THE GEOGRAPHY OF URBAN TRANSPORTATION

Edited by

Susan Hanson
Clark University

The Guilford Press
New York London

fringe: Land-use issues of nonmetropolitan America (pp. 23–49). Minneapolis: University of Minnesota Press.

Miller, R. (1982). Household activity patterns in nineteenth-century suburbs: A time-geographic exploration. *Annals of the Association of American Geographers, 72*, 355–371.

Mills, E. S. (1970). Urban density functions. *Urban Studies, 7*, 5–20.

Muller, P. O. (1989). The transformation of bedroom suburbia into the outer city: An overview of metropolitan structural change since 1947. In B. M. Kelly (Ed.), *Suburbia reexamined* (pp. 39–44). Westport, CT: Greenwood Press.

Muller, P. O. (1981). *Contemporary suburban America*. Englewood Cliffs, NJ: Prentice-Hall.

Saxenian, A. (1994). *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.

Schaeffer, K. H., & Sclar, E. (1975). *Access for all: Transportation and urban growth*. Baltimore: Penguin Books.

Schwartz, J. (1976). The evolution of the suburbs. In P. Dolce (Ed.), *Suburbia: The American dream and dilemma* (pp. 1-36). Garden City, NY: Anchor Press/Doubleday.

Sommers, L. M. (1983). Cities of Western Europe. In S.D. Brunn & J.F. Williams (Eds.), *Cities of the world: World regional urban development* (pp. 84-121). New York: Harper & Row.

Stanback, T. M., Jr. (1991). *The new suburbanization: Challenge to the central city*. Boulder, CO: Westview Press.

Steiner, R. (1981). *Los Angeles: The centrifugal city*. Dubuque, IA: Kendall/Hunt.

Sternlieb, G. & Hughes, J. W. (Eds.)(1975), *Post-industrial America: Metropolitan decline and inter-regional job shifts* . New Brunswick, NJ: Rutgers University, Center for Urban Policy Research.

Tarr, J. A. (1984). The evolution of the urban infrastructure in the nineteenth and twentieth centuries. In R. Hanson (Ed.), *Perspectives on urban infrastructure* (pp. 4–66). Washington, DC: National Academy Press.

Taylor, G. R. (1970). *Satellite cities: A study of industrial suburbs*. New York: Arno Press. (Original work published 1915).

Tobin, G. A. (1976). Suburbanization and the development of motor transportation: Transportation technology and the suburbanization process. In B. Schwartz (Ed.), *The changing face of the suburbs* (pp. 95–111). Chicago: University of Chicago Press.

Vance, J. E., Jr. (1964). *Geography and urban evolution in the San Francisco Bay Area*. Berkeley: University of California, Berkeley, Institute of Governmental Studies.

Ward, D. (1995). *Cities and immigrants: A geography of change in nineteenth-century America*, 2nd ed. New York: Oxford University Press.

Warner, S. B., Jr. (1962). *Streetcar suburbs: The process of growth in Boston, 1870–1900*. Cambridge, MA: Harvard University Press and MIT Press.

Webber, M. M. (1976). The BART experience—what have we learned? *Public Interest*, (Fall), 79–108.

White, M. & White, L. (1962). *The intellectual versus the city: From Thomas Jefferson to Frank Lloyd Wright*. Cambridge, MA: Harvard University Press and MIT Press.

3 | THE URBAN TRANSPORTATION PLANNING PROCESS

ERIC I. PAS
Duke University

The title of this chapter implies that there exists a single, definitive urban transportation planning process, but this is not the case. Transportation planning in urban areas is conducted at different temporal and geographic scales by various organizations having diverse objectives and responsibilities. Furthermore, urban transportation planning is constantly evolving and has undergone considerable change during its lifetime of approximately 40 years. Nevertheless, there is a general understanding of what is meant by "the urban transportation planning process," and it is this process that is described here.

The traditional view of planning is that its purpose is to guide future decisions, that is, to develop a master plan to be used as a framework within which specific decisions can be made in a rational manner. This view of planning, often referred to as Bolan's (1967) "classical model," underlies the urban transportation planning process that developed during the 1950s and 1960s. This type of planning emphasizes long-range forecasts of the performance of regionwide systems, with the transportation plan being the backbone of the urban master plan.

By the end of the 1960s, societal changes began pushing the urban transportation planning process in new directions, and urban transportation planning began increasingly to be recognized as an activity that provides information to decision makers on the consequences of alternative courses of action. Planning can serve a number of other purposes as well, including (1) educating planners, decision makers, and the general public, (2) responding to regulations, and (3) supporting the image or position of the planning agency or important decision maker (deBettencourt, Mandell, Polain, Sauter, & Schofer, 1982).

The remainder of this chapter has five sections. The second section provides a brief historical review of urban transportation planning. This review shows how the process of urban transportation planning has been shaped by, and has responded to, broader societal changes. The third section provides an overview of the urban transportation planning process, which is viewed here as comprising three phases; namely, preanalysis, modeling and technical analysis, and postanalysis. Each of these phases is described in some detail in the middle sections of this chapter. The final section summarizes the chapter and concludes with a brief examination of the outlook for urban transportation planning.

This chapter describes the urban transportation planning process as it has evolved in the United States. Somewhat similar planning processes have developed and been applied in most of the Western industrial nations, although the processes and technical tools employed by planners vary somewhat across countries. These differences reflect, to some extent, variations in transportation policy formulation and decision making resulting from diverse political ideologies (Colcord, 1979).

HISTORICAL REVIEW OF URBAN TRANSPORTATION PLANNING IN THE UNITED STATES OF AMERICA

The Early Days

Prior to the mid-1940s, urban transportation was dominated by traffic engineers who were concerned with specific problems such as a congested bridge or intersection. In 1944, the Bureau of Public Roads conducted the first "origin destination" survey, which was the first attempt to collect data that would contribute to an understanding of observed traffic volumes. In earlier traffic-count studies no effort was made to understand the underlying traffic-generating process (Oi & Shuldiner, 1962).

The urban transportation planning process began developing in the United States in the early 1950s to address a problem that had existed in one form or another for many years, even centuries (Stopher & Meyburg, 1975). An important factor in the development of the analytical tools that formed the basis of early urban transportation planning studies was the emerging availability of digital computers capable of manipulating relatively large quantities of data. These computers, however limited by today's standards, allowed planners to examine urban travel patterns on a regionwide basis and encouraged efforts to develop mathematical equations describing these patterns.

A large number of other factors contributed to the development of the urban transportation planning process in the United States during the 1950s. They include (1) rapid population growth (particularly in urban areas), (2) rapid growth in car ownership, brought about by considerable growth in real income, (3) increasing movement of population to suburban areas, and (4) increasing federal involvement in funding urban development while requiring comprehensive urban planning.

Pioneering urban transportation studies that used the emerging analytical techniques were undertaken in San Juan, Detroit, and Chicago in the mid-1950s. The Detroit Study was the first to employ a process that included data collection and goal formulation, development of forecasting procedures, and testing and evaluation of alternatives. These studies were followed by a number of others in the late 1950s, including those in Washington, D.C., Baltimore, Pittsburgh, and Philadelphia. Each of these studies was a regionwide effort undertaken by a large full-time staff. Most employed the computerized procedures developed during the Chicago Area Transportation Study and had the objective of forecasting future trip-making patterns and producing a long-range, regionwide transportation plan. The emphasis in these studies was on planning a highway system that would cater to the expected large increases in automobile travel in urban areas.

The Institutionalization of Urban Transportation Planning

A major turning point in the development of the urban transportation planning process occurred with the passage of the 1963 Federal Aid Highway Act. This act required that urban areas employ a continuing, comprehensive, and cooperative transportation planning process (dubbed the 3C process) in order to qualify for federal matching funds for construction of urban transportation facilities. By referring to urban areas rather than to cities, the act ensured that transportation planning would take place at the metropolitan or regional level, rather than the city level. The act also allocated funds specifically for planning and research.

The Bureau of Public Roads soon began implementing the planning requirements of the legislation and issued memoranda pertaining to all aspects of the 3C planning process. Between 1963 and 1967, the Bureau published a large number of manuals dealing with the technical aspects of the planning process, and the procedures developed in the 1950s and early 1960s were thereby codified and institutionalized (and subsequently became the technical standards for the coming decade). Although this meant that forecasting tools became available to a larger community of planners, once a particular set of procedures became readily available and was institutionalized, there was great resistance to change. The early forecasting procedures were developed during ongoing studies by planners who needed practical tools that could be employed immediately, at a time when highway planning was the major concern, car ownership was increasing rapidly, and both natural and monetary resources seemed abundant. Thus, the technical procedures that became institutionalized as part of the urban transportation planning process were oriented almost exclusively toward analysis of long-term, capital-intensive expansions of the transportation system, primarily in the form of highways.

Adaptation to Change

The decade beginning in the early 1960s saw substantial changes in American society. The major new thrusts were the struggle for civil rights and increasing concern for the environment; both had important impacts on urban transportation planning. The civil rights movement highlighted the question of the distribution of the impacts brought about by transportation system changes and raised awareness concerning the transportation needs of the poor, the elderly, and the handicapped. The increasing concern for the environment during the 1960s culminated in the National Environmental Policy Act (NEPA) of 1969, which had direct effects on transportation planning and policy. (These effects are described in detail in Chapter 16 of this volume.)

In September 1975, the Federal Highway Administration (FHWA) and the Urban Mass Transportation Administration (UMTA) issued joint regulations to guide urban transportation planning (United States Department of Transportation, 1975). These new regulations may be seen, at least in part, as a response to the societal changes described above. A major change in the planning regulations required a transportation plan to contain both the traditional long-range element as well as a short-range transportation system management (TSM) element. In particular, the regulations published in 1975 specified that certain options be considered in the development of the TSM element. These options can be characterized as being low-capital-cost alternatives that can be implemented in a relatively short time frame and that aim to make better use of existing facilities, either by operational changes or by better management of travel demand. In addition, these options address concerns regarding energy, the environment, and the provision of transportation services for the elderly and handicapped. Options entailing operational changes include implementation of high-occupancy vehicle (HOV) lanes on freeways and arterials and bus priority schemes at signalized intersections. Options designed to manage the demand for travel include schemes for flexible and staggered work hours and automobile-free zones. The 1975 regulations also specified, for the first time, that urban transportation changes be programmed for implementation by requiring the formulation of a multiyear transportation improvement program (TIP) consistent with the transportation plan.

The 1975 regulations represent a major change in the philosophy of urban transportation planning. The regulations required planners to consider options that would either reduce the peak demand for travel or that would increase the person-carrying capacity (as opposed to vehicle-carrying capacity) of existing systems, rather than cater to the anticipated future demand for travel by increasing the supply of transportation services. The shift in emphasis away from highway systems and toward multimodal transportation systems is reflected by institutional name changes that occurred at that time. For example, the Highway Research Board became the Transportation Research Board, and the American Association of State Highway Officials became the American Association of State Highway and Transportation Officials, and State Highway Departments were generally renamed State Departments of Transportation.

Traditionally, urban transportation planning had been considered a technical process in which quantitative tools are used to perform objective analyses to arrive at objectively chosen solutions to technological problems. By the late 1960s, however, the political nature of urban transportation decisions began to be recognized together with the need to "open" the planning process to allow meaningful citizen participation (see Chapter 11 of this book). The roles of the technical team, the decision makers (usually elected officials), and the community required modification in this changed environment (Hansen & Lockwood, 1976). In the revised planning process, the planner works *with* the community, rather than planning *for* the community. The planner also provides information and ideas to the community and the decision makers, rather than making recommendations to the decision makers. Two major reviews of urban transportation planning studies, undertaken in Boston and Toronto during the mid-1970s, are prototypical examples of the "open" urban transportation planning process (Gakenheimer, 1976; Pill, 1978).

The considerable changes in urban transportation planning issues and concerns also had important implications for the methods used in the planning process to forecast travel on alternative transportation systems. First, the travel forecasting methods had to be able to deal with a much wider range of options, including so-called policy options (as opposed to physical facility options). Second, the forecasting tools had to be able to produce both long- and short-range forecasts. In particular, the short-range forecasting tools had to be able to produce results much more quickly and at much less cost than the traditional long-range forecasting tools. Third, the new planning process required forecasting methods that allowed the assessment of the impacts on specific groups of the population. Fortunately, during the late 1960s, transportation researchers had begun developing travel analysis tools that respond to these needs.

Federal Disengagement and the 1980s

Changes in the urban transportation planning process through the 1980s can be attributed primarily to the Reagan administration's desire to reduce federal involvement in what the administration considered local and state government responsibilities. The revised regulations issued jointly by FHWA and UMTA in June 1983 (United States Department of Transportation, 1983) mark another major turning point in the evolution of urban transportation planning in that they reduced, for the first time, federal requirements and responsibilities. In particular, although the federal government remained committed to an urban transportation planning process of the 3C variety, it no longer specified how that process was to be performed, and many of the elements were to be self-certified by local planning agencies (Weiner, 1992).

The latter half of the 1980s was a rather uneventful period in the history of urban transportation planning in that the *status quo* was generally maintained as far as the process itself was concerned. On the other hand, the continued entry of women into the labor force, decreases in average household size (with more households headed by a single parent or comprised of a single adult), and continued movement of jobs out of central city areas led to considerable increases in car ownership and vehicle-miles of travel through the decade, and travel patterns changed substantially. These changes placed increasing pressure on urban transportation facilities and services.

During the 1980s, suburb-to-suburb replaced suburb-to-city center as the predominant commuting pattern in the United States (Pisarski, 1987). The vast majority of such trips, from one low density area to another, are made in single-occupant automobiles on highways that are simply not designed to accommodate such high volumes of traffic. At the same time, the era of interstate highway construction was coming to an end, and capacity was not being expanded at a rate even close to the increase in traffic. As a result, suburban congestion became the focus of much attention. The irony of suburban congestion is that although the traffic is dense enough to cause congestion, the movement patterns are not spatially concentrated enough to support conventional forms of urban public transit.

As the final decade of the century approached, renewed concern about the environment, particularly air quality, surfaced around the world. In the United States, technological advances had led to large reductions in tailpipe emissions during the 1980s, resulting in large decreases in transportation-related emissions, in spite of a considerable increase in vehicle miles of travel (VMT). By 1988, however, 101 urban areas failed to meet national ambient air quality standards (NAAQS) for ozone, and 44 areas could not meet the carbon monoxide standards (United States Department of Transportation, 1990). In the United States, concern was also increasing about the decline in the quality of urban infrastructure, including transportation. This concern was heightened by the possibility that poor infrastructure might in part be responsible for a decline in the economy's productivity, hampering competitiveness of the United States in the global economy.

Renewed interest began to emerge in the application of technology to address transportation problems. In particular, the idea of employing new communication, information, and electronic technologies to develop a so-called "smart-car, smart-highway" system took hold. This initiative, which aims to develop advanced traffic control and information systems to reduce congestion, accident rates, and air pollution, is now known in the United States by the acronym ITS, or Intelligent Transportation System (previously known as IVHS, or Intelligent Vehicle Highway System). The Europeans and Japanese have also invested considerable resources in the development of this technology, and large-scale pilot projects are currently being deployed in a number of countries to assess the effectiveness of such systems. Real-time route guidance, in which motorists obtain routing advice from an on-board processor that is linked to a central computer, is one of the IVHS components currently under field testing.

At the same time, rapid advances in computer hardware and software were providing an environment in which new techniques could be developed. Geographic Information Systems (GIS) for managing, analyzing, and depicting large, complex, geographically coded data bases emerged as a potentially powerful new tool in transportation planning and analysis. (The uses of GIS in transportation planning are discussed in Chapter 10.)

As Weiner (1992) notes, many transportation organizations and agencies began strategic studies in the latter part of the 1980s, in part to redefine the surface transportation program and their mission in the post-interstate-highway era. These studies, which were long overdue, were conducted at a time when, as discussed above, many factors were emerging to mandate and facilitate a significant change in urban transportation planning.

The Dawning of a New Era in Urban Transportation Planning

When the history of urban transportation planning is examined in the future, the beginning of the 1990s will surely be seen as a watershed. The passage of the Clean Air Act Amendments (CAAA) in 1990 and the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, have clearly laid the foundation for a new era in urban transportation planning in the United States. It may well be that the CAAA, through the increased responsibility that is assigned to mobile source emissions for improving the air in the nation's cities and the related analysis and policy requirements, will be seen as the piece of legislation that really changed the face of urban transportation planning in the United States.

The CAAA addresses the attainment and maintenance of NAAQS, and nonattainment areas are classified in this act according to the severity of the air pollution problem in terms of ozone, carbon monoxide, and particulates. The act specifies controls to be implemented in each area that does not meet the NAAQS and further mandates transportation actions to be taken in nonattainment areas. These actions, which include conducting an emissions inventory and introducing transportation control measures (TCMs), are cumulative according to the degree of nonattainment. The TCMs referenced in the act include enhanced public transportation services, trip reduction ordinances, provision of HOV lanes, and congestion pricing.

The CAAA of 1977 introduced the idea that federally approved or financed projects had to conform to the State Implementation Plan (SIP), a document that, since 1971, has required states to describe how NAAQS are to be achieved and maintained. The conformity provisions of the 1990 CAAA are, however, considerably expanded, and new projects must conform to a SIP's "purpose of eliminating and reducing the severity and number of violations of the NAAQS and achieving expeditious attainment of the standards" (Weiner, 1992). In addition, the new act requires that conformity determinations be based more strongly on quantitative analyses.

The EPA recently issued guidance on the new conformity requirements, and it is too early to tell what the specific effects will be on transportation planning and analysis. It is clear, however, that these requirements will greatly affect urban transportation planning in the United States. As Weiner (1992) notes, the CAAA of 1990 have created a major challenge to transportation planners to continue to provide mobility while meeting requirements to improve air quality.

The ISTEA of 1991, the reauthorization of the surface transportation program, sets a new direction in transportation policy through the emphasis on intermodalism, the related provisions for flexible funding and local control over allocation of funds to the different modes, and its ties to the CAAA of 1990. The provisions of the ISTEA, in conjunction with the CAAA of 1990, have important implications for urban transportation planning and the analytical tools that support the planning process. Most importantly, the new direction in transportation policy is the use of transportation investment to achieve other societal objectives, including improved air quality, economic development, and equity (Meyer, 1992).

The ISTEA requires metropolitan areas to continue the practice of preparing a long-range plan that is updated periodically; but the development of such plans in nonattainment areas now must be coordinated with the development of TCMs for the SIP (Weiner, 1992). From the viewpoint of urban transportation planning, another important element of the ISTEA is that it requires (MPOs) to consider 15 interrelated factors in the development of the long-range plan, including the effect of transportation decisions on land use and the consistency of transportation plans and programs with land use plans. This requirement, coupled with the expanded conformity requirements of the CAAA of 1990, has added two important new Cs (conformity and consistency) to the three Cs of the traditional urban transportation planning process.

The ISTEA of 1991 designates all urbanized areas with more than 200,000 population as transportation management areas and requires that all such areas have their transportation planning process certified by the federal government at least every 3 years. In this respect (and in terms of the renewed emphasis on long-range, regionwide, and strategic planning), urban transportation planning in the 1990s has much in common with that of the 1950s and 1960s. On the other hand, the key objectives today are congestion management (through the use of travel demand reduction programs and operational strategies), improvements in air quality, economic development, and social equity, as opposed to the emphasis on system expansion that prevailed in the 1950s and 1960s.

Although the ISTEA provides for more flexibility and mandates a more open planning process, the CAAA require more precise (and hence technical) analyses. How the urban transportation planning process will develop in response to these mandates is yet to be seen. The concluding section of this chapter further examines this question and discusses emerging directions for urban transportation planning and analysis.

OVERVIEW OF THE URBAN TRANSPORTATION PLANNING PROCESS

As noted earlier, transportation planning is undertaken at many levels (from strategic planning to project-level planning) and at different geographic scales in any urban area. Furthermore, the regional studies that became synonymous with urban transportation planning in the 1950s and 1960s have undergone substantial changes over the years. Nevertheless, it is possible to identify a planning process and associated technical analyses that are commonly considered to be the urban transportation planning process. In this section, we provide a brief overview of this planning process. We do not present this as a recommended process for urban transportation planning nor do we suggest this as being the way in which urban transportation planning is always undertaken. Rather, we intend this to be a general framework within which our discussion of specific aspects can proceed.

The urban transportation planning process is viewed here as having three major, interrelated components, namely, the preanalysis phase, the technical analysis phase, and the postanalysis phase (Figure 3.1). A major reason for describing the process in this manner relates to the roles of the various actors (the technical team, the decision makers, and the citizens) at various stages of the process. The activities in the technical analysis phase are conducted almost exclusively by the technical team, whereas the decision makers and the citizens should be involved in the pre- and postanalysis phases.

The technical analysis phase of the urban transportation planning process is concerned with predicting the impacts of alternative courses of action. In this phase of the planning process, mathematical models (see Mathematical Models of Travel Behavior, below) are used to predict the transportation and related impacts (consequences) of alternative plans and policies. These impacts include capital and operating costs, energy usage, land requirements, air quality and noise levels, and accident rates, in addition to the quantity and quality (e.g., speed) of traffic flow on the transportation network.

The central component of the technical

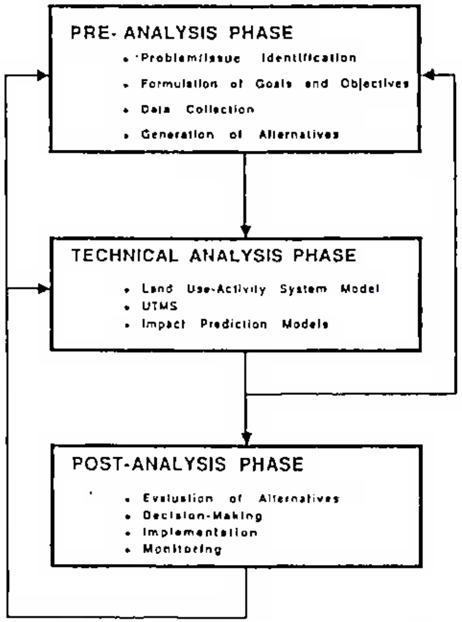


Figure 3.1. A general representation of the urban transportation planning process.

analysis phase is concerned with predicting the quantity and quality of traffic flow on each portion of a specified transportation network. The forecasting techniques used for this purpose are often referred to generically as the Urban Transportation Model System (UTMS). Important inputs to this model system are the distribution of employment, housing, and other activities in the urban area. These distributions are predicted by land use (or activity system) models. The output from the UTMS is the input for a set of impact models that are used to predict the range of impacts described above.

The activities in the preanalysis provide necessary inputs to the technical analysis phase. The preanalysis phase includes problem/issue identification and formulation, the development of study-area goals and objectives, the collection of data concerning the existing transportation and related systems as well as existing travel patterns, and the identification of the alternative solutions to be analyzed. That is, the preanalysis phase has two components. The first concerns defining the current situation and problems and specifying the desired characteristics of improvements. The second aspect of the preanalysis phase includes developing the data to be used in the technical analyses and formulating the alternative plans and policies to be tested.

The postanalysis phase is concerned with assessing the impacts of the alternative plans and policies, selecting the preferred alternative, implementing the preferred alternative, and monitoring the performance of the implemented plans. The monitoring activity emphasizes the continuing nature of the urban transportation planning process. Each of the phases of the urban transportation planning process is described in greater detail below.

THE PREANALYSIS PHASE

The preanalysis phase plays a vital role in the urban transportation planning process in a variety of ways, as discussed in the description below of each of the components of this phase. Manheim (1979) refers to this phase as "set-up."

Problem and Issue Identification

The objectives of this stage of the planning process are the identification and definition of the problems and issues to be addressed. Meyer and Miller (1984) stress the importance of including in this step the identification of opportunities as well as problems. The identified problems and issues should be defined as broadly as possible so as not to constrain the set of possible solutions.

No amount of sophisticated analysis and assessment can overcome problem definitions that are too narrow and that result in a very narrow set of possible solutions. For example, if the problem in a particular area is defined as being "limited highway capacity in corridors *X* and *Y*," all public-transit-oriented alternatives are ruled out of consideration. In addition, policies for reducing the peak-period highway traffic loads in corridors *X* and *Y* are also eliminated from consideration. In fact, the only alternatives consistent with the problem definition are ways of increasing the highway capacity. On the other hand, the problem definition would encourage a considerably broader set of possible solutions if it read "high traffic volumes, relative to highway capacity, during the peak periods, in corridors *X* and *Y*."

Formulation of Goals and Objectives

A second aspect of the preanalysis phase is the definition of the desired states toward which the planning process should guide the urban area. These broad general statements are termed "goals," and they are derived from consideration of the "values" of the society. Values are the basic desires and drives governing behavior (Wachs & Schofer, 1969). The goals are operationalized by a set of more specific "objectives" against which the performance of the alternative courses of action may be evaluated. The specific measures of objective attainment are termed "criteria" (or "measures of effectiveness"), and the minimum (or maximum) acceptable level of performance on a criterion is termed a "standard." The hierarchical relationship among values, goals, objectives, and criteria is illustrated by the example in Figure 3.2.

Values are observed, or they are assumed to be shared by groups of similar people. Thus it is possible to speak of societal or cultural values (Wachs & Schofer, 1969); although the diverse groups living in most urban areas do not necessarily share the same values, and they certainly have diverse goals. The planner

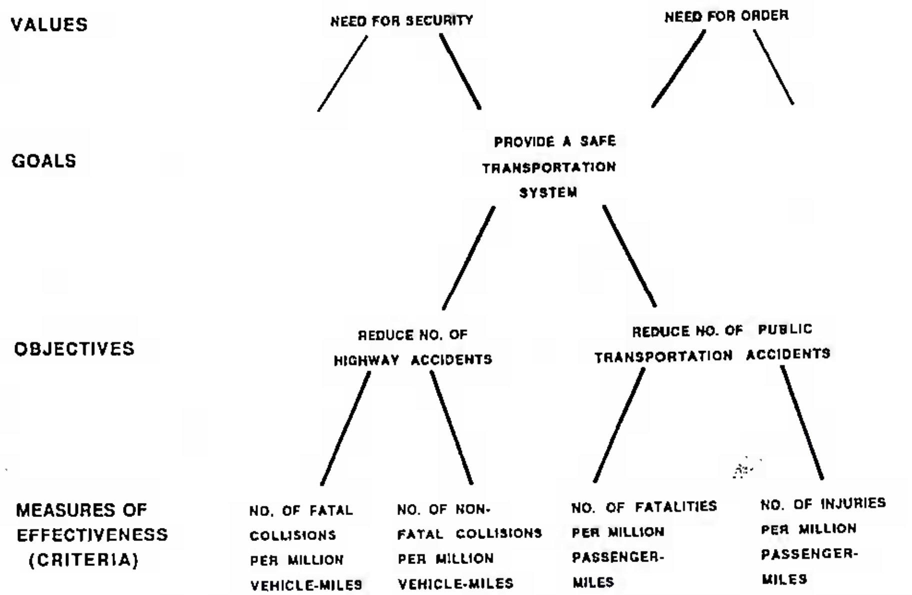


Figure 3.2. Hierarchical relationships among values, goals, objectives, and measures of effectiveness.

must be careful to recognize exactly whose goals are being employed to guide the planning process. Furthermore, Wachs and Schofer (1969) describe the difficulty of formulating goals and objectives in the absence of specific proposals. Although it is important to formulate representative goals and objectives to guide the planning process, doing so is a difficult task.

Data Collection

The urban transportation planning process and the UTMS generally require substantial quantities of data. In the 1950s and 1960s, a large percentage of the budget for urban transportation studies was spent on data collection and related activities, sometimes at the expense of other aspects of the planning process. Hillegass (1969) notes that early urban transportation planning studies typically spent approximately 30% of the study budget on data collection. In general, a conventional urban transportation planning study requires an inventory of the existing transportation system and land use patterns, a description of current travel patterns, and data on population growth, economic activity, employment, income, car ownership, housing, travel preferences, and other related factors.

The transportation system inventory gathers data concerning the existing transportation systems in the study area. For the highway system, these data include the physical attributes (e.g., number of lanes and grades), the quantity (volumes), and quality (travel speeds) of traffic flow on the transportation system. For the public transport system, the data include service area, route structure, passenger volumes, cost and revenue data, and system operation data. The transportation system inventory is compiled from maps, public transportation operator records, and field surveys.

The travel inventory data are obtained from household travel surveys, employment-based surveys, commercial vehicle surveys, on-board surveys, and roadside surveys. The most important of these is the household travel survey, which is used to collect travel and sociodemographic data from a sample of the residents of the study area. The early urban transportation studies used simple random samples of between 4% and 20% of the households in the study area, depending on the population of the area. More recent studies employ considerably smaller samples and use alternative sampling procedures.

A number of methods can be used to conduct the household travel survey, including the home interview survey, telephone survey, or mail survey. In a home interview survey, each sample household is visited by an interviewer who requests information about the household (such as number of people, number of cars, and so on) and the trips made by its members on the previous day. Mail and telephone surveys are generally cheaper to conduct than home interview surveys, although the latter yield higher response rates. Careful attention to survey administration details can improve the results obtained with the cheaper data collection methods, and they are increasingly being used in urban transportation planning studies (Stopher, 1983). Common approaches today include a combined telephone and mail-out, mail-back survey and the use of computer-assisted telephone interview (CATI) procedures.

A number of other methods are used to gather travel and/or traveler information. These include roadside origin–destination surveys and public transit on-board surveys. In a roadside origin-destination survey, interviewers intercept a sample of the vehicles crossing preselected points and briefly interview the occupants. In a public transit on-board survey, interviewers board a sample of vehicles and interview passengers on board the vehicle or ask passengers to complete and return a questionnaire. In both these methods, the population from which the sample is drawn is dependent on the particular mode of travel chosen, and such approaches are known as choice-based sampling (Lerman & Manski, 1979). The roadside origin-destination survey and the public transit on-board survey may be used to supplement the data gathered in a home interview survey. A commercial vehicle survey is also used to determine the current patterns of truck and taxi travel within the study area. Interviews are conducted with the owners or operators of a sample of commercial vehicles garaged in the study area. Employment-based surveys are becoming more common, especially with the interest in employer-based travel demand management (TDM) programs.

Generation of Alternatives

We have described the modern view of urban transportation planning as the provision of information to decision makers on the consequences of alternative courses of action. A crucial element in this activity is the identification and specification of the alternative plans and policies to be examined. Clearly, the quality of the information provided to decision makers is constrained by the set of alternatives analyzed, and therefore the latter should be as broad as possible and should facilitate identification of all the trade-offs necessary in making a decision.

Herald (1980, p. 26) examined the way in which urban transportation alternatives are generated and defined; he concluded that in both theory and practice the generation of alternatives is most commonly "a loosely structured creative trial-and-error method." Some structured techniques, including mathematical programming, have been proposed but have seen little application in practice.

THE TECHNICAL ANALYSIS PHASE

During this phase of the urban transportation planning process, mathematical descriptions of travel and related behavior are used to predict the consequences of each alternative transportation plan that is to be evaluated. This phase consists of three major components: the land use–activity system model, the urban transportation model system, and impact prediction (or resource consumption) models. Each of these components is described briefly below, after we introduce the general idea of mathematical models of travel and related behavior.

Mathematical Models of Travel Behavior

A general model of travel behavior may be represented as follows:

$$y = f(\mathbf{x}, \mathbf{b}) \qquad (1)$$

where y is the response (dependent) variable; $\mathbf{x}$ is a vector of explanatory (independent) variables; $\mathbf{b}$ is a vector of model parameters; and f is some function. For example, consider a model in which y is the number of daily trips made by a household. A typical model of this type is given by:

$$y = b_0 + b_1x_1 + b_2x_2 \qquad (2)$$

where y is the number of trips per household per day; x_1 and x_2 are the explanatory variables (such as household size and car ownership), and b_0, b_1, and b_2 are the model parameters (or coefficients).

An important question is "How are the parameters ($\mathbf{b}$) in a model such as equation 2 obtained?" Essentially, the parameters are obtained by collecting data on the response and explanatory variables (see Data Collection, above) and using one of a number of statistical procedures to *estimate* the parameters. This process is referred to as *model estimation* or *model calibration*. The two most commonly used estimation procedures are *least squares regression* and *maximum likelihood estimation*. Estimation procedures are simply mathematical–statistical tools, and the analyst is responsible for proper specification of the model. Model specification includes identifying those explanatory variables likely to be causally related to the response variable and identifying the functional form of the relationship.

Mathematical models of travel behavior are estimated using basically three levels of analysis: the person, household, and zonal levels of analysis. For example, the model of equation 2 is a household-level model. As noted in Chapter 1, a basic distinction is made between (1) models in which the response variable describes the behavior of a single household or person, and (2) models in which the response variable describes the (average or total) behavior of a geographic group of such households or people. We refer to the former as a *disaggregate model* and the latter as an *aggregate model*. In addition to theoretical distinctions between aggregate and disaggregate models, there are major differences in the types of data used.

A model estimated with a set of data collected at one time and place is generally used to predict travel in other times and/or places. Thus, data collected in City X at time t_1, may be used to estimate a model that is used to predict (1) travel in City X at another time, t_2, (2) travel in City Y at time t_1, or (3) travel in City Y at time t_2. In each case, we assume that the parameters estimated in the original estimation context provide useful information about travel behavior in the application environment. The question of model transfer from the estimation context to an application context received considerable research attention in the late 1970s and early 1980s (see, for example, Atherton & Ben-Akiva, 1976; Koppelman & Wilmot, 1982).

Land Use–Activity System Models

The spatial distribution of people, activities, and land use within an urban area (called the "land use–activity system") has an important impact on travel in the region. As noted in Chapter 1, travel is a derived demand that arises when people (or goods) are spatially separated from the locations at which they wish or need to be. In the short term, the land use–activity system can be considered fixed, but in the long run, it is itself affected by travel patterns and by changes in the transportation system. That is, the land use and transportation systems are interdependent, but this interdependence is only observable in the longer term because major changes in either system take considerable time. Because many other factors also change in the longer term, it is hard to separate out the relationships between the land use–activity system and transportation system. (Chapter 13 tackles this problem in detail.)

In practice, the planning and analysis of urban land use–activity and transportation systems are undertaken essentially separately in spite of the important interaction between these systems. The primary reason is that different agencies are generally responsible for land use and transportation planning. Thus, a land use forecast is generally used as an exogenous input to the traffic forecasting model, with the land use forecast itself predicated upon some assumed future transportation system. Consistency between the land use and transportation systems is, however, of major importance in the era of CAAA and ISTEA, and we can expect the development of integrated model systems in the next few years.

Land use–activity system models generally use regional population and employment projections as input, and they distribute these totals spatially over the region. Many techniques for predicting urban activity patterns have been developed and applied; however, in the past 10 years, the disaggregate residential allocation model (DRAM) and employment allocation (EMPAL) models have become the de facto standard in the United States. These models, which comprise the land use–activity system components of the Integrated Transportation Land-Use Package (ITLUP), developed by Putman (1993), are derived from a model originally proposed by Lowry (1968). At the heart of both the DRAM and EMPAL models is a travel impedance (or friction) function (see Trip distribution, below) that represents the effect of travel conditions on land development. The major weakness of the DRAM and EMPAL models is that they do not reflect the behavior of the housing and employment location markets through a pricing mechanism. An application of an alternative model, the EMPIRIC model, is described in Chapter 6.

The Urban Transportation Model System

The set of models that is commonly used to predict the flows on the links of a particular transportation network, as a function of the land use–activity system that generates travel, is generally known as the Urban Transportation Model System (UTMS) (see Figure 3.3). The UTMS that evolved during the early studies in Detroit and Chicago is often referred to as the four-step, sequential model because it comprises four submodels that are employed in a sequential process: trip generation, trip distribution, mode choice (or modal split), and trip assignment.

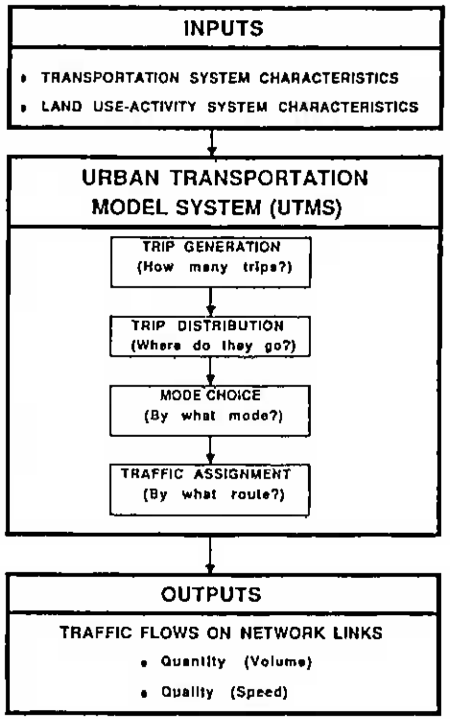


Figure 3.3. The Urban Transportation Model System (UTMS).

- *Trip generation* is concerned with predicting the number of trips produced by and attracted to each traffic analysis zone. That is, trip generation models address the question of how many trips are made to and from each zone of the study area.
- *Trip distribution* is concerned with predicting where the trips go. Thus, the trip distribution model links the origin and destination ends of the trips generated by the trip generation model.
- *Mode choice* (or modal split) addresses the question of how the various trips are made. That is, these models predict the proportion of trips by each mode of travel, between each origin and destination zone.
- *Trip assignment* (or route choice) is concerned with predicting the route(s) used by the trips from a given origin to a given destination by a particular mode.

The input to the UTMS comprises the characteristics of the transportation and land use–activity systems. In particular, UTMS requires estimates of the residential population and employment levels in each traffic analysis zone. These estimates are obtained from the land use–activity system models. Each of the submodels of the four-step traffic forecasting model is introduced below.

Trip Generation

Trip generation is the first submodel of the conventional four-step model sequence. This submodel is concerned with the total quantity of travel, whereas the other models allocate the total trips to alternative destinations, modes, and routes. Thus, trip generation is an extremely important part of the urban transportation model system.

Trip generation analysis is concerned with predicting the quantity of traffic that will flow to and from a given piece of land. That is, trip generation addresses the question of how many trips will be made to and from each zone within the study area. The basic idea is that the number of trips produced by or attracted to a given piece of land over some time period depends on the characteristics of that piece of land, including land use type and intensity and the socioeconomic characteristics of the activities using the land. The trip generation concept may be represented as follows:

$$t_i = f(L_i, I_i, S_i) \qquad (3)$$

where t_i is the number of trips generated by a given parcel of land (or zone), designated i; L_i is the type of land use; I_i is the intensity of land use; S_i is the socioeconomic description of the activities using the land; and f is some function.

Two basic approaches have been used to develop trip generation models: least squares regression and category (or cross-classification) analysis. These methods are similar, and each has been applied at the zonal, household, and individual levels of analysis. The fundamental difference is that least squares regression models are generally linear, whereas a category analysis model assumes no particular functional form for the relationship between the response and explanatory variables.

The majority of trips in an urban area are home-based trips; that is, they begin or end at the home of the person making the trip. Models of residential trip generation have therefore received considerable attention in the past, and they are described here. The earliest urban transportation studies employed least squares regression analysis at the zonal level to model residential trip generation. Each traffic analysis zone was treated as a single observation, although the data were collected from households (see Data Collection above). A *zonal-level* trip generation model attempts to explain the between-zone variations in trip making as a function of zonal characteristics; it ignores the within-zone (between-household) variations in trip making.

Most recent trip generation modeling efforts have been undertaken at the household level. When trip generation analysis is conducted at the household level, each household is treated as a separate observation, and the analysis attempts to explain the between-household variations in trip making as a function of household characteristics. A household-level least-squares regression trip generation model is given by

$$t = b_0 + b_1X_1 + b_2X_2 + \cdots + b_KX_K \qquad (4)$$

where t is the number of home-based trips per household per day; $X_1, X_2, \ldots, X_K$ are the explanatory variables (number of people in the household, household income, etc.), and $b_0, b_1, \ldots, b_K$ are the model parameters.

A household-level category analysis trip generation model is developed by classifying each household into one of a set of mutually exclusive classes, based on the explanatory variables used in the model. For example, we might have the following household categories: 0 cars, 1 person; 0 cars, 2 persons; 0 cars, 3 or more persons; and so on. The model consists of representing each category by the mean trip-making rate of the sample households in that category. Thus, we compute

$$\bar{t}_c = \frac{1}{N_c}\sum_{i=1}^{N_c} t_i \qquad (5)$$

where $\bar{t}_c$ is the mean trip-making rate in category c (for example, the average number of trips per household per day, for two-person, zero-car households); t_i is the measure of trip-making for household i of category c; and N_c is the number of households in category c. The appeal of the category analysis model is its intuitive simplicity. (Sample trip-generation models are presented in Chapters 5 and 8.)

Trip Distribution

A trip-distribution model links trip ends (that is, origins and destinations) and predicts how many of the trips originating in Zone i terminate in each of Zones 1, 2, . . . , J, and how many of the trips terminating in Zone j originate in each of Zones 1, 2, . . . , I. In other words, trip distribution is concerned with the question, "Where do the trips go?"

A variety of trip distribution models have been proposed. The discussion here focuses on the most commonly applied trip distribution model, the gravity model. The interaction (number of trips) from i to j(I_{ij}) is considered to be dependent on (1) the number of trips leaving i, (2) the attractiveness of j, and (3) the difficulty of traveling from i to j. This idea may be written in equation form as follows:

$$I_{ij} = f(O_i, A_j, d_{ij}) \qquad (6)$$

where I_{ij} is the interaction (number of trips) from i to j; O_i is the number of trips originating in zone i (the origin zone); A_j is a measure of the attractiveness of zone j(the destination zone); d_{ij} is the measure of the spatial separation of zones i and j; and f denotes some function.

Clearly, we expect I_{ij} to be directly proportional to O_i and A_j and inversely related to d_{ij}. The most commonly used form of the gravity model reflects these relationships, as shown by the following equation:

$$I_{ij} = O_i \frac{A_j f(d_{ij})}{\sum_k A_k f(d_{ik})} \qquad (7)$$

where $f(d_{ij})$ is known as a *friction factor* because it measures the resistance to travel caused by the spatial separation of zones i and j; and f is some decreasing function of d_{ij}, known as the *friction factor function*. The measure of spatial separation or the friction of distance (d_{ij}) is generally either travel time, travel cost, or a combination of time and cost. The calibration of a gravity model involves determining the friction factor function, as described in Chapters 5 and 6.

Mode Choice (or Modal Split)

Mode choice (or modal split) is concerned with predicting the number of trips, from each origin to each destination, that will use each mode of transportation. Thus, the objective of the modal split analysis is the prediction of t_{ijm}, the number of trips from i to j by mode m, given a prediction of I_{ij}. Clearly, modal split has considerable implications for transportation policy, particularly in large metropolitan areas. For example, the decision as to whether or not to invest in a new subway system depends on predictions obtained from the modal-split phase of the travel forecasting model. Similarly, the decision of whether to implement an exclusive HOV lane (for buses and/or car pools) should be informed by predictions of the number of people who will switch to high-occupancy vehicles.

Two basic model types have been used to predict the distribution of trips by mode of travel: modal split and mode choice models. The former term generally refers to aggregate models and the latter to disaggregate model forms. In general terms, the distribution of trips by mode is expected to be dependent upon the transportation system characteristics (*T*) and the characteristics of the users (*U*). That is, a modal split model may be expressed as follows:

$$p_{ijm} = f(\mathbf{T}_{ij}, \mathbf{U}_i) \qquad (8)$$

where p_{ijm} is the proportion of travelers from i to j that use mode m; $\mathbf{T}_{ij}$ is a description of the relative performance of the alternative modes of travel from i to j; $\mathbf{U}_i$ is a description of the characteristics of the travelers in zone i; and f is some function. The performance characteristics of the alternative modes ($\mathbf{T}_{ij}$)

include such variables as the relative speed of travel and the relative cost of travel between zones i and j. The users' characteristics ($\mathbf{U}_i$) include such variables as average car ownership

Mode choice models are concerned with the travel behavior of individuals. They attempt to predict the probability that individual n will use mode m (for a specific trip) as a function of the individual's characteristics and the attributes of the alternative modes for making that trip. These models may be represented mathematically as follows:

$$p_{mn} = f(\mathbf{X}_k, \mathbf{S}_n) \tag{9}$$

where p_{mn} is the probability that individual n will choose mode m for a specific trip; $\mathbf{X}_k$ is a description of the attributes of all modes (K) available for the specific trip (including mode m), $\mathbf{S}_n$ is a description of the characteristics of individual n, and f is some function.

The attributes of the alternative modes typically included in such models are the travel time and travel cost by each mode for the specific trip. The user's characteristics typically incorporated in such a model include the availability of an automobile and household income.

The most commonly used form for the mode choice model is termed a *multinomial logit model*. The general form of this model is given by

$$p_{mn} = \frac{e^{U(\mathbf{X}_m, \mathbf{S}_n)}}{\sum_{k=1}^{K} e^{U(\mathbf{X}_k, \mathbf{S}_n)}} \tag{10}$$

where $\mathbf{X}_m$ is a description of the attributes of mode m.

The function U in equation 10 represents the utility (or attractiveness) of mode m (with attributes $\mathbf{X}_m$) to individual n (with characteristics $\mathbf{S}_n$). Thus, the multinomial logit model essentially says that the probability that individual n chooses mode m for a particular trip is a function of the utility of mode m to individual n, relative to the utilities of the other modes available to individual n for this trip. (You will encounter further discussion of this type of model in Chapters 8 and 9.)

The development and application of individual choice models, such as the multinomial logit model, represents the major advance in travel demand modeling during the 1970s. Many of the applications of these choice models have been in the context of mode choice, primarily for the work trip. The use of disaggregate choice models in the context of mode choice modeling is accepted practice today. For a comprehensive text on the multinomial logit and related models (such as the nested logit model), see Ben-Akiva and Lerman (1985).

Trip Assignment (or Route Choice)

The final step in the conventional four-step model sequence is generally referred to as trip (or traffic) assignment (or route choice). The objective of this phase is to predict the number of trips from each origin i to each destination j by each mode m that uses each route from i to j by mode m. Thus, for example, if there are three different routes by automobile from origin i to destination j, the network assignment stage is concerned with predicting how many of the automobiles traveling from i to j will use each of the three routes. The assignment of traffic to the various routes between all origin–destination pairs results in an estimate of the quantity of traffic on each link (or piece) of a specified transportation network, because each route between a given origin–destination pair comprises a specific set of links. The link volume estimates, in turn, are used to predict the impacts of the particular transportation system alternative being tested.

The proportion of vehicles using each route between a particular origin–destination pair depends upon a number of attributes of the alternative routes, including travel time and distance, number of stops or traffic signals, aesthetic appeal, and perceived safety, but travel time is the attribute most commonly

considered in network assignment models. The travel time on any route is the sum of the travel times on the links that comprise that route, and the travel time on any link depends, in general, on the volume of traffic on that link. In particular, the travel time on any link of the highway network increases nonlinearly with the quantity of traffic using that link in some time period. Therefore, the assignment of traffic to the different routes between a given origin–destination pair depends upon the link travel times, which in turn depend on the link volumes. The volumes, however, are a function of the routes chosen. Furthermore, the traffic using any link in the network consists, in general, of traffic traveling from various origins to various destinations. Thus, the trip assignment problem is an extremely complex one.

Early trip assignment techniques were based on extreme simplifications of the problem. For example, in some early algorithms, link travel times were assumed to be independent of link volumes. Since the mid-1970s, considerable progress has been made in the development of sophisticated trip assignment techniques. A comprehensive text on assignment methods, including modern techniques employing mathematical programming formulations of the user-equilibrium and stochastic user-equilibrium problems, was published by Sheffi (1985). Current research efforts are focused on developing assignment algorithms that deal with the dynamics of traffic flow in networks, so as to be able to account for the build-up and dissipation of congestion and to model the response of drivers to advanced traffic information and pricing systems.

Impact Prediction Models

The UTMS predicts the quantity and quality (in terms of travel time) of flow on the links of a specified transportation network, given the land use–activity system as an input. Assessment of the consequences of alternative transportation system options, however, requires estimates of a broad range of impacts. These impacts include construction and operating costs, energy consumption, air quality, noise levels, and accident rates. In general, the models used to predict these impacts require as input the quantity and quality of traffic flow on the links of the transportation network. In addition, estimates are required of the energy, labor, land, and materials consumed in providing and operating a particular transportation system.

As described earlier, the CAAA of 1990 and the ISTEA of 1991 have changed urban transportation planning in a major way, with a renewed emphasis on the air quality implications of transportation system changes. Emissions from motor vehicles combine with emissions from other sources, and interact with meteorological conditions, to affect the air quality in our cities. The mixing and dispersion of pollutants is modeled using what is known as a dispersion model (Benson, 1979).

The emissions load produced by a motor vehicle depends on a number of factors, including vehicle characteristics (class, age, etc.), fuel parameters, vehicle operating environment (altitude, meteorological conditions), and vehicle operating conditions. Emissions rate models (California Air Resources Board, 1992; United States Environmental Protection Agency, 1988) relate emissions to vehicle operating conditions described in terms of standard driving cycles. Emissions produced in the standard test cycles are measured in the laboratory, and speed correction factors are used to estimate emissions at speeds different from the average speed in the test cycle.

We are now learning, however, that the existing emissions models tend to grossly underestimate emissions produced by motor vehicles that operate "off-cycle" (that is, outside the standard operating cycles). It is also becoming clear that in order to respond to the requirements set forth in recent legislation, we need to know much more about the emissions produced under actual driving conditions, as opposed to the standard test cycles. Much research is needed to develop improved emissions models, but such models will place additional burdens on the transportation models to predict travel at much finer temporal and spatial scales than the existing models are capable of doing.

The energy impacts of alternative transportation system options became a major concern in the 1970s, but over the past 10 to 15 years this concern has faded. The approach most commonly used to predict energy impacts is to estimate the change in the number of vehicle-miles of travel and multiply this change by a factor that reflects the average fuel consumption per vehicle-mile of travel. The latter is often disaggregated by vehicle type and model year. Both manual techniques and computer models are available for predicting the noise impacts of transportation systems (Bowlby, 1980; Bowlby, Higgins, & Reagan, 1982; Kugler, Commins, & Galloway, 1976). Some of these environmental impact models are described in Chapter 16.

THE POSTANALYSIS PHASE

The output of the technical analysis phase comprises predictions of the impacts of alternative plans and policies. The purpose of these predictions is to inform decision making. The postanalysis phase of the urban transportation planning process includes: evaluating the impacts of the alternatives analyzed; selecting the alternative to be implemented; programming, budgeting, and implementing the chosen alternative; and monitoring of system performance. Each of these aspects is addressed below.

Evaluation of Alternatives

The output from the technical analysis phase that we have just described answers the question, "What will happen if the transportation system is changed/expanded in this manner?" In particular, the travel forecasting model is used to predict the flow (quantity) and travel time (quality) on the various links of a set of specified transportation systems. The flows and travel times, in turn, may be used to predict other impacts, including the monetary and other resources (such as land and energy) consumed, noise levels, air quality levels, accident rates, and so on. Thus, for each alternative transportation system consisting of physical elements and operating policies, the technical analysis phase produces a set of predicted impacts. During the evaluation stage of the urban transportation planning process, the impacts of each alternative are summarized and compared.

Historically, evaluation included selection of the "best" alternative, which is a straightforward task only if all the impacts can be combined into a single numerical index for each alternative. Many early urban transportation studies reduced the positive and negative impacts (benefits and costs) to a common measurement scale (dollars) and thus derived a single numerical index that allowed for easy selection of the best alternative. This approach is commonly referred to as "economic evaluation." Two alternative approaches are "goal achievement" and "cost effectiveness." These three approaches are introduced briefly below.

Economic Evaluation

The overall benefit and cost of each alternative can be determined on the assumption that the benefits and costs of each alternative may be expressed in dollars. The time stream of costs and benefits is considered because of the time value of money. That is, because a dollar will be worth less next year than it is today, the costs and benefits in each year are discounted to obtain the *present value* of the costs and benefits of each alternative.

Two methods are commonly used to compare alternatives based on the present values of their costs and benefits: the net present value method and the benefit-cost ratio method. Wohl and Hendrickson (1984) note that if the latter method is applied properly, both methods lead to selection of the same alternative as best, in the economic sense.

Both the net present value and benefit–cost ratio methods require the analyst to select the discount rate for determining the present values of future costs and benefits. This is a very difficult task, and the choice of the discount rate has major implications for the results. The higher the discount rate, the less onerous are costs incurred well in the future. A higher discount rate therefore favors alternatives that have low capital costs and high operating costs relative to alternatives that incur substantial capital costs early in the analysis period and have low operating costs, and vice versa. The choice of the discount rate therefore can have a major influence on the conclusions drawn from an economic analysis.

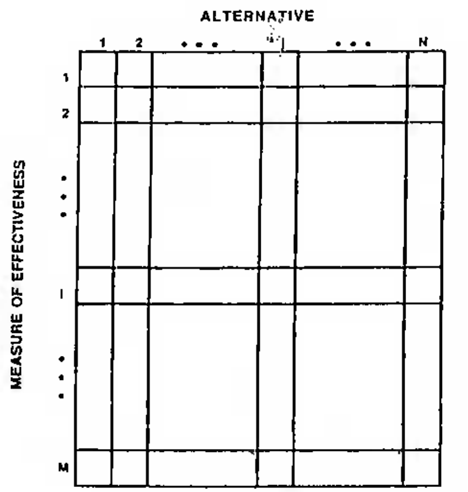
The internal rate of return method, on the other hand, does not require prior selection of the discount rate. Rather, an iterative procedure is used to determine the rate of return for each project for which the present value of benefits equals the present value of the costs. That is, the method determines the rate of return yielded by each alternative. The problem with this method is that more than one rate of return might be consistent with a given time stream of costs and benefits (Wohl & Hendrickson, 1984).

A major problem associated with all economic-based evaluation methods is the requirement that all costs and benefits be expressed in monetary terms. Many of the costs and benefits associated with a transportation system change cannot be expressed satisfactorily in monetary terms. For example, what is the monetary value of one fewer fatality per year or a reduction in average noise levels of 10 decibels? As a result of such difficulties, many early urban transportation studies simply ignored these impacts in evaluating the alternatives. The analyses generally included only the capital and operating costs of each alternative as well as the user benefits, which are generally measured in the form of reduced travel time. Travel time reductions were converted to dollar terms using an assumed or inferred value of time.

The minimal attention given in many early studies to environmental and social impacts is an important consideration in understanding the so-called freeway revolt that began in San Francisco in the 1960s. Basically, citizens were telling transportation planners that factors other than user travel time and capital and operating costs were important community concerns. Below, we introduce alternatives to economic evaluation.

Noneconomic Evaluation

The common feature of noneconomic-based evaluation procedures is that the impacts may be expressed in any units. Furthermore, the impact measures are explicitly related to the goals and objectives of the community. Thus, each alternative is described by a ma-



The value in cell i,j represents the performance on measure of effectiveness i of alternative j (e.g., number of days per year that air quality standards would be violated if the freeway expansion were implemented)

Figure 3.4. An impact matrix.

trix similar to that depicted in Figure 3.4. The methods differ primarily in whether or not the impacts of each alternative are combined to produce a single numerical index.

The goal-achievement method (Steger & Stuart, 1976) uses the information contained in the impact matrix (Figure 3.4) to derive a single numerical index for each alternative, where the index is a measure of the degree to which an alternative achieves the goals formulated for the study area. Each objective is assigned a weight representing its perceived relative importance. Each alternative is scored according to how well it meets each objective relative to the performance of the best alternative on each objective. A single numerical index is obtained for each alternative by summing of the weighted scores on each objective. Choosing one alternative out of the set is a relatively simple task once the alternatives are ranked according to their scores on the single numerical index that describes how well each alternative meets the various objectives. The obvious difficulty introduced by such a method is the subjective nature of the weighting scheme. Wachs and Schofer (1969) note that the assignment of weights to the various objectives is equivalent to the assignment of dollar values to the various nonmonetary impacts of a change in the transportation system.

Cost effectiveness (Thomas & Schofer, 1970) is an approach in which the analyst organizes information concerning the impacts of the alternatives and provides this information to the decision maker(s) and the community. The planner does not attempt to reduce all the information in the impact matrix to a single numerical index; rather, the decision makers must make the trade-offs necessary to reach a decision. The performance of each alternative on each measure of effectiveness may be compared with the cost of the alternative by means of a cost-effectiveness ratio. This is an index of the degree of objective attainment per dollar, for each measure of effectiveness. The cost effectiveness approach recognizes that urban transportation planning is a political decision-making process, and it implies a particular viewpoint concerning the role of the technical team in urban transportation planning (see Adaptation to Change, above).

The major advantage of the cost–effectiveness approach is that those individuals accountable to the public are responsible for making the trade-offs necessary in selecting a preferred alternative. Furthermore, if the performance of each alternative on each measure of effectiveness is specified according to socioeconomic groups, the decision makers can see who gains and who loses from the change. Of course, it is difficult to integrate such information and make a decision, but many consider this to be the proper responsibility of elected public officials. The planner, however, is responsible for presenting the information in a manner that facilitates decision making, particularly because the predicted impacts are only a part of the information provided to decision makers.

Decision Making

As noted earlier, decision making historically was essentially integrated with evaluation, in the sense that by scoring each alternative on a single numerical index (such as a benefit–cost ratio) selecting the "best" alternative is made simple. On the other hand, in the absence of a single numerical measure of the performance of each alterative, decision making is an extremely complex task appropriately performed by elected officials.

A number of models of decision making may be identified, ranging from the rational-comprehensive model to a political bargaining model (Meyer & Miller, 1984). It is unclear which model is actually employed in urban transportation decision making in the public sector, but given the social and economic implications of urban transportation decisions, the importance of political bargaining in urban transportation decision making should not be underestimated. In other words, the urban transportation planner must be aware of political realities if he or she is to have an impact on the decision-making process. These issues are taken up in Chapter 11.

Implementation

Implementation of the selected transportation plan includes two considerations. First, *implementation* requires compliance with the regulations and requirements of the appropriate institutions, such as the preparation of the environmental impact statement. Second, implementation requires consideration of the time when various actions will be taken and ways by which they will be financed. This is generally termed *programming*. As noted earlier, preparing for action (planning) and taking action (implementation, specifically programming) were first integrated into the urban transportation planning process by the joint FHWA and UMTA regulations of 1975 that specified that the transportation plan should include a transportation improvement program (TIP).

The major question to be addressed at the implementation stage is the programming of the transportation system changes. Programming has been defined as "the matching of available projects with available funds to accomplish the goals of a given period" (Transportation Research Board, 1978, p.3). A common goal is to use available resources as efficiently as possible; thus, the consideration of the time staging of urban transportation changes is very important. This aspect has received little attention in the past, however, and quantitative techniques are not much used.

System Monitoring

The evaluation stage described above deals with preimplementation evaluation; that is, the assessment of the performance of alternative transportation systems based on predictions. In one sense, system monitoring may be considered to be postimplementation evaluation, that is, the assessment of the performance of the transportation system as the programmed changes are implemented. System monitoring therefore, is the ongoing collection of data to be used in tracking the performance of the urban transportation system over time. Because such monitoring facilitates the identification of problems and opportunities, this stage emphasizes the continuing nature of the urban transportation planning process.

SUMMARY AND OUTLOOK

This chapter introduces the urban transportation planning process. In particular, the discussion focuses on the evolution of this process and on an introduction to the quantitative tools that support the planning process. We have noted how the planning process and the modeling and analysis tools have been shaped by changes in societal concerns. Although urban transportation planning has undergone many changes during the past 40 years and continues to evolve, many of the basic notions developed during the 1950s have endured.

The roles of technical analysis and model building in the urban transportation planning process have been highlighted here in order to place the chapters that follow in perspective. Technical analysis is only one component of the planning process, however, and analysis is not an end in itself. We have distinguished the analysis phase from the other elements of the planning process by pointing to the technical nature of the analysis phase. It is important, however, to note that even mathematical models of travel and related behavior implicitly employ subjective judgments and reflect particular perspectives on human behavior. For example, the disaggregate mode choice models developed during the 1970s emphasize the choice aspects of travel behavior, whereas the activity-based approach to travel analysis (see discussion below) emphasizes the constraints that influence urban travelers.

One might well ask whether urban transportation planning has been effective. Hassell (1980) addressed this question 15 years ago and concluded that there was little doubt about the effectiveness of urban transportation planning. The question cannot really be answered, however, without knowing what would have happened to urban land use activity and transportation systems in the absence of urban transportation planning studies. Would the same decisions have been made, or would the decisions have been better or worse? What is probably more important, however, is addressing the question, "How can the urban transportation planning process be effective in the future?"

It is, of course, hard to prescribe how the urban transportation planning process should be shaped to be effective in the future; particularly since, as described earlier in this chapter, the CAAA of 1990 and the ISTEA of 1991, have greatly altered the urban transportation planning and policy analysis landscape in the United States. Federal, state, and local government agencies are still grappling with the implications of the recent legislation, final rule making on certain aspects of the legislation was only recently published, and new research and development programs are still being developed in response to the mandates (and opportunities) presented in the recent legislation.

Continuing sociodemographic trends create additional challenges for urban transportation planners. These trends include the aging of the population, the continued entry of women into the work place, the increase in the number of single-adult households, and the reduction in average household size. Urban transportation planners are also being challenged to provide the "glue" that binds planning together as transportation investment is being used to achieve other societal objectives, including improved air quality, economic development, and equity (Meyer, 1992).

At the same time, the development and deployment of new information, communication, and computer technologies provide both challenges and opportunities for urban transportation planners. The challenges arise through the wider range of options that individuals will have for satisfying their wants and needs in the future, as well as through the wider variety of operating and management technologies that will need to be evaluated by transportation planners. The introduction of advanced traveler information systems will also, however, provide rich, new data bases describing travel patterns and behavior, while further advances in computer technology will allow us to develop and implement vastly more sophisticated transportation planning models than we could have conceived of only a short time ago.

Howe and Brail (1994) have examined the implications for urban transportation planning of the requirements and opportunities embedded in the ISTEA of 1991. They point out that the legislation redefines the set of problems to be addressed (with new emphasis on connectivity, choice, air quality, and cost efficiency) and the range of acceptable solutions (with priority being given to system management, rather than to construction of new capacity, and with emphasis on measures to manage travel demand, rather than on ways to increase travel supply). They suggest a new conceptual model of transportation planning to meet these needs, a framework they refer to as interactive transportation planning and decision support (ITPDS).

Howe and Brail (1994) argue that their proposed framework has a number of important characteristics that specifically respond to the needs of urban transportation planning in the 1990s. They note that ITPDS "flattens" the power relationships among the major players, facilitates bringing together a working group of people having a range of interests and perspectives (a characteristic they call "cross-functional"), operates in a data-rich environment, deals with a process that is "messy" (dynamic, nonlinear, evolving, iterative, flexible, complex, ad hoc, etc.), and facilitates a process that is customer oriented (where the customers are involved in the planning process and the transportation system is shaped by customer demands). They

also suggest that implementation of ITPDS would be enhanced by incorporating an interactive and accessible geographic information system (GIS).

The emerging planning framework is more dependent upon information that is derived from the technical analysis of data than transportation planning has been historically (Howe & Brail, 1994). Many of the limitations of the UTMS, described earlier in this chapter, have been recognized for a long time now. However, these shortcomings have been highlighted, and new ones have emerged, by the requirements of the current planning and policy-making environment.

Most importantly, the travel forecasting models used today were developed many years ago, primarily to evaluate alternative highway expansion projects. Pas (1990) argues that the existing model system is fundamentally no different from that introduced nearly 40 years ago. These models were certainly not intended to evaluate the effects of policies such as congestion pricing, transportation control measures, and alternative development patterns; it is not surprising, therefore, that the models are not well suited to these tasks. It is also worth noting that the need to upgrade the travel forecasting tools available to MPOs was brought to the fore by a law suit, filed by the Sierra Club Legal Defence Fund and Californians for a Better Environment, against the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area and the State of California. The irony of this landmark law suit, which was concerned with forecasting the air quality impacts of proposed freeway expansion, is that the MTC maintains one of the best travel forecasting model systems in the country.

A primary deficiency of the UTMS, especially in the contemporary context, is that it does not incorporate the time of day at which travel takes place. Thus, it cannot suitably be used to examine the effectiveness of policies in which the price of travel varies with the level of congestion and hence with the time of day (congestion pricing), nor can it be used to analyze the effects of providing travelers with pretrip information about the level of congestion in the transportation network (information that might cause travelers to change their departure time for a trip). Other important shortcomings of the conventional, four-step travel forecasting model are that trips are treated as if they are independent of one another, and trip generation is modeled independently of congestion or pricing. Further, the models are static and are based on cross-sectional data (that is, data collected at one point in time). Such models use variations in behavior across the sample as if they reflect the change in the behavior of each behavioral unit following a change in an influencing factor. Such extrapolation of cross-sectional differences is valid only under very restrictive assumptions (Goodwin, Kitamura, & Meurs, 1990).

The Federal Highway Administration, in cooperation with the Federal Transit Administration, the Office of the Secretary of the U.S. Department of Transportation, the U.S. Environmental Protection Agency, and the U.S. Department of Energy, has launched a Travel Model Improvement Program (U.S. Department of Transportation, 1993). The purpose of this major program is to remedy the deficiencies in currently available travel forecasting models by enhancing these models in the short term while developing completely new procedures in the medium to long term. Because of the joint sponsorship, we are likely to see more comprehensive and integrated model systems result from this effort and the application of substantially new perspectives.

One of the teams involved in an early effort of the TMIP to redesign the travel forecasting model proposed a new, comprehensive and integrated model system for land use activity and transportation system planning, based on multiple paradigm shifts from the status quo (Kitamura, et al., in press). The proposed model system includes a land use activity system model, a sociodemographic model, a vehicle transactions model, an activity-based mobility model, a dynamic network assignment model, and an air quality model. The activity-based approach places trips appropriately within the context of the activities that generate the demand for travel, emphasizes the interdependencies among trips made by an individual over the course of a day, and on different days, and also emphasizes the interdependencies among trips made by members of a household (Jones, Dix, Clarke, & Heggie, 1983). (See Axhausen and Garling, 1992, and Kitamura, 1988, for reviews of the activity-based approach; also see the discussion of travel–activity patterns in Chapter 8 of this volume). In addition to replacing the trip-based approach by the activity-based approach, this team proposed the use of stochastic, microsimulation in place of deterministic, aggregate extrapolation and the use of dynamic, longitudinal analysis and models in place of models based on cross-sectional data and analyses. In addition, the use of a GIS platform was recommended for most of the models in the proposed system.

It is clear that the travel forecasting models in use by the turn of the century will be considerably more behaviorally based than are those of today. They will take advantage of advances in computer technology and will be designed to provide the breadth and depth of information required by the new policy and planning environment. The urban transportation planning process will also no doubt continue to evolve and adapt in the future, as it has in the past, in response to changing planning and policy issues and societal values. In the immediate future, at the very least, the urban transportation planning process will need to be both more open and at the same time to incorporate more precise analyses in order to meet the mandates of both ISTEA and CAAA.

References

Atherton, T., & Ben-Akiva, M. E. (1976). Transferability and updating of disaggregate travel demand models. *Transportation Research Record, 610*, 12–18.

Axhausen, K., & Garling, T. (1992). Activity-based approaches to travel analysis: Conceptual frameworks, models, and research problems, *Transport Reviews, 12*, 323–341.

Ben-Akiva, M. E., & Lerman, S. R. (1985). *Discrete choice analysis: Theory and application to predict travel demand*. Cambridge: MIT Press.

Benson, P. E. (1979). *CALINE 3—A versatile dispersion model for predicting air pollutant levels near highways and arterial streets*. Sacramento: California Department of Transportation.

Bolan, R. S. (1967). Emerging views of planning. *Journal of American Institute of Planners, 33*, 233–246.

Bowlby, W. (1980). *SNAP 1.1: A revised program and user's manual for the FHWA level 1 highway traffic noise prediction computer program*. Washington, DC: Federal Highway Administration, U.S. Department of Transportation.

Bowlby, W., Higgins, J., & Reagan, J. (1982). *Noise barrier cost reduction procedure STAMINA 2.0/OPTIMA: User's manual*. Washington, DC: Federal Highway Administration, U.S. Department of Transportation.

California Air Resources Board. (1992). *Methodology to calculate emissions factors for on-road motor vehicles*, Sacramento: Author.

Colcord, F. (1979). Urban transportation and political ideology: Sweden and the United States. In A. Altshuler (Ed.), *Current issues in transportation policy*. Lexington, MA: Lexington Books, 3–15.

deBettencourt, J. S., Mandell, M. G., Polzin, S. E., Sauter, V. L., & Schofer, J. L. (1982). Making planning more responsive to its users: The concept of metaplanning. *Environment and Planning A, 14*, 311–322.

Gakenheimer, R. (1976). *Transportation planning as response to controversy: The Boston case*. Cambridge: MIT Press.

Goodwin, P., Kitamura, R., & Meurs, H. (1990). Some principles of dynamic analysis of travel behavior. In P. Jones (Ed.), *New developments in dynamic and activity-based approaches to travel analysis* (pp. 56–72). Aldershot, England: Avebury.

Hansen, W. G., & Lockwood, S. C. (1976). Metropolitan transportation process reform. *Transportation Research Record, 582*, 1–13.

Hassell, J. S. (1980). How effective has urban transportation planning been? *Traffic Quarterly, 34*, 5–20.

Herald, W. S. (1980). Generating alternatives for alternatives analysis. *Transportation Research Record, 751*, 17–27.

Hillegass, T. (1969). Urban transportation planning: A question of emphasis. *Traffic Engineering*, June, 46–48.

Howe, L. U., & Brail, R. D. (1994). Intermodal Surface Transportation Efficiency Act and Interactive Transportation Planning and Decision Support: A new conceptual model for interactive transportation planning and decision support. *Transportation Research Record*.

Jones, P., Dix, M., Clarke, M., & Heggie, I. (1983). *Understanding travel behaviour*. Aldershot, England: Gower.

Kitamura, R. (1988). An evaluation of activity-based travel analysis, *Transportation, 15*(1/2), 9–34.

Kitamura, R., Pas, E. I., Lula, C. V., Lawton, T. K. and Benson, P. E. (1994). The sequenced activity mobility simulator (SAMS): An integrated approach to modeling transportation, land-use, and air quality. *Transportation*.

Koppelman, F. S., & Wilmot, C. G. (1982). *Identification of conditions for effective transferability of disaggregate choice models. Report No. UMTA-429-1*. Evanston, IL: Transportation Center, Northwestern University.

Kugler, B. A., Commins, D. E., & Galloway, W. J. (1976). *Highway noise: A design for prediction and control. National Cooperative Highway Research Program Report, 174*. Washington, DC: Transportation Research Board.

Lerman, S., & Manski, C. (1979). Sample design for discrete choice analysis of travel behavior: The state-of-the-art. *Transportation Research A, 13*, 29–44.

Lowry, I. S. (1968). Seven models of urban development: A structural comparison, *Highway Research Board Special Report, 97*, 151–174.

Manheim, M. L. (1979). *Fundamentals of transportation system analysis*. Cambridge: MIT Press.

Meyer, M. D. (1992). Planning: The challenge of being the glue. *Transportation Research Board Special Report, 237*, 91–113.

Meyer, M. D., & Miller, E. J. (1984). *Urban transportation planning: A decision-oriented approach*. New York: McGraw-Hill.

Oi, W. Y., & Shuldiner, P. W. (1962). *An analysis of urban travel demands*. Evanston, IL: Northwestern University Press.

Pas, E. I., (1985). State-of-the-art and research opportunities in travel demand: Another perspective. *Transportation Research A, 19A*, 460–464.

Pas, E. (1990). Is travel demand analysis and modelling in the doldrums? In P. Jones (Ed.), *New developments in dynamic and activity-based approaches to travel analysis* (pp 3–27). Aldershot, England: Avebury.

Pill, J. (1978). *Planning and politics: The metro Toronto transportation plan review*. Cambridge. MIT Press.

Pisarski, A. (1987). *Commuting in America*. Westport, CT: Eno Foundation for Transportation.

Putman, S. H. (1993). *Integrated urban models: Policy analysis of transportation and land use*. London: Pion.

Sheffi, Y. (1985). *Urban transportation networks: Equilibrium analysis with mathematical programming methods*. Englewood Cliffs, NJ: Prentice-Hall.

Steger, C., & Stuart, R. C. (1976). Goals achievement as an integrating device for technical and citizens input into urban freeway location and design. *Man Environment Systems, 6*, 137–150.

Stopher, P. R. (1983). Data needs and data collection—State of the practice. In *Travel analysis methods for the 1980s. Special Report 201*, Washington, DC: Transportation Research Board.

Stopher, P. R., & Meyburg, A. H. (1975). *Urban transportation modeling and planning*. Lexington, MA: Lexington Books.

Thomas, E. N., & Schofer, J. L. (1970). *Strategies for the evaluation of alternative transportation plans. National Cooperative Highway Research Program Report, 91*. Washington, DC: Highway Research Board.

Transportation Research Board. (1978). *National Cooperative Highway Research Program Synthesis of Highway Practice, 48*. Washington, DC: Author.

U.S. Department of Transportation. (1993). *Travel model improvement program*. Washington, DC: Author (in cooperation with the Environmental Protection Agency and the Department of Energy).

U.S. Department of Transportation. (1983). Federal Highway Administration and Urban Mass Transportation Administration, urban transportation planning. *Federal Register, 48*(127), 30332–30343.

U.S. Department of Transportation. (1990). *National transportation strategic planning study*. Washington, DC: Author.

U.S. Department of Transportation. (1975). Federal Highway Administration. Guidelines for urban transportation planning, *Federal Register, 40*(181), 42976–42984.

U.S. Environmental Protection Agency. (1988). *User's guide to MOBILE4 (Mobile source emission factor model)*. Ann Arbor, MI: Office of Mobile Sources, U. S. Environmental Protection Agency.

Wachs, M., & Schofer, J. L. (1969). Abstract values and concrete highways. *Traffic Quarterly*, January, 133–145.

Weiner, E. (1992). *Urban transportation planning in the United States: An historical overview*, revised edition, Washington, DC: U.S. Department of Transportation.

Wohl, M., & Hendrickson, C. (1984). *Transportation investment pricing principles: An introduction for engineers, planners and economists*. New York: John Wiley & Sons.