In the area of longer-term travel analyses, there is a need to improve the forecasting of variables that input to the travel-forecasting methods. These include population, employment, income, automobiles, and economic indicators, both at the aggregate and the disaggregate levels.

Finally, many of these techniques are implemented by agencies and organizations with which planning agencies have little or no communication. These include transit operators, traffic engineering agencies, parking organizations, private ridesharing operators, maintenance departments, and social service agencies. If planners are to effect the selection of alternatives and the analysis of impacts to achieve communitywide benefits, a substantially increased level of cooperation will be required.

Travel Analysis Methods for Systems Management and Operations: The State of the Art

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As public budget pressures limit funds to expand and operate urban transportation systems, planners are searching for more productive ways to use existing transportation resources through improved systems management and operations. This transportation system management (TSM) philosophy presents many new challenges to highway and transit planners, traffic engineers, and system operators. In particular, planners must consider and assess numerous short-term (operational within one or two years) actions to improve traffic flow, parking, and public transportation services. Usually the most difficult planning task involves estimating the changes in travel demand due to the proposed actions.

During the past few years numerous research approaches have been tried and considerable empirical evidence has been accumulated in efforts to advance the state of the art in short-range TSM planning. However, the typical planner often does not use these newer techniques or have ready access to this information.

In this paper, we discuss the usefulness of the recent summaries and syntheses of travel responses to short-term actions. We then briefly review a large set of state-of-the-art travel analysis methods and comment on their application, ease of use, and data needs. Finally, we suggest some issues that need to be addressed as researchers and planners strive to improve the travel analysis methods needed for short-range transportation planning in the 1980s.

PLANNING CONTEXT: TSM AND OPERATIONS PROBLEMS

An important difference between short-range, small-scale TSM planning and longer-range planning is that usually little time (and money) is available in short-range planning for travel analysis or new data collection. Planners often have to respond relatively quickly to funding crises and political pressures to do something. Fortunately, for many of these short-term problems, it is not too costly if the travel demand estimates are not very accurate. Unlike the longer-term or capital-intensive projects, many of the short-term actions--transit and dial-a-ride service changes, ridesharing incentives, and some traffic operations and parking improvements--can be implemented on a smaller-scale trial basis and then modified as the demand develops (or does not). A trial-and-error approach, of course, cannot be used for some actions, and in all cases there may be real credibility and political costs for errors. For many short-term actions, however, we have to accept that spending more time and money for additional demand analysis and data collection may not really reduce errors. If we acknowledge this uncertainty and plan the implementation accordingly, the cost of wrong estimates often can be minimized.

Another distinguishing feature of this type of planning is the different types of planning backgrounds and approaches that may be involved, depending on the specific problem. Rather than a few persons in an MPO or other regional agency applying a relatively well-defined planning process, persons doing short-term planning exist in many places--transit agencies, city and county public works departments, carpool and vanpool promotional organizations, social service agencies, parking authorities, and private organizations such as taxicab companies. These persons all may make estimates of short-term demand responses, but their abilities, interests, institutional constraints, and planning approaches vary tremendously.

One illustration of the variety of planning and travel analysis problems is the list of the various TSM-type actions originally proposed in the 1975 DOT regulations. Other classification schemes also have been used to group TSM measures based on the compatibility of individual techniques, common institutional problems, the planning analysis detail, and the supply and demand system impacts. [For example, see reports by Remak and Rosenbloom (1), Voorhees (2), and Wagner and Gilbert (3).]

Recently, nine operating environments have been suggested as a way to organize TSM analysis and implementation (4). Operating environments relate to

1. Major transportation facilities, such as freeway corridors, arterial corridors, and modal transfer points;
2. Major urban concentrations, such as large employment sites, major activity centers, and outlying commercial centers; and
3. Geographical settings within urban areas, such as neighborhoods, CBDs, and regional environments.

Several advantages of using these operating environments for organizing analysis were suggested:

1. They delineate an approach that is consistent with traditional analysis,
2. They are compatible with existing planning techniques for projecting TSM impacts, and
3. Each environment can have identifiable goals and measurable objectives.

Public transportation planners are beginning to recognize the value of careful market segmentation for tailoring different services to specific user needs. We have found that public transportation actions can be grouped usefully into three broad categories depending on the type of travel market being served (5): high-density home-to-work travel, special-user-group travel (such as youth, elderly, handicapped, or low income), and general-purpose travel. Greater attention to specific market segments will be particularly important to public transportation planners as they consider ridesharing options, devise new services, change fare levels and structures, and modify existing services.

Since the different travel markets and operating environments produce such a diverse set of short-term planning problems, it is not possible to develop a set of universally applicable demand models or methods. About the only characteristics these methods may have in common is that they are not concerned with forecasting longer-term effects such as those due to land use changes and new transport technologies. Unlike the long-range problems addressed by the standard UTP approach, the range of short-term problems, the different types and abilities of planners, and the time and cost constraints all suggest that a large set of diverse travel analysis methods will be necessary.

The question planners face is how to find and apply the right kinds of experience or analysis methods to the problem at hand. As we will discuss in the next section, much empirical information exists, and there are many models, analysis techniques, and research approaches for estimating short-range travel demand. Undoubtedly, one reason many planners do not use very much of the newer information or analysis capabilities is that they are not aware of them. Even if they become aware of new methods, it is very difficult for them to determine whether results obtained using the new methods will really be better than their current judgments, rules of thumb, or other simple methods.

Like professionals in other changing fields, planners face a challenge to keep abreast of current developments and learn improved techniques. The rapidly developing microcomputer technology could be the future lynchpin to improve this situation. This technology could make the vast amount of empirical information that is accumulating on the impacts of short-term actions more accessible. Planners could then not only become aware of new actions and how they worked in other locations but also have more information to apply to the analysis of their particular actions. In addition, this technology could vastly improve the data-management and analysis capabilities of short-range planners.

REVIEW OF TRAVEL ANALYSIS METHODS FOR SHORT-RANGE PLANNING

Forecasts Using Actual Travel Impacts

During the past few years, increasing efforts have been made to monitor and document the travel impacts of numerous TSM and operations actions. The most comprehensive efforts are the demonstration programs sponsored by UMTA and FHWA, but several state departments of transportation also have programs. UMTA's Service and Management Demonstration (SMD) program provides an overall framework designed to formulate, implement, and evaluate a wide range of public transportation and TSM innovations. SMD has conducted numerous in-depth demonstration evaluations and studies documenting the travel demand impacts of actual transportation system and operations changes. FHWA, UMTA, NCHRP, and other organizations such as the Institute of Transportation Engineers have sponsored the development of a variety of synthesis documents that describe the demand, supply, and implementation results of TSM actions.

A list of 10 of the more recent and comprehensive summaries of this travel experience is given below. Based primarily on empirical evidence, these summaries try to present useful, generalizable guidelines and specific data from successful applications. Most of them provide extensive references for more detailed information.

Title	Coverage
Traveler Response to Transportation System Changes (6)	Extensive demand information on wide range of TSM actions; well organized with numerous references
Experiences in Transportation System Management (4)	Considerable information on TSM actions in nine operating environments; some demand impact information; good references
A Casebook of Short-Range Actions to Improve Public Transportation (5)	Provides case studies of and guide to numerous public transportation demonstration results; organized by travel markets and city size
Evaluation of Priority Treatments for High Occupancy Vehicles (7)	Considerable demand and supply information on more than 40 projects; good references
Guidelines for Using Vanpools and Carpools as a TSM Technique (8)	Considerable information on ridesharing programs and incentives; some demand guidance; good references
Study of Parking Management Tactics, Volume 2: Overview and Case Studies (9)	Information on range of parking supply and pricing changes; some demand guidance
Alternative Work Schedules: Impacts on Transportation (10)	Information on types of alternatives; some demand data; good references
Bus Route and Schedule Planning Guidelines (11)	Provides general review of practices and problems
Patronage Impacts of Changes in Transit Fares and Services (12)	Considerable information on elasticities by market segment
Ridership Patterns in Transportation Services for the Elderly and Handicapped (13)	Information on demand for specialized services for target groups

In many short-range planning efforts, we believe that taking actual demand (and cost) results from similar situations and adapting them to the specific local conditions is the best way to estimate impacts. The existing experience for numerous short-range transit improvements, ridesharing actions, parking programs, and traffic management schemes provides substantial qualitative and quantitative insights into the nature and magnitude of the travel responses. Also, some decisionmakers may be more inclined to accept the forecasts if they are based on actual successful results from similar situations rather than on predictions from models.

This planning-by-analogy approach, of course, presents several difficulties. Perhaps the primary one is finding good information on truly similar situations. Although the results of many examples are available, considerable planning judgment is required to find, interpret, and apply the right information. In many cases only the successful

endeavors are reported fully, and the failures may not even be mentioned.

A recent set of guidelines for short-range public transportation improvements relies heavily on the in-depth evaluations of SMD demonstrations (14). Although the travel impact data in some of these evaluations are among the best available, there are still travel demand consistency and definitional problems as well as difficulties determining the effects of external events. Ambiguous definitions of trips, how travel responds over time, and different types and qualities of traveler surveys can make it difficult to interpret observed travel data. Even if the reported travel results are relatively accurate, there may not be sufficient information on other significant factors influencing transferability, such as the active roles of certain individuals, fortuitous external events, and other unique conditions. (We should note that these same types of factors affect all travel-estimating approaches.)

Enhancing our ability to estimate travel impacts by analogy will require several steps. Better monitoring methods should be developed and applied to a wider range of traditional TSM and operations actions in various environments. In addition, we should continue to implement novel actions and closely track the impacts. As more demonstrations and case-study results are accumulated, more accurate generalized information on traveler responses can be produced.

Practicing planners, however, will still need help in obtaining and using this growing set of information. Although well-prepared and updated synthesis reports and guidelines may be sufficient for most short-range planning efforts, a more ambitious user-oriented automated information retrieval system might be useful in the future to help planners more quickly sort through and obtain the most relevant and recent information.

Forecasts Using Models and Other Methods

As more attention has focused on short-range TSM and operations problems, researchers and planners have devised many approaches--from sophisticated theories and models to simple and practical methods--to forecast travel impacts such as mode choice and ridership levels or traffic flows and parking spaces. Many of the approaches used for short-range estimates have evolved from adaptations and refinements (such as manual and pocket calculator sketch-planning methods) of the traditional multistage aggregate models used for long-range regional scale planning. Other model approaches and analysis techniques have been pursued to address specific short-range problems.

Table 1 presents an overview description of the major types of models and methods used for short-range travel analysis. We define seven general categories of approaches. Under each category, specific examples of the method or model are listed followed by typical applications to planning problems. For each category, we also assess the general ease of application and data needs and provide one or more important references.

Although we cannot claim that this list covers all of the techniques available, it certainly demonstrates that many different (or new) techniques exist. When we consider that there are several different versions of the specific examples, such as disaggregate mode-choice models, the number of existing short-term travel analysis techniques becomes even larger.

Many of the techniques have been developed specifically to forecast short-range impacts. Some attempt to develop consistent theories encompassing detailed transportation system variables and socio-demographic characteristics of travelers or households. Others merely describe and extrapolate aggregate trends or correlations. Some techniques--attitudinal surveys and activity-based studies, for example--attempt to improve the understanding of travel behavior rather than directly estimating impacts.

Leaving aside the more research-oriented techniques, our review of the literature and discussions with planners indicate that little useful information exists on how to assess and choose among the numerous techniques available. Although technique developers advocate their new and improved models and methods, potential users are skeptical and correctly wonder whether it will be cost-effective to learn and apply a new method or model. Some of this reluctance to accept new approaches is inherent in any field. Some of it, however, may be due to a lack of convincing evidence that a new approach will work better.

A recent review of demand forecasting for bus service route planning (27) sheds considerable light on the challenge facing developers of better forecasting techniques for short-range actions. Based on in-depth discussions with the planning staffs of 40 transit agencies, this report found that most of them use judgmental methods, similar routes, rules of thumb, or otherwise simple methods because these require the least time, costs, and technical ability. Another major reason was that they are only interested in having a general assessment of new routes or changes because actual performance is more important. In fact, very few of the agencies have any follow-up data on the accuracy of any of their techniques.

Until short-range and operations planners and decisionmakers perceive the value of better predictions for certain actions, developers of new techniques will be hard pressed to convince them to accept better methods. Unless much better follow-up data are collected on the forecasting accuracy of current practices as well as on the new techniques, efforts to improve forecasting for some short-range actions may be futile. In addition, if unverified simple forecasts are adequate for certain actions, then efforts to improve travel analysis methods should be directed at those actions requiring better forecasts.

IMPROVING THE STATE OF THE ART

We have argued that given the wide range of short-term actions, planning time and cost constraints, and staff capabilities, no single travel analysis approach can be universally applicable. The challenge will be to match methods to problems and to focus new development and research efforts where they are most needed. This suggests that researchers will need to work more closely with the staffs of operating agencies and with other short-term planners.

We also have argued that planners need improved general guidance and better access to the vast amounts of empirical evidence available. Helping planners obtain and use results from similar situations may be adequate for many demand-estimating problems, although successful transfers and adaptations of empirical results will still require considerable judgment and analysis.

Any proposed changes to current short-range demand analysis procedures can be evaluated in light of three criteria: relevance, accuracy, and economy (50). Improvements should be directly relevant to specific problems or planning issues. Searching for

improvements in very general methods and theories may not be very productive at this stage. Improving accuracy has to be weighed against the extra costs, in terms of planners' time and data needs. A very accurate forecast may be less important than a timely but less accurate one. Producers of new techniques will have to convince the potential users that it will be cost-effective to adopt new practices.

The preceding discussion suggests a number of issues regarding how to improve short-range travel analysis procedures. Some questions to be addressed include the following:

1. What steps can be taken to improve communication between researchers and practitioners? Is this communications gap a major barrier to matching the state of the art with the state of the practice?
2. Better travel data are always required but what types? Should more special-purpose travel surveys be made to monitor actual before-and-after impacts? Will travel diaries and long-term panels help?
3. Can operating agencies improve their monitoring capabilities and develop more efficient trial-and-error approaches for implementing certain short-term actions?
4. How can different planning-staff capabilities be increased? What training programs can be effective? What are the roles for consulting firms?
5. Is there a need for an objective broker to help users obtain and apply new techniques? Should DOT or another organization provide evaluative information on models and other methods to help users choose the best ones?
6. In which areas do we most need to improve our understanding of basic (short-term and longer) travel behavior?

Overall, we believe that improved communication between practitioners and researchers is an essential first step toward improving the state of cur-

Table 1. Characteristics of state-of-the-art models and analysis methods.

Approach	Application	Ease of Use and Data Needs	Reference
Multistate aggregate model			
UTP process	Medium or long-term land use and major automobile and transit system changes; computer and manual techniques	Considerable expertise, network detail and O-D trip table; manual techniques easier	Sosslau and others (15)
Disaggregate choice model			
Work and nonwork mode choice	Regional, suburban, or corridor TSM/air quality energy policy assessments (ride-sharing/parking/transit)	Pivot-point form relatively easy; disaggregate level requires considerable data and assumptions	Spear (16); Gomez-Ibanez and Fauth (17); Ben-Akiva and Atherton (18); Bullen and Boekenkroeger (19); Cambridge Systematics, Inc. (20); Burnett and Hanson (21)
Demand-responsive transit demand model	New dial-a-ride or shared-ride taxi systems, dial-a-ride service, and fare changes	Calibration and application not easy; considerable data and assumptions required	Lerman and others (22); Systan, Inc. (23)
Transit ridership	Transit service changes in a single route or in transit corridors with few routes	On-off counts by stop, fare, and route description; research version on microcomputer	Turnquist and others (24)
Cross-sectional data model			
High-occupancy-vehicle model	High-occupancy vehicle on freeways	Manual application; moderate data and assumptions	Charles River Associates (25)
Dial-a-ride model	General purpose and special user group dial-a-ride; service and fare changes	Straightforward application; moderate data and assumptions	Systan, Inc. (23); Peat, Marwick, Mitchell and Co. (26)
Transit ridership model	Small urban and rural systems; some route specific	Straightforward application; various data and assumptions required	Peat, Marwick, Mitchell and Co. (26); Multisystems, Inc. (27)
Survey approach			
Noncommittal survey	New transit and paratransit systems; park-and-ride use	Requires good survey expertise; moderate data collection	Hartgen and Keck (28); Keck and Liou (29)
Direct-value assessment; laboratory-type simulation	Transit and paratransit service changes; automobile and bus price and service changes	Considerable survey expertise and data collection	Louviere and Kocur (30); Louviere and others (31)
Market segmentation analysis	Transit, carpooling service-level changes	Tremendous survey expertise and data-collection requirements	Woodruff and others (32); Rubin and others (33)
Attitudinal survey	Carpooling and transit behavior	Variable survey expertise and data collection	Dumas and Dobson (34); Tischer and Dobson (35)
Combined attribute ratings and logit attribute choice model	Mode shifts due to diamond lane on freeway	Considerable survey and model calibration expertise necessary	Gensch (36)
Simulation model			
UC model, TRANSYT	Freeway ramp metering, high-occupancy-vehicle treatment; arterial networks; traffic signal changes	Considerable technical and data needs; computer requirements moderate	May (37); Weldon and Parsonson (38)
Transit pricing model	Transit fare structure changes	Considerable data and technical needs	Ballou and Mohan (39)
Time-series data model			
System-specific model	Transit fare and service changes	Moderate technical (regression analysis) and data needs	Kemp (40); Multisystems, Inc. (27)
Box-Jenkins time-series model	Automobile traffic trends; transit route rideship trends	Considerable technical and data needs	Nihan and Holmesland (41); Wang (42)
Simultaneous transit demand-supply model	Transit route service and fare changes	Tremendous technical and data requirements	Kemp (43)
Research method			
Unified mechanism of travel	Comprehensive urban model considering total daily travel time, distance, and money expenditures per traveler or household		Zahavi and others (44)
Activity-based studies of travel	Examine complexity of travel behavior		Heggie and Jones (45)
Life-cycle concepts	Examine complexity of travel behavior		Zimmerman (46)
Gap analysis (needs assessments)	Forecast rural elderly, low-income, or handicapped travel		Lee and others (47); Barton-Aschman Associates (48)
Travel diaries	Examine tripmaking of elderly and handicapped		TSC (in preparation)
Interactive computer and transportation design systems	Transit system and route-level ridership analysis		Andreasson (49)

rent practice and providing guidance for needed developments in the state of the art. Recognition of the diversity of travel problems and possible travel analysis methods for systems management and operations is also essential for formulating an approach to these topics. The uniform large-scale modeling approaches developed in the 1960s for long-range planning are clearly inappropriate for management and operations planning. Developing an improved conceptual framework acceptable to both practitioners and researchers in this area is a pressing challenge for the transportation planning profession.

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Transit and Highway Operations and Management Techniques: State of the Practice

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The shift in emphasis in transportation planning toward a focus on shorter-term, lower-cost improvements is well documented. The need to adapt the procedures and analytical tools developed for planning of long-range, capital-intensive projects to this new environment is equally clear but certainly much less advanced. The purpose of this summary is to examine the travel-forecasting methods currently in general use for analysis of operations and management strategies and their impacts on travel demand. Four subjects are discussed: the identification of planning applications within each of the five context areas where analysis of operations and management may be important, a survey of methods currently used to examine these issues, some thoughts on gaps between the states of the art and the practice, and suggestions on priorities for the planning community in addressing these emerging planning issues.

CONTEXTS

The topic of this workshop--operations and management techniques--is as much (or more) a planning context as it is a methodology. Thus, it is useful to first identify planning activities within each of the context areas in which operations and management issues are important. To simplify the discussion, it is useful to combine context areas that are quite similar and discuss planning in three general contexts: strategic and long range, project, and microscale and systems operations.

Strategic and Long-Range Planning

The anticipation of major changes in society and in factors influencing the transportation environment--fuel prices, transit funding--is a task whose scope and importance likely exceeds that of any management and operations issue when viewed from a broad perspective. The increase in workforce participation by women, for example, and the accompanying changes in household income, automobile ownership, and family size have had impacts on travel behavior that are more significant than the cumulative effect of all transportation system management (TSM) actions and system operating plans that have been implemented.

One important area for strategic and long-range planning of operating strategies, however, is transit system management. Changes in land use patterns, commuting trends, demographic characteristics, and funding availability create a continuously changing travel market and operating environment in which the transit agency must operate with acceptable effectiveness and economy. The implementation of operating policies, fare structures, and financing mechanisms is an effort that often extends over several years. Five-year transit development plans have typically called for staged implementation of new policies, although their focus has often been more on service expansion. More recently, several transit agencies have undertaken comprehensive assessments of their future operations in order to develop operating strategies that will maintain or improve their service quality and financial stability. An important and difficult task in these planning efforts is the estimation of patronage changes