL POLICY

Environmental justice became federal policy on February 11, 1994, when President William Clinton signed Executive Order 12898 (President, Proclamation 1994), the text of which appears in Appendix A. The order identified the U.S. Environmental Protection Agency (U.S. EPA) as the agency responsible for coordinating the administration, interpretation, and enforcement of programs, activities, and policies related to environmental justice. All major federal departments and agencies were directed to establish internal directives capable of ensuring that the spirit of the order is reflected in the full range of their activities.

On June 29, 1995, the U.S. Department of Transportation (U.S. DOT) published a proposed order (U.S. DOT 1995) to address the environmental justice policy objectives laid out in Executive Order 12898. Following a period of public comment, the U.S. DOT issued its final order on April 15, 1997 (U.S. DOT 1997). The text of the order is also found in Appendix A. Consistent with the executive order, the U.S. DOT order specifically addresses environmental justice for minority (defined as black, Hispanic, Asian American, American Indian, or Alaskan Native) and low-income (median household income below Department of Health and Human Services poverty guidelines) populations.

The central objective of the order is to ensure that all federally funded transportation-related programs, policies, or activities having the potential to adversely affect human health or the environment involve a planning and programming process that explicitly considers the effects on minority populations and low-income populations. Such effects are defined to include, but not be limited to:

- Bodily impairment, infirmity, illness, or death;

- Air, noise, and water pollution and soil contamination;
- Destruction or disruption of manmade or natural resources;
- Destruction or diminution of aesthetic values;
- Destruction or disruption of community cohesion or a community's economic vitality;
- Destruction or disruption of the availability of public and private facilities and services;
- Vibration;
- Adverse employment effects;
- Displacement of persons, businesses, farms, or nonprofit organizations;
- Increased traffic congestion, isolation, exclusion, or separation of minority or low-income individuals within a given community or from the broader community; and
- Denial of, reduction in, or significant delay in the receipt of benefits of U.S. DOT programs, policies, or activities.

It is important to note that the word "environmental" is given an appropriately broad interpretation in the U.S. DOT order. The term applies not only to the physical environment (e.g., air and water quality), but also to what is often referred to as the "built environment." The built environment pertains to the setting within which people live, work, and recreate. Applying this broader interpretation, aesthetically displeasing structures or traffic congestion are examples of phenomena that are antithetical to environmental justice.

In the context of environmental justice, the U.S. DOT order focuses on adverse impacts that are (1) predominately borne by minority populations and low-income populations, or (2) more severe or greater in magnitude for minority populations and low-income populations than for others. If a disproportionately adverse impact would result, the program, policy, or activity could not be carried forward using federal funds unless it could be demonstrated that:

- Alternative approaches or further mitigation measures that would avoid or reduce the disproportionate effect are not practicable, and
- A substantial need exists for the program, policy, or activity, based on the overall public interest, and alternative approaches that would have less adverse effects on protected populations either would (1) have other adverse social, economic, environmental, or human health impacts that would be more severe or (2) involve increased costs of extraordinary magnitude.

The U.S. DOT order places emphasis on ensuring that the public, including members of minority populations and low-income populations, has access to public information concerning human health or environmental impacts. Early in the development of a program, policy, or activity, the order requires four actions:

- Identifying and evaluating environmental, public health, and interrelated social and economic effects;
- Proposing measures to avoid, minimize, and/or mitigate disproportionately high and adverse environmental and public health effects and interrelated social and economic effects. Offsetting benefits and opportunities should be provided to enhance communities, neighborhoods, and individuals whenever permitted by federal law and policy;
- Considering alternatives when they would enable disproportionately high and adverse impacts to be avoided and/or minimized; and
- Eliciting public involvement opportunities, including soliciting input from affected minority and low-income populations in considering alternatives.

In summary, the U.S. DOT order adds a requirement that supplements traditional feasibility analyses when significant changes to transportation systems are considered. When minority or low-income populations would be adversely and disproportionately affected, it must be clearly established that the project in question is both meritorious and less harmful to these protected populations than other alternatives. Appropriate members of affected protected populations must be fully consulted.

NEED FOR GOOD INFORMATION

For environmental justice to be an integral element of transportation investment analysis, all affected populations must have accurate, comprehensible information on the nature and level of impacts. While the process through which planners share information with appropriate representatives of low-income populations and minority populations is beyond the scope of this report, establishing the content of what should be shared is the central objective of the chapters to follow.

An array of potential impacts can be identified that would be likely if one or several alternative investments were made. It is vital to present these impacts effectively for at least four reasons:

- Planners generally have the best interests of the community at heart, but they and most public servants are middle-income, non-minority, male-led, white-collar people who do not necessarily have a clear grasp of the needs, concerns, and preferences of populations that are less well represented.
- Transportation changes impact affected populations in myriad ways. A multidisciplinary approach to examining impacts is highly beneficial in presenting affected populations with full information on diverse impacts ranging from travel time savings to epidemiological issues related to air pollution.²

² It is worth noting that the National Environmental Policy Act of 1969 (NEPA) directs all federal agencies to “(u)tilize a systematic, multidisciplinary approach which will insure the integrated use of the nature and social sciences and the environment design arts in planning and in decision making which may have an impact on man’s environment” (NEPA 1996, Section 102.2(A)).

- Even within the same city, different neighborhoods with comparable ethnic and economic circumstances may vary considerably in terms of their priorities and concerns. It is important to provide comprehensive, understandable information on the likely impacts of alternative transportation system changes to enable affected populations to assess what their response should be.
- Traditionally, there has often been significant asymmetry among community populations as to their levels of information on the positive and negative impacts likely to occur with alternative transportation investments. Specifically, lower-income and minority populations have not always had the same degree of access to information on probable impacts as have members of other populations.

The overarching goal of this report is to identify a series of considerations related to environmental justice in the context of changes in transportation systems. If all populations affected by the changes gain a better understanding of the issues and impacts discussed in this report, it will be more possible for informed decisions to be made.

A TRIAL APPLICATION: WATERLOO, IOWA

To develop workable approaches for estimating a variety of impacts relevant to environmental justice, a trial application was essential. We chose not to conduct a full-scale investment analysis of an actual proposed transportation system investment because many elements of such an analysis would not be germane to the objectives of our research. To keep our work focused, we applied the methods and approaches developed in this project to an existing urban arterial. For an actual investment analysis, this arterial could constitute the base case (or do-nothing alternative). By field testing our methods and approaches this way, we were able to ensure their workability and appropriateness in evaluating an actual investment scenario.

An opportune trial application was selected in consultation with the Iowa and Minnesota Departments of Transportation. Seeking an urban arterial within a Midwestern city that was as racially diverse and economically heterogeneous as possible, we selected Waterloo, Iowa. The Iowa Northland Regional Council of Governments in Waterloo was highly supportive of a trial application of a comprehensive environmental justice analysis.

Waterloo is a city in northeastern Iowa that had a population in 1990 of 66,467. Black Hawk County (the Waterloo Metropolitan Statistical Area or MSA) had a population of 123,798. Table 1–1 provides a comparison of three summary indicators of how Waterloo compares with the states of Minnesota and Iowa. The city is more racially diverse and has a lower median income than is generally the case in the metropolitan areas of the two states.³

³ Median income levels within rural areas tend to be well below those of metropolitan areas in these states.

Waterloo has experienced difficult economic times during the past two decades. Between 1980 and 1994, the Waterloo MSA lost 10,094 manufacturing jobs (43.3 percent of the employment in this sector) (Bureau of Census 1982, 1996), although its total employment during this time period remained essentially unchanged.⁴ Between 1980 and 1990, the city lost 12.5 percent of its population, and the entire MSA lost 10.3 percent.

Table 1-1. Demographic and socioeconomic comparison of Waterloo, Iowa, and Minnesota

	Percent of population		
	Minority (1990)	In poverty (1989)	Median household income (1989)
City of Waterloo	13.2	16.7	\$23,578
Waterloo MSA	7.0	13.6	\$25,960
Metropolitan Iowa*	5.7	10.7	\$29,381
Metropolitan Minnesota*	7.0	8.6	\$35,054

*Metropolitan areas of the two states include all counties that are part of metropolitan statistical areas. Figures are weighted values for all metropolitan counties.

SOURCE: Bureau of the Census (1992a, Database C90STF3A, metropolitan statistical area and place summary levels).

Running north and south through the center of Waterloo is U.S. Highway 63 (see Figure 1-1), the corridor used in our analysis. U.S. Highway 63 connects with Rochester, Minnesota, to the north, and ties into U.S. Highway 218 which leads to Interstate 380 (the route to Cedar Rapids) on the southern edge of the city. The weighted average annual daily traffic on U.S. Highway 63 in Waterloo is 12,045, according to the Iowa DOT primary road base file. North of the city center this route runs through racially mixed and low-income neighborhoods, as is shown in Chapter 2. We model air pollution and noise at a typical major intersection on this portion of U.S. Highway 63 and examine such phenomena as children crossing this route on their way to and from school. While no changes to U.S. Highway 63 are currently under consideration, this corridor is a favorable location for a trial application of certain methods and approaches developed in this report.

OVERVIEW OF THIS REPORT

In the chapters that follow, we work toward an approach to including environmental justice in analyses of potential transportation system changes. Chapter 2 begins with a discussion of the necessary scale of analysis. Later in Chapter 2 we explore the role of geographic information systems (GIS) in determining relative concentrations of minority or low-income populations and we present methods for examining changes in access for these populations.

⁴ Most of the decline in Waterloo's manufacturing jobs occurred in the mid- to late 1980s; during the early 1990s, the city's manufacturing sector has experienced moderate growth.

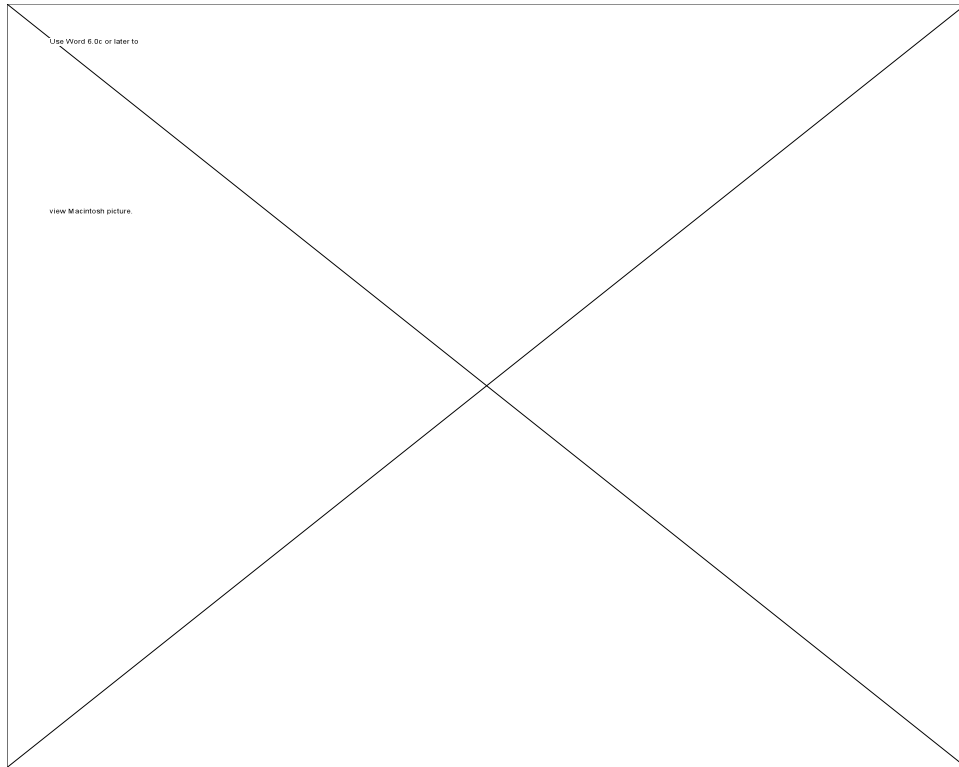


Figure 1-1. Waterloo area

SOURCE: Adapted from Iowa Department of Transportation (1996).

Chapter 3 focuses on measuring changes in air quality and noise levels at the neighborhood level. Using the GIS-based approach discussed in Chapter 2, we apply a system of models developed by the California Department of Transportation (Caltrans) to estimate air pollution concentrations. Taking into account traffic volume and mix as well as prevailing wind direction and speed, one can use these models to define contours of equal pollution levels. These contours can then be overlaid on population-based spatial data. The resulting methodology is applied at a trial intersection along U.S. Highway 63 in Waterloo.

Also in Chapter 3, we apply a noise model developed by the Federal Highway Administration and updated by the Minnesota Department of Transportation (Mn/DOT). Using traffic data for a growth scenario affecting U.S. Highway 63, we develop a noise gradient from the highway's centerline and establish a noise contour for the maximum allowable noise level. As is the case with air pollution, this contour can be compared with characteristics of affected populations.

In Chapter 4 we present a discussion of economic and social impacts relevant to environmental justice. For each of a series of specific types of impacts, we suggest indicators in the form of questions. Taken together, these indicators can provide a clear sense of whether a transportation system change would advance or worsen environmental justice. The indicators address such varied impacts as increased

brightness of overhead lighting and changes in the safety of children en route to and from school.

No single indicator should be taken as defining whether a transportation investment should or should not be made. Rather, a series of indicators are proposed as means for all concerned to understand the likely impacts of a transportation system change. Impacts that are most troublesome to affected populations can then be given priority for mitigation and can be considered by these populations when determining which of the viable alternatives is most suitable.

Finally, in Chapter 5 we summarize our findings regarding types of impacts and methods for estimating the nature and magnitude of these impacts. We also explain how the comprehensive information generated through the analyses suggested in this report can be of the greatest value. Specifically, we stress the need for effective approaches for obtaining public input.

CHAPTER 2

IDENTIFYING PROTECTED POPULATIONS

To evaluate the distributional impacts of transportation system changes on low-income populations and minority populations, referred to as protected populations, first it is necessary to identify where these populations reside and travel. By knowing the race and income composition of small geographic units of analysis, one can evaluate whether and how the impacts of a system change would disproportionately affect these populations. In this chapter we develop an approach for estimating the relative presence of these populations at the level of the census block, the smallest geographic unit for which U.S. census data are available.

SCALE OF THE ANALYSIS

The objective of most transportation investments is to reduce travel costs, and the resultant cost savings tend to accrue to a large number of users. Area-wide travel demand models enable analysts to estimate the magnitude of travel cost savings at the level of traffic analysis zones (TAZs).⁵ Because the primary interest of economic feasibility analyses is transportation system users, the TAZ is an appropriate scale of analysis for estimating travel cost savings. Other salient impacts, however, are best examined at a much smaller scale of analysis.

The neighborhood

Environmental justice is concerned with estimating the nature and magnitude of impacts on low-income populations and minority populations. To be able to discern differential impact levels for these specific populations in comparison to others requires a less aggregate spatial unit of analysis than that generally seen in economic feasibility analyses.

Ideally, the spatial unit of analysis would be small enough to be relatively homogeneous in terms of population characteristics. An informal spatial unit that is relatively homogeneous is the neighborhood, a physical space where residents interact on a frequent basis. Neighbors tend to share concerns over this space, its aesthetics, safety, and functionality.

A practical problem involves how we arrive at a uniformly acceptable definition of neighborhood boundaries. Neighborhood association boundaries are a logical starting point, but have significant limitations as definitions of neighborhoods. Residents of different associations who live close to one another may interact with each other more often than with many other members of their respective associations.

⁵ A traffic analysis zone is a defined geographic area, usually about ten to 20 times the size of a census block. It is the unit of analysis for travel demand models.

People tend to respond to their physical and social environments in rather different ways. Some people accept many others into their circle of acquaintances, while some prefer to be more private and limit their frequent interactions to only a few people. As a result, resident surveys may yield debatable boundaries. Keller (1968) determined that because of varying individual perceptions and preferences, people will draw different maps to define their neighborhood.

Most people identify adjoining households as their neighbors. A succession of neighbor relationships between households along residential blocks results in a “chaining” effect. Figure 2-1 shows how chaining prevents a rigid delineation of neighborhood boundaries. As one moves from household to household, each subsequent relationship or link in the chain pushes out the boundaries of the neighborhood, causing diffuse edges among residential areas (Mann 1970, p. 570).



Figure 2-1. Chaining effect in the definition of urban neighborhoods

One implication of this chaining effect is that a business or other activity center is often part of several neighborhoods. Figure 2-2 depicts a case in which a business acts as an edge for neighborhoods A and C, but lies near the center of neighborhood B. If this business were displaced or became inviable due to a significant change in accessibility, the impact would probably be greatest for neighborhood B, but could also be significant for the other two neighborhoods.

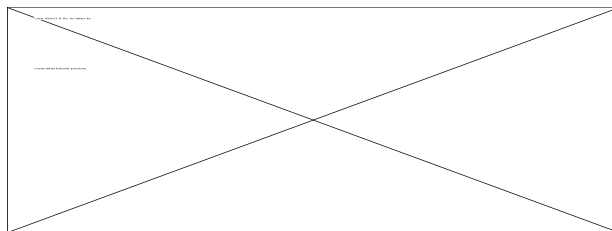


Figure 2-2. Interaction of a business with multiple neighborhoods

The census block

The most common unit of analysis within urban areas is the census tract. Tracts are defined to include approximately 3,000 people who are as similar as possible in terms of demographic and socioeconomic characteristics. To evaluate the distributional impacts of a particular transportation system change, however, a much smaller unit of analysis is desirable. People in one part of a tract may be significantly impacted, while those in another part remain substantially unaffected. Another reason smaller units of analysis are preferred is that they generally are more homogeneous.

Census block groups are the next smaller scale of analysis. Unfortunately, the U.S. Census provides far less data at the block group level than is the case with tracts. Yet

reasonably extensive data on ethnicity and income are available, along with a variety of other household characteristics. On average, block groups contain approximately 30 census blocks.

To adequately evaluate the proportionate impacts of transportation system changes on minority populations and low-income populations, a strong argument can be made for conducting the analysis at the block level, the smallest level of aggregation. In the more densely populated residential areas within many cities, a census block is the size of a city block. Because the Census Bureau must protect the privacy of individuals, only a limited number of socioeconomic variables (not including income data) are available at the block level.

Populations by race and income

Fortunately, data on race are provided at the block level. Figure 2-3 depicts the relative concentration of the minority population among census blocks in Waterloo with a large-scale section that shows census blocks along U.S. Highway 63. Data at the census block level allows spatial disaggregation that is precise enough to analyze the impacts of transportation rights-of-way on a fairly small band around a given transportation project.

When viewing maps such as those in Figure 2-3, it is important to keep in mind that population tends to be appreciably more dense near the city center than on the urban fringe. Percentages showing population characteristics by spatial unit of analysis do not reflect densities, so care must be exercised when interpreting maps such as those presented in Figure 2-3.

In many urban areas, TAZs are aggregations of census blocks. As a result, general travel patterns—trips beginning and ending in the respective TAZs—can be analyzed in the context of population characteristics. There are about 20 census blocks per TAZ in the central areas of Waterloo, however, so TAZ-based analyses involve a degree of aggregation. As a summary of the relative size of spatial units, Table 2-1 shows the total numbers of census tracts, block groups, and blocks, as well as TAZs within Black Hawk County.

Table 2-1. Number of analysis units within Black Hawk County

Unit	Number
Census tract	36
Census block group	130
Traffic analysis zone (TAZ)*	287
Census block	3,855

*TAZs are defined for the transportation study area that includes most rural areas of the county.

SOURCES: Bureau of the Census (1992b, Summary Tape Files 1B, 3A, and 3B); 1996 TAZ boundary data provided by Iowa Northland Regional Council of Governments.

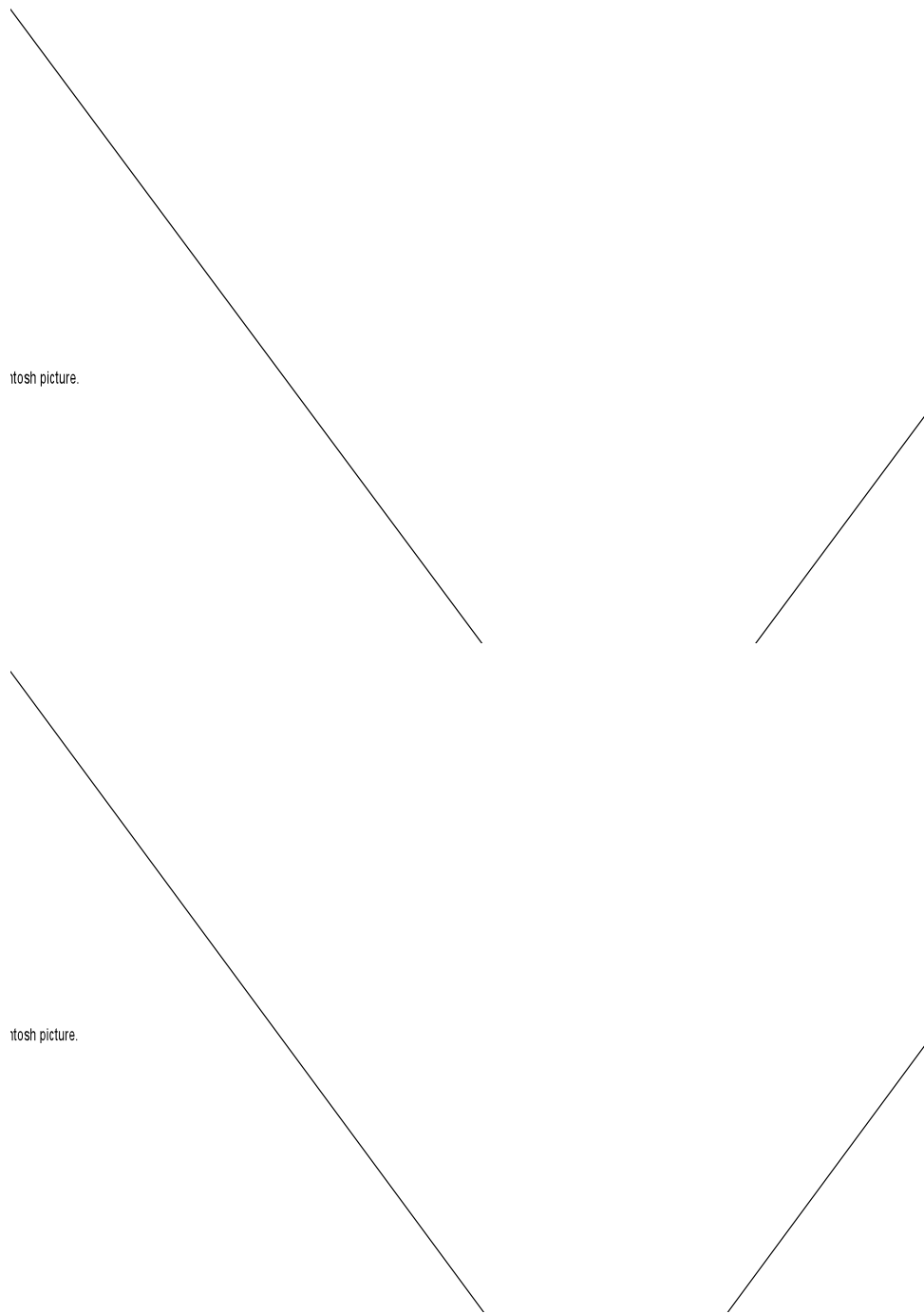


Figure 2-3. Minority population by census block in Waterloo, 1990

Estimating income levels

In its environmental justice order, the U.S. DOT defines a low-income person as one “whose median household income is below the Department of Health and Human Services poverty guidelines” (U.S. DOT 1997, p. 18380). The U.S. EPA also suggests using the poverty level to delimit low income (U.S. EPA 1996c, Section 2.1.2). Poverty data are not available at the census block level, but are available at the block group level. Good estimates at the block level of percent of persons living in households with incomes below the poverty level can be derived from block group data. Estimates in this report pertain to 1989, the year for which all income levels reported in the 1990 census are based.⁶

To estimate at the block level the percent of people living in households with incomes below the poverty level, we used several comparable socioeconomic variables available at both the census block and block group levels, and we established a statistical relationship between these variables and percent of people at the block group level living in households with income levels below the poverty level. After experimenting with alternative socioeconomic variables available at both levels of aggregation, we settled upon a regression equation for the Waterloo MSA that uses three variables at the block group level to predict the percentage of the block group residents living in households with incomes under the poverty level. The following equation was the result:

$$P = 69.8865 - 0.0002651v - 0.5318h - 0.4800e$$

(0.0000) (0.0000) (0.0001)

adj. $r^2 = 0.650$, F-level = 80.99 (0.0000), $n = 130$ block groups

values in parentheses are significance levels

where:

- P = percentage of persons in households with annual incomes below the poverty level
- v = median home value
- h = percentage of homes that are owner-occupied
- e = percentage of population over 65 years old

The equation is a useful estimation tool because it accounts for about two-thirds of the variation in low-income percentages among the Waterloo MSA’s 130 census block groups. Specifically, we can estimate the percentage of people within each census block living in households with annual incomes below the poverty level by multiplying the three coefficients by corresponding predictor variable values for each of the 3,855 census blocks in the Waterloo MSA. Figure 2–4 shows estimates of

⁶ Poverty levels vary by household size. In 1989, national poverty thresholds were as follows: \$6,310 for one person, \$8,076 for two persons, \$9,885 for three persons, \$12,674 for four persons, \$14,990 for five persons, \$16,921 for six persons, \$19,162 for seven persons, \$21,328 for eight persons, and \$25,480 for nine or more persons (Bureau of the Census 1994, Table 739).

these percentages both for much of the Waterloo MSA and a portion of the U.S. Highway 63 corridor.

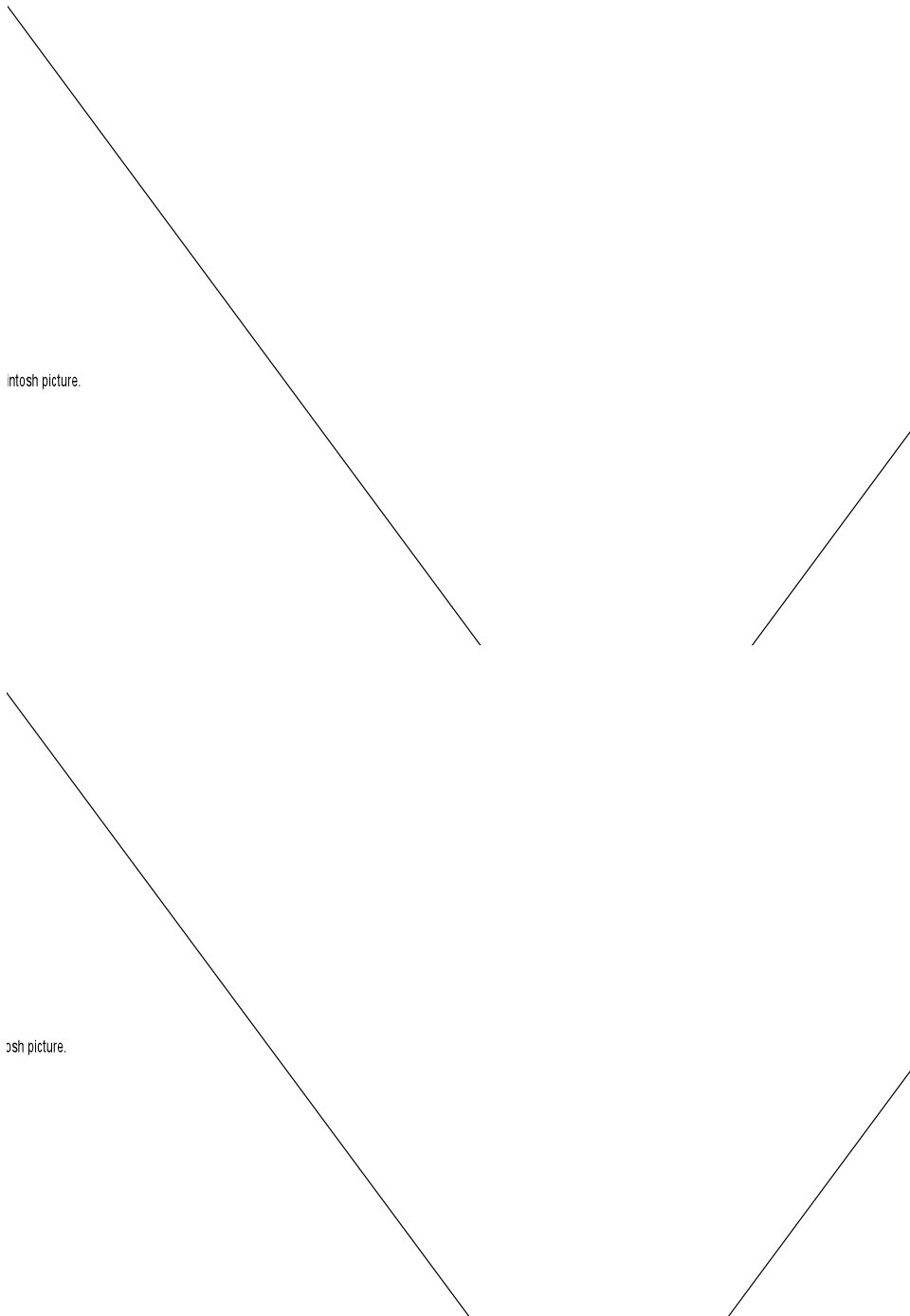


Figure 2-4. Low-income population by census block in Waterloo, 1990

We should stress that the equation we fitted for Waterloo may not be appropriate in other communities. Rather, our purpose was to demonstrate that it is possible to derive good estimates of income at the block level. We also use these estimates in the analyses reported in Chapters 3 and 4. For each community, it would be advisable to estimate an equation using block group data specific to that community.

THE ROLE OF GEOGRAPHIC INFORMATION SYSTEMS

It is possible to compare the spatial data on relative concentrations of low-income populations and minority populations discussed in the previous section with the locations of various impacts. Such comparisons enable one to determine whether the impacts fall disproportionately on areas with relatively high concentrations of protected populations; these comparisons are greatly facilitated by the use of geographic information systems (GIS).

GIS databases

The key data requirements of a GIS database for mapping the impacts of transportation systems are summarized in Table 2-2. Census TIGER/Line files (Bureau of the Census 1994) contain digital data that describe the street network for the entire U.S. and define census block group and block boundaries.⁷ TIGER files can be translated and imported as geographic files using compatible GIS software.⁸ Demographic and socioeconomic characteristics of the population from the 1990 Census of Population and Housing at block group and block levels are contained in Summary Tape Files (STFs) 3A, 3B, and 1B. These data can be linked to corresponding census boundaries from the TIGER files to build a GIS database. All of the necessary data are available for locations throughout the U.S. in CD-ROM format from the Bureau of the Census.

Table 2-2. Components of the GIS database

Information required	Data source
Street network geometry and address range information	Census TIGER/Line Files, 1994
Census block group and block boundaries	Census TIGER/Line Files, 1994
Socio-demographic data at the block group/block level of aggregation	1990 Census of Population and Housing, STF 3A and 3B for block group and STF 1B for block data

⁷ TIGER is an acronym for topographically integrated geographic encoding and referencing. See Appendix B.

⁸ Several compatible GIS software packages are available, including MapInfo, Arc/INFO, Atlas, ArcView, Maptitude, and TransCAD. We used the latter two in our analysis.

GIS analysis procedures

For environmental justice applications, two general types of GIS analysis procedures are useful:

- Comparing the contours of noise or air pollution generated by an upgraded transportation facility in an area with relative concentrations of protected populations, and
- Comparing the relative accessibility (i.e., distance, travel time, ability to use transit) of these populations to various trip destinations with and without the transportation facility upgrade.

Procedures for the first type of analysis are discussed in Chapter 3. In this section we focus on estimating relative accessibility to common trip destinations.

In simple terms, people travel to two sorts of destinations: involuntary and voluntary. Involuntary destinations are sites people are required to visit for normal activities in locations that cannot be chosen. Examples include schools, places of work, and government agencies. Voluntary destinations, on the other hand, are sites people *can* choose. Common voluntary destinations include supermarkets, health clinics, park and recreation facilities, and numerous types of commercial and retail establishments.

It is possible to estimate general changes in access to voluntary sites, but one cannot determine which site people living in a certain census block would choose if various travel constraints were removed. Many people do not select the nearest site because of brand loyalties, price differentials, or other attributes that affect individual choice. Still, travel demand models produce good estimates of overall propensity for travel to specific locations. GIS-based analysis can provide especially useful insights into changes in accessibility to important involuntary destinations. It can also enable one to estimate the number of pedestrians likely to cross a busy arterial en route to a particular destination, such as a school.

To assess relative changes in access to common involuntary destinations on the part of protected versus other populations, the following four general steps can be followed:

- 1) Geocode locations of households.** Ideally, one would have data on individual households, including presence of children and whether the household members belong to minority or low-income populations. Because block level data are the most geographically specific data available, coordinates of each block's centroid are used as proxies for actual locations of the households within the block. It is from these centroids that distances and travel times are computed.
- 2) Geocode locations of destinations.** Locational data are readily available on CD-ROM for all business, agencies, and most households in the U.S. For analyses related to environmental justice, schools and major employment centers are likely to be among the most commonly examined destinations. Regarding schools, two alternative approaches are possible to estimate

relative change in accessibility for children from low-income or minority households, compared to other households: (1) assume that most children attend the school closest to their households, or (2) obtain from each school lists of students and their household locations.

The second approach is more accurate, but the first is more expeditious and probably adequate for estimating the number and attributes of children crossing a transportation facility when traveling to or from school. An exception is in communities that have open enrollment policies or cross-district busing to achieve racial balance. In such cases, neither approach may be satisfactory, and direct observation of student journeys to school (particularly street crossings) may be advisable.

- 3) Compute shortest paths between origins and destinations.** The shortest path is that which minimizes the distance between two locations over a street network. The network analysis capabilities of GIS and related software such as TransCAD using TIGER files enable shortest paths to be computed from all address-matched population locations (block centroids or actual households when available from schools or human service agencies) to the nearest geocoded service location.
- 4) Estimate changes in access.** The analysis in 3) can be carried out using the transportation system (typically the street system), both before the system change and after it. Results can be expressed in terms of units of distance, time en route, or number of people crossing a particular street or corridor.

SUMMARY

Using a combination of census block data and estimation procedures that use census block group data, it is possible to accurately estimate the relative proportions of low-income populations and minority populations at the block level. Using spatial data and applying GIS software, one can develop easy-to-read maps of the relative locations of these populations.

Locations of these populations can be compared with contours of noise or air pollution that would be different if a significant change were made to a transportation route. Changes in accessibility to important involuntary sites—locations that cannot be chosen by individual travelers—can readily be estimated using geocoded transportation system data.

CHAPTER 3

MEASURING CHANGES IN AIR QUALITY AND NOISE LEVELS

A central objective of environmental justice is to ensure that low-income populations and minority populations not be subjected to disproportionately high and adverse exposure to such health-threatening phenomena as air pollution or noise. Federal and state standards exist for essentially all types of hazards to health, including those resulting from transportation facility construction and operation. Environmental justice efforts therefore focus on estimating where these standards might be exceeded if a particular transportation system change were to be implemented. Comparing the spatial pattern of areas where standards are exceeded with the relative concentration of minority or low-income populations enables one to evaluate environmental justice aspects of the system change under consideration.

In this chapter we present a geographic information system (GIS)-based approach to assessing whether minority or low-income populations would be disproportionately and adversely affected by vehicle-generated air pollution and noise. Applying this approach, it is possible to assess whether the system change is feasible and what sort of mitigation, if any, is called for. We summarize existing research on the health effects of vehicle-generated pollution and noise, and demonstrate the application of currently operational air pollution and noise models in conjunction with GIS software to map contours of these phenomena. Of particular interest, of course, are the contours that depict areas where standards are exceeded. Such areas can be portrayed using maps that show air pollution and noise levels, as well as relative concentrations of low-income populations and minority populations.

AIR POLLUTION

As Table 3-1 documents, motor vehicles are a significant source of air pollution. Pollution levels generally are highest near roadways (Balogh et al. 1993, p. 32; Nakai et al. 1995, p. 127), and wind and precipitation generally disperse pollutants downwind and possibly downhill from a roadway. Although dispersion varies with local weather conditions, most pollutants tend to reach background (normal) levels between 500 and 1,000 meters from the roadway (FHWA 1978, pp. 180-181).

Exposure to most forms of pollutants has much more severe consequences for persons with respiratory problems (U.S. EPA 1996b; Schwartz and Dockery 1992, pp. 602-603; Balogh et al. 1993, p. 25). To the degree that existing data permit, we note the extent to which susceptibility to respiratory problems varies among populations distinguished by race and income. We also review federal standards for the respective types of air pollution and summarize the generation rates of these pollutants by motor vehicles. Later in this section, we describe and assess the models available to predict pollution levels at specific distances from a roadway,

then demonstrate how the results of these models can be superimposed on maps that depict characteristics of the resident population.

Table 3-1. National emission estimates by source category, 1992 (percent)

Source category	Carbon monoxide (CO)	Nitrogen oxides (NO _x)	Volatile organic compounds (VOCs)	Sulfur dioxide (SO ₂)	Particulate matter (PM ₁₀)
Electric utilities	0.33	33.26	0.16	72.35	0.59
Industrial fuel combustion	0.69	13.57	1.16	12.93	0.48
Other fuel combustion	4.57	3.13	1.46	2.74	1.59
Industrial production	5.37	3.87	40.06	8.47	1.22
Storage and transport	0.06	0.01	7.98	0.02	0.12
Waste disposal	1.78	0.36	9.74	0.17	0.55
Highway vehicles	61.71	31.78	26.14	2.00	0.43*
Off-highway vehicles	15.71	12.76	9.47	1.27	0.87
Miscellaneous	9.78	1.26	3.83	0.05	94.15 [†]
Total	100.00	100.00	100.00	100.00	100.00

* Relates only to particulate matter generated by the vehicle itself (i.e., tailpipe emissions and dust from brakes and tires).

[†] Includes "fugitive dust" from all sources, some of which is road dust raised (but not generated) by vehicular traffic.

SOURCE: U.S. EPA (1994b).

Our analytic approach examines the major categories of vehicle-generated air pollution one at a time.⁹ It is important to stress that researchers have yet to determine the magnitude of synergistic health effects when exposure to multiple pollutants occurs simultaneously (Head 1995, p. 46; Cotton 1993, p. 3088). Additionally, we point out that although prevailing threshold amounts of various air pollutants matter greatly, these variations cannot be factored into the methods of analysis presented in this chapter. To be sure, a given amount of vehicle-generated air pollution becomes more critical when threshold levels are high than when the prevailing air quality is good. The several categories of air pollutants are discussed in turn.

⁹ Several important types of air pollution are mostly generated by immobile (point) sources, such as power-generating plants. We do not address them in this report. Also, we ignore lead pollution because it has ceased to be a significant form of vehicle-generated air pollution in the U.S. (Bureau of Transportation Statistics 1996, p. 120).

Particulate matter

Particulate matter (particulates) is essentially very small pieces of grit. Particulates found in the road environment range from 0.1 to 0.2 micrometers (microns) to ten times this size.¹⁰ Small and Kazimi (1995) conclude that of all measurable air pollutants, particulates very well may be the most detrimental to human health. Lave and Seskin (1977) have linked increased PM₁₀ exposures to higher mortality rates.

Different fuels release particles of varying sizes.¹¹ Table 3-2 shows the proportion of total particles resulting from each fuel type with aerodynamic diameters smaller than 0.2 µm (micrometer) and 10 µm. Because not all particulates are 10 µm or under, the cumulative proportions do not necessarily sum to 100 percent. All of the particles released by diesel engines, however, are smaller than 10 µm.

**Table 3-2. Particle size distribution
by type of fuel (cumulative percentage)**

Fuel type	Under 0.2 µm	Under 10 µm
Leaded	23	64
Unleaded with catalytic converter	87	97
Unleaded without catalytic converter	42	90
Diesel	73	100

SOURCE: Balogh et al. 1993, p. 26.

Small and large particulates disperse differently and have different health effects. Larger particulates fall to the ground quickly and, if aspirated, are easily caught in the upper respiratory system. Fine particulates (those of 2.5 µm or smaller), however, can remain suspended in the air for days or even weeks and can travel deeply into the lungs (U.S. EPA 1996b; Schwartz and Dockery 1992, pp. 602-603; Balogh et al. 1993, p. 25).

Because they interfere with breathing, particulates are more of a threat to people with respiratory problems. Two populations likely to have breathing problems are children and seniors. Seniors at greatest risk, in order of severity, are those who suffer from chronic obstructive pulmonary disease, pneumonia, and cardiovascular disease (Schwartz and Dockery 1992, pp. 601-602).

Growing children are susceptible to the health effects of particulate matter because their respiratory systems are still developing. Also, children breathe more air per

¹⁰ A micrometer, or micron, is one-millionth of a meter or one-thousandth of a millimeter. Particulate matter of under ten microns in diameter is termed PM₁₀.

¹¹ Small and Kazimi (1995, p. 8) point out that in addition to particulate matter directly emitted from motor vehicles, especially those powered by diesel engines, sulfur dioxide (SO₂) and nitrogen dioxide (NO₂) also are emitted. Both contribute to particulate formation, in addition to being irritants.

pound of body weight than do adults (U.S. EPA 1996b). Because children have comparatively higher rates of asthma, they are more susceptible to health problems due to particulates. According to the U.S. EPA, children make up 25 percent of the total population, but comprise 40 percent of all asthma cases (U.S. EPA 1996a).

We know of no evidence that vehicle-generated or mobilized particulate matter causes asthma, but particulates do irritate this condition in both children and adults. Asthma rates are negatively correlated with income, and the asthma mortality rate for African Americans is six times that of white Americans (U.S. EPA 1996b). Table 3-3 displays the number of reported asthma cases per 1,000 persons by income and age cohort. People who belong to households earning less than \$10,000 a year have a higher rate of reported cases of asthma than do those in households with higher incomes.

Table 3-3. Number of reported cases of asthma per 1,000 population by age and household income, 1994

Age cohort	Less than \$10,000	\$10,000 to \$19,000	\$20,000 to \$34,999
Under 45	84	60	55
45 to 64	81	63	51
65 to 74	47 *	42	61
75 and over	65 *	47 *	50 *

*Estimates with a relative standard error more than 30 percent because of small sample size.

SOURCE: Adams and Marano (1995, Table 59, pp. 87-90).

Carbon monoxide

When vehicles burn fuel, they emit carbon monoxide (CO). Carbon monoxide production is higher at low air-to-fuel ratios such as when an auto is started (especially in cold weather), idling, or improperly tuned (U.S. EPA 1993a, p. 1). According to Small and Kazimi (1995, p. 9), transportation contributes 66 percent of all carbon monoxide emissions.

Carbon monoxide forms carboxyhemoglobin in the lungs, reducing the flow of oxygen in the bloodstream (U.S. EPA 1995a). CO is, therefore, especially dangerous to populations who have difficulty getting adequate oxygen when they breathe. People most at risk from carbon monoxide exposure are those with heart disease, followed by those with anemia or other blood disorders and chronic lung disease. Table 3-4 shows the death rates from heart disease, by race, among men and women. African Americans have higher death rates from heart disease in every age cohort except over 85 years, in which case the rates for whites are higher. American Indian, Asian, or Hispanic people have lower death rates from heart disease than either whites or African Americans. Death rates are lower overall for women, but show the same trend with respect to race. To be completely accurate, then, death rates from heart disease are not higher for all minority groups than for whites. Age is a larger factor than race for both genders.

Table 3-4. U.S. death rates for heart disease, 1991 to 1993
(deaths per 100,000 resident population)

Age cohort	White	African American	American Indian	Asian	Hispanic
Men					
45 to 54	163	324	161	70	104
55 to 64	486	803	435	225	330
65 to 74	1,170	1,575	855	605	804
75 to 84	2,804	3,000	1,810	1,740	1,807
Over 85	7,390	6,259	3,541	5,113	4,598
Women					
45 to 54	48	153	52	21	37
55 to 64	184	425	188	93	142
65 to 74	560	980	471	293	417
75 to 84	1,784	2,220	1,080	1,080	1,210
Over 85	6,427	5,751	2,770	4,505	4,003

SOURCE: National Center for Health Statistics (1995, Table 37, pp. 126-128).

As with particulates, there is no solid evidence that carbon monoxide from transportation sources indeed causes higher rates of death for minorities than for other populations.

Nitrogen oxides and ozone

Nitrogen oxides (NO_x) are released from fuel combustion and can cause upper respiratory irritation, as well as lower resistance to pneumonia and streptococcus. NO_x exposures of greater than one part per million (ppm) can irritate airways; pulmonary effects can occur at greater than two ppm. Some asthmatics are sensitive to exposures greater than 0.6 ppm (Schlesinger 1992, pp. 424, 437).

Nitrogen oxides react with volatile organic compounds (VOCs are composed mainly of hydrocarbons emitted primarily as unburned components of petroleum) in the presence of heat and sunlight to form ozone. Because the rate of the reaction depends on the intensity of heat and sunlight, ozone formation is worse during the summertime.

Ozone has many of the same health impacts as particulates. According to the U.S. EPA (1996b), ozone can cause acute respiratory problems and temporary decreases in lung capacity of 15 to 20 percent in healthy adults. Unlike inert pollutants such as carbon monoxide, it is infeasible to model with confidence the dispersion of reactive pollutants such as ozone and nitrous oxides. We therefore do not model reactive pollutants in this report.

Vehicles have become cleaner since ground-level ozone and smog were recognized as serious problems in urban areas. The average per-vehicle emission of hydrocarbons was 17 grams per mile in 1960; by 1990, the average had fallen to roughly two grams per mile. During this same period, however, the total number of annual vehicle miles traveled increased from 600 billion to 2,000 billion (U.S. EPA 1993b, p. 3). Even though autos are cleaner, auto use is increasing (and, it is projected, will continue to increase), and the growth in vehicle miles traveled may offset the benefits of cleaner fuels, better emission control systems, and more efficient engines.

Sulfur dioxide

Sulfur oxides, primarily sulfur dioxide (SO₂), are emitted from motor vehicles powered by diesel engines, and to a lesser degree, gasoline engines. SO₂ is a serious irritant to asthmatic people; others may be annoyed by its unpleasant smell or taste (U.S. EPA 1994a, p. 10). It also contributes to particulate formation and acid rain. Under most conditions, motor vehicles account for a relatively small portion of SO₂, as Table 3-1 shows. Perhaps the most important effect of vehicle-generated SO₂ is its role in particulate formation which is generally of greatest concern to human health. Because particulate matter was addressed explicitly, we do not consider SO₂ separately.

Federal pollution standards

The regulation of air pollution continually changes as researchers discover more and more about health effects and dispersion patterns. The U.S. EPA currently is recommending new air quality rules and monitoring requirements for both particulates and ozone and will release the final particulate and ozone standards in 1997. Table 3-5 is a summary of the current and proposed federal standards for the pollutants discussed in this report. We should note that all pollutants are not measured in the same way; for some, like particulates, the U.S. EPA uses a mass measure of concentration (micrograms per cubic meter or $\mu\text{g}/\text{m}^3$), while for others, it uses a count measure such as parts per million (ppm).

Table 3-5. Federal pollution standards

Pollutant	Current standard	Statistic	Proposed standard
PM _{2.5}	—	annual mean	15 $\mu\text{g}/\text{m}^3$
	—	24-hour maximum	50 $\mu\text{g}/\text{m}^3$
PM ₁₀	50 $\mu\text{g}/\text{m}^3$	annual mean	unchanged
	150 $\mu\text{g}/\text{m}^3$	24-hour maximum	*
Carbon monoxide (CO)	9 ppm	8-hour mean	unchanged
	35 ppm	1-hour mean	unchanged
Nitrogen dioxide (NO ₂)	0.053 ppm	annual mean	unchanged
Ozone	0.12 ppm	1-hour maximum	revoke
	—	8-hour maximum	0.08 ppm

* This standard is currently in the process of being changed.

SOURCES: U.S. EPA (1996d, 1996e); *Code of Federal Regulations* (1995, Title 40, Sections 50.6-50.10).

Modeling air pollution

Available evidence strongly suggests that transportation-related pollutants have health effects and that some protected populations have higher rates of health problems that are complicated by these pollutants. The practice of correlating pollutant concentrations with the presence of at-risk populations has been common in epidemiology and public health planning for some time. Wadden et al. (1976) developed a methodology for associating the likely presence of air pollutants with the residential locations of people who are susceptible to types of health problems that are made worse by the presence of air pollution. These authors used average emission rates on highway corridors weighted by proximity of susceptible populations as a rating index for comparing a set of alternate highway alignments in northern Illinois.

In recent years, GIS computer software has brought about major improvements in our ability to evaluate the spatial patterns of air pollution emanating from motor vehicles. Medina (1994) formulated a framework for the integration of computer-aided design (CAD), GIS, transportation, and air quality models. Collins (1996) combined a pollution dispersion model with GIS to map air pollution. This approach has three main advantages for an environmental justice analysis:

- High resolution mapping,
- Ability to model many road segments, and
- Capacity to link pollutants to socio-demographic indicators.

Emissions (such as carbon monoxide) may be estimated using the federal MOBILE5 model (developed by the U.S. EPA) or California's EMFAC model. The design of MOBILE5 allows the analyst to change an array of factors such as traffic speed, percentage of cold starts, traffic mix, adjustments for inspection and maintenance programs, temperature, and the year of the analysis to account for demonstrated improvements in vehicle emission rates (U.S. EPA 1994c). Particulates, which are also treated as inert emissions, may be modeled using U.S. EPA's PART5 (see U.S. EPA 1995b) or ISC3 (for PM₁₀) and AP-42 (for PM_{2.5}).

Numerous researchers have documented the limitations of essentially all emission models. Small and Kazimi (1995, p. 11) contend that both MOBILE5 and EMFAC underestimate the emission levels of carbon monoxide in tunnel conditions.¹² One reason they suggest for this possible underestimation is that the models may underrepresent the frequency and severity of gross polluters (e.g., very poorly tuned engines). Analysts can, however, vary the overall traffic volume as well as the traffic mix in MOBILE5, suggesting that part of the problem may be with the accuracy of traffic mix data. Unlike MOBILE5 and EMFAC, AP-42 was found to overestimate the levels of fine particulates near roadways (Balogh et al. 1993,

¹² Researchers monitor pollutant levels along road segments in tunnels to control for the effects of wind.

p. 32).¹³ Despite the criticisms, these models do provide useable information on the amount of pollution generated by vehicles on a roadway.

Table 3-6 shows estimates of emission levels for three general types of vehicles in 1992. The difference in emissions between a gasoline auto and heavy-duty diesel truck illustrates how varying types of vehicular traffic on the roadway influence the total emission level for all types of pollutants.

Table 3-6. Emission factors for major vehicle classes, 1992 (average grams per mile)

Vehicle class	CO	VOC	NO _x	PM ₁₀
Gasoline auto	13.000	3.757	1.260	0.011
Light-duty diesel truck	1.607	0.362	1.492	0.122
Heavy-duty diesel truck	9.326	2.356	15.683	2.359

SOURCE: Small and Kazimi (1995, p. 13).

Emissions vary with vehicle speed as well as with vehicle type. Emissions for carbon monoxide are much higher at intersections, where vehicles spend time idling; the acceleration and deceleration phases through intersections also are more polluting than the steady speed cruising that occurs at mid-block (Matzoros and Van Vliet 1992, p. 316).

We can use emissions models to ascertain the level of pollutants from vehicles on the roadway under varying conditions. A dispersion model can then be applied to indicate how different pollutants are moved about by wind and rain. The most common type of dispersion model is Gaussian diffusion,¹⁴ which is based on the probable motion of pollutants treated as “particles” rather than as molecules.¹⁵ The dispersion of inert gases, like carbon monoxide, may be estimated using this approach. Particle dispersion is in essence an estimate of particle trajectory influenced by local weather and terrain. Most dispersion models treat roadways as “line sources” of pollutants, meaning that the level of pollutants is assumed to be constant along each segment of road.

A system of models developed by the California Department of Transportation (Caltrans), known as CALINE models, are line-source models based on Gaussian diffusion. When emission rates, meteorology and site geometry are specified, one

¹³ On the other hand, in northern states, sand used for winter traction leads to particulate matter from road dust, which is not taken into account in these models.

¹⁴ The models are Gaussian because of the assumption that the downwind concentrations of pollutants are normally distributed along the vertical and crosswind axes of a plume.

¹⁵ Molecules are subject to brownian motion (random movements that result from impact with molecules that make up the surrounding fluid or gas). Treating pollutants as particles, which are not subject to brownian motion, means that their dispersion can be expressed as a function of trajectory only.

Caltrans model, CAL3QHC(R), can predict pollutant concentrations from receptors located within 150 meters of the roadway and can model air quality near intersections (Benson 1994). CALINE models are currently used by Mn/DOT.

After discussions with noise and air modeling staff at both Mn/DOT and the Iowa DOT, we modeled an example intersection on U.S. Highway 63 using CAL3QHC (R). Figure 3-1 depicts the data and tasks necessary for mapping air pollution using these models. The names of the models and software used for our analysis are shown in brackets.¹⁶ We begin the process by collecting the data needed for the emission models, then combine emissions rates from the emission model with meteorological and traffic data to estimate pollutant dispersion. With GIS software, we show pollutant concentrations at determined distances from the road. Assuming that census block-level characteristics for race and income apply to households heterogeneously throughout the block, we can map pollutant concentrations with the likely racial and income composition of households along the road.

Contour lines are loci of points of equal noise/air pollution levels. The GIS software used in our trial application allows users to choose the elevation difference or level by which contour lines are separated and supports the creation of contour lines as both line features and area features. In other words, air/noise pollution contours can be visually displayed as lines (labeled with corresponding values) or areas (shaded in the form of a thematic map, with darker shades representing higher pollution levels).

Figures 3-2 and 3-3, respectively, show carbon monoxide (CO) and particulate (PM₁₀) pollution maps resulting from our sample analysis in Waterloo. The graphics show that concentrations of pollutants for the U.S. Highway 63 corridor in Waterloo are below federal standards. In the case of CO, the federal standard is 35 ppm per one-hour maximum concentration, but our results show a maximum concentration of only 31 ppm near the center of the intersection. The maximum estimated PM₁₀ level of 12.5 µg/m³ is well below the maximum allowable annual mean of 50 µg/m³.

Even though the example analysis shows no violation of federal standards, the maps produced for Waterloo demonstrate a methodology for linking air pollution concentrations to socio-demographic data. It is possible to show race and income data along with pollution concentration data either graphically or in tabular form to evaluate environmental justice impacts. Percent minority populations and percent low-income populations in census blocks surrounding the intersection in question are overlaid with pollution contours for carbon monoxide in Figures 3-4 and 3-5, respectively.

Another way of visualizing the pollution level of the landscape is by graphing the cross-sectional elevation at a chosen point. Using the GIS software, we can generate a surface profile drawing by defining the endpoints of the profile. The software then calculates elevations at regular intervals between these points and draws the profile in a chart window. Figure 3-6 shows two profile representations of the carbon

¹⁶ Appendix B contains a more detailed discussion of the models and data sources.

monoxide gradient along centerlines of U.S. Highway 63 and the intersecting street. Figure 3-7 depicts similar profiles for PM₁₀.

Summary

Using available pollution models of vehicle-generated emissions, along with dispersion models, it is possible to derive good estimates of air quality at specific points such as intersections. Air pollution levels with and without a transportation system change can then be compared. Each of these air quality levels can then be overlaid on spatial data pertaining to race and income level to discern whether a disproportionate impact would be experienced by protected populations.

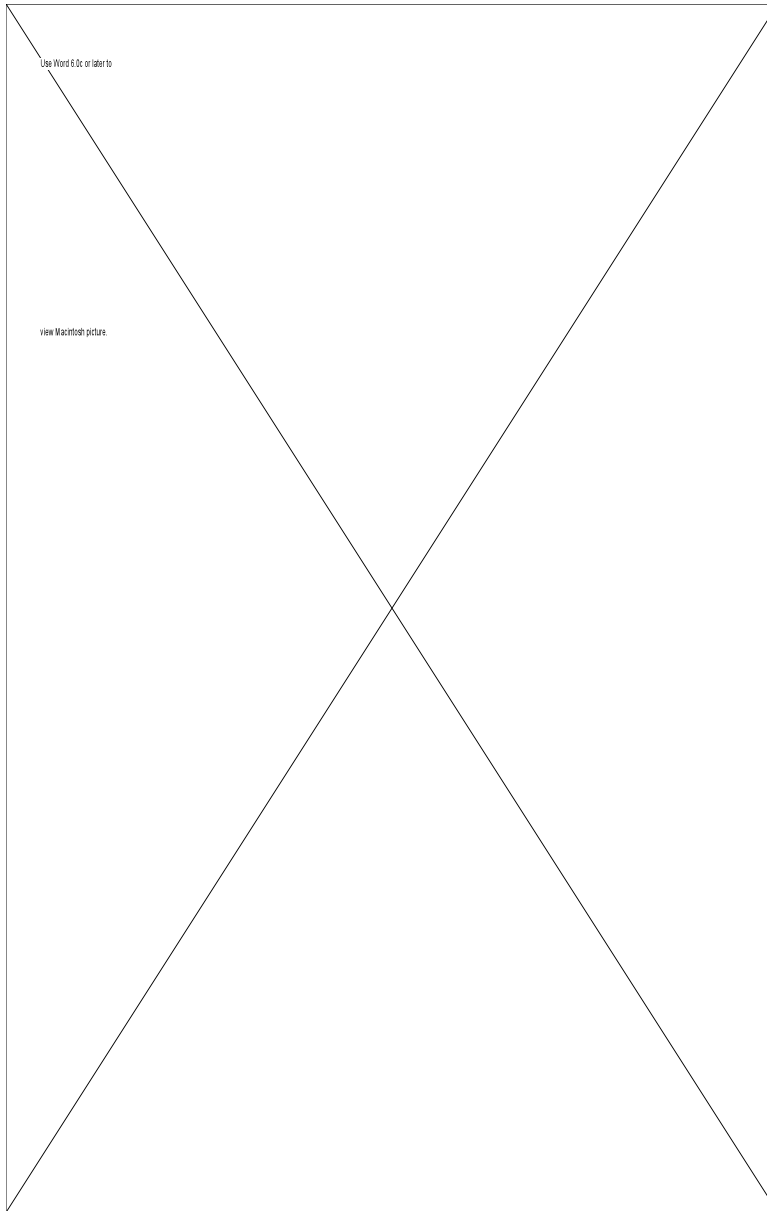
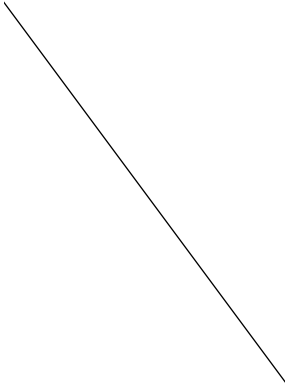
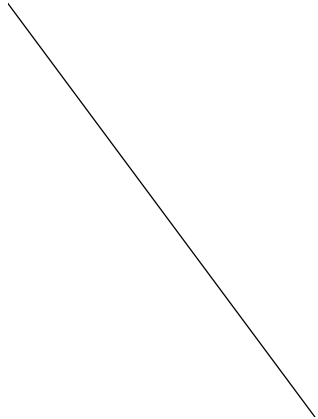


Figure 3-1. Air pollution modeling methodology



**Figure 3-2. PM₁₀ contours,
intersection along U.S. Highway 63**



**Figure 3-3. Carbon monoxide footprint,
intersection along U.S. Highway 63**

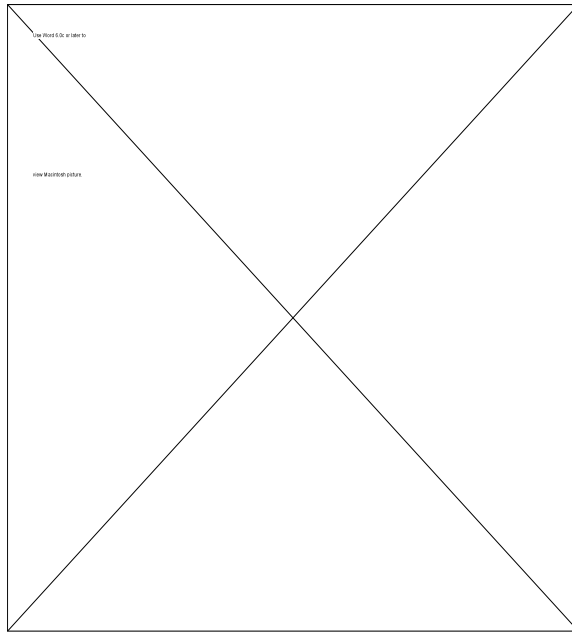


Figure 3-4. Carbon monoxide concentrations and percent minority, intersection along U.S. Highway 63

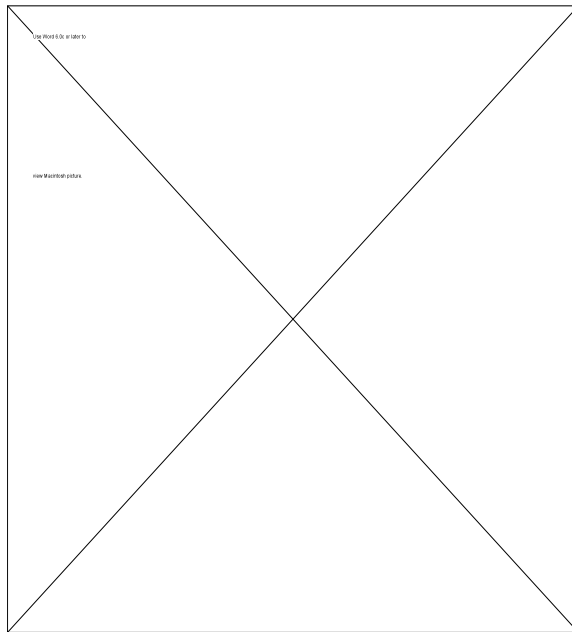


Figure 3-5. Carbon monoxide concentrations and percent low-income, intersection along U.S. Highway 63

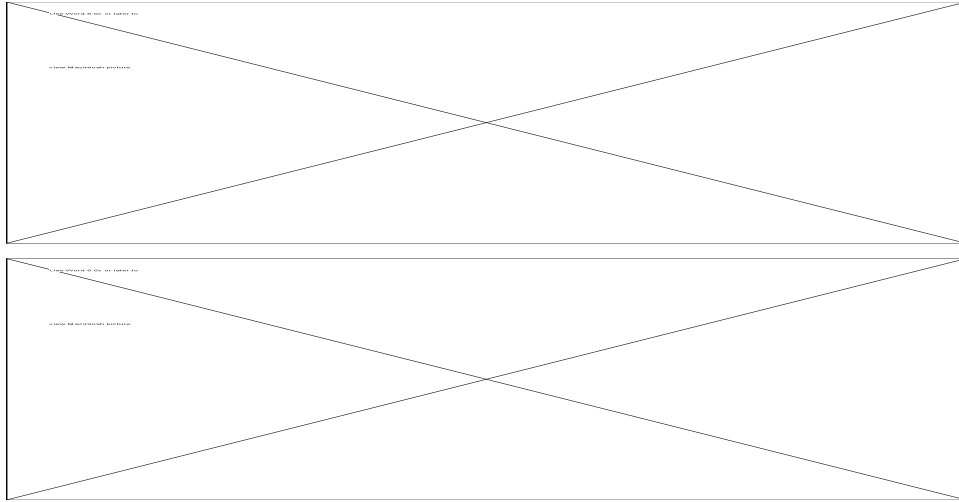


Figure 3-6. Profile of carbon monoxide gradient, intersection along U.S. Highway 63

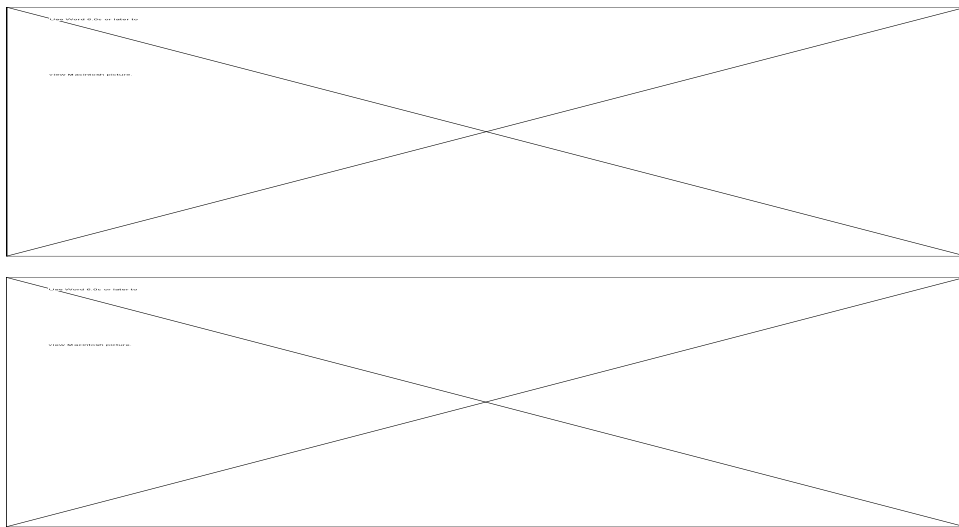


Figure 3-7. Profile of PM₁₀ gradient, intersection along U.S. Highway 63

NOISE

Noise is defined as unwanted or detrimental sound, and each area or neighborhood has an individual “noise signature,” or consistent level of background noise (Stutz 1986, p. 329). Sound is measured in units called decibels (dB). Measuring highway traffic noise involves an adjustment or weighting of high- and low-pitched sounds to approximate human hearing of these sounds. Adjusted sounds are called “A-weighted levels” (dBA).

Figure 3–8 provides a graphical representation of how the A-weighted decibel scale relates to commonly experienced noise. Zero dBA is the faintest sound humans can hear. To most people, noise that is 60 dBA (e.g., an air-conditioning unit) sounds twice as loud as noise at 50 dBA (e.g., a clothes dryer). Likewise, noise at 70 dBA (e.g., a pickup truck) is perceived to be four times as loud as noise at 50 dBA. In technical terms, the A-weighted decibel scale is logarithmic.

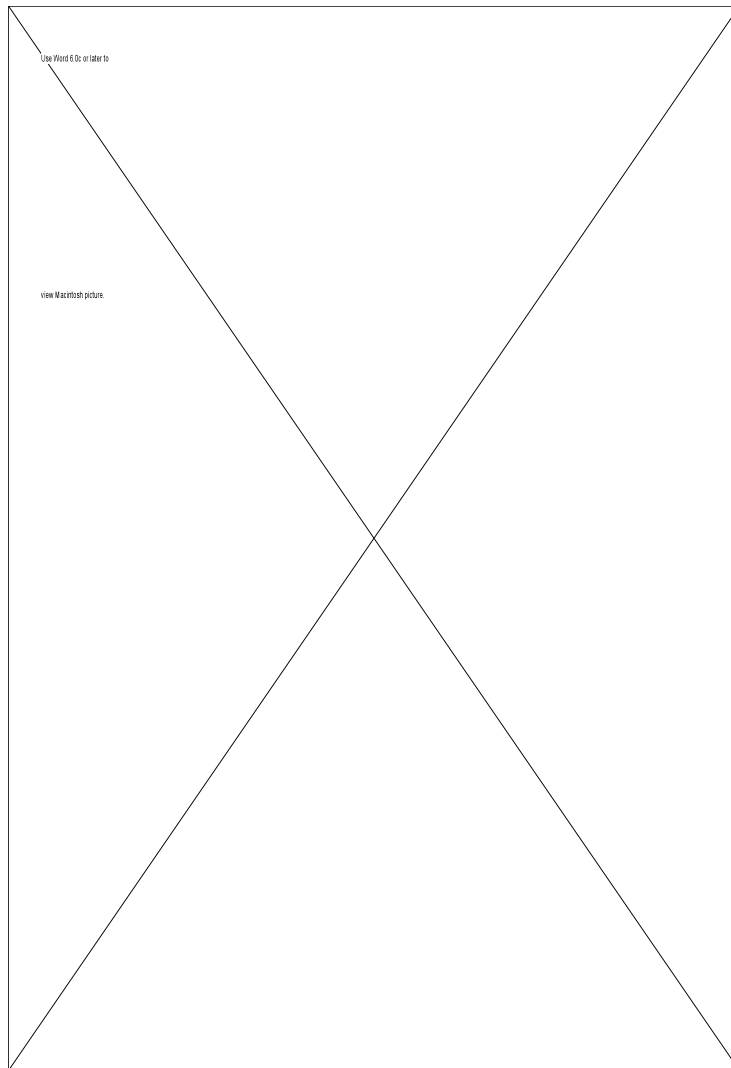


Figure 3–8. Commonly experienced noise levels

SOURCE: FHWA (1992, p. 3).

In surveys, residents have listed traffic noise as the most disruptive indoor problem caused by nearby highways (Williams and McCrae 1995, p. 80). How disruptive traffic noise is depends on the volume, speed, and composition of the traffic. As Figure 3–9 shows, traffic composition has the greatest effect: one combination truck

produces as much noise at 55 miles per hour (mph) as 28 autos. A traffic stream moving at 65 mph is twice as loud as one traveling at 30 mph. Traffic volume has less effect: 2,000 vehicles per hour sounds only twice as loud as 200 vehicles per hour. Highway noise is considered moderate to severe at 60–90 dBA, and non-annoyance levels are often considered to be 55 dBA or less.

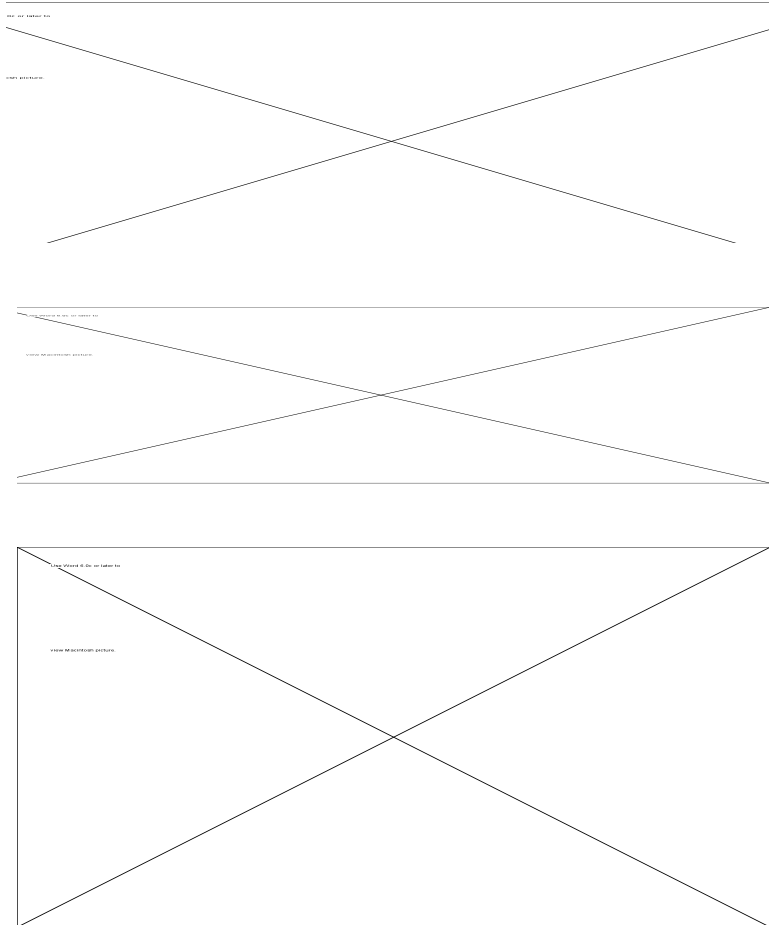


Figure 3-9. Effects of traffic volume, speed, and vehicle type on traffic noise

SOURCE: FHWA (1992, pp. 4–5).

Noise decreases at more than a linear rate with distance (Ishiyana et al. 1991, pp. 69–70). Traffic noise (dependent on traffic mix, speed, and volume) tends to dwindle away from the road until it reaches background levels at about 1,000 feet from a highway source (Hokanson et al. 1981, p. 17). Table 3-7 shows one example of the relationship between traffic volume, noise, and distance from the road. The noise levels in Table 3-7 should be considered approximations, as conditions other than distance can influence noise levels.

Second to distance, barriers (structures that, to a degree, block, deflect, and absorb noise) are likely to be the most important determinant of noise level. Because structures act as barriers, most noise impacts are absorbed by the first row of houses along a given transportation corridor (Stutz 1986, p. 333). The degree to which a building impedes traffic noise depends on the building's height relative to the height of the noise source (Ishiyana et al. 1991, p. 66).

Table 3-7. Decibel levels based on traffic volume and distance from the road (feet)

Average daily traffic	Distance (feet)	
	55 dBA	65 dBA
Up to 7,999	404	57
8,000–27,999	736	159
28,000–47,999	970	209
Greater than 48,000	1,339	289

SOURCE: Hokanson et al. (1981, p. 17).

Effects of noise

Depending on the individual person, noise can cause sleep disturbance, communication interference, and general annoyance. Communication interference occurs when nearby traffic masks normal conversation, causing people to strain in order to hear and be heard. “Annoyance” generally describes physical and psychological stress. Table 3-8 summarizes the results of increasing noise levels, including annoyance and communication interference.

Table 3-8. Effects of noise levels

Noise level (dbA)	Effect
55–64	Annoyance
65–69	Communication interference
70–79	Muscles and glands react
Above 80	Changed motor coordination

SOURCE: Bureau of Transportation Statistics (1994, p. 169).

Because people vary greatly in the degree to which they tolerate noise, an absolute change in noise level is not necessarily a predictor of annoyance. In the case of highway noise, for example, researchers have found that individual differences in noise tolerance explain more variance in comfort level than do differences in noise itself. Some individuals show high annoyance at 60 dBA, while others remain unconcerned at 80 dBA (Langdon 1985, pp. 163–167). The intensity, duration, predictability, and controllability of noise are related to the negative impacts noise has on each individual (Llewellyn 1981, pp. 192–196).

Even if noise levels are low on average, intermittent noise can be bothersome, especially for people who need to concentrate, rest, or maintain tranquillity. Schools, nursing homes, hospitals, and churches are places where intermittent noise is particularly intrusive. During an interview with the research team, the principal of Logan Middle School in Waterloo, for example, said that ambulance sirens disturb his students at least once during each class period.¹⁷

Noise levels

Noise abatement criteria are set to levels that are appropriate to the time of day and the type of activity immediately adjacent to the roadway. Table 3–9 displays noise abatement criteria established by the Minnesota Pollution Control Agency. These criteria are based on the reasoning that maximum acceptable levels of traffic noise depend largely on the type of activity close to the roadway. Although sound intensity is measured in terms of decibels, noise models use a descriptive noise exceedence scale to show the overall effects of noise over time. There are three commonly used sound intensity descriptors:

- L₁₀ the noise level in dBA exceeded ten percent of the time (e.g., six minutes per hour) during specified hours of the day. The hours typically conform to daytime, evening, and night, with standards becoming more restrictive during later times of the day.
- L₅₀ the noise level in dBA exceeded 50 percent of the time during specified hours. The standards for L₅₀ tend to be more restrictive than for L₁₀ because of the greater exposure.
- L_{eq} a composite descriptor that takes into account the variance in noise over time. It is a scale that converts a varying noise level to a constant equivalent noise level.¹⁸ L_{eq} for typical traffic conditions is about three dBA less than L₁₀ for the same conditions (FHWA 1992, p. 6).

Table 3–9. Minnesota noise abatement criteria
(maximum allowable noise levels outside buildings)

Area type	Day		Night	
	L ₅₀	L ₁₀	L ₅₀	L ₁₀
Quiet*	60	65	50	55
Recreational	65	70	65	70
Other	75	80	75	80

*Quiet areas include residential, medical, educational, religious, and cultural land uses.

SOURCE: Minnesota Department of Transportation (1991, pp. 70–71).

¹⁷ Logan Middle School is directly adjacent to U.S. Highway 63 in Waterloo; north of the school is Allen Memorial Hospital.

¹⁸ Technically, L_{eq} is the mean of the logarithmically-weighted sum of all noise levels over a period of time, measured at 5-dBA intervals (Tempest 1985, pp. 12).

Modeling noise

A number of models are available for assessing noise levels. Following discussions with Minnesota and Iowa Department of Transportation noise engineers, we selected MINNOISE to model noise levels surrounding an intersection of existing U.S. Highway 63. MINNOISE is a noise propagation model derived from the Federal Highway Administration's STAMINA model that Mn/DOT updated. MINNOISE computes L_{eq} , L_{10} , and L_{50} noise levels.

Using data on traffic volume, mix, and speed, MINNOISE can estimate noise levels at constant flow speeds. To model stop and go traffic, the roadway is broken into segments; vehicles in a given segment are designated as accelerating, cruising, or decelerating. The speed over each segment is not an average (as for air modeling), but an "equivalent" or constant speed estimated by the initial vehicle speed at the beginning of the segment and the final vehicle speed at the end of it. This method is appropriate for uncongested roads only and is not recommended for roads with a low (E or F) level of service (Mn/DOT 1991, p. 2).¹⁹

We used MINNOISE to estimate the likely severity of noise impacts from our trial scenario along U.S. Highway 63 (see Appendix B). We should stress that our trial application does not consider any mitigating effects of adjacent topography or structures. Therefore, the resultant noise impacts are likely overstated, but the approach will enable specific geographic areas to be identified that may exceed relevant federal or state noise level abatement criteria. In order to simplify the model for Waterloo, we ignored minor intersections along the cruising segments of U.S. Highway 63. To add further refinement to an evaluation of the intersection, one could add data on the position and height of barriers (primarily structures); the elevation of surrounding terrain; and traffic mix, speed, and volume of intersecting streets. These refinements would increase the accuracy of noise estimates along U.S. Highway 63.

To create an interesting hypothetical scenario for our test intersection, we added heavy truck traffic to U.S. Highway 63 to approximate the effect if a significant amount of industrial development were to occur near this route. At low traffic speeds, the majority of noise at this intersection would come from vehicle engines and brakes. The model shows that even if there were to be a substantial increase in truck traffic on the road, maximum noise levels during the day would remain below federal standards. Figure 3-10 depicts the profile of the noise gradient along U.S. Highway 63 at our test intersection. At the very center of the highway, the noise level reaches a maximum value of 64 dBA, and at 1,000 feet from the centerline, it attenuates to a little less than 55 dBA.

Because of the flexibility of the GIS, we can create maps to display maximum estimated noise levels interposed with socio-demographic data, as in Figures 3-11 and 3-12, or present the data in tables. Table 3-10 summarizes characteristics of the populations that reside within contours representing the maximum noise levels (dBA) for our hypothetical L_{10} scenario. The advantage of a table in displaying this

¹⁹ For definitions of levels of service, see Transportation Research Board (1994, p. 1-4).

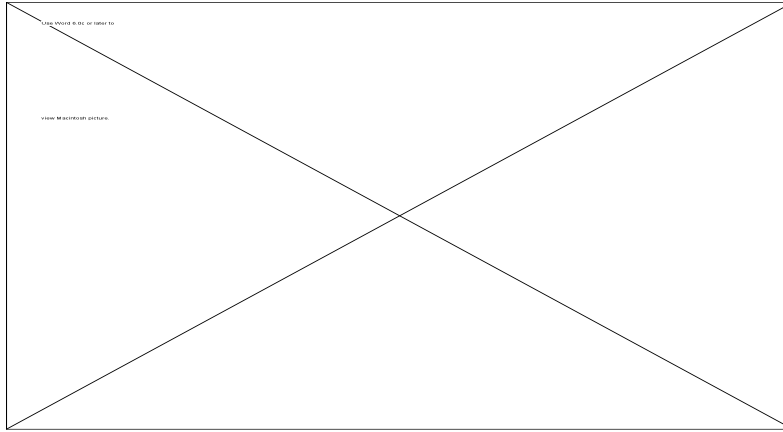


Figure 3-10. Profile of noise gradient, intersection along U.S. Highway 63

data is that one can show the number of persons residing within contours as well as their racial and income characteristics.

Summary

Similar to air pollution spatial analyses, it is possible to estimate the footprint of vehicle-generated noise. The level and type of traffic can be taken into account, and the results of computer model analyses can be integrated with GIS software. This integration enables one to ascertain the racial and economic characteristics of people whose residences would fall within the area defined by a specific noise contour; ordinarily the contour would pertain to the maximum noise level (dBA) for L10 or L50 standards.

Table 3-10. Population characteristics within noise contours (L10), intersection along U.S. Highway 63, 1990

Descriptor	dBA	Low-income		Minority	
		Number	%	Number	%
L10	65	189	15.8	499	41.8
L50	60	131	16.9	317	41.0

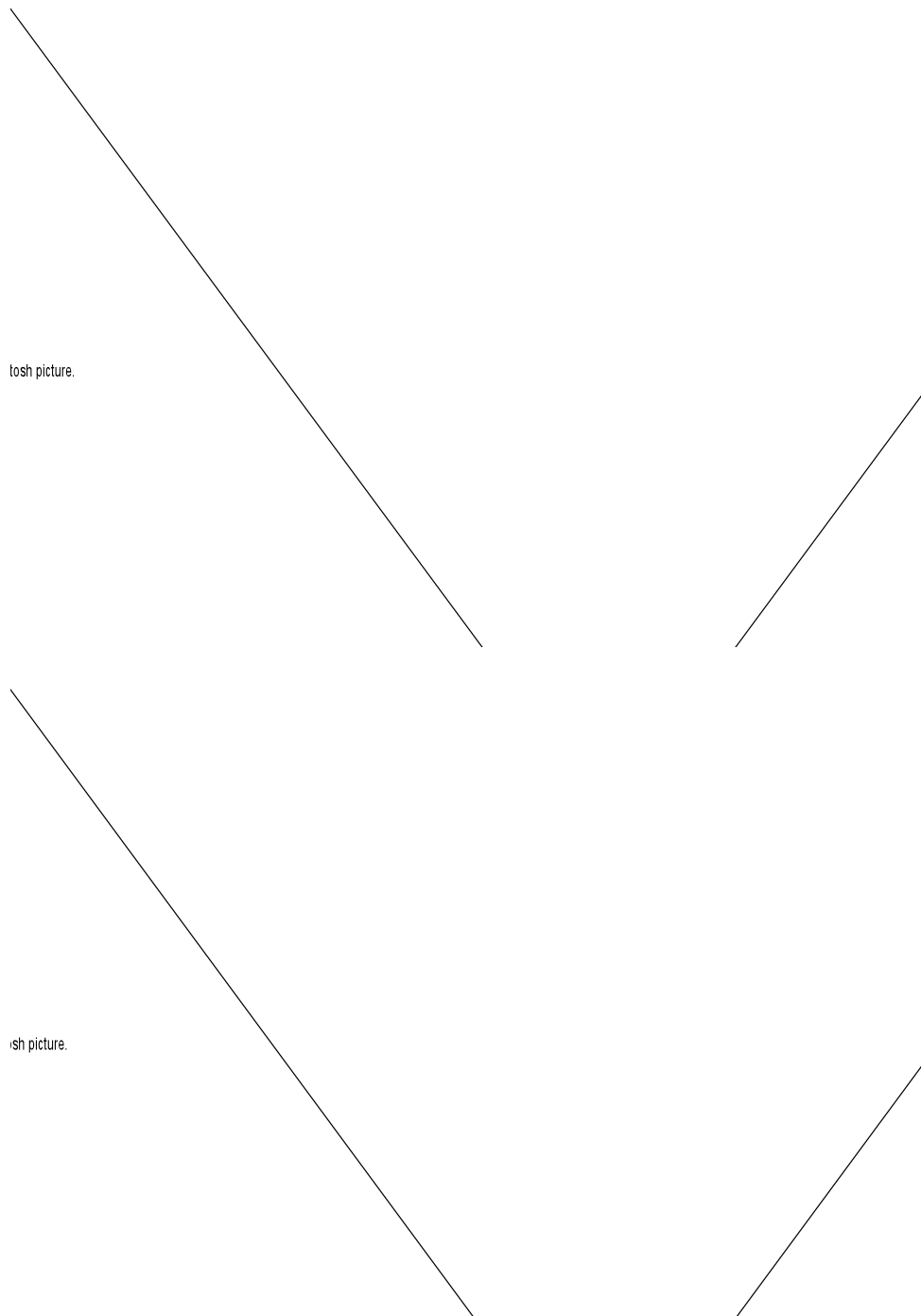


Figure 3-11. Maximum L₁₀ noise level and percent low-income, intersection along U.S. Highway 63, 1990



Figure 3-12. Maximum L₁₀ noise level and percent minority, intersection along U.S. Highway 63, 1990

CHAPTER 4

MEASURING ECONOMIC AND SOCIAL IMPACTS

Evaluating the magnitude of economic and social impacts of transportation system changes requires a complex blend of carrying out objective analysis and eliciting subjective opinions. While some types of economic and social impacts can be estimated quite precisely using existing tools, others can only be approximated, and still others are so elusive as to reduce analysis to little more than speculation. Throughout this chapter, we discuss what is known about potential impacts, and provide questions (in bordered boxes) for planners and neighborhood representatives to contemplate when evaluating transportation system changes.

To organize our discussion, we separate economic and social impacts. This distinction is somewhat artificial, in that many fairly specific types of impacts have both economic and social components. Thus, we should stress that issues discussed in one section frequently spill over into the other.

ECONOMIC IMPACTS

Transportation system changes tend to have dual effects: they can improve access for the public to opportunities of many forms, but they can also result in problems related to greater traffic levels within or near a corridor area. We address these two types of economic impacts separately.

Access to opportunities

Access can be defined as the ability to travel between two points. This ability is affected by both the traveler's circumstances and characteristics of the transportation system. If a would-be traveler for one reason or another cannot travel independently by auto, he or she is far less able to benefit by a road system, however well it connects the desired origin and destination. In this case, access is a function of the availability of public transit or someone who has an auto and is willing and able to drive the person.

Auto and transit access. By the same token, if a person has an auto and is able to drive, but the road system does not serve the desired trip well, other forms of access constraints exist (e.g., traffic congestion or poor connectivity of the road system). For example, if employment centers such as factories are located on the urban edge, low-income workers who live near the center of the city may find that their neighborhoods are not well connected to urban freeways or arterials leading to the factories.

To address the first point, access to public transit is a good proxy for transportation access by people without autos. Because autos are less likely to be available to low-

income people, a significant issue is whether a transportation system change will improve, leave unchanged, or worsen access of this population to transit service.

Access to transit is important because low-income populations and minority populations within most urban areas are more likely to use public transit. The Nationwide Personal Transportation Survey (NPTS) shows that in 1990, 27 percent of all urban transit riders were from households with incomes under \$15,000 (Black 1995, p. 290). African Americans made up 35.7 percent of all bus riders and Hispanics constituted 16.9 percent (Black 1995, p. 291).²⁰

As a general standard, transit use is feasible if bus stops are available within one-quarter of a mile of a person's origin and destination. It is likewise important to be able to avoid difficult or unsafe pedestrian routes to and from bus stops. Projects that make it more difficult or less safe for low-income or minority people to access transit can severely restrict their ability to travel within the urban area.

- Does the roadway to be upgraded serve or bisect a transit route?
 - ◆ If so,
 - Will transit service be significantly altered (e.g., bus stop locations, route configurations, headways)?
 - Will increased traffic, if it is expected, interfere with transit operations?
 - During construction, will access to transit service be significantly changed?
 - Will the proportion of minority or low-income households in the area that are within one-quarter mile of a bus stop change?

In situations where access to transit service is an important consideration, an on-board survey could be conducted to estimate current usage patterns. Additionally, a household survey could be carried out to determine the magnitude and nature of latent (unexpressed) demand among low-income or minority neighborhoods along the affected corridor. If a sizable number of households, for example, express a desire to travel to certain employment centers that are not well served by transit, planners may wish to explore the possibility of adjusting transit routes and schedules.

Many low-income and/or minority households in the Midwest have an auto available. For these households, the relevant concern is likely to be how a transportation system change would serve their more frequent origin-destination pairs.

²⁰ African Americans comprised 11.8 percent of total U.S. population in 1990, and Hispanics accounted for 9.0 percent (Bureau of the Census 1994, p. 18).

- Would the project reduce auto access for low-income or minority populations to common destinations?

Common travel demand analysis routines such as Tranplan enable travel times to be estimated between traffic analysis zones (TAZs). Such existing modeling approaches can be used to estimate changes in travel time between zones that are predominately comprised of low-income or minority households and their common travel destinations. One can correlate TAZs with census block maps to approximate the income and race composition of the respective TAZs along a corridor. Figure 4-1 depicts TAZ and census block boundaries for Waterloo and a portion of the U.S. Highway 63 corridor. In some cases, TAZ boundaries do not fall along the edges of census blocks, so a degree of interpolation may be necessary. Figures 4-2 and 4-3 show TAZ boundaries overlaid on census blocks depicting relative concentrations of low-income populations and minority populations, respectively. Table 4-1 shows the numbers and percentages of minority and low-income people in 12 selected TAZs of Waterloo, with census block data aggregated into TAZs.

Table 4-1. Percentage of population that is minority or low-income, selected traffic analysis zones (TAZs) in Waterloo, 1990*

TAZ number	Area (sq. mi.)	Population	Percentage of population	
			Minority	Low-income
1	0.04	250	33.60	13.44
25	0.14	674	34.16	5.28
50	0.26	448	97.54	21.77
75	0.12	136	3.68	2.71
100	0.09	568	4.93	0.87
125	0.16	550	6.91	1.26
150	0.07	200	2.50	1.25
175	0.08	502	1.99	0.40
200	0.21	370	0.00	0.00
225	1.59	230	2.61	1.13
250	1.21	13	0.00	0.00
275	1.00	18	0.00	0.00

*For illustrative purposes, every twenty-fifth TAZ is shown.

If the total travel time savings of protected populations divided by their original travel time is comparable to that for other travelers, quite likely both protected and other populations benefit similarly by the transportation system change. In cases where travel time savings to minority populations and low-income populations are proportionately less, it may be important to explore ways in which service to them can be improved.

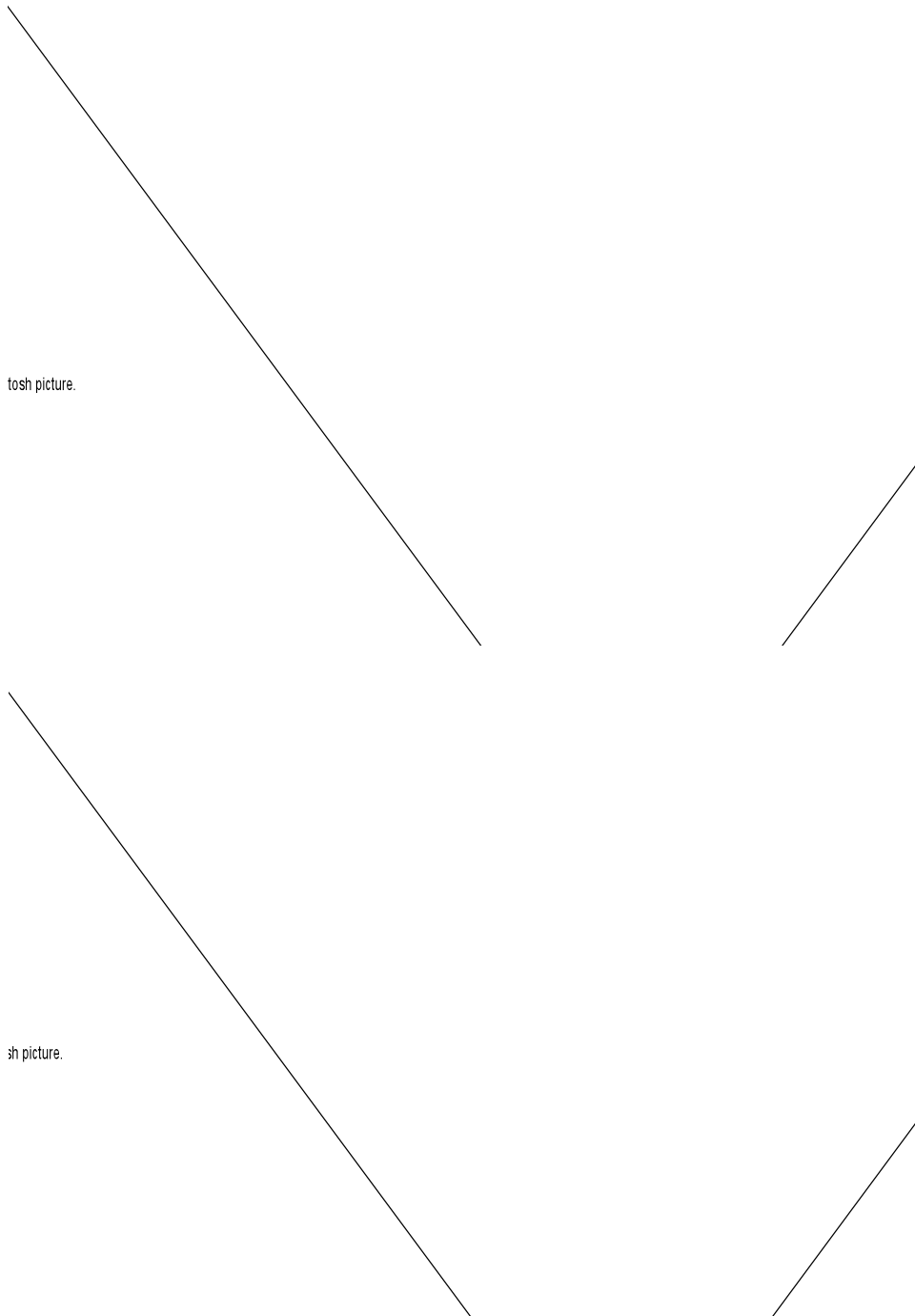


Figure 4-1. Traffic analysis zones and census blocks in Waterloo



Figure 4-2. Traffic analysis zones and low-income population in Waterloo, 1990

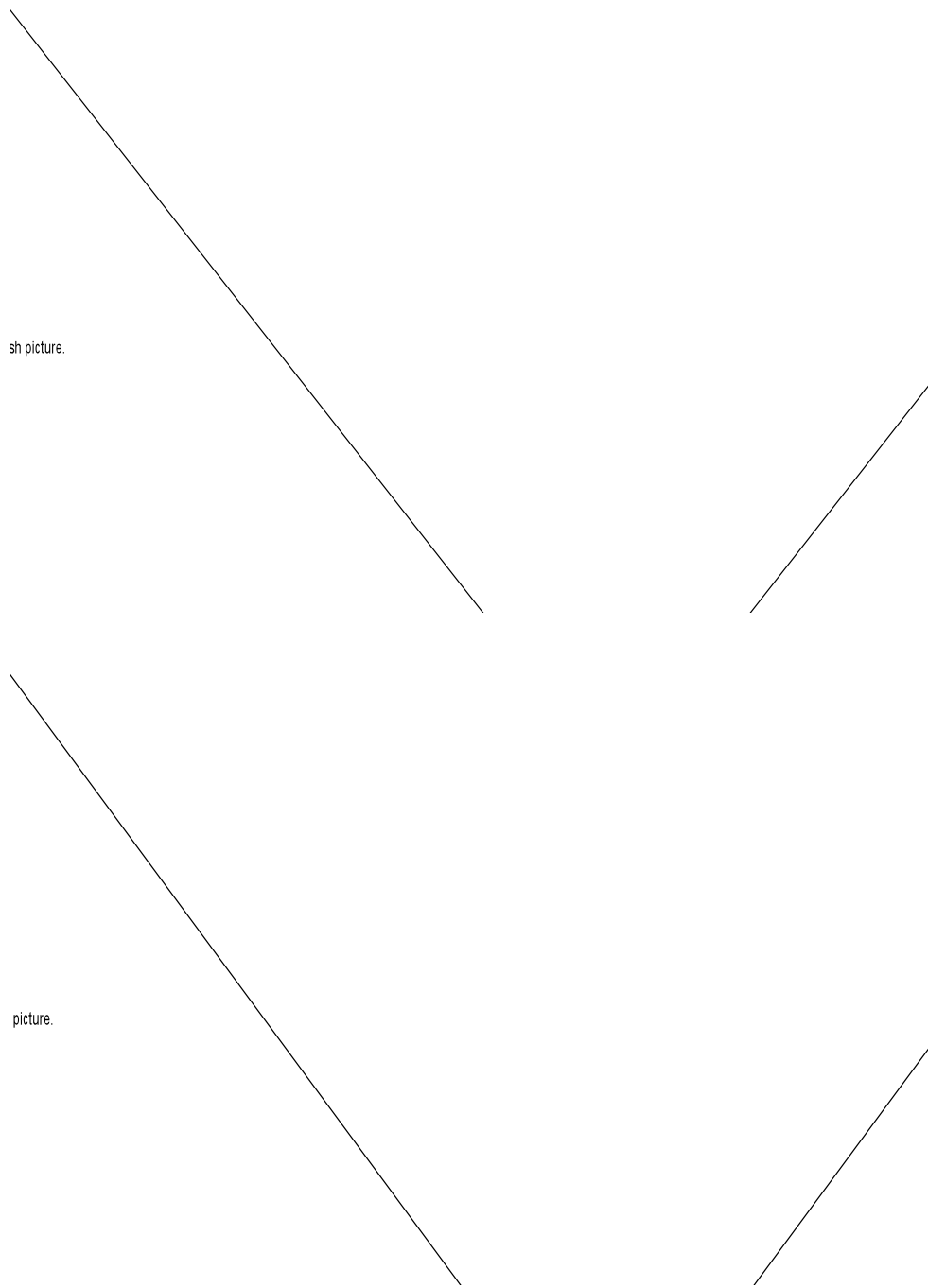


Figure 4-3. Traffic analysis zones and minority population in Waterloo, 1990

Access to public and private services. It is well understood that, in general, low-income populations and minority populations have less access to many types of services than do most other people. Lineberry (1977) contended that transportation availability is an important component in their restricted access. Goeing and Coe (1970, p. 318) concluded that “distance and the related costs of transportation were frequently specified as impediments to proper health care.” Access to health care is a severe problem, as well, for elderly low-income populations for whom transportation constraints often are worsened by their physical disabilities (DeLeaire 1994, pp. 20–22).

- Will the upgraded route make it more difficult for residents of predominately low-income or minority neighborhoods to travel to health care facilities?

Just as access to health care is an important issue, so too is the speed of emergency police responses. The probability of arresting someone in connection with a crime decreases as the time en route to the site increases. According to the National Institute of Law Enforcement and Criminal Justice (1978, p. 11), a one-minute increase in response time from a mean of four minutes to five reduces the likelihood of an arrest by five percent.

Similarly, fire suppression—limiting the damage once a fire starts—is affected by emergency vehicle response time. Coulter et al. (1976, p. 252) found that response times in excess of seven minutes result in substandard levels of fire suppression. Speed of response is critical, and the transportation system is a major determinant of response speed.

- Will police and fire response times to low-income or minority neighborhoods change as a result of upgrading the route in question?
 - ◆ If so, by how many minutes?
 - ◆ Can the locations of police and fire facilities be changed to compensate for any increases in response times?

Other key services to which access is likely to be necessary by low-income or minority populations include daycare services, residential care facilities, half-way houses, crisis centers, churches, social service agencies, and specialty food stores that cater to minority populations.

- Will access from minority or low-income neighborhoods to various necessary services be affected by the transportation system change?

Impacts of proximity to facilities

Property values. It certainly is possible that improved access to employment, shopping, and recreational sites can improve property values within a neighborhood. Yet close proximity to major transportation facilities, such as urban freeways, can adversely impact residential property values. The Federal Highway Administration (FHWA) compiled results of eight large studies analyzing property value changes near urban freeways and concluded that houses in the first row of structures abutting a freeway can experience up to a ten percent decline in value, compared to non-abutting houses (FHWA 1976, p. 23). The higher end of the range was for houses abutting an elevated freeway. Smaller property value declines were observed for houses next to at-grade or depressed freeways than for those abutting elevated facilities.²¹

Several studies of the effects of nearby freeways and rail transit lines on residential property values suggest that decreases in aesthetic quality, increases in noise, and less local access are detrimental to residential property values (see Finsterbusch 1980, pp. 213–215).

The preponderant evidence indicates that proximity to urban freeways is very likely to adversely impact residential property values, particularly houses abutting the right-of-way. From an environmental justice perspective, it is important to deduce the proportion of such houses that are occupied by minority or low-income populations. Using the GIS-based methodology discussed in Chapter 2, estimating this proportion is not difficult. One must assume, however, that the proportion of low-income or minority households along the right-of-way is the same as in the census block generally. Because census blocks are small, this assumption is very likely to be realistic; field surveys can add greater precision, if deemed necessary.

- How many houses will abut the new or upgraded right-of-way?
 - ◆ What proportion of these houses are occupied by minority or low-income residents?

Unless its access to customers is altered, proximity to an upgraded transportation facility rarely will adversely impact commercial properties (Vlachos 1976, pp. 3–25 to 3–27). Quite often, in fact, improved access to consumers and other businesses along the corridor will outweigh any adverse impacts of the facility. The magnitude of such gains will depend on such factors as commercial zoning and the amount of business activity in the general area.

Business displacement. The economic impact of businesses displaced by a transportation system change has several dimensions:

²¹ It should be noted that many of the studies that were the basis for this estimate are rather old. Although it is not stated directly, it appears that the percentage declines are in nominal (not deflated) dollars.

- Jobs for nearby residents,
- Shopping opportunities for nearby residents, and
- Viability of the business itself.

Regarding the third point, Berry et al. (1968, pp. 175–189) concluded that almost 30 percent of all smaller businesses that must relocate simply terminate operations. Of those staying in business, the authors assert that some do not remain viable, having lost their client base.

- How many businesses would be displaced by the transportation system change?
 - ◆ What fraction of these businesses are minority operated?
 - ◆ What fraction of the affected employees have low incomes or are members of minority populations?

Construction and land acquisition. The literature on transportation impact analysis suggests that the economic effects of system changes occur in several phases. Upon notification that a significant change is likely, some people react out of concern over the unknown (Finsterbusch 1980, p. 111–136). This suggests that providing accurate information at all phases of the planning process is valuable because overblown reactions may be reduced.

During the construction phase of a major project, existing businesses may experience losses in access and hence patronage. While the impacts of reduced access may be temporary, work by Buffington and Wildenthal (1993) suggests that some businesses abutting highway construction may suffer permanent losses, as patrons shift their activity patterns. In a study of Texas, they found that 41 percent of the businesses surveyed reported decreased sales and profits during highway construction. One year following this construction, about 20 percent of the long-term businesses continued to experience a decline in sales (Buffington and Wildenthal 1993, p. 63). Even larger reductions in sales during and following construction were reported by De Solminihaç and Harrison (1993). Especially severe sales declines were experienced by general merchandise, food, auto, and home furnishings stores (p. 143).

According to Finsterbusch (1980, pp. 266–267), the consequences of such business closures are often felt predominantly by low-income or minority workers who tend to be less skilled and thus less able to find comparable positions. Several authors, particularly Buffington and Wildenthal (1993, p. 63), stress that temporary costs to local businesses can be kept to a minimum if

- construction is completed as expeditiously as practicable;
- local businesses do not require major remodeling or site reconstruction following completion of a highway project; and

- as much as possible, good access is maintained to businesses.

After construction is complete, there normally is an overall improvement in accessibility and economic vitality of an area. Exceptions, of course, are businesses whose accessibility is reduced by the construction of facilities such as limited-access freeways. In the case of businesses abutting upgraded transportation facilities and that serve low-income or minority residents, pedestrian access is an important consideration.

- How many businesses will have reduced accessibility during construction?
 - ◆ What proportion of businesses affected are minority operated?
- How long is construction programmed to take?
- Can reasonably good access to affected businesses be maintained?
- Will property owners need to undertake extensive remodeling or site redevelopment following construction?
- Will the amount of available parking for businesses be reduced?
 - ◆ If so, by how much?

Summary

It is difficult to make significant improvements to transportation systems without creating adverse economic impacts of one form or another. This being the case, the indicators contained in the foregoing discussion can be used to estimate the nature and extent of such impacts. The two most significant economic impacts related to environmental justice are likely to be changes in relative access to opportunities and changes in the value of real property. This said, it is vital that planners actively consult with low-income populations and minority populations affected by a transportation system change under consideration. Through this direct interaction, planners will gain needed insights both as to the types of impacts that would be likely to materialize and how important they are to the affected populations.

SOCIAL IMPACTS

Measuring and valuating the social impacts of a transportation system change is difficult because such impacts are inherently subjective. Each person has opinions as to what aspects of the built environment are important, what constitutes good living space, and what is aesthetically pleasing. Changes in transportation systems and services that are desirable to one person or group may be unacceptable to another. Thus, planners cannot predetermine what social impacts will be important to affected populations.

Keeping in mind the subjective nature of social impacts and the best means for addressing them, we discuss several general categories of these impacts. We also offer indicators (questions) that can serve as a basis for discussions with community and neighborhood leaders or concerned citizens.

Our discussion is presented under the general categories of community cohesion and aesthetics.

Neighborhood cohesion and functioning

Community cohesion includes but is not limited to sociability and safety. It is important to note that spatial definitions of community may be smaller for minority populations and low-income populations than for other socioeconomic classes. Studies by Lynch (1960) and others estimate that most low-income people identify a one- to three-block radius from their homes as their community (Finsterbusch 1980, pp. 86–88; Hester 1984, p. 40). Heavier traffic in residential areas can reduce residents’ sense of place, leading to significant decreases in social interaction with neighbors (Appleyard et al. 1981, pp. 21, 70). Increases in traffic volumes along an upgraded urban highway may or may not lead to greater traffic on neighborhood streets that intersect with the highway. Application of a travel demand model may provide an indication of the extent to which traffic will flow through neighborhoods en route to the upgraded highway. To the extent that traffic volumes through residential areas would increase, several considerations should receive attention. Among these are neighborhood sociability and safety.

Sociability. Barriers to mobility are closely tied to sociability along a street. Sociability, or comfort with surrounding neighbors, is an important part of community cohesion. Survey responses indicating the number of acquaintances living within the same neighborhood as respondents can be used as a proxy for the amount of friendly contact among neighbors. Appleyard et al. (1981, p. 21) found that when traffic volume is small (200 vehicles per hour during peak hours), residents are three times as likely to form friendships with neighbors and twice as likely to have acquaintances in their neighborhood than when traffic volume is heavy (peak load of 1,900 vehicles or more per hour). Projects that increase traffic density and speed in residential areas may therefore have a detrimental impact on community cohesion.

Safety within neighborhoods. In a San Francisco survey, Appleyard et al. (1981, p. 61) found that “sense of danger” increased directly with traffic volume. Subjects in the San Francisco study may have had a higher or lower tolerance for traffic than residents in other areas, but the general conclusion is that people perceive traffic as dangerous. Table 4–2 shows how the perception of risk varied with the amount of traffic in the minds of Appleyard’s survey respondents.

Table 4–2. Traffic volume and sense of safety

Average daily traffic on a street	Percent of respondents feeling a sense of danger
0 – 2,000	20
2,000 – 10,000	40
10,000 – 20,000	55
20,000 and above	64

SOURCE: Appleyard (1981, p. 61).

Whether low-income populations and minority populations would be differentially impacted by increased traffic volumes through residential neighborhoods, is an environmental justice consideration. There is significant evidence that sizable increases in traffic volumes on residential streets can be a safety hazard, particularly to low-income children.

Rivara (1990, p. 692) contended that pedestrian injuries to children struck by a vehicle constitute a leading cause of death among children. In 1985, such injuries accounted for 13 percent of all unintentional fatal injuries to children; for children aged five to nine years, these injuries constituted 22 percent of fatal, unintentional injuries (Rivara 1990, p. 692). Braddock et al. (1991, p. 1247) also found vehicle-induced injuries to pedestrian children to be an important cause of death, and Lapidus et al. (1991, p. 1110) studying Hartford, Connecticut, found them to be the largest single cause of childhood injury deaths (two per 100,000). Waller et al. (1989), Pless et al. (1987), Rivara and Barber (1985), and Lapidus et al. (1991) have also documented the magnitude of vehicle-pedestrian injuries and fatalities among children.

Children's accident rates are associated with their living environment. Mueller et al. (1990, p. 554) found that the risk of injury due to being struck by a motor vehicle is 5.5 times greater for children living in multifamily dwellings than for children living in single family homes. The absence of a play area was associated with a greatly increased risk. Braddock et al. (1991, p. 1244) found that children per acre was a strong predictor of vehicle-pedestrian accident rates among children.

Household income is another important factor related to vehicle-pedestrian accident rates when children are involved. Appleyard et al. (1981, p. 110) found that streets in a low-income Latino neighborhood of San Francisco experience from two to five times as many accidents as do children living near streets with similar traffic levels in middle income or higher neighborhoods. Research by Mueller et al. (1990), Roberts and Coggan (1994), and Durkin et al. (1994) produced very similar results; Dougherty et al. (1990, p. 207) studying Montreal found a four-to-one differential in accident rates between low- and high-income neighborhoods.

Minority children appear to be at greater risk than other children. Studying Memphis, Tennessee, Rivara and Barber (1985, pp. 377-379) found vehicle-pedestrian accident rates to be highest in nonwhite neighborhoods. Waller et al. (1989, pp. 313-315) found that African American children had twice the accident rates of white children. The highest rates, however, were found among Native American children. Table 4-3 shows Rivara's (1990, p. 692) findings on differential accident rates between white and minority children. For children of both genders, the fatality rate was higher for minority children up to nine years old. Overall, the fatality rate for white children was 2.5 per 100,000 and 3.16 per 100,000 for minority children.

The literature on accidents involving children being struck by motor vehicles is conclusive: higher traffic volumes flowing through higher density neighborhoods with very limited off-street play areas lead to higher accident rates. Especially high rates have been found in low-income or minority neighborhoods, suggesting that

particular attention to these neighborhoods is warranted when considering the safety implications of transportation system changes.

- Will traffic increase on streets adjoining the upgraded route?
 - ◆ If so,
 - How great is the increase likely to be?
 - Will the rate of increase be greater in low-income and minority neighborhoods?
- Will the availability and accessibility of neighborhood parks change?

Table 4-3. Fatal pedestrian injuries in children in the U.S., 1985 (deaths per 100,000 population)

Gender and age	White	Minority
Male		
0 to 4	3.52	5.98
5 to 9	3.23	5.37
10 to 14	2.00	1.74
15 to 19	3.91	3.00
Total	3.19	4.03
Female		
0 to 4	2.06	2.30
5 to 9	1.90	4.05
10 to 14	1.35	0.87
15 to 19	1.80	1.21
Total	1.78	2.27
Total	2.50	3.16

SOURCE: Rivara (1990, p. 692).

Safety to and from school. A different but related safety issue pertains to younger children traveling between home and school. Children will be in greater peril if they must cross a widened, higher-traffic highway when traveling to and from school. In our analysis, we used GIS to devise a method that approximates the number of children who would cross an upgraded urban roadway en route to or from school. The approach enables an analyst to estimate the proportion of all such children who are from low-income or minority households.

A key assumption in our estimation approach is that the preponderant fraction of children attend the school nearest their home. This assumption is less likely to be

realistic in open enrollment communities than in those where children are assigned to a specific school.

The following steps are suggested to estimate the number of children who would cross an upgraded transportation facility:

- 1) Determine the number of school-age children in each census block using census data; estimate the number of low-income or minority students.
- 2) Determine the locations of schools and insert their coordinates into the GIS data file.
- 3) Identify the street routes children are likely to follow when traveling between each block and the nearest school.
- 4) Estimate the number of children who must cross the upgraded urban route.
- 5) Estimate proportions of these children who are from minority or low-income households.

Figure 4-4 is a schematic depiction of the approach described above; Table 4-4 presents the results of its application along U.S. Highway 63 in Waterloo, north of the business district. In this instance, over two-thirds of the schoolchildren crossing the highway on their way to and from school are members of minority populations, although only about 28 percent are from low-income households.

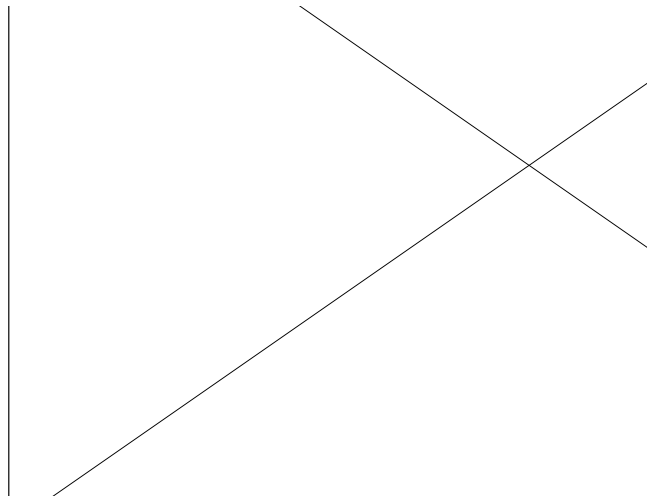


Figure 4-4. Schoolchildren crossing a major transportation route

Table 4-4. Characteristics of schoolchildren crossing U.S. Highway 63 in Waterloo

Total number	Minority		Low-income	
	Number	%	Number	%
274	189	69.0	77	28.1

- Approximately how many school-age children would cross the upgraded facility daily?
- What proportion of these children would be from low-income or minority households?
- Would the upgraded facility be widened?
- Based on expected changes in traffic volumes, what is the change in probability that a time gap in traffic will be long enough to accommodate pedestrian crossing at unsignaled intersections?²²

Aesthetics

The National Environmental Policy Act of 1969 (NEPA 1996) states that the federal government is to use appropriate means to “assure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings” (Section 101(b)(2)) and that all Federal agencies include in every proposal for an action “significantly affecting the quality of the human environment” a detailed statement on the impact of the action (Section 102(C)). In a U.S. DOT report, Heder has identified problems with the ways in which aesthetic impacts are taken into account:

Most impact studies treat aesthetics separately from other impacts and do not adequately recognize the tradeoffs [sic] that exist between aesthetics and other project considerations or the relative value placed by the affected community on aesthetic qualities. Aesthetic impacts are often examined after the location has been completely worked out, leaving room for only cosmetic treatment (Heder 1980, p. 187).

Though aesthetic valuation is extremely subjective, we point to measures of or reasonable surrogates for transportation-related factors that may contribute to adverse impacts.²³ From an environmental justice perspective, it is important to consider impacts that fall disproportionately upon low-income or minority neighborhoods or communities. Changes in peoples’ living environments that alter the following measures can cause emotional and physical stress.

Views and lighting. Disruption of views or light sources can have a significant impact. Although most sources cite elevated rail structures, elevated highway structures can also block light to surrounding homes for all or part of the day. Households not directly in the shadow that have views that are blocked and therefore degraded by a structure also experience a loss, if prior to construction of

²² According to the Highway Capacity Manual (Transportation Research Board 1994, p. 13–14), the additional number of feet in width times 4.5 seconds gives an estimate of the additional time it takes for an average pedestrian to cross the street.

²³ Recent advances in computer-aided design (CAD) have enabled reasonably accurate representations to be generated of the visual impact of changes to the built environment.

the structure they once enjoyed a pleasant view. Direct observation or geometric analysis of structures can identify angles and view obstructions that would exist if the proposed structure were to be constructed (Schaenman 1976, p. 28).

- How many households or establishments will be covered in shadow as a result of the transportation project?
 - ◆ Of these, how many are protected households or establishments?
- How many households or establishments' views will be blocked or degraded by the project?
 - ◆ Of these, how many are protected households or establishments operated by minority populations?

Excessive light can also be a problem. Kendig et al. (1980, pp. 173–174) identify lighting levels that are appropriate for residential, commercial, and industrial areas. Table 4–5 summarizes the maximum illumination and the maximum height recommended for the three general categories of land use. Using these general guidelines, planners and engineers can determine if the overhead lighting from a roadway project would result in a change to a residential neighborhood that would increase maximum illumination or height of light sources to levels more typical of a commercial or industrial area. In general, recommended lighting in residential areas is 0.10 foot-candle lower than in commercial areas and a change of 0.10 foot-candle or more can be considered aesthetically displeasing.

Table 4–5. Maximum height and illumination in residential, commercial, and industrial land uses

Land use type	Maximum illumination (foot-candles)	Maximum height (feet)
<i>No cutoff*</i>		
Residential	0.20	10
Commercial	0.30	20
Industrial	0.30	20
<i>Cutoff greater than 90 degrees</i>		
Residential	0.30	15
Commercial	0.75	25
Industrial	1.50	35
<i>Cutoff less than 90 degrees</i>		
Residential	0.50	20
Commercial	2.00	30
Industrial	5.00	60

* Cutoff angles pertain to how well directed the light is. A cutoff of less than 90 degrees provides the most focused light, so that less illumination is observed off the roadway.

SOURCE: Kendig et al. (1980, pp. 173–174).

Accordingly, changes to the roadway that increase the height of the light source can also lead to a more commercial or industrial ambiance in a residential neighborhood. Raised highways may also pose problems for nearby residents, even though light fixtures, as seen from street level, have less than 90 degree cutoffs.

We should stress that desirable light levels depend heavily on individual preferences. Some residents prefer higher levels of neighborhood lighting because, as pedestrians, they perceive themselves to be less vulnerable to crime and more visible to motorists. Other people prefer softer and lower light levels because they believe it gives the neighborhood a more rural or suburban look and they are able to see the stars at night (Appleyard et al. 1981).

Given such differences in individual preference, establishing rigid rules about lighting impacts would be counterproductive. It is more useful to consider how a project will *change* lighting from existing levels on the corridor.

- Will the project increase overhead lighting on the corridor?
 - ◆ If so:
 - will the height of the light source increase more than 10 feet?
 - will the level of illumination increase by more than 0.10 foot-candle?
 - If so, what is the total number of blocks with increases in illumination of more than 0.10 foot-candle or in height of more than 10 feet, and how many of these blocks contain a predominance of low-income or minority households?

Landmarks. Most urban sociologists agree that the presence of identifiable landmarks in an area can lead to greater satisfaction and community attachment. Survey research has linked proximity to landmarks with increases in community cohesiveness (Hummon 1992, p. 257; Guest and Lee 1983, p. 176). In his pathbreaking book, Lynch (1960, pp. 78–79) defined landmarks as anything with historical or visual significance to a community. Even if they are not historically significant, these structures or features may have been in the area for a long time and may be associated with shared experiences in the community (Riley 1992, pp. 24–27). In general, the greater its historical significance, the more importance an object has as a community focal point.

Objects that contrast sharply with surroundings often have visual appeal as landmarks. For example, a small older building in the midst of modern skyscrapers can serve as a community focal point. The water tower district in Chicago is named for the only structure in the area to survive the great Chicago fire, the tower

standing as a symbol of the past. Landmarks can be anything from a corner grocery store to a unique or unusual house that serves as a community focal point.

There are several actions that can greatly diminish the role of landmarks in a community. The most severe of these is removal, but blocking visual or physical access to the landmark by placement of a transportation structure can also result in individual and community loss. Increasing vehicular traffic past a park so that pedestrian access is more difficult is another example of how a transportation system change may construct a barrier to a landmark. Generally speaking, direct observation will reveal whether a proposed facility would impede visual access to a given landmark from adjoining streets.

- How many structures built before 1940 (the accepted basis for historic significance designation is that the structure be over 50 years old) are to be razed?
 - ◆ Of these, how many are to be razed in protected areas?
 - ◆ Of these, which structures are recognized by community leaders in protected areas to be community landmarks or focal points?
- Will the project move, destroy, alter, or block visual or physical access to common landmarks such as parks, churches, statues, or established businesses?
 - ◆ If so, would it be feasible to move the landmark instead of destroying or blocking it?

The rarity of a landmark or its distance to a similar one should be ascertained if the project must move or destroy the landmark in question. Local perceptions of the cultural, historic, or symbolic importance of a landmark or valued focal point are factors when considering community aesthetics.

Signage and fencing. Impacts of changes in signage can be measured with surveys that use artists' depictions of the area before and after construction to determine protected residents' feelings about proposed designs. Brower (1988, pp. 86, 89) proposes using sketches of the same scene and changing variables such as the presence of high fences or street ornamentation to determine which aesthetic properties are valued most highly by individual neighborhoods.

Similar to roadway lighting, signage and fencing are important components of roadway safety. Design and placement of signs and fencing are dictated by what is suitable to the type and level of traffic and the surrounding environment. Nonetheless, increasing the number, scale, or height of signage and fencing can contribute to a commercial or industrial appearance and constitutes a potential aesthetic impact.

Kendig et al. (1980, p. 178) provide guidelines on the type, number, height, and scale of signs appropriate to residential, commercial, and industrial areas. In his opinion, commercial and industrial areas should be allowed three freestanding signs and

three wall signs per type of land use in each block. In contrast, residential areas should be allowed one freestanding and one wall sign. Increasing the number of signs along the right-of-way in a residential area to greater than a single freestanding sign may indicate that the area is becoming more cluttered.

- Will there be an increase in signage along the corridor in a residential area?
 - ◆ If so:
 - Will there be more than five signs per block and, if so, how many such blocks are occupied by predominately low-income or minority populations?
 - Will there be additional flickering signs?
 - If so, how many blocks will have additional flickering signs, and how many of these blocks have predominately low-income or minority residents?
 - Will the project have signs with spotlights or backlights visible from adjoining properties?
 - If so:
 - How many blocks will have views of backlit or spotlit signs, and how many of these blocks are occupied by predominately low-income populations and minority populations?
 - Considering each sign, can it be shielded from the neighborhood without interfering with its function?
- Will the project require fencing?
 - ◆ If so, how many households' views will be obstructed by fencing, and how many of these households are in blocks whose residents are predominately members of protected populations?

Scale or stimuli balance. Studies show that the combination of tall buildings and raised highways can lead to a sense of enclosure that is aesthetically displeasing (Garnham 1985, pp. 48–49; Heder 1980, p. 193). For example, the 1977 and 1981 studies of San Francisco and London by Appleyard and his colleagues indicate that comparatively narrow streets and tall buildings also magnify the impacts of traffic noise, vibration, and pollution, compared to the wider street spaces and setbacks in many U.S. cities (Appleyard et al. 1981).

If highway overpasses decrease the horizontal space used for walking and driving to a relationship less than a one unit vertical to two units horizontal, intensified feelings of enclosure can lead to anxiety. On the other hand, parking lots or large multilane highways can add excessive open horizontal space or “dead space” to an area. Transportation projects that create undefined horizontal spaces with height and width relationships greater than one to four can substantially detract from the aesthetics of an area (Garnham 1985, p. 49). This is particularly true in residential

neighborhoods that have no comparable open spaces. Figure 4–5 illustrates these relationships. One indication of “dead space” is the amount of land devoted to a transportation system right-of-way that was formerly available for usable open space or was formerly part of adjoining properties.

- Will the project replace existing open space with unusable open (or dead) space for street and right-of-way?
 - ◆ If so, what is the total amount of land removed from use for dead space and how much of the land removed is in protected blocks?

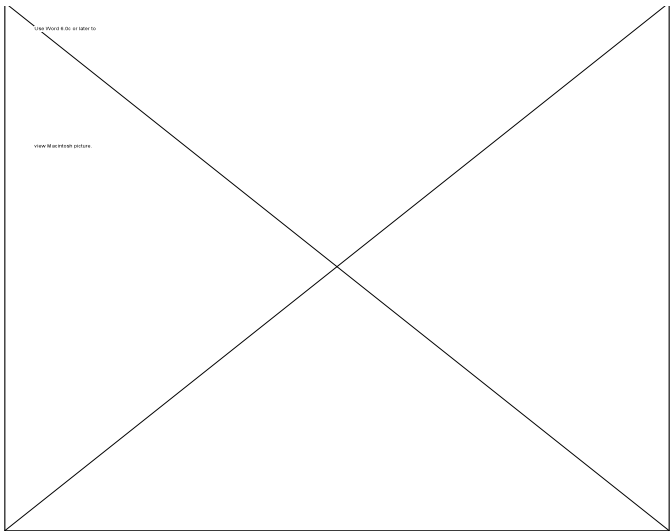


Figure 4–5. Spatial relationships at the street level

SOURCE: Adapted from Garnham (1985, p. 49).

Landscaping. Individual or collective garden plots are often an attractive feature of residential areas. Though rows of trees are not as effective as noise walls, they typically are more aesthetically and psychologically appealing and can reduce energy costs for nearby homes. These attributes contribute to higher property values for abutting land and even for an entire neighborhood (Garnham 1985, p. 58). Most design guidelines encourage good landscape design along roadway projects, and roadway designers are usually careful to remove only those mature trees that absolutely cannot be spared. Especially in recent years, vegetation has often been replaced and enhanced when urban highways have been upgraded.

The literature suggests that replacement landscaping does not compensate entirely for the loss of original on-site vegetation (Appleyard et al. 1981, pp. 66–67). One reason is that replacement trees take time to reach the level of shading and ground coverage of the original trees; another is that small trees and plants can go unnoticed, leaving an area with a deforested appearance.

Residents often become very attached to trees and plants they have on their property and in their neighborhoods. Removing the original vegetation, even if it is replaced, often affects the overall aesthetic quality in a residential block, particularly in the short run. An artist's depictions of a landscape plan can show residents what the finished landscape will look like when the vegetation fills in.

- Will the project remove local landscaping?
 - ◆ If so,
 - How many mature canopy trees will be removed and how many of the trees to be removed are in protected blocks?
 - Will the number of canopy trees along the corridor in a protected neighborhood fall below five every 300 feet?²⁴
 - ◆ If the trees and vegetation are to be replaced, how long will it take for the landscape to reach maturity?

Summary

Social impacts of transportation system changes can take many forms, and the magnitudes of these impacts are bound to vary greatly from place to place. We have attempted in this chapter to categorize social impacts and have suggested a series of questions that constitute a basis for determining whether or not a particular system upgrade would be likely to result in significant impacts. While these questions are quite comprehensive, they are not necessarily all-inclusive. A particular project may involve very specific issues of importance to the people who would be most affected. One strength of a community-specific assessment is its ability to address these issues.

We began by discussing neighborhood cohesion and functioning. The discussion focused on possible impacts of changes in traffic volumes on neighborhood streets in terms of sociability and safety. Our emphasis was on safety, and several indicators have been suggested to ascertain the degree to which children's safety would be affected.

A second general area we explored is aesthetic considerations, an area often ignored in impact and feasibility studies. Aesthetic impacts include lighting, fencing, views, presence of landmarks, scale, and landscaping. The indicators in this section are not definitive, but they do enable a reasonably thorough assessment to be made.

²⁴ Kendig et al. (1980, p. 172) recommends five canopy trees for every 300 feet or every ten dwelling units in residential areas.

CHAPTER 5

IMPLEMENTING ENVIRONMENTAL JUSTICE

In this report, we have explored a range of conceptual, practical, and methodological issues related to environmental justice. Specifically, we have focused on impacts that may arise from significant changes to transportation systems. This chapter suggests further actions that would advance the objectives of environmental justice in transportation investments.

We have argued that distributional equity—the incidence of benefits and costs across income levels—should be considered in combination with economic efficiency when evaluating potential transportation investments. Economic efficiency means that the total benefits to society exceed total costs, and thus society in the aggregate would be better off if the investment were made. Transportation system changes should be efficient and should not produce disproportionate costs for low-income populations and minority populations. We stress throughout this report that peoples' values, priorities, and needs vary considerably, so changes that might make one person better off in an overall sense may worsen the situation of another. There really is no substitute for presenting to affected populations as much information as possible about the probable impacts of transportation system changes under consideration. These populations can then determine which types of impacts matter the most and thus define priorities for mitigation or modification of proposed transportation changes.

TYPES OF IMPACTS

During the course of this research, we identified a variety of types of impacts. These impacts emerged from conducting a broad literature review and applying concepts from disciplines ranging from economics to the visual arts. We also integrated several methods of analysis to enable geographic information system (GIS) techniques and air pollution and noise computer models to be applied in combination. A brief summary of our research results follows.

Analysis scale

Transportation system changes can range from widening an expressway to adding a subway station. While economic feasibility studies generally examine these changes at a system scale, environmental justice is concerned with project-specific impacts on populations relatively near it. To estimate the extent to which disproportionate impacts would be experienced by low-income populations and minority populations, a small scale of analysis is appropriate. Small scale units are likely to be relatively homogenous, and impacts will tend to vary less within them than would be true across larger spatial units. The smallest unit for which U.S. Census data are available is the census block; it is the unit of analysis we recommend for environmental justice-related transportation studies.

Air pollution and noise impacts

An important component of our research has been to develop methods for estimating the extent to which vehicle-generated air pollution and noise would adversely and disproportionately impact minority populations and low-income populations. Regarding air pollution, we focused on carbon monoxide (CO) and particulate matter under ten microns in aerodynamic diameter (PM₁₀). We applied computer models to predict levels of CO and PM₁₀ near an intersection along U.S. Highway 63 in Waterloo. We found that it is feasible to use these computer models in combination with GIS software and census data to estimate the degree to which pollution would disproportionately affect low-income populations and minority populations.

Similarly, we applied a computer model to estimate the likely severity of noise impacts at the same intersection along U.S. Highway 63. Our methodology allows a noise gradient to be estimated by the computer model and contours of equal noise levels to be constructed. Using GIS software, we were able to compare these contours with the racial and income characteristics of residential areas near the corridor.

In short, it is feasible to determine with a reasonable level of accuracy whether the air pollution and noise impacts of a transportation system change would be experienced disproportionately by low-income populations and minority populations. Existing computer models and GIS software can be used in tandem to make this determination.

Economic impacts

The key economic aspect of environmental justice in relation to transportation system changes is the extent to which access to opportunities is affected. The relative availability of transportation services and ability to travel to locations where public and private services are provided are critical elements of an environmental justice assessment. Accordingly, we developed a series of indicators that pertain to changes in access to opportunities. We also constructed indicators related to residential property value impacts and effects on existing business. Such indicators constitute a practical basis for assessing the likely economic impacts along a corridor where a transportation system change is contemplated, particularly the impacts affecting minority or low-income populations.

Social impacts

We developed a series of questions pertaining to the social impacts of a transportation system change. These questions are presented under the general categories of community cohesion and aesthetics. While both categories are highly subjective, the questions will enable planners to help affected populations gain a clear understanding of possible impacts. These impacts could include neighborhood sociability and safety, lighting, landmarks, signage and fencing, changes in urban scale, and landscaping.

A unified approach

Taken together, discussions of the several types of impacts provide a basis for understanding how a transportation system change would affect people nearby. This report does not evaluate the relative importance of the several impacts, but rather it helps make it possible for those who would experience them to do so.

OBTAINING PUBLIC INPUT

The objective of this report has been to lay out the types of information nontechnical people should have access to if they would be affected by a transportation system change. Such information is quite extensive, and much of it is the product of rather technical analysis. A need exists to make this information fully comprehensible, so that all affected populations can acquire a sound understanding of the likely impacts, favorable and adverse.

Beyond the scope of our study is the important element of devising strategies for involving affected populations, especially those with low incomes and those who are members of racial minorities, in the process of evaluating the sorts of information on impacts discussed in this report. It certainly is the case that for a constructive community participation effort to occur, useful information on environmental, economic, and social impacts must be made available to all participants. On the other hand, technically correct, thorough information is of limited value if it is not available to or well understood by the people who stand to be affected by a transportation system change.

A U.S. DOT-sponsored conference on environmental justice and transportation planning produced a series of recommendations regarding involvement by protected populations in the process of determining whether to make particular changes in transportation systems (Federal Transit Administration 1995). Among the general principles mentioned in the conference proceedings are:

- Strengthen the role of neighborhood and community-based organizations in the planning process (p. 17); hold community leaders accountable for participation (p. 56);
- Educate planners on ways to actively promote citizen involvement (p. 27); for example, it is important to develop culturally sensitive communications (p. 52) and to conduct sensitivity training to help decision makers and agency staff understand different cultures (p. 19);
- When appropriate, use intermediary or liaison organizations to make linkages between neighborhoods and area-wide planning (p. 28);
- Recognize the limitations of traditional public hearings and opportunities to comment on proposed transportation system changes (p. 28);
- Involve minority populations and low-income populations in the facility planning process at the early stages (p. 52); and
- Provide information on key issues related to the system changes under consideration at such common locations as grocery stores, churches, and

schools (p. 52); also use prime-time advertisements and announcements (p. 58).

LOOKING AHEAD

A recurring theme in the limited materials available on environmental justice and transportation investment is the need for improved capabilities to assess project impacts. Social and economic considerations have received minimal attention in impact analyses (Federal Transit Administration 1995, p. 18), and methods of analysis need further development. Based on our review of the salient literature and observations while conducting this research, needs for increased knowledge include:

- Development of improved baseline assessments that estimate current levels of inaccessibility and adverse impacts.
- Improved mobility assessment methods. The current focus on corridor analyses can lead to traditional solutions, such as highway capacity expansion.
- Air pollution and noise models that are more capable of micro-scale (neighborhood) analysis, taking into account such factors as building heights and spacing.
- More effective methods for reaching affected populations and gauging neighborhood-level priorities regarding elements needing preservation or enhancement.
- Better predictive approaches for estimating trip geography and travel desires of low-income populations and minority populations in specific situations.
- Location analyses for public and private facilities that take into account protected populations' abilities to conduct their daily activities.
- Improved techniques for communicating probable impacts, positive and negative, of contemplated transportation system changes, perhaps including multimedia approaches, taking into account the need to reach low-income populations and minority populations.

CONCLUSION

A growing awareness of the pivotal role played by the transportation sector in the quality of life for low-income populations and minority populations has led environmental justice advocates to place considerable emphasis on this sector. This report is an attempt to improve the quality of information available to all interested parties, including those who traditionally have had comparatively little knowledge about the consequences of proposed transportation system changes. We stress that more work is needed to further upgrade our ability to generate the salient information. Also needed are improved approaches for including minority populations and low-income populations in the planning process from conceptualization to effectuation.

Environmental justice is a public policy objective that has the potential to significantly improve the quality of life for people who often have been left behind as communities grow and change. This report represents a step toward a more equitable sharing of knowledge regarding the benefits and costs brought about by investments in transportation systems.

**APPENDIX A
FEDERAL ENVIRONMENTAL JUSTICE
POLICY STATEMENTS**

EXECUTIVE ORDER 12898 OF FEBRUARY 11, 1994

Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations

By the authority vested in me as President by the Constitution and the laws of the United States of America, it is hereby ordered as follows:

Section 1-1. Implementation

1-101. *Agency Responsibilities.* To the greatest extent practicable and permitted by law, and consistent with the principles set forth in the report on the National Performance Review, each Federal agency shall make achieving 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 in the United States and its territories and possessions, the District of Columbia, the Commonwealth of Puerto Rico, and the Commonwealth of the Mariana Islands.

1-102. *Creation of an Interagency Working Group on Environmental Justice.*

(a) Within 3 months of the date of this order, the Administrator of the Environmental Protection Agency ("Administrator") or the Administrator's designee shall convene an interagency Federal Working Group on Environmental Justice ("Working Group"). The Working Group shall comprise the heads of the following executive agencies and offices or their designees: (a) Department of Defense; (b) Department of Health and Human Services; (c) Department of Housing and Urban Development; (d) Department of Labor; (e) Department of Agriculture; (f) Department of Transportation; (g) Department of Justice; (h) Department of the Interior; (i) Department of Commerce; (j) Department of Energy; (k) Environmental Protection Agency; (l) Office of Management and Budget; (m) Office of Science and Technology Policy; (n) Office of the Deputy Assistant to the President for Environmental Policy; (o) Office of the Assistant to the President for Domestic Policy; (p) National Economic Council; (q) Council of Economic Advisers; and (r) such other Government officials as the President may designate. The Working Group shall report to the president through the Deputy Assistant to the President for Environmental Policy and the Assistant to the President for Domestic Policy.

(b) The Working Group shall:

- (1) provide guidance to Federal agencies on criteria for identifying disproportionately high and adverse human health or environmental effects on minority populations and low-income populations;
- (2) coordinate with, provide guidance to, and serve as a clearinghouse for, each Federal agency as it develops an environmental justice strategy as required by section 1-103 of this order, in order to ensure that the administration, interpretation and enforcement of programs, activities and policies are undertaken in a consistent manner;
- (3) assist in coordinating research by, and stimulating cooperation among, the Environmental Protection Agency, the Department of Health and Human Services, the Department of Housing and Urban Development, and other agencies conducting research or other activities in accordance with section 3-3 of this order:
- (4) assist in coordinating data collection, required by this order;
- (5) examine existing data and studies on environmental justice;
- (6) hold public meetings as required in section 5-502(d) of this order; and
- (7) develop interagency model projects on environmental justice that evidence cooperation among Federal agencies.

1-103. Development of Agency Strategies.

- (a) Except as provided in section 6-605 of this order, each Federal agency shall develop an agency-wide environmental justice strategy, as set forth in subsections (b)-(e) of this section that identifies and addresses disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations. The environmental justice strategy shall list programs, policies, planning and public participation processes, enforcement, and/or rulemakings related to human health or the environment that should be revised to, at a minimum:
 - (1) promote enforcement of all health and environmental statutes in areas with minority populations and low-income populations;
 - (2) ensure greater public participation;
 - (3) improve research and data collection relating to the health of and environment of minority populations and low-income populations; and
 - (4) identify differential patterns of consumption of natural resources among minority populations and low-income populations. In addition, the environmental justice strategy shall include, where appropriate, a timetable for undertaking identified revisions and consideration of economic and social implications of the revisions.

- (b) Within 4 months of the date of this order, each Federal agency shall identify an internal administrative process for developing its environmental justice strategy, and shall inform the Working Group of the process.
- (c) Within 6 months of the date of this order, each Federal agency shall provide the Working Group with an outline of its proposed environmental justice strategy.
- (d) Within 10 months of the date of this order, each Federal agency shall provide the Working Group with its proposed environmental justice strategy.
- (e) Within 12 months of the date of this order, each Federal agency shall finalize its environmental justice strategy and provide a copy and written description of its strategy to the Working Group. During the 12 month period from the date of this order, each Federal agency, as part of its environmental justice strategy, shall identify several specific projects that can be promptly undertaken to address particular concerns identified during the development of the proposed environmental justice strategy, and a schedule for implementing those projects.
- (f) Within 24 months of the date of this order, each Federal agency shall report to the Working Group on its progress in implementing its agency-wide environmental justice strategy.
- (g) Federal agencies shall provide additional periodic reports to the Working Group as requested by the Working Group.

1-104. *Reports to the President.* Within 14 months of the date of this order, the Working Group shall submit to the President, through the Office of the Deputy Assistant to the President for Environmental Policy and the Office of the Assistant to the President for Domestic Policy, a report that describes the implementation of this order, and includes the final environmental justice strategies described in section 1-103(e) of this order.

Sec. 2-2. Federal Agency Responsibilities for Federal Programs

Each Federal agency shall conduct its programs, policies, and activities that substantially affect human health or the environment, in a manner that ensures that such programs, policies, and activities do not have the effect of excluding persons (including populations) from participation in, denying persons (including populations) the benefits of, or subjecting persons (including populations) to discrimination under, such programs, policies, and activities, because of their race, color, or national origin.

Sec. 3-3. Research, Data Collection, and Analysis

3-301. *Human Health and Environmental Research and Analysis.*

- (a) Environmental human health research, whenever practicable and appropriate, shall include diverse segments of the population in epidemiological and clinical studies, including segments at high risk

from environmental hazards, such as minority populations, low-income populations and workers who may be exposed to substantial environmental hazards.

- (b) Environmental human health analyses, whenever practicable and appropriate, shall identify multiple and cumulative exposures.
- (c) Federal agencies shall provide minority populations and low-income populations the opportunity to comment on the development and design of research strategies undertaken pursuant to this order.

3-302. *Human Health and Environmental Data Collection and Analysis.* To the extent permitted by existing law, including the Privacy Act, as amended (5 U.S.C. section 552a):

- (a) each Federal agency, whenever practicable and appropriate, shall collect, maintain, and analyze information assessing and comparing environmental and human health risks borne by populations identified by race, national origin, or income. To the extent practical and appropriate, Federal agencies shall use this information to determine whether their programs, policies, and activities have disproportionately high and adverse human health or environmental effects on minority populations and low-income populations;
- (b) In connection with the development and implementation of agency strategies in section 1-103 of this order, each Federal agency, whenever practicable and appropriate, shall collect, maintain and analyze information on the race, national origin, income level, and other readily accessible and appropriate information for areas surrounding facilities or sites expected to have a substantial environmental, human health, or economic effect on the surrounding populations, when such facilities or sites become the subject of a substantial Federal environmental administrative or judicial action. Such information shall be made available to the public, unless prohibited by law; and
- (c) Each Federal agency, whenever practicable and appropriate, shall collect, maintain, and analyze information on the race, national origin, income level, and other readily accessible and appropriate information for areas surrounding Federal facilities that are:
 - (1) subject to the reporting requirements under the Emergency Planning and Community Right-to-Know Act, 42 U.S.C. section 11001-11050 as mandated in Executive Order No. 12856; and
 - (2) expected to have a substantial environmental, human health, or economic effect on surrounding populations. Such information shall be made available to the public, unless prohibited by law.
- (d) In carrying out the responsibilities in this section, each Federal agency, whenever practicable and appropriate, shall share information and eliminate unnecessary duplication of efforts through the use of existing

data systems and cooperative agreements among Federal agencies and with State, local, and tribal governments.

Section 4–4. Subsistence Consumption of Fish and Wildlife

- 4–401. *Consumption Patterns.* In order to assist in identifying the need for ensuring protection of populations with differential patterns of subsistence consumption of fish and wildlife, Federal agencies, whenever practicable and appropriate, shall collect, maintain, and analyze information on the consumption patterns of populations who principally rely on fish and/or wildlife for subsistence. Federal agencies shall communicate to the public the risks of those consumption patterns.
- 4–402. *Guidance.* Federal agencies, whenever practicable and appropriate, shall work in a coordinated manner to publish guidance reflecting the latest scientific information available concerning methods for evaluating the human health risks associated with the consumption of pollutant-bearing fish or wildlife. Agencies shall consider such guidance in developing their policies and rules.

Section 5–5. Public Participation and Access to Information

- (a) The public may submit recommendations to Federal agencies relating to the incorporation of environmental justice principles into Federal agency programs or policies. Each Federal agency shall convey such recommendations to the Working Group.
- (b) Each Federal agency may, whenever practicable and appropriate, translate crucial public documents, notices, and hearings relating to human health or the environment for limited English speaking populations.
- (c) Each Federal agency shall work to ensure that public documents, notices, and hearings relating to human health or the environment are concise, understandable, and readily accessible to the public.
- (d) The Working Group shall hold public meetings, as appropriate, for the purpose of fact-finding, receiving public comments, and conducting inquiries concerning environmental justice. The Working Group shall prepare for public review a summary of the comments and recommendations discussed at the public meetings.

Sec. 6–6. General Provisions

- 6–601. *Responsibility for Agency Implementation.* The head of each Federal agency shall be responsible for ensuring compliance with this order. Each Federal agency shall conduct internal reviews and take such other steps as may be necessary to monitor compliance with this order.
- 6–602. *Executive Order No. 12250.* This Executive order is intended to supplement but not supersede Executive Order No. 12250, which requires consistent and effective implementation of various laws prohibiting discriminatory

practices in programs receiving Federal financial assistance. Nothing herein shall limit the effect or mandate of Executive Order No. 12875.

- 6-603. *Executive Order No. 12875.* This Executive order is not intended to limit the effect or mandate of Executive Order 12875.
- 6-604. *Scope.* For purposes of this order, Federal agency means any agency on the Working Group, and such other agencies as may be designated by the President, that conducts any Federal program or activity that substantially affects human health or the environment. Independent agencies are requested to comply with the provisions of this order.
- 6-605. *Petitions for Exemptions.* The head of a Federal agency may petition the President for any exemption from the requirements of this order on the grounds that all or some of the petitioning agency's programs or activities should not be subject to the requirements of this order.
- 6-606. *Native American Programs.* Each Federal agency responsibility set forth under this order shall apply equally to Native American programs. In addition, the Department of the Interior, in coordination with the Working Group, and, after consultation with tribal leaders, shall coordinate steps to be taken pursuant to this order that address Federally recognized Indian Tribes.
- 6-607. *Costs.* Unless otherwise provided by law, Federal agencies shall assume the financial costs of complying with this order.
- 6-608. *General.* Federal agencies shall implement this order consistent with, and to the extent permitted by, existing law.
- 6-609. *Judicial Review.* This order is intended only to improve the internal management of the executive branch and is not intended to, nor does it create any right, benefit, or trust responsibility, substantive or procedural, enforceable at law or equity by a party against the United States, its agencies, its officers, or any person. This order shall not be construed to create any right to judicial review involving the compliance or noncompliance of the United States, its agencies, its officers, or any other person with this order.

William J. Clinton
THE WHITE HOUSE
February 11, 1994

[FR Doc. 94-3685 Filed 3-14-94; 3:07 pm]
BILLING CODE 3195-01-P

Editorial note: For the memorandum that was concurrently issued on Federal environmental program reform, see issue No. 6 of the *Weekly Compilation of Presidential Documents*.

DEPARTMENT OF TRANSPORTATION

Office of the Secretary

[OST Docket No. OST-95-141 (50125)]

**DEPARTMENT OF TRANSPORTATION (DOT) ORDER TO
ADDRESS ENVIRONMENTAL JUSTICE IN MINORITY
POPULATIONS AND LOW-INCOME POPULATIONS**

AGENCY: Departmental Office of Civil Rights and Office of the Assistant Secretary for Transportation Policy, DOT.

ACTION: Notice of final DOT Order on environmental justice.

SUMMARY: The Department of Transportation is issuing its final DOT Order, which will be used by DOT to comply with Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. The Order generally describes the process that the Office of the Secretary and each Operating Administration will use to incorporate environmental justice principles (as embodied in the Executive Order) into existing programs, policies, and activities. The Order provides that the Office of the Secretary and each Operating Administration within DOT will develop specific procedures to incorporate the goals of the DOT Order and the Executive Order with the programs, policies and activities which they administer or implement.

FOR FURTHER INFORMATION CONTACT: Ira Laster Jr., Office of Environment, Energy, and Safety, Office of the Assistant Secretary for Transportation Policy, (202) 366-4859, or Marc Brenman, Departmental Office of Civil Rights, (202) 366-1119, U.S. Department of Transportation, 400 7th Street, SW., Washington, DC 20590.

SUPPLEMENTARY INFORMATION: Executive Order 12898, as well as the President's February 11, 1994 Memorandum on Environmental Justice (sent to the heads of all departments and agencies), are intended to ensure that Federal departments and agencies identify and address disproportionately high and adverse human health or environmental effects of their policies, programs and activities on minority populations and low-income populations.

The DOT Environmental Justice Order is a key component of DOT's June 21, 1995 Environmental Justice Strategy (60 FR 33896). The Order sets forth a process by which DOT and its Operating Administrations will integrate the goals of the Executive Order into their operations. This is to be done through a process developed within the framework of existing requirements, primarily the National Environmental Policy Act (NEPA), Title VI of the Civil Rights Act of 1964 (Title VI), the Uniform Relocation Assistance and Real Property Acquisition Policies Act of

1970, as amended (URA), the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), and other DOT applicable statutes, regulations and guidance that concern planning; social, economic, or environmental matters; public health or welfare; and public involvement. The Order is an internal directive to the various components of DOT and does not create any right to judicial review for compliance or noncompliance with its provisions.

In order to provide an opportunity for public input, a proposed version of this Order was published for comment on June 29, 1995 (60 FR 33899). A total of 30 written comments were received. Fifteen comments were received from state transportation or highway agencies, representing 20 state agencies (one letter was signed by ten state agencies, but four of those also sent individual comments). The other 15 comments included four from transit agencies, four from national organizations, two each from local governments, metropolitan planning organizations, and citizens objecting to one particular project, and one from a professional association.

Most of the comments from the state agencies suggested that the proposed Order would duplicate existing processes and impose additional burdens on the state agencies, and urged that greater flexibility be granted to states.

The DOT Order reinforces considerations already embodied in NEPA and Title VI, and the final version has been revised to make this clearer. It is intended to insure that a process for the assessment of environmental justice factors becomes common practice in the application of those, and related, statutes.

Many other comments suggested ways in which the Order might be clarified or simplified, or addressed specific details of individual agency implementation. As this Order is only intended to provide general guidance to all DOT components, detailed comments on each agency's implementation are premature, and should be made during opportunities for public input on agency implementation (para. 5 of the Order).

Several commenters suggested greater reliance on existing procedures, particularly those implementing NEPA.

One commenter noted, "Over the past number of years we have seen rules and laws initiated with laudable intent, only to be slowly transformed into bureaucratic mazes only dimly related to their original purpose."

The Department does not intend that this Order be the first step in creating a new set of requirements. The objective of this Order is the development of a process that integrates the existing statutory and regulatory requirements in a manner that helps ensure that the interests and well being of minority populations and low-income populations are considered and addressed during transportation decision making.

To further advance this objective, explanatory information has been provided in this preamble and several changes have been made in the Order. Most notably:

- Further clarification has been provided concerning the use of existing NEPA, Title VI, URA and ISTEA planning requirements and procedures to satisfy the objectives of Executive Order 12898.
- The application of the Order to ongoing activities is discussed in this preamble.
- The Order has been modified to further clarify the relationship and use of NEPA and Title VI in implementing the Executive Order.

Further, in developing and reviewing implementing procedures, described in paragraph 5a to comply with Executive Order 12898, the emphasis continues to be on the actual implementation of NEPA, Title VI, the URA and ISTEA planning requirements so as to prevent disproportionately high and adverse human health or environmental effects of DOT's programs, policies and activities on minority populations and low-income populations.

One of the primary issues raised in the proposed Order concerned the actions that would be taken if a disproportionately high and adverse human health or environmental effect on minority populations or low-income populations is identified. The proposed Order set forth three options. A variety of comments were received on this issue, both for and against the various options.

The final Order adopts a modified version of Option B from the proposed Order. While Option B implements a new process for addressing disproportionately high and adverse effects, the Department believes that Option B is consistent with existing law and best accomplishes the objectives of the Executive Order. Option B (now incorporated in paragraphs 8a, 8b and 8c of the final Order) provides that disproportionate impacts on low-income and minority populations are to be avoided, if practicable, that is, unless avoiding such disproportionate impacts would result in significant adverse impacts on other important social, economic, or environmental resources. Further, populations protected by Title VI are covered by the additional provisions of paragraph 8b. Three commenters expressed concern and uncertainty as to the implementation of paragraph 6b(1) of Option B as proposed, that provided for an agreement with populations protected by Title VI. DOT agreed with the comments and, accordingly, that paragraph has been deleted from the final Order.

Several commenters asked about the effective date of this Order. In particular they wanted to know whether it applies to ongoing projects. The effective date of the Order is the date of its issuance. However, to the extent that the Order clarifies existing requirements that ensure environmental justice principles are considered and addressed before final transportation decisions are made, its purposes already should be reflected in actions relating to ongoing projects.

Several commenters recommended that insignificant or de minimis actions not be covered by this Order. It is noted that the definition of "programs, policies and/or activities" in Section 1f of the Appendix does not apply to those actions that do not affect human health or the environment. Other actions that have insignificant effects

on human health or the environment can be excluded from coverage by a DOT component.

One commenter suggested that this Order might be inconsistent with the Supreme Court's decision in *Adarand Constructors v. [redacted]*. DOT has concluded that, since the purpose of this Order is unrelated to the types of programs which were the subject of *Adarand*, this Order is not affected by the *Adarand* decision.

Dated: February 3, 1997

Federico F. [redacted],
Secretary of Transportation.

Department of Transportation,
Office of the Secretary,
Washington, D.C.

ORDER

Subject: Department of Transportation Actions To Address Environmental Justice in Minority Populations and Low-Income Populations

1. Purpose and Authority

- a. This Order establishes procedures for the Department of Transportation (DOT) to use in complying with Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, dated February 11, 1994. Relevant definitions are in the Appendix.
- b. Executive Order 12898 requires each Federal agency, to the greatest extent practicable and permitted by law, and consistent with the principles set forth in the report on the National Performance Review, to achieve environmental justice as part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects, including interrelated social and economic effects, of its programs, policies, and activities on minority populations and low-income populations in the United States. Compliance with this DOT Order is a key element in the environmental justice strategy adopted by DOT to implement the Executive Order, and can be achieved within the framework of existing laws, regulations, and guidance.
- c. Consistent with paragraph 6–609 of Executive Order 12898, this Order is limited to improving the internal management of the Department and is not intended to, nor does it, create any rights, benefits, or trust responsibility, substantive or procedural, enforceable at law or equity, by a party against the Department, its operating administrations, its officers, or any person. Nor should this Order be construed to create any right to judicial review involving the compliance or noncompliance with this Order by the Department, its operating administrations, its officers or any other person.

2. Scope

This Order applies to the Office of the Secretary, the United States Coast Guard, DOT's operating administrations, and all other DOT components.

3. Effective Date

This Order is effective upon its date of issuance.

4. Policy

- a. It is the policy of DOT to promote the principles of environmental justice (as embodied in the Executive Order) through the incorporation of those principles in all DOT programs, policies, and activities. This will be done by fully considering environmental justice principles throughout planning and

decision-making processes in the development of programs, policies, and activities, using the principles of the National Environmental Policy Act of 1969 (NEPA), Title VI of the Civil Rights Act of 1964 (Title VI), the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended, (URA), the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and other DOT statutes, regulations and guidance that address or affect infrastructure planning and decisionmaking; social, economic, or environmental matters; public health; and public involvement.

- b. In complying with this Order, DOT will rely upon existing authority to collect data and conduct research associated with environmental justice concerns. To the extent permitted by existing law, and whenever practical and appropriate to assure that disproportionately high and adverse effects on minority or low income populations are identified and addressed, DOT shall collect, maintain, and analyze information on the race, color, national origin, and income level of persons adversely affected by DOT programs, policies, and activities, and use such information in complying with this Order.

5. Integration With Existing Operations

- a. The Office of the Secretary and each operating administration shall determine the most effective and efficient way of integrating the processes and objectives of this Order with their existing regulations and guidance. Within six months of the date of this Order each operating administration will provide a report to the Assistant Secretary for Transportation Policy and the Director of the Departmental Office of Civil Rights describing the procedures it has developed to integrate, or how it is integrating, the processes and objectives set forth in this Order into its operations.
- b. In undertaking the integration with existing operations described in paragraph 5a, DOT shall observe the following principles:
 - (1) Planning and programming activities that have the potential to have a disproportionately high and adverse effect on human health or the environment shall include explicit consideration of the effects on minority populations and low-income populations. Procedures shall be established or expanded, as necessary, to provide meaningful opportunities for public involvement by members of minority populations and low-income populations during the planning and development of programs, policies, and activities (including the identification of potential effects, alternatives, and mitigation measures).
 - (2) Steps shall be taken to provide the public, including members of minority populations and low-income populations, access to public information concerning the human health or environmental impacts of programs, policies, and activities, including information that will address the concerns of minority and low-income populations regarding the health and environmental impacts of the proposed action.

- c. Future rulemaking activities undertaken pursuant to DOT Order 2100.5 (which governs all DOT rulemaking), and the development of any future guidance or procedures for DOT programs, policies, or activities that affect human health or the environment, shall address compliance with Executive Order 12898 and this Order, as appropriate.
 - d. The formulation of future DOT policy statements and proposals for legislation which may affect human health or the environment will include consideration of the provisions of Executive Order 12898 and this Order.
6. Ongoing DOT Responsibility Compliance with Executive Order 12898 is an ongoing DOT responsibility. DOT will continuously monitor its programs, policies, and activities to ensure that disproportionately high and adverse effects on minority populations and low-income populations are avoided, minimized or mitigated in a manner consistent with this Order and Executive Order 12898. This Order does not alter existing assignments or delegations of authority to the Operating Administrations or other DOT components.
7. Preventing Disproportionately High and Adverse Effects
- a. Under Title VI, each Federal agency is required to ensure that no person, on the ground of race, color, or national origin, is excluded from participation in, denied the benefits of, or subjected to discrimination under any program or activity receiving Federal financial assistance. This statute affects every program area in DOT. Consequently, DOT managers and staff must administer their programs in a manner to assure that no person is excluded from participating in, denied the benefits of, or subjected to discrimination by any program or activity of DOT because of race, color, or national origin.
 - b. It is DOT policy to actively administer and monitor its operations and decision making to assure that nondiscrimination is an integral part of its programs, policies, and activities. DOT currently administers policies, programs, and activities which are subject to the requirements of NEPA, Title VI, URA, ISTEA and other statutes that involve human health or environmental matters, or interrelated social and economic impacts. These requirements will be administered so as to identify, early in the development of the program, policy or activity, the risk of discrimination so that positive corrective action can be taken. In implementing these requirements, the following information should be obtained where relevant, appropriate and practical:
 - Population served and/or affected by race, color or national origin, and income level;
 - Proposed steps to guard against disproportionately high and adverse effects on persons on the basis of race, color, or national origin;
 - present and proposed membership by race, color, or national origin, in any planning or advisory body which is part of the program.
 - c. Statutes governing DOT operations will be administered so as to identify and avoid discrimination and avoid disproportionately high and adverse effects on minority populations and low-income populations by:

- (1) identifying and evaluating environmental, public health, and interrelated social and economic effects of DOT programs, policies and activities,
 - (2) proposing measures to avoid, minimize and/or mitigate disproportionately high and adverse environmental and public health effects and interrelated social and economic effects, and providing offsetting benefits and opportunities to enhance communities, neighborhoods, and individuals affected by DOT programs, policies and activities, where permitted by law and consistent with the Executive Order,
 - (3) considering alternatives to proposed programs, policies, and activities, where such alternatives would result in avoiding and/or minimizing disproportionately high and adverse human health or environmental impacts, consistent with the Executive Order, and
 - (4) eliciting public involvement opportunities and considering the results thereof, including soliciting input from affected minority and low-income populations in considering alternatives.
8. Actions To Address Disproportionately High and Adverse Effects
- a. Following the guidance set forth in this Order and its Appendix, the head of each Operating Administration and the responsible officials for other DOT components shall determine whether programs, policies, and activities for which they are responsible will have an adverse impact on minority and low-income populations and whether that adverse impact will be disproportionately high.
 - b. In making determinations regarding disproportionately high and adverse effects on minority and low-income populations, mitigation and enhancements measures that will be taken and all offsetting benefits to the affected minority and low-income populations may be taken into account, as well as the design, comparative impacts, and the relevant number of similar existing system elements in non-minority and non-low-income areas.
 - c. The Operating Administrators and other responsible DOT officials will ensure that any of their respective programs, policies or activities that will have a disproportionately high and adverse effect on minority populations or low-income populations will only be carried out if further mitigation measures or alternatives that would avoid or reduce the disproportionately high and adverse effect are not practicable. In determining whether a mitigation measure or an alternative is “practicable,” the social, economic (including costs) and environmental effects of avoiding or mitigating the adverse effects will be taken into account.
 - d. Operating Administrators and other responsible DOT officials will also ensure that any of their respective programs, policies or activities that will have a disproportionately high and adverse effect on populations protected by Title VI (“protected populations”) will only be carried out if:

- (1) a substantial 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 subparagraph (1) above), either (i) would have other adverse social, economic, environmental or human health impacts that are more severe, or (ii) would involve increased costs of extraordinary magnitude.
- e. DOT's responsibilities under Title VI and related statutes and regulations are not limited by this paragraph, nor does this paragraph limit or preclude claims by individuals or groups of people with respect to any DOT programs, policies, or activities under these authorities. Nothing in this Order adds to or reduces existing Title VI due process mechanisms.
 - f. The findings, determinations and/or demonstration made in accordance with this section must be appropriately documented, normally in the environmental impact statement or other NEPA document prepared for the program, policy or activity, or in other appropriate planning or program documentation.

Appendix


1. Definitions

The following terms where used in this Order shall have the following meanings:*

- a. DOT means the Office of the Secretary, DOT operating administrations, and all other DOT components.
- b. Low-Income means a person whose median household income is at or below the Department of Health and Human Services poverty guidelines.
- c. Minority means a person who is:
 - (1) Black (a person having origins in any of the black racial groups of Africa);
 - (2) Hispanic (a person of Mexican, Puerto Rican, Cuban, Central or South American, or other Spanish culture or origin, regardless of race);
 - (3) Asian American (a person having origins in any of the original peoples of the Far East, Southeast Asia, the Indian subcontinent, or the Pacific Islands); or
 - (4) American Indian and Alaskan Native (a person having origins in any of the original people of North America and who maintains cultural identification through tribal affiliation or community recognition).

* These definitions are intended to be consistent with the draft definitions for E.O. 12898 that have been issued by the Council on Environmental Quality and the Environmental Protection Agency. To the extent that these definitions vary from the CEQ and EPA draft definitions, they reflect further refinements deemed necessary to tailor the definitions to fit within the context of the DOT program.

- d. Low-Income Population means any readily identifiable group of low-income persons who live in geographic proximity, and, if circumstances warrant, geographically dispersed/ transient persons (such as migrant workers or Native Americans) who will be similarly affected by a proposed DOT program, policy or activity.
- e. Minority Population means any readily identifiable groups of minority persons who live in geographic proximity, and if circumstances warrant, geographically dispersed/ transient persons (such as migrant workers or Native Americans) who will be similarly affected by a proposed DOT program, policy or activity.
- f. Adverse effects means the totality of significant individual or cumulative human health or environmental effects, including interrelated social and economic effects, which may include, but are not limited to: bodily impairment, infirmity, illness or death; air, noise, and water pollution and soil contamination; destruction or disruption of man-made or natural resources; destruction or diminution of aesthetic values; destruction or disruption of community cohesion or a community's economic vitality; destruction or disruption of the availability of public and private facilities and services; vibration; adverse employment effects; displacement of persons, businesses, farms, or nonprofit organizations; increased traffic congestion, isolation, exclusion or separation of minority or low-income individuals within a given community or from the broader community; and the denial of, reduction in, or significant delay in the receipt of, benefits of DOT programs, policies, or activities.
- g. Disproportionately high and adverse effect on minority and low-income populations means an adverse effect that:
 - (1) is predominately borne by a minority population and/or a low-income population, or
 - (2) will be suffered by the minority population and/or low-income population and is appreciably more severe or greater in magnitude than the adverse effect that will be suffered by the non-minority population and/or non-low-income population.
- h. Programs, policies, and/or activities means all projects, programs, policies, and activities that affect human health or the environment, and which are undertaken or approved by DOT. These include, but are not limited to, permits, licenses, and financial assistance provided by DOT. Interrelated projects within a system may be considered to be a single project, program, policy or activity for purposes of this Order.
- i. Regulations and guidance means regulations, programs, policies, guidance, and procedures promulgated, issued, or approved by DOT.

Federico F. ,
Secretary of Transportation.

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APPENDIX B

MODELS AND DATA SOURCES

This appendix provides additional information on the technical analyses presented in this report. First, we discuss the several computer models used to estimate air pollution and noise impacts on populations living near the trial application road corridor. These models by necessity contain simplifying assumptions and have certain technical limitations, which we explain. Then, we review data requirements of the respective analyses and the sources we have used to obtain these data. Finally, we provide an overview of the geographic information system (GIS) methodology used to portray the spatial incidence of noise and air pollution and the relative presence of low-income populations and minority populations.

COMPUTER MODELS

During the course of our research, we used four computer models:

- MOBILE5a for carbon monoxide emissions,
- PART5 for particulate matter (PM₁₀),
- CAL3QHC(R) for dispersion of both carbon monoxide and particulates, and
- MINNOISE for noise levels.

All of these models are FORTRAN programs that use text files coded for input information. Each of the models is discussed in turn.

MOBILE5a

MOBILE5a is a computer model that estimates carbon monoxide, hydrocarbon, and nitrogen oxide emissions from gasoline- and diesel-powered vehicles. The U.S. EPA Office of Mobile Sources released this version of its MOBILE5 model in 1993. For a given road segment, the model estimates an aggregate emission level, based on emission rates for the types of motor vehicles of each model year expected to operate on the road. A user of the model specifies traffic mix and volume data. Base emission factors exist in the model for eight vehicle types and model years.²⁵

The model can be adjusted to compensate for several conditions that vary among communities and change over time. Conditions that can be specified include:

- **Region.** By indicating the region of the U.S. within which the community is located, the model adjusts for whether or not the community is at a high

²⁵ These base emission factors were derived from test measurements performed on in-use vehicles at various odometer readings. The emission rates are represented by a new vehicle level and a deterioration rate that factors in the increase in emissions as the vehicle ages.

altitude. Motor vehicles run at a richer fuel mixture (a higher fuel-to-air ratio) when operated at high altitudes, so emissions tend to be greater.

- **Temperature.** Motor vehicles also run at a richer fuel mixture when operated at low ambient temperatures. The user specifies minimum, average, and maximum temperatures for the community.
- **Calendar year.** Emission rates of new motor vehicles are gradually being reduced. MOBILE5a imputes fleet emission rates for the reference modeling year that is specified by the user, with generally lower rates applying to more recent years.
- **Average flow speed.** The speed at which traffic moves influences emission rates. Emissions are higher at low speeds, under 20 mph, and at speeds higher than 55 mph. For each segment that is modeled, the user specifies the average flow speed.
- **Vehicle operating temperature.** Three alternative prevailing operating temperatures can be specified: cold starts (newly started vehicles), hot starts (vehicles that have been running, turned off, and then restarted), and hot stabilized operating temperature.

Using information specified by the user, MOBILE5a estimates the emission rate of each vehicle class and model year. It then assigns an emission rate based on a weighted average of vehicle miles traveled (VMT) by vehicle category to estimate an overall emission level for the road segment.

PART5

PART5 is a computer model developed by the U.S. EPA Office of Mobile Sources that performs the same function as MOBILE5a, but it applies to particulate matter. The types of particulates emitted from motor vehicles include lead (no longer significant in the U.S. with the advent of lead-free fuel, see Bureau of Transportation Statistics 1996, p. 120), remaining carbon portion (RCP) due to incomplete combustion, sulfate emissions, brake and tire wear dust emissions, and road dust which is modeled as fugitive dust. The model estimates particulate emissions from 12 default vehicle types. As with MOBILE5a, PART5 allows the user to specify vehicle type and traffic volume; it also is possible to take into account the presence of buses powered by diesel engines.

The local conditions input to PART5 are similar to those for MOBILE5a, but in addition to region, modeling year, and flow speed, the model requires that the user specify the percentage of road silt (loose dirt) by type for unpaved roads and the presence of silt lying on the surface of paved roads. Alternatively, one can use estimates based on guidelines provided by the U.S. EPA for areas where no data on silt type or presence are available.

CAL3QHC(R)

CAL3QHC(R) is an air quality computer model developed by the California Department of Transportation (Caltrans) to estimate carbon monoxide and particulate matter concentrations generated by stop and go traffic at points near

roadway intersections. This model is an enhanced version of CALINE3, a line source model also developed by Caltrans. It uses vehicle emission estimates generated by MOBILE5a and PART5 in combination with climatological data and site geometry to predict dispersion patterns of pollutants in a small area (within 150 meters of the source).

Site geometry attributes input to CAL3QHC(R) include the physical layout of the respective road segments being analyzed and locations of people who may be affected by the pollution generated on the roadway. For each road segment, the user specifies parameter values related to the physical layout of any intersections, traffic characteristics including volume and speed, and prevailing climatological conditions. These inputs are discussed more fully in the section of this appendix on data requirements.

To address the issue of exposure to pollutants by people at varying distances from the roadway, CAL3QHC(R) allows a grid of receptor locations to be input. This grid enables the model to estimate carbon monoxide and particulate levels at multiple locations specified by the user. The process of developing the receptor grid is explained later in this appendix.

MINNOISE

MINNOISE is a computer model designed to estimate noise levels at various distances from a roadway, taking into account the presence of barriers that can impede noise propagation. The model was developed at the Minnesota Department of Transportation and is an enhanced version of the Federal Highway Administration STAMINA model. MINNOISE first estimates fluctuating traffic noise in one location along the roadway and then translates this estimate into a constant measure of acoustical intensity (sound pressure, as measured by A-weighted decibels, or dBA) at another location.

The amount of traffic noise estimated along a roadway depends on flow speed and density of various types of vehicles. MINNOISE has three default vehicle types: automobiles, medium-sized trucks, and heavy trucks, but the user can specify up to 14 vehicle types. For each user-specified vehicle type, however, one must provide emission parameters.

Noise levels at various locations along a roadway are dependent upon a person's position (distance from the roadway and angles from road segments where vehicles are accelerating, decelerating, or cruising); sound propagation rate; and presence of barriers such as buildings, high shrubbery, or trees. Regarding propagation rate, the model allows for two types of attenuation. Distance attenuation is assumed to occur essentially as an inverse square of distance from receiver to source. MINNOISE allows the user to adjust the sound propagation rate, taking into account surface conditions such as pavement. MINNOISE estimates how noise attenuation is influenced by various types of barriers. A series of "shielding factors" can be specified to represent actual conditions as accurately as possible.

Like CAL3QHC(R), MINNOISE enables the user to specify a series of receptor locations. For each location, MINNOISE estimates a mean constant level of acoustical

intensity. Percentage descriptors, such as L₁₀ or L₅₀ require further calculations, but they too can be generated. Specifically, percentile measures require the assumption that fluctuations in traffic noise are normally distributed during a time period, usually an hour.

BASIC DATA REQUIREMENTS

In the foregoing descriptions of the four computer models we used to estimate air pollution and noise in our trial application, we frequently mentioned the general types of data that are needed. In this section of the appendix, we examine more closely these data requirements, along with general sources for the data. Our discussion is organized around the categories of vehicle mix, traffic characteristics, climatological conditions, and road segment geometry, including receptor locations.

Vehicle mix

All four computer models depend on accurate data regarding the mix of vehicle types operating on the roadway being examined. In our trial application on U.S. Highway 63 in Waterloo, we relied on the Iowa Department of Transportation's primary road base file which contains data on VMT by vehicle type on each segment of the state's primary road system. Fortunately, U.S. Highway 63 is part of this system, so good data on vehicle mix are available.

In the case of local streets that intersect with U.S. Highway 63, we applied the default proportions contained in MOBILE5a and PART5, in combination with vehicle mix data for Black Hawk County contained in the Iowa Department of Transportation's *Vehicle Fleet Summary* (1995). This summary is based on vehicle registrations, which in Iowa are carried out at the county level. In using these data, we had to assume that the mix of vehicles operating on the city streets of Waterloo is comparable to the distribution of vehicles registered in the county.

Traffic characteristics

The three key traffic characteristics needed by the several models are volume, speed, and change in speed.

Volume. The Iowa primary road base file contains estimates of traffic volume for each segment (segments average 0.41 mile in length). Cross street traffic volumes rarely are measured because they typically are low-volume residential streets or urban arterials that are not part of the primary road system. We used estimates of traffic volumes for cross streets based on values for the appropriate road classes contained in the Highway Capacity Manual (Transportation Research Board 1994, p. 11-4).

Speed. On both U.S. Highway 63 and the cross streets, we used cruising speeds equal to posted speed limits. Alternatively, results of a traffic model can be used.

Change in speed. Speeds during acceleration and deceleration phases of traffic flow in appropriate segments are handled similarly in CAL3QHC(R) and MINNOISE: vehicle speed is a function of initial speed entering the segment and final speed exiting it. More specifically, these models require realistic information on vehicle

speed changes near the intersection being modeled. To achieve realism, each intersection is represented as having at least four speed phases: steady speed (cruising) approaching the intersection, deceleration, acceleration, and a return to steady speed. CAL3QHC(R) further requires a fifth phase for idling in a queue when vehicles are either stationary or moving at very low speeds.

To estimate the length of road over which each of the respective phases is occurring, traffic volumes and road capacity must be taken into account. Figure B-1 depicts the transition points between phases that result from these traffic data being input to the model. Each dot in the figure represents a point, denoted as x,y coordinates for input to the models, where vehicles leave one phase and begin another. Each approach to an intersection can be assigned its own set of phase characteristics in both CAL3QHC(R) and MINNOISE.

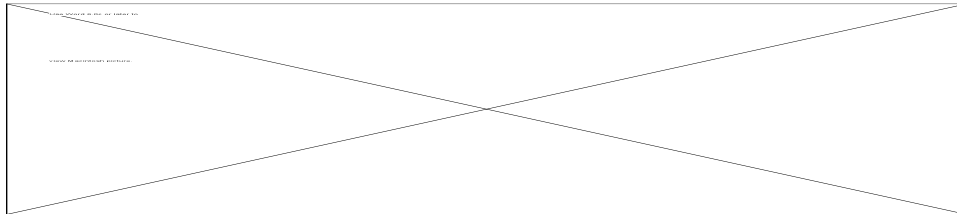


Figure B-1. Traffic phases

MINNOISE requires that the user calculate queue lengths manually, but CAL3QHC(R) contains an algorithm that estimates queue lengths based on traffic volume, type of traffic signal, light cycle length, red time length, saturation flow rate in the intersection (vehicles per hour of effective green time), and the extent to which vehicles arrive in clusters (or “platoons”).

Site geometry

Both the air pollution dispersion model, CAL3QHC(R), and the noise model, MINNOISE, require data on the physical layout of each intersection modeled, as well as the locations of people who may be affected by the air pollution or noise. The geometric description of these phenomena is presented in a system of x,y coordinates.

Figure B-2 depicts how site geometry is taken into account in the two models. They treat each road segment as a straight line; in the case of example segment A, the endpoints are x_1,y_1 and x_2,y_2 . On Segment A, traffic characteristics such as volume and speed are assumed to be constant. For example, the vehicle in segment A may be decelerating as it approaches a queue where other vehicles are idling at an intersection.

The person in Figure B-2 is located some perpendicular distance, D , from the roadway. His or her location is referred to as a receptor point, or receptor. Receptors, like road segments, are assigned x,y coordinates such as x_3,y_3 . Without altering the basic program, CAL3QHC(R) allows for 60 receptor locations within an x,y,z plane, while MINNOISE (and the STAMINA model) allows for 40 receptor locations. Multiple model runs enable additional receptor locations to be included.

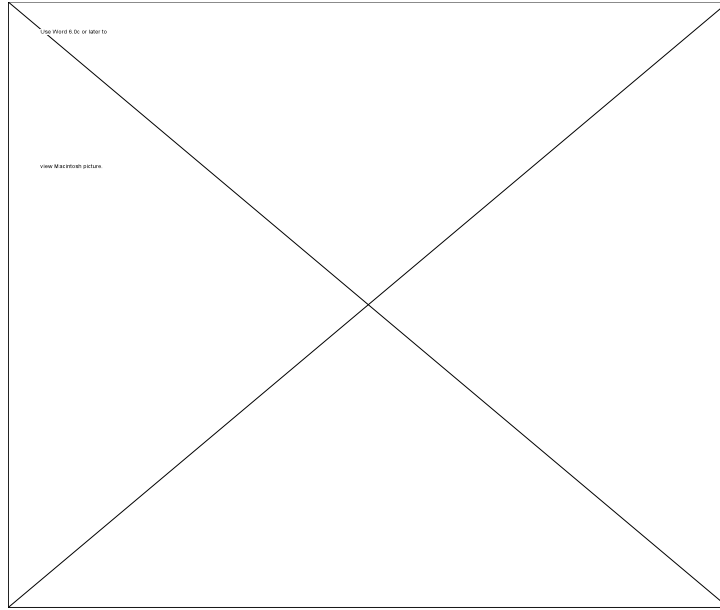


Figure B-2. Basic site geometry

SOURCE: Adapted from FHWA (1982, p. A-2).

Figure B-3 shows the layout of a receptor grid relative to U.S. Highway 63 (vertical axis) and an intersecting street (horizontal axis). The figure depicts a simple x,y plane in which the points are separated by 20 feet. The person in Figure B-2 (circled point) is located about 100 feet southeast of the intersection, and segment A begins 120 feet east of the intersection.

Creation of a simple grid eliminates the need to find the exact position of each building for every model run because any site within the receptor grid will be included. Once receptor locations are plotted, they can be used for any number of projects.

Climatological conditions

Emissions models, MOBILE5a and PART5, require climatological data to estimate emissions from vehicles on a roadway. CAL3QHC(R) needs these data to estimate the dispersion of pollutants. In our trial application, we obtained average winter temperature, number of precipitation days, and prevailing wind speed and direction from the National Climatic Data Center of the U.S. Department of Commerce for calendar years 1990 through 1993.

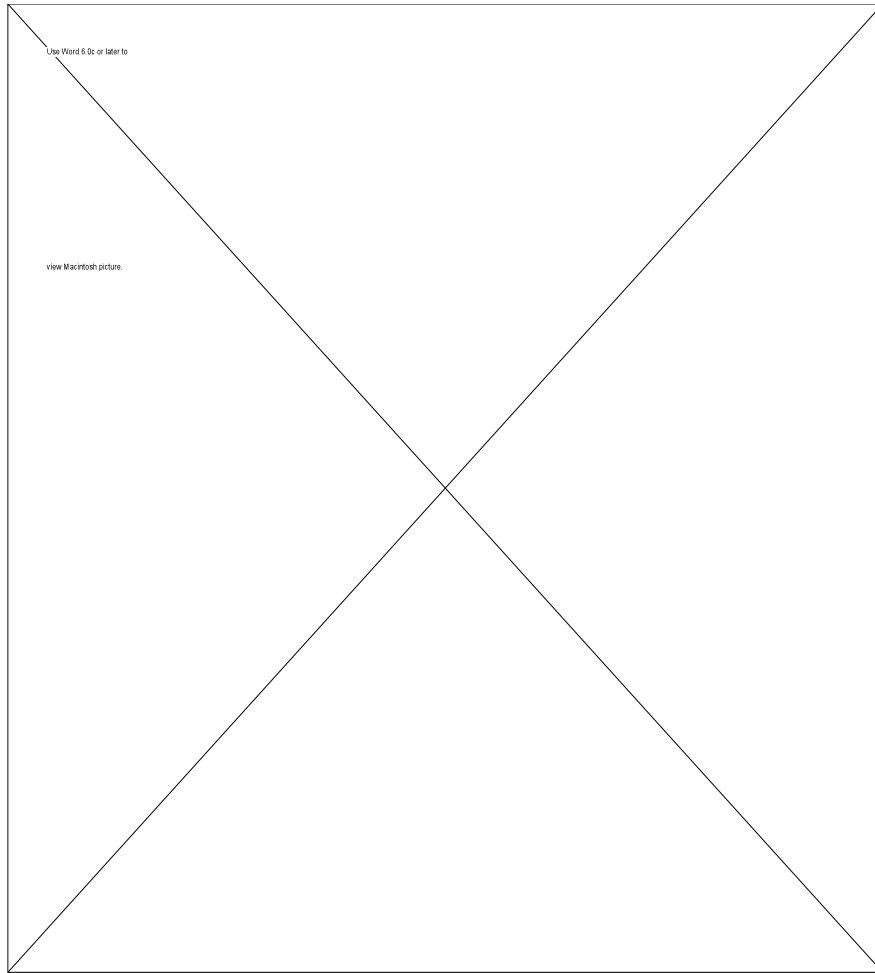


Figure B-3. Receptor grid, U.S. Highway 63 and an intersecting street

Wind speed and direction are key elements of the CAL3QHC(R) air pollution dispersion model. The model treats the air directly over the road as a mixing zone where there is uniform turbulence and emissions. This mixing zone traverses the entire width of the road, including all lanes and an additional three meters on either side to capture horizontal dispersion due to wake-induced turbulence.

Figure B-4 represents the forces acting on pollution particles as they leave the tailpipe. Mechanical turbulence is caused by vehicle movement, and thermal turbulence is brought about by hot vehicle exhaust gases. The plume of pollution particles is assumed to be normally distributed in both lateral and vertical dimensions.

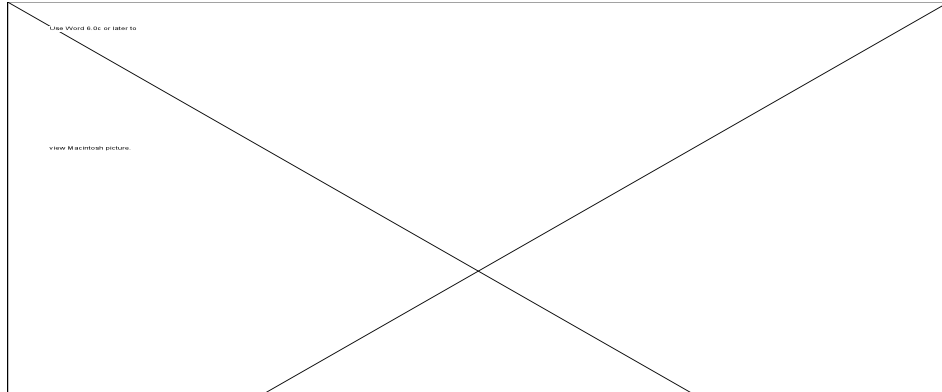


Figure B-4. Forces contributing to particle movement

As pollution particles enter the mixing zone, the wind and gravity act on the particles simultaneously; the particles are subjected to longitudinal, lateral, and vertical forces. The resulting dispersion is represented by x, y, and z axes of a coordinate system. CAL3QHC(R) estimates pollution levels at each receptor location for numerous wind angles on either side of the prevailing wind. For instance, the prevailing wind direction in Waterloo is 330 degrees (from north); the model estimates pollution levels at angles from a user-specified range, such as 323 degrees to 337 degrees. In our trial application, we estimated pollution levels resulting from wind coming from 330 degrees and input the results into a geographic information system (GIS) file.

GEOGRAPHIC INFORMATION SYSTEMS

In Chapter 3, we applied GIS to link the spatial incidence of air pollution and noise to census block demographic and economic characteristics. We now provide a summary of the general methodology for such linking of spatial data using GIS. Figure B-5 presents a schematic representation of how GIS integrates spatial data from more than one source and enables such integrated data to be shown graphically or in tabular form. GIS is particularly valuable when analyzing environmental justice implications of transportation system changes because data on such phenomena as air pollution or noise can be compared with data on population characteristics.

A major value of GIS software is its ability to convert geographic data that are not directly compatible to a common structure that is amenable to analysis. TransCAD and Maptitude are two GIS software packages with this capability.

The most commonly used federal data source is TIGER (topographically integrated geographic encoding and referencing) files. These digital files contain line and polygon information representing boundaries and areas that can be used by GIS software to create maps. The files contain boundaries of census tracts, block groups, and blocks, as well as the locations of streets and roads. Using these spatial references, information on such population characteristics as race and income from the Census of Population and Housing can be mapped using TIGER files.

Figure B-6 provides a sense of how GIS software incorporates road segment endpoint latitude and longitude coordinates to define the segment, enabling it to be represented as a line. The result can be a street map, and it can be integrated with such spatial phenomena as census block boundaries or traffic analysis zones (TAZs). In this way, population characteristics near an actual or proposed road alignment can be ascertained.

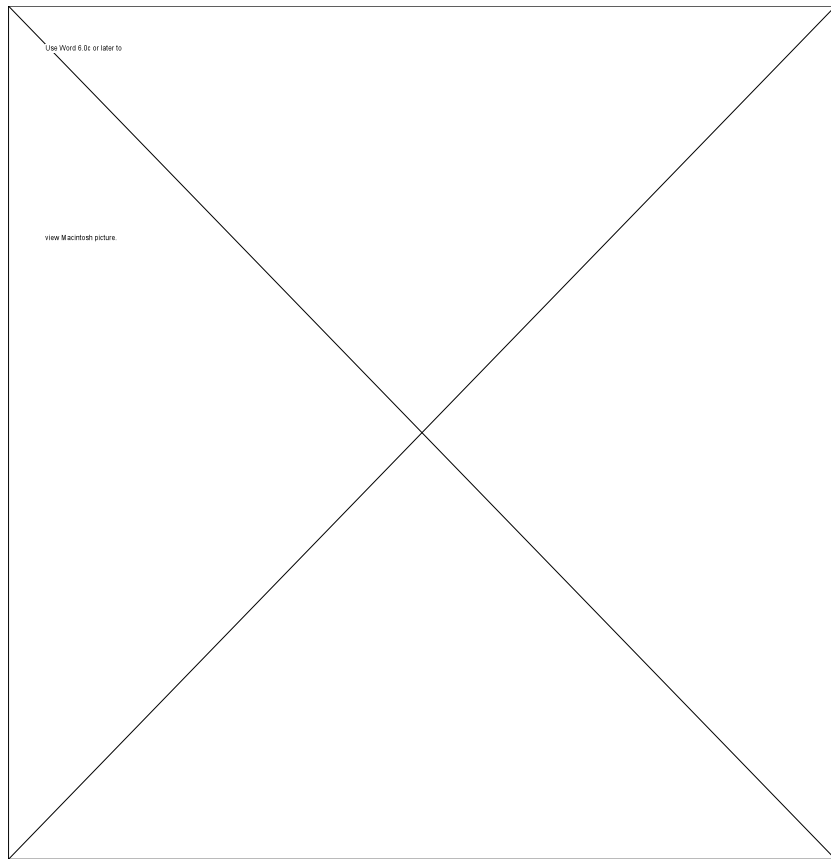


Figure B-5. GIS elements

Additionally, GIS can be applied to depict three-dimensional characteristics of an area to create a contour map. This capability is particularly useful in generating air pollution and noise maps that are based on values at receptor locations. Models such as CAL3QHC(R) and MINNOISE provide x,y coordinates of receptors and associated pollution or noise levels at the respective receptors.

Using software that enables one to create and maintain three-dimensional data sets, the “height” of spatial phenomena such as air pollution or noise can be represented. Literally, the z value of an x,y,z coordinate system pertains to the magnitude of what is being depicted.

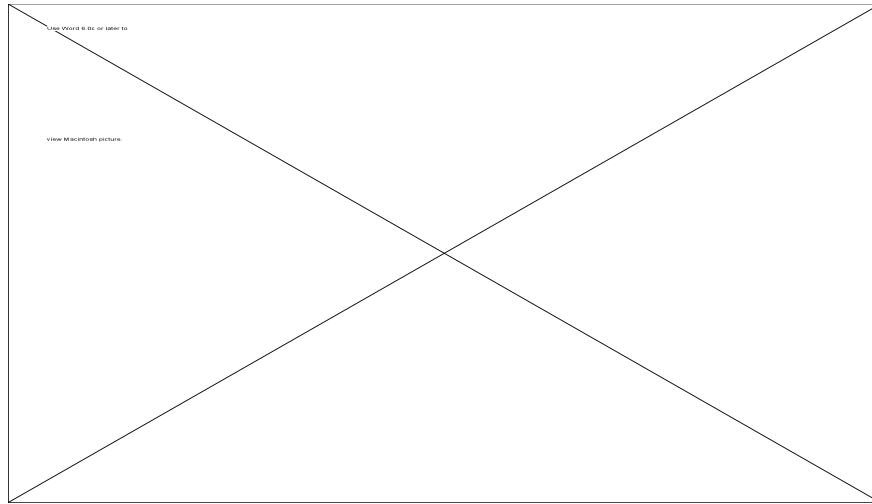


Figure B-6. Mapping road segments and a network from point references

A digital elevation model (DEM) enables a surface to be generated from a series of x,y,z points (Caliper Corporation 1996, p. 484). The model interpolates between known values at specific points, using a form of triangulation. GIS software can either represent the surface as a series of contours or it can summarize what is enclosed by the contours. This valuable capability allows analyses of levels of air pollution or noise within specified contour values and percentages of minority persons or low-income households, based on census block data.

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