SECTION 10: VISUAL QUALITY

OVERVIEW

Steps in the analysis	Methods
• Define the study area • Determine the changes to be considered and possible alternatives • Select a medium or media to simulate and present the environment • Identify respondents who will observe the environment and assess the likely effects of the project • Develop a procedure to record observer responses to the environment • Analyze the responses and provide feedback	• Visual preference surveys • Analogous case studies • Artist's sketches • Photo-realism techniques • GIS-based approaches • Virtual metropolitan models

Definition

Occasionally, transportation projects cause a significant visual effect on the surrounding built environment when they require new structures to be built, older structures to be torn down, or the view of pleasant settings or landscapes to be obscured. It is important to consider the magnitude of a project's effect on visual quality by making an assessment regarding its suitability within and compatibility with its particular urban setting. The visual effects of a project can best be estimated by using various simulation techniques and then consulting area - residents as to their perceptions and - preferences. These techniques allow residents to view the environment as it might look if alternative projects were constructed. The ultimate objective is to evaluate a project's visual effect in a comprehensive and systematic way that exposes the nature and distribution of visual consequences so that residents can express their preferences. Mitigation measures can then be evaluated based upon these preferences.

Transportation factors affecting visual quality in a community

Transportation projects can directly affect the visual quality of an area in the following ways:

- Construction of new structures may disrupt the visual quality of an area by the addition of a sizable new element.
- Projects that require the addition of new elements to an area also affect visual quality by blocking views of existing community features, including significant landmarks, open space, and special vistas.
- Projects that remove significant community features also change the visual structure of an area. For example, the removal of a memorable landmark may cause a significant visual effect.

- Projects that require items such as signage and lighting add visual clutter to the environment. Additionally, light may intrude on personal space as it trespasses onto private property.

Measuring visual quality

Perhaps the most highly regarded approach to assessing the visual quality of an urban area and how a particular change, such as a major transportation project, would affect that quality has been developed by Lynch (1960). Lynch advanced the concept of the "legibility" of an urban landscape, which he defined as "the ease with which its parts can be recognized and can be organized into a coherent pattern" (pp. 2–3). A legible urban environment helps a person feel a sense of place, and it adds to the depth of human experience. Lynch identified a series of five topological (i.e., not quantifiable) elements that affect how legible an urban landscape is:

1) **Paths** represent linear features in the landscape along which vehicular or pedestrian travel occurs.

2) **Edges** also are linear landscape elements, but they are seen as boundaries. Examples might include walls, boundaries of development or different types of land use, and major transportation features.

3) **Districts** are distinctive areas of a community that have some underlying character or unity about them.

4) **Nodes** are points or strategic spots that often are the intersections of paths. They also may be the core or identifiable centers of districts.

5) **Landmarks** also are point locations, but they are viewed externally, often from considerable distance. They can be used as a reference point within an area of a community.

Lynch's research led him to conclude that paths (roadways, in particular) are the dominant feature in most people's image of a community. He offered several suggestions that are worth considering during the development of an urban road and highway project, or the construction of any form of transportation superstructure, to make these facilities more pleasing to people traveling on them and to nearby residents.

- Features should be placed along the roadway to give it continuity. These features might include a boulevard planting of trees, a repetition of breaks in facades along the route, or clusters of plantings.

- Visual checkpoints along the route give order and texture to it. Examples are landmarks (i.e., well-defined features that people remember) and nodes (i.e., major points, such as attractive bridges or vistas).

- Placement of design features, such as attractive lighting or street furniture, that differentiate the particular roadway from other parallel routes can help it evoke a stronger and more positive image.

- Boring, featureless roadside visual environments that fail to interest passersby should be avoided. A good test is how much detail people living in or traveling through the area can provide when describing the place (i.e., is it "imageable"?).

Lynch's work is conceptual in nature, but it provides a useful context within which to think about visual effects and apply the several methods discussed in this section. Of particular salience to this guidebook is his observation that roadways can easily become edges that function to separate land uses on one side of a roadway from the other. This separation may be beneficial, or it may operate counter to neighborhood cohesiveness. Above all, Lynch's concept of legibility can serve as a criterion for assessing how a major transportation project would affect the landscape in a portion of a community. Most of the methods and techniques that follow in this section enable the concepts developed by Lynch to be applied.

Special issues

Values. There is no getting around the fact that the perception of what is aesthetically pleasing or offensive is inherently subjective. A visual effect that appears negligible to one person (e.g., a transportation analyst) may seem severe to others in the affected area. There really is no objective way to assess the severity or acceptability of visual effects; thus, our focus is on methods that allow one to present visual effects as effectively as possible so that people in the affected area have accurate information as they weigh the pros and cons of a transportation project.

Impact area. The area of a community affected visually by a transportation system change varies with the specific project and the changes to the area associated with it. Effects can be highly localized or broad as well as minor or major. For example, a project that causes a street light or vehicle lights to shine into a residential window has a localized effect, whereas a project that disrupts an entire neighborhood's view of a community landmark has a broad effect. A project that places a single sign in a neighborhood would have a minor effect, whereas a project that would mean closing a neighborhood park would have a major effect. The important point is that it is necessary to consider the impact area for each project based on the characteristics of the particular project.

WHEN TO DO THE ANALYSIS

Changes in the visual quality of an area should be estimated before any major street or highway project is carried out. This is especially true for projects that are likely to make significant visual changes to the abutting land uses.

Assessment of visual quality effects through simulation of the new visual environment serves a number of purposes:

- The assessment can serve as a presentation tool to provide information about the project's appearance to the public and decision-makers.
- It can serve as an analytical tool that the public can use to assess the effect of the project on surrounding properties, including views of scenic vistas.
- The assessment can serve as documentary evidence in environmental reports.

STEPS IN THE ANALYSIS

Step 1. Define the study area.

Transportation system changes occasionally bring about a significant visual effect in residential or commercial areas. The visual effect may include not only the actual appearance of the structure or facility, but also the view of key community landmarks that the transportation project may obstruct. To take into account the effect on the views of all affected properties, it may be necessary to include in the analysis more than the immediate area where the project would be located.

Roadway lighting, for example, may affect properties surrounding the roadway. One must consider both the lighting needs of the particular standard of roadway and the effect that the lighting may have on the types of land uses and activities located nearby. The impact area in this case would include the geographic area that might be expected to experience the glare. Different forms of visual effects are likely to require the analysis of varying impact areas.

Step 2. Determine the changes to be considered and possible alternatives.

By the time an analysis of visual effects occurs, the feasible alternatives for the project will normally have already been determined. At this point, one can consider what the visual effect would be for each specific alternative—for example, if a road were widened or if a transit route were added.

Step 3. Select a medium or media to simulate and present the environment.

Based on the scale of the project alternatives and the physical environment, as well as on the resources available, a simulation method must be selected. Simpler methods include using artist's sketches or analogous case studies. At times, a more comprehensive or detailed method may be desired, such as virtual computer models or photomontage techniques. Often, it may be beneficial to use a combination of approaches.

Step 4. Identify the respondents who will observe the environment and assess the likely effects of the project.

Several different groups of respondents may be useful in the evaluation process, including members of the public, nearby residents and local business owners, city officials, users of the proposed facility, and other interested parties. The review of the project may best be completed in several phases by different groups of respondents. After the respective groups are identified, the role they are to play must be determined.

Step 5. Develop a procedure to record observer responses to the environment.

Using the chosen approach or combination of approaches, participants can evaluate the environment without and with the simulated transportation project. Based on this input, the level of visual effect can be evaluated.

Step 6. Analyze the responses and provide feedback.

Based on input from the respondents, the proposed project can be redesigned or mitigation measures can be taken to lessen the visual effect. Follow-up meetings with the respondents allow proposals to be evaluated throughout the design stages so that the project is developed in such a way as to minimize the negative visual effect on the community.

METHODS

The ability of respondents to evaluate each alternative effectively will vary with the technique or method used to simulate the possible visual effects of each alternative. For example, a computerized “fly-through” of the scene would give viewers a more dynamic perspective of an alternative than would an artist’s rendering. On the other hand, cost, time, and knowledge of techniques also play a significant role in selecting the most appropriate method to use. Artist’s renderings provide a simpler, lower-cost solution than complex computer simulations. If multiple views or alternatives are to be considered, or if the project area is large and the project is likely to have a major visual effect, it may be more appropriate to use a computer simulation or photomontage slides.

In choosing a particular technique or combination of techniques, two evaluation principles should be considered. First, it is important to take into account the ability of the simulation technique(s) to depict the environment without and with the transportation system change. Important attributes of the presentation include accuracy, comprehensibility, and freedom from the creator’s bias. Second, it is also necessary to consider operational criteria, including production time, staff capabilities, and cost.

Method 1. Visual preference surveys

Visual preference surveys (VPS) are a form of resident survey that allows respondents to express their preferences for certain types of aesthetic features or design concepts. This approach may not actually involve presentation of the project in question, but rather generalized design approaches. Through their response to a series of slides, respondents rate their attitudes regarding images, which are later analyzed to produce a consensus of resident preferences. If the slides are well selected and able to give participants a clear sense of the choices to be made, this can be an effective tool. It is best used early in the project planning and design process.

See:

- Appendix B: Survey Methods, p. 211.

Information collection. Slides must be taken of a variety of alternative types of design and (re)development in an area surrounding a transportation project. Although one generally must use slides from a different area than the one in question, the key is to make the slides as analogous as possible to the conditions present at the project site.

Analysis. The slides are grouped into pairs, with each pair giving insight into preferences for a certain type of design. For example, one pair may depict two elevated superstructures, one with a pedestrian walkway attached. Other pairs could include different types of street lighting or signage. The slides are placed in a random order so that no pairs are presented together. This allows the analyst to gain insight regarding respondent preferences without the results being constrained by pairwise comparisons. Respondents view each slide in the series for only a few seconds and then rate it on a scale of +10 to -10. They are not allowed much time to consider the merits of each slide; the object is to measure their immediate reaction.

Measurement and presentation. Following viewing by a series of respondents, the mean scores and standard deviations are found for all slides. Then each pair of slides can be compared to assess what features were considered more or less desirable. By determining the highest- and lowest-ranking slides, one may also infer which components are necessary for the most preferable development or which visual effects are least acceptable.

Assessment. VPS are useful early in the development process to aid planners in assessing what types of structures, development strategies, and mitigation methods are preferred and what types are undesirable. Because this approach only provides insight into general types of development, it should be regarded primarily as a preliminary screening mechanism.

Method 2. Analogous case studies

Often, as a result of limited time or resources, it is best to use analogous case studies to assess the probable visual effects various project alternatives will have in a community. In this approach, numerous photos of alternative designs and mitigation devices (e.g., different noise abatement wall designs) are shown to focus groups or groups of local residents, business people, and decision-makers. Explanations are provided regarding the choices available.

Information collection. Case studies are available that enable one to assess a wide variety of visual effects, including transportation structures, buildings, vegetation, lighting, and even highline electric cables. Many of these case studies build upon each other, and thus provide a wide variety of perspectives in terms of how to assess visual effects and the types of effects that may occur. A number of the published case studies on visual effects employ the concepts developed by Lynch (1960).

In the information collection stage, one must be careful to select case studies appropriate to the potential visual effect of the project under consideration. It is important to consider the extent of transferability when selecting case studies—the type of project may not match up, or the visual context may be too dissimilar.

Analysis. Once case studies have been selected, the circumstances surrounding the current project alternatives can be compared with the case studies to evaluate what effects are likely to occur. For example, if a project requires a superstructure to be built, one can examine the visual effects caused by the construction of superstructures in other communities. When using a case study approach, it is good practice to consider the visual elements defined by Lynch and to present as many views as possible of such features as edges, landmarks, and nodes.

Measurement and presentation. Following the development of a list of likely effects and their acceptability, perhaps through a visual preference survey, the case studies can be used to provide guidance regarding how certain types of negative visual effects could be avoided or mitigated.

Assessment. Analogous case studies can provide a cost-effective means by which to assess visual quality because they require very little additional data to be collected. The case study method, however, lacks the precision that some other methods afford. It is unlikely that any given case study will contain exactly the same set of visual circumstances as the current project. In each potential application, one has to assess whether the best case studies available are similar enough to the proposed project to provide information that is not misleading.

Method 3. Artist's sketches

Artist's sketches are a traditional method of presenting preliminary proposals for a transportation project. Respondents can be given an early opportunity to react to renderings of a design proposal.

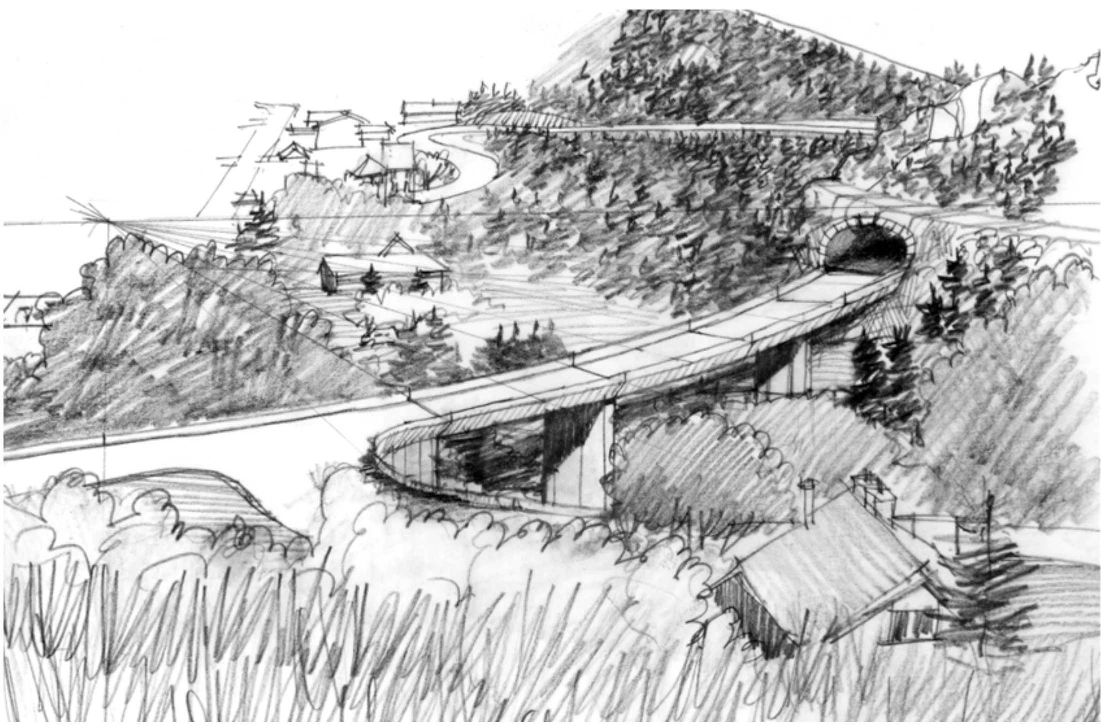
Information collection. Prior to producing the sketch, photos are taken of the area where the project is to be developed. These photos are used as a basis for the various sketches showing the visual environment without and with the project in place. It is useful to produce individual sketches of possible variations in the alternatives before combining the project sketches with a rendering of the background environment.

Analysis. Once the photos are taken and design options for the alternatives are constructed, the sketches can be created. Such sketches allow the artist to include variations in weather and vegetation that would not necessarily be possible with photomontage techniques (see Method 4). The artist can also create fine detail by including amenities such as decorative lighting, landscaping, or pedestrian areas that may be added to the design. Some of these amenities may be important to nearby residents and users of the facility, and the level of importance can be assessed using the sketches.

Example. A new highway alignment would bridge a river gorge. Near the gorge is a picturesque hill that must either be cut into or tunneled through to enable the road to have an acceptable grade. Because the gorge is highly visible to the adjacent community, residents are likely to want to minimize the visual effect of the highway.

Figure 10.1 presents artist's sketches of the two feasible approaches to constructing the highway. The sketches are sufficiently detailed to convey a reasonably clear image of how each alternative would fit with its natural surroundings.

Alternative involving cutting into hill.



Alternative involving a tunnel.

Figure 10.1. Artist's sketches of alternative highway designs
SOURCE: Burkart 1996.

Measurement and presentation. Respondents are given an opportunity to study the sketches and to indicate their preferences for specific designs and features. Based on a compilation of responses, one can generate descriptive statistics regarding preferences or simply provide a list of ideas regarding how the project under consideration could be improved. Then, based on the statistical analysis or the summary of ideas, the project alternatives can be redeveloped to include respondent preferences.

Assessment. Artist's sketches are useful when one is presenting only a small number of alternatives or views, as they are time-consuming to produce. Sketches do allow for particular attention to be paid to detail, which may enhance respondents' understanding of the alternatives. In a sense, it is the ability to add features deemed important to area residents and businesses that make artist's sketches a particularly valuable tool. A significant limitation of this approach is that artistically attractive sketches may produce an unrealistically favorable representation.

Renderings, including sketches, drawings, and paintings, present fixed views of a project, and it is difficult to show how the appearance would vary with observer position, weather, lighting, and project age. Also, the credibility and accuracy of individual renderings vary by their level of abstraction; usually, favorable responses increase in proportion to the amount of complexity and color in the renderings. When only a limited number of views are necessary, however, this method can save a considerable amount of time and expense. It allows general preferences and concerns to be understood at an early stage in the project planning process.

Method 4. Photo-realism techniques

Photomontage techniques are useful for evaluating how a number of alternatives may appear in a consistent visual environment. Using computer imaging techniques, various project alternatives are superimposed on digitized photographs of an existing environment. Respondents can evaluate the positive or negative effects of the proposed project in relation to this environment.

Information collection. Initial information collection involves preparing the photographs to be viewed. There several considerations regarding the visual setting and the proposals to be evaluated. First, one must decide if multidirectional views of the environment and alternatives will be necessary or if one view will be sufficient for all aspects of the analysis. For example, if a road corridor is being considered, a number of specific view points may be of concern. Although some views may show little effect or visual change, this lack of visual change may in itself be an important consideration. Second, the number of photographs to be used in the analysis must be determined. More photographs would enhance the ability of people to understand the true visual effect of the project, but the cost and time necessary to conduct the analysis is roughly proportional to the number of views presented. Third, one must determine whether the actual environment where the development would take place can be portrayed or whether a simulated setting should be used. A simulated setting is preferable when one is interested in how an alternative would look in a variety of environments, rather than in one particular location.

Once the visual images are generated, one must determine how they will be used. Two considerations are central here. First, one must determine the manner in which respondents will view the photos, including their number and sequence. Second, methods must be selected for superimposing images of the proposed project on the representation of the current visual environment. One method that is becoming more widely used is wire-frame scale models. This approach involves three steps: (1) generating the physical structure of the image of a facility with wire models, (2) superimposing photos of the wire-frame model on photos of the visual environment, and (3) incorporating renderings of the actual materials and colors over the wire-frame image. This technique allows the respondents to evaluate exactly what will be constructed, eliminating the subjective element of an artist's rendering.

As photo angles are chosen, one is well advised to keep Lynch's concept of imagability in mind. The real objective is to enable people viewing the photo renderings to gain an accurate sense of the "feel" of the visual environment, not just an idea of the appearance of isolated features.

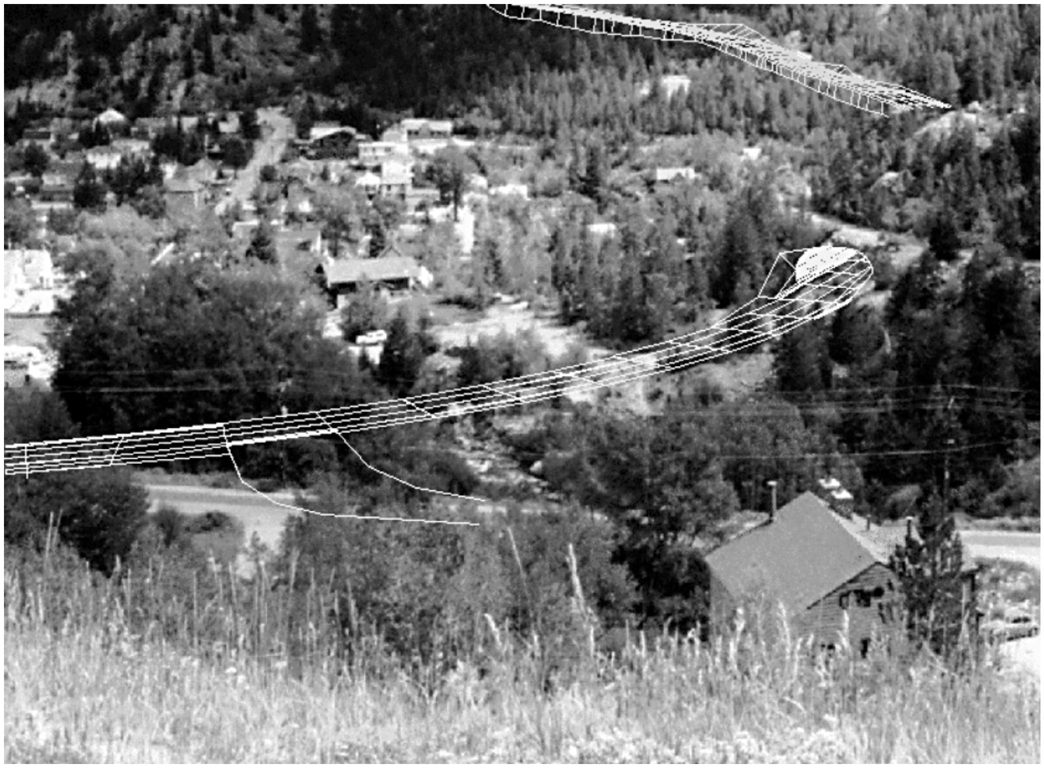
Analysis. Three dimensional (3-D) views of the area created on the computer can be matched to photos of the site, including lens angle, and sun angle for the date and time of the photo. The model can simulate the colors and materials that will be used in construction of the proposed alternatives, including asphalt, wall materials, guardrails, and vegetation conditions. Prior to viewing the photographs, respondents are given information about the simulation and any specific criteria on which they need to rate the slides. The procedure by which respondents will rate the project must also be determined. Possibilities include non-metric scaling, correlation analysis, and semantic differential scaling, among others.

Example 1. In the earlier example of a bridge traversing a river gorge, planners wanted to ensure that the proposed bridge was represented as accurately as possible in sketches to be presented to the public. A scale model of the bridge was built of wire and photographed. This photo was then superimposed over a photo of the affected area, as shown in the top frame of Figure 10.2. An artist then completed the rendering shown in the bottom frame of Figure 10.2 with greater assurance that the bridge would look like the one depicted in the sketch.

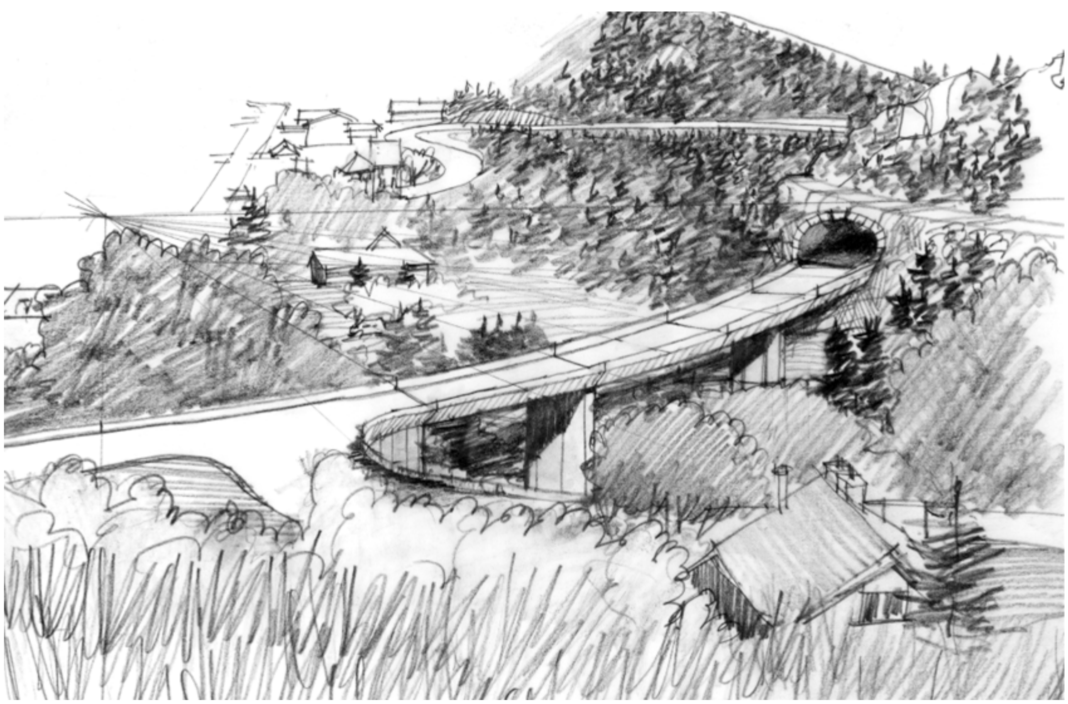
Example 2. An existing low-standard road runs through a heavily treed natural area. If the road were upgraded to a modern two-lane highway, one might wonder how the roadside environment would be affected. The top frame of Figure 10.3 shows a photo of the existing 16-ft wide asphalt roadway. The bottom frame presents a computer rendering of the proposed highway. Notice that near the top of this rendering there is a distant view of the highway as it works its way up the side of a hill. The rendering gives an accurate sense of how the highway and its environs would look to a traveler on the facility.

Measurement and presentation. Like artist's sketches, photomontage techniques allow respondent preferences for a particular design to be summarized and statistically analyzed. The results can then be used to help select from among alternative designs and to guide design revisions.

Assessment. Photomontage techniques allow for a high level of accuracy and precision because they use current photographs of the environment in tandem with representations of projects generated from wire-frame models. These techniques remove much of the bias associated with the quality and aesthetic appeal of artist's sketches.



Wire-frame model superimposed on landscape photo.



Rendering of wire-frame model and landscape.

Figure 10.2. Wire-frame model used to make rendering

SOURCE: Burkart 1996.

Photo of existing road.

Computer rendering of the proposed highway.

Figure 10.3. Computer rendering of a proposed highway and its environs
SOURCE: Burkart 1996.

Photomontage techniques require special skills and equipment that many public agencies do not possess. If the visual quality of a project is a major concern, however, these techniques may well be the best means for gauging public acceptance and preferences. Many colleges of architecture within universities have the capacity to carry out this form of analysis as do architecture and engineering consulting firms. As computer technology advances, imaging techniques are likely to become increasingly flexible and realistic.

Method 5. GIS-based approaches

See:

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

GIS can aid in the analysis of visual effects by enabling one to combine a spatial-referencing system with data on physical features and demographic statistics. One possibility for GIS applications is to use the GIS to locate key visual features (based on Lynch's concept), including (1) nodes as significant intersections of paths or concentrations of activity, (2) landmarks that are important elements of the environment, (3) boundaries of districts, and (4) important edges.

It is possible to superimpose elevation contour lines on a map to estimate horizontal and vertical lines of sight. These lines of sight can provide a sense of which of the significant features noted above would be visible from the transportation facility and how visible the facility would be from various vantage points. By evaluating the physical proximity of the facility to landmarks and scenic vistas and the line of sight from the facility to them, visual effects can be estimated.

Information collection. To perform this type of analysis, digital data on the roadway or transit line in question are a first-order requirement. A hand-held GPS receiver can be used to locate the perimeters of districts, the alignment of edges, locations of nodes, and placement of landmarks. Digitized elevation data often are available from municipal public works departments.

Analysis. Various maps can be constructed that depict the relationships between the transportation facility and various urban phenomena that are important to the visual quality of the affected part of the community. In places where an unwanted obstruction or other undesirable effect would exist, mitigation measures can be developed. The ability of these measures to screen or improve the visibility of certain features can also be assessed using the GIS database.

Measurement and presentation. A map developed using GIS data can be presented in a rendered form, making it more amenable to public viewing. Such a map could have lines of site depicted on it using contours and shading, along with distance scales and highlighted depictions of important features. A substantial amount of precise information can be presented that relates the proposed transportation project to what would be its surroundings.

Assessment. Especially when visual effects related to more distant objects or views are under consideration, a GIS-based approach may be preferable. This approach also is propitious when assessing proximity to what Lynch refers to as edges and districts, both of which can easily be depicted on a digital map. A shortcoming of this approach is that it does not actually provide elevation perspectives, so one can gain only a limited sense of the visual effects.

A logical approach may be to combine a GIS-based approach, which is able to provide a plan view of the project and environs, with a photomontage approach, which would provide elevations but no clear sense of relative geographic placement.

Method 6. Virtual metropolitan models

Virtual models combine many of the previously discussed computer techniques. Among these techniques are rendered wire models representing planned transportation structures such as bridges or elevated rail lines, aerial photographs, street-level imagery, and 3-D cityscapes. The objective is to produce realistic simulations of urban environments. With the integration of computer-aided design and GIS, and with visual simulation capabilities, the models can present neighborhoods as they currently exist, as well as the same neighborhoods if a new highway or other structure were added.

Information collection. Virtual models are expensive and time-consuming to develop; it can take years to build a complete model of a large urban area. Normally, it is more realistic to build smaller, linkable models that can range in size from approximately 1 to 15 square miles. Each high-resolution model can then be inserted into a database that may eventually become a comprehensive virtual model of the entire urban area.

The model's database requires information from a number of sources, including engineering maps and site visits. The database is constructed from simple 3-D models combined with aerial photographs and street-level video recordings, as well as interactive fly-through and walk-through demonstrations. Wire-frame representations of structures may form the basis for rendered pictorial depictions in the database.

Analysis. Virtual models can represent neighborhoods with a high level of detail, including street signs and plants. Once the model is operational, it is not difficult to evaluate how a transportation project would affect the visual quality of its surrounding area. It also is quite simple to alter the design of the facility to minimize unwanted visual effects.

Models can also include a time feature that allows trees and vegetation to "grow" over time or the construction of a transportation or housing project to be viewed in several phases. Such a time feature requires that a separate model be built for each time phase.

The user can also take advantage of "fly/drive" controls to travel within the modeled environment and accurately view any part of the model, including dynamic objects such as automobiles and pedestrians, which the user can follow as they move through the model. It is possible to manipulate 3-D objects within the model, including removing an object from the scene, substituting alternatives, comparing different design proposals, or accessing data associated with an object.

Measurement and presentation. A virtual model has many design-related applications, including the ability to present areas as they currently exist and to evaluate the effects of inserting potential transportation facilities. The accuracy of the presentation can be assessed by simply comparing the current environment in the model with personal observation in the real world. Applying the model, one can compare the visual effects of various alternatives and view these alternatives in future environments. Respondent reactions can then be used to guide revisions of the project proposal.

Assessment. Developing large-scale virtual models is a very complex, time-consuming, and expensive task. Particularly in situations in which a series of major transportation and other sizable projects are under consideration, such models can provide the best possible means for assessing how such projects would affect the visual quality of the area. Very rarely is an agency likely to be able to (or even need to) model a large portion of the community. More likely are applications in downtown areas or renewal districts. University planning and design departments have been among the most common developers of these large-scale models, and perhaps their resources can be combined with those of an agency if clear and substantial benefits would result from such a model.

RESOURCES

1) Appleyard, Donald. 1981. *Livable Streets*. Berkeley, CA: University of California Press.

   This book presents a survey conducted to assess people's attitudes and feelings toward heavily traveled streets and the community adjacent to them. Appleyard conducted 12 1-hour interviews with residents living on blocks of three streets in San Francisco and observed pedestrian and traffic activity on those streets.

2) Jepson, William, and Scott Friedman. 1998. "Simcity of Angels." *Civil Engineering*. Vol. 68, No. 6, pp. 44–47.

   This article details the creation of a virtual metropolitan model of the Los Angeles basin. It includes a history of the model's development, technical specifics, and current and possible future applications.

3) Pollock Shea, Cynthia. 1999. "Tools for Community Design and Decision Making; Part II: Inventory of Place-based Planning Tools." Florida Sustainable Community Center. Available at http://sustainable.state.fl.us/fdi/fscc/news/state/0004/tools2.htm.

   At this web site are connections to specific web sites of firms that specialize in various methods for assessing visual effects. Many of the sites feature demonstrations that illustrate creative applications of these methods. Among the methods included are visual preference surveys, photomontages, artist's sketches, and virtual metropolitan models.

4) Singh, R. R. 1999. "Sketching the City: A GIS-Based Approach*." Environment and Planning*. Vol. 26B, pp. 455–468.

   This article describes a GIS-based approach to creating sketch plans of cities, based on Kevin Lynch's theory of nodes. The method involves the use of digital data to create an algorithm able to identify nodes by using general specifications about them.

REFERENCES

Burkart, Roger. 1996. "Guanella Pass Visual Inventory." Denver, CO: DHM Design Corporation.

Lynch, Kevin. 1960. *Image of the City*. Cambridge, MA: The MIT Press.

SECTION 11: PROPERTY VALUES

OVERVIEW

Steps in the analysis	Methods
• Identify associated direct effects • Identify the setting of affected areas • Assess effects based on relationship of relevant factors to property value	• Market studies • Property comparisons • Case studies • Regression models

Definition

A transportation project may lead to, or contribute to, changes in the value of surrounding property (both land and buildings) and the use of surrounding land. Residents and businesses located in areas near proposed transportation facilities are thus often concerned about whether the project would lead to changes in the nature of the area's neighborhoods (i.e., affecting their desirability as places to live, work, and conduct business) or to changes in the value of their property (i.e., affecting personal wealth). These concerns are often topics of interest for both public discussion and environmental impact assessments.

Relationship of property values and land use

Property values are most often measured in terms of the average price for a specific type of land. Land use is most often described in terms of intensity and mix. Within most urbanized areas and in some rural areas, there are constraints on the allowable use for specific parcels of land, so transportation projects tend to most affect the value of land and the intensity of its use.

In this guidebook, we lump land use and property values together because they are closely related. Both reflect changes in the same basic factor—the *demand* for land (including the buildings on it). If a place becomes more desirable as a place to live or do business, then demand for that location increases as more people or businesses attempt to locate there, and property values are driven up. Changes in property values are a direct measure of shifts in demand for a location, and thus they represent a leading indicator of subsequent changes in the intensity of land use. For that reason, most of the discussion in this section is expressed in terms of property value effects.

Derivative relationship to other effects

It is important to note that property values and land use differ from most other factors addressed in this guide because they are actually the *results* of those other factors. In other words, changes in property values are driven by, and hence mirror, the value associated with local changes in accessibility, safety, noise, visual amenity, community cohesion, and business productivity. In general, a transportation project would only lead to changes in property values (and in subsequent land use) if it caused a direct change in one or more of these other local factors that affect the desirability of a location. That is why economists view changes in property values as a reflection of the "capitalized valuation" of other local factors.

From the viewpoint of public discussion and environmental impact analysis, property values and land use are still perfectly legitimate topics to be addressed. However, from the viewpoint of understanding causal relationships and conducting analyses, they must be considered as derivative effects in that they are driven by other social and economic factors. Any evaluation of potential project effects on land use and property values must thus first consider the expected effects on those other factors.

Transportation factors affecting property values and land use

Transportation projects affect property values and land use as a result of their direct effects on other social and economic factors. This is illustrated through the following examples that are expressed in terms of effects on property values (although they also apply for subsequent changes in the intensity of development for land that is not already built up).

- **Changes in accessibility**—Improved accessibility can increase property values. Proximity to highway off-ramps or transit stations often makes locations more convenient and desirable as places to live and do business, thus increasing property values. Conversely, projects that eliminate direct driveway access from an arterial to a commercial property or that create a barrier to its pedestrian access may reduce property values for the affected locations. Often, changes in accessibility also lead to distributive effects in terms of property values—shifting demand for property to the area with improved access and increasing rents there, while other areas experience reduced demand and therefore lower rents. Access improvements also can make it easier for local residents to travel to more distant businesses instead of patronizing local businesses, so in some cases access improvements could actually lead to reductions in economic viability and, hence, in local property values.

- **Changes in safety**—Improved safety can increase property values. Improvements such as traffic controls or separated pedestrian and bicycle routes can make nearby areas safer for children and other residents, thus increasing both the areas' attractiveness and property values. Conversely, greater traffic levels on neighborhood streets can make them more dangerous locations for pedestrians and children, thus reducing property values there.

- **Changes in noise**—Increased noise can reduce residential property values, even though roadway projects that increase noise may improve accessibility and, thus, property values for other land uses. New highways, rail lines, bus transfer stations, and airports can increase ambient noise levels and decrease the attractiveness of adjacent residential locations, thus diminishing property values (and possibly discouraging new residential development there). On the other hand, bypass highways or roads that divert traffic away from some existing arterials may reduce noise levels in some neighborhoods, thereby increasing residential property values.

- **Changes in visual quality**—Blocked views, visually unattractive scenes, or loss of privacy can reduce property values. For example, transit stations, bus terminals, parking structures, and elevated rights of way can potentially block views of scenery or be perceived as visually incompatible with existing adjacent park or residential properties, thus reducing residential property values. On the other hand, such facilities could also fill problematic vacant land and provide better visual continuity of a streetscape, thus increasing commercial property values.

- **Changes in community cohesion**—Projects that run through neighborhoods and cut off internal pedestrian access within them can affect the functioning of neighborhood activity centers and diminish residential property values. Highways, rail lines, or other forms of right of way can potentially split a neighborhood and cut off (or create roundabout routes for) access to schools, houses of worship, or neighborhood centers. Such effects would reduce property values in the affected areas. On the other hand, projects that create new pedestrian routes, divert heavy traffic that previously divided a neighborhood, or fill vacant parcels with desirable activity centers can potentially enhance community cohesion and increase property values.

- **Changes in business productivity**—Commercial and industrial property values typically reflect the revenue-generating potential of the location. New transit services or highways that increase market accessibility to a specific commercial or industrial area can increase the potential customer market that can be served by businesses there. They can also increase the potential labor market from which businesses can draw. Such effects allow businesses to grow and to achieve greater productivity through economies of scale. The resulting potential for additional revenue and profitability are reflected in increased property values for commercial and industrial land and buildings. On the other hand, right-of-way acquisitions may leave odd-shaped pieces of land with few practical uses, thus reducing their economic productivity and property value. Highways, rail lines, or busways that bisect a farm or a business center's parking area may reduce the productivity of the remaining property.

Special Issues

Different effects by location. The property value effects of an individual transportation project are often positive in some areas and negative in other areas. The variability of these effects results from differences in the individual factors: some effects, such as accessibility, can occur over a wide area, while other effects, such as noise, often involve a much smaller area. A new highway may reduce property values adjacent to the route between off-ramps due to the greater noise and reduced view, but increase property values near off-ramps due to the improved accessibility and potential business productivity. The same can happen for rail lines, where property values are decreased adjacent to the right-of-way, but increased near the stations. Therefore, any analysis of property tax effects must take into account the differential size of areas associated with accessibility, safety, noise, visual amenity, community cohesion, and business productivity.

Different effects by type of land use. The property value effects of an individual transportation project can differ for residential and commercial land. Widening an arterial can have short-term economic development effects that then have long-term ramifications in terms of property values. Specifically, the arterial may increase the value of parcels zoned for commercial uses due to the increased customer access and pass-by traffic, but reduce values of parcels zoned for residential use due to the effects on noise and view.

A transportation project can also sometimes influence a parcel's market category. A road or rail improvement may make what was previously considered marginal farmland suitable for commercial real estate or suburban residential development. Such shifts from one land use to another can have significant effects on land values, but such changes are typically limited to fringe locations where the affected land is not already built up or to urbanized areas where it has been underutilized. Conversely, negative effects on customer access to a property can make it unsuitable for its previous uses (such as retail), leading to its redevelopment for other uses (such as office space) that are less dependent on convenient access to pass-by traffic. Such changes in use for already built land are typically limited to special cases in which local accessibility has been substantially reduced or in which the property has been effectively cut off from adjoining activities.

Difficulty in observing and predicting property values. All of the methods for assessing effects on property values hinge on some form of observation of the property-value effects associated with similar types of projects in similar types of areas. To be useful, such observations require observable changes or differences in property values, reflecting a competitive and efficient market for land and buildings, unbiased by subsidies, price controls, or location restrictions.

WHEN TO DO THE ANALYSIS

Property value analysis. Analyses of the effects on property values should be conducted only when required for compensation programs or mitigation programs or when necessary to assess environmental justice issues (i.e., equity concerns involving vulnerable, low-income populations or minority populations). Although the direction of any potentially major (positive or negative) changes in property values can be reasonably identified in many cases, the estimation of actual monetary values is bound to be inexact. Furthermore, if relevant changes in accessibility, noise, visual quality, community cohesion, and business productivity have already been analyzed separately, there may be no need to make dollar estimates of their effect on property values.

The estimation of monetary values is not only inexact, it also raises public concern over whether some property owners would potentially reap future windfalls in wealth, while others would potentially suffer from unavoidable losses. In fact, it is the policy of most public agencies in the United States to compensate property owners only when their property must be taken or if they would be unable to continue with their current activities at the location in question. If local property owners would be able to continue their activities, public agencies typically would not compensate them for subsequent downturns in property values—nor would they ask owners to pay if property values subsequently increased.

Land use effects. Analysis of land use effects is necessary only when there is reason to expect major changes. Forecasting any long-term changes in the nature of neighborhoods is speculative and subject to a certain amount of controversy. Many exogenous factors such as business cycles, downturns and upturns in specific industries, shifts in regional economies, housing-market cycles, population inflows and outflows, and local levels of development activity can intensify or prevent future changes in land use. Thus, forecasts of land use changes, made using either land use models or local professional judgments, are subject to substantial uncertainty. Such analysis methods are of greatest use when there are concerns that a project would lead to substantial changes in the nature of a neighborhood or community. For example, there may be concerns that a proposed bypass highway would weaken commercial activity in a community's central core and change outlying farmland into sprawled strip commercial development. In such cases, studies of economic markets, as previously covered in Section 8 on economic development effects, can help address the issue and estimate the likely validity of those concerns.

Fiscal stress. Occasionally, a transportation project may require demolition of buildings, the owners of which pay property taxes. In some cases, enough real property may be removed from the tax rolls to weaken a community's fiscal strength; this in turn could force reductions in certain municipal services.

STEPS IN THE ANALYSIS

Following are the basic steps required for assessing the property value effects of transportation projects:

Step 1. Identify the associated direct effects.

One first should identify the specific nature of the project in terms of proposed right-of-way facilities (such as highways, rail lines, or bikeways), entry/exit facilities (such as train stations, bus terminals, or highway interchanges), and ancillary facilities (such as parking lots and maintenance sites). Based on the location of those facilities, one can identify the locations and breadth of areas that would experience effects in terms of accessibility, safety, noise, visual quality, community cohesion, and business productivity. From this information, it is possible to identify the types and the range of effects that are expected to be significant enough to possibly affect demand for a location and, hence, property values and uses.

Step 2. Identify the setting of affected areas.

For each of the affected areas identified in Step 1, one should identify the existing setting in terms of current land use mix and density, current property values, and rate of change in property values and development. For commercial or retail activity, one should also identify the location, size, and condition of major competing locations. This profile will provide a basis for establishing local vulnerability to changes in property values and for identifying factors that may increase or decrease the magnitude of such changes.

Step 3. Assess effects based on relationship of relevant factors to property value.

For each type of effect identified in Step 1, one should estimate the expected effect on property values through consideration of (1) normally expected effects on valuation and (2) aspects of the local setting that would mitigate or enhance the valuation of those effects. The first element may use one or more of the four basic methods discussed below. The second element may use local developer and planner interviews or case studies to refine the estimates of effects given local conditions.

METHODS

The most difficult element in the three steps just discussed is determining the effect on property values of local factors that influence how a transportation project would affect a particular area. There are essentially four methods for accomplishing this. They are described below.

Method 1. Market studies

See:

- Section 6: Accessibility, p. 77.
- Section 8: Economic Development, p. 107.

The value of commercial property is typically determined by its potential for generating income, a reflection of its productivity and accessibility to markets. Transportation projects can affect commercial property values through expanding business access to supplier markets, workforce markets, and customer markets. Such market expansion can both allow existing businesses to grow and attract additional businesses to the affected areas. Prior sections have addressed the estimation of these effects.

Information collection. One should develop a profile of the types of land use and commercial business activity occurring in the area that could be affected by proposed transportation improvements. Then, one estimates the extent to which the proposed transportation projects would affect pedestrian, automobile, and public transit access to the area.

Analysis. It is necessary to determine the extent to which the specific types of local businesses are sensitive to changes in market accessibility as well as how much external competition they face. This should be done following the process for measuring changes in customer and workforce accessibility, as previously discussed in Section 6. One then determines how these changes would affect the relative cost of doing business in the affected area and, hence, encourage or discourage business revenue growth there. This latter step should be done following the process for measuring business growth discussed in Section 8.

Example. If a small retail store sees its revenue potential grow from $300,000 to $350,000 per year, this $50,000 annual revenue increase, over a period of 20 years, could have a net present (i.e., capitalized) value as high as $470,000 (assuming 3 percent inflation and a 6 percent real discount rate, representing the time value of money).

Measurement and presentation. The analysis results should be translated into estimates of the annual change in business revenue in the affected area and the discounted present value of that additional revenue stream. This value, when expressed on a per-acre or per-square-foot basis, should represent the incremental effect of the proposed transportation project on the capitalized value of surrounding land and building space.

Assessment. This approach is primarily applicable for retail and service businesses that require access to a surrounding residential or business-oriented customer base. There is bound to be considerable uncertainty in forecasts of business performance, so this method can only be expected to provide a rough order-of-magnitude estimate. That said, such an estimate is often important to the area affected by the project.

Method 2. Property comparisons

For most residential properties, value is determined by features and desirability of location rather than by the potential for revenue generation. Real estate appraisers often derive estimates of real estate market values based in part on market prices for property in comparable situations located elsewhere in the community or region. These are known as "comparables" (or more commonly, as "comps"). The idea is that if there is a neighborhood that is to receive a new transportation facility such as a highway interchange, bikeway, or light-rail line, the effect on that neighborhood can be estimated by examining how property values currently vary among locations in and near similar neighborhoods that already have such facilities. Of course, this method can only be used if comparable situations currently exist in the local area.

Information collection. One must first identify a place in the local area where there is a transportation facility similar to that which is being proposed. This place should also share land use and socio-economic characteristics with the area around the proposed transportation project. It should definitely be within the same city, county, or metropolitan area as the proposed project location to ensure that the areas share the same regional economy, labor market, development industry, and zoning policies. If such a comparable situation exists, information should be collected on current market rents and current property prices for locations at varying distances from the existing transportation facility.

Analysis. The information on property prices within the comparison area is applied to calculate a rent or price gradient, reflecting the variation in existing property values associated with proximity to (or distance from) the proposed transportation project site. This gradient should in theory represent the combined market valuation of accessibility, noise, visual quality, community cohesion, and business productivity effects. It should be interpreted as reflecting the degree to which property values increase or decrease with proximity to transportation facilities similar to those being proposed.

Example. Property owners whose homes are near, but not adjacent to, a proposed new highway interchange are worried that the project would reduce their property values. Analysis is conducted of property values in a roughly similar type of neighborhood elsewhere in the city where there is an already existing highway interchange. It is found that property values in the comparable area currently rise with proximity to the interchange, as long as they do not actually abut it. The finding from the comparable situation is that proximity to an interchange does not necessarily reduce property values in the given type of neighborhood being studied.

Measurement and presentation. Often comparables are not available. Even when they do exist, they are often less-than-perfect matches to the proposed project and setting. When this is so, findings concerning price gradients need to be adjusted in light of the differences between the two areas to determine whether the proposed new facility location has unique characteristics that would increase or reduce the property value effects of the proposed project relative to those found in the comparison area.

Assessment. This method has limited applicability. It is appropriate only if (1) there are similar transportation facilities already existing elsewhere in the local area and (2) the nature of those facilities and the neighborhood(s) surrounding them, including characteristics of accessibility, noise, visual quality, community cohesion, and business productivity, are comparable with the proposed new facilities and the locations surrounding them.

Method 3. Case studies

The observed effects of similar transportation projects located elsewhere—locally, statewide, or nationally—may provide a basis for estimating the nature of transportation project effects on property values. Sometimes, while there may be no local comparables, there may be cases elsewhere in which reasonably similar projects were implemented in quite similar types of situations. A community facing a proposal for a bypass highway or a light-rail line may well find that there is no existing bypass highway or light-rail line in the region. In that case, the experience of similar neighborhoods in similar communities may be instructive.

The most important difference between this and the preceding method is the difference in time frame and in the geographic area for comparison. The preceding method derives its estimates of transportation effects by comparing current property values among different locations and is technically known as a "static comparison." In contrast, the case study method derives its estimates of transportation effects by comparing before and after conditions in a single case study area where a project was implemented and is technically known as a "time series comparison."

Information collection. To implement this method, one must identify similar types of transportation projects in other cities and obtain information regarding the nature of subsequent changes in surrounding property values—and intensity of land development—following the completion of those projects. The needed information may come from formal studies of sales price trends in the affected area (with some adjustment for trends also occurring elsewhere in the urban area), or it may come from interviews with knowledgeable persons (e.g., from real estate agencies, land development firms, or planning organizations).

Analysis. Findings from case studies elsewhere can help inform estimates of the potential effects of a proposed transportation facility in an entirely new location. Of course, adjustment must still be made to account for differences in starting prices of property as well as possible differences in characteristics of the nearby population base and employment base.

Example. In a comparable community, it was found that property values decreased 1 percent for each 100 additional average vehicles per day on residential streets. Assuming that similar effects would occur near the project in question, reducing traffic from 1,000 to 600 vehicles per day on a particular residential street would be predicted to increase property values by 4 percent. If there are 500 residential properties along that street with an average value of $100,000 each, the project can be predicted to increase total property values by $2 million (500 x $100,000 x 4 percent).

Measurement and presentation. The results can be presented to show which areas, streets, and groups of people around the existing transportation project experienced property value changes. GIS data files enable maps to be constructed that illustrate the locations and magnitudes of property value changes.

Assessment. Again, this method has limited use. Findings from prior case studies can be directly applied to the assessment of a proposed project only if the nature of the projects and their settings are very similar. When this is not the case, it will be necessary to distill applicable conclusions from case studies using the statistical regression method that is discussed next.

Method 4. Regression models

Although effects on commercial property values can typically be estimated on the basis of expected changes in the revenue-generating potential of a site, estimations of residential property values depend on the personal values assigned to locational improvement factors. Regression modeling is the most common statistical estimation technique used to relate differences in housing or land prices to characteristics of the property (e.g., building size, age, amenities, and lot size), characteristics of the neighborhood or location (e.g., average income and density of development), and special location features (such as accessibility, crime, noise level, and business market size). By comparing the values of many different homes across many different location settings within a region, it is possible to statistically estimate a series of coefficients that represent the incremental effect on property value associated with each individual characteristic of a building and its setting. Economists often refer to these regression estimates of property values as "hedonic price models" because they represent the implied prices that people place on obtaining desirable features in a property and avoiding undesirable ones.

The results of hedonic price models may be used to provide an estimate of the marginal value that people would place individually on noise, visual effect, accessibility, and other transportation effects *if all other features were to be held constant*. The limitation of these models is that they will usually have been estimated for data from other cities, so their transferability is at times questionable. In addition, the wide range of effect estimates found in such studies indicate that there is much variation in revealed effects for similar types of projects implemented in different settings and different cities. Table 11.1 shows findings from a sampling of regression (i.e., hedonic price) studies.

Information collection. Information is collected on changes over time in property sale prices and rents in a given area. Data should include price, size, and features of the land and building as well as accessibility and exposure to environmental impacts. The data must cover a variety of different properties and locations representing a range of land uses, lot sizes, and locations and of different exposures to changes in accessibility and other social and economic effects brought about by comparable transportation projects. A wide range of data is critical for the statistical analysis to work in isolating the values associated with the different factors.

Analysis. Multiple regression analysis, a commonly used statistical technique, is applied to isolate and estimate the effects that individual factors such as accessibility, noise, visual quality, community cohesion, and business productivity have on property values; it is also used to estimate the weight of each factor relative to other factors and the statistical significance of the results. The analysis provides "coefficients," multipliers that represent the average change in the dependent variable (i.e., property values) resulting from a given change in the independent variable (e.g., traffic volumes, noise levels, or proximity to transit service).

Table 11.1. Summary of regression studies of property-value effects

Study	Transportation factor	Observed effect
Residential property values (observed effects after project completion)		
Grand Rapids, MI (Bagby, 1980)	Change in traffic volume in a residential neighborhood	Property values decreased roughly 2% per additional 100 vehicles per day on residential streets.
Baton Rouge, LA (Hughes and Sirmans, 1992)	Difference in traffic volume on a street	On high-traffic streets, each additional 1,000 vehicles per day reduced property values by 1% in urban areas and 0.5% in suburban areas.
Brisbane, Australia (Williams, 1993)	Proximity to a freeway	Property values increased $1.78 per meter closer to an on-ramp, but decreased $4.48 per meter closer to the freeway (where there was no on-ramp).
Washington State (Palmquist, 1982)	Proximity to a newly constructed highway	Property values increased 15–17% where there was highway access, but properties located nearby decrease 0.2–1.2% per dBA of traffic noise.
San Francisco, CA (Bernick and Carroll, 1991)	Proximity to a rail transit station	Rents increased $0.05 per sq.ft. for each mile closer to a station.
Toronto, Canada (Bajic, 1983)	Proximity to a rail transit station	$5,370 premium for homes close to a station.
Commercial/Office rents (observed effects after project completion)		
Santa Clara, CA (Weinberger, 2000)	Proximity to a light-rail transit station	Rent values increased 3–6% for sites within a mile of a light-rail station.
Atlanta, GA (Bollinger et al., 1996)	Distance from a heavy-rail transit station	Rents increase 4% for sites close to a station.
San Francisco, CA (Landis and Loutzenheiser, 1995)	Distance from a heavy-rail transit station	No effect in San Francisco or Oakland; elsewhere rents increased 16% for sites up to 3/8 mile from a station.
Washington, DC (Rybeck, 1981)	Distance from a heavy-rail station	9–14% premium for sites close to a station.

It is important to include all potentially relevant variables in the statistical analysis. If a variable is omitted that has a significant effect on prices and is correlated with other variables that are included, the results can be biased. For example, if houses along busy streets tend to be older and smaller than those on quieter streets, but age and size are not considered in the regression analysis, the results may exaggerate the effect vehicle traffic has on housing prices. Thus, although regression analysis is relatively easy to perform using modern computer programs, such a study should be overseen by experienced researchers who can advise on survey techniques and data analysis and help to review results.

Example. To determine how traffic volumes affect adjacent property values, it is necessary to match data on traffic volumes with data on real estate sales. Regression analysis can then calculate a coefficient that reflects how each additional 100 vehicles per day on a street reduces adjacent residential property values. If the regression analysis indicates that residential property values would tend to decline 0.5 percent for each additional 100 vehicles per day on a street, and 500 properties with an average value of $100,000 are exposed to an average increase of 250 vehicles per day, then total effect would be $6,250,000 (500 x 0.05 x 2.5 x $100,000).

Measurement and presentation. The regression coefficients resulting from the statistical analysis can provide estimates of the total dollar value of effects or the percentage change in dollar value of property per unit change in proximity to particular types of transportation facilities. The proximity measure is typically considered to be a proxy for changes in accessibility, noise, visual quality, community cohesion, and business productivity associated with that type of transportation facility. Care must be taken, however, in the estimation and resulting extrapolation of such effects from one situation to another. For example, it might be inappropriate to assume that a change in traffic noise from 50 to 53 decibels has the same value as a change from 70 to 73 decibels.

Assessment. Statistical methods such as regression analysis are intended to isolate the effects of transportation projects from other confounding factors such as differences in the location and setting of the project. It should be kept in mind that the findings from regression studies to date indicate that there is significant variation in effects occurring in different places.

RESOURCES

1) Appraisal Institute. 1996. *The Appraisal of Real Estate*. Chicago, IL: The Appraisal Institute.

This book is a collection of instructions and injunctions that describe real estate valuation theory and current appraisal practice. It visits the traditional approaches to valuation and introduces new techniques for real estate appraisal.

2) Bookout, Lloyd W. Jr., Kenneth Leventhal and Company, The William E. Becker Organization, Economics Research Associates, and D. Scott Middleton. 1990. *Urban Land Institute Residential Development Handbook.* Washington, DC: The Urban Land Institute.

This book offers comprehensive information on important aspects of residential development. It covers project feasibility, financing, design principles, marketing, and other areas of residential development.

3) Delucchi, Mark A., and Shi-Ling Hsu. 1998. *External Damage Cost of Direct Noise from Motor Vehicles.* Report 14 in the Series: The Annualized Social Cost of Motor Vehicles in the United States, Based on 1990–1991 Data. Davis, CA: University of California, Davis, Institute of Transportation Studies.

   This report, from a series on the annualized social cost of motor vehicle use in the United States, summarizes research findings on property value impacts of transportation-related noise.

4) Fanning, Stephen F., Terry V. Grissom, and Thomas D. Pearson. 1994. *Market Analysis for Valuation Appraisals*. Chicago, IL: The Appraisal Institute.

   This text relates the concepts and techniques of market analysis directly to the appraisal of real estate. It presents applications to demonstrate each step in the market analysis process and provides information on financial feasibility analysis.

5) Ryan, Sherry. 1999. "Property Values and Transportation Facilities: Finding the Transportation and Land Use Connection." *Journal of Planning Literature*, Vol.13, No. 4, (May), pp. 412–427.

   This journal article discusses a study that reviewed empirical studies of the relationships between transportation facilities and property values. The article's main objective is to explain inconsistent results presented in literature over the past few decades.

REFERENCES

Bagby, Gordon. 1980. "Effects of Traffic Flow on Residential Property Values." *Journal of the American Planning Association*, Vol. 46, No. 1 (January), pp. 88–94.

Bajic, V. 1983. "The Effects of a New Subway Line on Housing Prices in Metropolitan Toronto." *Urban Studies,* Vol. 2, pp. 147–158.

Bernick, M., and M. Carroll. 1991. *A Study of Housing Built Near Rail Transit Stations: Northern California*. Working Paper 724. Berkeley, CA: Institute of Urban and Regional Development, University of California at Berkeley.

Bollinger, C., K. Ihlanfeldt, and D. Bowes. 1996. *Spatial Variation in Office Rents Within the Atlanta Region*. Working Paper. Atlanta, GA: Policy Research Center, Georgia State University.

Hughes, William, and C.F. Sirmans. 1992. "Traffic Externalities and Single-Family House Prices." *Journal of Regional Science*, Vol. 32, No. 4 (November), pp. 487–500.

Landis, J., and D. Loutzenheiser. 1995. *BART @ 20: BART Access and Office Building Performance.* Working Paper 648. Berkeley, CA: Institute of Urban and Regional Development, University of California at Berkeley.

Palmquist, R.B. 1982. "Impact of Highway Improvements on Property Values in Washington State." *Transportation Research Record 887.* Washington, DC: Transportation Research Board, National Research Council, pp. 22–29.

Rybeck, W. 1981. "Transit-Induced Land Values." *Economic Development Commentary*, Council for Urban Economic Development (October), pp. 16–20.

Weinberger, Rachel. 2000. "Commercial Property Values and Proximity to Light Rail: Calculating Benefits with Hedonic Price Model." Paper 00-0356, presented at the 2000 Transportation Research Board Annual Meeting, Washington, DC.

Williams, Alan W. 1993. "Transport, Rights-of-Way and Compensation: Injurious Affection from an Economic Perspective and Some Australian Evidence of Freeway Impacts." *International Journal of Transport Economics*, Vol. 20, No. 3 (October), pp. 285–294.

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SECTION 12: DISTRIBUTIVE EFFECTS

OVERVIEW

Steps in the analysis	Methods
• Do an initial screening • Develop a community profile and baseline inventory • Analyze project-related effects • Create maps showing relevant data and areas affected • Evaluate how various effects may lead to other effects • Compare the effects on protected populations with those in the entire impact area	• Buffer analysis • Travel demand modeling • Focus groups, interviews, and surveys • Travel diaries • Case study and comparison analyses • GIS overlay analysis • Barrier analysis

Definition

Distributive effects analysis examines the differences in the potential effects of transportation projects among different communities and population groups. One of many challenges facing transportation professionals is the need to find ways to measure the incidence (i.e., the spatial and demographic distribution of costs and benefits) of transportation projects. Increased information about the distribution of project effects can enable one to gain a more comprehensive under- standing of the effects of potential projects over both the short and long term.

As we discuss in Appendix D, distributive effects and environmental justice have become the focus of a growing body of federal laws and regulations. To get federal approval and certification, transportation agencies must be able to demonstrate the equity of their activities. To be sure, equity in transportation services involves a number of factors. Two important components are (1) project-related distributive effects and (2) ways to ensure equity throughout transportation and systems planning (e.g., equitable methods of public involvement and planning). In this guidebook, we focus on the first set of issues—those related to the distribution of the costs and benefits resulting from specific transportation projects. Although we do not discuss ways to promote equity during project and systems planning, the resources at the end of this section include publications that provide guidance on such issues.

More than most of the effects discussed in this guidebook, an analysis of distributive effects builds on the results of other analyses. In the previous sections, we have suggested methods for assessing the likely effects of a proposed transportation project. In this section, we focus on the important issue of *who* is likely to feel those effects (whether positive or negative). We must stress that it is necessary to understand the general nature of social and economic effects before considering the incidence of these effects.

As a general rule, the analysis of distributive effects should be at least a two-stage process. The first stage is a preliminary screening that can be as brief or as detailed as the situation warrants. This is a reconnaissance phase in which neighborhood characteristics and flash points are established so that the analysis of the project's effects can be tailored to the community. The second stage of the analysis occurs after the other effects have been determined; at this point, the nature of the effects are known, and it is time to look at how those effects are distributed among the populations and communities affected by the transportation project.

Transportation factors affecting distributive effects

With changes in transportation systems, as with almost any type of government project, the beneficiaries of a particular project may be difficult to identify because they are dispersed across a region. But the negatives associated with the projects—the noise, community disruption, and other effects we cover in this guidebook—often occur along a relatively narrow area immediately adjacent to the facility. Even when a project provides net gains across a region, the relative benefits and costs accruing to individuals and groups within the region vary so that those who must tolerate the worst effects may not be enjoying benefits commensurate with the costs they bear.

This may be especially true for low-income populations and minority populations. Members of minority groups and those who have lower incomes tend to rely more heavily on alternatives to the personal automobile (although this may be changing as more households acquire automobiles). As a result, many of the intended benefits of transportation system improvements—shorter travel times or lower vehicle operating costs, for instance—may result in fewer benefits for these communities than others.

For this reason, distributive effects analysis must consider the distribution of both the costs and the benefits of a transportation change—looking only at the negative effects can be misleading. To illustrate this point, Figure 12.1 shows two charts of the cost and benefit incidence (measured in dollars per person) by income of two proposed transportation projects. In Project A, the benefits accrue more extensively to low-income persons, while the costs generally rise with income; as such, it is a progressive project. Unlike Project A, Project B is a fairly clear example of a regressive project; the primary beneficiaries of the project have higher incomes, but those expected to bear the costs of the project have lower incomes.[1]

As we consider both the benefits and costs of a transportation project, the mismatch between them becomes apparent. Figure 12.2 is a Venn diagram that illustrates how transportation costs and benefits may be distributed within a region. In this diagram, we have four circles: the largest one represents the total regional population; a large circle (A) represents people who benefit (in either a large or small way) from the transportation change; a smaller circle (B) represents the

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[1] The regressive nature of this project does not necessarily mean that Project B is not worthwhile. The project may produce many systemwide benefits that, in conjunction with a future project, serve myriad network functions. It may also be the case, for instance, that the admittedly small monetary benefit to those with low incomes represents a relatively important addition to the community, such as a pedestrian overpass that members of the community feel strongly about. The question of regressivity is only one of many factors that should be considered, but mitigation of costs and compensation for the disproportionate costs that remain should be taken into account.

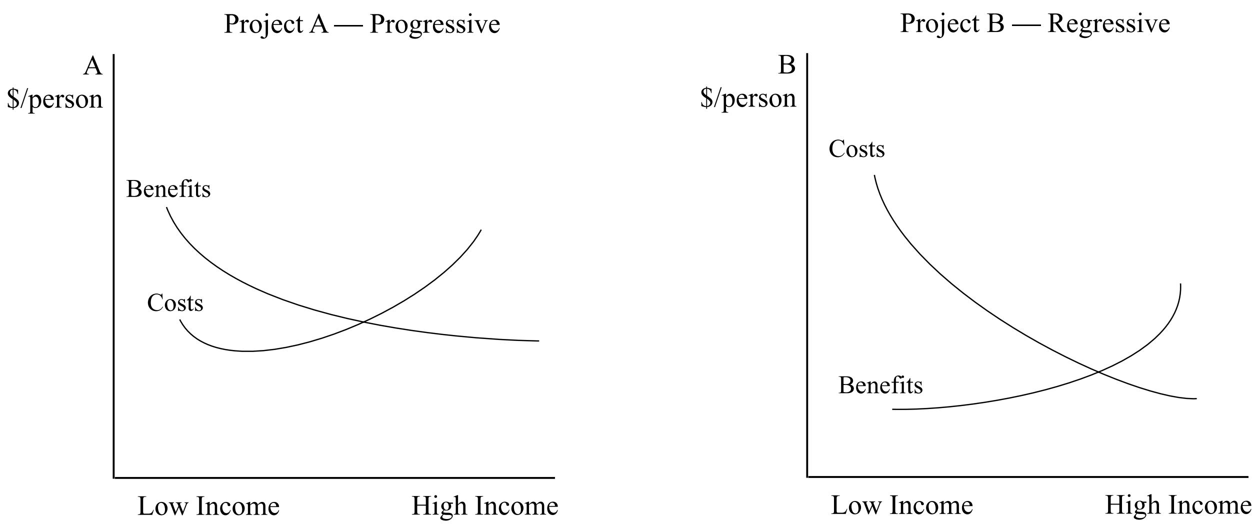

Figure 12.1. Benefit-cost incidence of two proposed transportation projects

smaller, more concentrated set of people who tolerate the costs associated with it; and finally, the smallest circle (C) represents populations who are protected by federal law and regulation—those who have incomes below the poverty line or belong to minority groups. In this diagram, we can see that many people who benefit from the project do not bear the most onerous costs. Conversely, some who must bear the costs of the project reap none of the benefits. There are those for whom the project brings both benefits and costs, however; they are represented as the area where the circles A and B overlap. In this case, protected populations mirror the dynamic of the population in general with some members gaining, some losing, and some getting a mix of both benefits and costs.

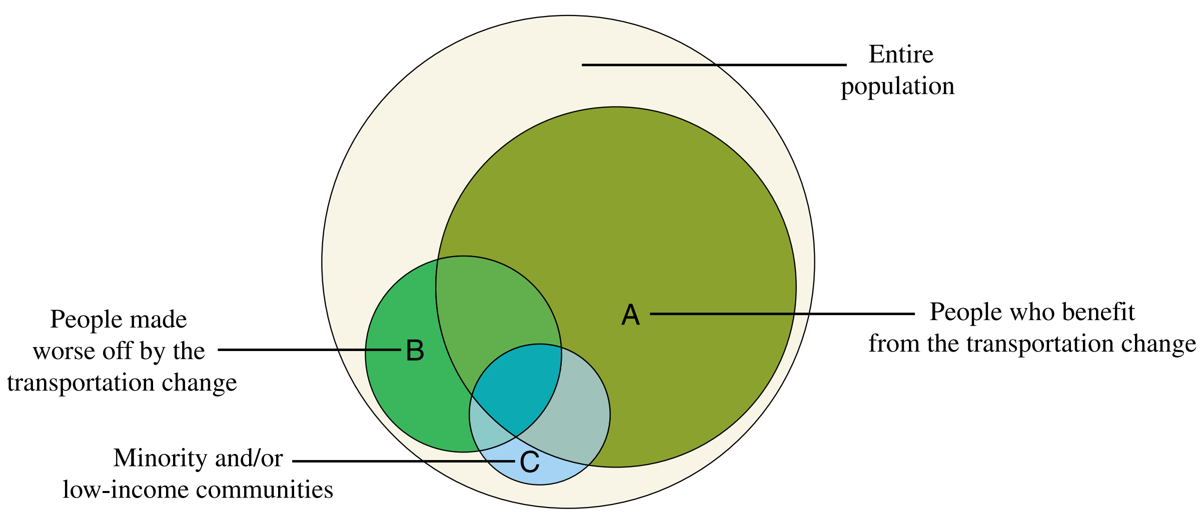

Figure 12.2. The distribution of project benefits and costs within a regional population

Although Figure 12.2 shows the mismatch, we can not conclude much about the distributive effects of the project unless we can get more specific information about the degree of effect for each group. It may be, for instance, that most people in circle B bear only very minor project-related costs, but that those contained in the area where circles B and C overlap—the area representing the costs borne by protected populations—face extreme losses to their community because of the project. The opposite also might be true, with the primary benefits of the project flowing to those who belong to protected populations (where circles A and C overlap).

Special Issues

Differing transportation needs and community values. In the previous sections of this guidebook, we have briefly discussed the equity considerations of various types of effects. Transportation changes bring about different consequences depending on the neighborhood in which they occur. For example, a transportation project that diminishes the mobility of people who have low incomes—many of whom have lower levels of mobility at the outset—has a considerably greater effect than does a reduction in mobility in a community of people with higher levels of mobility.

Table 12.1 provides a brief summary of the special transportation considerations for various population groups. The statements in Table 12.1 are generalizations; the only way to know a community's needs for certain is to ask its members. Although transportation needs generally vary even among the members of a particular community, the table lists a set of factors to bear in mind when considering a project's distributive effects within a specific community.

Racial and ethnic minority communities may have unique values and practices that a proposed project could disturb. For example, a community might have regular parades, block parties, or outdoor religious services. In rural areas, the landscape may support subsistence fishing, hunting, and vegetation gathering that could be adversely affected by a proposed project. The importance—or even existence—of such considerations may not be commonly known to outsiders. Unbiased site observations and information collection from the affected communities are essential to an understanding of a community's values and practices. Basic qualitative research techniques such as interviews and focus groups can be very helpful. These approaches must be carefully tailored to the characteristics of the population and the specific types of information needed for equity distribution analyses. Biased, flawed instruments will yield biased, flawed results, and incomplete information collection will impede comparative equity analyses.

Scale of analysis. An analysis of the distribution of transportation effects affecting neighborhoods must be at a microlevel. Adverse effects, such as noise, local traffic disruptions, and barrier effects, are typically most pronounced closest to the proposed project, while project benefits may accrue to the population of a much broader area. Even analysis at the traffic-analysis-zone (TAZ) or census-tract level may be too generalized to pick up some critical effects. Because each contains about 3,000 people, not all census tracts have homogeneous populations or uniform distributions of population types. To compare effects that would be experienced by low-income or minority groups with those of other population groups located within the same area, the scale of analysis must be fine-grained enough to differentiate between these groups in terms of both population and effects of given actions upon them.

Table 12.1. Summary of the special concerns related to low-income and minority communities

Social or economic effect	Special concerns
Changes in traveler costs	• The choice of residential location may be limited for many community members; they may be unable to relocate as a result of increased travel costs, and they may have no choice but to tolerate longer, more difficult commutes.
Transportation choice	• These populations tend to use non-motorized and transit modes more heavily than other communities do. • Patronage of local businesses may depend heavily on pedestrian and transit access.
Accessibility	• Communities with lower-income households tend to be less mobile; as a result, their options for employment and other activities are constrained.
Community cohesion	• Long residential histories, strong community ties (e.g., where residents exchange childcare or other services), and fewer housing choices deepen the effects of transportation disruptions and relocations in these communities. • Locally owned businesses tend to suffer because of disruptions of community cohesion because they are dependent on local clientele. • These populations may have unique value systems and community preferences significantly different from what outsiders would predict.
Traffic noise	• Baseline noise levels in these communities may already be higher than in other communities (due to proximity to existing highways or industrial areas). • Housing characteristics, such as poor-quality construction, less insulation, and open windows in the summer, may allow more traffic noise into the indoor environment.
Visual quality	• Cultural influences may form unique community visual quality standards that may be significantly different from what outsiders would predict.

Policy consistency. Projects that are not integral parts of established, comprehensive transportation plans may generate effects that run counter to transportation and other policy goals. Conflicts between land use planning and transportation planning goals due to poor planning integration are well known; less attention has been given to conflicts between transportation plans and social policies. Renewed attention to the civil rights of affected disadvantaged groups and to the access of automobile-less, low-income populations is changing that. Recent federal welfare reform legislation has spotlighted issues of unequal transportation access to jobs and high traveler costs facing low-income populations or minority populations. Transportation projects exacerbating either of these factors even temporarily can seriously impede welfare-to-work policy goals and result in economic harm to disadvantaged populations.

WHEN TO DO THE ANALYSIS

Given the importance of distributive effects, at least a brief initial screening should be performed for any given proposed transportation project. For projects that would affect protected populations, a comprehensive, in-depth analysis of a project's distributive effects is necessary.

Distributive effects analyses are best carried out in tandem with analyses of the other effects discussed throughout this guidebook.

STEPS IN THE ANALYSIS

There are six steps to a full-blown analysis of distributive effects, but in many instances, if not most, not all of these steps are likely to be necessary. The number of steps and the depth of the analysis is dependent on the nature of the proposed transportation project and on how it would affect the community. When several alternative projects are under consideration, the distributive effects of each must be assessed. The six steps are discussed in turn.

Step 1. Do an initial screening

The initial screening should be done at two levels—first at the systemwide level, and then at the neighborhood scale. Systemwide effects involving travel time savings, safety, and VOC can vary substantially across the community. For example, the construction of a freeway could reduce access to an employment center in some parts of the community, even though in most areas access would be improved. A travel demand model can provide a basis for assessing how transportation costs would change for each area of a community. In short, a systemwide analysis will enable one to evaluate which areas of the community would benefit by reductions in transportation costs and which (if any) would become worse off.

At the neighborhood scale, one should conduct an initial screening to evaluate how intensive an analysis is called for. Figure 12.3 shows the decision tree one can use in assessing whether the transportation project would affect neighboring residences, employment centers, or other activity centers. If a preliminary screening shows no neighboring land uses would be affected in any way, then no further analysis is necessary.

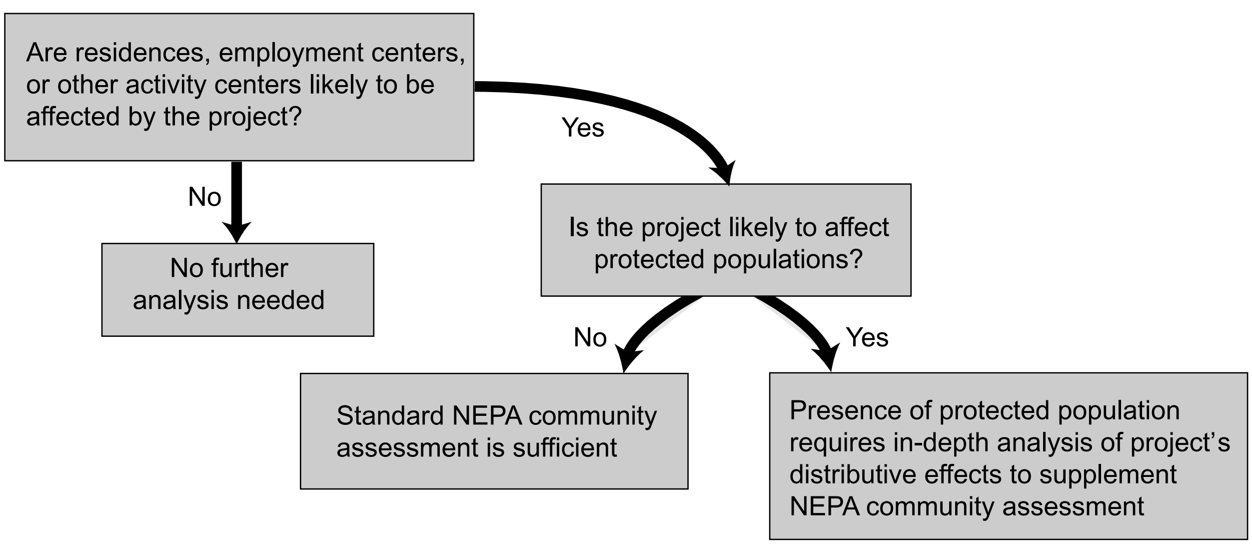

Figure 12.3. Steps in a preliminary screening

In most cases, however, the initial screening will that show some neighboring activities are likely to change because of a transportation project. One must then examine the proximate neighborhoods to see if the transportation change is likely to affect low-income populations or minority populations. To ascertain the presence of protected populations, the initial screening should include detailed information on the geographic distribution of the population by race, ethnicity, and income; in addition, the screening should identify any tribal lands or resources within the affected area.

An initial screening can be as detailed or as brief as is warranted by the project. It may, however, be useful to take the time to develop a fairly comprehensive inventory of neighboring communities during the initial screening. Even if there are no protected populations present, information gathered during the initial screening can be used for analyzing other effects, such as community cohesion, economic development, noise, or accessibility.

Methods useful for information gathering during the initial screening include the following:

- GIS buffer analysis to do a brief survey of the number of people, businesses, or activity centers that may be affected by the project;

- Reviews of existing community resources, such as community profiles done for city comprehensive or neighborhood planning purposes;

- Site visits to gain initial impressions; and

- Focus groups and public meetings to discover issues (especially flash points) and vital facilities and locations (e.g., community centers, social organizations, travel paths, and other features that may not be well known outside of the community).

In general, a combination of the above methods will give the richest results. Information on community history, relationships, and values are not evident in statistics and may be revealed only through direct contact with members of the affected communities.

Distributive effects analysis often relies on GIS as a means to organize and correlate impact analysis results and demographic data. GIS overlay analysis can be used to reconcile areas with dissimilar boundaries: socio-demographic data are generally available in administrative units, such as census blocks. The relevant impact area of a given transportation project is best determined by distance from the project, such as a radial distance (e.g., from an intersection or transit stop), or a fixed corridor distance on either side of a project (when the effect under consideration is something like noise).

It is advisable to make a preliminary estimate of the distance away from the roadway where effects are likely to be experienced in order to set basic geographic boundaries for the analysis. The boundaries should be based on the following:

- The scale of the project and the area expected to be affected (e.g. distance from the project, based on experience, case studies, and consultation with affected community members);

- The location of protected populations relative to the project; and
- The neighborhood boundaries as identified by local area planners, neighborhood associations, and community residents.

The boundaries of the analysis may have to be adjusted as the analysis progresses. It is important to keep in mind that space may not define community; a community generally will have a cultural identity, but it may not be concentrated and contained entirely within a geographic unit such as a town, county, or zip code. A transportation project that restricts access to a house of worship, for instance, may disrupt a community of people from disparate locations across the region. GIS-analysis will miss this type of information unless public input or expert interviews supplement the screening analysis in some way.

Step 2. Develop a community profile and baseline inventory

If the proposed project is likely to have a major effect on a community, a profile of that community should be developed to serve as a baseline against which various sorts of social and economic effects can be assessed. Table 12.2 lists the types of information one might consider including in a community baseline, along with possible data sources. Region 3 of the Environmental Protection Agency (EPA) has prepared a document useful in creating a community profile (see *Green Communities* at http://www.epa.gov/greenkit).

In practice, it is rare that a large number of the measures listed in Table 12.2 will be needed in any given situation. Data on the commuting patterns of neighborhood residents, for instance, are not relevant if a project's sole effect is to convert a parcel of land from a neighborhood park to the right-of-way for a street or road.

Example community profile. Figure 12.4 contains a map showing the neighborhood boundaries that a city uses in its comprehensive plan. Consultation with members of this community did yield slightly different boundaries, but there was a consensus that the boundaries shown in the figure generally reflect three distinct neighborhoods. One can use a GIS to aggregate information into neighborhood-level statistics, if needed.

Once the community profile is completed, it is possible to begin assessing the various effects the proposed transportation project is likely to have. After project effects have been assessed, these various effects can be mapped. The effects should then be examined qualitatively to estimate the cumulative effects of the project on the affected communities. The maps and the cumulative effects analysis should be reviewed to find areas of multiple effects. In consultation with affected populations, the project effects can be ranked in terms of their importance to the community and in terms of severity. Finally, the project's effects on protected populations and on the community as whole should be compared both qualitatively and quantitatively.

Table 12.2 Information to be included in a community baseline and possible sources

Information desired	Possible source
Employment	
• levels of employment • status of employment (part-time, temporary) • employment by type and location	• Census data • local economic or community development staff • travel diaries, surveys, focus groups
Mobility characteristics	
• automobile ownership and availability • common destinations within and outside of • community, including employment and other activities • use of alternative and non-motorized modes	• Nationwide Personal Transportation Survey • (NPTS) data • regional transportation planners • travel diaries, surveys, focus groups • digital phonebooks or business databases
Accessibility characteristics	
• transportation connectivity to region • degree of system fragmentation • efficiency and ease of intermodal connections	• regional transportation planners • surveys, focus groups, and image mapping
Quality of transit service	
• frequency and hours of service • access locations • system connectivity from neighborhoods • rates of usage • fare structure	• local and regional transit and paratransit • providers • rider or user surveys
Environmental or social stress factors	
• unemployment rates • incidence of serious illness • vehicle crash and pedestrian accident rates • proximity to polluting industries • proximity to other major roadways • existing noise levels	• Census data • local community development staff • state DOT accident databases • city public works or engineering departments • local land use maps • surveys and focus groups
Status and location of neighborhood resources	
• childcare centers (hours of operation, waiting lists, • costs) • medical facilities • public libraries • police and fire protection facilities (response times)	• digital phone books • police and fire department staff • local social services coordinators
Level of public infrastructure investment in community	
• reconstruction and repair of facilities (age of facilities or serviceability) • maintenance quality, such as snow removal	• site visits • city public works or engineering departments • surveys and focus groups

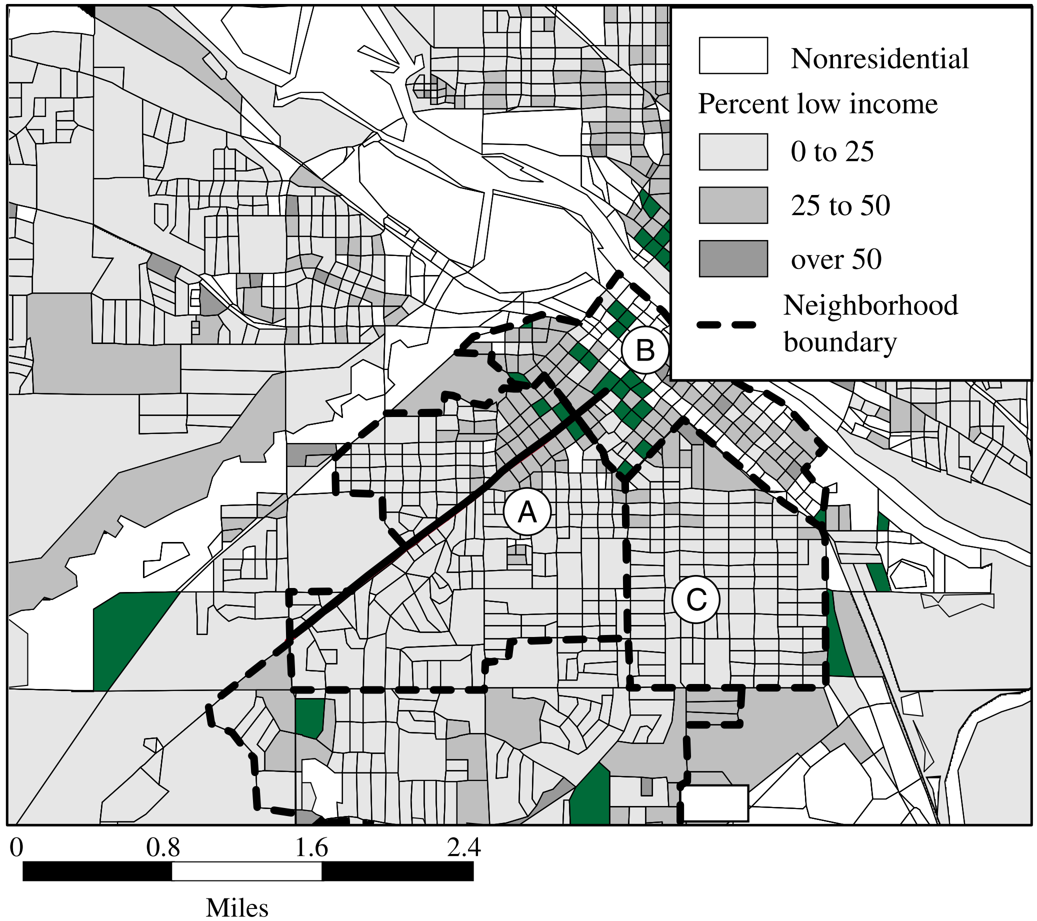

Figure 12.4. Sample neighborhood map

Neighborhoods A and B in Figure 12.4 fall within the buffer shown in Figure 12.7, so the community profile should concentrate on the baseline conditions in these two areas. Table 12.3 is a summary of a sample community profile that corresponds to the area in the map.

Step 3. Analyze project-related effects

The community profile and baseline inventory data can be useful for specific analyses, as discussed in the preceding sections. If possible, results of the various analyses of social and economic effects should be geocoded (or linked by distance to the project) even if the distances are only estimates.

Step 4. Create maps showing relevant data and areas affected

Focus groups and stated preference techniques can serve to identify what community members and analysts feel are the most serious costs and the most desirable benefits of the project. What are judged to be key effects can be mapped to show the spatial relationship between project costs and benefits using GIS overlay analysis. Map layers must include demographic data to perform a distributive effects analysis; the content of other map layers, of course, will depend on the types of effects being addressed.

Table 12.3. Information from a sample community profile

Employment

- Of the employed neighborhood residents, 91 percent work within the city; 9 percent work in the small, neighboring city (not shown).
- One of the largest employers of those with lower incomes in neighborhoods A and B is a plant southeast of the city. Travel demand models show that the proposed project would improve access to the plant for those in neighborhoods A and B who travel by automobile.
- Unemployment levels—even in the blocks with the highest concentrations of low-income persons—are only slightly higher (5 percent) than the rest of the metropolitan area (4 percent).

Mobility characteristics and major activity centers

- More than 95 percent of the residents of neighborhoods A and B own automobiles. For those in low-income areas, the percentage is lower, at 90 percent. These numbers are not unusual for the city, as it is an automobile-oriented community.
- Most people in our survey rated transit access from their neighborhood as "extremely poor." None of the survey respondents depended on city transit for work-related trips. During focus group discussions, however, several residents mentioned that they rely on an employer vanpool provided by the aforementioned plant for its employees. The company reports transporting about 50 employees a day from neighborhoods A and B.
- The adult residents of the area do not report extensive bicycle or pedestrian travel. Children in neighborhood A, however, bicycle to a school playground area frequently. Focus group participants expressed concern that the existing traffic on the three-lane facility is already dangerous for children; with the proposed project, many fear that children would face increased danger. This would require special attention during the analysis.
- Major activity centers include a thriving, retail-oriented downtown area in neighborhood B (represented as the nonresidential blocks just north of the cluster of blocks occupied by low-income populations). The retail area is a ten-block corridor with capacious parking on side streets. The transportation project would increase automobile access to the downtown, but increased traffic may impede pedestrian and bicycle access. Many of the downtown business owners strongly favor the expansion.

Other community characteristics relevant to the project

- Residents described a comparatively high level of community interaction and interdependence. Many, however, commented that the heavy traffic on the existing facility has already diminished neighbor-to-neighbor interaction in the area surrounding the road.
- Because there are very few nonresidential areas within the impact area, there are not many locally unwanted facilities. Residents do, however, point to a citywide recycling center as a traffic nuisance and an eyesore. Travel demand models show that the proposed project would increase access to the facility from other parts of the city.
- Noise levels sampled at various locations in neighborhoods A and B are lower than those found in other, similar residential areas sampled around the metropolitan area.

Figure 12.5 is an example of a map from the earlier case analysis. The location of the project relative to the neighborhood boundaries clearly shows areas that are effectively separated by it from the larger community. For areas A and B, the division from the larger neighborhood is obvious. In area C, it appears that the project would separate two blocks with high concentrations of low-income persons. The project runs directly through the low-income cluster.

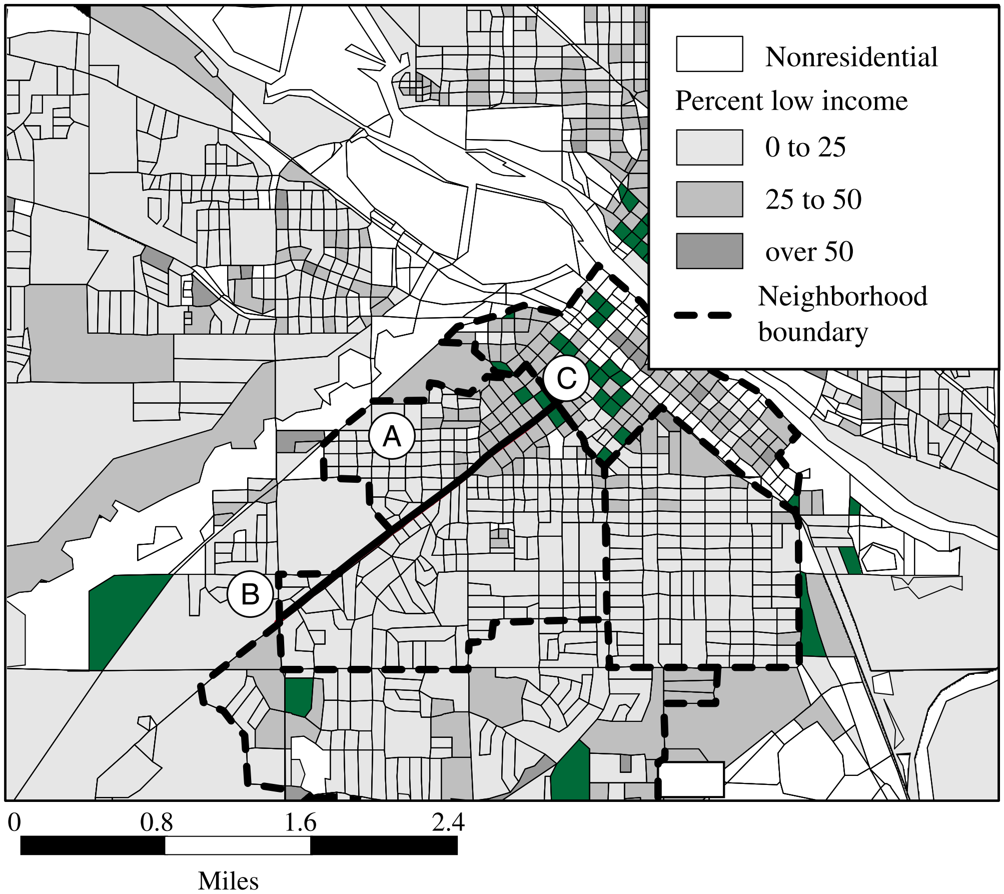

Figure 12.5. Community cohesion effects

Step 5. Evaluate how various effects may lead to other effects

Impact tree diagrams can be a useful way to summarize potential secondary and later-stage effects from a transportation project. Figure 12.6 is an example of an impact tree diagram that traces the long-term effects of residential relocation. The focus in the figure is on the economic changes likely to occur because of residential relocations. In another situation, the focus could be on relocation effects on community cohesion. The most important elements in Figure 12.6 are the secondary effects that would result from the removal of homes. It is these effects that should receive the most extensive analysis.

Step 6. Compare the effects on protected populations with those in the entire impact area

The outcome of this final step can be a quantitative summary or a qualitative assessment—or a mixture of both. Using GIS, various effects can be presented graphically (see, for example, Figure A.2 in Appendix A), and statistical summaries of distributive effects can be made (see Table A.2 in Appendix A). In one common application, the area within a specific contour line defined by a certain parameter value (e.g., level of noise or walking time to a public park) can be examined in terms of its ethnic and income composition. Such an analysis enables one to assess the extent to which the costs or benefits of a proposed project would be experienced by protected populations.

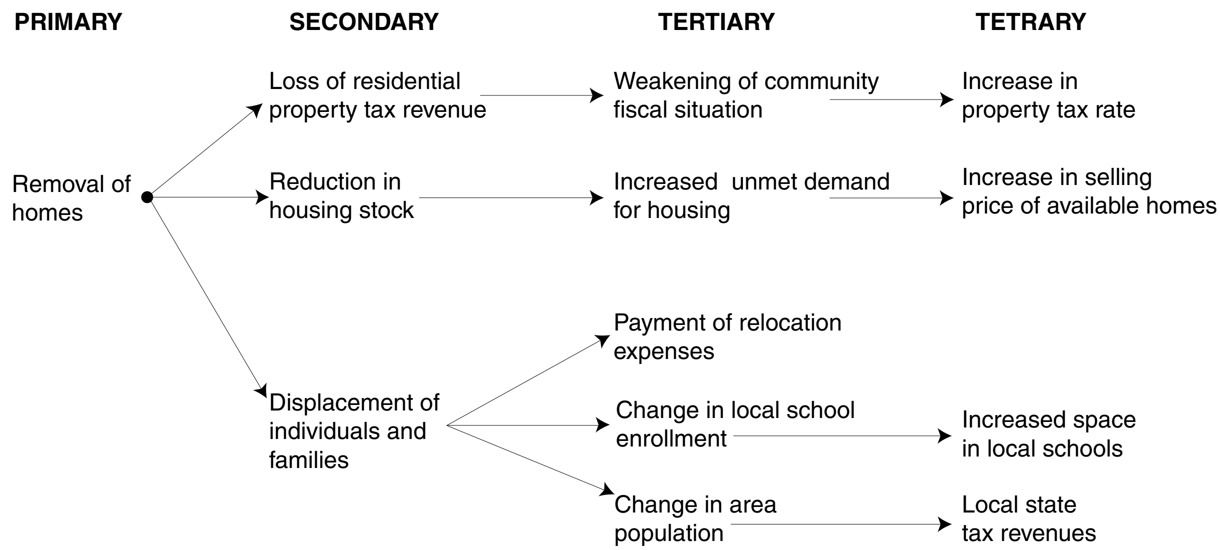

Figure 12.6. Example impact tree diagram

METHODS

Method 1. Buffer analysis

A buffer is an area of a specified width that surrounds one or more map features. Buffer analysis is used when examining areas affected by activities or events that take place at or near the map features. Buffer analysis is best used in the analysis of social and economic effects as a screening tool to determine if social or economic effects actually are likely in the predicted impact area before proceeding with a more in-depth analysis.

See:

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

Most GIS software packages include an analysis tool dedicated to creating buffers. All that is usually required is selecting the map feature to be buffered and then selecting the buffer tool. GIS packages include dialog boxes that walk a user through the buffering process. Many software packages offer different options for buffering, such as creating buffers of different specified sizes, creating evenly spaced buffers, or creating buffers of variable sizes using a database field as a reference.

Information collection. Demographic information may be available from the U.S. Census or from local area planners. Some information, such as incomes, may have to be estimated. Regional or municipal planning or engineering departments can usually provide geocoded street and network data. Specific activity centers or major employers may be identified during focus group discussions or interviews with local leaders. These may be geocoded using address-matching, hand-held GPS locators, or digital phonebooks.

Analysis. The analysis requires the creation of at least two choropleth maps: one representing low-income populations and the other representing the location of minority populations. To do the buffer, it is necessary to represent the proposed project in the GIS in whatever way best reflects the nature of the project: a line can represent a corridor, for instance, or a polygon feature can represent a district. Select a reasonable buffer distance based on the scale of the project, and create it. Once the buffer has been created, check the resultant map for low-income or minority populations within the buffer. If protected populations are present, proceed with a more in-depth analysis.

Example of buffer analysis. Figure 12.7 depicts a buffer analysis that might be performed as part of an initial screening. The map shows a representation of the proposed project—roughly a 2-mile stretch of a 3-lane arterial that the city proposes to widen to 4 lanes. We chose a relatively generous 1-mile buffer because at this point in the analysis it is unclear what the nature of the effects would be. When the project and its buffer are juxtaposed with a map showing the racial make-up of the area, it becomes evident that the population within the buffer is almost exclusively white. The map in Figure 12.7, however, shows the percent of the population that is estimated to have incomes below the poverty line. With this map, we can clearly see that there are some low-income areas clustered on the northernmost part of the buffer.

The other important feature of Figure 12.7 is the location of the emergency housing shelter. During discussions with local area planners, one of the area's residents disclosed that a church in the area provides both emergency housing and free hot lunches. When the address of the church was geocoded, it was possible to display the location of the church relative to the buffer and the proposed project. Although the church does not directly adjoin the project, it would be worthwhile to address project effects because they may affect this community resource. As the assessment of effects progresses, other neighborhood resources will become known; their locations can be mapped using the same method.

Measurement and presentation. The results of a buffer analysis are generally presented visually in maps (as in Figure 12.7). In addition, the spatial analysis features of the GIS enable one to calculate the number of people within the buffered area.

Assessment. Buffer analysis is a good tool for quick visual representation. It is a convenient way to do an initial screening for protected populations. Data problems, however, are one of the limitations of this technique. The most readily available data on race and income come from the Census, so often one must rely on comparatively old data for the demographic map layer; in areas with rapid growth and change (such as neighborhoods experiencing gentrification), there is a risk of creating an inaccurate map. Moreover, updating the Census data can be time-consuming, and the resulting data may not be much more accurate.

How wide a buffer to consider is another significant technical issue. If the buffer is too wide, it may bias the analysis as most (but not all) of negative project effects fall along a comparatively narrow area immediately adjoining the roadway. Yet, too narrow a buffer risks missing the presence of protected populations.

Finally, some very important aspects of a community may be missed with a buffer analysis. For projects in nonresidential areas, for instance, a buffer analysis cannot show the socio-demographic characteristics of the people who use those areas. For instance, a project that diminishes pedestrian access to an office building may seem to affect all groups equally. If the city's major social service provider were located in that building, however, the effects on protected populations might be much more serious. As a result, buffer analysis should be supplemented with community input.

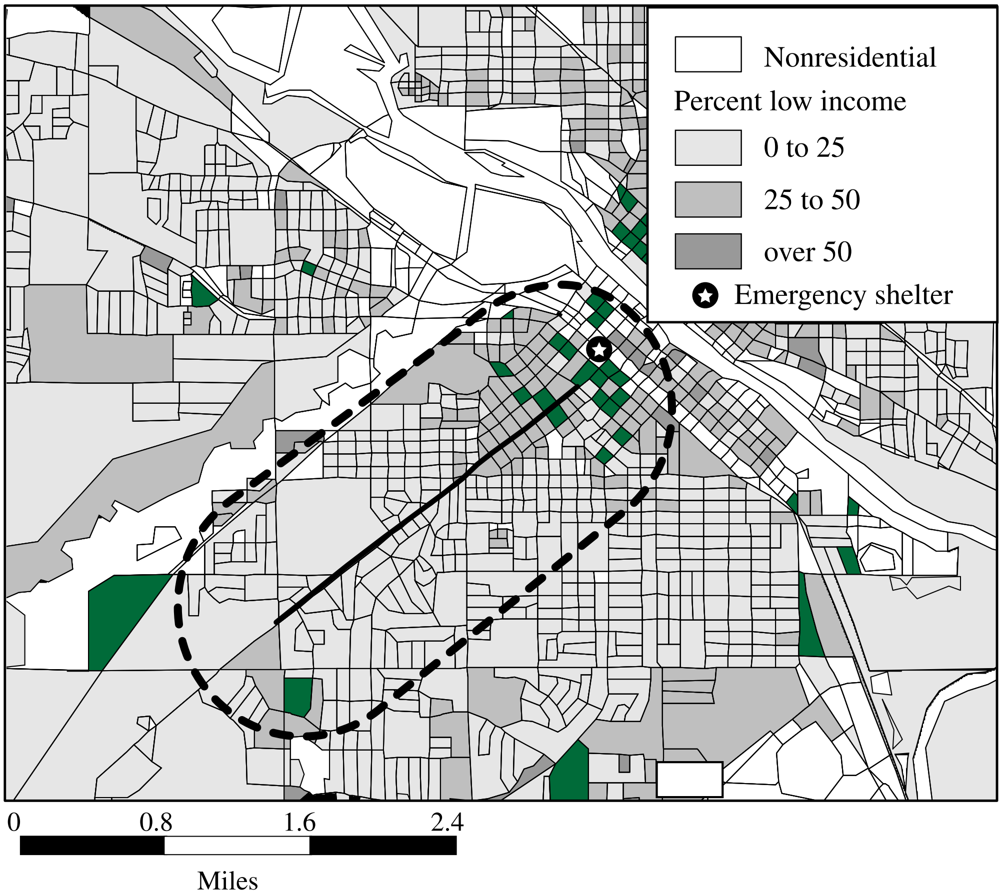

Figure 12.7. Sample buffer analysis

Even with its limitations, buffer analysis is a good, preliminary technique that is easy to do and yields results that are easy to understand and present.

Method 2. Travel demand modeling

See:

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

The basic framework and purposes of travel demand modeling are described in Appendix C of this guidebook. Travel demand models are usually constructed to estimate the benefits of a change to a region as a whole. Even though a proposed action may show a net economic benefit to a region, this benefit may come at a disproportionate cost to particular groups in the population. Regional travel demand models are not designed to pick up such local, disproportionate effects, although they are useful for indicating expected changes in regional travel patterns as they may affect a given community. In short, a travel demand model (used with caution) can be used to estimate benefits as well as costs to protected communities.

Information collection. Collection of information specific to the population in question—travel patterns (including trip linkages), automobile ownership and access rates, modal choices, destinations, times of travel, demographic characteristics, local economic indicators, housing conditions and trends, and the location and nature of public facilities and community institutions—is key to meaningful determinations of local effects and comparisons among them. Regional data for many of these attributes exist in most MPOs, although much of it may be outdated and not disaggregate enough for use in small-scale analyses. To the extent that it is available, locally specific information can be used to create small-scale models that show local changes in travel demand that may be caused by a given project. Local information can also be used in GIS mapping to show changes in access of protected populations to various destinations.

Analysis. It is generally not feasible to modify a travel demand model to reduce the scale of analysis below the TAZ, so a fairly aggregate level of analysis must be accepted. A TAZ typically contains approximately 20 census blocks. Nevertheless, it is possible to examine travel patterns and times en route to and from particular areas of the community. One can then assess the relative accessibility to TAZs containing activities likely to be important (e.g., employment sites, schools, parks and other recreational facilities, houses of worship, and various other public facilities). Changes in accessibility with the transportation system change in question can be estimated.

Measurement and presentation. Model output should show total changes in travel times and travel patterns expected to result from a transportation project as they would affect low-income or minority residents of affected communities. Analyses of changes revealed in regional models should be combined with analyses of changes shown in local models to provide an overall estimate of effects on individual communities or neighborhoods. It is good practice to compare these combined travel changes as they affect a given population with the effects of combined travel changes affecting other populations within the project impact area.

The standard valuation of travel time changes in terms of a regional wage rate tells little about the effects on individuals, nor does it suggest how changes in travel time might affect modal choices, among other things. Equity considerations center on the relative effects on individuals or specific population subgroups, not on the effects changes would have on the regional economy. Standard qualitative research tools, such as stated preference or revealed preference studies, can help establish the likely responses given populations would have to changes in travel costs.

Assessment. Standard travel demand models have limited use for microlevel analysis, although they can suggest ways that changes in regional travel, such as an increase in pass-through traffic, might affect a given community. It may take significant organizational resources to build a current, local database for a local model. Such a model, however, is much more likely to pick up changes in the travel patterns within the community.

In high-density urban areas, even spatially small TAZs may have multiple, distinct population sub-groups within them. These models use zone centroids as location approximations and calculate trip paths as travel between centroids or transportation system nodes; this can produce good approximations for many purposes, but may obscure effects on specific neighborhoods, depending on how accurately the TAZs reflect neighborhood boundaries.

Despite the limitations, travel demand models are one of the few methods available that can demonstrate changes in access for low-income and minority communities (at least for those in the community who use an automobile).

Method 3. Focus groups, interviews, and surveys

See:

- Appendix B: Survey Methods, p. 211.

To a certain extent, the quality of distributive effects analysis depends on how accurately the analysis captures the knowledge and preferences of those living in the affected area. Focus groups, interviews, and survey methods are a good means of acquiring information about residents' values, attitudes, and day-to-day travel needs. Focus groups and surveys are useful at any stage in the analysis, from the preliminary screening to the final stage of evaluating the severity and incidence of project effects. In the early stages of an analysis, they can provide insights into preferences and priorities; later, they are a means for gauging reactions to estimated effects and possible mitigative measures.

Information collection. For distributive effects analysis, surveys can be structured to elicit information about existing attitudes towards the community or reactions to a proposed project. One of the most productive uses of surveys and focus groups is to learn about the types of trips and the destinations that are important to various types of community residents. One can learn about current capabilities to make desired trips and how a project would change these capabilities. Surveys should be carefully pretested, especially in cross-cultural situations. In certain situations, it may be necessary to prepare questionnaires that have been translated into another language. Appendix B provides a general discussion of survey methods, focusing on helpful tips.

Analysis. As is true of any data-gathering method, focus groups and surveys are most useful when one has a very clear idea as to the purpose the data are to satisfy. The most common use of surveys in distributive effects analysis is likely to be in determining which social and economic effects are considered most important or serious within the community. The greater the specificity of these effects and the more precise the information about their potential magnitudes in survey questions, the better. For this reason, when drafting survey questions, it is helpful if at least a preliminary analysis has been carried out as to the nature of the probable effects.

Results of the survey and accompanying focus group meetings are an important source of information as to the sorts of social and economic effects that should be carefully examined. A well-crafted survey can provide the basis for determining how to proceed with the entire analysis of how a proposed transportation project would affect the community as well as what mitigative actions would be called for.

Measurement and presentation. Survey and focus group results can be analyzed and presented using descriptive statistics. During presentation, it is important to aggregate the data to protect the privacy of respondents, especially in sparsely populated areas.

Assessment. These techniques are particularly useful in developing information for distributive effects analyses. They can be customized for population literacy levels, respondent time availability, and other special needs. Some special accommodations may be necessary to encourage full participation from community members, and planning assistance from trusted community leaders should be enlisted. It may also be necessary to hold meetings not only in the evening, but also on weekends or even during the day, as some community members are likely to work night shifts. On-site childcare should be provided.

Method 4. Travel diaries

Microscale data about the travel choices and behavior of individuals at the neighborhood level are scarce. Travel diaries are one means of gathering information about the origins, destinations, and modal choices of particular groups of people. Information of this type can be extremely useful for designing projects that address the travel needs of special populations.

Information collection. Travel diary data are original data collected from members of the relevant public. One of the major issues in compiling diaries is how to ask for enough information to compile a thorough profile without invading the privacy or overtaxing the time resources of the diarist. Some researchers offer prizes or other incentives for filling out diaries because completing a travel diary can be a time-consuming and onerous task for the individual.

Analysis. Data recovered from travel diaries are exceptionally specific. These data should be aggregated by the origin of the traveler or by personal characteristics. In this way, one can deduce how trip-making behavior correlates with place of residence or personal attributes. It then becomes possible to infer how area residents' travel needs would be affected by a transportation project.

Measurement and presentation. Depending on the scale and scope of the information gathered in the diary, the information in travel diaries can be analyzed in a variety of ways, including mapping and descriptive statistics. Information can be compiled on trip length, time, and modal choice, along with trip-chaining and individual comments on transportation needs and problems. In general, people can be sensitive about reporting their travel behavior, so travel diary information should be treated with discretion. The format of diaries should be designed for ease in transferring data for subsequent analysis.

Assessment. Diaries can be a very effective means of obtaining detailed behavioral data. The usual cautions on representative samples apply. Extra effort may be necessary to ensure accurate completion of the diaries and their timely return. Preliminary observation of the population to be sampled can be helpful in designing format and content to elicit the best and most complete responses. Foreign language and literacy issues may be significant. If the sample is representative of the community, means of including non-English-speaking or illiterate community members must be employed.

Travel diaries are time-consuming and expensive to administer. As a result, this method may be worth the effort only for very large projects or as part of a larger effort to gather transportation-related planning information (as part of a city's comprehensive planning effort, for instance). They also provide information only on the trips people are *able* take; little can be learned about trips that could not be taken because of mobility restrictions.

Method 5. Case study and comparison analyses

The value of case studies is that one can learn from the experiences of others who may have addressed issues similar to those one is currently facing. Although it may be difficult to find case studies that are very similar to a particular set of circumstances, general lessons may be transferable.

Information collection. Both practitioners and academics have written up reasonably detailed case studies involving both environmental justice and distributive effects. Two examples are Kennedy (2000) and Bullard and Johnson (1997). It may prove beneficial to contact members of relevant Transportation Research Board committees as well as planning units of state DOTs for leads on applicable case studies.

Analysis. Once a reasonably comparable, adequately documented case study is located, one should focus on how the issues most important in the current project were dealt with in the case study. In some instances, it may be possible to contact planners, community members, or attorneys associated with previous case studies to get their impressions of the situation. Case study analysis should seek to glean a series of specific insights, which taken together will aid one in assessing social and economic effects in a somewhat different venue.

Measurement and presentation. The product of a case study analysis is a qualitative description of how the participants, policies, and actions in the case analogous to the proposed project culminated in a set of either desirable or undesirable outcomes.

Assessment. Case studies are problematic to apply with confidence. To be maximally helpful, they must share at least some basic similarities with the existing situation. As a way to avoid pitfalls or to look for possible cumulative effects, however, case studies offer the opportunity to learn from others' successes and failures. Used in tandem with other methods, case studies can be a valuable tool, especially when one is faced with a transportation project that could involve complex distributive effects.

Method 6. GIS overlay analysis

Overlay analysis involves the integration of different data layers. Analytical operations to assess distributive effects require two or more data layers to be joined physically. The physical overlay of geographic data allows estimates of the number of persons who would be affected by the various types of effects brought about by transportation projects. How many people in which of the census units would be affected at varying levels can be estimated using this approach.

See:

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

Information collection. For purposes of determining distributive effects, attributes must be carefully chosen to measure the effect(s) under consideration and to allow for data comparisons among population groups within the study area. Many useful geocoded data already exist in various public-use and commercial packages. For some analytical purposes, customized, geocoded databases can be developed from public records such as real estate transfers, tax records, and crash reports. Qualitative information collected through surveys and questionnaires should be geocoded whenever possible to make it amenable to GIS analyses.

Analysis. GIS data analyses permit visual presentations of a wide variety of characteristics. Location-specific demographic data can be presented in map form, allowing spatial comparisons of attribute measures from one location to another. For example, pattern- or color-coding can be used to differentiate average income levels. The maps of municipalities within a metropolitan area can be used to present income data by census tract, block-group, or block. GIS can be used to generate overlays that reveal distribution patterns for various types of effects, such as noise levels. GIS overlays also can be used to show the locations of public facilities and services and the levels of service by mode. These overlays also can be applied to indicate the potential barrier effects a project may create that may interrupt existing travel patterns, or the potential interactions of a project with natural, historical, or social resources. Appendix A describes basic and advanced GIS-based analytical approaches in greater detail.

Measurement and presentation. Readily available GIS packages with data importing and overlay creation capabilities, standard statistical packages, and geocoded data are the basic tools needed to create simple data representations in map form. The output from a typical GIS analysis are maps, which show the spatial patterns of the data input, and data in tabular form.

Assessment. Overlay analysis is a highly versatile technique, once data have been geocoded. If properly presented, GIS maps can be interpreted easily by members of the public, and they can present numerous effects in a single format. The same data problems that plague the buffer analysis also pertain to the overlay analysis (or any other GIS analysis dependent on socio-demographic data).

The results of GIS-based analyses for estimating the social and economic effects of transportation projects are not precise, and it should be understood that they are only estimates. Much of the lack of precision in the analyses stems from the lack of homogeneity in census blocks and the scarcity of exact data on the individual makeup and precise location of households within those blocks. Very rarely do impact-area boundaries follow actual data collection–area boundaries.

For example, it may be known that a particular census block group (approximately 30 census blocks) has a racial mixture that is 50 percent African American and 50 percent Caucasian. Perhaps only one-half of the block group would be affected by noise generated from increasing the capacity of a highway running adjacent to the block group. Most GIS-based analyses implicitly assume that the African American and Caucasian populations are intermixed and spread evenly over the entire block group, whereas in reality populations may tend to cluster together. A GIS-based analysis would estimate that the affected population in the census block would be 50 percent African American and 50 percent Caucasian. In reality, due to clustering habits, it may be that 80 percent of the African American population in the census block is affected by the elevated noise, while a small fraction of the Caucasians are affected, or vice versa. The so-called “modifiable units” phenomenon suggests that, in general, one should use the smallest geographical units feasible for a spatial analysis of project effects.

The result of some GIS-based analyses is a visual map depicting the location of an affected area (often shown as a buffer around the source of the effect) and the location of affected groups. Such maps can occasionally be misleading, however. Simply because an analyst has the ability to map the supposed effects of a transportation project does not mean that a map is the most informative way to display the results of the analysis. For instance, GIS-based-analysis map products can give false impressions regarding community cohesion and linkages. In the case of two contiguous areas, a map may show a very close spatial connection between the two places, when in fact residents of the two areas seldom mingle. The same misinterpretation can happen with non-contiguous communities when represented on a map. Two areas may be homogenous in make-up and closely linked by a social institution—such as a common place of worship—but the areas may be separated by some distance. Maps are limited in their abilities to depict this situation.

Method 7. Barrier analysis

In this more sophisticated method, GIS is used to estimate how many people are likely to experience problems accessing their neighbors or community activity centers as a result of a transportation change. Transportation projects that widen roads or increase traffic may create barriers to community cohesion by diminishing access to neighbors or neighborhood resources. GIS software can simulate the effects of such a barrier; it can also estimate how many people the barrier is likely to affect.

See:

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

Information collection. GIS barrier analysis needs several types of digital data; information on demographics, the street/transportation network, facilities that are important activity centers (e.g., schools, houses of worship, shopping and work sites), and local community landmarks is frequently necessary to determine the potential effects of a transportation project on community cohesiveness and safety. Demographic and transportation network data are readily obtained from the U.S. Census Bureau. Local or regional planners are likely to have geocoded street, and possibly sidewalk, information.

What may be more difficult to obtain are the geocoded locations of activity centers or landmarks. The latitude and longitude of some activity centers, such as houses of worship, grocery stores, libraries, and work sites, can be found in digital yellow pages or by using the address-matching function of the GIS. Places without a phone number (e.g., parks or strip commercial areas) are not generally as easy to find. Also, activity centers such as parks are often not appropriately represented as points, but rather should be represented as polygons. Municipal planning or public works departments may have parks geocoded for their land use planning activities. Otherwise, it may be possible to generate a representative polygon—one that is similar enough to the actual layout for the study's purposes—using as few as four points generated as nodes at street intersections bounding the park or gathered using a mobile global positioning system (GPS) unit.

A handheld or mobile GPS device is also an easy, accurate way to geocode the location of landmarks central to community identity. Another, less accurate way is to geocode (i.e., address-match) the address of a proximate home or business to use as proxy point for the landmark. With this method, accuracy depends on how close the address is to the landmark.

Analysis. To assess the relative disruptions in community cohesiveness created by transportation projects, six steps should be followed:

1) Geocode the locations of the local community landmarks that are identified as critical to community cohesion.

2) Drawing on previous research and local-area knowledge, select the blocks that are likely to be affected by a barrier.

3) Determine the locations of households in the community using the geocode function in a GIS. Census block data are the most geographically specific data available. The coordinates of the block's centroid are used as a proxy location for the households in the block. It is from these points that distances and travel times are computed.

4) Identify the location of the street that would act as the "barrier" in the analysis.

5) Compute the shortest paths between the block centroids and destination(s), such as a local activity center. The shortest path is that which would minimize the distance between two locations over a street network. The network capabilities of a GIS and related software enable shortest paths to be computed from all block centroids.

6) Estimate the changes in access to each local landmark or activity center by estimating the number of trips that require people to cross the barrier to access the activity center, landmark, or other community resource.

The analysis can be carried out using the existing transportation system, both before and after the barrier is in place on the network. Results can be expressed in terms of units of distance, time en route, or numbers of persons crossing a street corridor.

Example of barrier analysis. Building on the community profile example discussed earlier in this section, we can examine how a proposed transportation project would affect the safety of children as they walked or rode their bicycles to a local elementary school playground directly adjoining the roadway. Using a hand-held GPS locator, the schoolyard was located so that it could be mapped in Figure 12.8.

Unfortunately, no data exist as to who uses the playground or who walks to school (the school only keeps records on its bus riders). Drawing from discussions with parents and school officials, we settle on a 0.75-mile radial distance around the school to represent the walking and bicycling

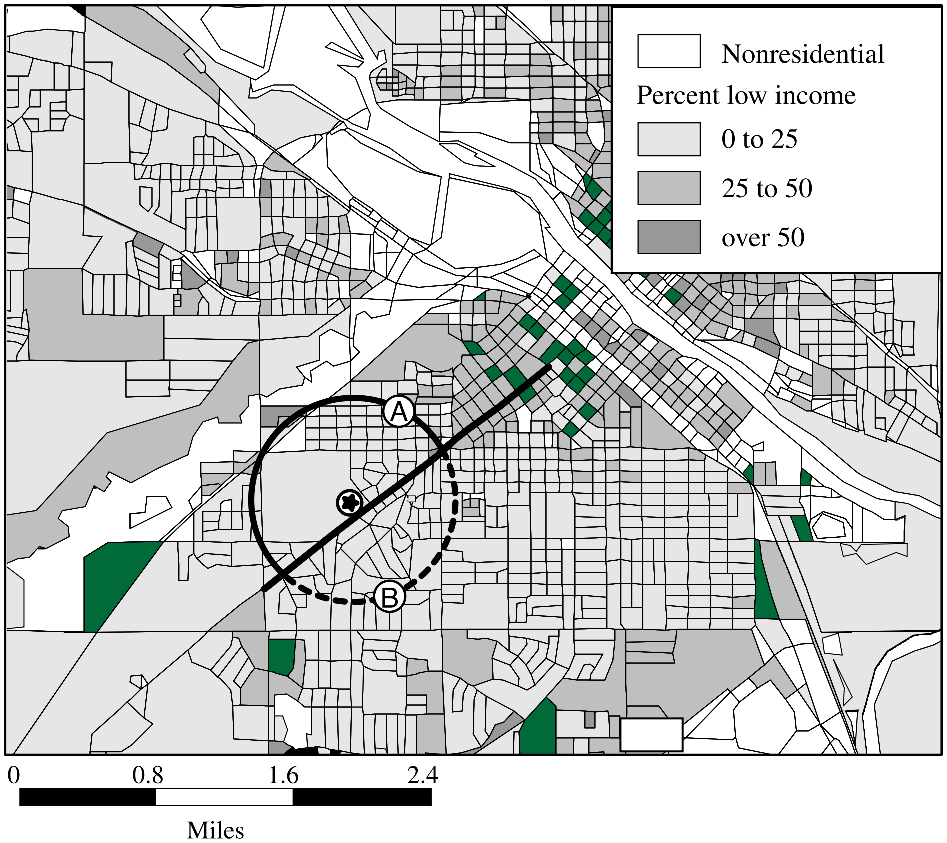

Figure 12.8. Schoolyard access
(Schoolyard is designated by a circled star)

area. Only those children living in area B are counted in the analysis because those in A (although within the buffer) do not have to cross the newly created barrier of the proposed road project. None of the blocks within area B contain a preponderantly low-income population or minority population, but Table 12.4 shows the number of children affected by the widened road. We assume that children under the age of 12 are most likely to use the playground.

Measurement and presentation. Longer travel times and greater distances to local landmarks or activity centers, along with the reduced ability of pedestrians to cross a street corridor, indicate significant effects. Results can be presented in tabular form depicting values before and after the placement of the barrier on the transportation network. Visual maps may also be produced showing which commonly traveled routes are likely to be affected by the transportation project and the alternative routes that would have to be taken.

Assessment. GIS barrier analysis is a complex method that requires a moderately high degree of computer literacy and familiarity with a GIS and its functions. If sufficient technical resources are available, barrier analysis can be an effective way to estimate the extent to which a transportation project would act as a barrier within a community. It can provide an estimate of how many people would be affected and in what ways. A limitation of barrier analysis relates to its data requirements. Because microlevel (e.g., household-level) data may not be available, larger units of analysis may excessively generalize changes in travel time, safety, and distance.

Table 12.4. Number of children with reduced access to playground
(Values in parentheses are percentages of total children)

Number of census blocks	Total children	Affected children		
		Low-income children	Minority children	Total protected children
11 partial blocks	110	8 (7)	3 (2)	5 (5)
23 full blocks	276	12 (4)	0 (0)	12 (4)

RESOURCES

The following documents are guides that provide readers with further information regarding the methods and techniques to be used in assessing distributive effects of transportation projects. Each title is followed by a short description, which draws its text from the summary or introduction provided with that report.

1) Anderson, Patrick. 1999. *Environmental Justice Web Page.* Lansing, MI: Anderson Economics Group, Inc. (online). http://www.aeg1.com/Environment/EJ/EJ.htm.

This web site provides an overview of issues regarding the assessment and presentation of environmental justice impacts of projects and programs.

2) Environmental Protection Agency (EPA). 2000. *Green Communities: On the Path to Becoming a Green Community.* Washington, DC: U.S. Environmental Protection Agency (online). http://www.epa.gov/greenkit. Available August 8, 2000.

This web site provides basic guidance for creating a community profile. It includes information on how to get started, tools and resources for doing a community assessment, and several case studies of community self-assessments.

3) Federal Highway Administration (FHWA). 1996. *Community Impact Assessment: A Quick Reference for Transportation.* FHWA Report No. FHWA-PD-96-036. Washington, DC: U.S. Department of Transportation, Federal Highway Administration.

This FHWA report outlines the community impact assessment process in a "how to" fashion and describes how community impact assessment is important for quality of life, responsive decision-making, coordination, and non-discrimination.

4) Federal Highway Administration (FHWA). 1999. "Community Impacts." In *The Environmental Guidebook Vol. 2: The Built and Social Environment.* Washington, DC: U.S. Department of Transportation.

This document, available both online and on CD-ROM from the Federal Highway Administration (http://www.fhwa.dot.gov/environment/guidebook/contents.htm), lists and

provides documents dealing with effects on a community. The listing includes legislation, regulations, and FHWA policy and guidance publications.

5) Forkenbrock, David J., and Lisa A. Schweitzer. 1997. *Environmental Justice and Transportation Investment Policy*. Iowa City, IA: The University of Iowa, Public Policy Center.

   This publication provides insights into how to estimate social and economic effects of transportation system changes. Specifically, it provides detailed information on the use of geographic information systems (GIS) in determining relative concentrations of minority populations and low-income populations and the spatial effects of noise and air pollution.

REFERENCES

Bullard, Robert, and Glenn Johnson. 1997. *Just Transportation.* Gabriola Island, BC: New Society Publishers.

Kennedy, Lori. 2000. "Environmental Justice and Where It Should Be Addressed in the 21st Century Concerning the Transportation Industry: Historical Perspective and Summary." In *Conference Proceedings 20: Refocusing Transportation Planning for the 21st Century,* Washington DC: Transportation Research Board, National research Council.

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APPENDICES

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APPENDIX A: GEOGRAPHIC INFORMATION SYSTEMS

Geographic information systems (GIS) allow one to analyze and present the spatial nature of predicted social and economic effects. Using various types and scales of maps, it is possible to compare effects between one location and another. Thus, GIS can be used to display the distributive patterns of effects at varying scales. This feature makes GIS an important tool for analyzing the social and economic effects of proposed transportation projects.

In this appendix, we assume that one has at least a basic working knowledge of GIS. Our intent is not to teach basic GIS, but rather to discuss the particular data, techniques, and software issues that may arise during analysis of the social and economic effects of a transportation project.

GEOGRAPHIC AND DEMOGRAPHIC DATA

The U.S. Census Bureau has a web site (http://www.census.gov) with numerous demographic data available for downloading. Other basic data needed for GIS analysis can be accessed or developed from existing public records, such as tax and real estate databases. Table A.1 lists the data and possible data sources commonly used when mapping transportation-related effects. Not every analysis requires all the types of data listed in the table, but it provides a sense of where to search for location-specific data.

Table A.1. Data and data sources for GIS analysis

Data Type	Source
Demographic	• U.S. Census Bureau, local planning departments (for updates and detailed forecasts)
Topographic	• U.S. Geological Survey (USGS), metropolitan planning organizations, state departments of natural resources, local planning departments
Street network	• TIGER/Line Census files (available from U.S. Census Bureau), local planning/engineering departments, commercial GIS data vendors
Land use	• Local planning departments, city public works departments
Accessibility points of interest (local landmarks/activity centers)	• Local planning departments, neighborhood organizations, geocoded yellow pages
Activity centers (major employers, schools, houses of worship, shopping, and public services)	• Digitally geocoded yellow pages, local (or regional) economic development or planning departments

Topographical data usually must be collected on a local-to-regional level. The United States Environmental Protection Agency (EPA) mandates reporting on some environmental factors;

thus, the EPA may have data available for use. Otherwise, good sources for obtaining environmental features include the United States Geological Survey (USGS), state departments of natural resources, and metropolitan planning organizations. Data on road networks are usually available from the U.S. Census Bureau in the form of topographically integrated encoding and referencing (TIGER)/Line files. If greater detail or accuracy is desired, local planning and engineering departments may have GIS files depicting road networks, or such files usually can be purchased from a growing number of commercial GIS data suppliers.

Data issues

Conversion. Once data for measuring the effects of a transportation project have been obtained, several issues may arise. Data are available in different formats for use with GIS software packages, including several different types of coordinate systems and projections. Projections relate to how spherical data from the face of the earth are transformed to flat maps. Some distortion is inevitable. Fortunately, most GIS software packages now include data and file translators that automate the conversion of data to the projection currently being used for the impact analysis. It still is important to remain aware of the projection used for each data file. Although conversions from one GIS to another are not generally likely to be a problem, travel demand or other impact models may only be able to use one specific projection.

Another data incompatibility issue arises when data have been created using different software packages than the one being used for the impact analysis. Because most GIS software is capable of converting incompatible file types to data that are recognizable by the software, this form of incompatibility is rarely a serious problem.

Privacy and data suppression. Obtaining detailed household data raises privacy issues. The Census Bureau publishes income and other sensitive data (such as welfare status) only at the block-group level—not at the census-block level, the level of aggregation we want for most project-impact analyses. Typically, there are about 30 blocks in a block group.

Often, however, local city or regional city planning departments may have done their own estimates of personal income and poverty at the block level; those data can be useful for transportation-related analyses. If no other estimates exist, it is possible to estimate block-levels from data at higher levels of aggregation.

Example. Being careful to use explanatory variables available at *both* the block and the block group, one can fit a regression model that predicts the percentage of persons living in poverty at the block-group level (see Forkenbrock and Schweitzer 1999). Once the coefficients of the regression have been estimated at the block-group level, it is possible to apply these coefficients to explanatory variables at the *block* level to predict the number of persons living in poverty at the block level.

Forkenbrock and Schweitzer (1999) built such a model for a metropolitan area using three variables (median home value, percent of homes that are owner-occupied, and percent of population over 65 years of age) at the block group level to predict the percentage of persons at the block level. The following regression equation was the result:

$$P = 69.8865 - 0.0002651v - 0.5318h - 0.4800e$$
$$\qquad\qquad (0.0000) \qquad (0.0000) \quad (0.0001)$$

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

Software requirements

Several GIS software packages are suitable for analyzing the social and economic effects of transportation projects. Choosing which specific software package to use can be difficult, however, because of the wide variety of functions and tools available in different packages. It is necessary to assess which tools and techniques will be needed to complete the analysis as well as what data type and format is being used. Almost any analysis of social and economic effects will require basic GIS tools such as:

- Database query capability;
- Geocoding and address matching; and
- A data re-projector and translator.

Very few GIS packages consist of only these tools; most contain a comprehensive array of capabilities for spatial analysis.

For more complicated functions—such as barrier or buffer analysis—a GIS software package needs additional tools. Most GIS packages include scaled-down tools for statistical analysis, but often it is necessary to use a more powerful, separate statistical analysis package. When this is the case, data must be exported out of the GIS software and into the statistical package. The tabular data in the GIS software must be compatible with the data format that the statistical package uses and vice versa. Usually, this presents only minor problems.

The most complex analyses of the social and economic effects of transportation projects require GIS tools that are often not included with basic GIS software packages. These tools normally are available in groupings with other complex analysis tools as extensions or add-ons to the software. Two examples of complex tools that may only be available in this way are irregular polygon information aggregation and triangulated irregular network (TIN) creation and analysis.

TIN creation and analysis is important for impact analysis because of its ability to depict areas of equal effects at various distances from a roadway (e.g., to generate noise level contours from sample sound receptor locations). Irregular polygon information aggregation allows identification and counting of households and their associated demographic data within selected contours.

COMMON TYPES OF GIS-BASED ANALYSES

Many different types of GIS-based analyses can be used to estimate the social and economic effects of transportation system projects. Most require the use of network analysis for transportation impacts. Network analysis can include travel demand analysis and traffic simulation studies. Such analyses can be extremely complex and may require the use of large data sets and powerful computers to predict effects on a road network.

Estimating the social and economic effects of transportation projects may require the use of any or all of the following analysis techniques, which are briefly discussed in turn:

- Buffer analysis,
- Barrier analysis, and
- Overlay analysis.

Buffer analysis

A buffer is an area of a specified width that surrounds one or more map features. Buffer analysis is used when examining areas affected by activities or events that take place at or near these map features (Caliper Corp. 1996). It is most often used in social and economic impact analysis as a screening tool to determine if social or economic effects actually would exist in the predicted impact area before proceeding with a more in-depth analysis. To perform buffer analysis, it is necessary to know the specific width (i.e., distance) from a map feature within which an effect may occur.

Most GIS software packages include an analysis tool dedicated to creating buffers. Performing the analysis simply involves selecting the map feature to be buffered and then selecting the buffer tool. GIS packages include dialog boxes designed to guide users through the buffering process. The program will ask for a specified distance at which to buffer the map feature(s). Many software packages offer different options for buffering, such as creating buffers of different specified sizes, creating evenly spaced buffers, or creating buffers of variable sizes using a database field as a reference.

Carrying out a buffer analysis typically involves four steps:

1) Select the map feature(s) to be buffered. Map features may include specific locations (i.e., points), road network links (i.e., lines), or established areas and districts (i.e., polygons).

2) Determine the distance(s) necessary to buffer the selected map feature. This distance should reflect the expected spatial extent of the social or economic effect under consideration (e.g., the area within a quarter-mile of bus stops, as an indication of transit service availability).

3) Using a GIS buffer tool, create the buffer and overlay it on appropriate demographic or economic data, generally displayed at the census block level.

4) Observe the resultant map and determine whether potential social or economic issues exist. If potential issues are observed, then proceed further with a more in-depth analysis.

Figure A.1 depicts a buffer analysis, using a narrow buffer. For initial screenings, a wider buffer may be a good idea, to make the analysis more inclusive.

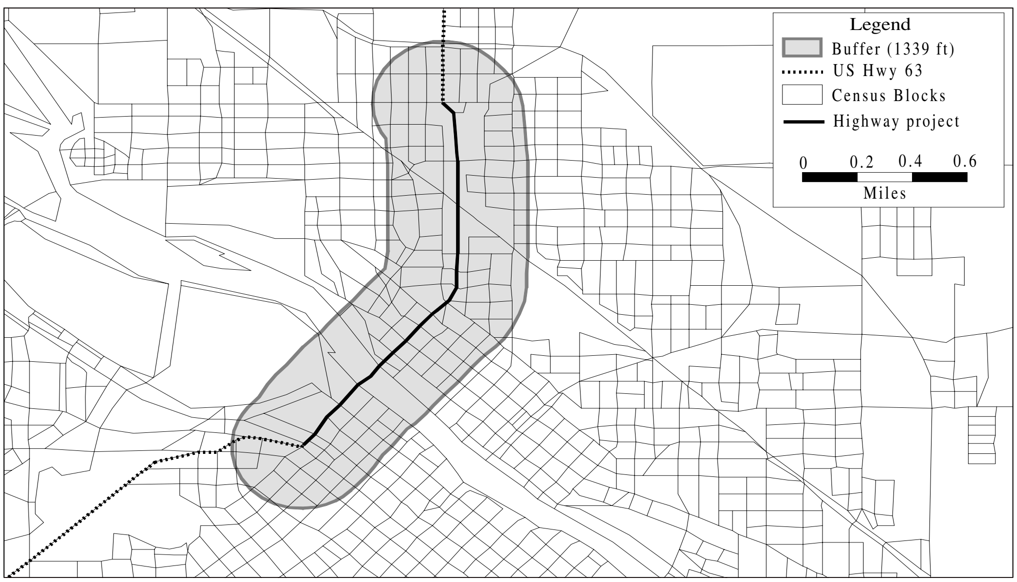

Figure A.1. Sample of a buffer analysis
SOURCE: Chakraborty et al. 1999, Figure 4.

Barrier analysis

Barrier analysis involves the creation of a barrier such as a road construction zone or a road that prohibits non-motorized travel across it. The analysis estimates the change in level of access that has occurred due to the creation of the barrier. A GIS-based analysis can provide useful insights into changes in the accessibility of important destinations.

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

1) Determine the general locations of households using the geocode function in GIS. Census-block data are the most geographically specific data available, so the coordinates

of the block's centroid may be used as a proxy for the locations of households in the block. It is from these centroids that distances and travel times are computed.

2) Geocode the locations of important destinations. Locational data are readily available for businesses, agencies, and most households in the United States. Analyses related to environmental justice, schools, houses of worship, and major employment centers are likely to be among the most common.

3) Compute the shortest paths between origins and destinations. The shortest path is that which minimizes the distance between two locations over a street network. The network capabilities of GIS and related software enables shortest paths to be computed from all block centroids.

4) Estimate the changes in access. The analysis can be carried out using the existing transportation system, both before and after the barrier is in place on the network. Results can be expressed in terms of units of distance, time en route, or numbers of persons crossing a street corridor.

Overlay analysis

Overlay analysis involves the integration of several discrete data layers. Analytic operations in estimating most types of effects require two or more data layers to be joined physically. Overlays, or spatial joins, can integrate spatial data on concentrations of different population groups with the incidence of one or more types of effect.

To perform an overlay analysis, it is necessary to have data layers already created. For example, to estimate the number of persons who would be affected by noise pollution resulting from a proposed transportation project, layers containing data on (1) population characteristics, and (2) the estimated air or noise pollution extent (represented by contours) must already exist. In most GIS packages, it is possible to choose the overlay tool and then follow the instructions in the dialog boxes for inputting the desired layers. Generally, four steps are required:

1) Using transportation noise modeling software (such as the Minnesota Department of Transportation's MINNOISE model; see Mn/DOT 1991), generate noise levels and point distances from the transportation project. Distances can be specified by the user with an x,y coordinate plane and standard units of measure (e.g., feet or meters), or distances can be calculated using geocoded locations.

2) Create TIN structures by triangulating the values between points using extrapolation. Equal value noise contours will be created with this process. This can be done using the TIN creation and analysis tool within the GIS software.

3) Overlay the noise contours on the street network or transportation project area and demographic data layer. Figure A.2 is an example of a TIN structure representing worst-case noise levels juxtaposed with demographic data.

4) Use a GIS spatial analysis feature to count the number or calculate the percentage of persons within the noise contour considered likely to experience an effect. Table A.2 shows how the information from the map in Figure A.2 can be presented in tabular form.

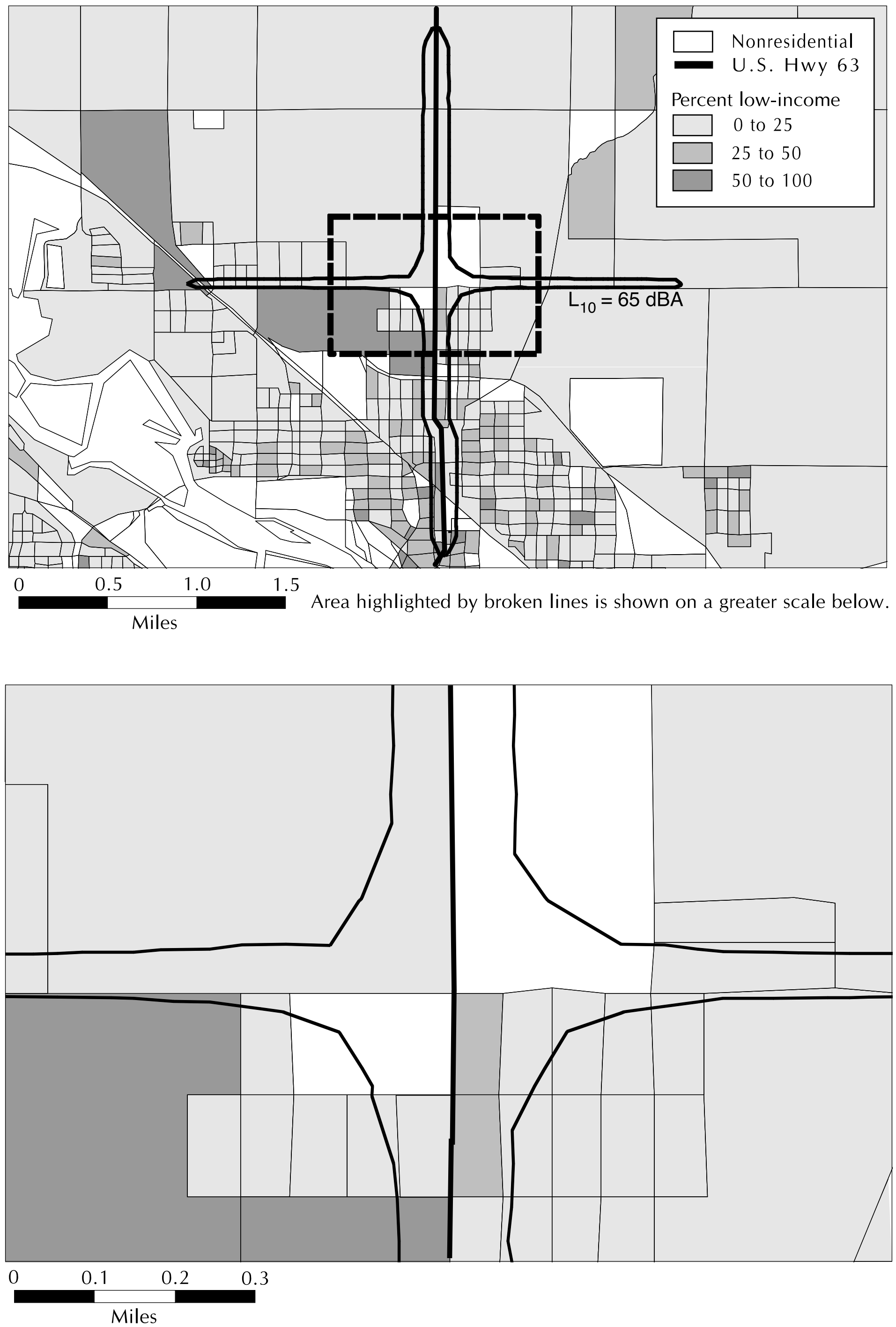

Figure A.2. Maximum L_{10} noise level and percent low-income at an intersection

Table A.2. Population characteristics within noise contours (L_{10}) at an intersection

		Low-income		Minority	
Descriptor	**dBA**	**Number**	**%**	**Number**	**%**
L_{10}	65	189	15.8	499	41.8

RESOURCES

Publications

1) Mitchell, Andy. 1999. *The ESRI Guide to GIS Analysis, Volume 1: Geographic Patterns and Relationships.* Redlands, CA: Environmental Systems Research Institute (ESRI) Press.

   This book offers a review of basic GIS concepts and provides an easy-to-understand guide to GIS analyses. Many real-world examples are used to illustrate the GIS analyses presented. This is not an introductory text; it assumes some prior knowledge of GIS concepts.

2) DeMers, Michael. 1996. *Fundamentals of Geographic Information Systems*. New York, NY: John Wiley and Sons.

   This book is a comprehensive text that presents information on geographic information systems without excessive detail. It covers all basic GIS concepts and most advanced concepts. This text may be too advanced for persons with no GIS experience.

3) Environmental Systems Research Institute (ESRI). 1999. *GIS for Everyone*. Redlands, CA: Environmental Systems Research Institute Press.

   This book is a basic beginner's guide to GIS. It includes detailed GIS data, a full working version of GIS software, and tutorial exercises. No previous experience with GIS is necessary, but experience with computers is very helpful for understanding the tutorials.

Internet sites

4) http://www.esri.com/library/jumpstation/jump_dom.html.

   This site is ESRI's jump station with links to other GIS sites in the United States, sorted by type of site, including government, commercial, noncommercial, and university.

5) http://www.esri.com/library/jumpstation/jump_dom_state.html.

State and local sites involving GIS are accessed through this site. It provides information about GIS projects and resources used by different state and local government agencies.

REFERENCES

Caliper Corp. 1996. *TransCAD 3.0 User's Guide.* Newton, MA: Caliper Corporation.

Chakraborty, Jayajit, Lisa A. Schweitzer, and David J. Forkenbrock. 1999. "Using GIS to Assess the Environmental Justice Consequences of Transportation System Changes." *Transactions in GIS*, Vol. 3, No. 3 (June), pp. 239–258.

Forkenbrock, David J., and Lisa A. Schweitzer. 1999. "Environmental Justice in Transportation Planning." *Journal of the American Planning Association*, Vol. 65, No.1 (Winter), pp. 96–111.

Minnesota Department of Transportation. 1991. *Noise Analysis: Stop and Go Traffic Procedures*. Noise Group of Environmental Engineering, Engineering Services Section, St. Paul, MN.

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APPENDIX B: SURVEY METHODS

Transportation planners frequently use surveys for three general purposes:

- To measure community attitudes about a public issue.
- To increase people's awareness of the policy options regarding a particular issue.
- To measure people's attributes (e.g., age, ethnicity, or income), situations (e.g., home ownership or employment status), or behavior (e.g., the mode of transportation used).

We briefly explore two key aspects of surveys in this appendix: sample size determination and questionnaire design. Our objective is to provide basic insights into how one develops a survey to support the applications discussed in the various methods presented in this guidebook. When designing a survey, however, it is highly advisable to consult a good textbook on survey methods. The advice of a competent statistician may prove useful, as well.

SAMPLE SIZE

Larger samples yield more precise results. Large samples, however, can be expensive. In most situations, one must trade off three attributes when mapping out the strategy for a survey:

- Accuracy of the estimate (e.g., estimating the percent favoring a road expansion within 3 percent instead of within 4 percent).
- Statistical precision (i.e., significance level, or the likelihood that the result could have emerged randomly; a 5-percent chance of this occurrence is a commonly used level).
- Cost of the survey (larger sample sizes and more refined sampling strategies cost more).

For example, if one were willing to accept a ± 4-percent error in calculating the percentage of neighborhood residences favoring a widened street, a smaller sample could be used to be 95 percent certain that the result could not have occurred randomly than would be the case if a ± 2-percent margin of error were necessary. Likewise, if one only had to be 90 percent certain that the result could not have occurred randomly, a smaller sample would be necessary than if a 95-percent level of certainty were required.

A common issue is how large a sample of neighborhood residents must be surveyed to estimate the proportion of people who have a certain preference about a possible project, such as our example of a road widening. If prior to conducting the survey one has no idea what the proportion of people favoring the project is, a good place to begin is to assume that half favor the project and half oppose it. A 50/50 split will require the largest sample size of any possible split; the more skewed the proportion gets (e.g., 90 percent for and 10 percent against), the smaller the sample size needed to estimate a given proportion at a specified level of statistical significance (e.g., 95 percent certainty).

Table B.1 is a quick reference for determining how large a sample size one needs to estimate a proportion within different levels of error. More precise calculations can be made using formulas available in most elementary survey textbooks, such as Babbie (1990).

Table B.1. Sample size, proportional distribution of results, and percentage error levels

(Values in the table are plus or minus errors; the table is based on a 95% confidence level)

	Percentage distribution				
Sample size	**50/50**	**60/40**	**70/30**	**80/20**	**90/10**
100	10.0	9.8	9.2	8.0	6.0
200	7.1	6.9	6.5	5.7	4.2
300	5.8	5.7	5.3	4.6	3.5
400	5.0	4.9	4.6	4.0	3.0
500	4.5	4.4	4.1	3.6	2.7
600	4.1	4.0	3.7	3.3	2.4
700	3.8	3.7	3.5	3.0	2.3
800	3.5	3.5	3.2	2.8	2.1
900	3.3	3.3	3.1	2.7	2.0
1,000	3.2	3.1	2.9	2.5	1.9
1,100	3.0	3.0	2.8	2.4	1.8
1,200	2.9	2.8	2.6	2.3	1.7
1,300	2.8	2.7	2.5	2.2	1.7
1,400	2.7	2.6	2.4	2.1	1.6
1,500	2.6	2.5	2.4	2.1	1.5
1,600	2.5	2.4	2.3	2.0	1.5
1,700	2.4	2.4	2.2	1.9	1.5
1,800	2.4	2.3	2.2	1.9	1.4
1,900	2.3	2.2	2.1	1.8	1.4
2,000	2.2	2.2	2.0	1.8	1.3

Example. Referring to Table B.1, suppose that one wishes to be 95 percent certain that the proportion of people favoring a street widening is estimated within 3 percentage points. If the proportion of people responding to the survey who favor it is 50 percent, 1,100 surveys will be needed. If the proportion is 80 percent, only 700 will be needed.

The best way to minimize cost when trying to reach a specified level of statistical significance and an error level not to exceed some percentage is to recalculate the proportion for and against the issue in question repeatedly as surveys are completed. Gradually, the proportions will tend to stabilize, and one can a gain clear idea of how many surveys will be needed to reach the specified levels of certainty and accuracy.

It should be noted that the closer the proportions are to 50/50, the smaller the error one can tolerate. If one needs to know whether a majority supports the road widening, and the proportions are 53 percent for and 47 percent against, an error of greater than ± 3 percent would produce a highly uncertain result. Thus, when the proportions hover around an equal distribution, a large sample size is likely to be required.

QUESTIONNAIRE DESIGN

Designing a good survey questionnaire is a mixture of art and science. One must have a clear sense of what information is needed and must ensure that the questions are unambiguous and easily understood. There are several widely recognized principles to follow in writing survey questions, and there are certain pitfalls to avoid. The following ten points summarize basic considerations in questionnaire development.

1) Do not try to be too precise. Oftentimes, more basic questions (e.g., “What mode of transportation do you usually take to work?”) elicit more reliable answers than more precise questions (e.g., “How many work trips did you take last month riding transit?”).

2) Use three to five response categories with agree–disagree format questions, always with a neutral response category (i.e., neither agree nor disagree) in the middle. Besides the odd number of response categories, be sure that the wording on both the agree and the disagree sides is symmetrical (e.g., “strongly agree” and “strongly disagree”).

3) Avoid hypothetical questions as much as possible. Most people have difficulty giving meaningful responses to questions that do not reflect the situations that they actually face (e.g., “If you rode a bicycle to work every day, how frequently spaced would you want foot and cycle bridges over freeways?”).

4) Do not use “double-barreled” questions (e.g., “Do you favor bicycle trails and higher parking rates?”). A respondent might agree with one part of the question and not the other, so responses may be arbitrary and meaningless. Use separate questions for each point.

5) Avoid “loaded” questions that tend to direct the respondent toward a certain response (e.g., “Many say that the bus service in our community is terrible; what do you think of it?”). The question wording can bias the responses.

6) Beware of vague or imprecise question wording that might cloud the meaning of the question (e.g., “Do you favor a special property tax for public transit?”). It is difficult for a respondent to give a sensible answer, not knowing exactly what is being asked. In this example, one should state how large the tax increase would be.

7) Watch out for overly strong or inflammatory words (e.g., “Should we *forbid* parking in the downtown area?”). The strong words may instill a bias in respondents’ minds.

8) Be sure to pretest all questions. By asking a small sample of people similar to those who will be surveyed the questions one intends to use, problems can be identified and resolved before the full survey is initiated.

9) Ask sensitive questions last. Questions such as those asking for household income or home value may cause a respondent to terminate the interview.

10) Use open-ended questions sparingly (i.e., those in which the respondent can give any response he or she desires). Summarizing the responses to these questions can be difficult. On the other hand, this is a valid format for questions when one is unclear as to what the likely response categories should be or when complete spontaneity is desired.

OTHER CONSIDERATIONS

Beyond ensuring that the sample is large enough to provide the desired precision and statistical significance and that the questionnaire contains workable questions, there are two other important considerations that we briefly note.

Type of survey

The most common type of survey is the telephone interview. It avoids the problems of intrusion that face-to-face interviews can create. On the other hand, the few households without telephones will be excluded, and they are likely to be among the poorest in the community. Mail-out/mail-back questionnaires are very inexpensive to use, but the response rate tends to be lower than for other types of surveys. Household face-to-face interviews allow one to use graphics and to look at the respondent to see whether he or she seems to understand the question. Follow-up questions are easier to include in the interview. One limitation of this type of survey, however, is that people may be uneasy having a stranger come into their homes.

Sampling strategy

Often, a stratified random sample is the best choice of sampling strategy, but it is not necessarily the easiest to implement. With this strategy, one calls randomly selected households (a random-digit-dialing approach often is used). A refinement is to randomly select an adult member of the household using a randomized selection table. The advantage of random selection within a household is that it avoids a bias resulting from over-sampling types of people who tend to be home more (e.g., retired persons, homemakers, and unemployed persons). A problem with this approach is that many more call-backs are likely to be needed to reach the person who has been selected within the household.

RESOURCES

1) Babbie, Earl. 1990. *Survey Research Methods* (Second Edition). Belmont, CA: Wadsworth Publishing.

This textbook on survey methods is exceptionally well written and easy to understand. Babbie presents all phases of conducting surveys in a thorough, but not overly technical, manner.

2) Fowler, Floyd J., Jr. 1988. *Survey Research Methods* (Revised Edition). Applied Social Research Methods Series, Volume 1. Newbury Park, CA: Sage Publications.

This reference book has significant chapters on questionnaire design and sample strategy. It is not technical in its presentation.

APPENDIX C: TRAVEL DEMAND MODELING[*]

This appendix explains the urban travel demand modeling process, the assumptions made, and the steps used to forecast travel demand for urban transportation planning. Transportation planning uses the term "models" to refer to a series of mathematical equations that are used to represent how choices are made when people travel. Travel demand occurs as a result of thousands of individual travelers making individual decisions on how, where, and when to travel. These decisions are affected by many factors, including family situation, characteristics of the person making the trip, and the choices (e.g., destination, route, and mode) available for the trip. Mathematical relationships are used to replicate (i.e., model) human behavior in making these choices. These models require a series of assumptions in order to work, and they are limited by the data available to make forecasts. The coefficients and parameters in the model are set (i.e., calibrated) to match existing data. Normally, these relationships are assumed to be valid and to remain constant into the future.

Travel demand modeling was first developed in the late 1950s as a method for highway planning. As the need arose to consider other issues such as transit, land use, and air quality, the modeling process evolved to incorporate additional techniques for dealing with these problems.

ROLE OF TRAVEL DEMAND MODELS

Travel demand models are important; transportation plans and investments often are based on what the models say about future travel. Models are used to estimate the number of trips that will be made on a proposed transportation alternative at some future date. These estimates then become the basis for transportation plans and are used in major investment analyses, environmental impact statements, and in setting priorities for investments. Models are based upon assumptions about the way in which travel occurs. A clear understanding of the modeling process is important to an understanding of transportation plans and their recommendations.

Models provide forecasts only for those factors and alternatives that are explicitly included in the equations. If the models are not sensitive to certain polices or programs, they will not show the effects of these policies. This could lead to the erroneous conclusion that such polices are ineffective, whereas the results would actually reflect only that the models were not capable of testing the policy. For example, travel forecasting models usually exclude pedestrian and bicycle trips. Plans that include bicycle or pedestrian system improvements will not show any effect from the modeling procedure if the models ignore these types of trips. It would not be correct, however, to conclude that pedestrian or bicycle improvements are ineffective; the actual effect would be unknown. Therefore, it is critical that the assumptions used in the modeling process and the model limitations be explicitly stated and considered before decisions are made.

Transportation modeling is used to generate information that can help in making decisions about the future development and management of transportation systems, especially in urban areas. It is

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[*] This appendix was adapted from Beimborn (1995), with the author's permission.

used as part of an overall transportation planning process that involves a forecast of travel patterns 15 to 25 years into the future, and it develops plans for a transportation system that will work effectively at that time.

STRUCTURE OF TRAVEL DEMAND MODELS

The travel forecasting process is at the heart of urban transportation planning. Travel forecasting models are used to project future traffic and to determine the need for new road capacity, transit service changes, and changes in land use policies and patterns. Travel demand modeling involves a series of mathematical models that attempt to simulate human behavior while traveling. The models are done in a sequence of steps that answer a series of questions about traveler decisions. Attempts are made to simulate all choices that travelers make in response to a given system of highways, transit services, and policies. Many assumptions need to be made about how people make decisions, the factors they consider, and how they would react to a particular transportation alternative.

The travel simulation process follows trips as they begin at a trip-generation zone, move through a network of links and nodes, and end at a trip-attracting zone. The simulation process is known as the four-step process for the four basic models used: (1) trip generation, (2) trip distribution, (3) mode split, and (4) traffic assignments. These models are used to answer a series of questions, as will be explained in the remainder of the appendix.

How is the city represented for computer analysis? (zone/network system)

Travel simulations require that an urban area be represented as a series of small geographic areas called traffic analysis zones (TAZs). Zones are characterized by population, employment, and other factors and are designated as the places where trips begin (i.e., trip generators) or end (i.e., trip attractors). Trip making is first estimated at the household level and then aggregated to the zone level. All trips are assumed to begin at the center of activity in a zone (i.e., zone centroid). Trips that are very short, beginning and ending in a single zone (intra-zonal trips), are usually not directly included in the forecasts. This limits the analysis of pedestrian and bicycle trips in the typical travel demand modeling process because such trips tend to be short.

Zones can be as small as a single block, but typically they are one-quarter to 1-mile square in area. A planning study can easily use 500–2,000 zones; a larger number of zones will increase forecast accuracy, but will also require more data and computer-processing time. Zones tend to be small in areas of high population and larger in more rural areas. Internal zones are those within the study area, while external zones are those outside of the study area. The study area should be large enough so that nearly all (i.e., 90 percent or more) of the trips begin and end within its boundaries.

Highway and transit systems within the study area are represented as networks for computer analysis. Networks consist of links, which represent highway segments or transit lines, and nodes, which represent intersections and other points on the network. Data for links include travel times on the link, average speeds, capacity, and direction. Nodal data includes information about intersections and the location of the node (i.e., coordinates).

How many trips will there be? (trip generation)

The first step in travel forecasting is trip generation. In this step, information regarding land use, population, and economic forecasts is used to estimate how many person trips will be made to and from each zone. This is done separately by trip purpose. Trip purposes can include home-based work trips (i.e., work trips that begin or end at home), home-based shopping trips, home-based other trips, school trips, non-home-based trips (i.e., trips that neither begin nor end at home), truck trips, and taxi trips. Trip generation forecasts use trip rates that are averages for large segments of the study area. Trip productions are based on household characteristics, such as the number of people in the household and the number of vehicles available. For example, a household with four people and two vehicles may be assumed to produce 3.00 work trips per day. Trips per household are then expanded to trips per zone. Trip attractors are typically based on the level of employment in a zone. For example, a zone could be assumed to attract 1.32 home-based work trips for every person employed in that zone. Trip generation is used to calculate person trips, and these are later adjusted in the mode split/automobile occupancy step to estimate vehicle trips.

There are five limitations that may be of concern in trip-generation modeling.

- **Independent decisions.** Travel behavior is a complex process in which decisions of one household member are often dependent on others in the household. For example, childcare needs may affect how and when people travel to work. This interdependency of trips is not considered.

- **Limited trip purposes.** With no more than four to eight listed trip purposes, a simplified trip pattern results. All shopping trips are treated the same whether the shopping goal is groceries or lumber. Home-based "other" trip purposes cover a wide variety of travel objectives—medical appointments, visits to friends, or banking, which are influenced by a larger range of factors than those used in the modeling process.

- **Limited variables.** Trip making is viewed as a function of only a few variables, such as automobile ownership, household size, and employment. Other factors such as the quality of transit service, ease of walking or bicycling, fuel prices, land use design, and so forth are not typically included.

- **Ignored trip chaining.** Travelers may often combine a variety of purposes into a sequence of trips as they run errands and link activities. This is called trip chaining, and it is a complex process. The modeling process treats such trip combinations in a very limited way. For example, non-home-based trips are calculated only on the basis of the employment characteristics of the zones and do not consider how members of a household coordinate their errands.

- **Feedback, and cause-and-effect problems.** Trip-generation models sometimes calculate trips as a function of factors that, in turn, could depend on how many trips are made. For example, shopping trip attractions are found as a function of retail employment, but it could also be argued that the number of retail employees at a shopping center will depend on how many people come there to shop. This "chicken or egg" problem comes up frequently in travel forecasts and is difficult to avoid. Another example is that trip making depends on automobile availability, but it could be also argued that the number of automobiles a household owns would depend upon the number of trips residents needed to make.

How do the trip ends connect together? (trip distribution)

Trip generation estimates the number of trips that begin or end at a particular zone. These trip ends are linked together to form an origin-destination (O-D) pattern of trips through the process of trip distribution. Trip distribution represents the process of destination choice (i.e., “I need to go shopping, but where should I go to meet my shopping needs?”). Trip distribution leads to a large increase in the amount of data that needs to be dealt with—O-D tables are very large. For example, a 1,200-zone study area would have 1,440,000 possible trip combinations in its O-D table. Separate tables are also developed for each trip purpose.

The most commonly used procedure for trip distribution is the gravity model. The gravity model takes the trips produced in one zone and distributes them to other zones, based on the size of those zones (as measured by their trip attractions) and on their distance. A zone with a large number of trip attractions will receive a greater number of distributed trips than one with a small number. Distance to possible destinations is the other factor used in the gravity model. The number of trips to a given destination decreases with its distance (i.e., it is inversely proportional). The distance effect is found through a calibration process, which tries to achieve a distribution of trips from the model similar to that found from field data.

“Distance” can be estimated in several ways, the simplest of which is to use automobile travel times between zones as the unit of measurement. Another approach might be to use combinations of automobile travel time and cost as measurements of distance. Still another way is to use a combination of transit and automobile times and costs (i.e., composite cost). This method involves multiplying automobile travel times and costs by a percentage and transit time or cost by another percentage to obtain a composite time and cost for both modes. Because of calculation procedures, the model must be iterated a number of times to balance the trip numbers to match the trip productions and attractions found in trip-generation model results.

There are four limitations that may be of concern in trip distribution.

- **Constant trip lengths.** In order for the model to be used as a forecasting tool, it must be assumed that the average lengths of trips that occur now will remain constant in the future. Because trip lengths are measured by travel time, this means that improvements in the transportation system that reduce travel times are assumed to be balanced by a further separation of origins and destinations.

- **Use of automobile travel times only to represent “distance.”** The gravity model requires a measurement of the distance between zones. This is almost always based on automobile travel times rather than on transit travel times and thus leads to a wider distribution of trips (i.e., they are spread out over a wider radius of places) than if transit times were used. This process limits the ability to represent travel patterns of households that locate on a transit route and travel to points along that route. This may be particularly important if a rail transit system is being analyzed.

- **Limited effect of socio-economic-cultural factors.** The gravity model distributes trips only on the basis of size of the trip ends (i.e., trip productions, trip attractions) and travel times between the trip ends. Thus, the model would predict a large number of trips between a high-income residential area and a nearby low-income employment area or between a Spanish-speaking neighborhood and a nearby non-Spanish-speaking neighborhood. The actual distribution of trips is affected by the nature of the people and activities involved, on their socio-economic and cultural characteristics, and on the size and distance factors used in the model. Factors such as differences in income, crime conditions, and attractiveness of the route are not considered. Furthermore, groups of travelers might avoid some areas of the city and favor others based on socio-economic-cultural reasons. Adjustments are sometimes made in the model to account for such factors, but it is difficult to quantify the effects of such factors on travel, much less to predict how they would change over time.

- **Feedback problems.** Travel times are needed to calculate trip distribution; however, travel times depend upon the level of congestion on streets in the network. The level of congestion is not known during the trip distribution step, as it is found in a later calculation. Normally, travel times are assumed first and checked later. If the assumed values differ from the actual values, the model should be iterated a number of times to get the inputs and outputs of the model to balance.

How will people travel? (mode choice/automobile occupancy analysis)

Mode choice is one of the most critical parts of the travel demand modeling process. It is the step where trips between a given origin and destination are split depending on whether they are transit trips, car pool trips, automobile passenger trips, or solitary automobile driver trips. Calculations are conducted that compare the attractiveness of travel by different modes to predict their relative usage. All proposals to improve public transit or to change the ease of using the automobile are passed through the mode split/automobile occupancy process as part of their assessment and evaluation. It is important to understand what factors are used and how the process is conducted in order to plan, design, and implement transportation projects.

The most commonly used process for mode split is the "logit" model. This involves a comparison of the "disutility" of travel between two points for the different modes that are available. Disutility is a term used to represent a combination of the travel time, cost, and convenience involved with using a mode between an origin and a destination. It is found by assigning multipliers or weights to these factors and adding them together. Travel time is divided into two components: in-vehicle time, which represents the time a traveler is actually in a vehicle, and out-of-vehicle time, which includes travel time spent outside of the vehicle (i.e., time spent walking to and from transit stops or parking places, waiting time, and transfer time). Out-of-vehicle time is used to represent "convenience" and is typically multiplied by a factor ranging from 2.0 to 7.0 to give it greater importance in the calculations; travelers do not like to wait or walk long distances to their destinations. The size of the multiplier will differ depending upon the purpose of the trip, as it has been found that people tend to be more willing to wait or walk longer distances for work trips than for shopping trips.

Travel cost is multiplied by a factor to represent the value that travelers place on time savings for a particular trip purpose. For transit trips, the cost of the trip is given as the average transit fare for that trip, while for automobile trips, cost is found by adding the parking cost to the length of the trip as multiplied by a cost-per-mile value. Automobile cost is based on a "perceived" cost per mile (on the order of 5–7 cents per mile); it only includes fuel and oil costs and does not include ownership, insurance, maintenance, and other fixed costs (total costs of automobile travel are 25–40 cents per mile). Travelers have been found to consider only the costs that vary with an individual trip when making mode-choice decisions, rather than all costs.

Disutility calculations may also contain a "mode bias factor," which is used to represent other travel mode characteristics that may influence the choice of mode (such as a difference in privacy and comfort between transit and automobiles). The mode bias factor is used as a constant in the analysis and is found by fitting the model to actual travel behavior data. Generally, the disutility equations do not recognize differences within travel modes. For example, a bus system and a rail system with the same time and cost characteristics will have the same disutility values. There are no special factors that allow for the difference in attractiveness of alternative technologies.

Once disutilities are known for the various mode choices between an origin and a destination, the trips are split among modes based on the relative differences between disutilities. The logit equation is used in this step. A large advantage in disutility will mean a high percentage for that mode. Mode splits are calculated to match splits found from actual traveler data. Sometimes a fixed percentage is used for the minimum transit use (i.e., percent captive users) to represent travelers who have no automobile available or are unable to use an automobile for their trip.

Automobile trips must be converted from person trips to vehicle trips with an automobile occupancy model. Mode split and automobile occupancy analysis can be two separate steps or can be combined into a single step, depending on how a forecasting process is set up. In the simplest application, a highway/transit split is made first, followed by a split of automobile trips into automobile-driver and automobile-passenger trips. More complex analyses split trips into multiple categories (single-occupant automobile, 2-person car pool, 3-to-5 person car pool, vanpool, local bus, or express bus). Automobile occupancy analysis is often a highly simplified process that uses fixed automobile occupancy rates for a given trip purpose or for given household sizes and automobile ownership categories. This means that forecasts of car pooling are insensitive to changes in the cost of travel, the cost of parking, and the presence of special programs to promote car pooling such as may occur as a result of clean air legislation.

Five limitations that may be of concern in mode split analysis follow.

- **Mode choice is only affected by time and cost characteristics.** An important thing to understand about mode choice analysis is that shifts in mode usage would be predicted to occur only if there were changes in the characteristics of the modes (i.e., there must be a change in the in-vehicle time, out-of-vehicle time, or cost of the automobile or transit for the model to predict changes in demand). Thus, if one were to substitute a light-rail transit system for a bus system without changes in travel times or costs, the model would not show any difference in demand. People are assumed to make travel choices based only on the factors in the model; factors not in the model will have no effect on results predicted by the models.

- **Factors are omitted.** Factors which are not included in the model, such as crime, safety, and security concerns, have no effect. They are assumed to be included as a result of the calibration process. If an alternative has different characteristics for some of the omitted factors, however, no change will be predicted by the model. Such effects need to be factored in by hand, a process that requires considerable skill and significant assumptions.

- **Access times are simplified.** No consideration is given in the choice process to factors such as the ease of walking in a community or the characteristics of a waiting facility. Strategies to improve local access to transit or to upgrade the quality of waiting places do not have an effect on the models.

- **Weights are considered constant.** The importance of time, cost, and convenience are assumed to remain constant for a given trip purpose. Trip-purpose categories are very broad (i.e., shopping or "other"). Differences in the importance of time and cost within these categories are ignored.

- **Differences in the importance of time and cost are ignored.** The importance of time and costs vary with trip purposes (e.g., work trips, shopping trips, and other trips) but this variation is ignored.

What routes will be used? (traffic assignment)

Once trips have been split into highway and transit trips, the specific paths that they use to travel from their origins to their destinations must be found. These trips are then assigned to that path in the step called traffic assignment. Traffic assignment is the most time-consuming and data-intensive step in the process, and it is done differently for highway trips and transit trips. The process first involves calculating the shortest path from each origin to all destinations (usually the minimum time path is used). Trips for each O-D pair are then assigned to the links in the minimum path, and the trips are added up for each link. The assigned trip volume is then compared with the capacity of the link to see whether it is congested. If a link is congested, the speed on the link needs to be reduced to result in a longer travel time on that link. Changes in travel times mean that the shortest path may change. Hence, the whole process is repeated several times (i.e., iterated) until there is an equilibrium between travel demand and travel supply. Trips on congested links will be shifted to uncongested links until this equilibrium condition occurs. Traffic assignment is the most complex calculation in the travel modeling sequence, and there are a variety of ways it can be done to keep computer time to a minimum.

Transit trip assignment calculation is similar to that for automobile trip assignment, except that transit headways are adjusted instead of travel times. Transit headways (i.e., minutes between vehicles) affect the capacity of a transit route. Short headways mean more frequent service and a greater number of vehicles. Normally, short headways are assumed initially. Trips are assigned to vehicles, and if the vehicles have low ridership, headways are increased to provide fewer vehicles and higher ridership per trip. This process is repeated until transit supply and demand are in balance.

It is important to understand the concept of equilibrium. If a highway or transit route is congested during the peak hour, its excess trips will shift to other routes, other destinations, other modes, or other times of day. Increases in capacity will cause shifts back to the facility to reach a new equilibrium point. Furthermore, it may also lead to additional trip making in the form of "induced" trips. These would be trips that did not take place before the facility was expanded. The new equilibrium may mean that the congestion is reestablished on the facility.

Considerations of time of day are also important. Traffic assignment is typically done for peak hour travel, while forecasts of trips are done on a daily basis. A ratio of peak hour travel to daily travel is needed to convert daily trips to peak hour travel (for example, it may be assumed that 10 percent of travel occurs in the peak hour). Numbers used for this step are very important in that a small change in the values assumed will make a considerable difference in the level of congestion forecast on a network. Normally, the modeling process does not deal with how traffic congestion dissipates over time.

There are five limitations that may be of concern in traffic assignment.

- **Intersection delay is ignored.** Most traffic assignment procedures assume that delay occurs on the links rather than at intersections. This is a good assumption for through-roads and freeways, but not for highways with extensive signalized intersections. Intersections involve highly complex movements and signal systems. They are simplified substantially in traffic assignment, and the assignment process does not modify control systems in reaching an equilibrium. Use of sophisticated traffic signal systems, freeway ramp meters, or enhanced network control of traffic cannot be easily analyzed with conventional traffic assignment procedures.

- **Travel only occurs on the network.** It is assumed that all trips begin and end at a single point in a zone (i.e., the centroids) and occur only on the links included in the network. Not all roads and streets are included in the network, nor are all possible trip beginning and endpoints included. The zone/network system is a simplification of reality and excludes some travel, especially shorter trips. To estimate total travel, for example for air pollution analysis, a certain percentage of off-network travel must be added to assignment results.

- **Capacities are simplified.** Estimating the capacity of roadways and transit systems involves a complex process of calculations that considers many factors. In most travel forecasts, this is greatly simplified. Capacity estimates are based only on the number of lanes of a roadway and its type (e.g., freeway or arterial). Most travel demand models used for large transportation planning studies do not consider factors such as truck movements, highway geometry, and other circumstances affecting capacity in their calculations.

- **Time-of-day variations are not considered.** Traffic varies considerably throughout the day and among the days of the week. Travel demand forecasts are made on a daily basis for a typical weekday and then converted to peak hour conditions. Daily trips are multiplied by a "hour adjustment factor," for example 10 percent, to convert them to peak hour trips. The number assumed for this factor is very critical. A small variation—for example, ± 1 percent—will make a large difference in the level of congestion that would be forecast on a network.

- **Peak hour travel is emphasized.** As described above, forecasts are done for the peak hour on a typical weekday. A forecast for the peak hour of the day does not provide any information on what is happening the other 23 hours of the day. The duration of congestion beyond the peak hour (i.e., peak spreading) is not estimated. In addition, travel forecasts are made for an "average weekday." Variation in travel by time of year or day of the week are usually not considered.

What are the effects of the travel?

Equilibrium traffic assignment results indicate the amount of travel that can be expected on each link in the network at some future date with a given transportation system. Levels of congestion, travel times, speed of travel, and vehicle miles of travel are direct outputs from the modeling process. Link traffic volumes are also used to estimate other effects of travel for plan evaluation. Some of the key effects are crashes and estimates of air pollution emissions, each of which needs to be estimated through further calculations. Typically, these are done by applying crash or emission rates by highway type and by speed. Assumptions need to be made regarding the speed characteristics of travel for non-peak hours of the day and for variation in travel by time of the year.

REFERENCE

Beimborn, Edward A. 1995. *A Transportation Modeling Primer*. Milwaukee, WI: University of Wisconsin-Milwaukee, Center for Urban Transportation Studies.

Available at the following web site: http://www.uwm.edu/Dept/CUTS/primer.htm.

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APPENDIX D: DISTRIBUTIVE EFFECTS—LEGAL BASIS

The distributive effects of transportation system changes are a key aspect of estimating social and economic effects. Not only are distributive effects a logical element of impact assessments, but there is also a clear legal basis for including them. Distributive effects draw together two separate strands of federal legislation: one based in nondiscrimination policy and the other based in environmental policy. These legal requirements flow mainly from the National Environmental Policy Act of 1969 (NEPA) and Title VI of the Civil Rights Act of 1964. Executive Order (EO) 12898 on Environmental Justice (issued in 1994) merged environmental and equity concerns. In this appendix, we provide a brief overview of the salient portions of the major laws and mandates that pertain to distributive effects in transportation.

THE CIVIL RIGHTS ACT OF 1964

The Civil Rights Act is the foundation for most federal rules, regulations, and mandates concerning nondiscrimination in federal activities. Title VI of the Civil Rights Act of 1964 requires that any program or activity receiving federal financial assistance be free of discriminatory effect on the ground of race, color, or national origin.

The key section states:

> "No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance."

Later, the Civil Rights Restoration Act of 1987 clarified Title VI to cover all programs and activities of federal-aid recipients, sub-recipients, and contractors, whether or not their programs and activities are federally funded.

THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969

Just as the Civil Rights Act is the root of federal nondiscrimination policies, NEPA is the cornerstone of most federal environmental policies affecting transportation. To protect the environment, NEPA requires a "systematic, interdisciplinary approach" to evaluating environmental and community factors in several contexts, including society as a whole, the affected region, the affected interests, and the locality (40 C.F.R. § 1508.27[a]).

NEPA establishes the definitions for "significant" and "adverse" for impact assessment purposes; these definitions are much narrower than interpretations of the same terms under civil rights law.[1] Under civil rights law, the central question is whether a reasonable person would find the effects

[1] In instances in which minority populations or low-income populations would be affected in disproportionate and adverse ways, adhering to the broader interpretations of these terms contained in civil rights law may be advisable, to reduce risk of environmental justice challenges under civil rights law.

to be significant. Courts look for generally accepted scientific standards to document claims of significant and adverse environmental impacts (even in civil rights cases). From both the civil rights and NEPA perspectives, determinations of adverse effects take into account pervasiveness, duration, frequency, magnitude, and severity of effects. But the focus under civil rights law is on how low-income populations and minority populations would be affected. A significant finding in any one of these characteristics may be sufficient to generate a civil rights challenge, especially if the disadvantaged community has historically borne environmental burdens of regional transportation projects but enjoyed few, if any, direct benefits.

Special care should be taken to identify *all* possible significant adverse effects. A project-related effect may seem insignificant in and of itself, but in the context of other effects—including those not related in any way to the proposed project—it may have clearly adverse and significant effects on a disadvantaged population. Thus, the effects discussed in various sections of this guidebook should be taken together in assessing the significance of adverse effects.

The NEPA process should be considered a preliminary means of identifying adverse effects; it should be supplemented with a more detailed examination of the distributive effects and with environmental justice analyses when protected populations are present. Low-income communities and minority communities may have more adverse baseline conditions. Such existing conditions must be identified and evaluated along with expected project-related effects when threshold levels are being set for establishing significant adverse effects.

Distributive effects must be considered throughout the NEPA process because equity issues may arise at any time. Even if an environmental impact assessment (EIS) is not required because of a categorical exclusion or some other reason, the possibility that a disadvantaged community may be adversely and significantly affected means that an analysis of distributive effects should be conducted "to ensure that the otherwise applicable process or procedure for a federal action addresses environmental justice concerns" (CEQ 1997).

Under NEPA, distributive effects determinations are not necessary if an *intensive* preliminary examination of the project impact area shows the following:

- There is no protected population present;
- A protected population is present, but would suffer no adverse effects from the project; or
- A protected population is present and would suffer adverse effects, but not significant ones nor disproportionate ones, compared with non-protected populations in the project area.

If a protected population is likely to be affected adversely and significantly, the expected effects on that population must be compared with the expected effects on non-protected populations.

The requirements related to incidence of adverse effects in NEPA pertain solely to race and ethnicity, not gender, religion, or other differentiating characteristics. Project effects on other population groups (e.g., persons with disabilities) are governed by other laws and regulations such as the Americans with Disabilities Act (ADA). These other provisions may apply because low-income and minority communities often have disproportionately high numbers of disabled persons.

FEDERAL-AID HIGHWAY ACT OF 1970

A year after NEPA was passed, the Federal-Aid Highway Act of 1970 further clarified the role of community and environmental impact assessment regarding transportation investments. The law (Title 23, Section 109[h]) requires that

> "possible adverse economic, social, and environmental effects relating to any proposed project on any Federal-aid system have been fully considered in developing such project, and that the final decisions on the project are made in the best overall public interest, taking into consideration the need for fast, safe and efficient transportation, public services, and the costs of eliminating or minimizing such adverse effects as the following:
>
> 1. air, noise, and water pollution;
> 2. destruction or disruption of man-made and natural resources, aesthetic values, community cohesion and the availability of public facilities and services;
> 3. adverse employment effects, and tax and property values losses;
> 4. injurious displacement of people, businesses and farms; and
> 5. disruption of desirable community and regional growth."

One type of transportation effect set aside for special consideration in 1970 was residential relocation due to transportation projects. The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 provided that all groups should be treated uniformly and fairly in the case of residential relocations resulting from eminent domain.

EXECUTIVE ORDER 12898 ON ENVIRONMENTAL JUSTICE

EO 12898 on Environmental Justice stipulates that discriminatory effects, whether intentional or not, should be avoided. "Environmental justice" is a term commonly used to describe equity in treatment of low-income populations and minority populations resulting from governmental actions, in terms of both negative effects, such as disproportionate exposure to environmental harms, and benefits, such as improved range of access. The U.S. Environmental Protection Agency (EPA) defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." Fair treatment is defined to mean "that no group of people, including a racial, ethnic, or socioeconomic group, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies" (U.S. EPA 2000). (See http://es.epa.gov/oeca/main/ej/index.html.)

EO 12898 obliges each federal agency to identify and address "disproportionately high and adverse human health or environmental effects of their policies, programs and activities on minority populations, and Indian tribes." The pivotal test is whether disparate effects attributable to a federal action are likely. To determine disparateness, comparison must be made of the magnitude, severity, duration, pervasiveness, and egregiousness of injury or damage of project impacts affecting protected populations and non-protected populations.

The U.S. Department of Transportation's EO-implementing regulations require agencies to consider alternative actions or plans with less disparate effects when project-related disproportionately adverse effects on low-income populations or minority populations are likely (U.S. DOT 1997). If the originally preferred alternative is likely to result in such disparity, additional comparisons must be made of distributive effects between plan alternatives. Federally funded transportation actions must also adhere to procedural equity. In October 1999, the U.S. Department of Transportation issued a Memorandum on Implementing Title VI Requirements in Metropolitan and Statewide Planning, stating that the law (Title VI and related regulations) "applies equally to the processes and products of planning" (Wykle and Linton 1999). The Memorandum calls for the Federal Transit Administration (FTA) and the Federal Highway Administration (FHWA) to determine

> "what, if any, processes are in place to assess the distribution of impacts on different socio-economic groups for the investments identified in the transportation plan and Transportation Improvement Plan (TIP). If the planning process has no such capability in place, there needs to be further investigation as to how the metropolitan planning organization (MPO) is able to annually self-certify its compliance with the provisions of Title VI."

RESOURCES

1) http://es.epa.gov/oeca/oej/nejac/.

   This is the site for the National Environmental Justice Advisory Council, a federal advisory committee established to provide consultation on matters related to environmental justice.

2) http://www.epa.gov/R5Super/ej_exrht.htm.

   This web site contains the full text of the Executive Order 12898 on Environmental Justice. It is the executive order signed by President Clinton on February 11, 1994.

3) http://www.fhwa. dot.gov/environment/ej2.htm.

   This web site contains the Federal Highway Administration's comprehensive listing of environmental justice and transportation resources, rules, policies, publications, and training opportunities.

4) http://www.fhwa.dot.gov/environment/ejustice/facts/index.htm.

This site provides an overview of the legal aspects of environmental justice legislation.

REFERENCES

Civil Rights Act of 1964, Public Law 88–352, 42 U.S. Code, Section 2000d.

Council on Environmental Quality. 1997. "Environmental Justice Guidance Under the National Environmental Policy Act." Executive Office of the President (online). http://ceq.eh.doe.gov/nepa/regs/ej/justice.pdf. Available June 19, 2000.

Federal-Aid Highway Act of 1970, 23 U.S. Code 109(h), December 31, 1970.

National Environmental Policy Act of 1969, Public Law 91–190, 42 U.S. Code, 4321–4347, January 1, 1970, as amended by Public Law 94–52, July 3, 1975, and Public Law 94–83, August 9, 1975.

President, Proclamation. 1994. "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations." Executive Order 12898. Federal Register, Vol. 59, No. 32 (February 16), pp. 7629–7633.

Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970. 42 U.S.C 4601 as amended by the Surface Transportation and Uniform Relocation Assistance Act of 1987.

U.S. Department of Transportation. 1997. "U.S. Department of Transportation Order on Environmental Justice." Order 5610.2. *Federal Register,* Vol. 62, No. 72 (April 15), pp. 18377–18381.

U.S. Environmental Protection Agency. 2000. "Environmental Justice." U.S. Environmental Protection Agency (online). http://es.epa.gov/oeca/main/ej/index.html. Available August 11, 2000.

Wykle, Kenneth R., and Gordon J. Linton. 1999. Memorandum to FHWA Division Administrators and FTA Regional Administrators on Implementing Title VI Requirements in Metropolitan and Statewide Planning. TOA–1/HEPH–1 (7 October).

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GLOSSARY

Accessibility	Accessibility measures the relative ease with which one can reach desired destinations. See mobility.
Artist's sketches	A method of presenting alternative proposals for a transportation facility whereby respondents can react to renderings of aesthetic features.
Average annual daily traffic (AADT)	The average number of vehicles passing a point on a roadway per day, based on an annual average of daily traffic rates. Actual daily traffic rates may vary somewhat from the AADT because of seasonal variations, special events, and other phenomena.
Barrier effect	The reduction in mobility and safety of non-motorized travel caused by the construction of new transportation projects such as those that increase traffic volumes and speeds on existing roads.
Benefit-cost analysis	An analysis that compares the potential benefits of a project with the estimated costs of the project. If the potential benefits outweigh the expected costs, the analysis suggests that the project will benefit society in general.
Bicycle Compatibility Index (BCI)	A composite level-of-service measure for bicycle condition evaluation. Standard BCI values represent abilities and preferences of average adult cyclists.
Bicycle Safety Index (BSI)	An index that enables one to estimate the safety of bicyclists riding on a roadway that has certain characteristics. These characteristics include traffic levels, speed limit, and a series of physical attributes.
Categorical exclusion (CE)	A component of the NEPA process. A CE can result from a determination that a project would have no significant environmental impacts and therefore that an expedited permitting process can be followed. See environmental assessment and environmental impact assessment.
Census Transportation Planning Package (CTPP)	A data package available from the U.S. Census Bureau for most major metropolitan areas that contains demographic data and self-reported journey-to-work travel times. The data are available by jurisdiction within the metro area.
Charrette	A meeting to resolve a problem or issue. Within a specified time limit, participants work together intensely to reach a resolution. The sponsoring agency usually sets the goals and time limit and announces them ahead of time.

Community cohesion	The amount and quality of social networking among members of a community.
Cost-effectiveness analysis	Several alternatives are compared to determine which would achieve the desired outcome at the lowest total cost.
Delphi process	A survey analysis process whereby experts are surveyed individually, the initial results are reported back to them, and they are then given the opportunity to revise their estimates in light of their colleagues' expectations. This process is intended to achieve consensus on an expected outcome.
Descriptive statistics	The branch of statistics concerned with (1) summarizing the distribution of a single variable or (2) measuring the relationship between two or more variables.
Distributive effects analysis	An analysis that compares potential effects, positive and negative, of publicly funded projects or services on various population groups and (in some instances) on individuals or subgroups within groups.
Double-counting	Counting a particular effect twice, either explicitly or implicitly. For example, adding transportation cost savings to the economic effects brought about by these savings may result in an overestimation of the economic effect of a project.
Economic development	The process of expanding economic activity in an area to provide more jobs and income to that area's residents.
Environmental assessment (EA)	A component of the process mandated by the National Environmental Policy Act of 1970, as amended. An EA is a concise public document that includes a brief discussion of the rationale behind the proposed project, of alternatives to the proposed action, of the probable environmental impacts of the proposed action and its alternatives, and a listing of agencies and persons consulted. The EA must show why the impacts are not significant or how they can be mitigated to become non-significant. See categorical exclusion.
Environmental impact statement (EIS)	Also a component of the NEPA process. An EIS is an analytic document that informs decision-makers and the public of the potential environmental effects of the proposed project, as well as those of any reasonable alternatives. It must be completed when impacts would likely be significant, and it must show how they would be mitigated.

Environmental justice	Environmental justice is concerned with a variety of public policy efforts to ensure that adverse human health or environmental effects of governmental activities do not fall disproportionately upon minority populations and low-income populations.
Executive Order (EO) 12898	An executive order on environmental justice signed by President Clinton on February 11, 1994. The order obligates each federal agency to identify and address disparate effects of policies, programs, and activities on low-income populations and minority populations.
Equity	An often-elusive concept that pertains to fairness of distribution of the benefits and costs of a transportation project among population groups. There are several measures of equity, but in the end, what is equitable depends on personal, individual definitions of fairness.
Federal Highway Administration (FHWA)	The administrative unit within the U.S. Department of Transportation charged with improving and maintaining designated roadways across the nation. It also is responsible for carrying out various federal policies that apply to surface transportation.
FONSI (finding of no significant impact)	Part of the NEPA process. In a FONSI document, an agency briefly explains why an action will not have a significant impact on the human and natural environment and, therefore, why an EIS will not be prepared. The document is a possible conclusion of an EA.
Fixed-guideway transit	Any public transit service that uses exclusive or controlled rights-of-way or rails, entirely or in part. This includes heavy rail, commuter rail, light rail, trolleybus, aerial tramway, inclined-plane cable car, automated guideway transit, ferryboats, the portion of motor bus service that operates on exclusive or controlled rights-of-way, and high-occupancy vehicle (HOV) lanes.
Focus group	A small group discussion with professional leadership. A carefully selected group of individuals convenes to discuss and give opinions on a single topic. Participants are selected in two ways: random selection is used to ensure representation of all segments of society; non-random selection can help clarify a particular position or point of view.
Geographical information system (GIS)	A computer system capable of assembling, storing, manipulating, and displaying geographically referenced information. GIS enables spatial data files to be layered for purposes of analysis or presentation.

Gravity model	A method of analysis that generally assumes the number of trip ends at a destination location to be proportional to the size or attractiveness of the destination and inversely proportional to a measure of separation between this location and various origin zones. Gravity models are routinely used in travel demand models to forecast how many trips will be made to each destination from a given origin.
Gross regional product (GRP)	GRP is the total market value of all final goods produced within a region within a given time period.
Highway Economic Requirements Model (HERS)	A computer model developed for FHWA to assist state and local governments in programming their highway resources. HERS contains routines to estimate the economic benefits of potential transportation projects.
Horizontal equity	Horizontal equity refers to the equitable distribution of benefits and costs *within* a group.
Incident	An event that reduces the performance level of a roadway, including crashes, vehicle breakdowns, and debris on the road. Incidents are random events, but the likelihood of their occurrence is affected by the design and condition of the roadway, as well as by the congestion level on the roadway.
Input-output (I-O) model	A model that tracks industry purchasing patterns. It provides a means for calculating the indirect and induced effects on business sales and spending in a given area that may result from a particular change in relative costs, such as that brought about by a transportation project.
Just-in-time delivery (JIT)	Companies using JIT organize their suppliers to deliver smaller batches of supplies precisely when they are needed in a factory.
Level of service (LOS)	A concept that describes traffic conditions and associated traffic flow rates. Six levels of service are typically recognized: A (free flow) through F (stop-and-go waves). The concept of LOS also is applied to gauge the performance of non-motorized transportation (e.g., the ability of pedestrians to cross a major urban street).
Likert scale	A composite measure that attempts to improve levels of measurement through the use of standardized response categories in survey questionnaires. Response categories may include “strongly agree,” “agree,” “neither agree nor disagree,” “disagree,” and “strongly disagree.”

Mobility	The ability of people to move about and make use of various transportation modes. See accessibility.
Mode	The method of transportation by which people travel.
National Environmental Policy Act of 1969 (NEPA)	A federal law enacted January 1, 1970, to ensure that federal agency decision-making takes environmental factors into consideration. State and local entities must comply with NEPA when they are involved in federal actions (e.g., using federal funding for a project).
National Personal Transportation Survey (NPTS)	A survey conducted periodically by FHWA to measure travel of American households, focusing primarily on local, repetitive travel. NPTS data are intended to provide insights on travel by trip purpose and mode, social and economic characteristics of the trip makers, changes in vehicle ownership, vehicle and fuel usage, the changing travel patterns of women and minorities, and changes in the mobility of the older driver population.
Network	An integrated series of road segments that behave as a system. Thus, a change in one road segment often will affect the performance of others.
Noise abatement criteria (NAC)	Noise levels established by FHWA for a series of activity categories (i.e., land uses). If a proposed project would result in noise levels higher than the NAC, noise abatement measures must be taken.
Origin-destination (O-D) pair	The passage of traffic originating at one node on the network and traveling to another along a unique path.
Paratransit	The use of small buses or vans to provide transit services for transportation-disadvantaged groups, such as people with significant physical disabilities, and non-drivers who require medical or social services. Paratransit may also include flexible route, door-to-door transit service to the general public.
Pass-by traffic	Traffic that both originates in and is destined for locations outside of the local area in which it is traveling.
Photomontage	A photo-realism technique in which images of various alternatives are superimposed on an image of the existing environment. It allows respondents to evaluate the positive or negative effects of each project alternative in relation to the existing environment.
Price elasticity of demand	A measure of consumer response to a change in price. Calculated by dividing the percentage change in quantity by the percentage change in price.

Privacy — An issue in socio-demographic data, privacy generally is understood to mean that the information conveyed is not specific (i.e., disaggregate) enough for the attributes of a single household, person, or business to be revealed. To ensure the privacy of individuals, the U.S. Census Bureau may suppress data when only very small numbers of observations are present.

Progressive — A project or financing approach in which the cost burden is disproportionately higher for persons with larger incomes or the benefits accrue primarily to persons with lower incomes.

Qualitative analysis — An approach that involves considering qualities or attributes that do not lend themselves to quantification. It can be applied to assess people's general feelings toward alternatives by evaluating the way they respond to a series of non-metric indicators, such as aesthetic quality.

Quality of life — A general way of expressing the presumed ultimate objective of any form of public action. There are numerous dimensions to quality of life, which are valued differently by different people. Among the normally included dimensions are safety, access to opportunity, clean air and water, and social tolerance.

Raster — A method of coding and storing a graphic image as a pattern of dots. Also known as a bitmap.

Regression analysis — A statistical technique used to assess the extent to which one or more measures are related to a criterion measure. For example, household rent may be affected by a series of attributes of a property. How much each of these attributes affects rent, given the presence of the other attributes, can be assessed using regression analysis.

Regressive — A project or financing method that results in persons with lower incomes paying a larger share of their income for a project, or a project whose benefits largely accrue to those with higher incomes. See progressive.

Rent theory — A concept that explains how increased access to a location tends to encourage more intensive use of land at that location.

Road segment — A short portion of a roadway, often a half-mile or so in length, that is the unit of analysis in safety evaluations and in road network models.

Roadway geometry — Specific design elements of roadways, including number of lanes, lane width, median type and width, length of acceleration and deceleration lanes for on- and off-ramps, curve radii, and roadway alignment.

Scale economies Reductions in average costs that come about through increases in the output (i.e., scale) of plants and equipment.

Sensitive noise receptor A person or activity that is particularly vulnerable to traffic noise (e.g., hospitals, rest homes, schools, or houses of worship).

Sensitivity analysis The process of analyzing how changes in one factor (e.g., population growth assumptions) influence a key outcome such as traffic volume. Often the factor to be varied is the basis for several scenarios. For example, one might construct several scenarios based on different population growth projections.

STAMINA A highway noise prediction model developed for the Federal Highway Administration that is used to predict noise levels associated with major highway projects. STAMINA is a DOS-based computer program that calculates noise levels using a noise-propagation algorithm that employs data on road geometry, barriers, traffic conditions, and terrain.

Stated preference surveys A form of citizen survey in which respondents are asked to state their preference for one of two attributes at a time. A series of such pairwise comparisons are made to estimate how people's preferences are ordered.

TNMLOOK Noise-calculation software used with Traffic Noise Model (TNM) Look-Up Tables developed by the Federal Highway Administration as a simple screening tool. It performs noise calculations on single, straight-line highway configurations.

Traffic analysis zone (TAZ) Small geographic areas that represent urban areas in travel simulation models. TAZs are characterized by population, employment, and other factors and are the places where trips begin (i.e., trip producers) or end (i.e., trip attractors).

Traffic calming A combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior, and improve conditions for non-motorized street users. Expected consequences include safer roadways for pedestrians, bicyclists, and neighborhoods in general. Specific road design characteristics include speed bumps and traffic circles.

Traffic demand modeling Models used to calculate changes in travel time between specified origins and destinations. These changes might be the result of transportation projects, such as changes in road capacity. A limitation of these models is that they rarely take into account non-motorized transportation modes.

Traffic noise Any unwanted noise generated from four major sources: tire/pavement interaction, engine noise, exhaust noise, and brakes.

Traffic Noise Model (TNM) Noise-prediction software. TNM is the successor to STAMINA and offers clear improvements over it, including modeling for free-flow and stop-and-go traffic conditions.

Transportation choice The quantity and quality of transportation options available in a geographic area. Choice is an especially complex issue for those who are economically or physically challenged.

Transportation demand management (TDM) Programs designed to maximize the people-moving capability of the transportation system by increasing the number of persons in a vehicle or by influencing the time of (or need to) travel. TDM programs must rely on incentives or disincentives to make those shifts in behavior attractive.

Transportation disadvantaged People who face significant unmet transportation needs.

Travel time variability Uncertainty as to the amount of time a trip will take or the time at which one will arrive. For just-in-time industries or commuters, travel time variability often is as important as average travel time.

Triangular irregular network (TIN) A surface representation derived from irregularly spaced sample points and break-line features. Each sample point has an x,y coordinate and a surface, or z-value. These points are connected by edges to form a set of non-overlapping triangles used to represent the surface.

Trip purpose The reason why a trip is made. The purpose of a trip influences the mode used, the time at which the trip is made, the length of the trip, and other trip attributes. Common trip purposes include work and work-related business, shopping, and social/recreational interaction.

Universal access Transportation facility design that accommodates people with a wide range of needs, including wheelchair users, people who walk with difficulty or are vulnerable to falls, people who have visual disabilities, and pedestrians who are pushing strollers or handcarts.

Urban form The array of land uses and their densities within an urban area. Urban form is influenced by transportation facilities that affect the relative accessibility of different locations.

Vehicle hours traveled (VHT) — The number of hours spent on a specific road segment or within a road network by the vehicles operating on it per unit of time, generally a day. For a given volume of traffic, higher flow speed (e.g., less congestion) will lead to a reduction in VHT.

Vehicle miles of travel (VMT) — The number of miles driven by the vehicles using a specific road segment per unit of time, usually a day. VMT is equal to the traffic volume multiplied by the length of the roadway. See AADT.

Vehicle operating cost (VOC) — The variable cost to vehicle owners of operating these vehicles on roadways per mile of travel. Included in VOC are fuel and oil consumption, wear and tear, depreciation, and insurance. Flow speed, as well as road geometry and other physical attributes, can influence VOC.

Venn diagram — A graphic presentation technique that includes several overlapping circles of different sizes. The relative size of the circles connotes the magnitude of the phenomena being represented, and the extent of overlap indicates the degree to which the phenomena are interrelated.

Vertical equity — Equitable distribution of benefits and costs *among* groups. Groups are usually distinguished by wealth or income.

Virtual metropolitan model — A model that combines several visual computer models to create a comprehensive virtual model of an entire metropolitan area. Virtual metropolitan models are constructed by combining aerial photographs with street-level imagery and 3-D geometry to produce realistic simulations of large urban environments.

Visual acuity — The ability of the eyes to resolve detail.

Visual preference survey (VPS) — A form of resident survey that allows respondents to express their preferences for certain types of development rather than for specific proposals. Through a series of slides, respondents rate their attitudes regarding images, which are later analyzed to produce a consensus of resident preferences.

Volume-to-capacity (V/C) ratio — The ratio of the number of vehicles traveling on a roadway to the number that would result in a slowing of traffic to a specified speed. This level of traffic is defined as the effective capacity of the roadway. In general, congestion begins to set in at a V/C ratio of about 0.8.

Weighted decibels (dBA)
Units of sound that include an adjustment whereby high- and low-pitched sounds are given higher scores. The objective is to approximate the way humans hear sounds.

Windshield survey
An inventory of land uses and an observation of natural and human environments collected visually, generally by driving through a corridor in which changes are proposed.

Wire-frame model
A type of visual computer modeling commonly used for proposed transportation projects. Wire-frame models are derived from a continuous series of roadway cross sections that are linked together to form a 3-D model of the proposed roadway design.

The **Transportation Research Board** is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research results. The Board's varied activities annually draw on approximately 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purpose of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation

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