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Travel Behavior Models: State of the Practice

ROBERT E. PAASWELL and RICHARD M. MICHAELS, University of Illinois at Chicago

Transportation planning as a discipline must undergo significant changes to keep pace with the changes in our transportation systems. Strategic planning as envisioned in the 1960s is no longer practical or presumed to be needed. There is an obsession with project-level planning, caused both by a lack of resources and an emphasis on the measurement of costs and benefits of each decision mode and by an inability to understand or cope with long-term needs.

But is is precisely because we are undergoing rapid change--in population composition, economic structure, and geographical distribution, which simultaneously changes how we live, work, and play--that we need to develop procedures that will improve our abilities to conduct strategic planning.

At the same time, as we make those investment decisions that lay the groundwork for long-term change, we must be sure that we have all of the pertinent information to evaluate those investments.

The state of the practice of behavioral models at both short-term and long-term levels of planning is dealt with here. The need for a greater integration of the models with practice will be discussed and it will be shown which specific behavioral techniques can be used now.

Planning is approached in a hierarchical sense. After discussing the needs of strategic planning and short-term planning, we discuss social and economic change and then the influences on our thinking about planning. We raise specific questions linking planning and modeling that should be addressed by this workshop. Finally, we conclude with examples of behavioral modeling used in practice.

TRANSPORTATION PLANNING AND BEHAVIORAL ANALYSIS

The use of many behavioral techniques in transportation planning, analysis, and evaluation has been limited. Other than in travel behavior research, which has been extensive over the past decade, the applications of behavioral science methodology have not found their way into general practice. The only major exception has been in the application of dis-

aggregate mode-choice models based on utility theory and in evaluation studies of transportation systems, both internal and external. Both areas have had significant influence on transportation planning and policy but in a largely derivative rather than in a direct way. To be specific, service, design, or operational changes in transportation have been evaluated by using behavioral measurements. There are few cases, however, in which behavioral science methods were employed to define such service, design, or operational changes.

There are major reasons for the limited diffusion of behavioral theory and methods into transportation planning and policy. First, transportation analysis as we now know it is a relatively closed subspecialty of civil engineering. It developed with a focused concern on facility (highway and bridge) construction. Planning did not emerge until the 1930s and it grew as an adjunct of construction programming. At this time, travel was seen as an aggregate process in order to set capacity requirements, to define design criteria such as lane width, or to improve operating performance such as by signing or lane delineation. The same frame of reference was adopted in planning, i.e., aggregate, descriptive, and retrospective models. The object of the process was to set construction investment priorities. Thus, a milieu developed in which quantitative and directly observable criterion functions were made the acceptable measure for decisionmaking.

Another reason that behavioral science theory and methods do not lead directly to design or investment decisions is in part the nature of the methodology and in part the fact that transportation engineering has been concerned with marginal improvements in outmoded technologies, e.g., highway or rail transport. The relevant behavioral science theory is essential in defining the attributes required of mobility technology to satisfy essential social needs. For planners and engineers whose lives are bounded by capacity, pavements, edge marking, and bus headways, abstract mobility considerations are not particularly useful.

It seems clear that so long as transportation is concerned with the readily described technology rather than with the choices that prescribe the technology, behavioral techniques will be disregarded. The methods themselves are not particularly useful for the narrow objectives of the current practice of transport planning and engineering. Occasionally they will be found as an evaluative tool, as will be exemplified below. But in general those methods will not be, as they have not been, used as integral planning and policy tools within the current social organization of the transportation profession.

When we begin to discuss in detail the application of behavioral techniques to transportation problems, it is necessary to look first at the work of Oi and Shuldiner (1). In the 1960s, they made one of the most significant contributions to transportation planning analysis methodology when they identified the household as the unit of analysis. They paved the way for such techniques as segmentation when they specified that variables such as household income had strong explanatory powers for trip generation. Their analysis was carried out by using straightforward multiple-regression techniques.

In 1982, we have reached a point where it is possible to identify the strides made in application of behavioral techniques since the 1960s. In the intervening two decades, the focus on transportation problems has shifted from macroscale and strategic to small-scale and immediate. In addition there has been a negative reaction to the use of complex models in practice and a concurrent scaling down of planning and analysis budgets per problem with which to generate plans necessary for today's transportation improvement plan (TIP), transportation system management (TSM), or alternatives analysis.

It is important that this conference and this workshop address the following questions:

1. What are the current transportation problems, categorical and general, to which behavioral techniques can and should be applied?
2. What are the ways in which such techniques can be applied and which technology transfer problems can we anticipate?
3. What is the value of the information gained by such techniques or, quite bluntly, do those who need the information find it cost-effective to apply to the problems identified in the first question above?

As we examine the shift from tactical to strategic transportation planning, we note that there must be a concurrent shift in the analytic and modeling process. At present we simply have no methodology for conducting strategic planning. What we do know is that this process will involve highly sophisticated measurement of behavioral goals and intentions, analysis of locational and functional decisionmaking in production systems, and the modeling of technological change in the production and delivery of goods and services. These are of course interdependent and there is no obvious modeling methodology for analyzing the three individually, to say nothing of simultaneously. It is, however, the challenge of the times to begin this kind of analytic effort.

The difficulty that transportation planning faces is made evident by asking certain basic questions that must be answered to make rational investment decisions in mobility technology. We will list some of those that have been discussed in the literature:

1. Family size has dropped markedly in the past 15 years. Will that continue and what effect will it have on housing choice or location, density, and size?
2. Women now constitute 52 percent of the college population and the proportion that has entered engineering has tripled in a decade. How will this affect the labor force structure? Does this indicate a change in perceived roles of women in this society?
3. Are attitudes toward travel changing? If so, will alternative mobility systems be adopted, e.g., communication for transportation?
4. Are public attitudes toward work timing and structure changing? If so, will alternative work patterns be adopted, e.g., flextime, staggered hours, or working at home?
5. It has been estimated that by the year 2000 production labor requirements will drop from 30 percent of the work force to around 3 percent. How will this reindustrialization process affect plant location, size, and management organization?
6. If product diversity continues to increase, especially in biological materials, what will be the transport requirements for such products in terms of volume, time, reliability, and cost?
7. What will be the changes in resource allocations among consumption functions? How will such changes affect development decisions, e.g., shopping centers, size of outlets, and methods of distribution of goods and services?

Thus, transportation problems of a decade ago were different in scale and scope from today's problems. Research methods that were developed, tested, and calibrated were often formulated for problems

that are not necessarily the problems we now face. It is to be noted that we have learned enough about methodology and the utilization of these newer models to be able to apply them, where appropriate, to current problems.

For example, much of disaggregate modeling was originally tested on simple mode choice (1970s). We were interested first to see how people made their choice and then to determine whether we could project how choices would be made if a critical variable, such as cost, changed. Today, perhaps, we are more interested in how vanpools or commuter clubs or new paratransit modes will affect public transit operations. We may also be interested in diverse questions that deal both with decisions affecting employment location (by the employee) and with decisions affecting residential location (by the household).

These are all pertinent questions to which behavioral methods can and should be applied. Yet, by examining the state of the practice, we note that few applications of behavioral methods are actually being used.

Some preliminary comments may be necessary to focus discussion on why this situation continues to be true:

1. There are a wide number of models, techniques, and procedures that pass under the rubric of behavioral modeling. These range from market segmentation to multivariate analysis (including scaling techniques), survey sampling and survey design, the use of simulators, and the use of disaggregate demand models. This catalog is certainly more difficult to grasp and use than was the traditional sequential aggregate demand process. The applications and subtleties of each use in practice are not yet clear. However, there is no question that two of this battery of techniques--market segmentation and disaggregate demand models (primarily the logit model applied to mode choice)--are becoming more acceptable as tools of the trade.
2. Strategic planning spawned the development of the large-scale models. As noted above, local practitioners are concerned with short-term planning and decisionmaking. There is uncertainty as to which role any modeling should play in this process. Yet this is precisely the time that carefully conceived analytic techniques should be used.
3. Large-scale data sets are no longer collected. Work on older data sets, although useful in model calibration, is not necessarily appropriate or applicable. There have been shifts in population characteristics, regional economies, housing location, and household composition. It is important to collect new data, perhaps of a different form from the traditional origin-destination (O-D) set, more tailored to the specific problems at hand.
4. Finally, there is a belief that most of the models, regardless of title, deal only with problems at a macroscale level. It is difficult to see, with the exception of some work on the problems of the elderly and handicapped, how the use of behavioral models has alleviated urban congestion encouraged more shifts to transit, or dealt with major problems of equity.
5. What is apparent is that there is a major problem of education reaching both the practitioners and the modelers. The process of education will be discussed more fully in a later section.

We now turn to some examples. The examples, rather than serving as an exhaustive review of the literature, will expand the discussion above and, it is hoped, provoke important dialogue between the model developers and the practitioners.

EXAMPLES OF APPLICATION

As noted, behavioral models have been used in many aspects of transportation planning. Essentially two groups have put the techniques into practice: (a) academics and consultants working with practitioners and (b) practitioners in planning agencies. To date, more has been done by the former group. If these techniques are as good as we believe, there should be greater adaptation by the practitioners.

A main purpose of behavioral analysis is to establish motivation for travel and to interpret how decisions to travel are made. Interestingly, a dichotomy was established by Burnett and Hanson (2) and articulated by Tardiff and his co-workers (3) between more behavioral approaches and what is presumed to be the rationale for choice models.

In choice models, Tardiff notes (3, p. 110):

> (1) Behavior is relatively simple and can be defined in terms of a trip; (2) behavior involves choices among alternatives; and (3) decision processes are complex, involving trade-offs among a large set of characteristics of alternatives. The counter hypotheses are ... (1) travel behavior is complex; (2) constraints, rather than choice, may be more important in explaining behavior; and (3) decision processes are simple and involve consideration of only a small number of characteristics.

It seems that both positions are correct, and the degrees of complexity and simplicity have been shown by Heggie and Jones and their co-workers in the development of HATS. What we have learned from these studies is that travel decisions at the household level are complex, are subject to externalities (the constraints) that may affect the prime traveler in the journey to work, and have a ripple effect on the rest of the household. But some in the household simply choose modes, destinations, etc., in the manner that earlier mode-choice models presumed. And, in the aggregate sense--the Oi and Shuldiner variable--the household is still a prime level of analysis.

The concern with how traveling populations behave, however, is becoming more critical to planners as investment decisions themselves become more critical. Thus, it is important for us to cite the nature of some of those planning decisions and to illustrate behavioral methods that will be absorbed into practice.

Short-term decisions are being made among low-capital choices. While these decisions are being made (TSM, infrastructure, etc.), population shifts and economic shifts as noted are taking place rapidly in all of our urban and rural areas. It is difficult to imagine which attributes of transit will attract 10-20 percent more riders when transit subsidies are disappearing, service is being cut in many cities, traditional transit is beginning to feel competition from paratransit of all forms, and economic development takes place almost independently of public transit decisions.

Quite simply, the practitioners ask, Do we have the methods to look at the new bevy of problems and what can we abstract from the old solutions? Behavioral modeling and the important early work of Paine (4), Hartgen and Tanner (5), and Golob and Dobson (6), to cite only a few, have taught us to view transportation problems in a complex, multidimensional mold. Recent work by Koppelman (7) and his co-workers has shown clearly how successful such approaches can be when it is necessary to evaluate how both the individual's decisions for choice among modes and structure of local policy affect transit

systems. Koppelman attempts to make the link between the dichotomies stated earlier when he notes, "The critical factor present in consumers' decision making, but absent in traditional demand models, is consumers' perceptions which mediate the relationship between system characteristics and travel choice behavior."

Koppelman uses an extensive array of techniques to evaluate how perceptions lead to choice and choice to mode use in data collected for Evanston, Illinois. The techniques include market segmentation and a number of multivariate techniques, which arise from the evaluation of a detailed survey. The most critical of these techniques is factor analysis and the utilization of the behavioral components from the multivariate analysis in the choice model. This array of techniques has been used by others in whole or in part: Wachs (8) in establishing patterns of travel for the elderly, Recker and Golob (9) in travel choice, Benjamin and Sen (10) for the handicapped, and Dobson and Tischer (11) for carpools. These studies all relied, as noted, on detailed and complex surveys. The surveys were designed to test certain modeling approaches and to permit complex multivariate analysis.

What is lacking in the literature that would be of use to the practitioner is an analysis of the transferability of behavioral data. The reasons are straightforward. First, the data sets are too complex. Koppeleman's surveys were generally 15 pages long, compared three modes with 25 attributes each, and asked a series of travel and socioeconomic questions. Benjamin asked a series of questions that dealt with more than 100 attributes of modes and characteristics of disability. Benjamin and Paaswell (12), in a housing choice model, asked well over 100 questions on attributes as well as social attitude of the respondent. Brög (13) in his seminal work on the disabled in Germany asked questions not only of the respondent but also of those who interact with the respondent. By the time one gets to factor analysis or to do a posteriori segmentation, these sets become highly personalized. Yet the information gained is so insightful--and not necessarily from the Burnett-Hanson perspective or the Ben Akiva-McFadden perspective, but from the practitioner's perspective--that it seems that more should be done to translate such survey design and variable analysis into simpler forms for on-the-line use.

Benjamin, in particular, noted the importance of being able to use both a priori and a posteriori segmentation (Koppelman applied a priori segmentation in Evanston and showed that variables such as education might tell us more than car ownership in mode preference). Benjamin states that segmentation is important for the following reasons:

1. The method provides a way of relating travel behavior to mode choice and
2. Results produced by the method can be used directly to identify target groups for transit marketing effects.

He further notes how these data feed into cost-benefit analyses (4). These complex surveys and market-segmentation techniques lead to the development of factors that can lead to identification of choice-variable sets (Koppelman's bus disposition and walk disposition) or descriptors of general attributes (security, comfort, etc.). Further, they make it possible to cluster groups of respondents according to dimensions of interest or, conversely, make it possible to see whether population clusters can be formed along dimensions of interest to the analyst.

Transferability, or the development of a general set of attributes describing modes, has not been attempted because of the implicit assumption that populations and their responses are unique to specific situations. The formidable task of survey design and the costs of data collection would then make the feasibility of using such techniques seem poor to practitioners. In addition, practitioners must overcome their historic ties to the types of information collected in simple O-D studies.

There is no question now that for short-term planning studies, market segmentation (a priori) should be utilized. This is quite different from oversampling, or searching a major survey sample for a specific cluster. Segmentation suggests that the planners have a sense of possible outcomes of the issues being addressed when strategies are being developed. Segmentation will assist in identifying and understanding citizens' groups during plan discussion phases as well as key in on variables that effect responses to change that are unique.

Traditional market studies are now done as commonplace parts of transportation impact studies. Such studies, often done to establish retail potential near station areas or due to transit improvements (new lines, malls, etc.), provide information to planners that complements the readily available O-D data. The value of this information lies in the fact that such studies attempt to establish both a motivation for conducting a specific activity (retail shopping downtown, retail shopping in a mall, eating out at lunch) and the propensity of the respondents to carry out that particular activity. Samples for such studies are established through a priori segmentation. One drawback of such market studies is that the survey instruments are not developed fully enough to establish, develop, or calibrate behavioral models to the level at which they currently can be constructed. Market studies often establish current patterns of choice, several factors that influence choice (quality, accessibility, safety, etc.), and socioeconomic factors that help clarify the market segment. Studies should involve more trade-off analysis, ranking, and attribute scaling to help establish segments through cluster analysis (a posteriori) and to permit factor analysis and other multivariate techniques to be conducted.

Some of the more academic contributions toward dealing with retail impacts of transit recognize the importance of the need for depth in a data set. Kern and Lerman (14) examined the impact of control policies on retail shopping in Denver. They used both regression models and disaggregate demand models to "analyze a limited set of issues rather than seeking to forecast all of urban spatial structure."

Paaswell and Berechman (15) established a sample probability model of shopping choice that incorporated an accessibility component. Through use of a detailed survey instrument that combined questions of preference with scaled attitudes, it was possible to establish that very real constraints existed in retail choice and that accessibility was not necessarily the major factor, nor even an inducing factor, for retail trips. These findings are clearly in harmony with the assumptions of Burnett and Hanson (2).

HOW TO APPROACH APPLICATION

There is no question that behavioral techniques must find their way into application more quickly than is occurring. Investment decisions must be made with a greater sense of the range of outcomes and choices than they are now made. Some of the emerging meth-

ods and techniques are still peripheral to daily application. The use of HATS or the development of new theories is necessary to give us insights into why choices are made or how well our theoretical constructs hold.

But today and in the next decade, more decisions will be based on quantitative analysis than on qualitative analysis (excluding pure political decisions).

We have a battery of well-documented, well-used techniques that should be a part of every planner's notebook, starting with the classroom in undergraduate and graduate school. These techniques include

1. Problem identification
   a. Population and sample identification
   b. Pretesting of impacts
2. Survey design (survey sample)
3. Market segmentation
   a. A priori
   b. A posteriori
4. Multivariate analysis
   a. Multiple regression
   b. Factor analysis
   c. Cluster analysis
   d. Scaling
5. Use of disaggregate models

The gap between theory and practice can be bridged by education. Modelers cannot always bemoan the fact that no one will pay for the large, comprehensive data sets. Perhaps problems should be addressed on a much smaller scale. There should also be new work done on establishing the concept of transferability of much of the data analyzed by multivariate techniques. What are the situational constraints? How may variables usually describe mode choice, retail choice, housing choice? How much does a developer rely on transportation at the site location?

Practitioners should recognize that there is a dollar value to be gained from in-depth behavioral analysis. There is a big difference between learning that 50 percent of a sample say Yes to "Will you stop at x if we put a transit stop in front of the store?" and learning that that 50 percent now have shopping patterns and attitudes that indicate that they will not shop there.

The above, of course, is a broad illustration. But it emphasizes that behavioral techniques can be used in practice now. They can be applied to decisions on investment. They are ideal to be applied in very specific, well-defined problems. They can circumvent major surveys (but replace them with targeted samples questioned in depth). We must strengthen the process of mutual education of practitioners and modelers now. It is here that we must turn to the broader implications of behavioral applications.

OVERVIEW OF BEHAVIORAL METHODS IN PRACTICE

We have noted how behavioral techniques can be used in practice in a number of short-term or controlled-scale applications. However, it is necessary to establish how such approaches can be used when the longer-term issues of planning and policymaking are addressed. How can such techniques enter the practice under such conditions? The answer to these questions is quite obvious. It is that behavioral science will enter the practice only when transportation policy, planning, and design are seen as distinct from traditional constraints of technology, that is, when transportation is seen not in terms of highways, rails, and vehicles but rather in terms of the mobility requirements of our populations.

We ought to make the implications of such a change clear. In an industrial age (in the United States, 1870-1970), mobility required time-synchronized movement of masses of people for the 60 percent of nonagricultural jobs that characterized a labor-intensive, manufacturing-centered society. These institutions also required transportation that was capable of distributing large quantities of raw materials and finished goods over long distances. The industrial age has been characterized as physical in the sense of action in space. For all practical purposes, this age required the technology to ensure economic transport of goods and people. Civil engineering formed around transport with an early emphasis on bridges, tunnels, and roads. The construction of major public works gave the profession its own identity and in turn the profession made its commitment to those technologies and defined itself in terms of their structure. At least four generations of engineers have been trained to that tradition and that tradition has dominated the policy, planning, and design of transportation.

However, the industrial age is coming to an end. In a world reaching the limits of conventional resources and one in which the social goals and objectives of Western society, at least, are decreasingly physical or quantitative and increasingly informational and qualitative, the values of the industrial age have less moment.

As this social evolution proceeds, the needs of transportation are changing and will continue to undergo significant change. In addition, the technological requirements for mobility systems are changing and will continue to change. Finally, the criteria for acceptable transportation have differed and will increasingly differ from those that have formed the basis of transportation policy, planning, and design.

If these changes are occurring, then the logical questions for transportation planners are as follows:

1. What are the emerging requirements for mobility?
2. What are the appropriate if not optimal technological means of satisfying those requirements within given socioeconomic constraints?
3. What are the economic and political strategies for implementation of a necessary and sufficient mobility technology?

Other than a do-nothing alternative, there is no way to answer the last question without answering the first two. There is, however, no way to answer either of the first two questions within the framework of the existing planning and decision process. On the contrary, in a period of rapid technological and social change the only way that planning can be relevant and efficient is through analysis of the behavioral processes that determine mobility requirements and define system performance criteria.

In essence, without some understanding of individual and group perceptions, goals, and attitudes, there is no way to estimate the qualitative or quantitative properties required of mobility systems. For example, if for value reasons the American economy is shifting from heavy manufacturing production to fragile and low-volume high-technology products, how will that change the per-

formance characteristics required of goods-movement systems? For example, if people do not wish to work in time-constrained environments, how will linkage to work be carried out? For example, if people do not wish to be housed in low-density, quasi-rural environments but prefer smaller, denser configurations, what kinds of transport systems will be required to serve that kind of land use form?

Questions of this type can be expanded for production systems, consumption systems, and social groups. The answers are critical to planning and investing, and certainly to investment decisions in transportation over the next two decades. They cannot be answered, however, without using the basic tools that have been developed within the behavioral sciences, since these are the only techniques available for specifying in quantitative terms the desired goals and criteria. The fact is that most of the crucial questions are only answerable if these methods are used.

The nature of the problem before transportation policy and planning is relatively straightforward to bound. It necessitates the separation of strategic from tactical planning. The short-term issues of resource allocation among existing modes in a oneto five-year time frame require little innovation, only straightforward supply-and-demand analysis. It is for the longer term that behavioral considerations become central. This is true simply because it is the nature of the changes in both social and structural organization that will determine future mobility requirements.

A basic triadic relationship exists between social, structural, and transport systems. Abundant evidence suggests that social forces have become the driving force for both structural and infrastructural development over at least the past 20 years. In a postindustrial society, this is the situation one would expect. Further, these forces have had an impact on physical development greater than most transportation planners have recognized. If this is the case, then long-range transportation policy and planning must be derived from the projected changes in social structure, economic organization, and the social constraint set within which transportation must operate. In detail, strategic planning must involve the rationalization of these sets, the product of which establishes the functional requirements for and the performance characteristics of mobility systems. Variables in each of these sets are listed below:

Social Organization	Structural Organization	Constraint
Work/occupation	Production system	Economics
Housing	Population	Physical resources
Food	Demographic distribution	Environment
Clothing	Technology	Energy
Health care	Land use	Safety
Protection		Politics
Education		
Social factor		
Recreation factor		
Cultural factor		

The functional question is what kind of mobility systems are required to satisfy the priority needs of individuals and groups defined in the first two sets.

It should be recognized that these needs are fundamentally qualitative, since they reflect perceived values. For example, future work environment depends on subjective meaning of work as involvement in the production of goods and services as much as it does on employment opportunity. People will seek or create occupations that are perceived to be subjectively acceptable and meaningful. This helps in understanding the proliferation in the helping professions in the 1960s, e.g., social work and medicine. In the 1980s there seems to be a similarly motivated shift toward technical occupations but on a small-business scale. There is little doubt that current behavioral science methods would allow the definition of why such changes are occurring and how these changes will affect work, housing, and travel over the next decade. Similarly, how people perceive the importance of free time will markedly influence work hours on the one hand and the amount of time they will accept for travel on the other. These attitudes will be a major factor in determining the substitution of communication for transportation. In sum, the essential forces in determining future transport requirements are the life-style goals and attitudes that people--as individuals and as groups--hold toward social organizations and institutions. These are not, of course, facts or data, but processes or forces. Without an understanding of these processes, there is no way to predict the transportation technology to build for any long-term future. Further, without the measurement of these forces, there is no way to predict the changes in the structural organization of time and space, the template that must be laid over any transportation technology.

At its heart, this discussion defines the classic issue that has separated transportation planning and engineering from those concerned with travel behavior and values. That issue is observed versus perceived behavior as the basis of strategic planning. The former predicates future behavior on current and past behavior or on simplistic assumptions about human perceptual, cognitive, choice, and decision processes. The latter predicts future behavior on perceived attitudes, values, and goals. Given that perceptions are stable, general, and measurable, as behavioral scientists generally believe, it becomes possible to consider modeling transport as a process and hence to define transportation as a set of performance criteria. It is well to note that the characteristic that distinguishes high technology from low is the capacity to design systems in terms of performance criteria. Indeed, it is in these fields that the behavioral sciences are an integral part of the planning, analysis, design, and evaluation process. There is in principle no difference between these fields and transportation except that the set of user requirements is much larger for transportation.

In essence, transportation modeling activities have been embedded in tactical planning, i.e., the optimal deployment of a set of given technologies. In this context, manifest travel behavior is necessary and sufficient and any more sophisticated analysis of traveler behavior is of marginal utility. It is only at the strategic-planning level that attributes and values become crucial.

As the organization of American society is undergoing major change, industrially as well as socially, two things are becoming clear. One is that the transport technologies now in place are at least obsolescent. This fact is most evident in the older, most transport-rich regions of the Northeast. As a result of this obsolescence, the planning methods developed over the past quarter century are irrelevant for the essential task of creating the cost-effective mobility infrastructure that the emerging society will require.

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Research Needs

1. Refinement of activity analysis

2. Determination of relationships among activity patterns, travel and land use characteristics, and sociodemographics

3. Restricted land use and economic feasibility studies (models are available for large-scale studies, but methods need to be developed for one sector of a city or region)

4. Obtaining employment data by workplace

5. Variables underlying trip generation and employment location

6. Complex relationship model with surrogate variables

7. Reconstruction of trip-chaining

8. Better use of census and O-D data