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# Assessing the Social and Economic Effects of Transportation Projects

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# SECTION 1: INTRODUCTION

The objective of this study, supported by the National Cooperative Highway Research Program (NCHRP Project 25–19), is to develop a practical guidebook capable of assisting transportation professionals in assessing the social and economic effects of transportation projects. The guidebook has been published as a separate document. In this final report for the project, we present much of the background research carried out in the course of the project.

In brief, this final report contains three main sections.

- Section 2 contains a comprehensive literature review that discusses the methods, tools, and techniques currently available for assessing the social and economic effects that may arise from a transportation project. This review contains an evaluation of the approaches discussed, including how capable they are of predicting the effects of a project before it actually is carried out.

- Section 3 presents an analysis of a survey we mailed to the planning and environmental units of all 50 state departments of transportation (DOTs) and to all metropolitan planning organizations (MPOs) within the United States. The survey inquires as to the current nature and level of use of a series of general categories of methods, tools, and techniques. It also asks these agencies for their assessment of the quality and usability of these modes of analysis. Appendix A contains tabulations of the responses to the survey.

- Section 4 provides an evaluation of the current state of the practice in assessing social and economic effects of transportation projects and suggests research that could help transportation professionals advance this state of the practice. Research needs are presented under 11 topical headings that correspond to the major sections of the guidebook.

This final report, then, should be regarded as a supplement to the main product of NCHRP Project 25–19, which is the guidebook titled, "Guidebook for Assessing the Social and Economic Effects of Transportation Projects." In this report we provide additional documentation of previous research to develop methods, tools, and techniques for analyzing the social and economic effects of transportation projects, citing a total of 120 reports and articles. In presenting this research, we stress predictive ability as it is generally more valuable to have even a basic sense of the probable effects of a project before it is carried out than an exact knowledge of the effects that are being experienced from a completed project. A limited portion of the research we discuss involves methodologies for examining phenomena other than transportation; we included it when there are clear applications to the analysis of transportation impacts.

The survey of current practices of state DOTs and MPOs regarding the analysis of social and economic effects of transportation projects helps set the stage for the guidebook. We examine the extent to which both types of agencies examine these effects, and we present summaries of what they see as pressing needs or priorities. In preparing the guidebook, we took into account these perspectives. Some of the agencies' needs cannot be fully met by existing methods, tools, and techniques. Our suggestions for further research are based on these unmet needs, as well as on our assessment of the adequacy of current approaches and the potential to improve upon them.

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# SECTION 2: LITERATURE REVIEW

For ease of presentation, we structure the discussion of existing methods, tools, and techniques around a taxonomy with four elements: social effects, economic effects, effects on aesthetics and livability, and distributive effects. We discuss existing approaches that have been applied in various settings under one of these four elements.

## SOCIAL EFFECTS

The social effects of transportation system changes can take many forms, some of which are particularly difficult to estimate with much precision. Perceptions as to the relative importance of different sorts of social effects may also vary quite widely. Perhaps in part because of these factors, relatively little work has been done in terms of developing methods, tools, and techniques to rigorously estimate the probable social effects of transportation system changes. Yet there are approaches that hold considerable promise. While our purpose in this discussion is primarily to present existing methods, tools, and techniques, we do occasionally note especially promising approaches. Our discussion is structured around types of social effects rather than around types of analytic approaches.

### Community cohesion

Community cohesion stems from the social interaction among members of a community. Such interaction can involve regular participation in community social events or neighborly exchanges on the street. Cohesion also is likely to involve a sense of closeness among residents, and a sense of being safe in one's neighborhood. While it is easy to define in general terms what community cohesion is, expressing it analytically is difficult because it is the product of myriad interacting factors that are difficult to quantify.

Much of the research on community cohesion stems from the literature of community psychology. In these studies, cohesion may be characterized as social cohesion, neighborhood cohesion, community cohesion, or place attachment. Researchers in this field have assessed cohesion for a wide range of communities using a variety of indicators. Cohesion research has focused on assessment at different levels of human interaction (neighborhood, community, and city) and for different groups of people (minorities, suburban residents, older adults, and blue-collar workers). Such research attempts to estimate cohesion based on a number of community or neighborhood characteristics.

**Neighborhood surveys**. Studies on cohesion typically take the form of surveys of residents, although they are often supplemented with visual and mapping exercises. These surveys are unfortunately designed only to measure a community's level of cohesion at a specific point in time; they are unable to predict how cohesion might be affected by a significant change in the community. Furthermore, these surveys can be lengthy, time-consuming, and data-intensive, making them impractical for assessing impacts of a particular project. It is probably the case that the most promising survey approaches are those that limit the number of questions to a few key indicators. To be useful for assessing the social and economic effects of transportation projects, such surveys will need to include questions related to how residents would react if a specified change were to take place in their neighborhood. It is possible, however, that hypothetical responses may not be identical to those resulting from an actual change.

Studies aimed at the neighborhood level question residents of a geographically-defined area about their interaction and feeling of closeness to their neighbors. Brown and Werner (1985) studied feelings of attachment to the block, reports of neighbors' behavior, and the use of exterior house decorations as indicators of neighborhood attachment. They interviewed residents of houses located on cul-de-sacs and houses on through streets, and collected data regarding decorations during the week prior to major holidays. The survey instrument contained three classes of variables—neighboring behaviors, attitudes toward the block, and attitudes toward a particular house—organized in 11 scales. Analysis of the data occurred in three steps. First, the proposed indices of cohesion were correlated to determine whether a coherent pattern emerged. A multiple regression analysis was then used to clarify the association between decorations and other symbols of cohesion. Additionally, the association between street form and cohesion was explored in a multivariate analysis of covariance. The authors concluded that the strength of attachment was related to respondents' general attitudes toward their block, their reported contact with neighbors, and their use of holiday decorations.

Weenig et al. (1990) developed a typology of social systems in neighborhoods through a questionnaire that measured a number of indicators related to neighboring and sense of community. For each respondent, mean scores of identification and interaction frequency were computed. Relations between the mean scores and the rest of the data were analyzed with a principal components analysis, in which each dimension is represented by a vector of correlated variables. The authors concluded that neighborhood cohesion consists of the frequency of interaction and amount of social support, but also involves identification, solidarity, mutual involvement, gossip, and disapproval of deviancy.

Some studies have focused on a more general notion of cohesion at the community level. Sagy et al. (1996) sought to link the analysis of sense of community at the macro (city) and micro (neighborhood) level by examining the relative effects of variables on a person's sense of community. They surveyed residents of newly formed neighborhoods (five to six months after being established). The dependent variable was the individual sense of community, which was measured by the "sense of community scale" (SCS), and independent variables consisted of a series of variables derived from the survey responses. Stepwise multiple regression was used to analyze the predictive strength of the several variables. The authors concluded that different factors underlie development of a sense of community in different groups of people.

Expanding cohesion research beyond the neighborhood or community to consider how it functions at the city-level, Widgery (1982) utilized a 240-item questionnaire to study the quality of life of residents in Flint, Michigan. Multiple linear regression was used to test the predictive strength of 38 factors in explaining two dependent variables: (a) overall satisfaction with the quality of life in the neighborhood, and (b) overall satisfaction with the quality of life in the Flint area generally. The five independent variables that were the most important predictors of satisfaction within Flint area included "trust in government and the political system," "satisfaction with family and friends," "aesthetic quality of the community," "years in the community," and "optimism about the community." The strongest predictors of satisfaction within neighborhoods included variables entitled, “neighbors,” “home,” “aesthetics,” “government and community services,” and “neighborhood security.”

In a study aimed at assessing cohesion at several different urban scales, Cuba and Hummon (1993) studied people’s identification with places ranging from the home to the community to the region. Four sets of variables formed the basis for the study: place-identity variables, demographic and migration variables, social-participation variables, and locus-of-activity variables. The authors performed three discriminant analyses, one each for the dwelling, community, and regional dichotomies. Variables that met the minimization criteria of Wilks’ lambda were entered via stepwise selection into the analysis. The bivariate and multivariate discriminate analyses resulted in similar conclusions:

1) Dwelling place-identities were strongly influenced by demographic and migration characteristics, as well as by a dwelling-related place affiliation.

2) Community place-identities were largely a function of social-participation attributes, in addition to friendship, organizational, and dwelling-related place affiliations.

3) Regional place-identities were principally a result of participation in activities in communities outside of one’s town of residence.

Some research explores cohesion in terms of different groups of people. Liebow (1998) surveyed an urban Indian population to determine its present degree of social cohesiveness. Respondents were selected through a random walk strategy, and were questioned on personal attributes, on situations where an individual might need or want assistance from someone else, and on links to people they would know well. Sociometric and network analyses were conducted on the data. The author concluded that recent arrivals faced more difficult circumstances than those who had lived in the metropolitan area longer, and that they were less integrally engaged in the urban Indian community’s social network.

Kweon et al. (1998) developed a model to explore the relationship between older adults’ exposure to nearby green common space and their level of social integration and attachment to local community. The authors also sought to explore the degree to which spending time in green common space might be related to older adults’ sense of community. The analysis involved computing intercorrelations among variables such as exposure to nearby outdoor common spaces, social integration, sense of local community, physical health, and fear of crime. Following the correlation analysis, the authors carried out a least squares multiple regression. They concluded that for older adults in the age-integrated setting, spending time in green, outdoor common space was systematically related to stronger social integration and a stronger sense of local community.

Research on the strength of community ties also takes the form of studies of place attachment, or the ties that community members have to their dwelling place. Cantrill (1998) studied the extent to which citizens’ stated preference for various activities relates to their sense of place and length of residency. Respondents were asked to describe (a) what it was like to live in the area, (b) what features contributed to the sense that the place was *special* in any way, (c) the qualities that made them feel *connected* to the region in one way or the other, and (d) why they planned to remain in or leave the area in the future. The author employed an open-coding methodology to characterize responses to interview questions, as well as a nonparametric test of independence and a simple regression analysis. He concluded that residents' opinions regarding various activities was linked to how they described their sense of place, largely independent of age and length of residence.

In a similar study, Mesch and Manor (1998) looked at the extent to which people are attached to place and how much local social ties and environmental perceptions affect place attachment. A 67-item questionnaire was administered through telephone interviews; respondents were asked how proud they were to live in their neighborhood, if they would be sorry to move out of their neighborhood, and if they had plans to move away within the next year. A logistic regression analysis was used in the multivariate analysis. The results indicated that features of the physical and social environment—such as the presence of open space, the lack of air pollution and noise, and the kind of people who reside in the area—are characteristics that bind people to a particular place.

In a rare study that considered cohesion in terms of future impacts, Kaltenborn (1998) studied the relationship between sense of place and the perception of environmental conditions and responses to environmental problems among residents in Svalbard in the Norwegian high Arctic. To measure perceptions of environmental conditions, respondents indicated their level of agreement with ten statements about the condition of the natural environment on a five-point scale. To assess behavioral response to environmental changes, respondents were asked how various impacts would affect recreational activities. Respondents indicated whether they would, as a result of impacts such as an oil spill or increased tourism, relocate activities to other places, choose other activities, contribute to solutions to the problems, or not react at all. Finally, respondents stated what their overall reaction would be if a major oil spill hit the Svalbard coasts. The author concluded that residents who expressed a strong sense of place were most emotionally affected by the potential impacts, even though they would be less displaced geographically in terms of recreational activities than those with a weaker sense of place.

The majority of community cohesion research involves lengthy, time-consuming surveys. Fortunately, there are a few exceptions that offer more feasible, flexible options for assessing the impact of a project on a neighborhood or community. Bollen and Hoyle (1990) designed and tested a method to study perceived cohesion as a previously neglected aspect of the community cohesion construct. They devised a scaling system, the Perceived Cohesion Scale (PCS), that evaluated two dimensions of perceived cohesion (sense of belonging and feelings of morale) using three questions for each. Their six-item questionnaire was administered to two samples, a high-cohesion group and a low-cohesion group, and the data were analyzed using a maximum likelihood fitting function, in tandem with chi-square and goodness-of-fit measures. The authors concluded that the PCS has indicators with high reliability, validity, and some degree of invariance in different groups.

Buckner (1988) developed an 18-item Neighborhood Cohesion Instrument (NCI) to measure cohesion at an individual level and at a neighborhood level of analysis. Each question in the self-administered questionnaire focused on one of three scales measuring (1) attraction to neighborhood, (2) degree of neighboring, and (3) psychological sense of community. Cohesion was calculated for three Washington, DC, suburbs with one-way analyses of variance. Buckner concluded that the instrument has potential for assessing a particular neighborhood's cohesion and for evaluating an intervention that would influence cohesion. One of its limitations, however, is that it measures cohesion in a relative sense rather than in an absolute sense. Robinson and Wilkinson (1995) successfully utilized 17 items from the Buckner's instrument to measure the level of cohesion in a remote mining town. Although their study area differed significantly from Buckner's, they too concluded that the instrument was able to measure community cohesion.

Nasar and Julian (1995) constructed an 11-item questionnaire for evaluating psychological sense of community and its effects, based on Glynn's (1977) measure for assessing sense of community of place. Their questionnaire was shorter than both Glynn's and Buckner's, and it covered more aspects of community than Buckner's Neighborhood Cohesion Instrument. Nasar and Julian tested their questionnaire in several different applications, comparing residents of neighboring apartment buildings, areas with different levels of land-use diversity, and couples with children to other groups. Analyses of variance were used to compare the resulting scores. They concluded that their scale provides a convenient, reliable, and broad measure of sense of community, with the ability to differentiate among people of different demographic characteristics and in different land-use mixes.

Finally, Skjaeveland et al. (1996) designed a 14-item Multidimensional Measure of Neighboring (MMN) to assess neighborhood social characteristics along several dimensions: overt social activities, social ties, sense of mutual aid, sense of community, attachment to place, and annoyance. The authors performed a principal-component analysis to determine whether the 14 items clustered into theoretically meaningful factors (essentially indices). They assert that their instrument can be administered in a short time to construct a profile of the distinct dimensions of a neighborhood's social life.

**Limitations of cohesion surveys.** Because most of the instruments developed to measure neighborhood cohesion are lengthy, time-consuming surveys, they are not often realistic options for planners under time constraints. Also, their usefulness is limited in that they gauge attitudes only about current levels of cohesion. They do not consider how cohesion might change as a result of a project that creates an intrusion in the area. Furthermore, they often assess cohesion in relative rather than in absolute terms. It probably is reasonable to conclude that the most appropriate applications are those that use a very small number of questions that can be administered realistically in a short amount of time, such as the surveys developed by Buckner, or by Nasar and Julian. The method suggested by Kaltenborn is among the most promising as a means to consider cohesion in terms of future impacts.

## Pedestrian and bicycle safety

Changes in transportation systems may affect the safety of persons as they go about their daily lives in their neighborhoods or places of work. Increased traffic or changes in traffic patterns may transform a pedestrian-friendly environment into one in which residents are at greater risk of injury. It also may make it more difficult and unsafe to walk or travel by bicycle. Such changes necessitate a consideration of pedestrian and bicycle traveling patterns and of possible alternative routes for pedestrians and cyclists.

In the case of pedestrians, methods to estimate safety—the ability to cross streets, go for walks, and travel without the undue threat of harm—involve examining pedestrian movements.

Pedestrian movement research studies how pedestrians move through their environment. This literature is supplemented by research on the adequacy of pedestrian environments for pedestrian movement, which typically employs simulation models.

**Pedestrian movement.** Timmermans et al. (1992) discussed and evaluated four different modeling approaches for pedestrian movement: regression models, spatial interaction and entropy-maximizing models, Markov models, and simulation models. Generally, such models are of limited value in predicting the likely effects of changes in the transportation network on pedestrian movements.

Spatial interaction/entropy-maximizing models can be used to assess a variety of interactions. Butler (1978) developed one such model that consisted of three submodels:

1) A trip-attraction submodel to predict the total number of stages that start or end in a particular zone of the city center;

2) A distribution submodel to predict the distribution of the trips across various destinations; and

3) An allocation submodel to assign the predicted flows between the origins and destinations to the transportation network.

One disadvantage of spatial interaction models is that they lack a component to represent the sequencing of stops in any coherent fashion.

Markov models are typically used for analyzing the kind and intensity of functional relations in multi-purpose trips. These models involve an interaction matrix that describes the probability that a particular destination $j$ will be chosen, given that the previous stop was at destination $i$. The transition probabilities are derived from observed choice patterns. Such models have the ability to derive some general aspects of trip-changing behavior by manipulation of an interaction matrix. Significant limitations exist because Markov models are not able to predict future behavior resulting from changes in the variables that are presumed to govern the trip-chaining process. In an attempt to overcome this problem, Borgers and Timmermans (1986a) developed a model that assumes pedestrian movements can be represented as multipurpose trips consisting of both planned and impulse stops.

Simulation models of pedestrian movements are structured around a number of principles that can be used to replicate pedestrian travel behavior. Borgers and Timmermans (1986b) developed one such model in which the number of goods purchased by a random pedestrian is determined by randomly drawing from a distribution corresponding to the observed relative frequency of purchases. The links where the selected goods are bought are then predicted. Once it has been determined where the first purchase is made, the model simulates the choice of links for the remaining goods. Finally, the model simulates a pedestrian’s route-choice behavior, according to information on the location of the entry point and the links where goods will be bought. The point of completion of the trip is assumed to be the same as the point of entry. The whole simulation process is repeated for each consumer at each entry point in a series of replications.

Once it is understood how pedestrians move through their environment, one can consider barriers to pedestrian movement and the adequacy of pedestrian walkways. Aultman-Hall et al. (1997) demonstrated that differences exist in pedestrian accessibility to neighborhood destinations and that these differences can be measured with the use of geographic information systems (GIS). They chose distance as the quantitative measure of accessibility because it is a common reason for not walking. It should be noted, however, that while distance may represent the ease with which a destination can be reached by walking, it does not necessarily define the likelihood of a person making a particular trip by foot. The study's target value for the average walking distance to neighborhood destinations was 400 meters. Three alternative designs for a proposed neighborhood were studied: an original design, an original design with walkways, and a substantial redesign. Each plan was digitized using GIS, and programs were written to calculate the shortest walking distance from each residence to the school, the nearest open space, and the nearest transit stop using a minimum path algorithm. The authors concluded that the GIS-based approach was an effective tool for the evaluation of walking accessibility for alternative neighborhood designs.

In another study of the adequacy of pedestrian walkways, Gassaway (1992) considered walkways in terms of the needs of particular land uses. He proposed a typology of walkways, including sidewalks, raised curb-shoulder separations, edgeline shoulder separations, edgeline shoulder separations with implanted reflectors, natural footpaths, constructed footpaths, and roads with no walkways. After an area's walkways are mapped in the field and classified into one of the groups in the typology, each walkway is evaluated for (a) pedestrian safety from motor vehicles, (b) quality of walking surface, and (c) minimum width for pedestrian passing according to a number of criteria. Further information should be obtained regarding the adequacy of the walkways, such as data on the average number of motor vehicles per business day on specific street segments, the number of passengers on and off public buses for specific segments of routes, and the actual or estimated number of persons using institutions on public land on specific days (e.g., school days, holy days). Finally, problems are discerned by identifying areas that do not meet the adequacy criteria and by comparing mapped walkway patterns with pedestrian needs for given land use classes.

Futterman et al. (1999) devised what they refer to as the "Pedestrian Geographic Resources Database" (Ped-GriD), a quantifiable method to identify the best places for building livable communities based on maximizing the pedestrian potential of a particular place. Ped-GriD creates inventories of pedestrian and livability resources, including community facilities (e.g., parks, libraries, schools, and civic centers), land uses (e.g., retail, office, residential, industrial, and parks), transit nodes (e.g., park-and-ride, rail stations, bus stations, and airports), and vehicular, bicycle and pedestrian routes. The method is intended to distinguish between places that are pedestrian dependent and places that are pedestrian generators. Demographic indicators can be compared with geographic indicators to find the areas with the highest pedestrian potential.

**Bicycle compatibility.** Research into the ability of people to circulate on bicycles in a safe and pleasant manner parallels the analysis of pedestrian safety. Harkey et al. (1998) developed a methodology for deriving a bicycle compatibility index (BCI) that could be used by bicycle coordinators, transportation planners, traffic engineers, and others to evaluate the capability of specific roadways to accommodate both motorists and cyclists. The study expanded upon previous work by others to produce an instrument that can be used to predict bicyclists' perceptions of a specific roadway environment, and ultimately to determine its level of bicycle compatibility. The BCI methodology was developed for urban and suburban roadways, and uses variables that bicyclists typically feel are related to the comfort and "friendliness" of a facility. Among the key variables are curb lane width, traffic volume, and vehicle speeds. The end result of a BCI analysis is a level-of-service rating for shared use operations by motorists and cyclists.

Rintoul (1995) presented a four-step method for quantifying the socio-economic impacts of motor vehicle traffic on pedestrians and cyclists. The method addresses both the transverse effect (the impact on pedestrians and cyclists attempting to cross a roadway) and the longitudinal effect (the impact on cyclists as they travel in the traffic flow). This research contains the assumption that the barrier in question is passable, and therefore may not be applicable to high-speed highways, where safe crossings are more likely to be tunnels or overpasses. While the author points out that further research is needed, the methodology is useful in quantifying the effects on pedestrian and bicycle travel of changes in low- to medium-volume streets within an urban setting.

The American Association of State Highway Transportation Officials (AASHTO) (1999) provides various standards that can be used to evaluate cycling facilities. This publication specifically looks at ways to make transportation facilities safer and more convenient for bicyclists, pedestrians, and motorists. The guide includes planning considerations, design and construction guidelines, and operation and maintenance recommendations. It also includes an expanded look at accessibility on shared paths.

Reitveld (2000) estimated that the actual number of non-motorized trips is six times greater than conventional surveys had previously indicated. Non-motorized transport modes such as walking and bicycling are environmentally friendly, cheap, and reasonably fast alternatives for trips up to 3.5 km in distance. The author found that the importance of non-motorized modes for longer trips emerges when one adopts a multimodal perspective, in that the use of a car implies short walking trips to or from a parking place. The same holds true for transit, as most users walk or bike to public transport stops. Recognition of the multimodal character of such travel means that the number of pedestrian trips increases by a factor of about six, and the distance by about 40 percent. Rietveld also discussed implications for average travel speeds, daily travel-time budgets, parking policies, and policies to stimulate public transport.

Most methods for assessing the ease of pedestrian movement and the adequacy of roadways are not designed to estimate a project's future impacts on the safety and viability of this form of travel. They do provide the means to evaluate current levels of pedestrian movement, however, and subsequently to consider how a project may alter this movement. In the case of bicycle travel, several methods are available to estimate how a proposed transportation project would affect safety and ease of movement.

## Accessibility to family, friends, and community resources

Few would disagree that an important element in quality of life is easy access to family, friends, and community. Transportation system changes can significantly limit or enhance people's opportunities for interaction in their community by altering routes of access. Like the research on pedestrian safety and movement, accessibility research tends to focus on measuring current levels, not on predicting effects of transportation projects. A number of models have been developed to measure accessibility based on a variety of indicators, but models that consider access to public and personal resources in terms of spatial equity offer the most promise for assessing how a project may affect future accessibility.

Gutiérrez et al. (1998) developed an accessibility indicator for transportation infrastructure planning that expresses the access conditions of each node of a network. For each node, a weighted average of the ratio of the impedance through the network between node *i* and destination activity center *j* (based on actual system performance) and the Euclidean impedance between the two (based on distance, thus assuming optimal infrastructure efficiency) is calculated. The economic activity levels of the destination centers are used as weights. The ratio expresses the relative ease of access in each relationship: the closer network impedance comes to the Euclidean impedance, the lower this figure will be. Network impedance from any node on the network to each economic center is obtained by the minimum time route, taking into account the turn impedances on several nodes. The authors concluded that the accessibility indicator would be useful in decisions to invest in transportation networks.

Handy and Niemeier (1997) discussed three types of accessibility measures: cumulative opportunities measures, gravity-based measures, and utility-based measures. Cumulative opportunity measures represent the number of chances one has to perform desired functions within a given travel time (or distance). Such measures offer a sense of the range of choices available to residents. Gravity-based measures weigh opportunities by impedance, which is generally a function of travel time or travel cost. The closer the opportunity, the more it contributes to accessibility; the larger the opportunity, the more important accessibility to it is. Utility-based measures have their roots in random utility theory, in which the probability of an individual making a particular choice depends on the utility of that choice relative to the utility of all choices. In this formulation, an individual assigns a utility to each destination choice in some specified choice set and then selects the alternative that maximizes his or her utility. The utility function includes variables that represent the attributes of each choice, reflecting the attractiveness of the destination and the socioeconomic characteristics of the individual. Utility-based measures are similar to gravity-based measures, but have theoretical and empirical advantages. The authors also discussed a number of interrelated issues that must be resolved in the specification of any accessibility measure: the degree and type of disaggregation, the definition of origins and destinations, and the measurement of attractiveness and travel impedance. Finally, they presented case studies in which the accessibility measures were tested.

Truelove (1993) discussed alternative methods for measuring spatial equity in the provision of public services and then applied the methods to a case study on the location of daycare centers in Toronto. One method involves mapping areas beyond the defined range of existing facilities; any region beyond the defined standard of distance to facilities is considered to be at a disadvantage. In the case study, the number of daycare spaces within 1 kilometer (km), 3 km, and 5 km of each census tract centroid was calculated. It was assumed that a child would attend a daycare center within a certain distance of home. The map indicated that access to daycare spaces varied systematically with distance, with every census tract having at least one daycare center within 5 km of the census tract centroid.

Another method Truelove examined involves calculating a service-to-needs ratio. Correlation analysis can then be used to evaluate whether the distribution of a service is related to need. The higher the correlation, the more equitable the distribution. It is difficult, however, to define the appropriate level of spatial aggregation, and this affects the value of correlation coefficients. Difficulty also arises in the interpretation of correlation coefficients. The author correlated socioeconomic, demographic, and family-structure variables with spaces per 1000 children who were 0-4 years of age and found that nonprofit centers were weakly correlated with need measures, that municipal centers were negatively correlated with average income, and that commercial-center space had a high correlation with the proportion of English-speaking population. Truelove also calculated indices of spatial equality to measure how equally daycare centers were distributed across metropolitan Toronto. The results indicated that at a short distance (0.5 km) daycare center spaces were distributed quite unequally, but at a distance of 5 km they were distributed fairly equally.

Another spatial-equity measurement technique has been suggested by Talen and Anselin (1998), who evaluated the importance of methodology in assessing whether or not—or to what degree—the distribution of urban public services is equitable from a spatial perspective. They studied the distribution of playgrounds in Tulsa, Oklahoma, relative to the residential location of children and minority populations. The authors defined access in terms of distance between the centroids of census tracts (as a proxy for residential location) and the coordinates of public playgrounds by calculating distance with a shortest-path algorithm. Four accessibility indexes were considered: the standard measure of access (the number of services per ward, neighborhood, or tract), as well as three alternative accessibility indices that took into account distance, road network, and/or facility characteristics.

Data on the number and location of public playgrounds were obtained from the Tulsa Metropolitan Area Planning Commission's Park, Recreation and Open Space Plan for 2005; a total of 88 playgrounds were located. GIS software enabled the authors to create tract and street network layers from the census Tiger files. Access measures were computed using the shortest path distances over the actual street network between the centroids of each census tract and the centroids of the parks as distance inputs. Socioeconomic data by tract on the percentage of nonwhite population, the percentage population under 18 years of age, and the median housing value were obtained from the 1990 census files.  Statistical analyses (Moran's I) were conducted, and outcome maps were produced.

Kwan (1999) argued that defining accessibility according to space-time feasibility instead of location proximity would enable a better understanding of people's accessibility to desired facilities. To study differences in individual accessibility, the author employed a network-based GIS approach to establish space-time measures based on the concept of a "daily potential path area" (DPPA). Each person has a daily activity program that consists of some spatially and/or temporally fixed locations, along with activities that can be undertaken at various locations or times of the day. The feasible region for an individual on a particular day can be derived based on the space-time coordinates of consecutive pairs of fixed activities. A certain amount of time is available for flexible activities in between a given pair of fixed activities. Based on the locations of the fixed activities, a spatial search is performed on the transportation network to find all urban opportunities within reach given the time constraint. The resulting area is the potential path area (PPA). These individual areas are aggregated to form a daily potential path area.

To empirically test this concept, Kwan acquired data from travel diaries recorded in Franklin County, Ohio. The author also used digital data representing the local transportation network and a land parcel geographic database of the study area. Activity locations in the travel diary were geocoded relative to streets. To examine gender differences in access to urban opportunities, three space-time accessibility measures were computed for each individual: the number of opportunities in the DPPA, the sum of the weighted area of these opportunities, and length of the network arcs or road segments included in the DPPA. The weighted area of a parcel equaled the parcel's area (in acres) multiplied by a building-height factor based on the number of stories of structures on the parcel. Significant gender differences were found in individual access to urban opportunities for full-time employed women and men, although there did not appear to be a difference in the composition and types of opportunities available to these individuals.

Finally, Talen (1998) discussed the concept of equity mapping, which provides an analysis of the accessibility of public resources to spatially-defined social groups. The objective is to analyze the spatial incongruity between resource need and resource distribution. Equity mapping requires a standard GIS package, a statistical package, location information on public facilities (or proposed locations), and census data. It allows the analyst to determine a number of methodological alternatives, including the type of facility, attributes of the population, type of accessibility and distance measurements to be used, and appropriate parameters of the access measures. Additionally, other components, such as travel constraints, may be included to increase the complexity of the measure. After the accessibility measures have been calculated, the locational and attribute data are entered into a GIS for mapping and analysis, including facility attributes (planned or existing) and population attributes measured in units of census blocks. The analysis involves spatial univariate, bivariate, or multivariate analysis and a review of the mapped distribution of the data and spatial patterns to assess the spatial equity of public resource distribution.

## Construction disruptions

Transportation projects inevitably create disruptions in normal vehicle operations during the construction phase, creating delays for motorists or forcing them to take alternative routes. Construction delays may last from a few days to many months, and often require people to allow more time for travel. Much of the literature on estimating the disruptions caused by the construction of a project prior to its initiation takes the form of estimating motorist delay for specific road types. Most of this research focuses on traffic diversion and lane or road closures, rather than on the impact construction may have on neighborhood quality or business viability.

Both Cassidy et al. (1994) and Martinelli and Xu (1996) presented methods for estimating motorist delay using mathematical models. Cassidy et al. developed a procedure for estimating user-specified percentile values of average vehicle delay per operating sequence at two-lane highway work zones; the model is only applicable to work zones that are operating at unsaturated levels. Martinelli and Xu evaluated alternative longitudinal roadway closure patterns to estimate the optimal workzone length in terms of delay, traffic control, and safety criteria under different roadway and traffic conditions for a given four-lane divided freeway reconstruction project with complete closure of the roadway in one direction.

In a more comprehensive model, Robertson et al. (1995) assessed the impacts of the expressway reconstruction of Metropolitan Boulevard on adjacent traffic operation in Montreal, Canada. They sought to develop lane and road closure requirements, to assess the quantitative impact of the construction on adjacent intersection and cross-street traffic operations, and to develop appropriate traffic engineering responses to accommodate the construction impact. The study was conducted before construction began, and it took into account two types of impacts: the diversion of expressway traffic to arterial roads and the need for lane closures on roadways beneath the facility. Eight major intersections along the service roads were selected for analysis. The signalized intersections module of the Highway Capacity Software (HCS) package was applied to determine levels of service for each intersection under three separate scenarios: existing conditions, construction period conditions with no lane closures, and construction period conditions with lane closures on the cross-street. The authors concluded that about a third of the intersection approaches would be seriously impacted by the reconstruction project, that lane width reductions should be used instead of complete lane closures whenever possible, and that no more than two adjacent minor streets should be closed at the same time.

Finally, Krammes (1990) proposed a set of steps to follow in evaluating the travel impact of major highway reconstruction projects and guidelines for selecting appropriate analysis tools. The first step is to inventory the affected corridor, and includes defining the boundaries of the corridor, recording the transportation facilities and services in it, as well as the current usage in the corridor, and estimating the operational measures of effectiveness for existing conditions. In the second step, traffic-handling options are identified. The third step involves determining the changes in capacity through the reconstruction zone to evaluate traffic-handling options. If the traffic handling capacity proves inadequate, then corridor-wide traffic volumes and capacities should be compared. If corridor-wide capacity is also inadequate, Krammes argues that it may be necessary to develop a traffic management plan, including a traffic-handling option, impact mitigation techniques, and a public information program. Fourth, corridor-wide capacity estimates are obtained based on estimates of how motorists would respond to a particular traffic management plan. Changes in travel patterns are then translated into more meaningful measures of travel impacts on motorists.

In general terms, five categories of analysis tools exist for use in the travel impact evaluation process. First, network-based planning models perform travel demand estimation functions and are useful if a corridor-wide evaluation is required. Second, quick-response estimation techniques perform some or all of the same travel demand estimation function using simplified, non-network-based analyses that require less time, labor, and data than network-based models. Third, highway capacity analysis approaches estimate the volume of reconstruction zones and the feasibility of alternative routes and modes, and provide operational measures of effectiveness, including level of service and average speed on the reconstructed highway and alternative routes. Fourth, traffic simulation models evaluate the nature of traffic flows and the complex interactions among highway geometric elements. Finally, traffic signal optimization models develop optimal signal phasing and timing plans for isolated signalized intersections, arterial streets, or signal networks.

Highway capacity analysis procedures or traffic simulation models are sufficient if the evaluation is restricted to the highway being reconstructed. If corridor-wide evaluation is required, an analysis tool needs to have traffic assignment capabilities (network-based planning models, quick-response estimation techniques, or freeway corridor simulation models). There are three considerations for selecting among the available analysis tools:

1) the complexity of the traffic management for the project;

2) the size of the corridor likely to be affected; and

3) the time, data, and labor resources that are available.

If alternative geometric and traffic control conditions must be evaluated, a simulation model generally should be used in lieu of a network-based planning model. Quick-response estimation techniques are faster and easier to use than network-based models, but they were not designed to analyze large or complicated corridors. Quick-response estimation techniques, however, can provide acceptable levels of accuracy for preliminary assessments of the order of magnitude of impacts.

## Need to relocate

Some transportation projects necessitate the relocation of residents of a particular area. This raises strong concerns among planners and residents regarding the quality of the area to which residents will relocate, and the ability of residents to adjust to their new surroundings, form social relationships, and travel to work, school, or other important destinations.

The majority of relocation research takes the form of neighborhood/community surveys and is based on displacement events that occurred in the 1970s or earlier, typically from the perspective of how poorly the displaced residents fared after they were relocated. Research also exists on factors that influence the ability of residents to adjust to a new location, regardless of their motivation for moving. Very little research has attempted to estimate impacts, but some has looked at the displaced population before, as well as after, the displacement, and considers the emotional impact on residents who expect to be displaced sometime in the future.

**Neighborhood/Community surveys.** Although not specifically considering the impact of forced relocation, Bolan (1997) explored the role of the mobility experience and individuals' motivations and attitudes regarding entering a new neighborhood in explaining neighborhood attachment. He obtained data from the 1978-1979 Seattle Community Attachment Survey on two dimensions of attitudinal attachment: evaluation (an individual's satisfaction with the residential environment) and sentiment (a person's emotional attachment to a community). Bolan also examined two dimensions of behavioral attachment: interaction or informal participation (a resident's ties to other people in the neighborhood) and involvement (one's formal participation in the community). Additionally, data were obtained on mobility experience: the number of moves a person has made since age 18, the number of months it took to find a home, reasons for moving to a new home, and the distance between the last and current addresses. Control variables included length of residence, home ownership, children 6-17 present in the home, age, education, marital status, and income. Analysis was conducted to assess the short- and long-term effects of the mobility experience on attachment. Separate dummy variable ordinary least squares regression models were estimated for each of the five attachment measures (evaluation, sentiment, organizations, interaction with neighbors, and neighbors known by name) for those in the full (long-term) sample and those with a length of residence less than two years (short-term). Bolan concluded that familiarity with the environment, greater pre-move exposure to the new environment, and perceived control during transition between environments had an impact on individuals' post-move attitudes and behaviors.

In another study examining factors influencing adjustment to a new environment, Churchman and Mitrani (1997) hypothesized that place attachment to Israel would be related to immigrants' motives for migrating to Israel and to the perceived differences between their physical environment in the Soviet Union and their physical environment in Israel. Personal interviews were administered to students from the former Soviet Union who were currently studying in Israel. They were asked a variety of questions related to the physical attributes of different levels (country, city, neighborhood, building, and apartment) of the two environments. At all four levels, the students were asked one direct and four indirect questions related to attachment. Except for one question, attachment at one level was not related to attachment at other levels. Students were also presented with a list of eight city-related attributes of the physical environment and 18 neighborhood-related attributes and were asked to indicate if a difference existed between where they had come from and their current place of residence in terms of each attribute. If they indicated a difference, they were asked to explain the nature of the difference and to state which of the two they preferred. Respondents were also asked an open-ended question about their motive for coming to Israel. The authors concluded that on the country and city/neighborhood levels, a relationship existed between the number of perceived differences and attachment, but not in the same direction. Furthermore, on the country and building/apartment levels, the greater the number of differences where the USSR was preferred, the less attachment to Israel. Also, on all three levels, the greater the number of differences where Israel was preferred, the greater the attachment to Israel.

Studying a displaced population before and after relocation, Rubenstein (1988) evaluated the impact of the Uniform Relocation Act using the experience of a group in Baltimore as a case study. He sought to determine the extent to which those who were displaced moved into housing that was standard and affordable, and the extent to which displaced persons moved to neighborhoods less desirable than the neighborhood where they had lived previously. To evaluate the quality of the housing, the author utilized data from case files, including data on the structural condition, tenure (owner or renter), and rent or value of the dwelling before and after displacement. He also considered household income, relocation payments received, whether the household split into more than one unit after displacement, and whether the replacement dwelling was in a public housing project. To evaluate the extent to which displaced persons moved into more desirable neighborhoods, Rubinstein obtained addresses before and after displacement, as well as race and income data. Additionally, he determined the distance and compass direction from each individual's first residential location to their second, as well as the census tract of each new address. He concluded that the Uniform Relocation Act had been successful in moving displaced persons into standard housing, but that it was not clear whether this housing was affordable.

Also focusing on a displaced population before and after relocation, Colony (1972) conducted a study aimed at improving the processes of property acquisition and relocation of residents in order to minimize adverse social, psychological, and economic impacts. The study focused on residential relocation resulting from a right-of-way for the proposed route of Interstate 90 on the west side of Cleveland. Data were obtained from 228 interviews of relocated households and from case files of the Ohio Department of Highways. Information was obtained on five variables: age, income, occupation, education of household head, and score of household head on the Srole anomie test. The Srole anomie test measures the sense of social mal-integration of a population by counting the number of statements to which a respondent agrees. Social status of neighborhoods was determined using the Farber-Osoinach Index of Socio-Economic Rank. Scores were assigned to each of 127 census tracts according to the percentage of white-collar workers, median school years completed, median income, and percentage of nonwhite persons. Each tract was then assigned a social status category ranging from one (highest social status) to five (lowest social status). Then, demographic data were compared in terms of percentages. Colony concluded that persons who were relocated tended to move to homes as close as possible to their old homes, that they tended to select a new neighborhood of equal or higher social status, and that they tended to maintain or upgrade the social status of their neighborhoods in a manner similar to that of an independent sample of voluntary movers.

Lev-Wiesel (1998) took a different approach to relocation research by examining how stress levels prior to relocation impact residents. She sought to develop a multivariable paradigm to determine the contribution of personal resources in explaining stress. In her research, she formulated three hypotheses:

1) the greater the degree of demand, the higher the level of stress;

2) the greater the degree of the affective, instrumental, and cognitive resources, the lower the degree of the demand and the lower the level of stress; and

3) potency will be more effective than cognitive and instrumental resources in lowering the level of stress.

A questionnaire was mailed to male and female permanent residents of several communities in the Golan Heights of Israel. To measure stress, the author employed the State-Trait Anxiety Scale and the Psychological Equilibrium Scale. Demands were measured in terms of instrumental demands, affective demands, and cognitive demands, and were assessed at two levels pertaining to seriousness and direction. Resources studied included potency and psychological sense of community (affective demands), political orientation and education (cognitive demands), and gender and family status (instrumental demands). Potency was measured with the Potency Scale developed by Ben-Sira (1985), which consists of 19 items to which respondents indicate their level of agreement. Psychological sense of community was measured with Buckner's (1989) Psychological Sense of Community Scale. Political orientation was measured through four items aimed at positioning the political orientation of the respondent between two poles: pro-territories and pro-peace. The author conducted a one-way analysis of variance (ANOVA) to examine differences among residents of different communities. Hypotheses regarding effects were tested using a multivariate analysis of variance in which the demands were the independent variables and stress and anxiety were the dependent variables. The author concluded that potency had a greater impact on stress that did education or psychological sense of community, and that anxiety had an intervening role between demands and stress.

In a similar study focusing on stress in marital couples, Lev and Shamai (1999) studied the threat of forced relocation on the marital quality of couples living in the Golan Heights. The authors constructed three hypotheses:

1) the higher the level of stress, the lower the level of marital quality;

2) the higher the number and quality of the resources, the lesser the perceived demands of the stressor events; and

3) the higher the degree of perceived demands, the higher the level of stress.

Data were collected from married couples in the Golan Heights through an anonymous questionnaire. The questionnaire consisted of five parts, in addition to demographic questions. First, the Enrich Scale measured marital quality on the basis of spouses' attitudes about themselves and feelings towards their partner. The Psychological Equilibrium Scale evaluated level of stress based on six physical and emotional conditions. The Potency Scale measured confidence in both one's own capacities and in society that is perceived to be basically ordered, predictable, and meaningful. The Demands Scale included instrumental demands, affective demands, and cognitive demands. Finally, the Appreciation of Spouse's Coping Ability Scale measured spouses' assessment of each other's degree of success in coping with perceived threats and demands. Regression analysis was performed on all data, and the hypotheses were supported. The authors found that the stress-producing event created the perceived demands, which were influenced by both shared and personal resources. This affected the level of stress, which in turn affected marital quality.

**Risks and reconstruction model.** Cernea (1997) took a different approach to considering a displaced population before relocation in order to analyze the risks for resettling displaced populations. The risks and reconstruction model performs four functions: diagnostic (explanatory and cognitive), predictive (warning and planning), problem-resolution for guiding and measuring reestablishment, and analytical for forming hypotheses and conducting theory-led field investigation. The author posited eight impoverishment hazards that result in economic and social deprivation, including landlessness, joblessness, homelessness, marginalization, increased morbidity and mortality, food insecurity, loss of access to common property, and social disarticulation. Each affected categories of vulnerable people differently, but some groups tend to be hurt more than others, including women and children.

The predictive/planning capacity of Cernea's model provides insight into possible future effects based on the outcomes of many prior displacements. He stressed four steps as essential to minimizing the risks of adverse outcomes: a situation-specific risk assessment in the field; adequate response of decision makers and planners to predicted risks; the proactive response of the population at risk; and transparent information and communication between decision makers, planners, and populations at risk. To attempt to reduce risks, planners must begin searching for technical alternatives to obviate the need for displacing people or to reduce the number of persons displaced. Planners should also conceive special measures targeted against each impoverishment risk. Those relocated should develop coping and resource-mobilization strategies. Such involvement requires these people to be well informed, to understand the impending displacement, and to overcome disbelief about relocation.

## Choice of travel modes

New transportation projects have the potential to provide individuals with the opportunity to choose travel modes that were previously not a viable option. Occasionally, such projects may also remove options for some individuals. It is important to consider how a transportation change may affect individuals' mode choice and the compatibility of modes.

Most of the studies we reviewed employ combinations of statistical analysis, surveys of individuals, and simulation models. The majority of the research on the impact of a transportation system change on mode choice focuses on the effect after the change has taken place. For example, Bel (1997) studied the impacts of changes in road travel time on the demand for rail in Spain. Bel hypothesized that road and rail journey times were widely responsible for the inter-regional changes in the demand for inter-urban rail from 1988 to 1991. His dependent variable was the change in rail demand (the change in the number of tickets sold in 1991 compared to 1988). Independent variables included rail journey time, journey time by road, and changes in national air services. The author's estimation procedure took the form of two demand equations and was estimated for three different intervals: journeys of short or medium distance by mainly day trains, journeys of long distance by day- and night-time trains, and journeys of long distance by mainly night trains. The author concluded that journey time by rail had a negative relationship with rail demand, with a strong impact at all distances, although lower for night trips. Journey time by road coach had a positive relationship with rail demand, with its impact appearing to be especially strong at short and medium distance trips, and decreasing as distance grew or night trains were introduced. Furthermore, the author found a negative relationship between flight frequency and the demand for inter-urban rail. Bel concluded that the results indicated the need to consider the impact of changes in travel times across modes when studying the demand for inter-urban travel.

In another study that considered the effect on mode choice resulting from a transportation system change, Boarnet and Sarmiento (1998) argued that empirical evidence does not support the New Urbanists' claim that land use can be manipulated to influence travel behavior. The authors developed a regression model to measure the effect of land use on travel behavior within the context of a consumer demand framework. The model assumes that if land use affects travel behavior, it does so by influencing the generalized price of travel to various destinations. In their research, the authors specified and estimated a demand function for travel, focusing on non-work automobile trips. The number of non-work automobile trips taken by an individual was a function of the time cost (or price) of such trips, of individual income, and a vector of socio-demographic variables (primarily gender, age, and education). Individual time values were measured in terms of accessibility, which is influenced by densities, street grid orientation, the mix of commercial and residential uses, and other land use variables. Land use variables included population density, the percentage of the street grid within a quarter-mile radius of the person's residence characterized by four-way intersections, retail employment divided by land area, and service employment divided by land area.

Data for the authors' study came from travel diary data for 769 southern California residents, the 1990 census, and the Southern California Association of Governments. The dependent variable in the study was the number of non-work automobile trips made by an individual during the 2-day travel diary period. The authors concluded that a link between non-work travel and land-use patterns at the neighborhood level does not exist. This result led the authors to suggest that New Urbanist claims should be analyzed more carefully than in past studies. They also concluded that their regression models provided a useful framework for understanding the link between non-work travel and land-use patterns.

Kroes et al. (1996) took a different approach by considering a transportation system change both before and after construction. They discussed a study on the impact that a major extension of the urban motorway system would have on travel demand in Amsterdam. The study consisted of two stages: the use of available simulation models to predict what the impacts would be and a "before-and-after" survey targeted at households likely to be affected by the new tunnel. The "before" study took place four months before the new connection opened and the "after" study was carried out two months following the opening. Respondents were interviewed by telephone about their individual travel behavior with essentially the same questionnaire before and after the connection opened. The analysis consisted of comparing characteristics of specific trips reported by the same person before and after the Zeeburgertunnel was completed, including the chosen route, the departure time, the chosen mode, the destination within the Amsterdam area, and the frequency of the trip. The authors concluded that changes in choices of route and departure time were significantly larger than would have been expected without the tunnel, but that the changes in mode choice, destination choice, and travel frequency were small enough to be the result of sampling fluctuation.

### Summary

The foregoing summary of existing methods, tools, and techniques for evaluating the social effects of transportation system changes highlights several points. First, neighborhood surveys are one of the most promising approaches for estimating the social effects of transportation projects. These surveys enable planners to deduce the qualities or attributes of neighborhoods valued by residents; they can then take care to consider these attributes when formulating transportation system changes and mitigating negative impacts resulting from them.

A second key point emerging from our review is that many of the methods, tools, and techniques that may be useful and appropriate for estimating social effects must be adapted from studies that were not directly related to transportation. There is a reasonably direct applicability for studies of neighborhood cohesion, pedestrian safety, accessibility to people or places, and housing relocation.

A third important conclusion is that few of the methods, tools, and techniques currently in use to assess social effects have been applied to *predict* the impact of a planned change. These approaches have almost exclusively been applied to study current circumstances.

## ECONOMIC EFFECTS

Transportation system changes tend to have dual effects: they can improve the public's access to many forms of opportunity, but they can also result in problems related to greater traffic levels within or near a corridor area. In this discussion, we examine a rather wide range of existing approaches to assessing the economic effects of transportation system changes. We begin with methods, tools, and techniques for estimating changes in traveler costs, and then explore economic development effects, land and property values, construction effects on businesses, and linkages between residences and jobs.

## Changes in traveler costs

Transportation system changes may significantly affect travelers, often by increasing or decreasing the amount of time required to reach a destination. Projects that aim to reduce congestion often provide significant time savings for motorists. On the other hand, transportation system changes may increase time en route for some travelers, while creating longer journeys for others. Likewise, changes in transportation systems often improve the safety of system-users. Occasionally, however, they may reduce the safety of particular groups, such as pedestrians. Vehicle operating costs are reduced by smoother, more direct facilities involving fewer stops and starts, but higher speeds may actually increase the per-mile cost of operating a vehicle.

There are a variety of methods for assessing how a transportation change affects travelers, including: gravity models; analyses of travel time savings, safety effects, and changes in vehicle operating costs; geographic information systems (GIS); and comprehensive economic models. The method chosen will likely depend on the time frame and type of project. A drawback of most—but certainly not all—of the methods is that they are designed to evaluate the impacts of a transportation system change after it has been completed. Using these methods to predict impacts can be problematic.

**Gravity models.** Using a basic gravity model, Thompson (1998) offered a method for estimating the effect of a transit service change on different groups of transit users. His approach was to estimate the spatial incidence of benefits from the service change and then compare it with the income patterns of his case study city of Sacramento. Estimates of the transit trips that potentially could be produced in any tract *i*, the attractiveness of any tract *j* as a destination for travel, and the transit travel difficulty (or "travel friction") between the two tracts *i* and *j* were obtained from a standard transit demand model, a type of gravity model. Summing across all destination tracts, Thompson's model attempts to estimate the total number of potential transit trips from tract *i* to destinations throughout the region. The author suggested that accessibility could be calculated for each tract *i* both before and after the change in transit service. It would then be possible to determine whether the service change would improve or worsen equity across income groups at the tract level.

**Travel time savings**. Estimates of time savings are often conducted after a transportation system change has taken place in order to determine the extent to which the change has achieved certain goals or expectations. One approach to estimating the change in travel time was suggested by Dahlgren (1998). She developed a model to compare the benefits of high occupancy vehicle (HOV) lanes with general-purpose lanes to determine the effects related to delay and vehicle emissions. The author employed a model that bases estimates of the proportion of people using HOVs on the time differential between the HOV lane and other lanes. The model calculates benefits of HOVs (reduced person-delay and reduced emissions) for four alternatives: adding an HOV lane, adding a general-purpose lane, converting an existing lane to an HOV lane, and doing nothing.

In order to estimate delay, she developed an idealized queue that can be constructed from data on the length of the congested period, the maximum delay (maximum travel time minus free-flow travel time), the time at which the maximum delay occurs, and the freeway capacity. By combining the idealized queue with vehicle occupancies for HOVs and low occupancy vehicle (LOV) lanes, and the changes in freeway capacity for HOVs and LOVs, the four alternatives can be evaluated. Additionally, Dahlgren used a logit model to determine the probability that a particular individual would use an HOV. The approach was to define the probability of making a trip in an HOV as a function of:

1) whether the trip is made in a high-occupancy vehicle,

2) whether the trip is made via a low- or single-occupancy vehicle, and

3) characteristics of the person making the trip.

Specific HOV attributes included waiting time, travel time, time and inconvenience of arranging the carpool, ambience in the waiting area and the HOV, and cost. LOV attributes included travel time, parking availability and cost, vehicle ambiance, driving conditions, and vehicle operating cost. Finally, traveler attributes included regularity and flexibility of working hours, work and home location, childcare requirements, income, and availability of an automobile. The author concluded that HOV lanes are superior to general-purpose lanes only if a substantial travel time difference exists between the lanes and if the HOV lane is well utilized, which requires a high proportion of HOVs and a high volume of traffic.

Methods that estimate impacts before construction on a project begins, such as the one presented by Diamandis et al. (1997), can prove useful in weighing the merits of different alternatives. The authors estimated the value of time as revealed by travelers choosing between alternative modes with different prices and times for two broad categories of travel—business and non-business. The method was applied to a case study of the Rion-Antirion suspension bridge, which when built, was expected to provide a better connection between the southern and western parts of Greece than the existing ferryboat services. Data involved in the analysis included the number of passenger trips (including inter-region trips), price, and time. The authors used a disaggregate modeling approach (allowing individual travelers to be the units of observation), and applied a multinomial logit model to simulate the allocation of traffic across market shares of transport modes. They estimated the model with ordinary least-squares regression and two maximum likelihood methods. Using workers' average gross wage rate as a basis for comparison, they found average values of time for business travel to be 77 to 90 percent of the wage rate; for non-business travel, the value was 52 to 63 percent.

Ortuzar and Garrido (1994) compared three stated preference survey data collection methods and their associated model estimation techniques on the basis of the precision of the estimated models versus the costs of data generation and analysis. Stated preference data in the form of ratings, rankings, and choices were collected from a sample of individuals coming to work or study at a university in Santiago, Chile. All methods produced quite similar results, and fairly subjective values of time. In terms of production costs, the ranking method was the clear loser, although the experimental design was slightly biased against it. The authors highly recommended the use of computerized interviews, particularly for collecting data from low-income persons.

McElroy (1992) provided an introduction to the Highway Economic Requirements System (HERS) model developed by the Federal Highway Administration (FHWA). The HERS model represents a significant advancement in the methodology available to estimate highway investment requirements. Results from the model provide a “highway-user dimension” to needs analysis. The HERS system is designed to readily accommodate refinements as new research findings are available. This is accomplished through using an open framework, or modular structure that will use the best data and highway engineering knowledge available. The HERS model is viewed as a work in progress, with the FHWA’s intent being to update and refine HERS as the results of various research efforts become available.

Cohen and Southworth (1999) offered a model for estimating the mean and variance of time lost due to incidents on freeways. They also reviewed methods for assigning a monetary value to the variability that such incidents introduce into daily travel. Two of those simple models were chosen to demonstrate the size of the potential time-use benefits involved with using their model. The authors suggested an easy-to-implement approach to measuring the performance of freeway incident reduction strategies, which should be useful in early project selection exercises where sketch planning processes are used to identify promising policies for incident reduction.

Hensher et al. (1990) presented an approach to investigating the valuation of travel time savings in the context of proposed tolled urban road facilities using stated response methods. They contend that with careful design and application of a choice experiment, a set of plausible values of time savings can be obtained. The empirical findings are convincing when compared to previous revealed-preference efforts. Their study is the first to evaluate travelers’ sensitivity to urban road tolls, and it should provide a reference source for the growing number of studies pertaining to the economic and financial feasibility of tollways in urban areas.

Walsh et al. (1990) addressed the problem of estimating a statistical demand function for the recreational activity of pleasure driving (sightseeing) by car on a scenic highway in the Rocky Mountains. The authors show that single-day trips with one-way travel times of less than two hours have increased because households consider travel time devoted to pleasure driving as a benefit rather than a cost. In their approach, net willingness to pay for travel time is a function of distance traveled, type of trip, opportunity cost of time, income, age, price of substitutes, consumer preferences, and quality of scenery along the route. The estimates presented are sufficient to demonstrate that recreational use would represent a substantial benefit of programs to protect and enhance scenic roads.

**Traveler safety.** In a major report for the FHWA, Miller et al. (1991) summarized the results of a research effort on the comprehensive costs of highway crashes. The study used databases from the Fatal Accident Reporting System (FARS), the National Accident Sampling System of NHTSA, and the National Council on Compensation Insurance. The methodology involved estimating the implicit willingness-to-pay expressed by the public to avoid various sorts of mishaps that could result in serious injury of death. Their estimates of the comprehensive costs (including pain and suffering) constitute the most widely applied values by federal agencies.

Forkenbrock and Foster (1997) developed an approach for estimating the accident cost savings that will result if a series of highway attributes are changed. The authors developed two semi-logarithmic regression models to estimate crash rates and costs for rural non-interstate highways in the state of Iowa. Data on 21,224 crashes occurring between 1989 and 1991 on 17,767 road segments were used in the analysis. Applying the resulting regression models to typical highway upgrade situations, the present value of crash cost savings can be computed. The sensitivity of the estimated cost savings to values for fatal, personal injury, and property-damage-only crashes was tested. The authors found that it is feasible to estimate the extent to which society will gain if very specific investments are made to make highways safer.

**Vehicle operating costs.** Hepburn (1994) described a simple model for estimating the average vehicle operating costs for different travel speeds. The model was developed as part of a larger travel cost model and is suitable for use in urban areas of Australia. The model splits vehicle operating costs (VOC) into tire costs, depreciation, maintenance costs, and fuel costs. Estimates are based on the assumption that road roughness and grade are unimportant in the estimation of VOC, and all costs are variable with distance, but only fuel cost varies with speed. Hepburn attempted to develop a simple but plausible relationship between traffic speed and vehicle operating costs; the model can be updated regularly using relatively few data, though there is a limitation on the availability of data for some types of vehicles. The model can be reduced to two simple functions for each vehicle type, thus making it easy to test changes in VOC for changes in average speed.

In a somewhat dated document, the FHWA (1982) provides general guidance on how to include changes in the grade of a road segment when estimating vehicle operating costs. The very basic technique is limited to two data elements: the slope and the flow speed before and after a roadway project is carried out. In most states, data are available for a series of relatively short road segments, perhaps a half-mile or less in length. The result is an estimate of the vehicle operating cost savings that result from the changes in the grade of various segments of an upgraded stretch of road.

**Geographic information systems.** Hartgen and Li (1994) also discussed a method for estimating the ultimate impact of a construction project before it is undertaken using GIS. They presented two case studies applying GIS to transportation corridor planning: a rural corridor upgraded to Interstate standards and a ring road around a large metropolitan area. They constructed a series of layers of data to describe conditions in each case study. Polygon layers included a variety of demographic and socioeconomic data for counties, towns, zip codes, and census blocks in the corridor. Road-related statistics were then included on a complete high-level highway network for the corridor, with attributes describing traffic volumes, capacities, speeds, truck usage, and intersections with an interstate corridor. Finally, point statistics were included with data on cities, respondents in business and citizen surveys, and characteristics of street intersections.

In the first example in eastern North Carolina, GIS software was used to analyze the accessibility of 22 exits from an interstate highway to surrounding communities and other travel corridors. Data describing each exit were used to predict the probability that that exit would permit sustainable growth. A GIS framework was also used to identify travel time contours from each major town within the corridor and to determine the number of residents and workers whose travel time to large metropolitan areas would be likely to change substantially.

In the second example, a GIS-based approach was used to forecast transportation demand and network flows on the Carolinas Parkway (a proposed outer ring road around the greater Charlotte metropolitan region). Traffic was forecasted by increasing future trip ends according to projections developed in land use forecasting. Trips were loaded directly onto the network at intersections on a sketch regional network about 100 miles across. Future road proposals were coded into the system to represent the transportation improvement programs of the regional organizations in the area. The authors then performed travel modeling using an all-or-nothing assignment methodology without a capacity constraint. The approach taken by the Hartgen and Li enabled them to show percentage changes in traffic volumes or ratios with base traffic and traffic on key road segments, as well as how changes in local road volumes would occur with and without the parkway.

**Comprehensive economic models**. As mentioned previously, the Federal Highway Administration (FHWA) has been working with several contractors to develop the Highway Economic Requirements System (HERS) (FHWA 1999). HERS is a computer model designed to assist agencies in the selection of highway improvement projects based on benefit-cost analyses of alternative improvements. The user can specify any one of three analysis objectives:

1) Maximize the net present value of all benefits of highway improvements subject to specified funding constraints during the period.

2) Minimize the cost of improvements necessary to achieve a specified goal for the performance of the highway system at the end of the funding period.

3) Implement all improvements with a benefit-cost ratio greater than some specified threshold value.

HERS estimates the three traditional types of highway user benefits arising from potential improvements: travel time, vehicle operating costs, and safety. It also estimates two types of benefits to highway agencies: maintenance cost savings and the “residual value” of an improvement at the end of the analysis period. Finally, HERS estimates the reduction in damage caused by vehicle emissions. A refinement in the current version of HERS is the effects of “induced traffic” and “induced demand,” based on highway users’ responses to changes in travel costs over the short and long term, respectively. A key element in the model is a staging of improvements based on the selection of one of two procedures, both of which are based on benefit-cost analysis: alternative improvement selection or mandatory correction of defined unacceptable conditions. Current conditions of included road segments (generally a state primary road system or a metropolitan area arterial system) are based on the FHWA Highway Performance Monitoring System (HPMS) database, and conditions in future years are based on a series of deterioration factors.

When fully operational, possibly within the coming year, HERS will be a useful tool for programming highway improvements based on their economic effects. Unlike some earlier economic models, HERS is flexible enough to allow key parameters to be tailored to local conditions. Considerable background research has been carried out to provide guidance on key parameters. For example, the value of time considers a series of characteristics: business versus non-business, driver versus passenger, autos versus trucks, and inventory costs.

## Economic Development

It is important to distinguish the literature on *economic development* impacts from more traditional analysis of economic effects in general. When referring to "economic development," researchers and policy makers are interested primarily in expanding jobs and income in a particular corridor or region. In such cases it may not matter whether impacts are generative (expansion through productivity improvements) or redistributive (local benefits resulting from the transfer of investment from outside areas to the study area). This is in contrast to the national analyses of economic benefits by economists, which focus on how transportation investment leads to net economic gains, or generative impacts.

Many different methods have been employed to predict the economic development benefits of transportation investments, ranging from qualitative surveys to comprehensive econometric modeling. In most cases of project assessment, the economic development analysis compares a no-build or base case scenario to one or more transportation investment scenarios. Impacts are often forecast 20 years or more into the future. From a social perspective, analysts and decision-makers are interested in the economic development impacts of a transportation project measured in terms of job creation and changes in personal income or wages, changes in the types of jobs available, changes in property values, and net changes in business activity and investment in corridors where new business development is a goal.

**Input-output tools.** The tools most commonly used to forecast the employment, income, and occupational impacts of transportation investments are input-output (I-O) models, and more complex econometric models that incorporate I-O models. I-O models contain information on inter-industry relationships, including accounting tables that describe, for each industry included in the model, the amount of input the industry requires from other industries to produce one unit of output. Using such purchase and sales data, multipliers are calculated to forecast impacts, as the dollars spent on a transportation investment ripple through the economy. Measures of impacts include industrial output, employment, and earnings by industry. I-O models are built using county level data, and therefore cannot be used to estimate impacts for any geographic area smaller than a county.

Several I-O models are currently available to researchers, including IMPLAN, RIMS II, and PC I/O, each of which can be purchased from vendors who provide support to the user. Drawbacks of I-O models include the fact that they are static: they can only predict impacts for a single year and cannot be used to forecast impacts over time. Also, the development of an I-O model takes many years; most of the models in use today were developed several years ago, and they include data on inter-industry relationships that are somewhat dated.

Because I-O models are static and can only provide impacts for a single year or investment, such models are most often used to estimate the construction impacts of transportation projects, as these are of short duration. For example, the University of North Carolina, Charlotte (1991), used an I-O model to estimate the economic development impacts of the construction of Interstate 40 between Wilmington and Raleigh, which passes through a relatively rural and underdeveloped area of the state. Employment and wage impacts associated with construction, although not permanent, were considered important to this region. Similarly, Burgess and Niple, Limited (1998), used the RIMS-II I-O model to estimate the job creation and wage impacts of alternative highway investments in the I-71 corridor through Ohio, Kentucky, and Indiana. The PC-I/O model was used for estimating job creation and wage impacts of a proposed high speed rail service (in lieu of continued reliance on highway and air transport) along the northeast corridor. In all of these cases, additional external calculations were necessary to assess the direct effects of the business cost savings (from the new facility) on the creation of additional jobs.

To assess the economic development impacts of highway investments in the I-66 corridor in southern Kentucky, Thompson et al. (1997) combined an earnings growth model with an I-O model. The direct earnings impacts of the investment, calculated using the earnings growth model, were used as inputs into the I-O model to estimate job creation by major industry group.

Babcock et al. (1997) provided a good discussion of a general model-procedure for measuring the output, income, and employment impacts of specific types of highway improvements. The authors outlined ten steps for adjusting state survey-based input-output models.

1) The types of impacts to be measured are determined for particular types of highway improvement.

2) A secondary data search is conducted, such as the national input-output model compiled by the U.S. Department of Commerce, Bureau of Economic Analysis.

3) Construction firms eligible to obtain state highway contracts are listed.

4) Highway improvement types are placed in homogenous classes with similar types of cost structures requiring similar inputs.

5) The total expenditure for each highway improvement type during the time frame of the study is established.

6) Survey samples for each highway improvement type are selected, focusing generally on construction firms with the largest highway contracts.

7) A questionnaire is designed, with emphasis on brevity and clarity.

8) The survey is carried out through mailed surveys and personal interviews.

9) Consistency checks are performed to check for errors, inconsistencies, and omitted data.

10) Output, income, and employment multipliers for each highway improvement type are calculated.

Economic simulation models are modeling systems that include both an I-O model and a production function. These model components are integrated, and allow the researcher to calculate how changes in economic conditions and policy decisions will impact the output measures. Unlike I-O models, which are static and allow only a one-time snapshot of the impacts of a transportation investment, simulation models allow the researcher to track the regional economic impacts of an investment over time (a 20-year analysis period is typical).

During the past decade, the use of simulation models to estimate the economic development impacts of transportation investments has increased substantially. The most frequently used model is the REMI Forecasting and Simulation Model developed by Regional Economic Models, Inc. The REMI model has been used extensively for highway investment studies in Wisconsin, Iowa, Michigan, Indiana, Louisiana, and Kentucky (Cambridge Systematics, Inc. 1988a; Wilbur Smith Associates 1990; and Wilbur Smith Associates and HNTB Corp. 1998). Some state DOTs (Wisconsin, Indiana, and Iowa) have purchased the model and either have integrated, or plan to integrate, economic modeling and economic development impacts into their investment decision-making process.

Economic models have been used to estimate a wide range of impacts. In some cases, researchers have simply calculated the direct user cost savings associated with the investment and have input these savings into the model. Many studies have included not only user cost savings, but also estimates of changes in spending in the tourism industry and changes in employment due to business expansion and attraction opportunities over and above the direct cost savings. To estimate tourism impacts and business expansion and attraction effects, researchers have conducted market studies to develop the inputs for the simulation models (Bernardin Lochmueller & Associates and Economic Development Research Group 1997). Effects are often measured in terms of personal income, output, value added, gross regional product, and employment.

**Hybrid economic/transportation models.** Cambridge Systematics, Inc. (1996), working with the Indiana DOT, developed an integrated modeling system that includes a macroeconomic simulation model to estimate economic effects. Indiana's five-step modeling system includes:

1) a travel demand model to estimate traffic volumes and travel times on the highway network both with and without improvements;

2) a program designed to estimate travel efficiencies related to different types of roadway improvements;

3) a set of linked spreadsheet models developed to calculate direct economic benefits by estimating how different types of businesses respond to changes in transportation access and travel time;

4) the REMI econometric forecasting model to estimate direct, indirect, and induced effects; and

5) a benefit/cost framework for aggregating and discounting the economic benefits, and for calculating the stream of capital and operating costs in order to arrive at a benefit/cost ratio.

The Indiana DOT has applied this modeling system in three corridors to date.

An econometric model was used, in conjunction with a market analysis, to estimate the economic impacts of a proposed Trans-Labrador highway on Labrador, Newfoundland, Quebec, and Canada as a whole. Proponents of the highway hoped that its development would spark economic development in an undeveloped area of the province. At the same time, there was concern that negative impacts would occur in neighboring Newfoundland as tourism and other industries were attracted to Labrador. A nine-sector econometric model was used to measure the employment and income impacts of alternative alignments (Fiander-Good Associates Ltd. 1993).

**Surveys.** Typically, three different types of survey methods have been used for economic development impact analysis. These include business interviews, business and user surveys, and truck origin-destination logs.

***Business interviews.*** Generally these provide qualitative information about the expected impacts of changes in transportation services or infrastructure on business activity within a corridor. Researchers ask businesses to estimate the amount of their sales generated by users of the existing transportation system, and how these sales might change if transportation access is improved or inhibited. This method was used to study the effects of replacing the elevated Orange Line light rail service though some of Boston's poorer neighborhoods with an underground heavy rail service and supplementary bus service (Cambridge Systematics, Inc. 1988b). Planners and residents of the neighborhoods served by the elevated service were concerned that removal of the elevated system, which had frequent stops within the neighborhood, would diminish the amount of pass-by traffic frequenting neighborhood retail establishments. The interviews were designed to collect information to allow an estimation of the dependence of these establishments on existing transit users in order to estimate the change in sales and potential for business closures that might result from removal of the elevated service.

***Business surveys.*** These are designed to collect the same information as business interviews, but because they can easily be sent to a large number of businesses, much larger samples can be obtained. Unlike business interviews, however, surveys do not allow for follow-up questions and discussion of key points of interest. Both business and economic development agency interviews and surveys were used in an NCHRP study of the impacts on businesses of restricting left turns (Weisbrod and Neuwirth 1998). The survey results were used to develop a spreadsheet model that can be used to estimate lost business sales by type of business associated with roadway access restrictions. Researchers also used shopper surveys and bridge-user surveys to identify how a new bridge across the St. Croix River, designed so that bridge traffic would bypass the downtown of Stillwater, Minnesota, would impact the downtown economy (Economic Development Research Group 1999b).

***Truck origin-destination logs.*** Several studies have used business origin-destination surveys and truck surveys to identify how an existing transportation network is used by businesses, including what products are shipped, the value of shipments, and modes and routes used for shipping various products. These survey data can then be used in conjunction with an economic model to forecast how changes in the transportation network can decrease transportation costs for area businesses, resulting in expanded economic activity. Examples of business origin-destination studies include projects in Kentucky, Wisconsin, and Louisiana (Thompson et al. 1997; Cambridge Systematics, Inc. 1988a; and Economic Development Research Group 1999a).

**Land/Real estate development market studies.** Real estate market studies are sometimes used (either alone or in conjunction with other methods) to evaluate the economic development effects of proposed transportation investments. These studies generally forecast one or more of the following: the square footage of development likely to occur if a new transportation facility is constructed; the increase in property values (and related tax revenue) that will accrue from new development at land parcels served by a new transportation facility; and the increased employment that will occur as land is developed. Market studies are generally site or corridor specific, and may be used either to support an investment decision or as a part of the environmental analysis for a proposed project. The results of market studies often are used to develop inputs for more detailed economic modeling approaches to economic impact analysis.

Researchers in Maryland (Maryland State Highway Administration 1998) used a market analysis to identify how alternatives for improved access to an employment center would affect land development, and therefore job creation. The research team: evaluated the marketability of the site for development, given alternative transportation access improvements; identified whether or not each alternative would provide sufficient access for a target list of businesses; and conducted an assessment of competing sites in the region to identify absorption rates and rents to determine the value of the land for development, as well as the level of employment the land could support.

**Transportation and land use economic modeling systems.** In recent years, many regional planning agencies have attempted to integrate transportation and land use modeling to better predict future transportation demand. Most of these modeling systems do not reflect economic factors and interactions, and are thus not relevant here. However, two models have been developed that attempt to include economic factors to better reflect how markets respond to changes in land use and transportation access.

The Transportation, Economic, and Land-Use System (TELUS) was developed to help metropolitan planning organizations (MPOs) select projects for their transportation improvement programs (TIPs) (New Jersey Institute of Technology et al. 1998). TELUS has three components: 1) a data base with key information about projects, 2) an I-O model for estimating jobs created and the income and tax effects of projects, and 3) a land use model for estimating property tax impacts. A research team used national inter-industry relationships, as well as relationships developed from New Jersey bid sheets to develop impact vectors and multipliers for the I-O model. Multipliers are expressed in terms of jobs (by industry), income, and gross regional product (GRP) per million dollars of original investment.

The METROSIM model is a unified and market-oriented computer simulation model of multi-modal transportation and land use.[1] The model takes into account both how transportation projects are affected by the current distribution of land uses, and how, in the longer term, transportation projects influence development patterns. Unlike most other land use allocation models, the model takes into account how land markets operate; it allows basic and service employment to respond to the transportation system through actions of the labor market and

[1] Current research by Dr. Alex Anas for the New York region

business decisions. The METROSIM model is a custom model, and requires extensive data collection. It is currently being tested in the New York metropolitan area

**Case study analysis.** Researchers frequently use case studies from other cities to evaluate the economic effects likely to occur from a transportation investment. Case studies are useful because they provide a real-life account of how development patterns can change when a transportation facility is built. This type of real-life experience is particularly useful when presenting information at public meetings, because it is easier for lay people to understand than more rigorous economic analysis that involves technical terms and concepts. A down side of case studies is that it is difficult (if not impossible) to find cases where conditions parallel the conditions in the study corridor. Thus, the results of a transportation investment elsewhere may not be transferable to the study corridor.

The State of Wisconsin used case studies to identify the likely economic development benefits of highway rehabilitation projects (Wisconsin Department of Transportation 1996). Researchers conducted case studies of locations in the state that had already benefited from highway rehabilitation. Four types of effects were evaluated:

1) cost/time savings realized by businesses and worker commute trips,

2) safety improvements which facilitate commodity flows and employee work schedules,

3) effects of highway rehabilitation on tourism, and

4) the relationship between highway rehabilitation and local economic development initiatives.

For the St. Croix River Crossing economic impact analysis, researchers used case studies to identify how bypasses had affected the economies of communities in Texas, Iowa, Kansas, and North Carolina (Economic Development Research Group 1999b). The case studies found that bypasses had little adverse impact on the economic activity in most communities, although smaller communities were most likely to suffer negative impacts.

**Site analysis.** Assessment of local effects related to business dislocations are a required component of environmental impact assessments. To identify the number of dislocations, researchers conduct site analysis to record the location and type of all business establishments likely to be dislocated by alternative transportation investments. Information on the number of jobs associated with these businesses is obtained through direct contact with the businesses, or estimates may be made based on the square footage of each business. This technique has been used in many projects, including the economic impact analysis for South Carolina I-85 (South Carolina Department of Transportation 1997). Displacement analysis usually includes an assessment of opportunities to relocate businesses within the same community, thus simply relocating jobs.

**Spreadsheet-based analysis.** Several studies have used spreadsheet-based analyses to estimate the loss of business for local establishments that is likely to result when a transportation improvement either inhibits access to or bypasses those businesses. Researchers in Wisconsin (Cambridge Systematics, Inc. 1988a) and Indiana (Cambridge Systematics, Inc. 1996) conducted "windshield surveys" (observations made while driving through an area) to estimate the number, type, and size of businesses that would be affected by transportation improvements. They then developed spreadsheets to estimate the dependence of each type of establishment on highway traffic, the volume of sales at each establishment, and the expected decrease in sales that would result from the highway improvements.

## Land and property value

Transportation system changes may affect property values in a number of ways. Changes may provide improved access to an area, thereby increasing property values. In this vein, transportation projects may serve as catalysts for comprehensive urban reinvestment projects with the expectation that they will increase property values. On the other hand, properties adjacent to projects may decline in value as a function of their proximity to the facility, or as a result of a new undesirable visual feature in the environment.

Most property value changes represent economic transfers—increases at one location are offset by reductions elsewhere, in which case there is no net increase in value. It may be the case, however, that improvements which increase the overall efficiency of the transportation/land use system may provide net property value increases related to economies of density.

**Hedonic price estimation**. The most common method for estimating effects on property value is hedonic modeling. It takes into account the effect of a particular attribute—such as an improvement on accessibility resulting from a transportation project—on market prices, controlling for the effects of other attributes. The technique is useful in determining both the positive and negative effects of many types of projects, including transportation system changes.

Although not a transportation-oriented study, Hamilton and Schwann (1995) studied the effect of an intrusion of high-voltage electric power transmission lines on property values. The authors estimated the impact on the value of properties sold after the transmission lines were in place. Data included sales of single detached dwellings in four separate neighborhoods in the metropolitan Vancouver area from 1985-91. Properties that were adjacent to the right-of-way and properties that were partially within the right-of-way were noted through the use of dummy variables. The number of towers that were visible from properties within a 200-meter band of the transmission line was determined. Property characteristics in the analysis included dummy variables for the presence of a garage, pool, sewer, curb, and corner lot, along with continuous variables for the age of the dwelling, number of fireplaces, basement rooms, bedrooms, full baths and partial baths, number of other rooms, and the width and depth of the lot.

The authors sought to determine the increase (or decrease) in property value one could expect if the transmission lines were removed. They calculated the change in property value for an average dwelling unit when a visible high voltage electric transmission line tower was removed. Their results indicated that removing visible towers would increase property values by 5.7 percent for parcels adjacent to the towers. No statistically significant change in property value was found for properties at greater distances from a transmission line.

In another study of the effects of an intrusion on property values, Clark and Nieves (1994) used an inter-regional framework in a hedonic analysis of wage and property markets to evaluate the effects of eight different categories of noxious facilities. Data included the value of individual housing units and the level of wages. Also included were data on a broad range of noxious facilities, amenities and disamenities, fiscal measures, and other control variables. A unique data set was constructed for each of the eight facility types. Two equations measured the influence of location factors on annual housing rent equivalent and annual market wages. Independent variables for human capital and industry controls were included in the wage equation, and housing structural characteristics were included in the housing rent equation. Both models were estimated using a double logarithmic functional form. The authors concluded that noxious facilities had a significant effect on property values and wages.

Many studies on property values consider the benefits and costs of increased land access from the development of transit, especially in terms of urban revitalization. Gatzlaff and Smith (1993) studied the impact of the Miami Metrorail system on residential property values near rail stations. Of particular interest to the study was the decision of policy makers to locate the rail line so as to revitalize certain areas along the northern extension of the corridor. Eight rail stations in township sections with only one rail station were selected for analysis. The data used in the study included the two most recent selling prices and selling dates for properties changing hands between 1971 and 1990, square footage, lot size, year built, homestead exemption code, township range and section number, and the owner's mailing address for every property in Dade County. Records were categorized by 100 land-use codes.

The study employed two alternative empirical methods to examine the magnitude and timing of the price impacts of adding rail stations. The first entailed a repeat-sales index using the pooled sample of properties surrounding Metrorail stations and comparing it to an identically constructed index for the entire county. The second method involved hedonic regression to evaluate the variation in property values before and after the announcement of the development of the Metrorail system. The authors concluded that there was no major effect on residential property values as a result of the announcement of development of the Metrorail, and the effects that did occur varied significantly by distance to a station. Some variation in effects was observed across neighborhood types, as well.

Also focusing on transit, Lewis-Workman and Brod (1997) used hedonic price estimation to assess the value of transit to neighborhood residents, including transportation benefits and nonuse benefits related to neighborhood form and general livability. The authors hypothesized that transit improves the livability of transit-oriented neighborhoods, producing benefits for the residents whether or not they use transit. For their analysis, they selected property value as the dependent variable. GIS was used to measure the walking distance to transit by calculating the shortest street distance from each parcel to a transit station. Three areas were studied: BART-Pleasant Hill (San Francisco), Queens MTA (New York City), and MAX (Portland East End). Individual regression equations were developed for each of the study areas. The results of the BART and MTA study areas suggested that strong property value benefits arise from proximity to transit stations, along with nonuser benefits as evidenced by the observed willingness to pay to live closer to the station and by comparing the observed time saving. The MAX-Portland study, however, did not find that benefits resulted from proximity to transit stations.

Cervero (1994) studied the land-use effects of rail transit and joint development using data from five station areas in metropolitan Washington, D.C., and Atlanta, where significant commercial development occurred from 1978-1989. Land-use impacts were measured for all commercial and office properties having over 100,000 square feet of floor space and sited within a one-quarter-mile radius of a transit station. Station-area averages of land use and transportation variables were measured, including station-area real estate market performance variables, transit service variables, regional and economic growth factors, and station-area transportation, infrastructure and development characteristics. Cervero used multiple regression to analyze the data, and for most models, first-order auto-regressive estimation was used to correct for serial correlation of error terms.

The study found "average office rent" to be closely correlated with the most transit factors, including ridership and joint development. Office rents were more strongly influenced by transit ridership than by the traffic volumes of a nearby freeway. In the case of locations close to terminal stations, the presence of transit had a fairly weak influence on rents. Near stations with joint-development projects, vacancy rates tended to be low.

In a study focusing not only on transit, but also on highway and rail access, Sanchez (1998) considered the distribution of net benefits from personal transportation facilities within the urbanized area of Atlanta. The analysis measured the capitalization of transportation benefits into residential property values using hedonic price analysis to test the hypothesis that the benefits of personal transportation system access are not distributed evenly. Total household personal transportation expenses were controlled to reveal the net benefits of transportation services. To detect whether biases existed in the pattern of benefits, the spatial distributions of income, race, and urban status were correlated with the spatial distribution of net benefits as reflected in property values.

Data were obtained at the census-defined block group level from a variety of sources. The study focused on three personal transportation system access measures: highway access, rail access, and bus access. Average owner-occupied residential property value per square foot was the dependent variable, with a set of variables pertaining to housing quality, accessibility, public services, land use attributes, and transportation costs as predictor variables. Sanchez concluded that low-income, nonwhite, central city homeowners do not realize lower per square foot benefits than do their affluent, white, urban and suburban counterparts.

Finally, Hughes (1992) studied the effects of traffic levels on the selling price of single-family houses. Data were obtained for two neighborhoods within the Baton Rouge, Louisiana, metropolitan area on sale prices of single-family houses, location and characteristics of these properties, and market conditions. The data were divided into city and suburban sub-samples by geographic location, and time trend variables were used to control for market conditions in the metropolitan area. Data from the Louisiana Department of Transportation and Development were used to identify houses on high-traffic streets. Hughes used a standard hedonic price equation to test the hypothesis that all else being equal, houses on high-traffic streets would sell for less than houses on low-traffic streets. In the data set, he separated houses into those on high- versus low-traffic streets (the high-low traffic variable was replaced with the actual daily traffic counts for all observations for which counts were available). High-traffic streets were defined as those for which the local department of transportation provides traffic counts; typically these streets provide direct access to employment and shopping nodes or serve as feeder streets. Low-traffic streets, on the other hand, provide access to only one street. He concluded that a negative price effect of being close to high traffic streets exists for residential properties.

## Effects on the competitiveness of businesses

Transportation system changes often involve major construction projects, as in the case of highway rehabilitation projects, which may disrupt routine business activity. Business owners may suffer customer losses as access to their business becomes restricted, which in turn will affect the number of employees the business requires. Customers who find alternative businesses during the construction period may not necessarily return once construction is completed. Likewise, businesses may lose parking spaces during construction and not be able to serve as may customers.

Methods to estimate construction effects typically take the form of surveys of business owners/managers in the area of the construction. These surveys are often conducted at various times throughout the construction process. Such surveys are frequently supplemented with land and property value studies, parking impact studies, and construction expenditure impact studies. In the literature, these methods are generally limited to the period of construction or after completion; they have not been used to predict effects at the time a project is under consideration.

Transportation system changes, and the construction related to them, are often prompted by efforts to revitalize an area, provide better access to it, or to alleviate congestion. During the construction period, business owners may anticipate disruptions in normal business activity. Boarnet (1996) focused on business losses caused by the disruption in the Los Angeles area transportation system following the Northridge Earthquake in 1994. His methodology is generally applicable to estimating the effects of major transportation system changes beyond those resulting from natural disasters. The author surveyed an equal number of manufacturing, retail, and wholesale firms in the San Fernando Valley, Los Angeles City, and Orange County. Orange County was used as a basis for comparison because, although it is part of the same consolidated metropolitan area as Los Angeles, it was more than 50 miles from the epicenter of the quake, and therefore much less affected by it. Respondents were asked questions about business losses, business losses attributed to transportation damage, the severity of a number of transportation and non-transportation impacts, and their response to the transportation damage. T-tests were conducted to determine whether the percentage attributing some loss to transportation damage differed among firm types and by location. Six different measures of proximity to transportation damage were used as independent variables in his analysis. The regression did not indicate that the incidence of transportation loss was related to distance from the damaged freeways or the epicenter, but it did show that both retail and wholesale firms were significantly more likely than other types of businesses to experience transportation losses.

Boarnet also asked firms to indicate the severity of ten different possible effects of the earthquake on a scale of one to five. The two highest ranking earthquake effects in terms of severity were shipping delays to the business location and shipping delays from the business location. The author found, based on the dollar value estimates as a result of transportation damage losses and the assessment of the severity of different earthquake effects, that transportation damage was a major source of business losses.

Several other studies have examined the economic effects of routine rehabilitation or reconstruction of roadways. In a case study analysis, Buffington and Wildenthal (1993) estimated the impact of a proposed widening of U.S. Highway 80 in Longview, Texas. The authors examined land use, land value, business, and parking before, during, and after construction. Businesses nearby the construction were interviewed to determine the impact on sales, net income, employment, number of customers, and number of parking spaces both during and after construction. Interview data from 1987 and 1992 following two separate periods of construction were collected. A parking space availability survey involved use of aerial photography and on-the-ground inspection of the premises of each business. Data were collected from the Gregg County Appraisal District, local real estate appraisers, and the city of Longview on property values, building permits, and property uses. Finally, they employed an input-output analysis to estimate the employment and output impacts of the construction expenditures on the state of Texas. Buffington and Wildenthal found (1) a higher than anticipated percentage of businesses with adequate parking after the construction, (2) few property-use changes during the period of the study, and (3) that business sales and property values along the highway were increasing.

In a later study, Wildenthal and Buffington (1996) examined the construction impact of widening TX-21 in Caldwell, Texas, a state highway that was upgraded from a two- to four-lane undivided highway with an open ditch into a four-lane divided highway with a two-way left-turn lane, curbs, and gutters. The study involved a survey of business managers along the widened section of TX-21, an analysis of property values, and an evaluation of user costs and construction expenditure impacts. This combination of methods was chosen because it allowed them to interpret psychological responses in light of factual data. Survey questions pertained to changes in sales, number of employees, and number of parking spaces. The survey also inquired as to impacts on the whole construction area, including changes in traffic volume, number of accidents, and travel time. Managers also provided information on the number of parking spaces, actual sales, and employment figures before and during construction.

To collect traffic data, engineers set up equipment to count the number of cars passing through each intersection for each hour of the day for three consecutive days during each year of construction from January 1991 to July 1993. Additionally, they counted turning movements at intersections for several 15-minute intervals and classified the vehicles as cars, trucks, or buses. The research team then drove through the study area in instrumented vehicles and recorded events, such as stopping at a stop sign or for a construction worker, and times of the events.

Finally, the authors asked contractors of the widening project to break down their expenditures in the Caldwell area versus elsewhere for the purpose of estimating construction expenditure impacts. Multipliers developed from the 1986 Texas Input-Output Model were applied to produce statewide estimates of the effects of TX-21 and TX-36 widening expenditures.

Bruinsma et al. (1997) studied the economic effects of construction of the A1 Highway, which connects the relatively inaccessible eastern part of the Netherlands with the national and international road network. The authors performed analyses at the regional level and at the level of individual businesses. For the survey among business people, questionnaires were sent to firms with at least 10 employees. Operators of businesses were asked about the infrastructure elements they considered to be the most important, as well as their perceptions on infrastructure bottlenecks. Additionally, the business people were asked (1) to assign values to impacts of the A1 construction on specific elements of their business' performance and (2) to consider the hypothetical case of the A1 highway not having been constructed. The authors found high consensus among respondents about the importance of road infrastructure and, to a lesser extent, telecommunications and public utilities. They also found that a high percentage of business people stated that their companies' accessibility had improved and that construction of the A1 led to a decrease in travel times.

De Solminihac and Harrison (1993) developed a methodology to quantify the economic impact of an expedited highway rehabilitation program on a business, which was applied to the expedited rehabilitation project on the Southwest Freeway (US-59) in Houston, Texas. The authors first developed five basic questions regarding the effect of road construction on business activity. Their study involved two approaches: (1) analyzing historical sales data of businesses located in the area of the construction and (2) interviewing owners of businesses along the road under rehabilitation.

In the first approach, sales data were aggregated by quarter for each of ten retail categories of interest, and for each of three geographic areas of interest. Then, a regression equation was developed for each case, resulting in a total of 33 equations. Sales for 1990 were predicted using the regression equations, and a confidence interval was calculated. Using their results, they compared the predicted value with the actual value for 1990. They assumed that if the actual value fell between the limits of the confidence interval, the expected value would be statistically similar to the actual value.

In the second approach, a random sample of businesses located on the US-59 corridor was selected for a comprehensive business survey. To identify businesses, a team drove along the frontage road, canvassing and categorizing each business passed. A sample of more than 20 percent of the businesses was collected for each of ten retail categories in the sales analysis. The survey was divided into four parts.

1) A number of general questions were asked, including how long the business had been at the location, whether they rented or owned, and how they were notified about the construction.

2) Questions were asked regarding business activities during the construction period, including the effect on sales, other internal or external factors that could affect business activities, the effect on employees, the efforts of the Texas Department of Transportation to ease adverse effects, and business strategies for mitigating these effects.

3) Questions were asked about the construction impact on businesses after completion of the feeder.

4) Business owners were asked whether they would consider selling temporary access rights to the contractor and close during an expedited construction period.

Results from both approaches led the authors to conclude that expedited construction has the potential to minimize the negative effects imposed on businesses abutting urban highway construction. Additionally, although adjoining business suffered negative effects, they did not find major overall regional effects. The authors also found that certain types of businesses were more vulnerable to negative effects than others, including general merchandise, food stores, automotive outlets, and home furnishings.

## Linkages between residences and jobs

The way in which a transportation system is structured often has a significant effect on the ability of persons to travel from their homes to their jobs. This is evidenced in the literature on reverse commuting and the jobs-housing balance. In particular, inner-city residents frequently face transportation disadvantages when trying to reach jobs located in the suburbs. Evidence suggests that if affordable housing were located near jobs, many persons who commute long distances would relocate. Transportation system changes have the potential to alleviate negative effects caused by the spatial separation of jobs and housing, so estimating how a change could affect the ability of persons to access jobs is an important consideration for planners.

Methods to assess the relationship between residences and jobs generally involve some form of spatial analysis. Discrete choice modeling and GIS have both been used to estimate the linkage.

**Discrete choice modeling.** Levine (1998) employed discrete choice modeling, which requires the definition of a "choice set." Although the choice set could be any spatial aggregation in location modeling, Levine selected the census "place" based on the assumption that households perceive the individual community as a reasonably homogenous unit and base their location choices on that community's bundle of characteristics. Variables used in the study were by definition community-wide and did not vary by neighborhood. He used data from a 1990 sample of the households in the Minneapolis Metropolitan Council Area, and estimated joint logit and nested logit versions of his location choice models. Variables in the models included commute-time variables and variables related to the physical and social characteristics of a community, as well as the quantity of local housing stock. The author concluded that if affordable housing stock were more available in the vicinity of employment centers, some households might choose to reduce their commute distances.

**Geographic Information Systems.** GIS is a useful tool for considering the effect a transportation system change may have on the relationship between jobs and housing. Using GIS, Peng (1997) studied the linkage between the jobs-housing balance and community patterns in terms of trip length and vehicle miles traveled (VMT) in a mid-sized metropolitan area. Data were obtained from a transport survey of the Portland, Oregon, metropolitan area, and included travel mode, trip length, and commuting time of respondents. Additional data included employment and household income levels. The author used GIS to aggregate jobs and housing data within a 5-7 mile radius for floating catchment traffic zones in the metropolitan area. This method was used because it avoided problems of using predefined and arbitrary areas with fixed boundaries that fail to consider jobs and housing in neighboring areas. A non-linear model expressed the relationship between the jobs-housing ratio and VMT. The author found evidence that jobs and housing were balanced in most areas, and that a non-linear relationship existed between the jobs-housing balance and commuting patterns in terms of VMT per capita and trip length.

## Summary

As our review indicates, the existing methods, tools, and techniques for estimating economic effects are substantially more advanced than is generally true of social effects. Perhaps the most attention has been given to travel cost savings, usually the most important element of economic feasibility studies, particularly benefit-cost analysis. It is impossible to escape a certain measure of subjectivity, however, in assigning critical parameter values that can significantly influence the outcome of the analysis. The background research for development of the HERS model is a step toward some degree of methodological standardization. Other methods, tools, and techniques for estimating economic effects attempt to address changes in accessibility (cost of travel between origin-destination pairs).

A separate line of inquiry pertains to economic development effects of transportation system changes. Most common economic development-related analyses attempt to estimate the types and magnitudes of changes in employment, income, property values, and business activity by sector resulting from reduced transportation costs. A variety of methods, tools, and techniques have been developed to estimate economic development effects; the most common are those based on input-output tables. Several firms offer fairly sophisticated computer models to estimate the probable effects of significant reductions in transportation costs, such as those accruing when a major highway leading to a metropolitan area is substantially upgraded. Such models are not workable for analyzing the effects of comparatively small projects.

Survey-based methods are seeing growing application in efforts to estimate how businesses would be affected by significant transportation changes. Likewise, models have been developed to assess effects on property values and related market dynamics. Hedonic price estimation is the most common approach in this line of impact assessment. Finally, logistical effects, especially those related to goods shipment, are receiving increased attention. This is especially true where time-sensitive economic activity is concerned. Overall, the state of the art in estimating economic effects of potential transportation system changes is quite advanced. The need is to narrow the gap with the state of the practice by making the more useful approaches more accessible.

# AESTHETICS AND LIVABILITY

Separate, but certainly closely related to social and economic effects, are effects on the aesthetics and livability of neighborhoods and communities. It is well known that transportation system changes can substantially affect an area's aesthetics and other aspects of quality of life, either positively or negatively.

Going back to the 1960s, some intriguing work has been carried out to better define how people perceive cities and districts within them. This work is vital to estimating how changes in the built environment would affect peoples' satisfaction with it. More recent work has focused on computer simulations, photomontage techniques, and other visual experiments to provide residents with a better sense of what the visual effect would be if a project were to be undertaken.

Other livability concerns have been more fully addressed in recent years, including air quality (especially localized pollution, such as that near streets upgraded to handle greater traffic volumes). Changes in noise levels are also being modeled with increasing sophistication. Accessibility to public buildings and spaces, the psychological effects of excessive glare from lighting on roadways and signage are among the livability issues we examine in this review.

## Visual quality

Often the most readily recognized effect of a construction project is its visual presence. The projects that result in the greatest visual impact are those which involve locating some sort of superstructure in a community. Yet smaller projects can also create a significant visual disturbance that may alter the entire character of a neighborhood. Visual effects may not be limited to the transportation structure itself; such effects may also include increases in lighting, signage, and traffic volumes, all of which may significantly affect the quality of life of those within their range.

Assessing how a transportation system change would affect the visual quality of a neighborhood or community may involve a broad range of methods, tools, and techniques, including photomontage techniques, virtual computer models, GIS simulations, three-dimensional models, sketches, surveys, and interviews. Many of these methods have an advantage over the methods we found for estimating social effects in that they have the capability to simulate the visual impacts of a project before it is actually undertaken. Thus, although they do not guarantee future outcomes, they provide a strong representation of the expected effects and a basis from which planners and citizens can make more informed decisions.

Current visual impact research typically takes the form of stimuli designed to evoke a response in an observer followed by an evaluation of that response. Rahman (1992) developed a Visual Impact Analysis and Assessment (VIAA) procedure to assess the visual impacts of a particular design on an existing urban area. A VIAA involves defining the environment that will be studied and choosing photographs to represent the environment, selecting and constructing a visual model through the collection of data, and digitizing the data into the program. Photographs, computer outputs, and combinations of computer wire-frame outputs and color renderings stimulate observer responses. Responses must be analyzed with a checklist of visual criteria and a rating scale in the form of magnitude estimates.

Peterson and Brown (1986) presented another perspective on visual impact assessment with the use of benefit cost analysis. They explained an approach to visual impact assessment that consists of five components:

1) identification of the physical characteristics of the visual environment that the project will change;

2) prediction or measurement of the nature and magnitude of the changes in these variables;

3) measurement of human perception of the changes;

4) measurement of the human preference response to these perceptions; and

5) measurement of "willingness to pay" (WTP) or "compensation demanded" (CD).

Measuring human judgements and responses involves the use of stimuli such as photographs, physical models, or verbal scenarios, combined with surveys or psychosocial models. The economic value of visual impacts is defined and measured with WTP or CD. Methods for economic valuation of non-priced visual impacts include market methods, which rely on relationships of complementarity or substitution between non-priced and priced goods.

Perhaps the most prominent work on visual quality is Lynch's (1960) *Image of the City*. Lynch conducted a study to determine what makes cities legible or imageable; in his words, "the quality in a physical object which gives it a high probability of evoking a strong image in any given observer" (p. 9). Imageable cities are comprised of five elements: paths, edges, districts, nodes, and landmarks. To test his concept of imageability, he performed a pilot study of the central areas of three American cities: Boston, Jersey City, and Los Angeles. Analysis of the cities involved a systematic field reconnaissance by a trained observer who mapped the presence of various elements and their visibility; image strength or weakness; connections, disconnections, and other interrelations; and special successes or difficulties in the potential image structure. Additionally, Lynch conducted lengthy interviews of a sample of city residents to evoke their images of their physical environment. The interviews included requests for descriptions, locations, and sketches. Lynch's methodology has clear applicability to the problem of estimating the effects of major transportation system changes on the visual quality of an area.

In 1981, Appleyard et al. presented another leading study of visual quality research in his well-known book, *Livable Streets*. The study involved one-hour interviews of 12 residents on each block of three streets in San Francisco, in addition to observations from pedestrians and auto travelers on the streets. The three streets selected were identical in appearance but very different in their volumes of traffic (labeled "heavy," "medium," and "light," accordingly). Interviews were guided by a survey instrument and focused on what each resident thought of his or her street and on suggestions they might have for street improvement. The survey instrument included five sets of issues: traffic hazards; stress, including noise and air pollution; neighboring and visiting; privacy and sense of territory; and environmental awareness. Appleyard found that people had withdrawn altogether from the "heavy" street because it was dangerous and noisy, whereas residents on the "light" street viewed the street as their own territory and were much more engaged in the street environment.

Bosselmann et al. (1999) proposed to extend Appleyard's study to test the multiple-roadway boulevard as a design solution for mitigating the unpleasant effect of high traffic volumes. They studied three boulevards with heavy traffic, three streets with medium traffic, and three streets with light traffic, and measured traffic volumes, speed, and noise levels for each of these streets. Unlike Appleyard's study, the authors included the effects of density on higher renter occupancy and on livability in their research. They asked residents to note the occurrences and frequency of certain activities on their block, to describe particular aspects of their street in their own words, and to make simple diagrams on maps of their blocks. On one map residents were asked to indicate homes of friends or acquaintances, while on the other they were asked to circle the area they considered their home territory. The authors concluded that residents on heavy-traffic boulevards rated their living condition as better than residents on conventionally designed streets with medium traffic. Appleyard's inverse correlation of high traffic volumes and poor livability did not hold true in this study. Consequently, Bosselman et al. suggested that boulevards with multiple roadways are worth considering as designs for residential streets that also function as traffic arteries.

Questionnaires and interviews also are useful when evaluating the features in a neighborhood or community that create value for residents. Yeung and Savage (1996) applied Lynch's concept of legibility in the context of Singapore's main street, Orchard Road. The study used a structured questionnaire to obtain data on the objective aspects, and in-depth interviews in order to obtain data on subjective aspects, of urban imagery. The survey consisted of three sections

1) Respondents were asked to locate different buildings and/or places on a blank map of Orchard Road and its immediate vicinity.

2) Respondents were then asked semantic differential questions that focused on subjective evaluations of the Orchardscape.

3) Finally, respondents were asked to sketch a map of Orchard Road on a blank piece of paper with as many details as possible.

The authors concluded that the Orchardscape is a legible landscape. They found that department stores, cinemas, and hotels were the most legible features. Additionally, they found the Orchardscape to be more legible to older, higher-income and English-educated Singaporeans.

Banai (1999) also carried out a study based upon Lynch's work using a matrix method to construct an index of the connective structure of nodes, paths, edges, districts, and landmarks. Respondents were graduate students, and the main campus of their university was the site for imageability. The students were instructed to survey the site strictly following the protocols described by Lynch. Respondents were to determine, in considering each pair of elements on a matrix, which element had greater dominance or importance in contributing to the legibility of a place as seen in the field. In order to determine if subjects were logically consistent in performing pairwise comparisons, Saaty's (1980) formula for measuring consistency was applied to each subject's judgments on the relative importance of the elements. Kendall's coefficient of concordance was then used to determine the level of agreement among the subjects in the perception of the relative importance of the elements. While logical consistency was maintained, a weak agreement was found among the subjects in terms of the degree of interrelation of the elements. According to the author, this suggested a lack of imageability or legibility in the campus design.

**Computer models.** Some of the more complex efforts to assess impacts on visual quality take the form of comprehensive virtual models of entire cities. Jepson and Friedman (1998) discussed a virtual model of the Los Angeles basin being developed by UCLA faculty, staff, and students that combines aerial photographs with street-level imagery and three-dimensional geometry. The model uses visual simulation and commercial modeling software to allow users to view images at different phases or times. The research team eventually expects to produce a realistic simulation of the Los Angeles urban environment to be used for modeling, display and evaluation of neighborhoods as they currently exist, after new highway or building construction, and following historic reconstruction.

Such comprehensive virtual models are time-consuming and costly to construct, but smaller-scale computer models, photomontage techniques, and personal interviews appear to offer widely applicable options for assessing a particular project's effects. Through a combination of GIS and virtual reality, small-scale computer models represent a breakthrough for the assessment of visual impacts, as respondents can view changes on the screen before they occur in the physical world. Respondents can view a variety of alternatives instantaneously and in 3-dimensions (3-D).

Singh (1999) developed a GIS-based approach to creating sketch plans of cities, based on Lynch's concept of nodes. The method involves the strategic use of digital data to create an algorithm capable of finding nodes. It uses a moving window zonal algorithm that visits each cell in the model and searches a radius around it for different land uses. In areas where residential, commercial, and institutional land uses are found, the cell is tagged with a number indicating how many different land uses are present within the search radius. When all the cells in the city have been tagged, their values are grouped into ranges and displayed on a map. White areas on the map indicate areas with no node-like properties. Areas with nodes are separated into three classifications (high, medium, and low), indicating the number of different uses found within the search radius. The author found that a detailed classification scheme with a number of important disaggregated land-use categories—for example, separating commercial into retail, hotels, restaurants/bars, and offices—produced the best representation of urban nodes.

Burkart et al. (1998) discussed several computer-aided techniques that were used in the visual analysis component of an environmental impact statement prepared for the Federal Highway Administration. The project involved a visual assessment of Guanella Pass Road, connecting Georgetown and Grant, Colorado. The road, which had deteriorated over the years as a result of increased traffic, needed lanes widened and the radius of the switchbacks increased. Additionally, a bypass was proposed to lessen the traffic impact on Georgetown, requiring the construction of a major bridge spanning the adjacent ravine and extensive cuts into the mountainside. The authors used this road as a trial application to test how computer-aided techniques could be used to enhance visual analysis. Computer models of roadway improvements were first constructed from a continuous series of roadway cross sections that were linked together to form a 3-D model of the proposed roadway design. Coordinates within the computer precisely identified the location of photographs taken in the field; 3-D views of the computer model were then matched with the lens angle of the site photo and with the sun angle for the date and time the photo was taken. The computer then simulated the materials to be used in the construction project, including asphalt, wall materials, guardrails, and vegetation. Finally, the computer images were combined with photos to create a photo-realistic image of the proposed improvements.

For the Georgetown project, locations were identified where the roadway improvements would be visible. A computer terrain model of the valley, mountainside, existing roadway, proposed improvements, and key view locations was generated. Computer renderings were produced that incorporated the actual colors and materials to be used in the project. The computer merged these renderings with on-site photos to create a photo-realistic view of the proposed alternatives.

Additional computer-aided techniques used in the Georgetown project included wire frames and sketches, and aerial views. Wire frame images were merged with site photos to develop a series of hand sketches showing alternative design concepts. These offered a less time consuming and less costly way to present the project to the public at open meetings. Finally, a series of aerial views were developed to help convey the overall design and context of the project. Color aerial photos were draped over the computer terrain model and then viewed from a series of bird's-eye perspectives. From this, a short computerized movie with drive-through animation of the entire road corridor was developed.

**Photomontage techniques**. Photomontage techniques for visual impact assessment involve superimposing images of transportation system changes onto an existing street scene. Observers view the existing the scene and react to the proposed changes. Photomontage techniques are useful when:

1) the proposed change would add a new visual element to the street scene, such as an elevated structure,

2) the change will block existing views of significant landmarks or green space in the area, or

3) the character of the street scene will be altered (e.g., with an upgraded intersection).

In another study examining various degrees of development, Evans and Wood (1981) studied the visual impact of sympathetic and unsympathetic human intrusion into a scenic highway corridor. Respondents were shown a simulated drive through the California Highway Scenic Corridor and were told to rate their overall visual impression of the route they had seen. The sympathetic development condition included 54 photographs of changes that had occurred on similar roads, including safety improvements, agricultural development, and rustic roadside fencing. The unsympathetic development condition included the photographs used in the sympathetic condition, but also photographs of housing, planted greenery, and metal fencing. They concluded that sympathetic and unsympathetic development depressed preference and scenic quality equally.

Photomontage techniques often involve assessing an area in terms of combinations of intrusions, whether positive or negative. Stamps (1997) studied the preference effects of trees, cars, highline wires, and building façades on streetscapes. Slides were taken of five contiguous houses on three blocks and of five randomly selected trees, five randomly selected cars, and five randomly selected telephone poles. The slides were digitized and separate layers were created for houses, trees, cars, and wires. Particular layers were turned on or off and the computer images were transferred to slides. Respondents viewed each slide and rated it on a semantic differential scale ranging from pleasant to unpleasant (1 to 9). Stamps employed a simple, balanced 3x2x2x2 crossed factorial design, and standardized contrasts between the levels of each factor (e.g., trees versus no trees) indicated the strength of each effect on preferences. He found that trees had a moderate positive effect, wires had a small negative effect, cars had a trivial effect, and the effect of building façades ranged from trivial to moderate.

Yamada et al. (1986) studied the impact of elevated structures of new transportation systems on streetscapes. The authors hypothesized that visual quality and streetscape type were major determinants of visual vulnerability. They conducted three separate experiments in which respondents were shown street scenes with an elevated transportation structure superimposed on them using photomontage techniques. Mean visual impact scores and mean oppression scores were calculated. Based on these scores, the authors determined which types of streetscapes were resistant to elevated structures and which were vulnerable.

## Traffic noise

Noise effects are often the most significant impact on the livability of an area because they are not confined to the outside environment but intrude into people's homes. Noise may result from a number of sources, including increased traffic or a new rail line, and may affect residents in a variety of ways, including creating sleep disturbances and heightening stress levels.

Noise prediction models employ mathematical formulas and graphical representations to predict noise from a variety of road types. Such models take into consideration a series of traffic characteristics, including traffic volume and composition and travel speed. They can predict noise for a number of different road scenarios, and for specific neighborhoods based on characteristics of the neighborhood and the chosen scenario.

To forecast and analyze urban traffic noise levels, Pamanikabud and Tharasawatpipat (1999) developed an empirical model for stop-and-go traffic noise. They measured traffic characteristics (traffic volume, traffic compositions, and average spot speed of vehicles), traffic noise levels, and geometrical dimensions of road cross-sections. Traffic noise was measured with an A-weighting scale of decibel units (dBA) for a one-hour period at each selected location. The authors concluded that a model that separated acceleration and deceleration segments provided the best forecasting results of traffic noise levels.

Barboza et al. (1995) developed the "Traffic Noise Screening" (TNS) procedure to predict traffic noise impacts on new developments or on receptors located near existing roadways. The TNS procedure involves graphical representations of traffic volume and roadway geometry, based on the computerized Federal Highway Administration's STAMINA2.0 noise prediction model. The TNS procedure offer graphs for a variety of scenarios. The procedure predicts noise levels from a two-lane roadway, a four-lane highway, and a six-lane divided highway. Each TNS graph presents various traffic volumes, receptor distances, and travel speeds, as well as a vehicle mix of 100 percent autos and light trucks (adjustments can be made to account for traffic that involves medium- or heavy-duty truck traffic). The model uses peak-hour traffic data for traffic volume and travel speed. Estimated noise is expressed in terms of hourly levels.

To conduct the TNS screening procedure, the user first establishes a roadway scenario, then selects the TNS graph. To predict the traffic noise level, one simply follows the total traffic volume on the TNS graph to the appropriate reception distance line and reads the estimated noise level (dBA) for the average speed being considered. Traffic noise impacts can then be assessed.

Hasebe and Kaneyasu (1991) proposed a quantitative prediction method for urban noise from trunk and access roads. They considered trunk roads as line sources for traffic noise, and access roads as plane noise sources. To compute the noise from access roads, the method assumes that the city is made up of finite planes, each with a land zoning description and sides measuring 500 meters. The planes are divided into residential, commercial, and industrial land uses. Taking into account all access roads in the city, the acoustic energy density at the observer point is calculated. The shielding factor and the atmospheric absorption constant also are calculated. Vehicles are classified as heavy or light, and the sound-power level of each kind of vehicle is averaged by weighting the ratio of heavy vehicles to light vehicles. Finally, the noise source density per unit area is calculated.

To calculate the noise from trunk roads, it is assumed that identical noise sources (moving vehicles) are randomly distributed over the centerline of the trunk road. The mean acoustic energy density is calculated as it is for access roads, and the traffic flow volume again determines the source density. The authors concluded that the method could be used to successfully predict the environmental noise distribution in an urban area from road traffic changes due to a transportation project.

Jiping (1993) offered a model for predicting noise levels on highways with both free flowing and jammed, heavy traffic conditions. To determine the noise of freely flowing traffic, the author stated that the interval between any two successive vehicles (time headway) in a free flow follows a negative exponential distribution. In contrast, during jammed, heavy traffic flow, the time headway meets a shifted negative exponential distribution. Mathematical formulas were presented to calculate these noise levels.

The FHWA (2000) discussed its newest traffic noise modeling software program (TNM) intended to replace the older STAMINA 2.0 highway noise prediction model and the FHWA noise barrier design program. The Traffic Noise Model (TNM) is a flexible Windows-compatible program. TNM has some clear advantages over STAMINA, such as modeling stop-and-go traffic and noise contours within the program itself. Previously, modeling stop-and-go traffic and noise contours was time consuming and complex. TNM requires basic data about the traffic, roadway conditions, and surrounding terrain of the study area.

## Availability of and accessibility to public space

Availability of and accessibility to public space serves significant social and recreational functions. A transportation system change may diminish or remove residents' access to public space, which may in turn have repercussions on levels of social interaction and cohesiveness within a neighborhood. It is therefore useful to consider the importance of public spaces to residents of an area when developing a transportation project.

Surveys are the most common method used for measuring the importance of public space to residents. As with community cohesion, however, the research is limited to considering the availability of and accessibility to public space at a specific point in time; generally speaking, it does not take into account how a change in these factors may affect the livability of an area.

**Neighborhood surveys**. In a study considering the effect of public space on quality of life in a neighborhood, Kuo et al. (1999) hypothesized that “greener” neighborhood common spaces give rise to stronger neighborhood social ties. The authors sought to define the mechanism underlying the relationship between common spaces and social ties and the implications of such a relationship. The study considered not only the use of common space, but also mental fatigue, stress, and mood as possible alternative mediators for a relationship between greenness of common space and neighborhood social ties. Furthermore, they studied whether, in an urban public housing community, higher levels of vegetation in common spaces produce not only stronger social ties but also a greater sense of safety and adjustment among residents. Structured interviews were conducted with 145 residents of the Robert Taylor Homes in Chicago in which residents were randomly assigned to levels of nearby vegetation. Survey questions asked residents about the “greenness” of their building’s common space, their use of that common space, their neighborhood social ties, sense of safety and of adjustment, and additional mediators. Questions were structured in the form of a 5-point Likert scale, except for mental fatigue, which was assessed through the Digit Span Backwards test.

To test the relationships between each of two complementary vegetation measures (“building greenness” and “apartment greenness”) and individual resident’s neighborhood social ties, a series of multiple regressions were conducted. The researchers then tested for the possible mediators of these relationships by conducting a series of ordinary least square regression analyses following the mediation testing procedure recommended by Baron and Kenny (1986). Mediation tests were also conducted to test whether greenness of common space increases sense of safety and sense of adjustment. The authors concluded that greener common spaces appear to attract people outdoors, increasing opportunities for casual social encounters among neighbors and fostering the development of neighborhood social ties.

## Lighting

Transportation system changes may increase lighting in a neighborhood or community in the form of roadway or signage lighting. It is useful for planners to have a basic understanding of light trespass and glare, and how to minimize their intrusion into residents’ homes. Unfortunately, the literature on estimating impacts of lighting as a result of transportation or land use changes is practically nonexistent. More needs to be learned because an effective presentation of potential lighting effects would offer planners and residents the opportunity to choose the lighting option that would have the least impact on an area. Computer programs may provide the opportunity for planners to simulate different types of lighting and to measure the resulting glare from each source.

**Lighting characteristics.** Shaflik (1997) provided a brief summary of the theory of lighting and the design of roadway lighting, including definitions for candela, lumen, illuminance, and luminance. He presented the basic calculation for roadway illuminance (average illuminance equals the luminous flux of the source multiplied by the coefficient of utilization of the luminaire and the light loss factor, divided by the spacing of the streetlight poles, and multiplied by the width of pavement to be illuminated). The formula for predicting roadway glare is dependent on luminaire type, the mounting height, and the observer’s position. Shaflik noted that glare calculations are complex, and are best handled by computer programs. He also discussed the three main aspects of light pollution that persons should consider when designing roadway lighting: light trespass, glare, and urban sky glow. Light trespass occurs when light strays from its intended purpose; glare is unwanted source luminance that results in annoyance and reduced safety; and urban sky glow occurs from stray light being scattered in the atmosphere, brightening the natural sky background.

**Lighting software.** The International Dark-Sky Organization (1997a, 1997b) explained the application of computer software for controlling obtrusive and upward light. The software, termed Obtrusive Light, Intensity and Vertical Illuminance Analysis (OLIVIA), is useful for designing exterior lighting applications where obtrusive light must be taken into consideration. OLIVIA determines lighting parameters for "real-world" locations in XYZ space. It has a number of features, including calculating five lighting parameters per calculation grid: horizontal illuminance, vertical illuminance with any horizontal orientation, intensity from each luminaire, threshold increment for an observer at each grid point, and illuminance normal to a camera. OLIVIA runs on a Windows platform.

## Signage

Increases in signage, as a result of transportation system changes, may have a significant effect on the visual quality of a neighborhood. It is advisable to consider residents' preferences for types of signs; such preferences can be assessed through neighborhood surveys and photomontage techniques. It is also important for planners to consider the overall increases in lighting in an area that may result from increased signage.

**Neighborhood surveys and photomontage techniques.** Nasar (1987) studied the effect of signscape features on perceived visual quality. He chose two signscape features, complexity and coherence, because of their relevance to sign control and their likely influence on perceived visual quality. Complexity is the amount of variation in the scene, and coherence is the degree to which the scene appears organized or unified. The study utilized photographs of a scale model of a streetside strip. Color photographs depicted the model with combinations of three levels of complexity and three levels of contrast. Each sign had only a label of a particular service or shop. The model consisted of simulated buildings, paving, sidewalks, street furniture, automobiles, vegetation, people, and a background skyline, all of which remained constant in the photographs. Complexity was manipulated by altering the amount of variation among the signs, their location, shape, color, direction, and lettering style. Contrast was manipulated by altering the size of the signs and lettering, and by varying the color and material of the signs and lettering in relation to the background. Respondents were interviewed in three separate studies and were asked to respond to the scenes. Analysis of the data utilized Friedman's two-way analysis of variance, Spearman rank order correlations, and the Mann-Whitney U test. The author found that high coherence and moderate complexity were most desired among respondents.

**Lighting considerations.** The International Dark-Sky Association (1997c) discussed considerations for lighting of billboards and roadway signs. In a comparison of top-lit and bottom-lit billboards, they argued that bottom-lit billboards waste energy by directing light into the night sky. They claimed that well-shielded top-lit billboards save energy because they only require a low-wattage florescent fixture, and they cause much less light pollution.

## Summary

Sound conceptual work on how people perceive their living environment has paved the way for increasingly effective visual impact studies. Advances in computer technology have enabled realistic and cost-effective visual representations of communities and neighborhoods with and without transportation projects in place.

Progress in other impact areas related to livability has paralleled visual impact analysis. Among these areas are small-area air pollution modeling; traffic noise modeling; measuring changes in accessibility to public facilities; estimating the effects of glare from roadway lighting, signage, and water runoff. While not as well developed as economic impact analysis, the existing state of the art could substantially improve many state and local agencies' abilities to consider aesthetic and livability issues when evaluating possible transportation system changes.

# DISTRIBUTIVE EFFECTS

Distributive effects are an important factor in any assessment of the social and economic effects of proposed transportation projects. As we use the term, distributive effects pertain to how transportation system changes affect specific groups, such as low-income populations or minority populations. It is possible that a transportation improvement might produce generally positive social and economic effects but worsen the conditions of groups such as these (e.g., through displacement or increased noise and pollution).

Existing work on the distributive effects of transportation system changes is limited. With the U.S. DOT's Environmental Justice Order (U.S. DOT 1997), it has become imperative that these effects be taken into account, and thus more work on methods, tools, and techniques to accomplish this is emerging. Most of these approaches are based on GIS methodologies because of the spatial nature of distributive effects.

## Effects on protected populations

The siting of new transportation facilities, such as freeways or fixed route systems, has significant implications for environmental justice. Much research in the area of environmental justice has indicated that locally unwanted land uses (LULUs), including certain transportation facilities, hazardous waste facilities, toxic industries, and landfills are disproportionately located in communities predominantly made up of minorities and low-income residents. In terms of transportation facilities, Almanza and Alvarez (1999), in discussing a proposed light-rail system for the Austin metropolitan area, argued that new transportation systems provide low-income and minority communities with limited transportation access, while also increasing noise and air pollution, reducing access to community resources, and reducing property values or forcing some residents to be relocated.

Bullard and Johnson (1997) offer a methodology for conducting case studies to assess the environmental justice and distributive effects of various sorts of transportation projects. The authors use these case studies to document the social and economic problems experienced by low-income populations and minority populations resulting from transportation projects. They show how case studies highlight the need to take social equity and civil rights directly into account when planning transportation facilities and services. The case study analyses focus on the question of who pays and who benefits from current transportation policies. The authors' primary objective is to show how current planning processes fail to adequately consider environmental justice.

Most research on environmental justice focuses on toxic facilities such as landfills and hazardous waste sites, rather than on transportation facilities. The value of the research lies in its transferability to efforts to attempt to understand transportation's role in environmental justice. Much of the research uses GIS to identify populations nearby noxious facilities, and to study the potential effects on those populations. Statistical analysis is also commonly used to identify impacts. Both of these methods provide opportunities for analyses to be conducted when a new transportation facility is being sited.

## GIS and spatial-statistical analysis

GIS is useful in evaluations of environmental justice because it allows for the spatial identification of protected populations and displays their proximity to adversely affected locations. GIS may easily be combined with standard statistical analysis, or specific GIS programs may be used to perform spatial-statistical analysis, such as the programs discussed by Levine (1996). He explained that spatial statistics serve three purposes for planners:

1) Measures of spatial distribution describe the center, dispersion, direction, and shape of the distribution of a variable, such as air or water pollution.

2) Measures of spatial autocorrelation describe the relationship among the different locations for a single variable, indicating the degree of concentration or dispersion.

3) Measures of spatial association between two or more variables describe the correlation or association between variables distributed over space.

The author described five statistical programs that analyze spatial processes, and suggested applications for their use.

1) "Spatial and Temporal Analysis of Crime" (STAC) is designed to group or cluster data, indicating concentrations and dispersions of things such as buildings, businesses, persons, events, or crimes. STAC utilizes two general modules. The TIME module describes temporal patterns of events broken down by day of the week and hour of the day, and can be used for time-sensitive data such as motor vehicle accidents. The SPACE module performs two basic functions: a radial search for incidents from a selected point and the identification of the highest concentrations of incidents within a study area.

2) "Hawaii Pointstat" analyzes the spatial distribution of points, either for comparison with other distributions or the same distribution at different points in time. The program calculates the distances between points and then produces the mean center, the standard

deviation of the distance of each point from the mean center, the standard deviational ellipse, the nearest neighbor index, Moran's "I," and several distance matrices.

3) "Venables & Ripley's Spatial Statistics Functions in S-Plus" includes various interpolation techniques, as well as functions that describe the spatial distribution of points. The interpolation can then be displayed as contours, three-dimensional perspectives, or image maps.

4) "SASP," a two-dimensional Spectral Analysis Package for analyzing spatial data, is a set of utility modules that uses a grid cell organization in order to detect patterns in spatial distributions. SASP can be used to model transportation patterns that tend to follow gridlike patterns, such as shifts in traffic flow over time, with the expectation that the flows will be repeated over a certain distance (e.g., between major arterials).

5) "SpaceStat" is a program designed to spatially analyze aerial distributions using data collected on zones or areas within a larger geographical area, such as traffic analysis zones. Through the creation of a spatial weights file, locations of areas in relation to each other are indicated.

**Spatial-statistical analysis and environmental justice.** Many studies of environmental justice use statistical analysis to estimate locations of low-income populations and minority populations and their proximity to hazardous facilities. This area of research has tended to focus on the location of such populations in relation to toxic chemical releases, rather than to transportation facilities. It also has tended to emphasize existing circumstances—whether a population is suffering injustice from a current site—rather than seeking to predict problems that might occur if a site were to be constructed.

For example, Sadd et al. (1999) studied patterns of proximity to environmental hazards by ethnicity and other variables in Los Angeles. They focused on air releases from the 1992 Toxic Chemical Release Inventory System (TRIS) database for the southern California region. Each cataloged site was geocoded to locate its host census tract, utilizing the 1992 Census TIGER files; sites were matched with demographic data obtained from the 1990 Census Summary Tape Files (STF-1 and STF-3), and 1992 land use data were obtained from the Southern California Association of Governments. The authors defined 11 different demographic variables, including ethnicity, economic status, land use, and population density. To compare the demographic characteristics of tracts that contain or are located near a toxic release site to tracts not located near a site, they began by constructing overlay maps with a GIS. They then tested the statistical significance of the geographic patterns with univariate analysis. This involved constructing subsamples of census tracts; for example, one analysis module included all tracts that contained at least one facility that had reported releasing a toxin into the air in 1992. The authors then compared the values of demographic, income, and land use variables for tracts with and without the defined hazard and distance range. Finally, they used binomial logit, ordered logit, and tobit regression analyses to evaluate the relative significance of demographic characteristics in predicting the location and degree of various toxic sites. They concluded that minority residents tend to be disproportionately located in neighborhoods surrounding toxic air emissions, with Latinos most consistently affected.

Shaikh and Loomis (1999) performed a similar statistical analysis, but they considered sites that were permitted rather than already constructed. The authors conducted a multivariate regression analysis to study correlations involving socio-demographic and racial factors in prospective plant siting decisions by considering the characteristics of the community when the stationary source was permitted for construction. The dependent variable was the number of newly permitted sites in a given zip code divided by the square miles of the zip code. There were three types of independent variables: race variables, demographic variables, and socioeconomic variables. The authors performed a correlation analysis which indicated that Hispanic and Native Americans were more likely than whites to be exposed to newly permitted sources of air pollution, but that African American residents were not. The correlation between ethnic minorities and pollutants, although significant, did not take into account other demographic variables that were also highly correlated with site density. In order to determine which race or socioeconomic variables were the stronger determining factors of the siting decision, Shaikh and Loomis employed multiple regression. They found that low-income, high unemployment, and high renter-occupied areas tended to attract more polluting industry.

**Applications of GIS to environmental justice.** Many studies of environmental justice rely on GIS, or combinations of GIS and statistical analysis, to determine if certain populations are disproportionately affected by hazardous facilities. These studies tend to focus on populations living near Superfund sites, landfills, industrial plants, or similar facilities that produce toxic substances. The use of GIS allows researchers to identify where protected populations reside spatially in relation to hazardous facilities. The researcher can then discern the relative effects on the population based on their proximity to the facility.

Bahadur et al. (1998) discussed the application of GIS in evaluations of environmental justice. They argued that GIS provides both qualitative and quantitative benefits, including the identification and visualization of the geographic dispersion of low-income populations and minority populations, in addition to quantitative values for racial, ethnic, and economic composition of potentially affected populations. A GIS analysis of environmental justice includes (1) defining the geographic areas potentially affected by projects or locations of facilities and (2) acquiring demographic data containing ethnic and income attributes. Demographic data may be obtained from the United States Bureau of the Census in the form of a Summary Tape File (STF-3A), which provides data for states and their subareas down to the block group level. The Census Bureau TIGER (Topologically Integrated Geographic Encoding and Referencing) files provide the most comprehensive database of digital mapping information, including roads, highways, and census boundaries for the United States. Each TIGER file covers one county and contains digital data describing cartographic features such as roads and streams. It partitions these features into one of three types of spatial objects: points, lines, or polygons.

The authors studied minority populations and economically-disadvantaged populations living near Superfund sites contained in the National Priorities List (NPL) at county- and block group level resolution. They used GIS software to build the input files and perform the spatial and statistical analysis of the data. To construct the point coverage of NPL sites, they created a file of latitude/longitude coordinates. Census Block Group Boundary coverages were created using the GIS software, and site attributes were joined to the block group polygons. Finally, the authors reconciled the buffer zone coverage with the block group boundary coverage and calculated the minority population and low-income housing statistics.

Also using buffers to identify protected populations, Werner (1997) evaluated whether environmental quality varies with race, age, and income in the Minneapolis/St. Paul metropolitan area. His spatial analysis focused on census block groups. To measure environmental quality, data on toxins released into the atmosphere were obtained from the Environmental Protection Agency's Toxic Release Inventory (TRI) data for 1990. A series of buffers were created to measure proximity to toxic releases. He then performed a GIS polygon-on-polygon overlay that intersected census block groups with the buffers and aggregated the data inside and outside the buffers. The author compared the demographic data inside and outside the buffers to determine if the number of toxic releases significantly differed according to whether people lived inside or outside the buffers. He then generated maps to show the spatial relationships between toxic releases and race, age, and income.

In a similar study, Glickman (1994) used GIS to compare proximity-based measurements and risk-based measurements of environmental equity in an analysis of industrial hazards in Pittsburgh and surrounding Allegheny County, Pennsylvania. To measure environmental equity based on people's proximity to facilities, he divided the county's industrial facilities into two types: (1) those that may pose chronic hazards, and (2) those that may pose acute hazards. He constructed circles with radii of one-half mile, one mile, and two miles around each chronic hazard and each acute hazard facility. Then, for each radius, the county was divided into two parts, the area within the circles and the area outside of all circles. The combined area within the circles became the "close-proximity region." The proportion of nonwhite residents and poor residents inside and outside of the close-proximity region was then estimated.

To calculate the risk-based measurement of environmental equity, Glickman developed a formula that multiplied the probability of an accidental chemical release by the size of the impact area and the population density in that area. He used residential census statistics and journey-to-work data to calculate both nighttime and daytime risks posed by each facility for nonwhites and lower-income populations. The author then calculated the total risk to nonwhites and to the poor for each facility, and the total for all facilities. The average risk was defined as the weighted combination of the nighttime risks and the daytime risks. He concluded that those most exposed to environmental risks are not always nonwhites and low-income.

Swift and Henderson (1997) discussed an ongoing study to investigate the problem of environmental justice resulting from land use conversion with the construction of a GIS database. The study focused on four topical areas: government structure and function, parks and recreation, land cover, and demographics. The study area encompassed much of the midsection of the Los Angeles River and San Gabriel River basins in Los Angeles County, and included cities (and unincorporated areas) that differed both in their predominant land use patterns, and in demographic profiles. For each topical area, different methods were used for data collection, automation, and integration.

The analysis involved a change comparison between land cover inferred from 1928 aerial photography and land cover inferred from 1995 aerial photography. The authors compared land uses using 120-meter grid cells at two-digit land cover classifications under the Anderson system for interpretation of remotely sensed data. They isolated the impacts of the loss of native vegetation and agricultural lands over time, rather than considering the entire extent of land use changes, in order to determine what significant correlations existed between conversion of native vegetation and present demographic characteristics of areas impacted by such conversion. Finally, they calculated correlation coefficients by comparing conversion of native vegetation to current demographic characteristics. Their preliminary findings indicate that less affluent people and persons of color tend to live in areas that have undergone disproportionate changes from natural or agricultural uses to industrial use, and live in areas with a significant lack of available park space.

**Environmental justice and transportation.** The research on environmental justice related to transportation is fairly limited, but a few authors have suggested methods for evaluating the extent to which effects due to transportation system changes disproportionately affect low-income populations and minority populations. For example, Werner (1998) presented a methodology for assessing the demographic effects of changing a bus route. The study involved assessing whether or not cutting back on a particular transit route would disproportionately affect populations of the elderly, poor, or minorities in Ramsey County, Minnesota. Data included Ramsey County TIGER files from the Census Bureau, census block group-demographic data, and bus route subsidies obtained from the local planning agency. A case study transit route was selected, and a three-quarter mile buffer around the transit route was created and then overlaid on the census block group to produce map outputs. The author chose to use the Mann-Whitney test for statistical analysis because it does not assume normally distributed observations and so is useful for skewed variables. Only the minority population inside the buffer versus outside the buffer was found to experience significant changes in transit service.

Lane et al. (1998) presented a more comprehensive approach to considering the effect of a transportation system change on protected populations. They discussed an environmental justice evaluation of two alternative routes for a bypass in Wilmington, North Carolina. The authors stressed that an environmental justice evaluation should reflect the values of the community, and thus should include public participation. Through project development meetings, community members were able to evaluate each alternative, develop lists of their concerns, and describe how these concerns could be minimized or mitigated. To consider potentially disproportionate effects on racial and socioeconomic minority groups residing near either of the alternatives, a reference population was established for comparison purposes. A survey was administered to determine the race, number of persons, and income level of residential dwellings likely to be displaced by either of the alternatives. Additionally, census data were obtained at the block group level. Effects considered for both alternatives included residential and business displacements, community impacts, community services, safety and traffic, noise, air quality, land use and value, and aesthetics. The authors concluded that neither of the alternatives for the Wilmington Bypass would have a disproportionately high adverse effect on minority or low-income populations in the study area.

Finally, in a similar study, Forkenbrock and Schweitzer (1999) considered various methods for assessing the environmental effects of transportation system changes by comparing the spatial occurrences of such effects with the locations of low-income populations and minority populations. Their analysis involved a trial application of methods for estimating impacts on low-income populations and minority populations along an existing urban arterial through Waterloo, Iowa. A more in-depth discussion of their analysis, as well as a discussion of social and economic impacts, may be found in Forkenbrock and Schweitzer (1997). The study involved modeling air pollution and noise at a major intersection of a route running through racially mixed and low-income neighborhoods. The authors identified where the protected populations were located using census block data. Using a travel demand model, they estimated the travel patterns of specific groups in individual traffic analysis zones (TAZs).

The major categories of vehicle-generated air pollution were then examined one at a time—first by modeling vehicle emissions and pollution dispersion, and then by mapping concentrations of pollutants relative to the location of protected populations. Additionally, to assess noise levels surrounding an intersection of the case study highway, the authors employed a noise propagation model. Heavy truck traffic was simulated on the highway to mimic the situation that could result if industrial development were to occur near the route. GIS was used to overlay maximum estimated noise levels with socio-demographic data. They found that low-income households were not disproportionately exposed to noise effects; minority households, however, were.

## Summary

As spatial analysis techniques continue to advance and become more widely used in planning agencies, analysts' abilities to blend distributive effects with social and economic impact assessments will continue to improve. Currently, there are enough good examples of progressive applications of readily available GIS software, pollution and noise models, travel analysis models, and the various livability indicators to enable competent evaluations of distributive effects.

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# SECTION 3: SURVEY ANALYSIS

The objective of this survey of state departments of transportation (state DOTs) and metropolitan planning organizations (MPOs) was to examine their use of methods, tools, and techniques to assess the social and economic effects of transportation projects. The survey questionnaire was mailed in October 1999.

We sent 235 surveys to MPOs and 151 surveys to state DOTs. For many state DOTs, surveys were sent to several offices within the DOT that may have a role in analyzing social and economic effects of transportation projects. Of the 235 surveys sent to MPOs, 63 surveys were returned, resulting in a 27 percent response rate. State DOTs returned 51 surveys, a response rate of 34 percent. In several of the state DOTs, more than one office responded; these DOTs include: Alaska, Arizona, Iowa, Kansas, Kentucky, Louisiana, Maryland, Ohio, Oregon, Texas, and Virgina (see Figure 1).

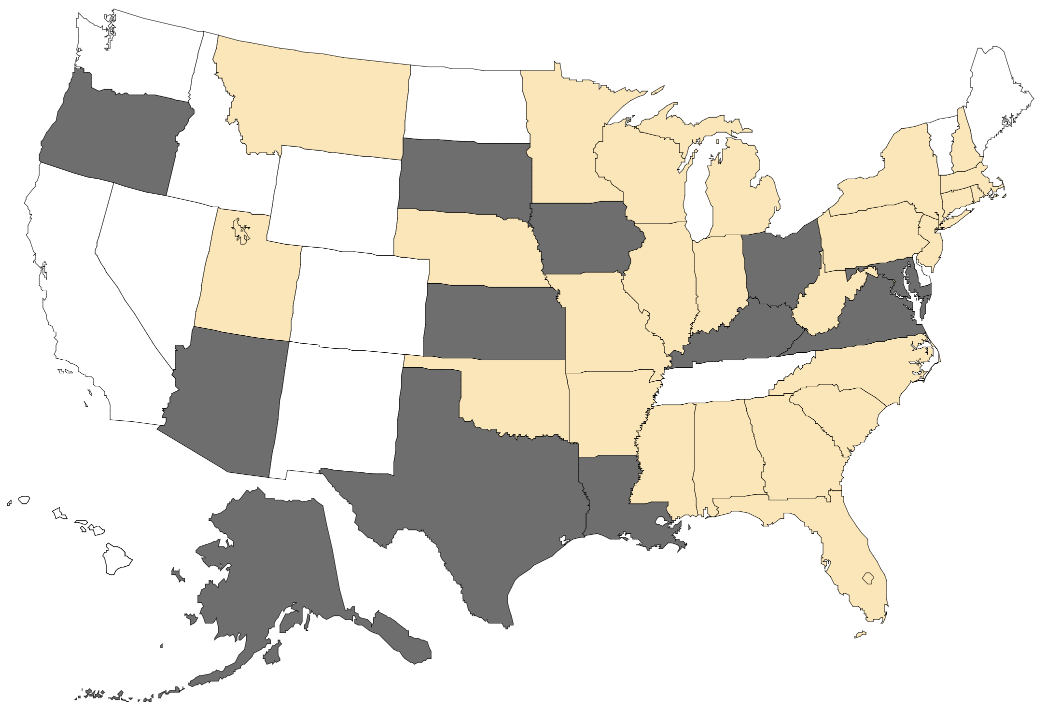

**Figure 1. States with DOT responses**

(Light gray indicates a single response, and dark gray indicates multiple responses.)

The Midwest, South, Southeast, and Northeast generally had the highest response rates with 32 of 37 (86 percent) state DOTs returning surveys. The West and Northwest had much lower response rates: 5 out of 13 (38 percent) states returned surveys.

## A. FREQUENCY WITH WHICH VARIOUS METHODS ARE USED

**Table 1. State DOT offices that always or sometimes estimate impacts of constructing a new road**
Number of offices (values in parentheses are percentages)

Analysis tools frequently or occasionally used by responding DOT offices (n=51)

| | |
|---|---|
| Traditional benefit/cost analysis | 39 (76) |
| Computer models of economic impacts | 15 (29) |
| Noise prediction models | 43 (84) |
| Social indicators | 38 (75) |
| Visual impact analysis | 39 (76) |
| Accessibility indicators | 41 (80) |
| Spatial-demographic analysis | 27 (53) |
| Analysis of pedestrian and bicycle access | 34 (67) |
| Analysis of natural systems | 44 (86) |

Of the surveyed state DOT offices, 100 percent responded that they always or sometimes estimate the impacts of constructing a new road. When estimating those impacts, the most commonly used methods or techniques are: noise prediction models (84 percent), accessibility indicators (80 percent), and analysis of natural systems (86 percent). Computer economic models (29 percent), spatial-demographic analysis (53 percent), and analysis of pedestrian and bicycle access (67 percent) are the least commonly used tools.

**Table 2. Agencies that always or sometimes estimate impacts of construction in or near a residential area**
Number of offices (values in parentheses are percentages)

| | State DOTs | MPOs |
|---|---|---|
| Number of agencies | 49 (96) | 45 (71) |
| Analysis tools frequently or occasionally used: | | |
| Neighborhood surveys | 20 (41) | 19 (36) |
| Social indicators | 37 (76) | 28 (53) |
| Observing travel behavior | 25 (51) | 30 (57) |
| Noise prediction models | 41 (84) | 5 (9) |
| Visual impact analysis | 37 (76) | 16 (30) |
| Spatial-demographic analysis | 26 (53) | 33 (62) |
| Analysis of pedestrian and bicycle access | 32 (65) | 27 (51) |

Of the MPOs responding to the survey, 45 (71 percent) answered that they always or sometimes estimate impacts of construction in or near a residential area. Of those 45 MPOs, the methods, tools, and techniques frequently or occasionally used pertained to spatial-demographic analysis (62 percent), observing travel behavior (57 percent), and social indicators (53 percent). The tools and techniques least frequently used by MPOs were noise prediction models (9 percent) and neighborhood surveys (36 percent).

State DOT offices responding that they always or sometimes estimated the impacts of construction in or near residential areas totaled 49, or 96 percent of all responding DOT offices. Tools and techniques most frequently used by those DOT offices included noise prediction models (84 percent), visual impact analysis (76 percent), and social indicators (76 percent). Neighborhood surveys (41 percent) and observing travel behavior (51 percent) appeared to be the tools least used by DOTs.

One important note is that noise prediction models, while widely used at state DOTs, do not appear to be used frequently by MPOs for measuring transportation project impacts in or near to residential areas. Also, as a whole, it appears that state DOTs are able to conduct more analyses and a wider variety of analyses for measuring those impacts.

**Table 3. Agencies that always or sometimes estimate impacts of projects intended to promote economic development**

Number of offices (values in parentheses are percentages)

| | State DOTs | MPOs |
|---|---|---|
| Number of agencies | 43 (84) | 53 (84) |
| Analysis tools frequently or occasionally used: | | |
| Computer economic models | 13 (30) | 8 (15) |
| Business interviews | 21 (49) | 15 (28) |
| Business dislocation analysis | 27 (63) | 17 (32) |
| Observing travel behavior | 23 (53) | 31 (58) |
| Accessibility indicators | 33 (77) | 36 (68) |

The same percentage (84 percent) of state DOTs and MPOs always or sometimes estimate the impacts of projects intended to promote economic development. The use of methods, tools, and techniques to estimate those impacts varies greatly, however. Of those state DOTs that always or sometimes estimate the impacts of economic development projects, 63 percent use business dislocation analysis. Conversely, their MPO counterparts responded that only 32 percent use business dislocation analyses. Other contrasts include the use of business surveys and computer economic models. In both cases, state DOTs use those tools much more frequently than do the responding MPOs. This analysis also shows that accessibility indicators are fairly widely used by both those state DOTs (77 percent) and MPOs (68 percent) that responded they always or sometimes estimate the impacts of projects intended to promote economic development.

## B. CROSS-TABULATIONS PERTAINING TO THE USE OF METHODS

**Table 4. Neighborhood surveys**
(Values in parentheses are column percentages)

State DOTs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 3 (33) | 8 (19) | 11 (22) |
| Does analysis in-house | 6 (67) | 34 (81) | 40 (78) |
| Total | 9 (100) | 42 (100) | 51 (100) |

MPOs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 4 (44) | 18 (33) | 22 (35) |
| Does analysis in-house | 5 (56) | 36 (67) | 41 (65) |
| Total | 9 (100) | 54 (100) | 63 (100) |

Only 9 out of 51 state DOT offices and 9 of the 63 MPOs responding to our survey do neighborhood surveys frequently (2 or more times per year). Of the state DOT offices using neighborhood surveys frequently, two-thirds conduct those analyses in-house. Of the MPOs that use neighborhood surveys frequently, 56 percent conduct those analyses in-house. These results show that neighborhood surveys are rarely done at all, and when they are, the work is often completed by a consultant.

**Table 5. Social indicators**
(Values in parentheses are column percentages)

State DOTs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 5 (19) | 6 (24) | 11 (22) |
| Does analysis in-house | 21 (81) | 19 (76) | 40 (78) |
| Total | 26 (100) | 25 (100) | 51 (100) |

MPOs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 4 (25) | 18 (38) | 22 (35) |
| Does analysis in-house | 12 (75) | 29 (62) | 41 (65) |
| Total | 16 (100) | 47 (100) | 63 (100) |

About half of the responding state DOT offices and 16 out of 63 MPOs use social indicators on a frequent basis. Of the DOT offices using social indicators, 81 percent conduct their analyses in-house, while 75 percent of the MPOs frequently using social indicators conduct their analyses in-house. These results indicate little use of consultants when using social indicators.

**Table 6. Visual impact analysis**
(Values in parentheses are column percentages)

State DOTs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 2 (11) | 9 (27) | 11 (22) |
| Does analysis in-house | 16 (89) | 24 (73) | 40 (78) |
| Total | 18 (100) | 33 (100) | 51 (100) |

MPOs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 3 (43) | 19 (34) | 22 (35) |
| Does analysis in-house | 4 (57) | 37 (66) | 41 (65) |
| Total | 7 (100) | 56 (100) | 63 (100) |

Eighteen of the 51 responding state DOT offices frequently conduct visual impact analyses, but only 7 out of the 63 MPOs do such analyses. Of the 18 state DOT offices frequently doing visual impact analyses, 89 percent do them in-house; a little over half of the 7 MPOs also do these analyses in-house. These results show some differences in the use of consultants for conducting visual impact analysis.

**Table 7. Spatial demographic analysis**
(Values in parentheses are column percentages)

State DOTs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 3 (17) | 8 (24) | 11 (22) |
| Does analysis in-house | 15 (83) | 25 (76) | 40 (78) |
| Total | 18 (100) | 33 (100) | 51 (100) |

MPOs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 9 (32) | 13 (38) | 22 (35) |
| Does analysis in-house | 19 (68) | 21 (62) | 40 (65) |
| Total | 28 (100) | 34 (100) | 62 (100) |

Fully 83 percent of the state DOT offices that frequently use spatial-demographic analysis tools do those analyses in-house, and 68 percent of the MPOs frequently using this analysis method conduct them in-house. This comparison shows that while about one-third of the responding state DOT offices and a little less than half of the MPOs do spatial demographic analyses, those that do do them have the capabilities to conduct these analyses within their own agencies.

**Table 8. Pedestrian/bicycle access**
(Values in parentheses are column percentages)

State DOTs

| | Does frequently | | Does not do frequently | | Total | |
|---|---|---|---|---|---|---|
| Has consultant do analysis | 5 | (23) | 6 | (21) | 11 | (22) |
| Does analysis in-house | 17 | (77) | 23 | (79) | 40 | (78) |
| Total | 22 | (100) | 29 | (100) | 51 | (100) |

MPOs

| | Does frequently | | Does not do frequently | | Total | |
|---|---|---|---|---|---|---|
| Has consultant do analysis | 6 | (27) | 16 | (39) | 22 | (54) |
| Does analysis in-house | 16 | (73) | 25 | (61) | 41 | (46) |
| Total | 22 | (100) | 41 | (100) | 63 | (100) |

Twenty-two out of 51 responding state DOT offices and 22 of 63 MPOs frequently study pedestrian and bicycle access. The table shows that 77 percent of state DOT offices frequently conducting this type of analysis do them in-house, and that 73 percent of the MPOs do those analyses in-house. These results show that a high percentage of state DOT offices and MPOs frequently conducting bicycle and pedestrian access analyses do not use consultants to complete the analyses.

**Table 9. Computer economic models**
(Values in parentheses are column percentages)

State DOTs

| | Does frequently | | Does not do frequently | | Total | |
|---|---|---|---|---|---|---|
| Has consultant do analysis | 2 | (29) | 13 | (30) | 15 | (29) |
| Does analysis in-house | 5 | (71) | 31 | (70) | 36 | (71) |
| Total | 7 | (100) | 44 | (100) | 5 | (100) |

MPOs

| | Does frequently | | Does not do frequently | | Total | |
|---|---|---|---|---|---|---|
| Has consultant do analysis | 2 | (29) | 23 | (41) | 25 | (40) |
| Does analysis in-house | 5 | (71) | 33 | (59) | 38 | (60) |
| Total | 7 | (100) | 56 | (100) | 63 | (100) |

Only 7 of 51 state DOT offices and 7 of 63 MPOs use computer economic models at least twice a year. Of the state DOT offices that frequently use computer economic models to estimate economic impacts, 5 apply the models in-house. Seventy-one percent of the MPOs frequently using computer economic models also conduct the analyses in-house. These results show low reliance upon consultants by the few agencies frequently using computer economic models to estimate impacts.

**Table 10. Business interviews**
(Values in parentheses are column percentages)

State DOTs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 5 (38) | 10 (26) | 15 (29) |
| Does analysis in-house | 8 (62) | 28 (74) | 36 (71) |
| Total | 13 (100) | 38 (100) | 51 (100) |

MPOs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 0 (0) | 25 (42) | 25 (40) |
| Does analysis in-house | 4 (100) | 34 (58) | 38 (60) |
| Total | 4 (100) | 59 (100) | 63 (100) |

Thirteen out of 51 state DOT offices frequently do business surveys, while only 4 of the 63 MPOs frequently do such surveys. Of the 4 MPOs, 100 percent do these surveys in-house, while 62 percent of state DOT offices frequently using business surveys complete them in-house. Thus, state DOTs have a moderate reliance upon consultants to complete the business survey process.

**Table 11. Business dislocation analysis**
(Values in parentheses are column percentages)

State DOTs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 4 (16) | 11 (42) | 15 (29) |
| Does analysis in-house | 21 (84) | 15 (58) | 36 (71) |
| Total | 25 (100) | 26 (100) | 51 (100) |

MPOs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 0 (0) | 25 (45) | 25 (40) |
| Does analysis in-house | 7 (100) | 31 (55) | 38 (60) |
| Total | 7 (100) | 56 (100) | 63 (100) |

About half of the responding state DOT offices frequently do business dislocation analyses, but only 7 out of 63 MPOs do them. Of the DOT offices frequently using business dislocation analysis, 84 percent conduct those analyses in-house. All of the MPOs frequently using this method conduct the analysis in-house. These results show a very low reliance on consultants by agencies frequently conducting this type of analysis, but the major point is how few MPOs do this type of analysis.

**Table 12. Accessibility indicators**
(Values in parentheses are column percentages)

State DOTs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 8 (29) | 7 (30) | 15 (29) |
| Does analysis in-house | 20 (71) | 16 (70) | 36 (71) |
| Total | 28 (100) | 23 (100) | 51 (100) |

MPOs

| | Does frequently | Does not do frequently | Total |
|---|---|---|---|
| Has consultant do analysis | 7 (25) | 18 (51) | 25 (40) |
| Does analysis in-house | 21 (75) | 17 (49) | 38 (60) |
| Total | 28 (100) | 35 (100) | 63 (100) |

A little over half of the state DOT offices and less than half of the MPOs frequently use accessibility indicators. Of the 28 state DOTs frequently using accessibility indicators, 71 percent conduct the analyses in-house; 75 percent of the MPOs frequently using accessibility indicators for measurement of economic impacts conduct the analyses in-house.

**Table 13. Capability to adequately analyze social effects**
(Values in parentheses are column percentages)

State DOTs

| | Does analysis in-house | Hires a consultant | Total |
|---|---|---|---|
| Has capability | 26 (67) | 2 (18) | 28 (56) |
| Does not have capability | 13 (33) | 9 (82) | 22 (44) |
| Total | 39 (100) | 1 (100) | 50 (100) |

MPOs

| | Does analysis in-house | Hires a consultant | Total |
|---|---|---|---|
| Has capability | 19 (46) | 7 (32) | 26 (41) |
| Does not have capability | 22 (54) | 15 (68) | 37 (59) |
| Total | 41 (100) | 22 (100) | 63 (100) |

Fifty-six percent of the responding state DOT offices feel that they have the capability to adequately analyze the social effects of transportation projects. Of the 63 MPOs, 41 percent believe they have such capabilities. Surprisingly, one-third of the state DOT offices that do not feel that they have the capabilities to adequately analyze social effects nevertheless conduct these analyses in-house. The results also reveal that about half of MPOs without the necessary capabilities to analyze social effects still attempt to analyze them.

**Table 14. Capability to adequately analyze economic effects**
(Values in parentheses are column percentages)

State DOTs

| | Does analysis in-house | Hires a consultant | Total |
|---|---|---|---|
| Has capability | 9 (25) | 4 (27) | 13 (25) |
| Does not have capability | 27 (75) | 11 (73) | 38 (75) |
| Total | 36 (100) | 15 (100) | 51 (100) |

MPOs

| | Does analysis in-house | Hires a consultant | Total |
|---|---|---|---|
| Has capability | 16 (42) | 10 (40) | 26 (41) |
| Does not have capability | 22 (58) | 15 (60) | 37 (59) |
| Total | 38 (100) | 25 (100) | 63 (100) |

Only 25 percent of the state DOT offices feel that they have the capability to adequately analyze economic effects. Of them, 9 do such analyses in-house. Of the responding MPOs, 41 percent feel capable to adequately analyze economic effects of transportation projects. It is surprising that 27 of the 38 state DOT offices and 22 of the 37 MPOs that feel they do not have the ability to adequately conduct such analyses still do them in-house.

**Table 15. Capability to analyze social effects vs. economic effects**
(Values in parentheses are column percentages)

State DOTs

| | Has ability to analyze economic effects | Does not have ability to analyze economic effects | Total |
|---|---|---|---|
| Has ability to analyze social effects | 22 (92) | 6 (23) | 28 (56) |
| Does not have ability to analyze social effects | 2 (8) | 20 (77) | 22 (44) |
| Total | 24 (100) | 2 (100) | 50 (100) |

MPOs

| | Has ability to analyze economic effects | Does not have ability to analyze economic effects | Total |
|---|---|---|---|
| Has ability to analyze social effects | 18 (78) | 8 (20) | 26 (41) |
| Does not have ability to analyze social effects | 5 (22) | 32 (80) | 37 (59) |
| Total | 23 (100) | 4 (100) | 63 (100) |

Fully 92 percent of the state DOT offices that feel they have the capability to analyze economic effects of transportation projects also consider themselves capable of analyzing social effects. On the other hand, only 22 of 50 state DOT offices have this dual capability. Among the responding MPOs, 78 percent believe they have the capabilities to adequately analyze both social and economic effects, but here again, only 18 of the 63 responding MPOs make this claim. These results indicate that a large percentage of DOT offices, and an even larger percentage of MPOs believe they are not able to adequately analyze both the social and economic effects of transportation projects.

**Table 16. Capability to analyze social effects vs. whether more staff resources are needed**
(Values in parentheses are column percentages)

State DOTs

| | Need more staff resources | Do not need more staff resources | Total |
|---|---|---|---|
| Have capability | 28 (90) | 15 (75) | 43 (84) |
| Does not have capability | 3 (10) | 5 (25) | 8 (16) |
| Total | 31 (100) | 20 (100) | 51 (100) |

MPOs

| | Need more staff resources | Do not need more staff resources | Total |
|---|---|---|---|
| Have capability | 5 (18) | 3 (9) | 8 (13) |
| Does not have capability | 23 (82) | 32 (91) | 55 (87) |
| Total | 28 (100) | 35 (100) | 63 (100) |

Of the state DOT offices that feel they need more staff resources, fully 90 percent think that they have the capability to conduct analyses of social effects. Conversely, only 18 percent of the MPOs that feel they need more staff resources think that they are able to conduct analyses of the social effects of transportation projects. Noteworthy, too, is the finding for both state DOT offices and MPOs that agencies that feel they currently are able to analyze social effects are more likely to see a need for additional staff resources.

**Table 17. Capability to analyze social effects vs. whether better data are needed**
(Values in parentheses are column percentages)

State DOTs

| | Need better data | Do not need better data | Total |
|---|---|---|---|
| Have capability | 2 (13) | 6 (17) | 8 (16) |
| Does not have capability | 13 (87) | 30 (83) | 43 (84) |
| Total | 15 (100) | 36 (100) | 51 (100) |

MPOs

| | Need better data | Do not need better data | Total |
|---|---|---|---|
| Have capability | 4 (15) | 4 (11) | 8 (13) |
| Does not have capability | 23 (85) | 32 (89) | 55 (87) |
| Total | 27 (100) | 36 (100) | 63 (100) |

Only 13 percent of the state DOT offices that feel better data are needed to analyze social effects feel that they currently have the capability to conduct such analyses. For MPOs the percentage is very similar, 15 percent. Eighty-three percent of the state DOT offices and 89 percent of the MPOs that responded that better data are not needed for help in analyzing social effects stated that they do not have the capability to perform such analyses. This result implies that better data are not the primary barrier to these agencies acquiring the capability to analyze social effects.

**Table 18. Capability to analyze social effects vs. the need for better guidelines**
(Values in parentheses are column percentages)

State DOTs

| | Need better guidelines | Do not need better guidelines | Total |
|---|---|---|---|
| Have capability | 6 (30) | 2 (6) | 8 (16) |
| Does not have capability | 14 (70) | 29 (94) | 43 (84) |
| Total | 20 (100) | 31 (100) | 51 (100) |

MPOs

| | Need better guidelines | Do not need better guidelines | Total |
|---|---|---|---|
| Have capability | 5 (24) | 3 (8) | 8 (13) |
| Does not have capability | 21 (81) | 34 (92) | 55 (87) |
| Total | 26 (100) | 37 (100) | 63 (100) |

Twenty out of 51 responding state DOT offices see the need for better guidelines for conducting economic analyses of transportation projects. Among responding MPOs, 26 of 63 would like such guidelines. Of the state DOT offices that see a need for better guidelines for conducting analyses of social effects, 30 percent currently feel capable to conduct these analyses. Among MPOs wanting better guidelines, 24 percent feel capable. This suggests that many agencies would like to see better guidelines in order to effectively use methods for analyzing social effects.

**Table 19. Capability to analyze economic effects vs. whether more staff resources are needed**
(Values in parentheses are column percentages)

State DOTs

| | Need more staff resources | Do not need more staff resources | Total |
|---|---|---|---|
| Have capability | 3 (15) | 5 (16) | 8 (16) |
| Does not have capability | 17 (85) | 26 (84) | 43 (84) |
| Total | 20 (100) | 31 (100) | 51 (100) |

MPOs

| | Need more staff resources | Do not need more staff resources | Total |
|---|---|---|---|
| Have capability | 5 (18) | 4 (8) | 9 (14) |
| Does not have capability | 23 (82) | 31 (89) | 54 (86) |
| Total | 28 (100) | 35 (100) | 63 (100) |

Of the state DOT offices that feel they need more staff resources, only 15 percent think that they have the capability to conduct analyses of economic effects. Likewise, only 18 percent of the MPOs that feel they need more staff resources think that they are able to conduct analyses of the social effects of transportation projects.

**Table 20. Capability to analyze economic effects vs. whether better data are needed**
(Values in parentheses are column percentages)

State DOTs

| | Need better data | Do not need better data | Total |
|---|---|---|---|
| Have capability | 1 (7) | 7 (19) | 8 (16) |
| Does not have capability | 14 (93) | 29 (81) | 43 (84) |
| Total | 15 (100) | 36 (100) | 51 (100) |

MPOs

| | Need better data | Do not need better data | Total |
|---|---|---|---|
| Have capability | 6 (22) | 3 (8) | 9 (14) |
| Does not have capability | 21 (78) | 33 (92) | 54 (86) |
| Total | 27 (100) | 36 (100) | 63 (100) |

Only 7 percent of the state DOT offices that feel better data are needed to analyze economic effects feel that they currently have the capability to conduct such analyses. For MPOs the percentage is a little higher, 22 percent. Eighty-three percent of the state DOT offices and 89 percent of the MPOs that responded that better data are not needed for help in analyzing social effects stated that they do not have the capability to perform such analyses. This result implies that better data are not the primary barrier to these agencies acquiring the capability to analyze social effects.

**Table 21. Capability to analyze economic effects vs. the need for better guidelines**
(Values in parentheses are column percentages)

State DOTs

| | Need better guidelines | Do not need better guidelines | Total |
|---|---|---|---|
| Have capability | 7 (35) | 1 (3) | 8 (16) |
| Does not have capability | 13 (65) | 30 (97) | 43 (84) |
| Total | 20 (100) | 31 (100) | 51 (100) |

MPOs

| | Need better guidelines | Do not need better guidelines | Total |
|---|---|---|---|
| Have capability | 7 (27) | 2 (5) | 9 (14) |
| Does not have capability | 19 (73) | 35 (95) | 54 (86) |
| Total | 26 (100) | 37 (100) | 63 (100) |

Twenty out of 51 responding state DOT offices see the need for better guidelines for conducting economic analyses of transportation projects. Among responding MPOs, 26 of 63 would like such guidelines. Of the state DOT offices that see a need for better guidelines for conducting analyses of economic effects, 35 percent currently feel capable to conduct these analyses. Among MPOs wanting better guidelines, 27 percent feel capable. This suggests that many agencies would like to see better guidelines in order to use economic analysis methods effectively.

**Table 22. Overly complex university methods for social analysis vs. the need for more useful guidelines**
(Values in parentheses are column percentages)

State DOTs

| | Need better guidelines | Do not need better guidelines | Total |
|---|---|---|---|
| Methods are too complex | 9 (45) | 4 (13) | 13 (25) |
| Methods are not too complex | 11 (55) | 27 (87) | 38 (75) |
| Total | 20 (100) | 31 (100) | 51 (100) |

MPOs

| | Need better guidelines | Do not need better guidelines | Total |
|---|---|---|---|
| Methods are too complex | 11 (42) | 14 (38) | 25 (40) |
| Methods are not too complex | 15 (58) | 23 (62) | 38 (60) |
| Total | 26 (100) | 37 (100) | 63 (100) |

Only 13 out of 51 (25 percent) of the state DOT offices believe social analysis methods from universities are too complex, while 26 of 63 (40 percent) of the responding MPOs believe this. Of the 20 state DOTs wishing for better guidelines for analyzing social effects, 9 (45 percent) believe that university methods for conducting such analyses are too complex. Among MPOs, 11 of 26 wishing for better guidelines (42 percent) believe the methods developed by universities are too complex.

**Table 23. Overly complex university methods for economic analysis vs. the need for more useful guidelines**
(Values in parentheses are column percentages)

State DOTs

| | Need better guidelines | Do not need better guidelines | Total |
|---|---|---|---|
| Methods are too complex | 9 (45) | 4 (13) | 13 (25) |
| Methods are not too complex | 11 (55) | 27 (87) | 38 (75) |
| Total | 20 (100) | 31 (100) | 51 (100) |

MPOs

| | Need better guidelines | Do not need better guidelines | Total |
|---|---|---|---|
| Methods are too complex | 11 (42) | 15 (41) | 26 (41) |
| Methods are not too complex | 15 (58) | 22 (59) | 37 (59) |
| Total | 26 (100) | 37 (100) | 63 (100) |

Only 13 out of 51 (25 percent) of the state DOT offices believe economic analysis methods from universities are too complex, while 26 of 63 (41 percent) of the responding MPOs believe this. Of the 20 state DOTs wishing for better guidelines for carrying out social analyses 9 (45 percent) believe that university methods of economic analysis are too complex; for MPOs, 11 of 26 see the methods as being too complex. The patterns of perceptions regarding methods of economic analysis closely mirror the patterns regarding the analysis of social effects.

## C. SUMMARY

Responses from 51 offices within state DOTs and 63 MPOs have given us a reasonably clear picture of the current state of the practice regarding the assessment of social and economic effects of transportation projects. One finding is clear—state DOTs in general are much more involved in this type of assessment than are MPOs. When they plan new or upgraded roadways, state DOTs often evaluate effects on user costs, noise, visual quality, and accessibility. They also consider indicators of social effects, though not as often or rigorously as economic effects. MPOs are likely to study traffic patterns to gauge accessibility and to analyze the area's demographic characteristics. Both types of agencies tend to take into account economic development effects when assessing proposed transportation projects.

We found that MPOs are more likely to engage the services of consultants when assessing social and economic effects. State DOTs are more likely to feel that they need additional staff resources to analyze these effects. A majority of MPOs that do not consider themselves capable of analyzing social and economic effects do not feel a need for additional staff resources. Comments from some responding MPOs indicated that they consider the state DOT to be the lead agency for conducting these types of analyses. A preponderance of both types of agencies (1) would like to see better guidelines for assessing social and economic effects and (2) do not feel that impact methods developed by university researchers are too complex.

# SECTION 4: RESEARCH NEEDS

In the course of completing NCHRP Project 25–19, we had the opportunity to evaluate both the state of the art and the state of the practice in assessing the social and economic effects of transportation projects. In this final section, we provide our assessment of the available methods, and we suggest a series of research and training efforts to increase the capacity of transportation professionals to conduct impact analyses.

## ASSESSMENT OF AVAILABLE METHODS

Based on the review of available methods, tools, and techniques in Section 2 of this final report, it is clear that the profession is better equipped to assess economic effects than social effects. This conclusion is supported by the survey reported in Section 3, the results of which indicate two main points: (1) economic effects are analyzed more frequently than are social effects and (2) fairly basic methods of economic analysis are the most commonly used. Below is our assessment of available methods, discussed in the order of the 11 major sections in the accompanying guidebook developed as part of this NCHRP project.

### Changes in travel time

Researchers have contemplated the elusive issue of travel time valuation for many years, but have yet to come to a consensus as to how to attach economic value to the time people spend traveling. Among the issues that remain to be resolved are:

- the fraction of the wage rate to be used for on-the-clock (i.e., work-related) travel;
- the fraction of the on-the-clock rate to be used for personal or off-the-clock travel;
- the fraction of the driver's hourly time value to be assigned to passengers in the vehicle;
- whether to use a lower time value for commuting trips that are shorter than the common travel time budget (i.e., the amount of time people are willing to spend journeying to and from work) and a higher value for the time increment that exceeds this time budget;
- whether to apply the same time value for very short periods of time saved (e.g., 30 seconds) as for longer periods (e.g., over 5 minutes);
- how to take into account variation in time en route and hence unreliability of arrival time; and
- how to include changes in travel time for pedestrians, cyclists, and other non-motorized transportation modes.

In general, the methods used to estimate the changes in travel time for road users are adequate, but the capacity to take into account variations in travel time need further development. This capacity is particularly necessary as the importance of reliability of arrival time is becoming greater due to the reliance on just-in-time operations in many industries. The other key need is generally-accepted approaches to placing a value on travel time.

## Safety

The three key research needs in evaluating changes in safety are (1) better methods for assessing the changes in crash rates likely if a transportation project were carried out, (2) the ability to more fully take into account the safety effects of a project on users of non-motorized transportation, and (3) more widely accepted approaches to assigning a value to safety improvements.

In our guidebook, we present an advanced regression-based predictive model for estimating the change in crash rates likely if a particular type of road improvement is made. We also present a method for estimating the effects on bicycle safety of changes in roadway design. Further advancement of these sorts of methods is needed. Also needed are better methods for estimating the effects on pedestrian safety of road upgrades. Often such upgrades make crossings more difficult for pedestrians, but there are few methods available for estimating such effects.

Several major studies have sought to develop defensible approaches to assigning dollar values to changes in fatalities, personal injuries, and property damage resulting from crashes. Most of this work is quite old, and more current estimates are needed. The methods used to make these estimates must be comprehensible to the public and supported by the research community. Lacking such widely-embraced estimates, assigning a value to safety improvements will continue to be an ad-hoc effort that is unable to produce anything close to standardized values.

## Vehicle operating costs

There was relatively little work accomplished in the area of estimating how vehicle operating costs would change if a transportation project were carried out until the Federal Highway Administration commissioned work to develop the Highway Economic Requirements System (HERS). As we summarize in the guidebook, the HERS model has a relatively detailed module to estimate vehicle operating costs. We recommend that additional work be completed to make the methods contained in HERS more workable and less data intensive. Our concern is that in the case of many projects, it would be impractical to acquire the extensive data needed to apply the cost model in HERS. We are confident that simpler approaches are indeed possible that would still enable good estimates of how vehicle operating costs would change following completion of a roadway project.

## Transportation choice

In the guidebook, we present a series of mode-specific methods for analyzing how the array of modal choices would be affected by a proposed transportation project. Used in tandem, these methods do allow one to gain a reasonably good sense of how those traveling by other modes than the auto would be affected, but there is considerable room for improvement. New approaches that use geographic information system (GIS) data and plotting routines are gradually emerging. For example, these approaches make it easier to estimate how accessibility to bus stops or rail stations would be affected by a change to the area's road system.

It is worth stressing that many of the elements of impact analysis are incomplete without consideration of how pedestrian and bicycle travel opportunities and conditions are affected by transportation projects. To fully measure transportation choice and its relationship to such considerations as accessibility and community cohesion, two types of data on pedestrian and bicycle travel are needed:

- *Trip patterns*—How much pedestrian and bicycle activity is currently occurring (or could potentially occur in the future) and what are the patterns of trip origins and destinations (including walking to/from parking spots and bus stops)?

- *Route factors*—What paths (sidewalks, and bicycle lanes), obstacles (walls, bridges, inclines, and road barriers), and access facilities (entrances, stairs, and bicycle parking) affect the movement of people?

These data would enable the following analyses:

- To properly assess *transportation choice*, it is necessary to determine which route factors (facilities and obstacles) most significantly affect the availability of options for walking and/or bicycling.

- To properly assess *local accessibility*, including accessibility via car or bus travel, it is also necessary to determine the movement pattern and routing factors affecting total (out-of-vehicle as well as in-vehicle) travel times between origins and destinations.

- To properly assess *community cohesion*, it is necessary to determine the volume and pattern of current pedestrian and bicycle movements, and the extent to which projects may impede them.

## Accessibility

Much more work is needed to develop methods for assessing accessibility to destinations deemed important by travelers originating in specific districts of a metropolitan area. Traditional methods that are based on gravity models do give a general picture of accessibility to large employment and commercial locations, but they are not especially capable of supporting more specific analyses. Among the limitations of these models are (1) the subjective nature of attractiveness (i.e., the physical size of a destination may not be the only or most important attribute), (2) the problem of distance measurement (i.e., the functional distance by bus transit may vary from that of an auto trip), and (3) the specific needs and preferences of an area's residents, which can vary widely.

Among the topics where more research is called for are:

- GIS-based methods that analyze accessibility by taking into account distance, time, travel barriers, and other forms of impedance;

- localized accessibility methods capable of estimating a traveler's ability to visit businesses and other destinations (taking into account travel by several modes, including by foot);

- regional accessibility methods with better developed behavioral elements that allow people's preferences to be factored in; and

- approaches for estimating intermodal accessibility (e.g., that allow one to consider travelers' abilities to use more than one transportation mode on a single trip to specified destinations).

## Community cohesion

There is a real dearth of methods available for estimating the effects on community cohesion of a proposed transportation project. Even the methods currently used to gauge community cohesion are very limited in their ability to get at the real issues in a neighborhood or area of a community that seem to define its cohesiveness. Methods currently used to assess cohesion often incorporate surveys and focus groups. While it is only natural to speak to the residents of a neighborhood to gain a sense of how cohesive it is, there needs to be better conceptual underpinnings to these methods: What are the dimensions of community cohesiveness that one is trying to assess?

Only when better basic conceptual bases are developed can planners hope to devise methods for estimating the *change* in cohesion that would result if a transportation project were to be carried out. Among the aspects of community cohesion that warrant further research are:

- practical methods for estimating the activity spaces of various population subgroups within a neighborhood and contiguous areas;

- a better understanding of the types of public actions that can substantially enhance the cohesiveness of a neighborhood or area of a community; and

- well-documented case analyses of how particular types of transportation projects have improved or worsened community cohesion in different circumstances.

One must keep in mind that insights derived in one locale or circumstance must be regarded as only one indication of the types of outcomes a similar action may bring about elsewhere. So many aspects of each community and its neighborhoods are unique that methods to predict the effects of a transportation project on cohesion must be flexible and cannot be expected to produce deterministic results. There is no substitute for working directly with neighborhood residents when assessing the likely effects of a proposed project, and methods of analysis must build on this interaction.

## Economic development

The effects of transportation projects on the economic development potential of a community have received considerable attention by researchers over the past decade or so. Methods for analyzing economic development effects fall into two general categories: (1) benefit-cost-based methods for estimating the magnitude of the savings in transportation costs that would accrue to industries within the community and (2) regional economic models that replicate the economy and thereby estimate the change in industrial competitiveness due to reduced transportation costs. The former mode of analysis is heavily dependent on the assumptions one uses regarding the value of time. Also, it is necessary to consult an input-output table to gain a sense of how large a cost share transportation constitutes for the industries that are important to the community. This enables one to speculate how great the potential improvement in competitiveness might be if the project were carried out. While this method of analysis is relatively easy to do, it can only give one a general sense of how local industries might benefit.

Economic models have made major strides during the past decade. They can be misleading, however, in that there is a host of strong assumptions in the equations that drive the models. Among these assumptions are elasticities that estimate how likely a particular industry is to move to an area whose transportation costs have decreased due to a certain improvement. Because there are economic forces acting on a local economy that often are not captured by an economic model, the results should be regarded as an indication of what might happen, not what one can expect with some certainty.

More research is needed to adapt computerized economic models to smaller scale (i.e., sub-county) analyses to shed light on the possible economic effects of a major project within a given community. Additionally, more work is needed to ensure that the key assumptions contained in economic models can be adjusted to better reflect actual conditions in the study area.

## Traffic noise

As we discuss in the guidebook, computerized models to predict noise levels generated by specified traffic conditions have progressed greatly in recent years. The new Federal Highway Administration (FHWA) Traffic Noise Model (TNM) constitutes the state of the art in noise modeling, and it represents significant progress over its predecessors. Yet there is room for further enhancements to make the model more capable of addressing real-world conditions. For example, the TNM does not allow for multiple, staggered barriers for variance in receptor height. It also considers only free-flow, one-speed traffic on a straight-line roadway. For accurate and flexible analyses to be carried out, more features need to be added to what already is a good model.

Using geographic information systems (GIS), it is possible to overlay noise contours over socio-demographic data, allowing thorough analyses of which population groups would be affected by changes in traffic noise levels. This capability is a major resource for impact analyses, but if local conditions such as barriers (e.g., buildings and vegetation) are added to the model, the results will be more accurate. The TNM enables some sorts of barriers to be specified, but more detail would be a positive step.

## Visual quality

In the guidebook, we discuss several relatively new techniques for presenting to the public how a proposed transportation project would alter the visual environment. These new techniques use various types of computer imaging approaches. The simplest involves superimposing a representation of the project on a digitized photograph. This approach allows one to change the physical attributes of a superstructure or other visually significant feature and to see how the change affects the aesthetic quality of the area. More advanced techniques include virtual metropolitan models that actually allow one to see a proposed facility and the surrounding environment from any number of perspectives.

Research is continuing to make these advanced techniques more affordable and capable of providing useful information on a timely basis. Such research is highly promising and worthy of increased support. Providing residents and facility users with a clear, accurate representation of a proposed transportation project is an important step in advancing the state of the practice in impact analysis.

## Property values

There is a well-developed theoretical literature on how transportation improvements influence the land market and property values. Yet practical methods for estimating the effects of specific impacts on property values still need much more development. Market studies and property comparisons can give a general idea of how a project may affect the values of nearby properties, but the conceptual underpinnings of these approaches are not strong. Because they do not have a clear theoretical basis, it often is difficult to identify which characteristics of a project are most likely to affect property values. As a result, planners are hard pressed to identify modifications to a project that could enhance desirable effects or lessen those that are adverse.

So-called "hedonic models" are regression models that are intended to provide estimates of changes in property values resulting from a transportation project, if all of the property's other characteristics are held constant. The advantage of these models is that one can statistically control for the other attributes of a property that influence its value. The key is to include the right attributes in the hedonic model. Failing to include attributes that can influence property values can lead one to overestimate or underestimate the effects of the transportation project. More research needs to be carried out to help planners identify the attributes to include when using such models to estimate a project's effects on property values.

## Distributive effects

Transportation analysts have long known that major projects tend to have distributive effects, in that some people become better off as a result of a project and others become less well off. Generally speaking, economic gains from a transportation project stem from improvements in accessibility to desirable destinations, such as employment or commercial centers. Those made worse off frequently experience such undesirable impacts as increased noise or air pollution, a less attractive visual environment, or a neighborhood that is bifurcated by a right-of-way. While these sorts of effects have been addressed through the methods of analysis discussed throughout the guidebook, determining who would experience them and to how great an extent is also highly important. Advances in GIS methods are allowing analysts to evaluate the spatial nature of various types of impacts, and this capability is enabling them to estimate who would be affected and how greatly.

More research is needed to enhance analysts' capacity to apply GIS-based methods to evaluate a broader spectrum of effects. In general the types of effects that can be examined in a spatial context are those that affect a relatively small geographic area (e.g., changes in the ability of neighborhood children to walk to school). Needed are capabilities to estimate such phenomena as

- changes in accessibility to important destinations across the urban area using any of several modes, including non-motorized transportation; and
- how to incorporate actual behaviors and preferences into spatial analyses, such as how contiguous neighborhoods *want* to interact.

## PRESENTATION METHODS

Just as transportation professionals need to be able to creatively apply impact assessment methods, they also must be able to present those findings in ways useful for planning and decision-making. The guidebook directly addresses the first need, but the latter need is beyond its scope.

Quite often, the hard-to-quantify types of impacts (such as neighborhood cohesion and visual quality) get skipped over in presentation of impacts because they are not easy to measure. Yet stepping back, it is clear from the guidebook that there are several possible approaches one could use to present various measures of social and economic effects. These approaches include: (1) actual dollar impacts, (2) a severity rating scale, (3) pass or fail guidelines, and (4) qualitative descriptions. Some of these presentation approaches are problematic or not feasible for certain types of effects, and some may not be appropriate for specific types of planning or decision-making. In other words, the appropriate form for presenting social and economic effects must depend on the type of effect and the intended use of the information generated by the analysis.

To address the need for effective approaches for presenting social and economic effects of a proposed transportation project, a natural follow-on of the current project would be a companion guide to the presentation of these effects. Such a guide would clarify:

- options for presentation to different audiences,
- measurement approaches for different circumstances,
- ways to avoid double-counting and under-counting of impacts, and
- methods for combining results for different types of effects into overall assessments or tradeoff analyses.

Such a companion guide could provide a structured framework to help one identify the most appropriate form of analysis and presentation, depending on the nature of the project, the motivation for the analysis, the type of audience, and the types of decisions to be made.

# Appendix A: Survey Instrument

# METHODS, TOOLS, AND TECHNIQUES TO ASSESS THE SOCIAL AND ECONOMIC EFFECTS OF TRANSPORTATION SYSTEM CHANGES

**ANSWER KEY**

Upper value = Department of Transportation responses

Lower value = Metropolitan Planning Organization and Regional Planning Agency responses

Values in parentheses are percentages of total responses

Total DOT responses = 51

Total MPO/RPA responses = 63

Transportation modes covered by your agency (*check all that apply)*

| | Road | Rail | Transit | Air | Water | Other (*please specify*) Bike and pedestrian |
|---|---|---|---|---|---|---|
| DOT | 51 (100) | 40 (78) | 45 (89) | 33 (65) | 27 (53) | 10 (20) |
| MPO/RPA | 60 (95) | 40 (63) | 57 (90) | 28 (44) | 16 (25) | 13 (21) |

Educational backgrounds of people in your division (*check all that apply*)

| | Economics | Geography | Urban and regional planning | Engineering | Other (*please specify*) |
|---|---|---|---|---|---|
| DOT | 25 (49) | 30 (59) | 38 (75) | 45 (88) | 32 (63) |
| MPO/RPA | 15 (24) | 35 (56) | 61 (97) | 31 (49) | 22 (35) |

Do any divisions in your agency, other than yours, analyze social and economic effects of transportation projects?

| | Yes |
|---|---|
| DOT | 8 (17) |
| MPO/RPA | 12 (21) |

**IMPORTANT NOTE:**

We define social and economic impacts as those pertaining to the general well-being of people affected by transportation projects. Among the examples of economic impacts are effects on neighborhood businesses, employment effects, reductions in the time required to make a trip, and changes in the value of one's property. Social impacts include many other phenomena, such as visual or aesthetic effects, pedestrian safety, neighborhood cohesion, access to community resources, and noise levels.

## PART 1. IMPACT ASSESSMENT PROCESS

**A.** Under which of the following circumstances does your agency estimate these impacts of transportation projects?

*(please mark only one answer)*

| | Always | Sometimes | Rarely | Never | Don't know | |
|---|---|---|---|---|---|---|
| Constructing a new road/highway | 46 (90) | 5 (10) | 0 (0) | 0 (0) | 0 (0) | **DOT** |
| | 40 (63) | 13 (21) | 5 (8) | 5 (8) | 0 (0) | **MPO** |
| Highway/road widening | 26 (51) | 24 (47) | 0 (0) | 1 (2) | 0 (0) | **DOT** |
| | 25 (40) | 23 (37) | 6 (10) | 8 (13) | 0 (0) | **MPO** |
| Adding an interchange | 33 (65) | 16 (31) | 2 (4) | 0 (0) | 1 (2) | **DOT** |
| | 33 (52) | 16 (25) | 6 (10) | 8 (13) | 1 (2) | **MPO** |
| Reconfiguring an intersection | 16 (31) | 22 (43) | 11 (22) | 0 (0) | 0 (0) | **DOT** |
| | 9 (14) | 24 (38) | 17 (27) | 12 (19) | 3 (5) | **MPO** |
| Projects currently experiencing public opposition | 33 (65) | 15 (29) | 1 (2) | 0 (0) | 1 (2) | **DOT** |
| | 26 (41) | 18 (29) | 7 (11) | 2 (3) | 8 (13) | **MPO** |
| Building a superstructure of some sort | 22 (43) | 16 (31) | 3 (6) | 4 (8) | 6 (12) | **DOT** |
| | 9 (14) | 13 (21) | 10 (16) | 8 (13) | 19 (30) | **MPO** |
| Construction in or near a residential area | 31 (61) | 18 (35) | 1 (2) | 0 (0) | 1 (2) | **DOT** |
| | 18 (29) | 27 (43) | 9 (14) | 5 (8) | 2 (3) | **MPO** |
| Projects involving residential condemnation | 35 (69) | 11 (22) | 2 (4) | 0 (0) | 2 (4) | **DOT** |
| | 23 (37) | 12 (19) | 13 (21) | 8 (13) | 5 (8) | **MPO** |
| Projects that reduce access to businesses | 27 (53) | 19 (37) | 3 (6) | 0 (0) | 1 (2) | **DOT** |
| | 20 (32) | 18 (29) | 10 (16) | 8 (13) | 3 (5) | **MPO** |
| Projects intended to promote economic development | 28 (55) | 15 (29) | 4 (8) | 0 (0) | 3 (6) | **DOT** |
| | 25 (40) | 28 (44) | 3 (5) | 2 (3) | 3 (5) | **MPO** |
| Potentially controversial projects | 31 (61) | 19 (37) | 0 (0) | 0 (0) | 1 (2) | **DOT** |
| | 29 (46) | 23 (37) | 6 (10) | 2 (3) | 1 (2) | **MPO** |
| Altering traffic patterns in an area of the city significantly | 27 (53) | 22 (43) | 2 (4) | 0 (0) | 0 (0) | **DOT** |
| | 25 (40) | 17 (27) | 7 (11) | 6 (10) | 5 (8) | **MPO** |
| Projects involving cooperative agreements to purchase land | 16 (31) | 15 (29) | 9 (18) | 0 (0) | 11 (22) | **DOT** |
| | 11 (17) | 14 (22) | 16 (25) | 7 (11) | 9 (14) | **MPO** |
| Projects that would affect: | | | | | | |
| Surrounding ecosystems | 31 (61) | 15 (29) | 3 (6) | 0 (0) | 2 (4) | **DOT** |
| | 27 (43) | 13 (21) | 11 (17) | 7 (11) | 3 (5) | **MPO** |
| Schools or hospitals | 27 (53) | 16 (31) | 4 (8) | 1 (2) | 4 (8) | **DOT** |
| | 18 (29) | 19 (30) | 12 (19) | 5 (8) | 3 (5) | **MPO** |
| Parks and recreation areas | 30 (59) | 15 (29) | 3 (6) | 0 (0) | 2 (4) | **DOT** |
| | 22 (35) | 18 (29) | 12 (19) | 5 (8) | 2 (4) | **MPO** |

**B.** What types of impacts does your agency focus on when conducting analyses of transportation system changes? (*check all that apply*)

| DOT | MPO | |
|---|---|---|
| 39 (76) | 32 (51) | Impacts that would primarily affect businesses. |
| 38 (75) | 34 (54) | Impacts that would primarily fall upon protected populations (e.g., minorties or low-income households). |
| 39 (76) | 32 (51) | Impacts that would primarily affect well-established neighbor-hoods. |
| 42 (82) | 46 (73) | Impacts that are likely to be sizable or visible, regardless of whom they affect. |
| 8 (16) | 10 (16) | Other |

**C.** Which of the following statements best describes the role of **social** effects in project evaluations? (*check all that apply*)

| DOT | MPO | |
|---|---|---|
| 27 (53) | 25 (40) | They potentially could cause a project to be abandoned. |
| 46 (90) | 40 (63) | We would try to mitigate at least the most significant negative impacts. |
| 35 (69) | 25 (40) | We would redesign the project as needed to address social impacts. |
| 15 (29) | 14 (22) | We would take these effects into account, but they would not be major factors in a project's fate. |
| 14 (27) | 11 (17) | If we thought the political pressures were likely to be great enough, we would conduct at least a limited analysis. |
| 3 (6) | 3 (5) | We often do not take such effects into account. |

**D.** Which of the following statements best describes the role of **economic** effects in project evaluations? (*check all that apply*)

| DOT | MPO | |
|---|---|---|
| 25 (49) | 25 (40) | They potentially could cause a project to be abandoned. |
| 43 (84) | 37 (59) | We would try to mitigate at least the most significant negative impacts. |
| 37 (73) | 25 (40) | We would redesign the project as needed to address social impacts. |
| 13 (25) | 14 (22) | We would take these effects into account, but they would not be major factors in a project's fate. |
| 14 (27) | 15 (24) | If we thought the political pressures were likely to be great enough, we would conduct at least a limited analysis. |
| 3 (6) | 3 (5) | We often do not take such effects into account. |

**E.** When carrying out an analysis of the likely **social** effects of a potential transportation improvement, which of the following best describes your agency's current practices? *(check all that apply)*

| DOT | MPO | |
|---|---|---|
| 40 (78) | 41 (65) | The analysis would be conducted in-house. |
| 47 (92) | 33 (52) | We would retain the services of a consultant. |
| 11 (22) | 19 (30) | We would seek the assistance of a college or university. |

**F.** When carrying out an analysis of the likely **economic** effects of a potential transportation improvement, which of the following best describes your agency's current practices? *(check all that apply)*

| DOT | MPO | |
|---|---|---|
| 36 (71) | 38 (60) | The analysis would be conducted in-house. |
| 44 (86) | 32 (51) | We would retain the services of a consultant. |
| 13 (25) | 17 (27) | We would seek the assistance of a college or university. |

**G.** What is the primary motivation within your agency for analyzing the **social** effects of transportation projects? (*check all that apply*)

| DOT | MPO | |
|---|---|---|
| 40 (78) | 44 (70) | Better project planning. |
| 18 (35) | 26 (41) | Ranking projects in terms of their desirability. |
| 41 (80) | 35 (56) | Public information or discussion. |
| 23 (45) | 19 (30) | Political pressure (actual or anticipated). |

**H.** What is the primary motivation within your agency for analyzing **economic** effects of transportation projects? (*check all that apply*)

| DOT | MPO | |
|---|---|---|
| 39 (76) | 45 (71) | Better project planning. |
| 24 (47) | 29 (46) | Ranking projects in terms of their desirability. |
| 38 (75) | 35 (56) | Public information or discussion. |
| 21 (41) | 17 (27) | Political pressure (actual or anticipated). |

**I.** Over the past 5 years, how has your agency's analysis of the **social** impacts of transportation projects changed? (*check only **one** response*)

| DOT | MPO | |
|---|---|---|
| 16 (31) | 10 (16) | We are doing a lot more in-depth analysis. |
| 20 (39) | 27 (43) | We are doing a little more analysis. |
| 14 (27) | 17 (27) | We are doing about the same amount of analysis. |
| 0 (0) | 5 (8) | We are doing less analysis. |

**J.** Over the past 5 years, how has your agency's analysis of the **economic** impacts of transportation projects changed? (*check only **one** response*)

| DOT | MPO | |
|---|---|---|
| 14 (27) | 14 (22) | We are doing a lot more in-depth analysis. |
| 20 (39) | 25 (40) | We are doing a little more analysis. |
| 16 (31) | 17 (27) | We are doing about the same amount of analysis. |
| 0 (0) | 3 (5) | We are doing less analysis. |

**K.** In circumstances when your agency does not analyze the **social** effects of a transportation project, which of the following best describes the main reasons why? (*check all that apply*)

| DOT | MPO | |
|---|---|---|
| 22 (43) | 30 (48) | No demand/audience for it. |
| 5 (10) | 17 (27) | Simple tools/methods are not available. |
| 4 (8) | 7 (11) | Too expensive to do. |
| 4 (8) | 4 (6) | Lack of familiarity with the subject. |
| 17 (33) | 13 (21) | Not applicable, we always analyze social effects |

**L.** In circumstances when your agency does not analyze the **economic** effects of a transportation project, which of the following best describes the main reasons why? (*check all that apply*)

| DOT | MPO | |
|---|---|---|
| 21 (41) | 32 (51) | No demand/audience for it. |
| 9 (18) | 17 (27) | Simple tools/methods are not available. |
| 5 (10) | 8 (13) | Too expensive to do. |
| 5 (10) | 5 (8) | Lack of familiarity with the subject. |
| 17 (33) | 13 (21) | Not applicable, we always analyze economic effects |

**M.** What is the nature of the **economic** analyses of potential major transportation projects carried out in your agency? (*check all that apply*)

| DOT | MPO | |
|---|---|---|
| 33 (65) | 32 (51) | Conducting benefit-cost analysis of potential investments. |
| 36 (71) | 30 (48) | Estimating economic development effects of projects. |
| 25 (49) | 25 (40) | Evaluating financing alternatives. |
| 31 (61) | 21 (33) | Estimating impacts on specific sectors (e.g., small businesses, low-income areas). |
| 38 (75) | 37 (59) | Compliance with federal directives. |
| 40 (78) | 24 (38) | Estimating the number and types of relocations. |

## PART 2. USE OF SPECIFIC METHODS FOR ASSESSING IMPACTS

Now we would like to ask about your agency's use of specific methods, tools, and techniques to assess the social and economic effects of transportation system changes. We have provided definitions of each one.

### A. Traditional benefit-cost

**Definition**

Comparing the value of the likely stream of benefits from projects (travel time savings, accident cost savings, vehicle operating cost savings) with the relevant discounted costs (capital and operating).

| DOT | | MPO |
|---|---|---|
| 31 (61) | **Frequently** (2 or more times a year) | 13 (21) |
| 9 (18) | **Occasionally** (once a year) | 14 (22) |
| 9 (18) | **Rarely** (once every two years or less) | 27 (43) |
| 3 (6) | **Never**, because we don't think this technique is useful. | 1 (2) |
| 1 (2) | **Never,** because we are not familiar with the technique | 3 (5) |
| 0 (0) | **Don't know** | 1 (2) |

### B. Neighborhood surveys

**Definition**

Questionnaire surveys of households likely to be affected by a project. The surveys measure the level of concern about specific impacts and the desired mitigative measures. The questionnaires can either be mailed out or administered through face-to-face interviews.

| DOT | | MPO |
|---|---|---|
| 9 (18) | **Frequently** (2 or more times a year) | 9 (14) |
| 13 (25) | **Occasionally** (once a year) | 16 (25) |
| 20 (39) | **Rarely** (once every two years or less) | 25 (40) |
| 3 (6) | **Never**, because we don't think this technique is useful. | 3 (5) |
| 2 (4) | **Never,** because we are not familiar with the technique | 4 (6) |
| 4 (8) | **Don't know** | 3 (5) |

### C. Social indicators

**Definition**

Using data from various sources, develop objective indicators of social effects (e.g., police response times, percent of children crossing major streets en route to school, number of households relocated, or choice of transportation mode).

| DOT | | MPO |
|---|---|---|
| 26 (51) | **Frequently** (2 or more times a year) | 16 (25) |
| 12 (24) | **Occasionally** (once a year) | 18 (29) |
| 8 (16) | **Rarely** (once every two years or less) | 19 (30) |
| 0 (0) | **Never**, because we don't think this technique is useful. | 0 (0) |
| 1 (2) | **Never,** because we are not familiar with the technique | 4 (6) |
| 4 (8) | **Don't know** | 3 (5) |

## D. Computer economic models

**Definition**

Economic models (e.g., REMI or IMPLAN) that estimate job and income growth within the region due to reductions in transportation costs. These models are used to estimate regional effects of major transportation projects.

| DOT | | MPO |
|---|---|---|
| 7 (14) | **Frequently** (2 or more times a year) | 7 (11) |
| 9 (18) | **Occasionally** (once a year) | 3 (5) |
| 13 (25) | **Rarely** (once every two years or less) | 9 (14) |
| 5 (10) | **Never**, because we don't think this technique is useful. | 5 (8) |
| 8 (16) | **Never,** because we are not familiar with the technique | 33 (52) |
| 7 (14) | **Don't know** | 2 (3) |

## E. Business interviews

**Definition**

Using surveys to assess the extent to which the transportation system change, during the construction and post-construction phases, would be likely to affect the viability of businesses serving areas/neighborhoods in which changes are contemplated.

| DOT | | MPO |
|---|---|---|
| 13 (25) | **Frequently** (2 or more times a year) | 4 (6) |
| 11 (22) | **Occasionally** (once a year) | 15 (24) |
| 15 (29) | **Rarely** (once every two years or less) | 23 (37) |
| 0 (0) | **Never**, because we don't think this technique is useful. | 2 (3) |
| 4 (8) | **Never,** because we are not familiar with the technique | 10 (16) |
| 6 (12) | **Don't know** | 5 (8) |

## F. Business dislocation analysis

**Definition**

Estimating the local effects of temporary or permanent loss of access to businesses through the use of "windshield surveys," expected changes in retail square footage, or employment projections.

| DOT | | MPO |
|---|---|---|
| 25 (49) | **Frequently** (2 or more times a year) | 7 (11) |
| 7 (14) | **Occasionally** (once a year) | 13 (21) |
| 10 (20) | **Rarely** (once every two years or less) | 22 (35) |
| 1 (2) | **Never**, because we don't think this technique is useful. | 4 (6) |
| 2 (4) | **Never,** because we are not familiar with the technique | 10 (16) |
| 6 (12) | **Don't know** | 6 (10) |

## G. Observing travel behavior

**Definition**

Measuring actual responses to transportation system changes, such as different traffic volumes following a road widening or observing changes in property values following increased traffic on a street (e.g., revealed preference

| DOT | | MPO |
|---|---|---|
| 18 (35) | **Frequently** (2 or more times a year) | 21 (33) |
| 9 (18) | **Occasionally** (once a year) | 16 (25) |
| 9 (18) | **Rarely** (once every two years or less) | 19 (30) |
| 4 (8) | **Never**, because we don't think this technique is useful. | 1 (2) |
| 4 (8) | **Never,** because we are not familiar with the technique | 1 (2) |
| 4 (8) | **Don't know** | 4 (6) |

## H. Noise prediction models

**Definition**

Computer models (e.g., FHWA's STAMINA 2.0) to predict changes in noise levels if traffic lanes were added, an intersection were altered, or other system changes were made.

| DOT | | MPO |
|---|---|---|
| 34 (67) | **Frequently** (2 or more times a year) | 4 (6) |
| 9 (18) | **Occasionally** (once a year) | 3 (5) |
| 2 (4) | **Rarely** (once every two years or less) | 8 (13) |
| 1 (2) | **Never**, because we don't think this technique is useful. | 7 (11) |
| 1 (2) | **Never,** because we are not familiar with the technique | 35 (56) |
| 4 (8) | **Don't know** | 3 (5) |

## I. Visual impact analysis

**Definition**

Superimposing the image of a possible facility (such as a superstructure) on a photograph or videotape of a streetscape or other landscape view. Comparing with and without images from a number of angles or views is used to estimate the perceived magnitude of visual impact in the minds of local residents.

| DOT | | MPO |
|---|---|---|
| 18 (35) | **Frequently** (2 or more times a year) | 7 (11) |
| 21 (41) | **Occasionally** (once a year) | 13 (21) |
| 5 (10) | **Rarely** (once every two years or less) | 15 (24) |
| 0 (0) | **Never**, because we don't think this technique is useful. | 6 (10) |
| 1 (2) | **Never,** because we are not familiar with the technique | 14 (22) |
| 3 (6) | **Don't know** | 4 (6) |

## J. Accessibility indicators

**Definition**

Use of travel demand models to assess expected changes in accessibility to common destinations if a transportation system change were made. Accessibility indicators are developed for specific traffic analysis zones to estimate how various areas/neighborhoods would be affected.

| DOT | | MPO |
|---|---|---|
| 28 (55) | **Frequently** (2 or more times a year) | 28 (44) |
| 13 (25) | **Occasionally** (once a year) | 12 (19) |
| 4 (8) | **Rarely** (once every two years or less) | 8 (13) |
| 3 (8) | **Never**, because we don't think this technique is useful. | 3 (5) |
| 1 (2) | **Never,** because we are not familiar with the technique | 4 (6) |
| 0 (0) | **Don't know** | 5 (8) |

## K. Activity analysis

**Definition**

Through the use of diaries or questionnaires, patterns of trip making and spatial interaction are sampled for populations likely to be affected by a major transportation system change. Changes in the ability of these populations to make desired trips or to otherwise interact with others are then assessed.

| DOT | | MPO |
|---|---|---|
| 11 (22) | **Frequently** (2 or more times a year) | 8 (13) |
| 7 (14) | **Occasionally** (once a year) | 8 (13) |
| 15 (29) | **Rarely** (once every two years or less) | 28 (44) |
| 3 (6) | **Never**, because we don't think this technique is useful. | 4 (6) |
| 5 (10) | **Never,** because we are not familiar with the technique | 10 (16) |
| 9 (18) | **Don't know** | 3 (5) |

## L. Spatial-demographic analysis

**Definition**

Development of geographic information systems (GIS) in combination with Census data to analyze characteristics of the population likely to be affected by a project, as well as access to such facilities as schools, hospitals and clinics, service agencies, churches, and shopping.

| DOT | | MPO |
|---|---|---|
| 18 (35) | **Frequently** (2 or more times a year) | 28 (44) |
| 10 (20) | **Occasionally** (once a year) | 14 (22) |
| 8 (16) | **Rarely** (once every two years or less) | 12 (19) |
| 2 (4) | **Never**, because we don't think this technique is useful. | 3 (5) |
| 5 (10) | **Never,** because we are not familiar with the technique | 3 (5) |
| 5 (10) | **Don't know** | 0 (0) |

## M. Integrated transportation-land use models

**Definition**

Regional models that estimate the effects of larger transportation system changes on land use patterns and on property values (TRANUS and MEPLAN, for example, estimate property values).

| DOT | | MPO |
|---|---|---|
| 6 (12) | **Frequently** (2 or more times a year) | 11 (17) |
| 6 (12) | **Occasionally** (once a year) | 10 (16) |
| 10 (20) | **Rarely** (once every two years or less) | 7 (11) |
| 2 (4) | **Never**, because we don't think this technique is useful. | 7 (11) |
| 15 (29) | **Never,** because we are not familiar with the technique | 22 (35) |
| 11 (22) | **Don't know** | 2 (3) |

## N. Relative value approaches

**Definition**

Methods such as "stated preference" that involve assessing the value of desirable attributes relative to each other (e.g., less noise versus more direct routing). The objective is to ascertain which attributes are the most important to respondents.

| DOT | | MPO |
|---|---|---|
| 4 (8) | **Frequently** (2 or more times a year) | 3 (5) |
| 12 (24) | **Occasionally** (once a year) | 7 (11) |
| 11 (22) | **Rarely** (once every two years or less) | 21 (33) |
| 3 (6) | **Never**, because we don't think this technique is useful. | 3 (5) |
| 12 (24) | **Never,** because we are not familiar with the technique | 21 (33) |
| 6 (12) | **Don't know** | 5 (8) |

## O. Placing a monetary value

**Definition**

Questionnaires are distributed to populations that may be affected by a transportation system change to establish what people would be willing to pay to have or to avoid an impact of some sort. The idea is to represent non-market impacts in monetary terms.

| DOT | | MPO |
|---|---|---|
| 4 (8) | **Frequently** (2 or more times a year) | 0 (0) |
| 4 (8) | **Occasionally** (once a year) | 4 (6) |
| 11 (22) | **Rarely** (once every two years or less) | 20 (32) |
| 12 (24) | **Never**, because we don't think this technique is useful. | 9 (14) |
| 9 (18) | **Never,** because we are not familiar with the technique | 21 (33) |
| 10 (20) | **Don't know** | 5 (8) |

## P. Pedestrian and bicycle access

**Definition**

Estimate the impact of a transportation system change on the ability to travel by foot or other non-motorized modes.

| DOT | | MPO |
|---|---|---|
| 22 (43) | **Frequently** (2 or more times a year) | 22 (35) |
| 12 (24) | **Occasionally** (once a year) | 10 (16) |
| 9 (18) | **Rarely** (once every two years or less) | 17 (27) |
| 1 (2) | **Never**, because we don't think this technique is useful. | 5 (8) |
| 1 (2) | **Never,** because we are not familiar with the technique | 7 (11) |
| 6 (12) | **Don't know** | 1 (2) |

## Q. Analysis of natural systems

**Definition**

Evaluate the loss of or damage to trees and effects on other aspects of nearby ecosystems when considering transportation system changes.

| DOT | | MPO |
|---|---|---|
| 41 (80) | **Frequently** (2 or more times a year) | 21 (33) |
| 3 (6) | **Occasionally** (once a year) | 15 (24) |
| 4 (8) | **Rarely** (once every two years or less) | 12 (19) |
| 1 (2) | **Never**, because we don't think this technique is useful. | 3 (5) |
| 0 (0) | **Never,** because we are not familiar with the technique | 5 (8) |
| 2 (4) | **Don't know** | 5 (8) |

## PART 3. ADEQUACY OF AVAILABLE METHODS, TOOLS, AND TECHNIQUES

We would like your opinion as to the adequacy of current methods, tools, and techniques for analyzing the probable social and economic effects of changes in transportation systems.

**A.** To enhance your agency's ability to evaluate the social and economic effects of transportation system changes, which of the following are needed?

(*please mark only one answer*)

| | Badly needed | Would help some | Not a big need | Don't know | |
|---|---|---|---|---|---|
| More resources for your agency, in terms of staff, time, or equipment. | 20 (39) | 22 (43) | 8 (16) | 0 (0) | **DOT** |
| | 28 (44) | 30 (48) | 2 (3) | 1 (2) | **MPO** |
| Better data relevant to analysis of social and economic effects. | 15 (29) | 27 (53) | 6 (12) | 2 (4) | **DOT** |
| | 27 (43) | 34 (54) | 0 (0) | 0 (0) | **MPO** |
| More useful guidelines in applying impact methods, tools, or techniques, such as a guidebook for agency use. | 20 (39) | 25 (49) | 6 (12) | 0 (0) | **DOT** |
| | 26 (41) | 28 (44) | 6 (10) | 0 (0) | **MPO** |

| | Agree | Neither agree nor disagree | Disagree | |
|---|---|---|---|---|
| **B.** Generally speaking, my agency has the capacity to estimate the **social** effects of transportation projects accurately and comprehensively. | 28 (55)<br>26 (41) | 15 (29)<br>27 (43) | 8 (16)<br>8 (13) | **DOT**<br>**MPO** |
| **C.** Generally speaking, my agency has the capacity to estimate the **economic** effects of transportation projects accurately and comprehensively. | 24 (47)<br>23 (37) | 19 (37)<br>30 (48) | 8 (16)<br>9 (14) | **DOT**<br>**MPO** |
| **D.** The methods, tools, and techniques developed by university researchers and consultants often are too complex for my agency to use in estimating **social** effects. | 13 (25)<br>25 (40) | 24 (47)<br>32 (51) | 14 (27)<br>4 (6) | **DOT**<br>**MPO** |
| **E.** The methods, tools, and techniques developed by university researchers and consultants often are too complex for my agency to use in estimating **economic** effects. | 13 (25)<br>26 (41) | 22 (43)<br>31 (49) | 16 (31)<br>6 (10) | **DOT**<br>**MPO** |
| **F.** There has been significant progress over the past decade or so in the ability of public agencies to estimate the social effects of transportation projects. | 27 (53)<br>32 (51) | 15 (29)<br>25 (40) | 9 (18)<br>5 (8) | **DOT**<br>**MPO** |
| **G.** My agency has the capacity to use GIS-based spatial data when estimating social or economic impacts. | 30 (59)<br>60 (95) | 10 (20)<br>1 (2) | 11 (22)<br>1 (2) | **DOT**<br>**MPO** |
| **H.** New computer-based techniques for presenting to the public the visual impact of proposed overpasses, elevated rail transit structures, and the like are unlikely to experience widespread application for at least a decade. | 12 (24)<br>17 (27) | 8 (16)<br>17 (27) | 30 (59)<br>27 (43) | **DOT**<br>**MPO** |
| **I.** Our ability to carry out economic analyses of potential transportation projects has improved because of the availability of more useful approaches. | 18 (35)<br>26 (41) | 25 (49)<br>23 (37) | 8 (16)<br>11 (17) | **DOT**<br>**MPO** |
| **J.** There is a problem communicating rigorous analyses in ways that are understandable to the public. | 27 (53)<br>42 (67) | 15 (29)<br>15 (24) | 9 (18)<br>5 (8) | **DOT**<br>**MPO** |
| **K.** The tools for estimating economic effects tend to be too difficult to apply for routine use by my agency. | 18 (35)<br>27 (43) | 21 (41)<br>28 (44) | 13 (25)<br>5 (8) | **DOT**<br>**MPO** |
| **L.** I am interested in learning more about methods, tools, and techniques that would help my agency conduct social and economic impact analyses of proposed transportation projects. | 40 (78)<br>52 (83) | 8 (16)<br>10 (16) | 2 (4)<br>0 (0) | **DOT**<br>**MPO** |

**Please use this blank space to give us your thoughts on social and economic impact analysis, especially how it is conducted in your agency.**

The following includes all comments we have received to date. We have transcribed all the comments verbatim in the interests of accuracy: we have not corrected errors in content or grammar. To preserve respondent anonymity, we have omitted agency names in the text below.

State departments of transportation comments:

In general, these analyses are conducted by environmental consulting firms that are responsible for developing project level environmental clearances. Little of this type of work is done in house.

Currently ---- DOT is making a diligent effort to conduct early (and) continuous public involvement practices to better analyze social impacts.
A number of factors make this survey difficult to answer. There does not appear to be a defined problem that warrants a solution. Compounding the lack of a problem statement are general questions that lack a specific focus. The extremely broad definition of social and economic impacts encompasses so many activities of an organization as large as a state DOT, that we are challenged to provide an answer in a check box.

Project opponents often use these types of studies to kill projects. Often their intent is not a legitimate analytical one, but is self-serving and reflects the common sentiment "not in my backyard." A more useful approach to the issue of social impact analysis would be to develop objective methods to analyze these impacts, while minimizing or eliminating opportunities for special interest groups to unfairly attack the project.

1. ---- does not have a sales tax. It is therefore very difficult to determine objectively if projects have had an impact on businesses.

2. We have engaged in several literature searches and find very little in the way of studies that would help us predict the economic outcome of several types of highway features. We are particularly interested in; Raised medians, right-in-right out, access limited to intersections, traffic calming in downtowns, one-way couplets, removal of parking on one or both sides in downtowns, reversing the trend – changing one way couplets to two-way streets with parking.

3. Surveys are used only on our largest and most contentious projects. Information is not objective for economic analysis. Best for identifying issues of concern.

4. We often measure what we have data for rather than what we are concerned about with respect to social impacts. Consultants are especially guilty of this.

5. Again, we need studies on which to base our "expert" judgement. Some questions: What are the long term effects of moving the elderly?, If we displace the two day care's in the area, what is the likelihood they will relocate in the neighborhood?, What are some of the solutions to pedestrian barriers such as "too wide" streets? What is the impact on the neighborhood and individuals?

6. We are doing a longitudinal study of the impacts of interchange access on resulting land use. Is it – build it and they will come? We are finding that they won't build it if there is no access, but on the other hand there needs to be water, sewer, zoning, no other environmental impediments, and a favorable economic climate locally, or they still won't come.

State departments of transportation comments, continued:

7. There is relatively little research sponsored by FHWA related to socio-economic impacts, yet these are the questions that concern the public the most. We give them back dry data that is often not relevant to the concerns raised by businesses and the public.

8. We do socio-econ scoping on all projects with federal funding

9. 2 sections, 1) Environmental and 2) Cultural

It is my understanding that formal analysis of social effects is limited to considerations for noise in metropolitan areas.

Economic development is considered in only two of ----DOT's programs. Benefit-cost is used in prioritizing intersection safety projects. The lack of skilled staff to interpret economic models is a significant deterrent.

There is knowledge, skills, tools which can be used to conduct both social and economic analyses, but staff limitations and availability do not allow time to permit thoroughness desirable.

The State of ---- is developing a high-tech approach to public involvement in the planning of Intermodal Travel.

A state wide long-range plan is being developed that will include modeling of traffic on roadways through out the state as well as with in Metropolitan Planning Organizations and an Intelligent Transportation System (ITS) deployment plan. Plans are also being developed to include the use of Global Positioning System (GPS) in the placement of counters for collection traffic counters and gathering roadway inventory data.
Each of these programs /systems are being considered and /or implemented to impact the process of considering the social and economic impact of improvement of travel ways in the state of ----.

Our districts (25 in ----) do most of the social & economic analysis for projects. Given that social & economic issues are not regulated in the same way as natural, historic & archeological resources are, less time & effort is spent in general. More effort is spent on projects where there is controversy or specific issues related to socio-eco impacts.

Environmental Justice (EJ) is an issue becoming more important. It is difficult to evaluate EJ because there are no quantitative measures for evaluation.

Because of EJ & other socio-eco issues, we are trying to improve our analyses & evaluation techniques.

We are very interested in your survey findings and think that the survey instruments you mentioned would be particularly useful to us. We would be very interested in what some of the other states have done in this area.

The survey findings and some of the techniques, if the tools and survey instruments were also collected, would make a great, best practices meeting and guidebook.

Please keep us informed of your progress in this important area.

State departments of transportation comments, continued:

We believe that a handbook such as you are proposing to prepare would be very useful both to State DOTs and to MPOs. In fact, ---- DOT has recently contracted with a consultant to prepare an economic development handbook for use by ---- State MPOs. We wish you well in your endeavor and look forward to seeing the final product. We ask that we be put on your mailing for any publications or updates produced in connection with this project that will be made available to the public and would especially like to receive a copy of the handbook itself.

Part 2 questions not well designed. An answer of "Never" may be due to reasons other than those indicated.

Economic and Social impact of projects has far less importance in certain parts of the country than in others.

Someone needs to address the issue of "should a transportation project (Highway) address economic and social issues as a primary function or should their prime concern be to provide a solution to safety and capacity problems." What are the moral assumptions for transportation agencies.

While more social and economic analysis will be accomplished soon, the traditional approach has been to do the minimum necessary to get the project accomplished.

The Bureau of ---- is responsible for reviewing all of the Department's projects early in the planning process. All of the projects are screened with particular emphasis on potential rights-of-way impacts. The vast majority of our projects are classified as "Categorical Exclusions" and as such they do not require the preparation of an Environmental Assessments or Environmental Impact Statements.

The social analysis focuses on the type and number of residential and/or business displacements, community cohesion, impacts to schools, churches, cemeteries, and recreational areas, and if applicable environmental justice concerns. The economic analysis is concentrated on the number of employee displacements; construction related employment, and tax base impacts. The Department does not attempt to quantify potential impacts to property values. Our land use analysis is limited to a discussion of existing land use patterns and the compatibility of the project with such patterns. Existing and future land use patterns are a major component of the Department's traffic projection model however.

----DT primarily addresses social & economic issues in the NEPA project development process. However, economic issues were addressed at the policy level in the statewide plan and the Department is looking at potential economic development goals to include in a new performance programming process that will guide project selection.

We've conducted only 1 S/E impact analysis since 1995. Data/staff limitations are balanced w/required duties vs. S/E.

Comprehensive land use/transportation model that is user-friendly and reliable is the most compelling need at present in our view.

State departments of transportation comments, continued:

Lack of major scale highway/road construction in our region significantly reduces the need for the social/economic analysis covered in this survey. This will be true in many parts of the U.S. which have funding constraints and/or are low population growth zones.

Title VI requests of U.S.DOT may be a new factor that will drive need for social/economic analysis as part of Regional Transportation Plan preposition process and is a priority agenda of some advocacy groups across the U.S.

Metropolitan and regional planning organization comments:

At ----, we usually have a variety of corridor analyses going on at one time. We use consultants as necessary when we either do not have enough staff or they can add expertise that we do not have on staff.

Our adopted land use plans take the place of detailed analysis for smaller projects—if a project is consistent with the plan, then little or no specific analysis may be required—depends on the complexity of the project.

Our interest in and use of these analyses are growing; more "pre-packaged" methods that come with widely accepted credibility would be appreciated.

Limited application—more done as a local government agency than an MPO. Particularly important when looking at creating or extending a road for economic development purposes. Is cost of road construction worth future economic benefits.

Philosophical issues such as growth management (smart growth) which restrict development to specific areas is also part of the equation in some areas.

The use of frequency under Part 2 is odd because small MPO's (like us) may only have a new project or construction every couple years. Use of social & economic impact on 100% of projects is translated to "Rarely" for a small MPO on 50% of projects may be "Frequently" for a large MPO. I think the frequency measure as presented here may be misleading other than whether it's used at all or never.

The use of various models to estimate social and economic impacts are helpful, but our agency lacks the data that must be input to the systems and few, if any, staff members have the expertise to use the programs. Consultants usually do have the means, but funding then becomes a critical issue. Finally, we lack a travel demand model, but will have it running within the next year or so (hopefully).

At our level, transportation planning, social and economic analyses are general is nature—except for a few, controversial projects. Detailed analyses are completed by the design agencies— ----DOT, local governments, consultants.

We have a policy to notify residents and businesses in the vicinity of projects where right-of-way is to be purchased or access to the roadway is being modified. We also have an ever-improving public involvement program to help gauge public opinion and obtain public input. The seemingly lack of frequency of application of analyses is due primarily to the frequency of major project planning. Social and economic analyses are completed in conjunction with major long-range plan updates – every 3 to 5 years.

Metropolitan and regional planning organization comments, continued:

Recently, the subject of economic analysis of projects has been more carefully evaluated. In conjunction with the University of ----, we have evaluated REMI and asked their marketing rep. to make a presentation. This model is still too expensive for our budgets. When we need an economic analysis of projects, we ask ---- to provide an analysis based on our transportation data.

As growth in ---- increases, there is increasing demand/need for better analysis techniques. We ask for better tools, at reasonable prices, that do not require an entire staff to collect data and complete the analyses.

1. Our agency seldom looks at individual projects in isolation, instead looking at a number of projects and their relative effects on these areas. ----DOT (state DOT) looks very closely at design mitigation for social and economic impact analyses.

2. ---- is developing and enhancing tools for assessing economic & social impacts. We are reviewing tools now, including our own "in-house" assessment mechanism, and STEAM (FHWA).

3. Much of assessment activities coincide with our long-range transportation plan updates.

There is a significant difference in the level of analysis required to analyze the social and economic impacts of transportation improvements at the systems, or planning, stage and the project implementation stage.

I strongly feel that it would be INAPPROPRIATE to complete anything other than a social, economic and environmental scan at the systems level of planning. Project details (i.e. alignment, exact number of lanes, etc) are not firm at this point. In addition, the number of projects, and alternatives, would make this process unwieldy and expensive for a study of little practical value.

Most of the social and economic issues are brought to the forefront by public and stakeholder involvement. Detailed analysis generally follows from raised issues or concerns.

These impacts are often overlooked by DOT, social disruption & trade-off analyses would be helpful.

Tools to make outcomes understood by public needed.

Resources to support acquisition of technology (hardware/software) training & implementation also needed.

Much of this survey did not apply to us in our role as a metropolitan planning organization. We do not do project-level analyses of social and economic impacts. We would like, however, to refine our process to do such analyses for our transportation improvement programs and 20-year transportation plans.

Metropolitan and regional planning organization comments, continued:

At the regional level, a general social—environmental—economic impact analysis is conducted at the time of development/update of the regional transportation plan, or at the time of a plan amendment.

Closer scrutiny is given to soc – env – ec impacts at project development/scoping phases. This evaluation is the responsibility of the project sponsor, typically the state DOT or a local government. Their evaluations, assuming federal funds are involved, are subject to final review by ODOT or FHWA approval.

Evaluation measures must be communicated to elected officials and the general public. Consequently they must be readily understood and relatively simple. Complex techniques are useful for research and for educating/training professionals, but of little use for public discourse and decision-making. The critical issue is getting agreement among feuding groups through dialogue and facilitation. More research needs to be directed to this latter subject.

---- does in-house analysis of system-wide impacts of alternative land use and network scenarios. We use MINUTP as our travel demand software. We use ARCVIEW to study spatial data and relationship to transportation system impacts.

We have done substantial additional analysis in recent years of impacts to adjacent/nearby properties through use of digital photos/parcel-based data for transportation system impacts.

We do substantial cost-benefit analysis for each major project, from street arterys, adding capacity to existing facilities, building new links/interchanges or transit service improvements, although the level of effort goes up substantially on large ($10 million +) capacity projects.

Limited basis because ---- is a small MPO, less than 200,000 population. A majority of the questions are addressed as part of a construction project, but much can and is done by ----DOT in conjunction with ---- staff.

When we seek federal funds, we have to follow the federal regulations that are associated with the use of those funds. The (i.e. EA) format is really one which ----DOT uses to satisfy the FHWA staff who review the EA information & data.

Our agency has recently lost all its transportation planning staff & is in no condition to implement any social or economic input analysis.

We are a small MPO that relies heavily on consultants. Therefore, all of the methods and resources available to perform social and economic input analysis are not always known, but depend on the hired consultants skills and resources.