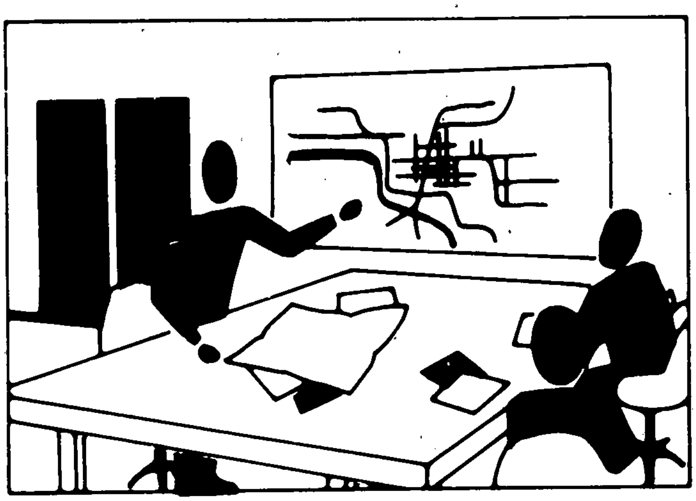
Special Report 201

Travel Analysis Methods for the 1980s



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Special Report 201

Travel Analysis Methods for the 1980s

**Proceedings of a conference held October 3-7, 1982,
Easton, Maryland**

Conducted by the Transportation Research Board

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and the Urban Mass Transportation Administration,
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Preface

The assessment of planning methods, in particular travel analysis methods and their applications, is the subject of this conference, which is a follow-up to the Conference on Urban Transportation Planning in the 1980s, held at Airlie House, Warrenton, Virginia, in November 1981. At the 1981 meeting new requirements for urban transportation planning were identified and issues requiring planning attention were discussed. These requirements and issues formed the basis for the 1982 conference. It is also a natural outgrowth of four international conferences on travel behavior and travel demand modeling. This conference, as have others, attempted to consolidate and codify the growing body of literature on travel analysis procedures. By bringing together practitioners and researchers to share ideas and concerns, it also focused on the interaction between theory and practice.

The aim of the conference was to determine how travel analysis methods can and should be applied to various problems. Therefore, identifying methods, defining the state of the art, describing how methods can and have been applied, identifying gaps between art and practice that require greater dissemination of current knowledge, and developing research were the focal points of the four-day meeting. The state of the art and the state of the practice of travel analysis procedures were assessed and evaluated with the express intent of determining their applicability to critical issues for the 1980s.

Introduction

Executive Summary

DAVID T. HARTGEN, New York State Department of Transportation

Transportation planning requirements in the 1980s will be significantly different from those of the recent past; shifts in government roles imply greater responsibilities by states and local governments for transportation analysis. To conduct these studies, better, simpler, and less cumbersome analysis methods will be needed.

To begin the process of developing new methods, a thorough review of travel analysis methods was undertaken at the Conference on Travel Analysis Methods for the 1980s, held at Easton, Maryland, on October 3-7, 1982. Some 75 experts from federal, state, and local government; the academic community; and consulting firms and research institutions reviewed how travel analysis methods are being or can be applied to various problems. The conference extended the work of a 1981 meeting sponsored by the Transportation Research Board (TRB) on urban transportation planning at which new requirements for urban transportation planning were identified and issues requiring planning attention were discussed. The proceedings of that meeting were published as TRB Special Report 196, Urban Transportation Planning in the 1980s. The Easton conference focused on travel analysis methods. The state of the art and the state of the practice of various analysis procedures were defined, applications of methods were described, and areas in which gaps between art and practice require greater dissemination of current knowledge, development, or research were identified. The conference was an outgrowth of a series of international conferences on travel behavior and modeling in that it consolidated and codified the growing body of literature on travel analysis procedures. However, this conference also focused heavily on the interaction between theory and practice by bringing together practitioners and researchers to share ideas and concerns.

The conference was organized around two sets of workshops. The first set focused on five levels of planning and on determining what issues and problems at each level would require new travel analysis methods. The second set then reviewed the state of the art and state of the practice for seven analysis methods. For each workshop, overview papers were prepared to set the stage and initiate discussions. Workshops covered the following:

Level of Planning	Analysis Method
Strategic	Data needs and collection
Long-range urban systems	Travel behavior characteristics and analysis
Project	Mathematical structures and uncertainty
Urban microscale	Quick-response and sketch-planning techniques
Systems operations	Long-range and strategic forecasting techniques
	Transit and highway operations and management techniques
	Investment and financial analysis techniques

This summary abstracts the deliberations, findings, and recommendations from the conference. The body of this report contains detailed workshop reports, background papers, and suggested research topics. The conference findings are summarized below.

1. Transportation investment decisions in the 1980s will require continued development and application of travel analysis methods.

Travel analysis is expected to remain an important element of transportation decisionmaking in the 1980s. Competition for scarce financial resources, greater accountability for transportation expenditures, the declining scale of many transportation projects, and the delegation of analysis responsibility for many projects to local government mean that the best investment alternatives must continue to be identified, evaluated accurately, and implemented. Effective project selection will depend on the strength of travel analysis methods.

2. Travel analysis methods available now are suitable for most problems and can be used immediately.

The state of the art of travel analysis is generally well advanced and capable of dealing with issues likely to need attention in the 1980s. Research into travel analysis in the 1960s and 1970s has improved conventional methods and led to the development of other procedures that are superior in many ways to those methods. Prototype demonstrations and the evaluation applications of certain methods, particularly disaggregate mathematical techniques, have resulted in superior tools that are adequate for many tasks. In addition, methods and principles from other disciplines, particularly the behavioral sciences, can be usefully applied to many transportation problems. In the areas of strategic long-range project planning, the methods are generally adequate, and the state of the art is appropriately advanced ahead of its application in practice. However, the behavioral theory underlying these procedures must be strengthened. In urban-microscale and operations planning, methods found in practice were judged to be weak and significantly behind the state of the art. However, the small scale and uniqueness of many projects does not justify the use of complex procedures or the development of theoretically stronger methods.

3. Newer travel analysis methods are not being used extensively in practice.

The gap between the state of the art and the state of the practice is considerably wider now than in the early 1970s, when a similar assessment of methods was undertaken (Conference on Urban Travel Demand Forecasting, Williamsburg, Virginia, December 3-7, 1972; TRB Special Report 143, 1973). This has occurred because the state of the practice has not improved appreciably, whereas the state of the art has continued to advance. Although some gap is necessary for healthy evolution of methods, the present gap appears to be larger than necessary.

Although newer methods offer significant advantages over conventional methods, criticism of newer methods is widespread. Most practitioners view them as excessively mathematical and/or theoretical, cumbersome and jargon-bound, poorly packaged and disseminated, difficult to understand in lay terms, of uncertain precision and accuracy, and of questionable relevance to the practicing profession. Few real-world tests have been made of the value of many procedures, and thus their increased usefulness over existing or more traditional techniques is not clear. Perhaps most important, research on travel analysis methods appears to have been largely irrelevant to practitioners' needs, which have therefore been bypassed unnecessarily. In the view of practicing planners, these problems outweigh the advantages of the methods (primarily data efficiency, better understanding of travel phenomena, and computational efficiency).

Middle-management training in these methods has not kept pace with the research in methods development. Support for training, dissemination, and implementation of methods has focused on entry-level professionals rather than on key middle managers, who make decisions on what methods to use. These problems are often compounded by poorly packaged and disseminated findings, tendency of results to be published in limited-circulation sources, and failure to demonstrate the practical value of the results to middle management. In some cases, the small scale of the proposal may not justify the use of advanced analysis tools, but often the awareness of such tools in the practicing profession is limited. Willingness of agencies and personnel to undertake retraining is also essential.

4. The 1980s should focus on technology transfer.

The conference concluded that the 1980s should be primarily a time in which the gains already made in travel analysis methodology are implemented. More widespread diffusion of the conventional as well as of the newer methods is needed for the practicing profession. The following approaches were suggested to speed technology transfer:

1. Short courses and "road shows" on the more readily usable techniques;
2. Dissemination of packages, materials, and very short courses for mid-level managers;
3. Documentation comparisons between procedures in real-world settings;
4. Coordinated local-based training, drawing together local planners, the university community, and consultants;
5. Syntheses of good practices and how-to manuals;
6. Pilot demonstrations and field tests of evolving methods;
7. Improved packages of techniques geared to user-friendly formats such as that of the microcomputer;
8. Reduced use of jargon in summaries and executive reports intended for the practicing professional and improved documentation;
9. Retraining programs for practitioners and interim reassignments or transfers; and
10. Use of large national meetings (e.g., those of TRB and the American Association of State Highway and Transportation Officials) to sponsor selected training seminars and sessions.

Although many agencies have responsibilities in these areas, the federal government or national-level bodies such as TRB should take the lead, since other agencies do not have the ability to mount such efforts on a national scale. A clear and strong commitment to technology transfer is essential.

5. Research on selected topics should continue.

Although the primary focus in the 1980s should be on technology transfer, basic research and methods development should not go unattended. Although progress has been made, more work needs to be undertaken:

1. Development of simplified demand methods in which complexity and accuracy are commensurate with time scale, level of detail, and importance of the issue;
2. Better understanding of travel behavior, particularly as influenced by social concepts such as life-cycle and life-style, activity patterns, perceptions, dynamics of choice, uncertainty in forecasts, and network equilibrium;
3. Certain subjects such as goods movement, parking, pricing, ridesharing, pedestrian circulation, and revenue forecasting;
4. Basic needs and direction for travel data collection and system operations monitoring;
5. Applications and use of microcomputers;
6. Forecasts of basic determinants of travel (population, cars, economy, energy, etc.); and
7. Distribution of impacts on users and nonusers.

The conference concluded that travel analysis methods are available and adequate but not adequately applied. Technology transfer of methods to the practicing profession is the primary need for the 1980s.

ACKNOWLEDGMENT

The activities and support of a number of individuals and institutions, which made this conference possible, should be recognized. First, great appreciation is expressed for the financial support provided by UMTA and FHWA for the conduct of the conference. The chairpersons of the workshops, authors, and panel members deserve thanks for their efforts in preparing materials and ensuring that sessions went smoothly. Members of the U.S. Steering Committee should be particularly recognized for their continuing assistance over a long period of time in undertaking the plans necessary to hold the conference. Members of the International Liaison Committee have provided us with continuing advice and assistance and have disseminated materials on the conference to interested individuals in their respective countries. Thanks go to each of these individuals and organizations. Finally, all conference members join in acknowledging particularly the staff support of James Scott, Mary Lou Damon, and Ian Kingham of TRB.

Opening Session

Keynote Address

RICHARD B. ROBERTSON, Federal Highway Administration

In October 1962 the 1962 Federal-Aid Highway Act was passed, and over the next few years considerable effort was expended by the federal, state, and local planners in defining methods for a new "3C" planning process. Since then, enormous advances have been made in the methods used to conduct urban transportation planning.

The catalyst for continual improvement in planning methods has been conferences such as this one, the Airlie House conference held in November 1981, and the series of four earlier conferences on travel behavior.

At the Airlie House conference there was a consensus that many policy changes were needed in the urban transportation planning process. There was discussion about methods, but it was obvious that more detailed discussion was needed on how planning methods relate to the issues raised at Airlie House and on the changing national issues in the United States and other countries.

For the United States this is a time of one of the most significant changes in national priorities and federal involvement in state and local roles since the 1962 highway act. With shifting roles come increasing responsibilities, which may not always be easy to cope with.

Now that policy changes are taking place, we must be sure that the technical planning process is sensitive to these changes. Good planning practice must be based on sound methods and continuing attention to the improvement of these methods.

At the federal level we have been engaged in several efforts to address these changing priorities, in particular, two studies. The first is a comprehensive review of the urban transportation planning process undertaken jointly with the Urban Mass Transportation Administration (UMTA). The second is a review of our role in providing technical assistance to state and local planning agencies. Our view of this role reflects the state of the practice in the transportation studies and is a good indication of needed improvements.

First, some details on the FHWA-UMTA review and new federal regulations. Since the 3C process was mandated by Congress in 1962, the additional congressional requirements and policies of five administrations have significantly expanded and in many instances unnecessarily complicated the scope of the process. Although I believe that the original precepts on which the 3C planning process is based are sound, it is time for a change. As you recall, FHWA and UMTA issued an interim final rule in August 1981 that provided for some moderate changes to the joint planning regulations that had been in effect since 1975 while it completely rejected the proposals issued on January 19, 1981. At about the same time, we started the comprehensive review that looked at all the requirements established since the 1962 highway act. We wanted to determine the appropriate federal, state, and local roles in urban transportation planning in light of the Reagan Administration's policies. The review was done in house but relied to a large extent on the views and comments of all organizations and individuals interested in urban transportation planning. Most of the issues covered were the same as those discussed at the Airlie House conference in 1981.

This review has resulted in the proposed new regulations, which were published in the Federal Register on August 26, 1982.

In general, the proposed regulations substantially reduce the heavy federal hand in planning activities that are essentially state and local concerns. The format is much more streamlined than the previous regulations, eliminating lengthy appendices and detailed lists of planning requirements. State and local officials, transit operators, and other implementing agencies will have much greater say in how they should work with one another in carrying out their roles and responsibilities in the urban transportation planning process. As prescribed by law, the metropolitan planning organization (MPO) is to be designated by the governor and local officials. We are recommending that principal elected officials of general-purpose local government be adequately represented on the MPO. However, the ultimate decision is with state and local officials, not the federal government.

The state and local agencies conducting transportation planning have shown over the years that they have the ability to judge the technical needs of their own planning processes. Some of the planning activities required in the past were time consuming, costly, and not necessarily of practical value to every urbanized area. We have eliminated the detailed planning requirements and advisory appendices in favor of the minimum regulation necessary for proper federal stewardship of the urban program. This approach recognizes the distinct differences among urbanized areas and provides the necessary flexibility to meet these needs. The basic requirements proposed are a transportation plan (without the requirement for long- and short-range elements) and a transportation improvement program/annual element (TIP/AE). State and local officials will have the flexibility to determine how these products will be developed and endorsed. Annual endorsement will no longer be necessary; it is required only when a new TIP/AE is submitted.

A unified planning work program endorsed by the MPO will still be required to support requests for federal planning funds in areas that have more than 200 000 population. But for areas with less than 200 000, a description in almost any format agreeable to state and local officials of how federal planning funds would be used is all that is needed.

One of the most significant changes is the provision for state and local self-certification. Rather than a federal stamp of approval, each area will have the opportunity to certify that its planning process is in accordance with all applicable federal laws and regulations, except for civil rights and private enterprise requirements, which will be maintained under a federal certification. This should give the states and local areas more flexibility and control in their planning process. There will be a need for a federal finding on the certification, but this is not an extensive review.

That is a broad picture of the new regulations. What are the implications of these changes on the technical planning process? Will the relaxation of the federal role have an effect on the scope and type of urban transportation planning being conducted at the local level? My answer is generally No, but with the new regulations the process should be a lot less onerous to the states and MPOs than in the past. Our intent is to ensure that federal requirements do not get in the way of good planning, and I believe that planning in the urbanized areas has been sound.

The increased flexibility for state and local decisions on how to conduct the planning process is likely to result in a call for more technical assistance and sharing of procedural information. With no detailed technical requirements in the regulations and with a wide-open format for the urban transportation plan, I think there will be a tendency toward a much broader array of technical procedures used to support plan development. This, coupled with the changing economy and a need for more emphasis on cost-effective transportation improvements, will create a demand for supportive analysis techniques. With shifting priorities and limited federal resources, local areas will also have to accept more responsibility in the programming and financing of transportation improvements. Overall, I see a continuance of the sound planning process that has evolved over the past 20 years. But I also believe that the shifting of responsibilities has implications for the scope of the analytical process and the type of research that needs to be explored more fully.

Because of the implications of these policy changes on the planning process, we recently undertook a review of the technical assistance needs of state and local planning agencies over the next few years. The objective was to assess our role in providing urban transportation planning guidance in relation to changing national policy and local issues. Technical support will be needed for a variety of areas, such as new and small urbanized areas, pavement management, mai nance, financing, and cost-effectiveness analyses. The review looked at technical assistance in its broadest sense, including training, research, manuals, guidelines, computer software, and other planner aids.

The findings of this review point to a continued need for assistance, particularly in the form of training, simplified planning techniques, and dissemination of information on the types of assistance available. In all cases, we will continue to view the federal level as playing a supportive role to the state and local planning agencies that perform the actual planning.

As I see it, our role will be that of a central clearinghouse for the dissemination of information and technology. FHWA and UMTA will continue to maintain a package of computerized transportation planning programs for large computers and will support a central source of information for applications of microcomputers to the transportation planning process. Finally, we will continue to improve and jointly distribute manuals, guidelines, and planning references to local and state planning agencies. I believe that in this way we can play the most cost-effective role in supporting state and local planning agencies but at the same time allow them to continue to be primarily responsible for the planning process.

One of the concerns in the study was the relevance of planning output to project decisions, and it appears that, in most cases, planning techniques can provide timely policy input and project support but more quick-response and short-range methods would help. These procedures have to be simple and used with judgment and insight.

Local areas will be undertaking more critical reviews to determine which projects are truly needed and are likely to examine a project's cost-effectiveness more intensively. Local governments, like the federal and state governments, will be pursuing only those projects that hold the most promise for the least investment. Various financing mechanisms and funding sources will have to be identified in each area in order to develop the best mix of revenue sources tailored to the area's specific needs.

At the federal level, we are encouraging greater reliance on local creative financing and are studying the use of private funds for major highway improvements. Part of the relationship between public and private sectors may be more financial support from the private sector that benefits from transportation improvements. We need to explore more fully the various aspects of financing transportation improvements, and I hope that some answers will be provided in the workshop on investment and financial analysis techniques at this conference.

Another area we are concentrating on is improving the management and performance of existing transportation facilities. This includes such activities as the Highway Performance Monitoring System (HPMS) and pavement management. We are also emphasizing cost-effective alternatives to costly capital improvements to the transportation system. Particular emphasis in FHWA is being placed on evaluating ridesharing and transportation system management (TSM) projects. These projects are testing innovative transportation alternatives such as transportation brokerage and arterial traffic management. Our evaluation approach to these projects will isolate those techniques that prove most promising and effective, thus crystallizing the best practices for dissemination to other agencies. These methods should be of great value to many areas preparing to undergo reconstruction of major facilities and needing to plan for handling the traffic. The results of these evaluations will serve as an important resource in our technology transfer program. A major focus of our efforts in the next three years will be on the dissemination of these state-of-the-art practices. We also intend to develop performance standards for our ridesharing projects so they may be compared with each other and to other types of transportation improvements. Once again, the goal is cost-effectiveness, both in ridesharing activities and in their choice over other alternatives. I hope these issues will be discussed in your operations and management techniques workshop later in this conference.

Computer technology (i.e., microcomputers) supporting urban transportation planning methodology will expand at an enormous rate over the next few years. But microcomputers will not be applicable in all cases and it will be necessary to ensure their proper application to appropriate problems at the state and local levels. FHWA and UMTA will be supporting microcomputer applications through user support centers and encouraging a wide range of technology sharing. We do not, however, see much new software development similar to PLANPAC or the Urban Transportation Planning System (UTPS) sponsored by the U.S. Department of Transportation (DOT).

It is clear that there will be a continued need for better accessibility to planning methods by city and county staffs. These methods will have to be simple, easy to understand, and quick to apply. More techniques of the quick-response variety [discussed in National Cooperative Highway Research Program (NCHRP) Report 187, Quick-Response Urban Travel Estimation Techniques and Transferable Parameters] are needed and will be the focus of our procedural development program. These will include planning for corridor TSM and traffic engineering improvements, microcomputer software for the quick-response procedures, and case studies in census use and small-urbanized-area planning.

Under FHWA administrator Ray Barnhart, research proposals are being subjected to closer scrutiny to ensure that the efforts are cost-effective and directly supportive of FHWA's programs. We have established a continuing process for assessing research needs and setting priorities. Major research project proposals are evaluated by top management to ensure that they are focused on mission requirements and provide a good return for their cost. To pass this review process, projects must be deemed essential and have a high probability of success.

We will continue to have an interest in a number of other agencies that support the highway program, such as NCHRP and TRB. These programs of federal-state cooperation represent the type of relationship with states that FHWA will continue to encourage.

Two things are clear from the technical review. One is the need for efficient implementation packaging and distribution of material and new procedures as they are developed, with adequate follow-up marketing and education. Second is the need for a sensitivity in the research community to the capabilities of state and local planning staffs (e.g., resources and time) versus level of effort needed for the various current planning methods and any new methods that are developed. Here again, education will have to play an important role in the implementation of new methods.

This week you will be discussing the relationships between policy issues and technical methods for the 1980s. The new regulations provide more flexibility in performing the technical analysis necessary to respond to state, local, and national priorities. The technical review pointed to the need for more simplified and responsive techniques in the short term.

Although the planning process is taking on a broader scope and shifts in policy are occurring, many issues and questions of a more detailed and technical nature still need to be considered. We will need to look more closely at what has been termed the traditional travel-forecasting process. With a much wider latitude of analysis possible to study a wider set of problems, the old standard four-step process may need to be overhauled. Will more special-purpose analysis methods be needed? What will be the technical planning needs of urbanized areas beyond the near-term planning for major reconstruction and system management? What methods will support the direction of policy movement in the urban transportation planning process in the longer term? Are these methods available and what needs to be improved? How can they be improved? What is the role of long-range planning? What will be the likely changes in life-style over the next 10 years and what will be the impact on urban transportation needs? What is the role of behavior analysis in urban travel demand estimation? What is the relationship between attitudinal and perceived variables and objective variables? Can they be used? Do they improve forecasts? Is it worth it? How can they be made part of the on-line planning process?

In short, you have your work cut out for you. We are entering a new period that deals with new issues and new challenges. We need answers and solutions to deal with these issues. The planning community will have to adapt to new policies and we need strategies that are workable and practical to help that adaptation.

The product of this conference should be clear, concise guidance on good practice in urban transportation planning in the 1980s and recommendations on where the need exists for development of specific practical procedures.

Panel Remarks

LEE H. BOWSER, Pennsylvania Department of Transportation

In an era of severely limited resources, top-level management must be intimately involved in the programming process. To be effective, in a management sense, the programming, budgeting, and authorization processes must be closely integrated. This becomes even more critical as the nation shifts from new highway construction to transportation system management.

Pennsylvania's traditional approach to transportation programming was based on a county-by-county allocation of anticipated resources. These county-by-county allocations drove the capital program development process. Noncapital program development was scattered among various organizational units within the Pennsylvania Department of Transportation (PennDOT). Other than the 12-year forecast of available federal aid, there was almost a complete lack of financial planning. State funds were provided through bond financing.

These conditions and an indication of serious concern by the Pennsylvania Assembly about PennDOT's ability to carry out its appropriate role led the department to reconsider and restructure its operation to be more effective in the areas of development and management. In a bold organization restructuring, PennDOT shifted from its traditional allocation approach of transportation programming to an integrated organizational approach. This restructuring was accompanied by a parallel realignment of fiscal and systems management functions. Program priorities as well as key program decisions are now made through the Program Management Committee chaired by the Secretary and made up of the department's nine top managers. Programs are developed by the newly created Center for Program Development and Management, which develops and presents options to the Program Management Committee. Fiscal implications are analyzed by the Fiscal and Systems Management Center. The entire process is monitored and managed through computerized management information systems maintained through the Fiscal and Systems Management Center.

In summary, the key to successful program development in Pennsylvania has been the department's ability to bring together programming and budget functions at the very top level of management. Information and monitoring systems have been instituted that allow top management to be involved not only in decisionmaking but also in monitoring implementation. This is accomplished by active involvement of metropolitan and county planning organizations in the program development process and continuous liaison with the General Assembly. The department's integrated organizational approach to programming has enabled Pennsylvania, within 20 months, to nearly double the amount of federal aid obligated to more than half a billion dollars. During this same period the department focused limited resources toward restoration of its extensive existing highway system.

Finally, open, effective programming has been one of the key contributing factors to rebuilding the department's credibility with the General Assembly. Two years ago a disenchanted General Assembly considered legislation to dissolve PennDOT. For the first time in a decade, the General Assembly as a body understands and endorses the department's program, believes that it will actually be accomplished, and because of this has provided the revenues to finance it.

GORDON A. SHUNK, North Central Texas Council of Governments

The crux of the most important issue before us today, and certainly for several more years and probably for many years thereafter, is how to cope with constraints on urban interaction. The list of constraints is endless, but it is headed by limitations of funding, available land, human tolerance (both physical and emotional), and natural resources. These constraints are increasingly affecting our ability to move people, to transport goods, and to effect many more types of interaction. The problem is worse in urban areas because more people and activity are located there, but it is also important in rural areas and for intercity activities.

The most important advantages we have in this situation are intellectual creativity and the human will to overcome. It is time, and this conference is an appropriate point of departure, to begin refocusing on the problems caused by these constraints and to develop creative ways to apply old and new technology to these situations. This does not mean that we should develop new tools, for too often we look for a new method to solve an old problem. We need to make better use of techniques we now have to solve the real problems. This reflects constraints on both funds and time available to solve these problems. The charge to us all is to better understand both existing situations and technology in order to attain the best fit of solution to problem.

IAN V. OLIVER, Ontario Ministry of Transportation and Communications

There are two major areas in which we see a critical need for more appropriate analytical tools to support transportation decisionmaking at the strategic policy and systems-planning levels. These are the areas of urban transportation and intercity goods movement and personal travel.

In the urban area, we need to be better equipped to test policy or system-level decisions by answering a series of "what if" questions, which would need to address the whole range of exogenous, as well as endogenous, variables affecting our traditional views of the transportation supply-and-demand relationships.

In the intercity area (nonautomobile mode), we are entering a period in which state or provincial levels of government in North America are identifying a role for themselves that is significantly different from the traditional regulatory one. We do not have the same in-depth knowledge and understanding of this essentially private-enterprise domain as we do of urban transportation and rural highway sectors.

New policies and programs are attempting to address intercity needs on the basis of minimal standards of accessibility, mobility, shipper and passenger service, etc., while at the same time seeking to preserve or enhance the commercial viability of the private carriers.

In the intercity area, we need methods of determining the current and potential market responses to any new initiatives for which government is the proponent. The implications of any initiatives proposed by government agencies need to be tested beforehand and monitored during implementation against factors related to public response, revenues and costs, carrier viability, and public expenditures.

More specifically, our future efforts in the area of demand analysis and forecasting techniques must emphasize the development and application of methods that are more responsive to the quick-turnaround requirements of today's decisionmakers. In other words, we need methods that are fast, economical in terms of cost and input data, and transparent to the decisionmakers. We must be able to easily comprehend the relationship among the model structure, the inputs, the outputs, and the sensitivity of the decision choices to these variables within the broader context of uncertainty in the environment that affects the transportation sector.

In order to be relevant to real-world requirements, travel demand analysis and forecasting methods need to be translated, simplified, and applied as the discrete steps of the traditional four-stage process rather than as mystical computerized operations contained within a black box.

AAD RUHL, Netherlands Ministry of Transportation and Public Works

If we look at transport from a European perspective, it should be kept in mind that in most European countries, and certainly in the Netherlands, the role of the private car is different from that in the United States. For most journeys there is an alternative to car use formed by a combination of public transport, cycling, and walking.

The 1960s can be characterized as a period of growth. The main questions for the analysts then were how fast and how far this growth would go. They had to produce growth rates and situation levels, and although social benefit-cost methods were developed, their influence on levels of investment and general policies was not very great.

During the 1970s we were faced with constrained growth. Constraints were encountered in the fields of energy, spatial aspects, and the environment. Also, the intentions for so-called minority groups or transport-disadvantaged developed.

Since the 1980s have only just started, it is very difficult to characterize this decade. It can be a decade of little growth, no growth, or decline. This implies that the uncertainty that was present in existing analysis methods due to insufficient understanding of the decision processes or inadequate mathematical analysis techniques is now overwhelmed by a fundamental uncertainty about the external factors influencing transport. This situation requires new planning methods in which forecasts with sensitivity analyses will have to be replaced by the development of diverging scenarios.

In the Netherlands you can now see a slight decline in car traffic (not car ownership) and a considerable growth in public transport. Similar developments are occurring in other countries on the continent of Europe.

Research needs can be qualified as follows:

1. Financial analysis methods for transit and highway operations linked to an evaluation of effects of policies on users;
2. Information on travel needs and their importance (not all needs can be satisfied--giving financial constraints and choices in transport policy will work to the advantage of some and the disadvantage of others; in France a proposal for inland transport law is based on the concept of satisfaction of needs);
3. Behavior of travelers in situations where available income declines; and
4. Development of life-styles and influences of opinion leaders in this respect.

In all these activities, individual differences in behavior and evaluations should not be considered as a statistical disturbance but respected as an essential element of freedom.

Planning-Context Workshops

Workshop on Strategic Planning

Workshop Summary

DAVID SCHULTZ, City of Chicago, and FRANK SPIELBERG, SG Associates, Inc.

The main function of strategic analysis is to identify issues that are likely to become critical in the future, to identify data and analysis techniques to deal with these issues, and to analyze alternative courses of action.

The major components of strategic analysis are

1. Sensing and analyzing the environment,
2. Anticipating changes and assessing their implications,
3. Specifying objectives,
4. Identifying and evaluating means for attaining objectives,
5. Providing direction, and
6. Allocating resources.

Although strategic analysis is generally thought of as a high-level, long-range activity, it is needed and should be applied (at an appropriate scale) at all levels of program and project analysis. Therefore, it should permeate all aspects of planning.

The methodology of strategic planning consists of a large number of technical activities, listed below:

1. Socioeconomic and demographic forecasts;
2. Data-management and evaluative information;
3. Performance monitoring;
4. Traditional urban transportation planning process, consisting of (a) trip generation (change in socioeconomic variables), (b) mode choice, and (c) assignment of traffic and peak hour and design elements;
5. Alternative scenarios;
6. Sketch planning for systems and for corridors (policy assessment and facility options);
7. Agency management planning and policy direction;
8. System policy planning;
9. Freight study, such as commodity flows (state);
10. Goods movement (urban);
11. Pavement management;
12. Revenue forecasting at state and area levels;
13. Impact assessment of short-range planning or project on long-range plan;
14. Impact assessment of change in exogenous variables;
15. Behavioral demand modeling and demand modification; and
16. Market segmentation.

Although many of these activities are often applied to higher-level contexts, most are also applicable, in principle, to other contexts as well.

The Workshop on Strategic Planning concluded that, for the most part, methods appropriate for strategic analysis are available. The major failings are not in methods but in lack of an institutional climate receptive to the strategic-planning function and availability of data relevant for strategic analyses.

The workshop recommended that planning agencies at all levels allocate some resources to strategic planning but insisted that issues addressed in the strategic function be relevant to the agency [e.g., strategic analysis at the U.S. Department of Transportation (DOT) would embrace a far wider scope than that of an individual MPO]. Results of strategic studies should be made available to agencies at other levels and illustrated with examples of successful applications.

A process for monitoring, analyzing, and describing the societal contexts should be established. It should include and analyze forecasts from other fields (individual and institutional behavior, technology, economy, physical environment). The process should maintain, monitor, and analyze multiperiod data related to perceptions, tastes, and values as they relate to travel behavior. It should also observe and analyze the effects of changes in institutional structures, impacts, and distributional effects. Technical work on methods to support this process includes

1. Further work on causal models relating travel behavior to tastes, values, and attitudes;
2. Basic work on travel response to pieces and other constraints;
3. Analyses of financial policies, especially those of private institutions;
4. Better understanding of causal factors influencing private investment; and
5. Simplified applications of demand-analysis techniques with special attention to techniques suited to high levels of aggregation.

Finally, the workshop recognized the need to spur interest and communication between practitioners and decisionmakers on the subject of strategic planning.

Issues in Strategic Planning

FRANK SPIELBERG, SG Associates, Inc.

A standard implicit assumption in transportation planning has been that there is temporal stability in travel behavior relationships. A model developed for a given urban area at a particular time may not be transferable to another geographic area but should hold with some validity when used to make future projections for the same geographic area. It should be obvious that there are problems with this assumption. Travel behavior data observed at time t_0 reflect the environment at time t_0. Numerous factors, including individual expectations of transportation system characteristics, dwelling unit composition, disposable income expenditures, and the like, affect all travel choices. All those factors are therefore implicitly represented in any travel demand relationship.

We know, however, that shifts are occurring in many of these implicit elements. During the 1970s there were dramatic changes in the composition of the typical household that have no doubt affected the validity of demand models in which dwelling units were a key variable.

The travel habits of women have changed as their role in society has shifted and they have entered the labor force in ever-greater numbers. Trip distribution or mode-choice relationships based on a typical population may no longer represent the population of the 1980s.

Automobile ownership and operating costs, in real terms, have risen. This shift may affect not only the choice of mode but also decisions regarding trip length and destination choice or even more basic residential location decisions.

Other illustrative examples of changes in basic conditions could be given. Rather than attempt to present an exhaustive list, however, let me mention only one more--the change in the real cost of home ownership. Although this shift started around 1976, it has been particularly noticeable in the past two or three years. This change may only be a short-term aberration or may represent a long-term phenomenon. The effects are still uncertain, but they could include a reversal of the trend to small family size, lessened residential mobility, or a shift in residential location patterns.

It is one thing to recognize that shifts in basic conditions affecting travel demand are taking place; it is quite another to know how to deal with the uncertainty in projections that these changes introduce. Even if we knew how to cope with the changes, we do not know whether or not the observed trends will continue. Put another way, we can deal with the unknowns; it is the unknown unknowns that give us trouble.

I will not attempt here to review the trends in basic social, economic, or demographic factors affecting travel demand. These are adequately addressed elsewhere. Nor will I attempt to suggest in detail how the strategic planning process will deal with the uncertainties introduced by the changing environment--that is the purpose of this workshop. Rather, the material that follows presents some of the issues that will need to be addressed. The list is not exhaustive; it is based only on my observations of demographic factors and of planning issues being raised in various cities.

GASOLINE PRICE AND AVAILABILITY

The transportation issue that seems to have the greatest public attention is the cost and supply of transportation energy, especially gasoline. The public mood ranges between gloom when prices rise and shortages are predicted and euphoria when the popular press reports an oil glut. The public swings from forecasts of restrictive conservation with limited mobility to projections of gas stations once again offering giveaways and the resurgence of Detroit.

Most serious analysts believe that neither of these extreme conjectures is likely to occur. Continued real increases in the cost of transportation energy are projected through the 1980s, but moderate conservation measures, especially improvements in vehicle efficiency, will keep the cost per mile of highway travel, in constant dollars, at levels roughly the same as those for the 1980-1982 period for at least the next decade.

Even these cost levels, however, are greater than the automobile travel costs prevalent at the time travel behavior data in most urban areas were collected. Thus, we have travel-forecasting models that in many cases are built on a data base in which real automobile travel costs are implicitly significantly lower than will exist over the next decade.

As a result, the issues we might consider include the following questions:

How should long-range forecasts be adjusted to reflect changes in the cost of automobile transportation?

Do current procedures permit accurate assessment of the effects on lower-income groups of alternative transportation policies?

Related to gasoline cost is the question of availability. Although the United States has made significant progress in reducing its dependence on the members of the Organization of Petroleum Exporting Countries (OPEC) for imported oil (and even greater progress in reducing its dependence on the less reliable OPEC sources), there is still the real probability of sporadic supply constraints. Some work has been done on contingency planning, but it is generally agreed that we cannot afford to maintain systems solely for use in periods of supply restriction. Questions appropriate for strategic study include

What types of programs should be available if gasoline restrictions occur? How should the programs be managed? How should the cost be allocated?

Should a proportion of the costs of nonautomobile systems be allocated to their stand-by function?

Actions to promote efficiency of petroleum consumption have already been implemented but as a result of legislative action based on balance-of-payments considerations rather than personal mobility. Since the cost of automobile use is projected to be reasonably stable, there is no need for action planning for price changes. Availability is a different issue. Here planning is useful but choice-oriented procedures are probably not appropriate. If shortages become sufficiently severe to warrant implementation of formal contingency plans, the requisite programs will be deterministic.

HOUSING PATTERNS

The shift in population from central cities to suburbs has not abated. In spite of well-publicized instances of gentrification, city to suburb movement has continued as middle-class blacks have followed the trend of middle-class whites. The most likely projections suggest that this trend will continue. The single-family home is still the desired goal of most families and the expanding suburbs remain the areas in which such homes are being built. If this in fact occurs, the strategic forecasting procedures in use will likely be applicable.

However, as we are all aware, the real cost of buying a new home has risen sharply. Prior to 1976 the true rate of mortgage interest, given inflation and tax incentives, was negative for most families. This is no longer true. Creative financing, downpayment assistance, variable-rate mortgages, and the like may succeed in bringing monthly payments into a range such that home purchase patterns experienced between 1950 and 1976 may again become the norm. If the mechanisms do not achieve this goal, changes in both housing and transportation patterns may occur.

Housing pattern changes could take several forms, including an end to the decline in family size due not to greater fertility but rather to a return to multigenerational families or expanded house-sharing adopted as cost-reduction strategies. Evidence of such arrangements is already appearing. Many older individuals who live in a large house purchased when the family had growing children are now renting out part of the dwelling. In some localities zoning laws have been changed to permit such use. Even where precluded by zoning, such arrangements are common. Frequently the boarder is another elderly individual. An interesting twist, however, is the reported situation in which an elderly owner offers a reduced rent to a young tenant, who in turn agrees to provide transportation for the owner.

These expanded households will probably have trip rates and trip patterns significantly different from those of the typical single-family household.

> How can demand forecasts recognize the probability of shifting household composition? How can the uncertainty element be taken into account?

The data suggest a continued trend to low-density living, although signs of a moderation or reversal may possibly be discerned. If the projected trends persist, suburban travel will become more difficult. However, even if there were agreement on desirable or efficient housing patterns, there is little, if anything, that could be done to promote these patterns. Transportation analysts can only monitor the housing patterns in their area and review their plans on a periodic basis to ensure that demands can be accommodated.

ELDERLY POPULATION

It has been recognized that age, or more properly life-cycle stage, is related to individual travel patterns. Aside from areas that have a substantial retirement population (e.g., Phoenix), however, metropolitan planners have not typically given special consideration to the elderly. Yet this segment of the population will grow rapidly for the remainder of the century.

Most studies of the elderly to date show them concentrated in central cities and more dependent on public transportation than the general population. Related studies suggest that these observations merely reflect choices made and habits developed by these individuals in previous years. The location and travel habits of the elderly in 1990, by contrast, will be those of people who were 30 to 40 years old in the 1950s. They will be found in suburbs rather than cities and, unless inhibited by physical impairment or reduced income, will choose to drive rather than use transit.

> If there is a significant suburban elderly population who cannot drive, what type of service can provide for their mobility? How can this service be efficiently provided? How strong a lobby group will the suburban elderly form?

Here again, the analyst's role should be to monitor the location of the elderly, their travel patterns, and their needs.

NATIONAL MIGRATION (SUNBELT-SNOWBELT)

Much has been written about the shift in population from the northeast and north central regions to the South and West. This generalization is broadly accurate, although selected northern cities are growing and selected southern cities are declining. The overall trend represents a continuation of the historic U.S. pattern of migration to open spaces, as well as a shift from the North to the South and West as the receptor areas for both foreign immigration and rural-to-urban migration.

The major transportation effects of this shift relate to trip patterns and mode choice. Cities of the North and East were developed at densities that permit reasonable transit service and have established transit systems. New cities of the South and West have expanded during the automobile era and lack both the established transit system and the population densities conducive to transit use. Yet, even some of these automobile-oriented cities are finding it increasingly difficult to cope with growing automobile demands.

> Will the more rapid growth of the South and West compared with that of the North and East continue?
>
> Will higher-density concentrations develop in these growing cities?
>
> What type of public transportation service is appropriate in these newer cities?
>
> Can the transit systems of the older cities be maintained and revived?

The effects of interregional migration are of primary interest to planners in each urban area. If their area is a growing region, additional facilities will be required; if the area is stable, greater attention can be directed to system maintenance. At a local level the principal action will be to monitor migration trends to see whether they are continuing or if other factors (e.g., water supply) are reversing current patterns.

Similarly, at a national level, continued South and West movement would suggest highway funding emphasis, whereas stabilization or reversal would suggest renewed attention to transit.

TRANSPORTATION FINANCE

The types of tactical transportation actions that can be considered are constrained by the strategic decisions made on the levels of financing and restrictions on the use of funds. Having come through a period of relatively free spending on all transportation modes, all agencies are now adjusting to reduced real funding levels. Both highway and transit systems have faced the combination of rapidly rising costs and reduced real revenue.

For highway systems the financial issues will focus on maintenance and reconstruction of all facility types and construction of arterial roadways. Methodologies to deal with issues of cost allocation among the several classes of users and between the public and private sectors will be essential. The demand-forecasting elements of the process, however, seem to be adequate for the job.

Several commentators have suggested that public subsidies for transit are out of control. The increased government contributions to transit operating budgets have resulted from decisions to maintain low fares, rapid increases in fuel and labor costs, and expansion of services into areas of lower transit use. It is almost certain that real increases in public contributions to transit costs will not continue to grow at the rates of the 1970s, and the public subsidy may in fact decline. The traditional responses to budget constraints are to raise fares and reduce service. In the public operating environment these actions have limitations. Fare increases contravene one of the stated public goals of low-income group mobility. Service reductions often endanger the political coalition developed for regional transit support.

Options being considered to avoid this dilemma include targeted fare increases, user-side subsidies, more specialized services, and increased private-sector involvement in the provision of transit service. In particular, it is argued that for the majority of the population (not necessarily the majority of transit riders) service is of greater importance than fares and the substantially higher fares would be paid were service quality improved. In selected cases, private entrepreneurs, freed of much regulation, including existing labor contracts, could provide tailored transit service at fare and cost levels that would lead to profit. Greater freedom from regulation in the provision of taxi and other paratransit services is also proposed.

> What would the effects be of greater competition in the transit market? Are profits for some services a reasonable expectation?
>
> For what routes or service types should market competition be encouraged?
>
> How would user-side subsidy affect user choice and transit economics?
>
> What are the mobility and economic effects of either reduced transit service or monopoly relaxation? What is the incidence of these effects?

The entire issue of transportation system financing is one in which the transportation professional can have a role in strategic planning. The key to influence in this area is to develop reasonable measures of need together with credible measures of the benefits associated with any type of transportation investment. The quality of transportation financing and investment decisions, overall, would be improved were there better methods for evaluating the joint effects of transportation and other public policy decisions on community development and on the economic activity in the community. Such analysis would encourage a more rational allocation of transportation resources.

TRANSIT SECURITY

The popular image of many transit systems is one of a lower-class service. Rowdy behavior, loud radios or tape players, smoking, graffiti, and similar conditions often lead to the perception that a transit station or transit vehicle is not a secure environment. This perception no doubt dissuades some individuals with middle-class mores from using transit and contributes to the eventual abandonment of at least some transit services by the groups who could afford or would pay reasonable fares.

> To what extent do perceptions of security affect transit ridership? What types of actions would be effective in changing this perception? How long would it take for actions taken to improve security to result in increased ridership?

DEVELOPMENT OF CENTRAL BUSINESS DISTRICT

In spite of the much-heralded decline of the central cities, there are many central business districts (CBDs) that are experiencing rapid growth in office space and project substantial additional growth over the next decades. Although Dallas and Houston are frequently cited as examples of this phenomenon, it is true for selected cities in all parts of the country. However, there are limits on the transportation capacity serving CBDs. Most of the radial freeways to be built under the Interstate program have been completed. The ability to add CBD-oriented freeway capacity is limited not only by financial constraints and neighborhood impact issues but also by the real problem of what to do with the cars when they reach the CBD. In the growing CBDs, land is becoming too valuable to devote to surface parking. The costs of structure parking, however, now require daily revenues in excess of $6 per space to achieve break-even levels. Drivers may not be willing to pay these rates.

Public transit, the alternative usually considered when highways are congested and parking is costly, can provide added capacity but is faced with its own financial difficulties. Peak bus services are quite costly and will require high fares if subsidies are to be contained. Rail systems can also provide capacity but few new starts will be considered in the present financial climate.

> Will existing transportation capacity be a constraint on CBD development?
>
> How can capacity be expanded within the financial abilities of metropolitan areas?
>
> How should the costs of capacity expansion be affected?

Growth or decline of the CBD in any specific region will relate to a host of factors other than transportation, including the economic base of the region, city policies, and historic practice. Transportation may be a necessary but not a sufficient condition for CBD development. The analyst will need to monitor CBD activity in his or her region to ascertain the rate at which existing transportation supply is being consumed. Methods and techniques will be required to assess spreading of peak traffic times and the effects of congestion (or of improvements) on economic investment in the CBD. The techniques will also need to be able to consider the effects of specific modal actions (e.g., automobile, ridesharing, transit).

SUBURBAN TRAVEL

The most rapid growth in travel demand has occurred in the suburbs of metropolitan regions. This results from the growth of population in the suburbs and the greater trip rates of suburban residents. Suburban-oriented travel continues to increase as employment centers in suburban areas become more prominent.

Suburban trip patterns differ from those of central cities. They are less focused (i.e., nonradial) and more automobile oriented. The transportation actions needed to provide central city access, although costly, are known. For suburban centers the solutions are less well defined.

Suburban centers are designed for automobile access, but congestion at suburban locations is becoming a common experience. The road space in suburban areas is frequently limited based on preexisting rights-of-way. Frequently, those existing arterials have been widened to practical limits. Existing neighborhoods restrict the availability of new rights-of-way, whereas dollar costs and environmental considerations serve as further constraints on roadway development.

Are there actions that can be taken either to reduce suburban highway congestion or to provide alternative mobility? (Conventional transit is not efficient in most suburban locations.)

Does the design of suburban commercial and employment centers contribute to inefficient transit service? What types of practical changes in design could be encouraged?

What will be the long-term effects (on development, on trip patterns) of increased suburban highway congestion?

The problems of the suburbs will be in many ways akin to those of the CBDs--how to provide service to concentrations of development. The difference is that most CBDs are served by established transportation systems including public transit and radially oriented freeways and have trip patterns amenable to use of those systems. Suburban centers are developing after the period of great highway expansion. They lack efficient transit and have more diverse trip patterns.

Analysis issues and required methodologies are similar to those for CBDs--how does congestion spread and how does congestion affect trip patterns? More work, however, will be required on developing practical solutions for analysis.

PLANNING FOR RECONSTRUCTION

Many of the urban freeways constructed under the Interstate program will be reaching the end of their design life during the 1980s. These facilities will need major reconstruction and maintenance, not only to restore their physical integrity but also to accommodate greater traffic and modern design standards. Frequently, closure of all or part of the facility for extended periods will be necessary to permit reconstruction.

Closing a freeway is quantitatively different from closing an arterial. Freeway traffic volumes are typically two to four times greater than those of arterials; there are rarely alternative facilities of similar quality that have the capacity to absorb additional loads; the limitation of access and egress traps drivers in traffic congestion; and even if alternative capacity exists, travel times may double. Since the condition is temporary, drivers will not adjust long-term patterns to accommodate the changed transportation supply.

What effect do temporary changes in transportation supply have on travel behavior?

Will travelers accept short-term mode or time-of-day changes when road space supply is restricted?

If alternative services are provided, how should they be funded?

How should major system reconstruction be planned?

TELECOMMUNICATIONS

Reading the popular press could lead one to believe that we are approaching the time when all communication and information transfer will be by wire. All travel, save that of those who repair communications equipment, will be abolished unless made for the pure pleasure of travel. Clearly, significant advances to improve the capability and reduce the costs of telecommunications are being made. Many types of tasks, ranging from computer programming to secretarial services, can be conducted from remote locations, frequently the individual's home. Even some retail shopping functions appear to permit substitution of communications for transportation.

Yet the workplace involves more than information exchange. Many jobs still retain a physical element. Face-to-face meetings in which subtle body language conveys more than spoken words are essential in many managerial or marketing activities. Even for those who deal solely with information, gathering at a workplace may offer psychic or social benefits that outweigh the inconvenience of travel.

Strategic planning for the 1980s and, more pertinently, the 1990s must recognize the potential for the communications revolution.

To what degree can communications substitute for work or other travel? What types of jobs are amenable to such substitution? Are person-miles of travel likely to be reduced?

Will communications lead to changes in workplace location? What functions could shift from the CBD to lower-cost suburban space? Will suburban remote offices develop? Will office dispersion affect midday travel patterns?

SUMMARY

The issues presented above represent a broad range, from the long-term effects of suburban growth to the immediate effects of facility closure for reconstruction. All are representative of the types of problems that will be faced by transportation analysts.

Existing, widely used methodologies are applicable to some issues. Most other items can be addressed by methodologies or techniques that have been reported in the literature but for various reasons have not been widely adopted by practitioners. I have in mind here, in particular, the issues of the effect of congestion on overall travel patterns and on economic development. These available methods will likely come into greater use as the issues come to the fore, as information dissemination continues, and as newly trained practitioners enter the field. Further work, however, is needed to assess the validity of these techniques and to develop tools to ease the application of the methods.

Several of the issues relate to allocations--of costs, of benefits, of use. Here demand forecasting is not the primary product but merely an intermediate step. The practical problems are credibility, reasonableness, and understanding when the results of the analysis are used for funding justification.

This conference is related to travel analysis and most of the discussions will likely be related to research needs, methodologies, and procedures. In these discussions we must remember that the issues will arise whether or not specific analysis techniques are available and that analysts on the firing line will be more interested in finding solutions than in sophisticated analysis. As they have in the past, these analysts will improvise by using existing procedures, modifications of available techniques, or ad hoc back-of-the-envelope methods. The products of the effort will depend more on the creativity of the planner in recognizing problems and devising options to test than on the specific techniques used to evaluate alternatives.

Research Needs

1. Relationship between regional investment in transportation infrastructure and regional economic activity

a. Analyze government policies and evaluate transportation funding needs
b. Assemble data on regional characteristics and economic activity and quantify aggregate transportation supply
c. Model observed relationships between transport investment and economic activity; isolate effect of transport investment and quantify its contribution to the regional economy
d. Make case studies of the impact of varying investment levels on regional economic activity

2. Causal models of travel

a. Determine how to transform underlying individual life-style values, priorities, and preferences into future travel behavior to provide a means of identifying changes in individual goals and objectives that underlie and/or determine changes in qualitative and quantitative characteristics required of transportation technology
b. Transfer the behavioral data through some modeling process that reliably and rapidly relates such data to transportation investment decisions

3. Causal models influencing private investment

a. Determine and use transportation investment trends; establish ratios of public and private involvement
b. Determine regional development objectives based on economic indicators, employment trends, and population shifts
c. Develop behavioral techniques for in-depth interview with investors and those in public sector responsible for leverage to establish influencing factors that create investment
d. Establish link between transportation for transportation-related variables and investment decisions; also establish thresholds of investment: at what point is investment decision made and how the timing of investment affects strategic plan

4. Simplified applications of demand analysis

a. Assess existing models and their relevance
b. Determine bounds on level of aggregation and level of complexity of techniques
c. Assign confidence intervals to forecast values
d. Develop forecasts according to a scenario of inputs
e. Explore new techniques and their applicability to the existing situation

5. Providing mobility in the suburbs

a. Categorize typical suburban trip patterns
b. Estimate probable trip densities and compare with typical supply density
c. Estimate probable congestion growth
d. Analyze actions to reduce congestion
e. Categorize and analyze institutional, financial, and physical constraints

6. Successful communication

a. Identify successful communication tools or methods now in use between strategic planners and decisionmakers
b. Survey, identify, and distribute good examples of successful communication between a strategic group and decisionmakers

7. Basic work on travel changes in response to price constraints
a. Determine distributional effects of increases in automobile operating costs
b. Identify pockets of emerging demotorization and their effects on life-styles, employment, etc.

Workshop on Long-Range Urban Systems Planning

Workshop Summary

DARWIN G. STUART, Barton-Aschman Associates, Inc.,
and JOSEPH L. SCHOFER, Northwestern University

The principal finding of this workshop is that the rate of development of new techniques for travel forecasting has outstripped the rate of innovation in planning and policy analysis practice, which has resulted in the use of inappropriate, ineffective, and inefficient procedures in some (perhaps many) aspects of practice. Particularly at a time when issues and resource availability are changing rapidly and difficult decisions with implications for the long-term future of transportation systems and their users are being faced, more responsive and effective tools are needed to support policy choices.

The gap between state of the art and state of the practice appears to be larger in the United States than in some European countries.

Most members of the workshop believe such superior tools are available. Some doubt the accuracy of such tools in forecasting, although what is known of the accuracy of traditional methods is both limited and discouraging. Resources are not being applied to answer such critical questions regarding accuracy. The very agencies that supported development of the innovative tools have not supported their testing or routine implementation but instead promote traditional and often unresponsive approaches.

It was agreed that the essential problem with respect to travel forecasting in long-range planning is this failure to implement potentially more effective tools. In today's planning environment in the United States, the policies of federal, state, and local governments provide no incentives for forecasts to be right, no penalties for being wrong. Since the marginal cost of innovation is greater then zero, professionals have a clear incentive to continue using old, often unresponsive travel-forecasting tools. Federal support for these tools, the unwillingness or inability of professionals to keep current, and the pressures of planning in a resource-constrained environment lead to a failure to use available, potentially better procedures.

It is noted that precisely the same issues were raised at the 1972 Williamsburg conference on travel demand forecasting. Many research ideas stated 10 years ago, through U.S. government funding, have borne fruit, which in the United States remains largely unharvested (although the European experience seems to have been better). Therefore, the conclusion is that the primary need in the area of concern is to move improved techniques into practice: technology transfer is the main issue.

Unfortunately, achieving this transfer is not easy, nor is it even clear how to go about it. However, many members of the workshop felt that significant institutional change is required, not only to encourage innovation, but to provide incentives and resources for it and to eliminate barriers to it caused by fostering the use of status quo approaches.

Emerging transportation issues and options call for improved methods--and better use of existing methods--to predict their implications. These include the following:

1. External trends
   a. Increasing resource prices
   b. Decreased system revenues
   c. Changes in economic structure
   d. Changes in life-styles
   e. Changes in the labor force participation rates by age and sex
   f. Changes in land development patterns
2. Policy options
   a. Pricing changes
   b. Service cutbacks
   c. Regulatory reform
   d. Work-time rescheduling
   e. Improved technology

Changes in key exogenous variables, not well predicted by other (nontransportation) forecasters, demand that we have better input data. This may require that transportation planners expand the purvue of their concern. It is clear that many of the improved forecasting tools available require better (more precise, more diverse, more timely) data than are now available.

Tools also need to change as the nature of options changes significantly. Emerging policy op-

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The degree to which forecasts are understood and used in the decision process seems limited, perhaps because of ineffectiveness at communicating results and the unresponsiveness of tools to the problems at hand. For example, more sensitivity to the informational needs of state and local decisionmakers, particularly for dealing with project-level questions and issues (in a long-range setting), is needed.

Furthermore, the uncertainty associated with forecasts seems to be increasing, yet the ability to define that uncertainty and to communicate it to clients (especially in the context of traditional forecasting models) is exceedingly poor. Uncertainty is covered up or ignored, in part because there is little incentive to do otherwise. Clients and decisionmakers tend to prefer oversimplified, single-valued forecasts and to have difficulty with forecast ranges and associated probabilities or uncertainties.

Three areas need action. First, there is a need to implement improved but existing (or available) methods. This is termed technology transfer. There appear to be many good targets for such implementation, including the following:

1. Sketch-planning methods,
2. Cost and revenue forecasting techniques, and
3. Planning methods for urban goods movement.

Technology transfer is critical, although it is unlikely to work without institutional change. What is needed is a useful, improved product, a receptive customer, and the resources to change. Existing theories of learning and communications can be applied to facilitate this process. This applies particularly to understanding decisionmaker behavior and seeking change through education on key transportation issues. There is a marketing dimension here that involves convincing decisionmakers of the utility of travel analysis tools and their outputs. Promising methods may include the following:

1. "Road shows,"
2. Professional seminars,
3. How-to manuals,

4. On-site demonstrations and "turnkey" delivery of new methods,
5. NCHRP and NCTRP syntheses,
6. Short courses, and
7. More effective use of nearby academic institutions.

The European experience with innovation of improved forecasting methods is rather better than that in the United States. It may be worthwhile to compare the contexts and determine what can be learned from non-U.S. colleagues.

Second, there are important needs to demonstrate the application of new methods to show their utility to potential users and to test their efficacy. Where appropriate (probably not in the long-range context, because of problems of measuring outcomes and comparing with predictions), such formal tests are desirable to show potential users that the use of such techniques is feasible, cost-effective, and likely to lead to more useful products than those available from traditional methods. This activity needs strong support, careful planning, and comprehensive documentation. This activity could be a program of well-designed experiments, perhaps in the context of several field-test sites. Candidates for such demonstrations include the following:

1. Market segmentation analysis methods,
2. Improved survey techniques (small samples, panel methods, etc.) for updating origin-destination surveys,
3. Attitudinal analysis methods and choice experiments,
4. Behavioral games and traveler decision simulation,
5. Trip generation and mode-choice modeling, and
6. Nested logit techniques, e.g., to analyze travel impacts of service cutbacks.

Comparative assessment of available travel analysis techniques by using site-specific demonstrative applications is also needed. Criteria, procedures, and specification tests for choosing among both traditional and newer analysis techniques should be developed to assist practitioners in application. For example, guidance regarding choice of available sketch-planning techniques is needed, showing under what conditions they are best utilized.

While other, more focused research is also needed and desired, the first priority must be technology transfer, so that the backlog of new ideas moves into practice.

Third, some key additional research needs relevant to long-range planning are as follows:

1. Improvement of methods of forecasting exogenous variables to capture and anticipate important changes;
2. Development of appropriate data bases for using responsive models to analyze emerging policy options and exogenous changes;
3. Development of improved capabilities to predict commodity movements, urban and intercity, given changes in facilities, policies, and the economy;
4. Characterization and communication to decisionmakers of uncertainty associated with forecasts;
5. Development of methods to utilize activity analysis and attitudinal data in improved travel-forecasting models, both passenger and freight;
6. Analysis of relationships between life-style and life-cycle trends and travel needs and behavior for use in improved travel models; and
7. Development of methods to analyze demand-reduction policies, going beyond mode choice toward understanding more fundamental changes in travel behavior.

Long-Range Urban Transportation Planning: Are We Creating New Life or Resuscitating a Dinosaur?

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Specifying future needs for long-range transportation planning is a challenge not easily met. This is because it is not at all clear what real needs long-range planning does, and can, meet in today's environment. True, this form of planning has been around a long time, and many exciting and lasting ideas and proposals have come from it (1). The idea of planning in general, and particularly long-range planning, is rich in logic. We need to prepare for the future by anticipating its attributes, exploring alternative ways to meet them, recommending preferred system development schemes, and specifying the resources required to implement them. Uncertainty about the future, the likelihood of major changes, and the high costs, large impacts, and long lead times associated with many options demands that we be cautious, exploratory, and prepared.

Indeed, the original long-range transportation plans took up this challenge, developed new methods and models, tested many interesting ideas, and produced reports that were rich with proposals, exciting, and sometimes influential. This was particularly true of the grand old studies such as those done in Chicago, Detroit, Pittsburgh, Philadelphia, and New York; many important methodological bells and whistles, not to mention policy-development contributions, have been added by later studies.

The federal government, responding to the successes of early long-range transportation planning efforts (and particularly to the availability of tools) as well as to the enlightened philosophy that planning, as exploration of and preparation for the future, makes sense, seemed to agree that long-range comprehensive transportation planning was good for almost everyone. Hence, an expanding, seemingly infinite series of regulations was promulgated that mandated this kind of planning for all major cities desiring federal capital grants, first for highways and later for transit.

With no dispute as to the methodological, conceptual, and pragmatic contributions of long-range transportation planning, it appears that somewhere along the way things changed. Although planning was to be an analysis process in support of decisionmaking, long-range planning, like a campus barbershop in the 1960s, began to appear increasingly like a service without a market. The reason? Although there was support for long-range planning, there appeared to be less and less explicit interest in long-range decisionmaking. And even now, looking back to the 1950s, it appears that a substantial portion of the action recommendations in those original long-range plans were ideas that had been around for a long time; in fact, some of the key recommendations represented prior political commitments, at least some of which might have been acted on in the absence of further planning.

There is very little explicit long-range decisionmaking because the time horizon of most elected officials is, on the average, equal to

$$T_{eo} = 1/2\overline{IE}.$$

where T_{eo} is the time horizon for the average elected official and $\overline{IE}$ is the average interelection interval, $\cong$ 2 years. Of course, the time horizon for a long-range plan is much longer, perhaps of the order of 20 years. Furthermore, from the date of commitment to the plan until the first serious implementation, there is a time lag for design, achievement of necessary legal clearances, etc., of perhaps three years. Now we might argue as follows:

IT = implementation time = three years.

If T_{eo} - IT > 0, i.e., the decision regarding the long-range plan occurs within the elected official's time horizon, commitment to the plan has serious meaning, is worthy of concern.

If T_{eo} - IT < 0, the decision is outside the elected official's time frame, so who really cares?

We argue that in the typical situation, T_{eo} - IT < 0.

True, many immediate decisions are made that have important long-term implications. But the eyes and the minds of most elected officials focus on the next election. Thus, reviewing long-range options, and even selecting them, is often not much different from taking an attitude survey about our future plans to ride transit: it may be fun at the moment, but fortunately no one can hold us to the promise. Furthermore, it makes sense to say the right things, no matter what our real intentions are.

A large fraction of the long-range transportation planning still being done--and there is less and less of this--we think is done in response to existing federal regulations (2) and with much federal support. To the extent that this is like subsidizing empty barbershops because we thought it was a good idea for people to buy haircuts, it is clear that the political winds in Washington and elsewhere are blowing our hair in a different direction. Through a stream of regulatory changes now flowing in the Federal Register (e.g., August 26, 1982), more flexibility is being introduced into planning requirements. In the fall of 1981, planners at many levels met to support the most constructive aspects of these changes and to defend their turf in other areas (3).

Even more important than the federal changes, we think, are the budget constraints that are tightening around state and local governments and that, together with a relaxation of national requirements, are likely to make local decisionmakers look to the cost-effectiveness of long-range planning just as they evaluate the efficiency of their police departments. Rather than being left to our own devices, those of us engaged in long-range planning will have to answer the question "What have you done for me lately?" In the absence of good answers, the doors may begin closing on some long-range planning agencies. In the New York region, this has already happened; the nature of the long-range planning activity--if any--that will remain is not at all clear. And although empathize with our colleagues from New York, we must look toward preparing ourselves for a difficult, challenging future, in which we must either respond effectively or find new roles.

It is past time to explore, openly and aggressively, the nature of those new roles for long-range planning. Otherwise, we must be prepared to acquiesce to the political choice to focus on the short term only. We can, of course, talk to each other about the important long-term demographic, resource, and technological changes that are occurring and use these to argue for the salience of long-range planning. Frank Spielberg, in a paper in this Report, and Martin Wachs (4), among others, have done this job well. Yet we are less than certain that such arguments alone will turn the heads of elected officials. Instead, we will concentrate in the remainder of this paper on the broader issue of what long-range planning can and must do to pique the interests of our clients, the political officials who ultimately sign (or do not sign) our paychecks and make use of our results.

We can no longer afford to devote energies to resuscitating this dinosaur that is long-range planning. Instead, we must explore the possibilities of creating and sustaining new life where it is needed in a form that will survive, adapt, and respond.

REDEFINING THE ROLES OF LONG-RANGE PLANNING

Perhaps even the most skeptical of us could be convinced that long-range planning does, and could, play an important role in the processes of developing and managing transportation resources and systems. To many at this time, however, these roles are cloudy and ill-defined. Part of the problem is that we have never clearly understood and evaluated the contributions of long-range planning in the past. Several studies (5,6) have credited long-range planning with all subsequent transportation successes and blamed it for none of the failures. Others have focused on the errors (7), which has defined our limitations but not treated our positive contributions.

It is probably fair to say that if all long-range transportation planning ceased today, except for the difficulties of meeting federal regulations, few people would notice for a while. Yet in many respects, long-range planning is the only context in which we can pay serious attention to the uncertainties associated with future transportation needs, performance, costs, and impacts (Spielberg, this Report). Indeed, it is dealing with such uncertainties that should and must be the strength of this form of planning, although our tools and processes do not even now respond well to this challenge. Part of the problem, of course, is that no one--decisionmakers, citizens, or planners--deals well with uncertainty (8). More successful procedures are clearly needed, not only for treating uncertainties analytically in the forecasting process, but also for conveying information about them to clients in useful ways. We will return to this issue later.

The existence of our long-range planning institutions and activities has made possible much of the short-term, decision-responsive planning that we do. The assembly and maintenance of timely data bases and the periodic calibration of travel behavior models happens, for the most part, within long-range planning agencies. It is a rare case when a regionwide, comprehensive data base describing travel characteristics and transportation system performance is prepared in the context of short-term planning. When there is an immediate need to prepare a short-term forecast to test alternative actions, we usually turn to the long-term data bases and models. And although it is common that such data bases are out of date, such models do not respond precisely to the policy choices at hand, and the forecasting procedures are cumbersome, we still produce, and often use, the resulting information in lieu of any other support for decisionmaking. The job could be done better, but it is being done now under the aegis of long-range planning.

Even those old, outdated long-range plans have served a function, providing a wish list of pretested ideas and serving as a broad background against which to assess new options. Sometimes proposals developed and tested in earlier long-range planning activities have sat on the back burner until it was in someone's short-term political interest to proceed with them. More typically, of course, the actions of today were never considered in the long-range plans of yesterday, but this reflects the limited vision of our predecessors in planning and politics as much as it indicates the shortcomings of the process.

Tomorrow's long-range planning, if it is to be, must be different from today's. At the very least, we need to conceive of and implement new and varied roles for this function. Long-range planning in the fast-growing Southwest needs to be different--more physically focused and more future-oriented--than it is in the Northeast or Midwest (3). It must also vary with the political context: Where a high degree of interjurisdictional cooperation exists, it can be more integrated, comprehensive, and commitment-oriented; in more fragmented regions, it will necessarily be more exploratory and vague.

We also need to accept and introduce more variation in the recognized products of long-range planning. In some contexts, we dwell too much on producing formal, slick reports containing The Plan, not facing the reality that data bases and models, informal advice and education, and many other such services are among our most useful contributions. To the extent that we explicitly recognize the wide variety of products that we can, should, and do produce, we will find it easier to improve our self-image and boost our support among decisionmakers and the public (2).

Sometimes we notice long-range planning agencies being overly secretive about sharing data resources, models, and analytic services with other competing and complementary agencies and with the public. Although there may at times be real needs to be defensive, one might argue that a broader and more substantial support base might be built if such agencies worked toward strengthening their role as the source of such technical support. What happens in the face of secrecy and isolationism, sometimes, is that parallel capabilities are built elsewhere, and the sympathy for ongoing financial support for the long-range regional agencies declines. To open the doors of such institutions, of course, it may be necessary to broaden their base of political support, so that it becomes a reality that they work for and serve the region, rather than speaking for the narrow interests of one jurisdiction. Incidently, that we occasionally observe such politically motivated secrecy is in itself a measure of the perceived power of the information that comes from long-range planning.

EMERGING ROLES AND CHALLENGES

Long-range planning, its professionals, and its institutions can fulfill at least five feasible and useful roles: preparation, monitoring, exploration of options, long-term budgeting, and ombudsmanship. We view each successive role as more challenging; in some contexts, only the first two or three roles may be appropriate. In others, all five and more may be feasible.

Preparation

Preparation entails gathering and maintaining a timely data base on travel characteristics, transportation system attributes, land development patterns, and resource availability and price, including public finances. This information is essential to planning, both long and short range. Data represent a major product of comprehensive planning agencies and should continue as such.

From the perspective of travel behavior analysis, there is a need for efficient new procedures for continuous, or at least frequent, updating of key data items, especially travel patterns. Small-sample surveys, by using telephone or mail-back methods, are probably appropriate. In addition, we need methods for updating large, older data sets with periodically collected, new data on a rolling basis. We also need the capability to bring new data on line quickly and cheaply, so that it may be used for short-term planning immediately. There are few things more frustrating than performing a 1982 study with 1970 data because 1980 data have been collected but are not yet available for use.

Preparation also includes developing and maintaining responsive forecasting tools that reflect the state of the art methodologically and the state of the world in terms of policy sensitivity. By the latter, we mean that, to the extent that existing knowledge permits, tools should be available that are sensitive to the key policy issues of today. If they are to be used and to have an impact, these tools must be efficient and appropriately scaled to respond to contemporary problems. We should not find ourselves using a four-step UTPS process to evaluate proposed rail grade crossings. This is a well-known requirement (9); the state of the art makes it possible to do this. The state of the practice is often far behind.

The output of the preparation role is the capability to pursue a wide variety of planning analyses, both short term and long term. Without this capability, we really cannot do serious planning.

Monitoring

Monitoring is concerned with using the data base, along with some forecasting capabilities, to detect current trends and project likely future patterns of land use, travel, transportation system characteristics, and resource price and availability. Monitoring may be viewed as an early-warning function that informs decisionmakers and their constituents of incipient issues, problems, and opportunities. Information on such trends should alert planners to the problems that may be on their near-term agendas, what tools may be needed, and what options should be investigated in preparation for formalized problem solving.

Trend monitoring can be viewed in two time frames. For the near term, it may be enough to assemble and review, perhaps graphically, emerging trends, comparing them with previous forecasts and reporting their implications for the performance of the existing transportation system. Studies of longer-term implications require forecasting capabilities that project, by using naive or sophisticated assumptions, key indicators 5-15 years into the future. In some cases it may be sufficient to use trend-extrapolation tools of the type readily available for use on home computers; in other situations it may be desirable to activate larger models better founded on accepted theories.

There appears to be a special need, in this era of increasing uncertainty, for the efficient capability to develop scenario-based forecasts, that is, several forecasts based on alternative assumptions about how the future will evolve. Although there is much in the literature about the value of scenario studies under conditions of uncertainty, there exist no routine, efficient ways to accomplish such a series of parallel forecasts (10-12). A key problem seems to be the translation of qualitative notions about the future into quantitative formats suitable for use in models. More attention might be directed toward models that combine judgmental and quantitative information to produce meaningful forecasts.

The output of the monitoring function is timely information on key trends likely to affect transportation, both a picture of today and useful forecasts (or speculations) about tomorrow.

Exploration of Options

Exploration of options is close to, and in some cases the same as, our traditional concept of long-range planning. It is concerned with defining, testing, and evaluating specific infrastructure, service, and policy options that respond to issues and problems of the type identified in monitoring. Sometimes long-range planners will play this role in response to specific requests or proposals emanating from their clients. At other times, particularly in rapidly growing regions, formal, long-range system planning activities will be required. In the latter case, a broad set of options would be tested at the regional scale. In the former case, the need may be simpler: testing a specific facility proposal or policy option.

Since presumably this is a task about which we know much already, perhaps we have said enough. It is important to emphasize, however, that in a future of diminished resources (and urban growth is one of those resources), there will be fewer needs to test major capital investments but greater needs to explore widespread policy options. Among the latter we include increasing privatization of transit, more flexible pricing of transportation services, modified working patterns, and more significant substitution of communications technology for transportation. Privatization, if the examples in the Chicago region can be generalized (13), means a greater diversity of services, with different qualities and prices. It also demands a role for private carriers in the planning process. Flexible pricing means, among other things, distance-based pricing, zone pricing, and peak-period pricing; these will require more sensitive mode-choice models with more explicit treatment of time of travel. Changes in work patterns--and shopping patterns as well--that arise due to work rescheduling and increased communications capabilities demand that we know more about the intricacies of the time-dependent characteristics of travel. Such policies also beg consideration of their long-term spatial impacts.

We also need effective capabilities to explore the travel and service implications of resource scarcity and increased price. This may demand a radically different forecasting technology, which not only makes such constraints explicit but also allows us to begin the forecasting process with assumptions about constraints and to produce estimates of feasible travel and service requirements. Nowhere is this brand of resource-constrained planning likely to be more important than in the consideration of our ability to finance both the capital and the operating costs of transportation in the future. Indeed, to the extent that any of us are to pursue traditional long-term transportation network planning, we will need to do so with direct consideration of budget limitations. This may reawaken those interested in developing transportation investment optimization models, not to give us optimal solutions but to give us the capability to explore a wide range of solutions under binding constraints (14).

The outputs of the exploration role include predictions of the long-term implications of a wide variety of options: new systems, specific facilities and services, and changed policies. These are all internally defined options that presumably respond to environmental challenges. In addition, emerging long-range planning must also be able to estimate the travel and transportation impacts of environmentally determined resource constraints. Finally, we need to be able to put these together to explore options that will meet our evolving need as resource availability changes. Although decisions about implementing options may be made in the short term, many have long-term implications worthy of careful consideration. A key challenge we face in this kind of planning is finding a way to produce information about the long-term future that is salient to today's decisionmakers. This is a problem that is not irrelevant to travel forecasting, for often it is the forecaster who writes the report or delivers the briefing.

Long-Term Budgeting

Long-term budgeting is not really budgeting in the true sense, because we began with the premise that not many long-term decisions are made, at least explicitly. What we mean instead is exploration of the relationship between (likely) available resources and projected costs to provide and operate transportation services and systems. Although this could be subsumed under the monitoring role, we think it is important enough to stand alone.

Far too much of our transportation planning, in all time frames, has been done without consideration of reasonable budget projections. In particular, we have had a tendency to make (far too low) estimates of capital costs (15) while ignoring operating and maintenance costs in investment planning (16). We must develop appropriate tools to predict the amount of money likely to be available to finance both capital and operating costs into the future, and this information should be used in planning. Under the long-term budgeting role, it may be both necessary and possible to test alternative allocations of financial resources over a time frame of 5-15 years. This may be done as a part of exploration of new options or as a periodic test of the emerging transportation system to assess its feasibility downstream.

The output of this function would be firm ideas about the affordability of various transportation packages, including those that exist and those that are proposed. The transit finance crisis that the Chicago area has experienced for the past few years was easily predictable--and it was predicted. Such forecasts, however, were not made as a part of routine planning activities, and so they had low visibility, were easily hidden, and had little evident impact on decisionmaking. Long-term concern for transportation finance needs to be brought into the open. Here, too, travel forecasting is a relevant task, because a major share of the revenues comes from user fees.

Ombudsmanship

The ombudsman's role, we think, is unique, important, relevant, risky, and potentially impossible. Here we see the need for someone to seize responsibility for the long run and to speak out when necessary to warn of incipient problems. Someone needs to be able to differentiate between political forecasts of regional growth allocation and what may be feasible or likely. Someone needs to point out the impossibility of implementing plans within available budgets or the likelihood that aging of facilities will someday overtake us. When necessary, we have the ethical responsibility to shout, "The emperor has no clothes."

This is a difficult role for long-range planning, for its agencies are necessarily and appropriately dependent on political support--it is through political support that we ensure a market for our ideas. Pointing out the errors or the risks in current policies or trends can sometimes damage political relationships. That, obviously, is why the ombudsman's role is risky. And yet we retain an important responsibility to the community at large, and at times this responsibility may require that we speak out.

The role of ombudsman for the future can be critically important as we enter an era of resource scarcity and increased, short-sighted politicization. Who should play this role and how they should play it are less clear. It is hard to imagine how a public agency can do this, although one agency may do it for another's forecasts. Perhaps we need to define new professional service organizations that can review planning and decisionmaking in particular communities and provide an even-handed evaluation. Alternatively, we can argue that university scholars should have a higher profile as critics, writing for public consumption about the logic, feasibility, and efficacy of plans and trends. The format cannot be decided here. The need exists, and those concerned with travel forecasting should not ignore it.

These are five key roles for long-range planning. We did not emphasize framework or blueprint planning (17); although it may be important in rapid-growth locations, its separation from decisionmaking suggests that it may not serve well as the front-line long-range planning activity. A significant amount of option testing should probably form the core of this function, but the products would not necessarily be in the form of a firm and complete system plan. Thus, the use of the term "exploration" here is quite intentional; it refers to the need to explore long-term, large-scale implications of specific proposals.

We do not claim that these are the only roles for long-range planning, but they are generally important roles that have direct implications for travel forecasting. It is not apparent that any substantial agency could exist on these activities alone, but such tasks relate naturally to planning in other time frames, and together they could provide a full and rich agenda for an organization.

FURTHER TECHNICAL CHALLENGES

The roles characterized above for long-range planning are embedded with several additional, technical challenges in the 1980s and beyond. Some of these are highlighted in this section.

Defining Travel Needs

Emerging resource constraints, particularly those affecting operating and maintenance costs of urban transportation, are beginning to force us to rethink our notion of travel needs. Transit cutbacks, deferred maintenance of highways, and the possibility of downgrading and even abandoning some elements of the highway network are becoming real options for the management of urban transportation systems in a period of scarcity. Our tools, on the other hand, were developed during an era of growth, when it made sense to extrapolate an image of today's travel to define future needs. We need to develop new concepts of travel needs so that we can be more realistic about defining essential services. Manifest demand in most U.S. urban areas is partly defined by ubiquitous, perhaps profligate, transportation services. What would it mean to travelers, the economy, and society to provide less of certain services? Will trips divert to other modes, other times, other destinations or will they not be made at all? What are the consequences of trips not made?

This may suggest that we need travel-forecasting and impact-evaluation models that presume reductions in service and produce estimates of the effects on the region. Through such inverted analyses we may be better able to understand the trade-offs between various budget levels and urban travel; ultimately it would be desirable to relate these trade-offs to the primary economic and social needs from which travel demand is derived.

Characterizing Benefits of Travel

Along the same lines, it may be appropriate to enhance and expand our concept of the benefits of travel and thus of the benefits associated with particular transportation investments. In particular, justification of future transit expansions may require a clearer understanding of the benefits of such services, not simply in terms of time and cost savings, but in a broader framework of utility and social worth. The utility functions at the heart of disaggregate travel behavior models offer a useful beginning point for such analyses; it may be beneficial to go further toward developing a firm capability to estimate the opportunity cost associated with limiting the growth, or reducing the current scale, of urban transportation services.

Evaluating Distributional Consequences

Scarcity of resources--including scarcity of urban growth--can be expected to raise increasingly more difficult questions about interjurisdictional and intergroup sharing of those resources. Underlying our most serious debates about financing both highways and transit is the issue of equity: who pays, who gets what benefits, and what is the balance? More responsive benefit-measurement tools will contribute positively to such debates, as will better methods of both cost estimation and cost allocation. From the perspective of travel behavior, this requires an improved understanding of who uses what services, both at this time and under various future policies.

In terms of the present, this suggests the need for efficient methods to monitor service use disaggregated by traveler and trip characteristics. Such data are commonly not available today, particularly for transit, where they are most needed. The task of collecting this type of data can seem formidable. Needed are straightforward procedures for maintaining a timely data base on system use.

This also presents a challenge to forecasting models to provide estimates of future system use by trip type, traveler characteristics, and time of day. Besides adding dimensionality to the estimation and forecasting processes, these requirements also call for improved accounting schemes for keeping track of trips in many categories as well as techniques for displaying this information in a meaningful way.

Predicting Development Implications

Competition for growth and the increasingly varied travel implications of different forms of growth can be expected to intensify the need to develop a better understanding of the factors affecting urban growth and the role that transportation plays. Such an understanding should then be used to create more successful ways of predicting both the impact of growth on transportation requirements as well as the consequences for growth of particular transportation actions.

Although some tools of this type are available, the underlying conceptual problem is immensely complex, and there is little evidence that existing, transportation-sensitive development models have sufficient validity to be useful for policymaking. Policies in fact appear to be more firmly founded on beliefs--more accurately wishful thinking--than on substantive knowledge. The evidence that major transportation investments can have significant growth impacts today is quite weak and equivocal at that. The competition for new economic and population growth, fundamentally a long-range problem, will demand that we derive effective ways to anticipate the allocation of new development between sunbelt and snowbelt and between city and suburb. Furthermore, if we cannot produce tools to accomplish this task, we ought to be more explicit about this limit to our capabilities, so that policymakers have a clearer notion of where to turn for advice.

Inverted Models for Inverted Planning

Although the traditional concept of the planning process embodies the sequence of setting goals, defining problems, identifying and testing options, and evaluating and recommending actions, it is apparent that many of the tasks assigned to transportation planners are framed differently. It is common to find that planners are given a tentative decision and then asked to test, evaluate, and perhaps justify that decision (18).

Although this might appear unacceptable from an ethical perspective, it is a reality of the decisionmaking process. Furthermore, there is greater likelihood that decisionmakers will be interested in the results of planning and analysis in this context than they might be if planners alone defined the problems and proposed the options. Thus, we might argue that inverted planning represents an attractive opportunity for transportation planners because a client is listening to us from the start.

Contemporary analytic tools can be used for inverted planning. However, it may be appropriate to pursue development of inverted models to facilitate such efforts. The models we envision would take the preferred action as given and derive the requirements to make that action successful. Such requirements might be in the form of needed demand levels (given cost-effectiveness criteria), performance levels, or even travel behavior characteristics. Defining the problem this way, it seems, leads to an underspecified system, where additional assumptions or constraints must be supplied to get a solution. Tools of this general form might be characterized as search techniques that map out the space of possible requirements, assumptions, and additional policies necessary to make a preferred option feasible and/or cost-effective.

With such tools, planners would be better able to respond sensibly and quickly to questions such as "We're going to build a light rail line in this corridor; is it feasible? What are the requirements? What are the implications?" Such responses, we think, would offer constructive assistance to the political process by building a firmer basis of support for planning in general and long-range planning in particular.

Uncertainty in Forecasting

One reason that long-range transportation planning has a limited influence in the policy process is the proven inaccuracy of our forecasts. A recent review of a number of long-range transportation forecasts, for example, found that errors (mostly overestimates of key factors) were so large as to have made it more accurate to have used current state descriptions in place of the forecasts themselves (7). Of course, it is in the nature of forecasts to be in error. We can never eliminate all such errors; instead, we should focus concern on anticipating them and limiting both their size and their consequences. We make forecasts to learn something about the future; the question is, how much can we really learn?

Much research in planning has focused on the source of errors in forecasting and ways to reduce them (19,20). Although this a worthy avenue to pursue, we suggest that an insufficient amount of attention has been devoted to characterizing uncertainty and conveying useful information about it to decisionmakers (18). These challenges are important to all aspects of transportation planning, but they are especially critical for long-range planning.

In characterizing uncertainty, we are primarily concerned with preparing realistic estimates of the likely range of key forecast values. Assessing the level of uncertainty in our final outputs is not easy, largely because of the multiplicity of inputs, estimates, and assumptions involved and the uncertainty associated with each of them. At least as important, we think, is finding constructive ways to convey the nature and significance of this uncertainty to the users of our products. This is essential from the perspectives of both ethical behavior and maintenance of our credibility. Yet the difficulty we all have in dealing with uncertainty suggests that there are both risks and challenges associated with revealing this information. The risks come from the possibility of frightening our clients and ourselves when we speak openly about the reality of uncertainty. The challenges come from the difficulty of explaining the nature and implications of probabilistic processes.

Progress must be made toward resolving these issues through learning to construct useful and understandable information for our clients on what the uncertainty is and what it is likely to mean to them. Although travel behavior forecasts must be a key target of such uncertainty studies, we must not overlook the fact that perhaps the major source of uncertainty lies in the input forecasts used in travel predictions (7).

FUTURE AND LONG-RANGE PLANNING

Eventually we will get to some aspects of the future on which long-range transportation planning focuses. On the way, the long-range planner can serve as explorer, scout, and guide. In only a few circumstances will he or she serve as the architect of that future. The challenges to create the kind of long-range planning to serve these purposes are many, and they affect those of us concerned with travel forecasting as well as others.

We would be lax if we failed to point out that decisionmakers themselves must share a major part of this burden, for they must make many of the choices that will help determine our joint future. The pressures of scarcity and the problems of growth--too much or too little--may help them realize the merits of future-scanning through some form of long-range planning. These characteristics of the environment can be expected to present decisionmakers with more questions about the future and options for it and with more difficult trade-offs and pressures to compromise, share resources, and switch targets.

Long-range planning could help them, if done right. A part of our role as planners, beyond redefining long-range planning, is to educate our clients about the services we can provide and the benefits that may result. This is not a small task, but only through education and communication can we help decisionmakers achieve the intellectual and political shifts necessary to cope with a changing, uncertain future.

The issues are technical, political, ethical, and interpersonal. We must face them because the outcome will help determine the future that is ours. The dinosaur is extinct; but the makings of new life are all around us.

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Research Needs

1. Demonstration of inverted transportation planning process

a. Illustrate a planning process that would not begin with goal setting but with a constraint, such as a specific transit operating subsidy unit

b. Set up demonstration involving an actual problem; develop and document inverted planning process used to address the problem (the issue could be a budget constraint or a preselected alternative such as a rail transit line)

2. Exogenous socioeconomic variables

a. Current need for research on such variables relative to travel needs and behavior includes the following type of study:

(1) Determination of key socioeconomic dimensions today that contribute toward differences in travel behavior

(2) Determination of factors likely to influence the level and distribution of identified socioeconomic dimensions in future years (development of behaviorally conditioned demographic models, which include influence of labor force participation, divorce rates, levels of unemployment, childbearing propensities, etc., on composition of households and components of travel activities)

b. Future data needs for expected policy problems include

(1) Identification of the constraints that current data capabilities have had (and continue to have) on the ability or willingness of various agencies to consider new demand-modeling procedures

(2) Investigation of data configurations stored on disks and the ability to retrieve or represent data in more disaggregated forms to take advantage of small (re)sampling of existing data

3. Life-cycle or life-style trends in relation to travel behavior and needs

a. Identify travel patterns by household life-cycle or life-style
b. Test stability of patterns over time and region (are the patterns constant, are there differences and, if so, can they be explained)
c. Evaluate and/or improve methods of predicting the exogenous variables necessary for predicting distributions of life-cycles
d. Develop models and techniques for predicting tripmaking from this perspective

4. Analysis of methods for travel demand reduction (gas-tax policies and cutbacks in highway systems and/or transit services)

a. Use existing data based on behavior observed in response to cutbacks and/or collect new data
b. Investigate the applicability of existing techniques and survey previous applications
c. Develop new approaches where needs are identified
d. Apply these approaches and demonstrate their applicability
e. Package the approaches for use by others

5. Forecasting internal urban goods movement

a. Determine the effect of future freight movements on urban facilities, specifically the impact of truck traffic on the highway network, by the following methods:
(1) Integration of external intercity goods-movement forecast
(2) Inventory of internal commodity flows by mode, route, vehicle, and terminal location
(3) Analysis of the economics and cost of production, storage, and distribution of goods
(4) Forecast of internal commodity flows by mode--water, air, rail, and truck
b. Test procedures on selected urban areas of different sizes and modal facility configurations

6. Behavioral activity pattern analysis (daily and weekly patterns of individuals and households)

a. Identify behavioral factors influencing the daily and weekly travel-activity patterns of individuals and households
b. Define behavioral processes that affect daily travel-activity patterns
c. Develop methodologies for modeling or analyzing travel-activity patterns
d. Identify segments of the population with respect to travel-activity patterns
e. Validate techniques and develop methods to facilitate technology transfer

7. Characterization of uncertainty

a. Identify the various sources of error and uncertainty that contribute to the uncertainty in model forecasts
b. Determine the interaction of these sources and methods of quantifying overall uncertainty
c. Estimate relative importance of the sources so that the majority of uncertainty may be evaluated more cheaply
d. Replace point-estimate forecasts by range estimates; decisionmakers should be aided in the use of this additional information
e. Focus on alternative models, which will result in difficult ranges; therefore, analysts and decisionmakers can appreciate improved reliability in forecasts

8. Forecasting interurban goods movement

a. Obtain base-year origin and destination matrix for the commodities that make up at least 90 percent of the cargoes moved between U.S. cities, by all modes
b. By means of waybill samples or otherwise, estimate the key volumes of cargoes moved between U.S. cities, in the base year, by all modes
c. Prepare and validate a model relating production and consumption matrix to cargo volumes on intraurban links, for all modes, with regard to movement rates and speeds
d. On the basis of assumed origin and destination tonnages and assumed cargo rates and speeds, estimate goods-traffic movement on intercity links, by all modes, in the design year

Workshop on Project Planning

Workshop Summary

DAVID S. GENDELL, Federal Highway Administration, and ROBERT E. SKINNER, JR., Transportation Research Board

The project-planning workshop began with presentation and discussion of the resource paper. With inputs from the various methods workshops, the subsequent discussions were fruitful and wide ranging. Key recommendations emerging from the workshop are applicable to project planning, but they also address broader concerns of the transportation planning community.

Summarized below are highlights of the workshop, beginning with the working definition used for project planning and concluding with the principal workshop recommendations.

DEFINITION OF PROJECT PLANNING

As a working definition, the workshop used the definition of project planning presented in the resource paper--project planning is the stage in the planning process at which facility and service alternatives are analyzed in sufficient detail to make firm implementation decisions. Under this definition, project planning

1. Is multimodal, encompassing the consideration of highway and transit modes;
2. Is applicable in both urban and rural contexts;
3. Includes the consideration of capital-intensive alternatives; and
4. Focuses on corridors or subareas.

TRAVEL ANALYSIS REQUIREMENTS

Requirements for project-planning travel demand analysis are derived from three related but different objectives:

1. Feasibility or desirability determination,
2. Impact estimation, and
3. Design input.

Although feasibility or desirability determination is probably the key project-planning objective, it is the other two objectives that tend to require the most detailed demand measures. The inclusion of the final objective, design input, recognizes that during project planning demand estimates are often developed that are subsequently applied with little or no change to design criteria.

Illustrative demand measures associated with each of these objectives are presented in the paper by Skinner in this Report.

APPROACHES TO DEMAND ANALYSIS IN PROJECT PLANNING

Two fundamental approaches to demand estimation were identified.

Survey-based approaches rely on surveys and counts to establish existing demand conditions. Then various special procedures and techniques are used to forecast the shifts from known conditions that can be expected as a result of the alternatives under consideration.

Four-step model-based approaches, on the other hand, rely on the conventional chain of sequential travel demand models to forecast demand characteristics for the alternatives under consideration, including no-build alternatives. Refinement procedures are applied to adjust or add detail to raw model results.

The selection of approach has been constrained and influenced by a variety of factors, including

1. Availability of four-step demand models,
2. Availability of data and data-collection resources,
3. Documentation of the practice elsewhere as well as state-of-the-art advances,
4. Staff capabilities, and
5. Past practice.

The four-step model approach has been used most often in urban areas on project-planning studies featuring major transit or highway capital projects. The survey-based approach is associated primarily with highway and toll-road projects but is also used in operational and short-range transit planning.

It was noted that before the 1962 Federal-Aid Highway Act, survey-based procedures were the rule rather than the exception. There was some feeling that the lack of recent experience in data collection has perpetuated use of the four-step model-based procedures.

EMERGING CONCERNS AND NEEDS

The key findings and recommendations of the workshop are presented in the next section. A number of other demand-related concerns and needs for project planning are summarized below.

1. Survey-based approaches are becoming more desirable. This is in part because four-step model-based procedures are predicated on antiquated home-interview surveys that are costly to update and in part because of the increasing need for very detailed forecasts with shorter time horizons. Survey-based procedures can efficiently estimate existing conditions without simulation error.
2. Integrated forecasting approaches are particularly promising. Integrated approaches potentially combine the best characteristics of survey-based and four-step model-based approaches and appear well suited for project planning. Pivot-point and incremental forecasting techniques are existing examples of integrated approaches.
3. Existing forecasting methods handle unconventional alternatives with difficulty. These alternatives, which are increasingly encountered in project planning, include 4-R highway improvements, demand management techniques, and nontraditional public transportation and paratransit services.
4. Project-planning methods should exhibit upward consistency with systems-planning methods and downward consistency with design and operational analysis procedures. Structurally, four-step model-based procedures are inherently consistent with the systems-planning procedures from which they are derived; however, they are not always consistent with subsequent design and operational procedures. Survey-based approaches tend to be just the opposite. For the future, the workshop saw a need for a reduced level of detail in systems-planning techniques; procedures would become more strategic, less detailed, and less data hungry. If so, there would be a concurrent need for upward feedback between project planning and systems planning that generally does not occur now.
5. Demand estimates should be expressed as ranges rather than as point estimates. The explicit acknowledgment and treatment of uncertainty is needed in project planning as it is in other stages of the planning process.
6. The need for quick-response techniques for project planning is increasing. Shorter planning horizons, less capital-intensive alternatives, and the desire for innovative financing create an opportunistic environment that cannot afford a slow, cumbersome project-planning process. Quick-response methods are needed and they should not be confused with sketch-planning procedures. In theory, any forecasting model can be abstracted to a quick-response method. In practice, the question is whether the level of abstraction is appropriate for the issues to be faced.
7. Basic issues must be faced concerning the maintenance of urban travel data bases. Decisions must be made with respect to data that are routinely maintained and data that are collected on a special-purpose basis. The workshop anticipated a trend toward having project planning rely heavily on special-purpose data collection.

PRINCIPAL WORKSHOP RECOMMENDATIONS

Described below are the major workshop recommendations. In many instances, these recommendations have applicability far beyond the limited purview of project planning.

Filling the Gap Between State of the Art and State of the Practice

Project planning requires the use of a wide range of methods, including effective data collection, analysis, modeling, and informed judgment. In many cases, there are already techniques available that would substantially assist in supporting project-planning activities. These techniques are not in wide use either because they have not been effectively field tested or because practitioners are unaware of how to use them. Efforts to close this gap between what is available and what is used are likely to be an extremely cost-effective means of improving the practice of project planning.

Specific actions that might be taken include the following:

1. Provide training courses for practitioners that include areas such as survey and sample design, sketch planning, project evaluation, and recent innovations in travel demand analysis.
2. Substantially alter the TRB Annual Meeting to reduce the number of papers that claim to report on new research and provide sessions with the objectives of demonstrating new project-planning methods in practice and providing educational reviews of the state of the art.
3. Draw on the resources now available in the universities to help in mid-career training.
4. Increase the role of NCHRP synthesis reports, including perhaps a presentation of results to practitioners as part of such contracts.
5. Fund pilot applications of promising new methods in actual planning contexts, perhaps requiring that researchers and practitioners cooperate in the pilot testing. These tests should include comparisons among alternative procedures.
6. Develop more user-oriented software that makes even relatively sophisticated procedures easier to use in project planning.
7. Whenever feasible, existing software should be used to implement available procedures. Many electronic spread-sheet and data-base management programs now available on microcomputers can be used for this purpose.
8. Provide training, primarily of an awareness nature, for managers and decisionmakers. This education process enables communication with users of project-planning output.
9. Make methodology for analysis of nontraditional alternatives (analytical techniques as well as models) more readily available to practitioners.

Implicit in any of the above processes is a recognition by the profession that documentation of research and practice must be in terms oriented to the user and widely understood by the target audience.

All of this may require a reallocation of the resources available for project planning and implementation. It is our view that a shift toward better transfer of methods from the research environment to practice will prove cost-effective. However, it is important to stress that appropriate field testing of new methods is essential before their widespread use is encouraged.

Comparative Studies

One of the most important bridges to be built between state of the art and state of the practice is the conduct of comparative studies of alternative data-collection and forecasting techniques. This is based on the fact that there exists a variety of different state-of-the-art techniques that may or may not have significant payoffs for improving the state of the practice. Further, a key ingredient in technology transfer is the ability to adopt the demonstrable benefits of a new technology.

In specific terms, carefully controlled and well-documented studies are needed in which an existing state-of-the-practice procedure for data collection or forecasting is used in parallel with a state-of-the-art technique. In this way, results of the two procedures can be compared and a determination made of whether the state-of-the-art technique offers tangible improvements over the state-of-the-practice technique. Such comparisons in data collection could also include two state-of-the-art techniques as a means of determining which techniques may be suited to certain problems, e.g., comparison of travel diaries with a recall interview and comparison of different sampling schemes. In the area of travel-forecasting procedures, the criterion of whether the state-of-the-art technique would change the outcome of the planning process (i.e., would result in recommending a different alternative, policy, or project) is an extremely important measure. Careful documentation is required of the costs of each procedure as well as the measures of effectiveness in the planning context.

These comparative studies must be undertaken in real planning contexts in order to maintain validity. Potentially, such projects could be funded through state departments of transportation and conducted at the metropolitan-area level and below. It is extremely important that the products of such studies be disseminated widely among practicing transportation professionals as well as being an input to the development of training programs and other procedures aimed at reducing the gap between the state of the art and the state of the practice.

Standards and Criteria

It is particularly important that the planning process respond adequately to the information needs of decisionmakers. The product of the planning process should not be just a facility improvement plan but information useful to the investment and priority-setting process. An understanding of the needs of decisionmakers in regard to the standards and criteria used and administered is a prerequisite to sound multimodal transportation planning.

For example, no measure comparable with the highway level-of-service concept exists for public transportation. At this time, measures do not exist to compare highway and transit investment decisions and set priorities on a constant basis. Comparable multimodal standards and criteria are also absent. Such measures are needed when one is making decisions between modal projects in a corridor and priority programming decisions between corridors. In addition, there is a need to examine and perhaps reverse the standards and criteria now used in the transportation decisionmaking process.

For example, with increased capital and operating costs and high interest rates, the level at which major facility investment is justified has changed. At this time commonly used criteria for highway project justification and design still revolve around the level-of-service concept in which C and D levels are viewed as acceptable in urban areas. E or F levels of service may have to be increasingly accepted, especially during peak periods.

Similarly, lower-level design standards and minor improvements to existing facilities may need to be considered in order to avoid overinvestment of limited resources in a single capital improvement as opposed to delivering improvements to facilities in several areas. The requirement for a 20-year design forecast year should be reviewed.

Travel Demand Analysis Needs for Project Planning

ROBERT E. SKINNER, JR., Transportation Research Board

The objectives of this paper are to review travel analysis needs for project planning and to provide a starting point for subsequent conference discussions of this topic.

At the outset of the paper, a working definition for project planning is presented that serves as a base line for the identification of necessary demand inputs to project-planning exercises. A rather broad definition is used on the assumption that at this point it is better to risk being overly comprehensive rather than being unnecessarily restricted in point of view. In discussing the demand requirements of project planning, some speculation is presented concerning how these requirements may change over the next decade as the nature of project planning changes.

Turning to the question of how well existing demand analysis methods meet existing and emerging requirements, we first present some generalizations concerning the current state of the practice. Then a set of idealized attributes for project-planning demand analysis is generated from several different perspectives. We conclude with a brief commentary concerning how well existing methods satisfy these desired attributes.

DEFINITION AND DESCRIPTION OF PROJECT PLANNING

Although most transportation planners have a fairly clear concept of what constitutes project planning, these concepts can vary depending on the perspective and past experience of the individual planner. In order to discuss the travel demand forecasting requirements of project planning, it is important that there be a common understanding and working definition of project planning.

As used here, project planning is the stage in the planning process at which site-specific transportation facility and service alternatives are analyzed in sufficient detail to support a firm implementation decision. Generally, project planning involves the consideration of capital-intensive proposals that are analyzed in comparison with alternatives involving less capital investment or no action at all. Geographically, project planning focuses on travel corridors or subareas and considers alternatives that, for the most part, could be implemented in their entirety and operate successfully independent of any other unbuilt facilities.

In this paper, as in the conference, we are concerned with project planning for both highway and transit facilities in urban and rural contexts.

With this background characterization of project planning stated, it is useful to go a bit further and identify the key aspects or objectives of project planning that in turn influence travel demand analysis requirements. There are three interrelated objectives that, although not mutually exclusive, are particularly useful for organizing our thoughts in this regard: feasibility determination, impact estimation, and design inputs.

Feasibility determination is concerned with both the absolute and relative feasibility of all alternatives under consideration. This includes the engineering, operational, and economic feasibility of alternatives, concentrating on the direct travel benefits and costs of each alternative. Impact estimation as used here examines the indirect impacts of the alternatives under study and considers concerns such as air quality, noise, economic development, and community disruption. The final objective--design input--recognizes that it is often during project planning that data and forecasts are developed that are subsequently applied with little or no change as inputs and/or requirements for final design. This relationship that project planning has to subsequent design and engineering activities is of critical importance, but it has sometimes been forgotten in the transition from transportation planners to design engineers.

REQUIREMENTS FOR PROJECT-PLANNING TRAVEL DEMAND ANALYSIS

The travel demand analysis requirements that arise during project planning respond to the key objectives cited above. In each case, it is the demand forecasts that tend to drive subsequent analysis activities.

Feasibility Determination

Determining the relative and absolute feasibility of alternatives is the key concern of project planning. Travel demand estimates are critical inputs to the determination of the travel benefits and costs associated with each alternative, and these estimates must be responsive to the overall evaluation methodology. Summarized below are some typical evaluation factors and examples of associated demand measures. Highway- and transit-oriented measures are included, but the lists are not intended to be comprehensive.

Category	Demand Measure
Facility or service use	Person trips, ADT, VMT, passenger miles, mode choice
Travel benefits	Travel-time savings, travel-cost savings, average speed, point-to-point travel-time reductions
Capital costs	Peak vehicles or passenger demands by direction, peak-hour vehicular turning movements, peak-hour station passenger volumes
Operating costs	Temporal distribution of travel demand by direction, peak-load-point passenger volumes

These travel demand estimates must be developed with sufficient accuracy and detail to distinguish between alternatives and enable clear-cut feasibility determinations. Moreover, they should be consistent with the accuracy and detail levels of the evaluation and estimation procedures for which they are inputs. Often the level of detail required in response to feasibility determination is not so great as that which will ultimately be required for design or for certain impact assessments.

Impact Estimation

Impact estimation is concerned with the ancillary, primarily nontransport impacts that would result from the alternatives under consideration. These impacts may be considered as environmental impacts in the broad sense of that term. Demand estimate requirements are dictated by the methodologies employed for impact estimation. Listed below are some illustrative impact categories that require demand impacts and associated demand measures:

Category	Demand Measure
Air-pollutant emissions	VMT by facility and subarea, vehicle speeds, vehicle age distribution and fuel type, stationary power sources and fuel type
Noise and vibration	Traffic volumes by time of day and by vehicle type, vehicle speeds
Public safety	Conflicting vehicular traffic volumes, vehicular speeds
Special user groups	Transit use by specific population subgroups (e.g., elderly, handicapped, or low income), mode choice by specific population subgroups, accessibility to major facilities and employment
Neighborhood impact	Station-access mode choice and volumes by mode, parking demand by location, change in local and through trip-making characteristics
Energy consumption	Fuel use during operation by trip type, trip location, mode, or facility or service
Economic impact	Station volumes and access or egress modes, accessibility to major facility and employment, traffic demand alternatives during construction

In comparison with the requirements for feasibility determination, the travel demand requirements for impact estimation require greater detail and specificity, e.g., traffic demand estimates by vehicle type, time of day, and speed characteristics.

Design Input

Like the impact-estimation requirements, the design input travel demand measures also tend to be more detailed than those needed for feasibility determination. Examples are listed below under highway and transit design categories:

Category	Demand Measure
Highway design	Design hour and time-of-day volumes for all network links; peak-hour turning movements; vehicular volumes by vehicle class, particularly truck volumes; vehicular volumes by occupancy level for high-occupancy-vehicle facilities; vehicular speeds and queue lengths
Transit design	Maximum load-point volumes for peak 15 min, peak-hour station volumes by direction, peak-hour station access volumes by mode

Changing Requirements for the 1980s

The preceding sections have listed requirements for project-planning demand analysis that have evolved over the past 20 years. Before discussing the current state of the practice and developmental needs, it is appropriate to look forward over the next decade and explore how these travel demand requirements may change. Generally, any changes will be related to shifting conditions and perspective regarding public infrastructure investments, transportation investments in particular.

Shift Toward Maintaining and Better Utilizing Existing Infrastructure

The declining condition of the nation's transportation infrastructure is gaining increasing attention in technical and popular literature. The Interstate highway system is now 95 percent complete but reconstruction and other repair needs by 1990 are estimated at more than $40 billion in 1979 dollars (1). Of the 558 000 bridges in the United States, approximately 44 percent are considered either structurally deficient or functionally obsolete (2).

It is estimated that properly maintaining and restoring the New York City subway system alone would cost approximately $11.6 billion over a 10-year period (3).

For highway project planning, attention is increasingly focusing on resurfacing, restoration, rehabilitation, and reconstruction (4-R improvements). For transit, the shift toward maintaining existing facilities coupled with the prospects of limited capital federal funding assistance for rail projects will shift the emphasis in corridor development from rapid-rail and light-rail projects to freeway and arterial high-occupancy-vehicle (HOV) projects.

There will be several implications on travel demand requirements for project planning. Emphasis on 4-R projects, for instance, may shorten the planning horizon and will certainly tend to increase the level of detail needed. Since alternatives will tend to differ primarily in terms of design features, the requirements for alternative evaluation and selection will be virtually the same as the requirements for design.

It also can be anticipated that there will be a greater need for consistency in project evaluation from project to project so that comparable measures are available for statewide capital budgetary exercises and needs studies.

For transit, greater emphasis on lower capital projects will not necessarily require new demand measures but may require greater accuracy to detect differences between alternatives defined within a narrower spectrum.

Greater Dependence on Private and Nonfederal Financing Opportunities

Limitations on the availability of federal capital and operating funds for transportation are shifting the financial burden for transportation to state and local government. For transit, federal operating subsidies are being curtailed and are scheduled for complete elimination by FY 1985. In highway transportation, there is much talk of reducing or eliminating federal assistance for secondary roads and urban streets.

Already this trend has renewed interest in highway toll facilities, and a number of states (e.g., Wisconsin, South Carolina, Maine, Pennsylvania, and Virginia) are considering the imposition or expanded use of tolls to generate additional revenues for maintenance and the construction of new facilities. With respect to private financing, FHWA is sponsoring a study to assess the transferability financing mechanisms that involve private funding. Linked to the development process, such methods have been particularly successful at the local level in certain areas.

For transit, these trends have generated fare increases and greater interest in innovative fare policies as transit authorities attempt to recover a greater portion of their operating costs through the farebox.

The implications of this trend are at least twofold. First and foremost, there will be an increased need to accurately forecast modifications in travel behavior resulting from user cost increases that are incorporated in the definition of project alternatives. These modifications range from trip generation through route choice. In this connection, we may see a need for a closer linkage and consistency between travel demand methodology typically applied in the urban transportation planning process and the methods and techniques used for toll studies involving revenue bonding or alteration of existing toll schedules. This concern over cost comes at a time when the relationship between consumer travel-related choices and automobile costs has been muddled by reduced new-car fuel consumption, higher vehicle capital costs, and resultant trade-offs between fixed and variable operating costs.

The second implication is that quick response in project-planning studies will become increasingly important. The prospects for involving private funds will certainly diminish if it takes two to three years to make a decision regarding project implementation. Generally, transportation studies--especially project-planning studies for major capital improvements--have a poor record for on-time completion.

Greater Emphasis on Demand Management

An inevitable result of the first two trends will be greater emphasis on demand management. Demand modification is becoming more acceptable as available resources for transportation supply changes become more scarce.

From an analysis perspective, this means that demand forecasting methods for project planning must be capable of addressing policies such as

1. Restrictions based on vehicle occupancy,
2. Employer-based mode-of-access restrictions,
3. Road pricing, and
4. Automobile-restricted zones.

Greater Concern Over Goods Movement

The lack of a constituency, combined with the technical complexities involved, has inhibited the development of goods-movement planning activities. Certainly, during the 1970s, goods-movement planning did not reach the level of activity many had expected at the outset of the decade.

Although these inhibitions will continue, there are two reasons to expect greater interest in goods movement, which may filter down to project planning. First, at least in relative terms, it is likely that projects aimed at supporting economic industrial development will increase. We have already seen this for rail and port planning (e.g., related to coal export), and it may become increasingly important in highway planning. Westway in New York City and selected federally funded highway projects in Appalachia are current urban and rural examples, respectively. Second, as noted earlier, highway project planning is becoming increasingly concerned with maintenance resurfacing and renovation, all of which is related to the extent and composition of truck traffic.

Thus, from these two widely divergent perspectives, the impetus will exist to increase our concern with goods movement. Analytically, the demand analysis requirements involve a more accurate estimate of truck traffic in terms of total trips, link volumes, temporal distribution, and composition by truck category.

Less Rigidity in Federal Planning Guidelines

Since the Reagan Administration assumed office, there has been a clear trend toward modified planning requirements that are less prescriptive and afford greater flexibility at the state and local levels. This is worth mentioning because it affects how rapidly the profession will be able to adapt to the trends of the 1980s.

Although there will be some sacrifice in consistency, less-prescriptive planning requirements should foster more rapid adaptation of innovative demand analysis techniques. This should happen because the factors that are changing the travel demand analysis requirements are being felt most directly by state and local governments--the level at which project planning is conducted.

To summarize, travel demand analysis needs in the next decade will

1. Reflect an increased level of detail and specificity with regard to forecast traffic and demand characteristics,
2. Require greater accuracy and sensitivity with respect to changes in user travel costs and demand management policies,
3. Be increasingly concerned with quick-response planning, and
4. Reflect greater emphasis on goods-movement and truck-traffic demands.

CURRENT STATE OF THE PRACTICE: SOME GENERALIZATIONS

Subsequent sessions and papers will discuss the state of the art and state of the practice with regard to specific categories of travel demand analysis methodologies. As part of this paper, it is important that the current state of the practice as it applies to project planning be examined in an overview context.

Project planning in practice uses a wide range of different modeling techniques for demand analysis; they range from conceptually elegant model formulations to very simple forecasting techniques. With the exception of aggregate modeling approaches (e.g., land use transport models) or microscale, operational techniques, most travel demand analysis methods have been applied in project planning at one time or another. Thus, travel analysis for project planning involves the fundamental demand modeling issues that are pervasive throughout the United States--lack of recent data, need for model validation, or inherent limitations of model structure.

Although there is considerable breadth to the travel analysis techniques used for project planning, some approaches are more common than others, so useful generalizations can be made. These generalizations will be helpful in the subsequent discussion of analysis problems and deficiencies.

Two General Approaches

There are two general approaches to project-planning travel demand analysis in current practice--one is based on surveys and counts of existing conditions and the other is based on the chain of travel demand models frequently maintained as part of the urban transportation planning process (UTPP). Although these two approaches are interrelated to some degree, there are fundamental differences in perspective between them.

The first approach, termed "survey-based," relies on detailed observations of existing conditions and is most frequently applied to highway project planning. Specifically, it is often used for studies involving toll roads and project planning oriented toward upgrading existing facilities, possibly related to new development. It is applied when the planning horizon is short, and it tends to be very responsive to design requirements. Consistency with systems planning demand forecasts is of relatively little concern. In the transit area, the survey-based approach is used for short-range, operationally oriented planning.

The second approach, UTPP-based, tends to be applied to more complex project-planning studies where alternatives may be multimodal, involving totally new capital facilities. Alternatives-analysis and corridor-refinement studies have generally used this approach. Usually, the approach has been employed in an urban context, but it has also been used in rural contexts. As a consequence, UTPP-based as used here refers to a technical approach that may be used in either urban or rural project planning.

Unlike the first approach, the second is very much concerned with consistency relative to system-planning work. It tends to be less concerned with travel demand analysis needs relative to design.

Refinement and Special-Purpose Procedures and Techniques

Both forecast approaches use special procedures and techniques to produce final demand estimates.

The survey-based approach begins with detailed observations of existing conditions (e.g., temporal demand distribution and vehicle mix) aimed not only at measuring conditions but also at understanding them. As a consequence, the special-purpose and ad hoc techniques employed are not needed to add detail but rather to forecast changes in demand that may result from the alternatives considered. For instance, the techniques can involve superimposing traffic demands from new development over existing conditions or altering traffic route selections and link volumes in response to new facilities or tolls.

For the UTPP-based approach, the refinement procedures used are aimed at adjusting and adding detail to the raw forecasts produced by UTPP models. Adjustments are required because the zone system and network abstraction used in the UTPP models are often so coarse that individual link or station volume estimates are not reliable. Therefore, a rationalization step is needed that produces more reliable network assignments while maintaining overall consistency with UTPP model outputs.

Added detail is also necessary. The 24-h assignments that are often produced by the UTPP models must be converted to time-of-day and directional distributions for specific network links and stations. Further refinements may be needed to address vehicle classifications, turning movements, and the interpolation/extrapolation for additional forecast years.

Informal Procedures

The special-purpose and refinement procedures and techniques common to both approaches are generally not formalized and are not well documented. In part this is a result of a tendency, and perhaps a need, to develop and apply ad hoc procedures on a study-by-study basis.

Over the past decade, the need for additional detail in travel demand forecasts for transit alternatives analysis studies was recognized and incorporated into the federal review process. Methodological development in response to the requirements has lagged behind.

In highway project planning, the design orientation of state highway agencies has traditionally recognized a need for considerable detail in traffic forecasts and this has led to the development of methods and techniques that are applied consistently within certain states. However, there had been little technology sharing in this area between states until a current NCHRP project was initiated. This project (Project 8-26, Development of Highway Traffic Data for Project Planning and Design in Urbanized Areas) is aimed at evaluating and synthesizing procedures for developing traffic data for highway project planning and design.

PROBLEMS AND DEFICIENCIES

The previous sections have laid the foundation for a discussion of the key concern of this paper and this session--the problems and deficiencies with existing travel demand analysis methods used for project planning. First some fundamental concerns stimulated by the preceding section will be reviewed, and then existing methods will be discussed in light of idealized characteristics or standards.

Fundamental Concerns

Earlier, two general approaches to project-planning demand analysis were identified--a survey-based approach and a UTPP-based approach. A major concern of mine is that there is no general recognition of these two significantly different approaches, existing side by side, for project-planning demand analysis. Certainly, this lack of recognition is related to the nature of project planning. As defined here it covers different modes and alternatives, with varying planning horizons and geographic settings. The survey-based approach is most often used for highway planning that is more likely to involve upgrading facilities than constructing new facilities on new rights-of-way. The UTPP-based approach is most often used when major new facilities are being considered, possibly in a multimodal setting.

Whereas most transportation planners are aware of the UTPP-based approach and it has been the subject of much research, the survey-based approach has received relatively little attention. As a consequence, there is little documentation of the survey-based approach, and no widely accepted guidelines for using one approach or the other exist.

As the nature of project planning evolves in the 1980s, with capital projects being of smaller scale, it seems likely that the survey-based approach will take on greater relevance. Also, the need for an integrated approach that draws on survey-based and UTPP-based methods will become increasingly desirable. Pivot-point, elasticity, and other incremental forecasting techniques are illustrative of approaches that include features of both survey-based and UTPP-based techniques.

Another major concern that affects the UTPP-based approach, and perhaps contributes to the need for an integrated approach, relates to the continuing maintenance and testing of the UTPP models. In many instances these modules, particularly the trip-distribution components, are based on data that are more than 15 years old. The lack of recent data for both calibration and validation has been a major question for some time and generally has remained unresolved. Now, with there being some uncertainty with respect to MPOs and the governmental responsibility for regional-level planning, it is not inconceivable that upgrading UTPP models will receive even less priority in the future. Although the specific demand analysis needs and prospects for system-level planning are being examined in other papers and sessions, it is important to recognize that problems and deficiencies at that level will trickle down to project planning.

As a footnote, it should be pointed out that the advent of microcomputer hardware and software presents a significant opportunity to address these concerns. In particular, microcomputers offer a relatively inexpensive means of formalizing and transferring survey-based methods. Similarly, they are very promising with respect to implementing integrated-analysis approaches.

Existing Methods in Light of Idealized Attributes

The desirable attributes of demand analysis methods for project planning are derived from several different perspectives:

1. Sound modeling practices: Sound principles of predictive modeling are applicable to travel forecasting for project planning. Although they may seem obvious, it is nevertheless important that existing models and techniques be reexamined periodically from this perspective.
2. Output requirements: The output requirements referred to are the basic demand analysis outputs needed to conduct project planning.
3. Emerging requirements: As the assumptions, constraints, and objectives for project planning shift, the demand analysis requirements will shift as well. Thus, idealized attributes for demand analysis developed at this time should be responsive to emerging trends and should incorporate these changing requirements.
4. Practical concerns: Finally, idealized attributes must reflect practical concerns related to the development and application of travel demand estimates for project planning.

Listed below are idealized attributes for project demand analysis methods organized under the perspectives they represent. Not all attributes are mutually exclusive, and the list is not necessarily complete. We hope that it will be a useful departure point for further discussion. Accompanying each attribute is a brief commentary concerning how well existing methods address that attribute.

1. Sound modeling practices

a. Behaviorally based: The major behavioral concerns and potential deficiencies with regard to UTPP-based methods involve forecasting

(1) Trip distribution,

(2) Automobile ownership and automobile occupancy (including carpool and vanpool use),

(3) The impact of cost and pricing policies as well as demand management techniques (e.g., HOV lanes), and

(4) Vehicle mix, time-of-day distributions, or other demand characteristics that are not produced by UTPP models and that require special refinement procedures.

With regard to survey-based techniques, behavioral issues arise concerning the special-purpose and ad hoc techniques used to forecast changes in demand from existing conditions.

b. Calibrated with recent and appropriate data: As noted previously, this is a major issue with regard to the UTPP forecast models. For the survey-based approach, this issue involves the relevance and applicability of data used to develop the special-purpose and ad hoc relationships that predict changes in travel characteristics from existing conditions. Because these relationships do tend to be developed in an ad hoc fashion, there appears to be considerable variability in their quality.

c. Consistent with systems-planning models and forecasts: By definition, a UTPP-based approach is consistent with systems-planning models in structure. Inconsistencies can be introduced, however, through differing model input assumptions (e.g., employment or population). The survey-based approach has no such inherent consistency with systems planning of models and forecasts, and often no explicit attempt is made to reconcile project-level forecasts developed in this way with regional forecasts.

d. Validated with recent and appropriate data: The issue of validation data is virtually the same as that for calibration data with respect to project-planning demand analysis techniques. In addition, it can be observed that in practice it is very unlikely that two recent, independent data sets will be available, one for calibration and one for validation.

2. Output requirements

a. Provide demand inputs for feasibility determination: Of existing methods, the UTPP-based methods tend to be the best in this regard, having a comprehensive, multimodal structure. Limitations and deficiencies are related primarily to inherent behavioral shortcomings in the demand models.

b. Provide demand inputs for impact determination: In current practice there appear to be some inconsistencies between the desired (or implied) levels of confidence and detail for impact estimates on the one hand and the available levels of confidence and detail of demand inputs on the other. The deficiencies of existing travel demand techniques in this respect cannot be evaluated without reexamining impact-estimation techniques. More specifically, there is a long-standing need to assess, in a consistent manner, the levels of confidence and detail needed for impact estimation in project evaluation. Such an assessment would provide a basis for subsequently examining travel demand analysis techniques from the standpoint of their ability to provide appropriate inputs for impact estimation.

c. Provide demand inputs for design: The need for considerable detail in demand inputs for design cannot be avoided. Of existing techniques, the survey-based approaches provide this detail in the most direct manner, whereas UTPP-based approaches require special refinement procedures. As with demand inputs for impact estimation, there is a potential trade-off between the limitations of existing demand analysis techniques and the costs or consequences of design errors. Thus, the deficiencies of existing procedures must be assessed with respect to these consequences and the sensitivity of design decisions to demand inputs, which tend to vary by mode and facility type in accordance with design practice and standards.

3. Emerging requirements

a. Responsive to project alternatives aimed at better use of existing infrastructure: Some implications for travel demand analysis techniques generated by this trend have already been mentioned:

(1) Reduced planning horizon,

(2) Added level of detail to evaluate alternatives that may differ primarily with respect to design features, and

(3) Greater consistency between project-planning studies to facilitate regional- and state-level priority programming.

b. Responsive to demand management and user pricing alternatives: Existing methods are better suited to analyze new, conventional highway and transit facilities than to analyze incremental changes in the operation of existing facilities or the development of new, hybrid facilities. Thus, existing demand analysis techniques have difficulty with projects such as arterial and freeway HOV lanes, automobile-restricted zones, park-and-ride lots, advanced traffic control systems, and pricing policies. To a large degree, these difficulties are related to inherent limitations in the structure of existing techniques or to behavioral weaknesses.

c. Responsive to goods-movement concerns: Existing methods for forecasting vehicle traffic related to goods movement are not widely used or accepted. Generally, neither UTPP-based nor survey-based methods are capable of anticipating basic shifts in goods-movement traffic.

4. Practical concerns

a. Minimize data requirements: There is a trade-off between minimizing data requirements and achieving many of the other desired attributes for project-planning demand analysis methods. Existing methods, though data intensive, are often applied without recourse to recent data for calibration or validation. A major advantage of the disaggregate modeling techniques developed over the past 10 years is their reduced data requirements. As new project-planning and related systems-planning techniques are developed, a major concern and constraint will be data requirements.

b. Improve documentation: A shortcoming with existing demand analysis methods is the lack of documentation for the special-purpose and refinement procedures that are used in both UTPP-based and survey-based approaches.

c. Use known and predictable variables as inputs: The reliability of any predictive model can be no better than the reliability of the inputs to that model. To a great degree, erroneous demand forecasts for project-planning studies can be related to the use of unreasonable but politically acceptable input variable values and assumptions.

d. Incorporate capability for sensitivity analysis: Since this attribute relates more to how a forecasting technique is used than to its structure or formulation, existing demand analysis techniques generally have this capability. In application, however, sensitivity analyses are not always conducted as part of project-planning demand analyses.

e. Facilitate quick-response planning: None of the existing approaches can be characterized generally as quick response. UTPP-based methods are cumbersome because of the nature of the UTPP process, whereas the survey-based methods often may require time for special data collection.

SUMMARY

By using a reasonably broad definition of project planning, current demand analysis requirements related to feasibility determination, impact estimation, and design have been identified. Over the next decade, these requirements will change in response to a number of trends, including

1. A shift toward maintaining and better utilizing existing infrastructure instead of building new infrastructure,
2. Greater dependence on private and nonfederal financing opportunities,
3. Greater emphasis on demand management,
4. Greater concern over goods movement, and
5. Less rigidity in federal planning guidelines.

Current project-planning demand analysis methods tend to fall within two related but significantly different approaches to demand estimation. One approach--survey-based--uses detailed surveys and counts to measure demands and understand the use of existing facilities, whereas the other approach--UTPP-based--relies on a chain of travel demand models often maintained as part of the urban transportation planning process. Both approaches use special-purpose techniques that are often developed on an ad hoc basis. The survey-based approach uses such techniques to forecast demand shifts from existing conditions, whereas the UTPP-based approach uses them to adjust and add detail to raw UTPP model outputs.

A fundamental concern related to existing demand analysis methods is that there is no general recognition that these two different approaches coexist. Although the UTPP-based approach has been the subject of much research and training, the survey-based approach has received little attention. As the nature of project planning evolves in the 1980s, it is likely that the survey-based approach will take on added importance and that the need for integrated approaches will increase.

As a starting point for session discussions, a set of idealized attributes for project-planning demand analysis methods has been presented. These attributes are derived from four different perspectives--sound modeling practices, output requirements, emerging requirements, and practical concerns. Comparison of existing methods with these desired attributes reveals a number of problems and deficiencies within existing methods.

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2. Third Annual Report to Congress: Highway Bridge Replacement and Rehabilitation Program. FHWA, March 1982.
3. R. Ravitch. Metropolitan Transportation Authority Chairman's Report. New York Metropolitan Transportation Authority, New York City, 1980.

Research Needs

1. Improved goods-movement demand estimation methods

a. Investigate truck travel, which is a significant component in many highway facilities and of particular concern for maintenance and restoration projects

b. Determine technique capable of addressing basic shifts in goods-movement traffic characteristics; neither existing survey-based nor four-step model-based techniques are applicable

2. Compilations of travel demand data, proved to be useful in two important respects (as back-up data when resource constraints prevent local data gathering and for a broadened understanding of demand characteristics in different contexts), should be updated and expanded in scope (e.g., manuals such as NCHRP Report 187, Quick-Response Urban Travel Estimation Techniques and Transferable Parameters: User's Guide, and Characteristics of Urban Travel Demand)

3. Measuring impacts of changing cost environment (changes in disposable income, relative transportation costs, and real or perceived automobile capital and operating costs)

a. Determine whether these relationships have been significantly altered

b. If so, develop a strategy for modifying existing forecast models

4. Assessing decisionmakers' needs

a. Reassess these needs

b. Objectively examine the usefulness of planning methods in meeting these needs

Workshop on Urban-Microscale Planning

Workshop Summary

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The resource paper prepared by Bautz emphasized the critical importance of changing institutions as a determinant of needs in the urban-microscale environment. A number of references were cited to support the contention that the United States is undergoing an important change in both societal structure in general and expectations with regard to transportation services in particular. Thus for the 1980s, Bautz foresaw the development of new models for public services involving nongovernmental providers, involvement of employers in work travel, a range of services and institutions, market segmentation, a decline in fixed-route service, deregionalization of transit operations, and the revitalization of market forces as important in service provision. For the planner, this would mean a broader range of alternatives and changes in the institutional framework within which planning would occur.

In the urban-microscale environment, alternative service planning, traffic, parking, and pedestrians will be of primary concern, according to Bautz. Strategies to be considered include service alternatives to provision of parking, pricing changes, automobile restrictions (including residential areas), and the need to design these strategies with specific users in mind rather than as services to aggregations of anonymous users. This need for attention to detail was described as an important gap in currently available methods.

DEFINITION

The ensuing discussion focused first on defining more specifically the urban-microscale planning environment. The consensus was that microscale planning involved projects that could generally be implemented in the short term within small geographic areas such as CBDs, major activity centers (MACs) such as suburban employment or commercial concentrations, neighborhoods, and areas close to large development projects for which site impact analysis was required. Planning in this environment would include both new facilities and changes in services and system operations. It was felt that this planning ought to address both the design of supply as well as, on the demand side, identification of problems and the activity needs of citizens.

The discussion leading to this definition emphasized that this was a multimodal problem and that although short-term, small-area planning was involved, longer-range demand would have to be served by the facilities and services provided and that the impacts of changes were likely to be felt in a wider geographic area. A number of participants also referred to the land use implications of transportation in this environment in terms of serving intensified development, mitigating negative effects of traffic on neighborhoods, and tying together the fine details of urban design. The need for demand- and activity-related thinking beyond simply designing services and facilities was also strongly supported.

The participants also identified a number of problems that are likely to be important in the urban-microscale environment. It was felt that good practice in this type of planning would focus first on assessing the problem to be solved, which would likely be among those listed below; identifying a range of alternative system changes; using demand forecasting techniques to assess the alternatives; and determining which was most cost-effective. Problems and objectives of microscale planning include

1. Improving the local urban environment in terms of livability, security, and social interaction;
2. Providing access to the microscale area;

3. Providing access within the area;
4. Balancing development and transportation system capacity in the broadest sense;
5. Reducing the negative impacts of traffic on the microscale area;
6. Improving the economic viability of an area--CBD, MAC, etc.;
7. Reducing the negative impact of new development and its generated traffic on neighbors;
8. Increasing a jurisdiction's tax base;
9. Providing for pedestrians; and
10. Reducing congestion within the microscale area.

FUTURE ENVIRONMENT

Serving demands in the urban-microscale context will be made difficult in the 1980s by constraints on funding for new facilities and services. The participants concluded that investments on infrastructure are likely to remain stable and few new major facilities will be constructed. More private involvement in transportation in the microscale environment was felt to be likely in the form of employers, merchants, and private provision of services. Economic conditions may also result in declining expectations with increases in dwelling units and automobile occupancy.

The European situation was contrasted with that in the United States. In Europe, some densification is occurring with increases in the use of transit and nonmotorized modes. Expenditures in new infrastructure were felt to be unlikely; the public sector will retain a large role in transit service provision.

REQUIRED CHARACTERISTICS FOR METHODOLOGY

Initial discussions on methods focused on the characteristics that demand forecasting methodology ought to have in order to be useful for urban-microscale planning. It was concluded that methods should be able to address what facilities, services, and policies should be chosen among a wide range of alternatives. Clear indications should also be given on what not to do. Demand forecasts should allow for the estimation of costs and benefits of all possible alternatives in terms of common measures of effectiveness.

A number of sample situations in urban-microscale environments were discussed to highlight the kinds of issues and strategies that methodologies must be capable of addressing. In one case, public policy supported revitalization of the CBD through redevelopment and a variety of small-scale urban design changes. In this situation, detailed forecasts were required in order to determine the investment in infrastructure required to support the increased activity expected. Further discussion highlighted the fact that a variety of parking policy measures could have a role in such decisions if methods were available to analyze them properly.

A related problem involved major expansion of a suburban employment center. A range of alternatives to the expansion of parking, including ridesharing, vanpooling, and subscription services, was considered. Convincing methods demonstrating that these modes would provide adequate work-trip service for employees in the absence of normal levels of parking capacity were required in deciding on site location and parking-lot sizing.

Other circumstances were covered in which fixed-route transit services would be compared with a variety of alternative nonconventional service types. In these cases, information is needed on the market for such services and on the resulting demand for the nonconventional service. To date, this analysis has typically been done on a trial-and-error basis without use of rigorous demand analysis methods. Recent research in market opportunity analyses and other behavioral-related techniques appeared to have some applicability in this area.

These examples led participants to conclude that techniques for microscale planning needed to be capable of dealing at a more detailed level than traditionally possible in demand forecasting. Much promise was seen in disaggregate, behavior-based techniques relying on data collected at a detailed level.

Concern was expressed about the gap between the state of the art and the state of the practice. The group perceived that many techniques and methods were available but were not being applied. From the point of view of methodology characteristics, it was concluded that underemphasis had been given to the importance of ensuring that theoretically well-based approaches were presented in ways that allowed for ease of application.

METHODOLOGICAL AVAILABILITY

Reports from the methods workshops allowed the participants to assess the availability of methodology to address the issues and strategies likely to be of interest in the urban-microscale environment. Methods described were judged against the criteria implied in the earlier discussions, primarily focusing on the existence of appropriate methods and techniques rather than the generality of their use. The discussion centered around methods from the workshops on data needs and collection, transit and highway operations and management techniques, and quick-response and sketch-planning techniques since these are most directly related to the kinds of problems and strategies and manner in which planning for urban-microscale areas was felt likely to occur.

The discussion was structured around consideration of a set of likely microscale strategies and the availability of methods capable of successfully addressing their impacts on travel demand.

In the area of traffic operations and engineering, it was felt that current methods were adequate, although forecasting of very small-scale impacts and alternatives could be improved. Quicker and more flexible methods with improved detail would also be helpful.

Better methods to address parking-management techniques such as pricing and supply changes are needed. More information is needed on the impact on overall travel demand of these policies as well as of residential permit parking programs.

The participants felt that adequate methods for fixed-route service planning were available but that these suffered from a lack of widespread knowledge. Improved technology transfer was felt to be more important than new research here.

Means of assessing fare policy changes such as small fare-free zones, fare prepayment, employer or merchant fare subsidies, or fare structure changes were felt to be in need of attention.

Additional understanding of the behavioral implications of employer-based ridesharing programs was felt to be needed to allow for better estimation of demand for these programs. These methods would allow for better estimation of site development impact where ridesharing is being proposed to allow for increasing the density of development without provision of new fixed facilities or to mitigate the impact on surrounding areas.

The impact of automobile restraints in CBDs or residential areas on trip generation and automobile ownership was identified as an area of need. The level of street activity in retailing areas that could be forecast if there were better information could aid in convincing merchants about such schemes.

Although it was felt that most special user services would be constrained by fiscal considerations, a better understanding of the demand for and travel behavior implications of these services was felt to be required.

Little activity in methods of assessment was identified in demand management such as flextime and staggered hours. It was felt that transfer of the European experience as well as information from the demonstrations on these techniques could serve to assist in these measures.

Although current analytical methods appeared adequate to support studies of road pricing, the group recognized that there had been limited experience and that there appeared to be limited interest in these measures.

Large gaps in methodology were identified in estimating demand in pedestrian travel. It appeared that the European experience would be instructive in this area, which was felt to be particularly important in the microscale environment.

Better knowledge about the demands for goods movement was felt to be needed. For most goods-movement measures, it was felt that forecasting was less important.

The key area of need in the urban-microscale environment was in estimating demands for alternative services such as vanpooling, subscription service, and other forms of paratransit. The likelihood that these measures would be implemented was judged to be quite high because of a variety of trends in urban transportation. Concern was expressed that without better knowledge about the likely demand for such service, poor projects would result or alternatives would be ignored.

BARRIERS TO IMPROVED METHODS

The discussion on methodology availability described above suggested to workshop participants that the gap tentatively identified earlier between availability and general use of methodology was real and problematic. In discussing the reasons for this, the participants identified a number of barriers to the introduction of the improved methodology available for urban-microscale planning.

These barriers appeared to be similar to barriers to the practice of objective, problem- or need-oriented planning in any environment. Such planning would involve rational, objective consideration of a wide range of alternatives. Participants were concerned that planning too often concentrated on design of specific solutions without adequate consideration being given to properly defining what problem in fact was to be addressed. Barriers to doing so were identified as follows:

1. There is a lack of knowledge on the part of both the planner and the decisionmaker about the full range of alternatives available;
2. There are institutional arrangements that prohibit planners from broad enough consideration of alternative solutions (e.g., transit planners who work for organizations typically concerned with operating fixed-route transit only);
3. The objectives for the planning exercise are often poorly, incorrectly, or inexplicitly specified by the decisionmaker;
4. The decisionmaker often prematurely selects among alternatives because of preconceived notions or a desire to maximize investment by outside agencies; and
5. Analytical techniques are not adequate to fully assess all alternatives to the same level of detail or against the same measures of effectiveness.

These issues suggested to the participants that additional work is needed in understanding how to better communicate with decisionmakers and about the decisionmaking process itself. It also suggested that information dissemination on service alternatives ought to be focused on the market or problem to be addressed as opposed to describing individual service types exclusively. This information should be designed to highlight the range of options available and avoid focusing the user's attention on specific solutions prior to an examination of exactly what problem ought to be addressed.

RESEARCH NEEDS AND ACTION AGENDA

The discussion concluded by developing a number of recommendations for further research and action.

The participants concluded that action is particularly needed in technology sharing. Steps should be taken to improve the packaging of improved analytical techniques to minimize the difficulty in their application in terms of cost and risk. Needed are easy-to-apply techniques that are developed from sound theory and perhaps from more complicated models. Increased dissemination and technical assistance ought to be undertaken involving the sponsors and developers of new methods. Significant useful feedback to the methods development process is likely if this occurs.

Research needs were identified by assessing areas where gaps exist, where limited work is under way, and where interest in implementation is likely to lead to use of the methods developed. It was recommended that increased attention be directed toward reducing the barriers to implementation of good planning practice. Additional study in the areas of problem identification and the decisionmaking process was recommended.

Areas in which additional new work is needed were development of methods capable of accurately and quickly predicting the travel demand impacts of the following microscale strategies:

1. Parking management, including price and supply changes as well as residential parking permit programs;
2. Transit fare policy changes;
3. Ridesharing incentives;
4. Automobile use restrictions, particularly in residential areas;
5. Pedestrian demand accommodation; and
6. Alternative transit service types.

It was concluded that although methodological gaps exist, adequate activity was currently under way in assessing traffic operation and engineering improvements.

Participants found that although current methods are not adequate, limited implementation of the following strategies due to other, external factors made further work of limited utility: special user-group services and central-area circulation services.

It was concluded that for the following strategies, methods were in existence that would adequately provide assessments but that these were not well known. In these areas, dissemination of such methods as well as demonstration results ought to receive priority over further research:

1. Fixed-route transit services,
2. Demand management measures,
3. Bicycle enhancement, and
4. Goods-movement data collection.

Urban-Microscale Planning for the 1980s

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A number of observers have noted a basic change in what the government, especially at the federal level, can be expected to do or afford to do. Because of this change, the manner in which public services, including transportation, are delivered will not be the same in the future as it has been in the past. There will probably be less money available for public services, and the emphasis in the coming years will be on more efficient use of existing resources, self-help, partnerships between the public and private sectors, and a more market-oriented delivery of public services.

The purpose of this paper is to identify some of the changes that are occurring that will affect transportation planners and to offer some opinions concerning approaches that should be taken during the next 10 years to make up for the cutbacks in public funding while the necessary level of urban mobility will continue to be provided.

The challenge to the transportation planner in the 1980s is to work with limited public resources to provide the free movement of traffic, effective alternatives to the single-occupant automobile, and an attractive urban environment for the pedestrian. The situation implies that new coalitions of support must be built at the local level and new institutional arrangements constructed to manage urban transportation systems. All parts of the urban transportation system--traffic, transit, paratransit, and pedestrian movement--should be planned and managed in a coordinated manner. There will be opportunities for the development of services that are not based on public policy statements but on the actual needs of the community.

Funding for urban transportation, whether highway or transit, has been threatened with cutbacks at all levels of government. The chances for major highway projects, significant transit fleet expansion, or new rail transit facilities appear slim over the next few years. Many believe that this is a phenomenon caused by a temporary swing to the right in the nation's politics. However, a number of observers of government and the political process feel that the change is more fundamental and that the current political situation is not the cause of the change but rather the result of it.

In a recent article in the New York Times Magazine, Theodore White reviewed the past several presidential elections and concluded that by 1980 the electorate was disenchanted with throwing money at problems and was receptive to the message that "government was choking them, wasting their money, forcing up prices, poking its nose into local affairs" (1, p. 77). The election in 1980, says White, "could be viewed only as a climatic episode in a stretch of history that went back for 20 years or more" (1, p. 32). John Naisbitt, senior vice president of Yankelvich, Skelly and White, sees some more basic changes in progress. He feels that the United States is shifting from an industrial society to an information society and that decentralization is taking place and power is shifting from the Congress to the states. He feels that we are entering a postindustrial society with more freedom for the worker (2).

The magazine Transatlantic Perspectives, in the preface to an article by Ted Kolderie, summarized their view of societal change by stating that "Western societies are searching for more effective and efficient ways of providing public services, and the search is leading them...toward new models built around concepts of choice and competion,...use of nongovernmental service providers,...self-help and user financing" (3, p. 6). A private-sector view is given by Robert M. Price, the president and chief operating officer of Control Data Corporation, who states that "many times the only way to assemble the resources to meet a great social need is cooperation with other companies and government" (4, p. 23).

These comments are included to show that basic changes are under way in the United States that will affect society as a whole and certainly the role that transportation and the transportation planner will play in that society. As Naisbitt points out, "Just as in 1800 the fact that 90 percent of the labor force were farmers dictated the societal arrangements of the day, the fact that most of us were in industrial occupations until recently dictated the arrangements of a mass industrial society--which are now out of tune with the new information society" (2, p. 11).

An illustration of the changes that are taking place is found in reports of new work schedules and the trend toward flexible hours (5, p. 76; 6, p. 27). These changes will have significant impacts on traffic flow and public transportation. A change to a four-day work week, for example, will cut peak-period transit ridership by 20 percent. Cities have lost most of their manufacturing jobs and the suburbs continue to grow as central cities decline in population.

The above references are important because, although they may not involve transportation directly, they confirm on a grand scale the experience and observations of transportation researchers over the past few years. Pikarsky and Johnson feel that the changes in transportation are dramatic enough to amount to "renegotiating the social contract" (7, p. 10). In other words, the roles of the individual and of the public and private sectors must change to meet the realities of present-day life.

Another interesting feature of the referenced articles is that they are remarkably similar in identifying the characteristics of the change we are encountering. In reviewing the articles, I detected a consensus that people have lost confidence in the ability of government to solve their problems, that they are tired of dealing with bureaucracies, that the private sector must play a role in the solution of social problems, that partnerships between public and private sectors must be created, and that the delivery of public services must be more market oriented. As Kolderie sums up the problem, "In the same way that, around the turn of the century, the United States needed a new conception of how to act in order to deal with the failures of the private sector, it now needs a new theory to permit it to deal with the failures that have begun to appear in the public sector" (3, p. 6).

This new social order should have a dramatic impact on highway and public transportation planning and implementation. Planning of transportation facilities and services in the past was affected by the considerable amount of money available for street and highway construction and more recently fixed-route transit, low-cost parking, and the seemingly limitless supply of land. The availability of federal funds tended to skew local decisions in the direction of whatever the government would pay for. Just as we tended to sacrifice homes, parks, and pedestrians to the automobile in the 1950s and 1960s, so we ignored the changing demands for public transportation and concentrated almost solely on fixed-route transit in the 1970s. As the DOT report Transportation Agenda for the 1980s (8) so aptly puts it, "Transit as we know it today remains ill-suited for our many travel needs."

Before determining how this social order will affect urban-microscale planning, it is important to define what the term means. There seems to be a lack of consensus on the meaning of urban-microscale planning, so for the purposes of this paper the term refers to the planning of transportation services for an area such as urban CBD or a non-CBD work location. It involves detailed planning of a variety of services to meet the specific needs of various market segments. Urban-microscale planning must be comprehensive and coordinate the various elements that make up the urban transportation system, including fixed-route transit service, commuter ridesharing, private bus service, social agency transportation, taxis, bicycles, and pedestrian movement. In addition, the involvement of employers and merchants must be considered since they can have a significant impact on the way services are provided and priced. An important subset of urban-microscale planning will be site impact analysis, which will consider many of the same services but only how they affect a specific major building or development.

Urban-microscale planning will differ considerably from the way planning was done in the past. There will be no solution to transportation problems or a single set of routine procedures to follow. The techniques that work for regional analysis will not be applicable, and the planner will be confronted by a need to analyze a number of different services affected by a variety of institutional structures.

This situation implies some basic changes in the way transportation is planned. First, the use of mathematical planning models will become relatively less important. This is not to say that they will not be needed, since detailed service design will depend on analysis of the market to be served. However, a good case can be made that the major service impacts will be caused by changes in the legal, regulatory, and institutional environment. Several years ago, a planner in a major city told me that we really needed a good demand model for vanpooling. However, at that time vanpooling was not legal in most states, and the best model in the world would not alter the fact that no one would ride because the service could not be legally provided. In a similar manner the involvement of employers and merchants in public transportation can have effects that will overshadow the operational features of a service. For example, it has been observed that strong employer involvement in a ridesharing program can cause other variables such as the desire to drive alone, smoking, and the lack of desire for social interaction to be reduced.

The importance of nonoperational variables raises questions about the role of the planner in dealing with these issues. Although I think a philosophical discussion of the extent to which planners should be involved in nonoperational issues is beyond the scope of this paper, it is certain that these issues cannot be ignored when transportation services are being planned.

During the coming years, I feel that it is important that fixed-route transit be seen for what it is, a service concept developed by some perceptive entrepreneurs in the 19th century to meet the travel needs of that time. As cities changed, the effectiveness of fixed-route transit declined. The International City Management Association (ICMA) recently surveyed city managers in small cities to get their views on fixed-route transit. Most felt it was not responsive to the needs of residents but was superimposed on the trip patterns of the city. Fixed-route transit is still the most effective way of moving large numbers of people along defined corridors. In certain cities it is an absolute necessity. In most cities it can be used to great effect in serving the CBD. But the fact remains that only about 6 percent of urban commuters use transit. We should not forget transit; in fact, the large capital needs of existing systems and justifiable new systems should be accommodated. However, we should worry a little more about the other 94 percent who do not use it.

Another aspect of dealing with fixed-route systems is to stop equating regional systems and monopolies. There is a tendency to think that it is necessary to have only one transit operator in an urban area and that allowing more will lead to fragmentation and the destruction of the system. Nothing could be further from the truth. Localities that operate their own transit services within the service area of a regional operator find them cheaper and more responsive to local need. Transit authorities should start to see themselves as mobility providers developing service options to meet market needs and not as bus and train operators.

The above discussion indicates a much more chaotic situation for the planner than exists today. In addition to the uncertainty of the institutions that must be dealt with, many more service options are available and resources must be used more efficiently. Parts of the transportation system can no longer be planned in isolation from one another, and we must try to understand the interaction between various parts of the system in order to make logical trade-offs. This situation raises many questions and points out the need for a battery of analytic tools to aid in making rational choices.

The task outlined above is easier said than done. However, a number of recent articles (9-11) have offered suggestions on ways to address urban mobility problems in the 1980s, and a considerable amount of experience has been gained through the projects sponsored by the UMTA Service and Methods Demonstration Program. The following suggestions are made for consideration in developing the planning tools necessary for the task.

The changes that are foreseeable in the coming years create a lot of problems but also offer a lot of opportunities--so many, in fact, that it is hard to know where to begin. However, I see the biggest change in public transportation planning to be the decline in the role of fixed-route transit and the creation of supplementary and complementary services that will most likely be operated in the private sector. This raises a number of key questions. How will the public and private sectors interact? What type of relationship will be the most appropriate? How will private bus services, taxis, and vanpools interface with public transit? If transit is replaced with a service such as a taxi feeder, will the demand be the same? How can market forces be used to the greatest effect in public transportation?

Many CBDs and suburban employment centers are significantly increasing their workforces. Since it appears that major new highway facilities will not be built, can the growth of traffic be controlled? If not, how will the increased traffic flow be handled? Tools are needed for a site-by-site analysis of long-term and short-term parking needs, pedestrian movement, alternatives to the automobile, and vehicular access. My feeling is that if developers are not confident that employees can come and go freely and shoppers will have easy access to the facility being built, the developers will go elsewhere.

In my opinion, a key element to any transportation plan is the management and control of parking. On-street parking is believed by some to be one of transportation's sacred rights. Others believe that only a superabundance of parking will ensure the success of office buildings and commercial facilities. I feel that both of these assertions are untrue, and planners will not only have to find ways to control parking but will also have to make parking growth and management part of the transportation plan.

Unrestricted on-street parking can have negative effects in residential areas. In CBDs it is often not a good use for scarce street space. Giving up a lane of street space so a few cars can sit idly for hours makes little sense, and the charges for on-street parking have no relation to the economic value of the street space. However, it is not enough to simply oppose the expansion of parking facilities. Parking proliferated because people drove cars; they drove cars in part because they had no alternative or were offered an ineffective transit service. This led to the adoption of zoning codes requiring large numbers of parking spaces in new office facilities. Parking management makes sense only when it is part of a plan that includes alternatives such as transit and ridesharing that are actively supported by employers and merchants. There are several precedents for controlling on-street parking through the use of residential parking permits, and a number of employers have shown that with an effective ridesharing program, the need for new parking facilities can be eliminated and land can be put to more productive use. A challenge for planners is to help local decisionmakers overcome their fear of not having enough parking and show how parking requirements can be lowered and the money and land put to more effective use.

Another important element of transportation planning that is often neglected is pricing. There are many facets to transportation pricing, including pass programs, employer subsidies of commuter trips, merchant support, distance-based fares, peak and off-peak fares, self-service fare collection, and the use of credit cards. Some of these concepts are still experimental but will be developed during the next few years. Whatever the number of proven pricing options may be, they should receive careful attention during the planning process. There is an obvious need for analytic tools to select and design the most appropriate pricing schemes.

A topic related to pricing is determining who the recipient of a subsidy will be. Traditionally subsidies are given to transportation operators in exchange for providing a certain level of service. However, subsidies can also be given to users, who can then purchase service in the marketplace. This concept, known commonly as the user subsidy, has generally been used to support taxi trips for target groups such as elderly persons. However, there is no reason why it cannot be applied to fixed-route services. For example, it can be used to lower the fare for low-income persons, thus removing a large barrier to fare increases that are considered discriminatory against the poor. Planners will need to know how to design user subsidy services and evaluate the trade-offs of fare, service level, and demand.

An often-neglected person on the urban transportation scene is the pedestrian. The habitat of the pedestrian has been sacrificed to the movement of automobiles without any consideration for the fact that there are many more pedestrian trips than automobile trips on many CBD streets. As an example, on one street in New York, most of the combined street and sidewalk width was devoted to vehicular traffic. However, 50 percent of the person trips on the street were made by pedestrians and another 25 percent were by bus. Therefore the lion's share of the space was devoted to 25 percent of the trips. Another anomaly was that pedestrian flow was not smooth because traffic lights were timed for automobile movement.

This does not mean that the automobile should be banished. There is a tendency to look at the extensive automobile-free zones in European cities and wonder why we cannot do the same in the United States. I do not think that the European experience is widely applicable in this country due to dramatic differences in the layout of our cities. However, there is a possibility of some middle ground such as the Woonerf concept developed in the Netherlands. This approach allows automobiles to enter urban spaces but not to dominate them. They are guests in a human environment rather than the other way around. The problem of planning for pedestrians is probably more complicated than some others because it is not just a transportation problem but is part of a more general question regarding the shape of our cities. Again the institutional issues may be paramount; however, the transportation planner will probably be called on to analyze how pedestrian facilities will affect other parts of the transportation system.

Another usually neglected person on the urban scene is the cyclist. Since bicycles do not mix well with people or automobiles, it is difficult to determine what to do with them. It is apparent that some people prefer bicycling. However, the number that currently use bicycles is probably no indication of true demand since only the most stalwart would venture forth into such a hostile environment. There appears to be a need for research into the demand potential and, based on that, an expenditure of funds on facilities that is commensurate with the anticipated demand. In the meantime we should discuss methods for making bicycling safer and more attractive and determine how bicycle facilities will affect other transportation modes.

Having raised a number of issues, I feel it appropriate to present a few examples to show how these problems can be addressed. In Hartford, Connecticut, and Denver, Colorado, attempts will be made to bring together the city government, the transit operator, employers, merchants, the ridesharing programs, and parking interests to manage all aspects of the urban transportation system in a coordinated fashion. Parking will not consume a disproportionate share of resources, but enough will be available for short- and long-term demands. It is envisioned that transit will serve the shorter commute trips and that ridesharing and private bus services will carry long-distance commuters. This approach, known as the transportation management organization, may not provide the whole answer, but it is a step in the right direction.

A more specific example of the challenge to microscale planners can be found at the El Segundo Employment Center in Los Angeles, California. Although there is a large workforce, the location is essentially built for the automobile age. Buildings are far apart and there are acres of parking. Attempts to serve the area with fixed-route transit failed for several reasons. Transit routes are designed to serve anonymous aggregates of people, but what is needed is a service to get Joe Jones near the front door of his place of work 5-10 min before his shift starts and to pick him up when it is time to go home. Transit buses met the morning starting time but were too early or too late in the afternoon. Buses stopped too far from the entrances or they did not come close to the homes of workers. In short, the service was not laid out to meet the specific needs of the employees.

In order to meet these needs, a fixed-route bus service concept known as employment center bus service was designed by the Aerospace Corporation and demonstrated under UMTA sponsorship. The service was operated by the Southern California Rapid Transit District (SCRTD), and the routes, based on market surveys, were designed to pick up passengers close to home or at park-and-ride locations and to take them to the entrance of their workplace. Several important lessons were learned. We found that the service was attractive to workers, and a respectable but not overwhelming ridership developed. More important, we discovered that SCRTD could not operate the service on a continuing basis. This was not due to operational problems but to the fact that this type of service was so personalized and required such a high level of planning and management that SCRTD did not have the staff resources to accommodate it. However, personalized service was the only type of transit that was successful for trips of less than 15 miles. It became apparent that the only hope for the service was heavy employer involvement. As a result of the project, employers saw that transit was a viable option for a portion of their workforce. A transportation organization was formed among the El Segundo employers, and they are promoting ridesharing and transit service. The important points to remember are that the success of the project depended on microscopic service planning, personalized service, and institutional development.

These brief examples indicate that the institutional change mentioned in the beginning of the paper is already taking place. Developers of non-CBD work locations such as the El Segundo Employment Center recognize the need for collective modes of transportation, and they need the assistance of planners to design effective service to meet their needs. Although attitudes are changing, it would be worthwhile to note the words of Robert Price that "the attitudinal barriers are also formidable. First is the ingrained resistance to change among some business people. Because many are uncomfortable with change, which involves considerable risk, they prefer to 'fine tune'" (4, p. 23).

We can no longer afford just to fine tune our current systems; change is upon us and the nature of the response to this change will determine what role one will play in designing the transportation system of the 1980s.

In summary, the planner of the 1980s will be faced with problems that will provide opportunities for the creative development of new approaches for providing transportation. However, in order to do this, planners must focus on market needs and plan services to meet them. Conventional solutions will still be appropriate in many cases, but unconventional services will have to be tried. Planning will not rely as heavily on a single set of mathematical analysis tools but will have to be more flexible to be able to analyze the variety of new services and institutional relationships that will occur. Market research and new-product development will be necessary to meet the diverse needs of different segments of the population.

The emphasis of the 1980s will be on more efficient use of existing resources. Fixed-route transit will receive less emphasis and will be viewed as one of a number of transportation resources that must be planned as a system that includes streets, parking, transit, automobiles, pedestrian rights-of-way, and nonmotorized modes. New institutional structures emphasizing partnerships between the public and private sectors will be developed to manage these services.

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Research Needs

1. Problem detection

a. Assemble, improve, and/or develop procedures that will, rapidly and at low cost, measure the type and severity of microarea problems; among these procedures might be

(1) Methods of measuring traffic delay, congestion, and level of service

(2) Method of measuring floor space and vacancy rates

(3) Methods of measuring and evaluating parking supply and utilization, including proximity to establishments

(4) Methods of measuring quality of transit service

(5) Methods for estimating automobile traffic or travel demand to, within, and through the microarea

b. Prepare guidelines to design processes for preparing definitive plans that span the issues identified

2. Alternative services

a. Assess demand for subscription, taxi-feeder, and paratransit service (existing demand methods not sensitive to these alternative service types)

b. Develop methods to allow for service design and for trading off among service alternatives in a subarea and on their ability to handle market shares

3. Fare policy

a. Determine methods for subarea planning, fare prepayment, and employer and merchant pass subsidies that are sensitive to subarea strategies such as employer or merchant transit subsidies or fare prepayment schemes

b. Determine demand-estimation methods capable of estimating use and impacts on mode choice

4. Parking management

a. Develop demand estimation techniques to assess parking pricing and supply

b. Provide methods and behavioral information to support them to assess the travel demand aspects of parking pricing changes and zoning policy toward residential parking

5. Ridesharing demand estimation

a. Develop methods capable of assessing the likely impact of ridesharing programs at major activity centers or major employers

b. Design (size) such programs, assess site impacts of major developments, and determine possible parking supply constraints in new or existing developments where increases in occupancy could reduce the need for parking

Workshop on Systems Operations

Workshop Summary

JAMES C. ECHOLS, Tidewater Transportation District Commission

This workshop reviewed travel analysis methods for transit fare and service proposals, including system retraction and mode substitutability, the relation of supply and cost to travel demand, and strategies for maintaining revenues. Barbatti's resource paper outlined the functional needs of such methods and the limitations of current methods.

The systems operations workshop focused on a short time frame with particular emphasis on how services will be provided two or three years from now. This workshop also noted the difficulty in trying to market transit services as long as they are regulated, because the regulatory restrictions may prevent the operation of services that may be justified from a demand viewpoint, or vice versa.

The following critical issues were identified:

1. Deregulation impacts: Analysis methods are required to determine mode shares of services with substantial similarity of attributes in order to determine impacts on the economy, finance, and new ridership market.
2. Financial consequences: Methods are needed to determine demand responses to service attribute changes, e.g., reliability, peak/base ratio, service cutbacks, and fare increases.
3. Market segmentation: Analysis methods are needed to identify market segments for service package development and impact assessment.
4. Social goals: Analysis methods are needed to evaluate transit effectiveness in meeting social (welfare) goals.
5. User-side subsidy: Analysis methods are needed to determine impact of user-side subsidies on transit patronage and revenue.
6. Equity: Analysis methods are needed to evaluate who benefits and who loses for various proposed service packages.

The workshop concluded that there is a wide gap between what is known and what is done in the areas of data-collection and analysis methods. Techniques are not being put into practice because of the following barriers:

1. Inadequate computer hardware capacity: There has been a lack of large-scale computers available in the small to medium-sized urban areas that would permit the utilization of many of the urban transportation planning (UTP) models. In addition, there has not been widespread use of remote terminals in these urban areas; these could be used for time-sharing of computers. Most likely, these deficiencies will not be corrected in the near future. One solution would be to program quick-response models

for small computers. These small computers, because of their low cost, will be available to most, if not all, urban areas in the next 5-10 years. This development would then make most of the UTP models (quick response) available to a wide range of practitioners. User-friendly software should be developed. This also applies to all types of models, including behavioral models.

2. Pay levels too low to attract necessary skills: Perhaps certification of expertise needed for use of UTP models should be initiated. Restrictions on available funds to local areas might be made if certification could not be made for selected positions. Alternatively, one might provide a salary supplement for certified individuals. That is, the state or federal levels of government might offer supplements to certified individuals.

3. Inadequate transfer of knowledge: There is a need to develop a wide range of technology-dissemination techniques to ensure adequate knowledge at local levels. The level of effort now expended in the technology transfer is small relative to that needed. Currently only reports and a limited number of short courses are used. Perhaps there is a need for regional training centers where courses are offered on a continuing basis to regional practitioners. In addition, more brief pamphlets are needed to give basic instruction on approaches to problem solving and where to seek additional assistance. More syntheses of research results should be prepared for use by practitioners. These syntheses should be promoted through structural promotional programs directed toward practitioners.

4. Current analyses too complicated for general use: Available methods have been criticized as too complicated, costly, slow, inflexible, policy-insensitive, and dependent on restrictive assumptions. Consequently, decisionmakers and managers are reluctant or resistant to support the use of these models. These shortcomings also hinder clear communication of methods and results as well as iterations and refinements of preliminary findings. Methods should be evaluated and improved to address these shortcomings. Better existing methods should be better documented and promoted, e.g., cost-saving improvements in sampling design or segmentation of large data banks. Caution should be used when quick-response techniques are employed by staff who lack appropriate judgement; these techniques should be refined with diagnostics and other aids to help less-experienced practitioners.

5. Lack of management support and acceptance of analysis outputs: The decisionmaking process is essentially political in nature. This applies both to public authorities (local, state, and federal governments) and to transport operators. Therefore, research to support policy decisions should be based on the understanding that (a) policymakers want to keep the final decision to themselves; (b) policymakers want to be successful rather than subject to criticism; (c) policymakers generally have no knowledge of research, methods, and especially not of mathematical formulas; and (d) help should be provided at the moment that it is needed, not at a moment convenient for researchers. Research will be considered a luxury unless it is made clear that research effort will give better information that can give policymakers an insight into the possible effect of their options and prevent them from pursuing ineffective strategies. A regular communication between research and policymaking is necessary in order to let researchers comprehend what the needs of today, tomorrow, and two years from now will be and to give policymakers the opportunity to rightly comprehend the value of research.

6. Failure to recognize limited skills and experience in data collection: Approval of large-scale expensive or regulation-required data collection should be conditioned on indications of adequate familiarity of responsible staff with scientific data collection. If this experience is lacking, approval might be conditioned on the use of data-collection methods suggested or required by others with such experience. Money, training programs, etc., should be available in an adequate, timely fashion to assist inexperienced staff and students in transportation planning. Experts should publicly or professionally evaluate and criticize data-collection efforts.

7. Lack of documentation of survey and data-bank content: Before a decision is formulated relative to analysis, the status and accuracy of any existing survey documentation and data-bank content should be assessed, along with identification of the staff, lead time, and costs needed to manage the data effectively. Adequate resources should accompany decisions to conduct analysis of incomplete data systems. New data sets, surveys, and methods applications should be carefully documented for further use.

The systems operations workshop concluded that efforts in the 1980s should be directed toward improving the state of the practice of travel analysis rather than improving the state of the art. There is a substantial difference in the quality of analysis between large and small urban areas, and many smaller areas need improvement.

The workshop also concluded that there is a distinct difference between U.S. and European practice in several areas. For example, European countries may have a national bus-operating entity that uses advanced travel analysis methods throughout the country, whereas U.S. practice has a large number of much smaller entities that provide service, not all of which are well skilled in analysis. Also, equity means interjurisdictional funding shares in Europe, whereas it means fares to low-income riders in the United States.

Systems Operations

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Service operators of necessity focus on the present and the immediate future. For an operations manager, analysis of travel demand is made at the point of purchase and is not an abstract mathematical formula. Rather, transit and paratransit services are perishable commodities. If the resources expended to provide service are not consumed by riders, they are lost to the community. Transit is analogous to its major competitor, the automobile, and should not be viewed as equivalent to the highway.

Demand analysis methods, with few exceptions, predict transit travel by using models derived from the highway planning practice.

Highway and transit planning were done separately until the 1960s. However, in 1962 the Federal-Aid Highway Act gave birth to the 3C process of comprehensive, continuing, and coordinated planning of transportation. This mandate took effect July 1, 1965, with the hope that it would stimulate alternative travel modes. Transit was included in the highway planning process as a legitimate component of the network. Transit planning had been a private business activity, but with the decline of the private operator, the emergence of government-owned systems, and the infusion of federal planning dollars, it became a public-sector planning problem. Conventional wisdom suggested that the highway engineering discipline was most capable of leading the effort.

Traditional transportation planning is based on aggregate sequential demand models that deal with trip generation, trip distribution, modal split, and traffic assignments. The process forecasts the number of trips being produced or attracted to a particular location; the trips are then allocated to travel zone by mode and the logical travel route is predicted, thus providing a picture of a highway network.

The Urban Transportation Planning System (UTPS) and Integrated Transit Network (INET) provide the state of the art in demand forecasting with this method.

The aggregate direct demand approach operates with the same elements of travel demand but accomplishes the estimation in a different manner. This procedure allows for testing modal variables but still deals with trip generation, distribution, and modal split.

Disaggregate behavior models are the third type of forecasting method. Based on the utility function, they therefore offer an approach compatible with the system operator's perspective since travel is predicted based on individual or household data. These models are frequently employed to explore the relationships between transportation policy and demand (1,2).

Predicting transit travel demand with these models has resulted in an overemphasis on capital investment and underemphasis on service design (3).

Transit demand analysis should be based on the fact that transit is a commodity, a product to be packaged, priced, and sold. If the service is neither efficient nor effective in meeting a demand, it will not be purchased by the consumer. The tools and techniques to be employed in travel analysis must be able to identify market demand rather than potential demand (4).

Techniques for analyzing transit demand must be compatible with a systems management planning process, provide operating planning information for the short term, and supply guidance for the strategic planning process in the long run. Unlike the highway demand analysis methods, which require large data-collection efforts over a long period of time, transit systems have the potential to compile a complete data set daily, which could allow adjustments based on a trend.

The difficulty is that the equipment and techniques for accomplishing this are usually beyond the resources of the average transit system. Therefore, the challenge is not only to develop techniques but to employ methods that are affordable and technically within the ability of the average system to implement. Moreover, at the operations level, the transit product is perishable, so time is also a factor.

In the future, transit services will be competing in a more open and deregulated environment, and travel analysis methods must recognize that there are numerous transit products, including taxis, vans, and regular transit vehicles, that have unique service characteristics and markets. The techniques must be able to discern the individual markets and subtle service design features. Adopting a market orientation offers the opportunity to judge how well, if at all, transit meets social goals (4).

A major requirement for advancing travel analysis is that monitoring and evaluation instruments to gauge the level of success in predicting travel needs must be incorporated into the techniques (5).

Operations managers require a market-oriented approach to travel demand that postures alternatives in terms of service variables. The techniques must dovetail with the management planning process. Further, the approach should be cost-effective to implement and include a follow-up evaluation procedure.

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Research Needs

1. Identification of major forecasting and behavioral-analysis methods and sites where they have been used

2. Comparison of predicted with observed behavior or predicted network variables with observed network variables

3. Explanation of variations in predictive capabilities and recommendation of appropriate uses for each forecasting or analytical method

4. Suggestion of means of improvement of methodologies

5. Preparation of separate technical and nontechnical reports

Methods Workshops

Workshop on Data Needs and Collection

Workshop Summary

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The objectives of this workshop were to assess the state of the art and current practice in the area of data needs and collection for travel forecasting and plan development. It was to address data-collection issues such as determining the necessary data for the problem, measuring concepts accurately, employing efficient sampling designs, and selecting and using appropriate data-collection procedures.

The session began with brief statements by participants from the earlier planning-context workshops. The overall impression was that data-collection issues were a primary concern for all the levels of planning from the broad area of strategies planning to systems operations. Two papers that were intended to spur discussion on the state of the art and the state of the practice were presented.

The proposed research projects arising from the Workshop on Data Needs and Collection are in response to the half-dozen or so general issues identified in the workshop presentations. In summary, these issues are as follows:

1. There is need to reduce the gap between state-of-the-art data-handling and collection methods and current practice, which by and large has changed very little in most transportation planning agencies from practices of two decades ago.
2. There are problems with maintaining appropriate data bases in a fiscally constrained environment, for example, the following:
   a. The well-entrenched travel demand models, regardless of whether they are applied in an aggregate or disaggregate mode, will still be widely used in long-range and project planning and some semblance of the data collected through travel surveys such as the traditional home-interview survey must be maintained.
   b. Current data files on system attributes must be available for project and urban-microscale planning as well as for evaluation of current transportation system performance.
   c. Other traditional and nontraditional data requirements not totally tied to travel demand or system performance that cut across the five planning levels, for example, land use and urban density, employment, accident, and goods-movement data, are necessary.
3. There is a general issue regarding accuracy, efficiency, and cost-effectiveness in data collection and reduction for data processing; this includes the treatment of errors to improve the quality of empirical data.
4. There is the issue of equity in transportation planning as it pertains to the problem of inadequate representation of certain strata of society in transportation surveys.

Research projects that address the first issue include

1. Sponsorship of a report by NCHRP or a similar agency to review and survey current data-collection and handling procedures, emphasizing the more innovative approaches;
2. Creation of a series of "how-to" manuals, for example, how to read and analyze a specific census tape; and
3. Development of a training program for data-collection personnel and survey designers similar to the training program developed for UTPS.

Research proposals directed toward data maintenance might consider the following:

1. Develop methods to update the available large sample, which is now usually dated, of home-interview travel surveys to which most transportation planning agencies have access by using limited-sized, special-purpose, and stratified sampling.
2. Develop methods to expand the home-to-work trip data reported in the census, again by using a more economical survey that primarily emphasizes nonwork travel.
3. Analyze capabilities of various management information systems to deal with the large data sets of transportation system attributes (road characteristics file, passenger counts, speeds).
4. Research other applications of financial and travel data required to be reported by transit operators to the federal government.
5. Study application of private-sector financial and economic planning models to public investment decisions especially as related to strategic planning.

Research directed toward improving the accuracy and efficiency of transportation data collection and reduction can probably be best accomplished through sponsorship of a series of well-documented and controlled case studies. The cost-effectiveness of different sample selection procedures, different designs for survey instruments, pilot surveys, and typical survey approaches can only be established in a real planning environment.

The last issue for research deals with the problems of inadequate subpopulation representation and nonresponse in transportation surveys. Two possible areas for study are the potential of using social service organizations instead of transportation planning agencies for data collection. Private church groups and advocacy groups for the handicapped are but two examples of organizations that might be used for data collection. The second area of research is the use of observation and secondary information to estimate special-population travel characteristics.

The participants in the Workshop on Data Needs and Collection agree that data collection is one of the most ignored areas of transportation planning. The lack of documentation of the data-collection procedures used in practice is almost universal. This lack of recognition of a process on which the subsequent forecasting and plan development activities are based compromises the quality of planning.

It was also agreed that the most important requirement for good data collection is for the transportation profession as a whole to recognize that there is an extensive discipline of survey design and execution and that undertaking a survey is neither a diversion nor a game. It is a serious concern that has wide-ranging impacts on policy and planning. Surveys also represent a point of contact between the transportation professional and the public at large. In this respect, bad surveys can do irreparable damage to the relationship with the public. This, in turn, can undermine the acceptance of the products of planning.

State of the Art in the Collection of Travel Behavior Data

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From an historical perspective, it was only recently that transport planning began to use various survey methods to meet the growing need for the refinement of information. Lacking the experience or research background in this field, the transport planners who needed this information took the relevant survey instruments from social science with what might be described as gay abandon. Since humans were the most intelligent form of life, they were also assumed to be the perfect source of information; the only challenge lay in convincing them to take part in the surveys.

In accordance with this point of view, the discussions and research relating to the survey (which had now become a necessary item among the transport planner's tools) were focused on the optimal design of the sample. Ensuring that every survey began with what became known as a representative sample was the prime methodological concern to most of those carrying out surveys. This development became particularly problematic because it is known that representativeness only plays a limited role among the possible criteria available to evaluate empirical results and that reliability and validity are equally, if not more, important. A biased questionnaire administered to a large sample of people may achieve a very high degree of representativeness but also, precisely because of this, a high representation of the errors generated by the survey instrument.

It has only really been within the last five years that those working in the area of travel survey design and analysis have realized that aspects other than sampling techniques need to be considered in order to obtain the most valid results possible. The interviewee is seen, after all, as a normal person just like themselves, who has a propensity not only not to respond but also not to respond perfectly and, above all, not to respond in a manner that eliminates the errors built into the procedure by the survey designers themselves.

In other words, it was becoming clear that not only random errors (which are produced mainly as a result of not sampling the whole population) but, more important, systematic errors (which are induced by other aspects of the measurement procedure) deserved the attention of those involved in data collection. In addition, when it was considered that current knowledge (notably based on very little thorough methodological research) points to the fact that systematic errors are often substantially more significant than the random errors, there were both research and political implications. It suggested, in fact, that an improvement in accuracy of results could be achieved more effectively through questionnaire refinements (which are relatively cheap) than through larger sample sizes (which are relatively expensive).

In addition to survey refinements as a means of increasing the quality, and thereby validity and reliability, of survey results, some attempts have been initiated to address the issue of nonresponse in travel surveys by using various methods to weight or correct the data. Recently, a substantial number of reports have been published on these efforts, and the limited research has pointed to the significance of these procedures.

In this paper our goal is to summarize the results of basic methodological research of recent years and to present the most recent methods that are generally available. It is recognized that surveys that collect information on the transport system and its performance, on traffic counts, or on land use are an integral part of traffic engineering and planning. In this paper, however, we concentrate on the types of surveys used in transport planning studies, i.e., on the collection of data from the individual, particularly in the context of the household.

Data collection or measurement can be considered to be composed of individual elements, which can be listed as follows:

1. Definition of the problem, theoretical framework, and analytical concept;
2. Sampling frame, sampling unit, selection sample, and selection techniques;
3. Survey methods and instruments;
4. Survey implementation and response rate;
5. Data preparation;
6. Data correction and weighting and expansion; and
7. Data evaluation, analysis, and interpretation.

In the first section of the paper, we discuss techniques of sample selection. In the next section, survey methods and their implementation are dealt with. Three examples of new quantitative survey instruments and their application are discussed:

1. Techniques of the diary survey applied to travel behavior,
2. Large-scale personal-interview survey of travel behavior in Australia, and
3. Large-scale written survey of travel behavior in the Federal Republic of Germany.

In the third section, the possibilities of the qualitative correction of systematic errors will be addressed. Finally, the fourth section is concerned with the so-called "interactive measurement" technique and the possibilities of introducing it into transport planning.

SAMPLING

Problem Recognition

Although not specifically related to the collection of data on travel behavior, the literature in the general area of sampling is extensive. It embraces all aspects of the sampling process, beginning with the definition of the study variable and delineation of the units of investigation and the sampling frame through the final estimation of the value of the study variable. As a general rule, most surveys in transport have considered many aspects of sampling theory in the sampling process.

The emphasis, however, has been on the necessity for a representative sample and little consideration has been given to the validity of the samples selected. A large sample size, for example, produces very representative results, but if a biased questionnaire is used, these results are also very representative of the errors of measurement induced by the inadequate survey instrument.

In general, only the random errors, which result from random sampling, and not the systematic errors, which result from other aspects of survey design, have been considered in the collection of travel data. Systematic errors, however, often have a much greater impact than their random counterparts. Since this problem could become serious because of research, and indeed political, grounds, recent studies in transport have investigated the problem and suggested measures for improvement. As has already been discussed, increasing the accuracy of empirical results can be achieved much more effectively by improving the survey instrument than by increasing the sample size.

The trend towards equating representativeness and correctness, which has been perpetuated by the media, has led to the fact that many people in many fields have been working with the wrong data. Recently, efforts have been made to address these problems by clearly identifying the errors attributable to sampling factors and attempting to introduce compensatory measures. Some aspects of the current thinking with regard to sampling are discussed below.

Definition of Study Variables, Units of Investigation, and Sampling Frame

The initial, and most basic, step in the planning of a survey is the definition of the study variables. In order to analyze travel behavior, two types of data need to be collected:

1. Data that describe the relevant behavioral characteristics (e.g., origin, destination, numbers of out-of-house activities) and
2. Data that may assist in explaining this behavior (e.g., sociodemographic characteristics or description of land use patterns).

The problem of defining the study variables is frequently underestimated. For example, if the difference between the behavior on the sample travel day and the usual behavior is overlooked, significant problems with the interpretation and use of the data have been shown to occur.

The unit of investigation (i.e., the travel-generating unit) is closely related to the study variables. The sum of all the units of investigation forms what is known as the sampling frame. The unit of investigation is, however, not to be confused with the sampling unit. In many studies of travel behavior, the household is considered both the unit of investigation and the sampling unit, although in individual travel-demand models the individual is used as the investigation unit even when the survey unit is represented by the household. In traditional planning practice this has often led to the situation where, in subsequent data processing and analysis, the sampled individuals are considered a restructured quantity and the relationship to the household is consciously neglected.

All the inaccuracies that result from the inappropriate definition of the study variables or the unit of investigation are systematic in nature and cannot be compensated for in subsequent steps of the survey process. It is the recognition of the importance of minimizing these systematic errors that is characteristic of the state of the art at all levels of the sampling process.

Sample Selection

In addition to the reduction of systematic errors that may be generated by inappropriate definition of the study variables, the units of investigation, and the sample frame, the importance of reducing errors during sample selection has also been recognized. The major problem in sample surveys is the choice of sampling units in order to obtain the highest level of representativeness.

Sampling Unit

The sampling units are selected from the sampling frame by using various selection techniques, which can be divided into random and nonrandom methods. Random-sample surveys permit the estimation of random error and therefore offer the only really appropriate method of investigating a subject as complex as travel behavior. Fundamentally, the following techniques are available for the random selection of households:

1. Simple random sampling,
2. Stratified and multistage random sampling,
3. Single-stage and multistage stratified random sampling, and
4. Multiphase random or stratified sampling on successive occasions.

The choice of sampling techniques largely depends on the base population and on the secondary information available about it, i.e., data from a census or from a person or household register.

Since most surveys have defined the unit of investigation as the individual and the sampling unit as the household, research has been necessary to define any problems related to this approach. It is argued that the random sampling of households followed by the surveying of all household members actually represents a cluster-sampling procedure where the cluster is formed by the household. Compared with simple random sampling by using the same sample size, this leads to a random error known as the cluster effect. The magnitude of this effect on the data collected has, however, been shown to be both measurable and minor, and researchers have concluded that the benefits of efficiency outweigh the problems associated with cluster sampling on the basis of households.

If the household is chosen as the sampling unit, the manner in which these households are selected has been recognized to influence the validity of results. The clustering of household addresses for a survey is particularly frequent when personal-interview methods are used, since it minimizes the travel time, and thereby costs, of the interviewers. This clustering can lead to substantial errors if the results are not corrected accordingly and in fact the problem can be much more significant than the within-household cluster effect just described. It is, however, rarely recognized in data-collection procedures.

If the individual is chosen as the sampling unit and if they are selected from a sampling frame of individuals rather than households (e.g., electoral rolls or personnel registers), other sampling problems need to be corrected. Large households will have a relatively high chance of selection in comparison with small households. If the data are used without taking this fact into account by appropriately weighting small households, the survey results will not validly represent the population's behavior.

Sample Size

Accuracy of survey results and the sample size are directly related. The size of the sample or the sampling fraction has been subject to a wide range of philosophies over the decades. Guidelines for surveys in the 1950s suggested that sample sizes of not less than 4 percent and up to 20 percent of households, depending on the size of the population, should be used. In contrast, the increasing use of disaggregate models to analyze survey results in the 1970s was associated with a trend toward the use of much smaller sample sizes. In recent years, however, even those surveys not conducted specifically for use with disaggregate models have tended to minimize sample size. Cost considerations have played an increasing role here, although the sophisticated techniques of correction, weighting, and expansion of results that have been developed recently (see section on correction and weighting) have tended to reduce the reliance on large sample sizes.

Nonresponse Problem

Sample-related problems occur not only in the sample-selection phase but also during the execution of the survey. In particular, even if the initial sample were to contain no errors, the fact that the response rate is never 100 percent would invalidate this condition. In addition, the concept of nonresponse includes the nonreporting of data elements (e.g., trips) even by those persons taking part in the survey. In general, this source of error has not been recognized by data collectors, even though research has shown that a high level of nonresponse results in data with very low statistical value.

The methods that have been developed to address this problem are discussed later.

Summary

It was stressed at the outset of this section that the current attitudes toward sampling have emphasized the importance of a representative sample at the expense of validity. There has been a recent realization that, although representative samples are important, the emphasis in survey design needs to be placed on the elimination of sampling problems leading to systematic errors that often cannot be corrected. For this reason, the nature of the possible problems occurring at each stage of the sampling process and the kind of errors they produce has been outlined in order to portray the level of development that has been reached in the area of sampling and travel surveys.

SURVEY INSTRUMENT

The survey instruments most commonly used to collect household travel data fall into two basic categories:

1. Written, self-administered techniques and
2. Personal-interview techniques.

Both methods have been used effectively under different circumstances and for different needs, and each method has advantages that the other does not. Personal interviews give the respondents contact with the survey team and thereby serve as a motivating element and information source. Also, use of trained interviewers who are capable of dealing with fairly complex questionnaire designs permits the collection of comprehensive information. With written, self-administered surveys, on the other hand, the respondents are free to complete the form in their own time and are therefore often more willing to detail their behavior much more accurately than with an interviewer. Self-administered surveys eliminate the problem of interviewer bias and when well designed can achieve very high response rates. In addition, if travel behavior is to be collected for several days, a self-administered design leads to much better reporting than the recall technique, which is usually used with interviewers.

Ideally, the advantages of both personal-interview and written self-administered methods can be gained by using a self-completing travel diary that is distributed, collected, and checked periodically by an interviewer. If there were no limiting factors such as cost or other constraints, a carefully controlled diary method would provide data collection that maximized the benefits of both interviewer and respondent participation. In order to describe the state of the art in the design and implementation of all three survey instruments--travel diary, personal interview, and self-administered questionnaire--an example of each will be discussed in some detail. In view of the growing needs of transport planners for travel data in the context of out-of-house activities rather than simply as a set of origins and destinations, the role of each instrument in collecting this kind of data will be emphasized.

Diary Technique

Problem Recognition

The travel diary is the survey instrument that allows respondents to record all daily activities (including travel) for a given time period on a survey form. In general, the travel diary as described here is designed for, and therefore best suited to, longer periods of information collection (e.g., several days or longer). A number of questionnaire designs have been developed with the aim of encouraging respondents to give comprehensive information. Most include some sort of memory aids, and some have identified form layouts that are conducive to accurate and detailed reporting.

The diaries are usually preceded by an introductory letter and are personally delivered by an interviewer. Collection of the diaries is also done by an interviewer, who can check for omissions and assist with any difficulties.

The recording of behavior over several days is most reliably done as soon as the activities occur, and the self-administered, written nature of the travel diary combined with the assistance of interviewers both from a motivational and practical point of view makes this the most appropriate method of collecting such information. This section discusses the problems that diary techniques are designed to address by using an early (1972), but not outdated, example.

Need for Diary Approach

Many transport studies contain one or more of the following characteristics:

1. Average or usual and not actual travel behavior is collected,

2. Some answers (e.g., travel time) have to be estimated by the respondent, and
3. Only a portion of individual mobility is studied (e.g., only motorized travel).

Recent studies in which objective secondary data have been compared with survey data have given substantial evidence that the inclusion of any of these approaches in a survey design leads to unstable results. Car drivers, for example, tend to underestimate their travel time, whereas public transport users tend to significantly overestimate their travel time. This example highlights the fact that errors produced in this way are systematic in nature and appear to be related to the mode used.

Survey methodologies, therefore, needed to include approaches that attempted to overcome these problems. The diary technique has offered options that address each of the problems arising from the three characteristics mentioned and thereby offers a solution to the systematic errors caused by them:

1. The diary has to refer to a specific day and usual behavior has no meaning in terms of an average day,
2. The necessity for estimation of answers is eliminated (the diaries are a manageable size and are designed to be easily carried throughout the day), and
3. All individual mobility is reported as are all activities and all modes used.

The travel diary, because it is designed to collect information over several days, does not need to be distributed to all participants on one day, and the spread of this task over several days is an important positive characteristic of the approach. Finally, the use of interviewers to deliver and explain the diary to the respondents allows the survey designers to make the sample travel day "tomorrow" instead of "yesterday." Preparing the respondents in advance for the level of detail expected has been shown to result in much more accurate travel information than asking for a previous day's behavior.

Development of Travel Diary

In order to portray the state of the art of the diary as a survey tool, an actual example will be described. Although variations on this method exist, they are largely based on the same pattern.

This diary was a brochure small enough to fit into a woman's handbag. On the front cover appeared the name of the respondent, the day of the week, and the date of the sample day. On the inside of the cover there were 12 horizontal rows in which 12 trips could be recorded. The trips were numbered from 1 to 12; the odd rows were in blue in order to give a pleasing appearance. On this page there was space for the most important details from the respondent's perspective, e.g.,

1. Origin of the first activity of the day (usually home),
2. Starting time of the first trip,
3. Activity associated with this trip (e.g., work), and
4. Arrival time at the destination.

All further trips for the remainder of the day were to be recorded on this page below the first trip. In this way the pattern for the day and the basis for various out-of-house activities was fixed. In other words, the activities and brief details about them (e.g., purpose) were filled in as they occurred and the remaining details (e.g., exact address) could be filled in at a later time.

On the right-hand page there was spiral at the top securing individual questionnaires for each trip. For each trip there were two sets of questions: the first referred to the person being surveyed and the second to any persons traveling with him or her. These individual questionnaires were clearly marked to indicate that two belonged to a single trip. In addition, those questions referring to odd trips were on blue paper to relate to the trips recorded on the left-hand page.

In the first set of questions the respondent had to record

1. Exact address of the destination,
2. Up to three accompanying persons (e.g., uncle, daughter, neighbor),
3. All modes used on this trip (in a structured format), and
4. Detailed description of the activity at the destination.

A window had been cut out of this part of the questionnaire so that the description of the accompanying person was visible on both sets of questions.

In the second group of questions for the trip, the following details were entered for all accompanying persons:

1. Whether they had been traveling with the respondent for the whole trip,
2. Whether they remained at the same destination as the respondent, and, if appropriate,
3. What they did after that.

Organizational Procedure for Delivering Travel Diary

Although the diary was expected to be self administered, it is clear that it could not simply be sent in the mail. The introduction of interviewers was therefore necessary, less for their function as the questioner than for their role as supervisor.

The procedure was as follows:

1. The interviewer carried out a preinterview with the respondent in which sociodemographic data were obtained;
2. The respondent was then shown how to fill in the diary and together with the interviewer, completed it for one day;
3. The respondent was given diaries to complete for the following days; and
4. After the survey period the interviewer returned to carry out a postinterview; among other things, experiences with the diary were discussed, corrections were made or expanded information was recorded, and the interviewer took the diary.

By using postsurvey contact in this way, it was possible to evaluate how well the respondent was able to handle the diary and to ensure the accuracy of the responses.

The travel diary presents advantages, however, not only in the information collected but also in the methodology. The side effect here was that by recording comprehensive activity patterns, information on walk and bike trips, which is often overlooked by transport planners, was obtained. Methodologically, the travel diary gains information on exact behavior and by using it over a number of sample days, the variation in individual mobility over time can be observed.

Since it was assumed that motivation would decline over the period, the supervisor visited the household every three days to encourage respondents to continue. Only highly qualified interviewers could be used for this difficult task, and the total sample was therefore divided into several subpopulations so that the starting dates could be spread over several days. This meant that the interviewers did not have to carry out all the preinterviews on one day and a detailed schedule was devised to allow this to operate smoothly.

Finally, it should be noted that in this example the travel diaries were intensively pretested over a period of 6 months. This is a requirement that belongs to the state of the art but is frequently omitted.

Summary

The travel diary can be described from a purely methodological viewpoint as the ideal method to gather out-of-house activity patterns. The diary technique has also been used as a control device for large-scale surveys; because of such travel diary studies, it was realized (e.g., in the self-administered mail questionnaire survey discussed earlier) that there were about 0.5 trip too few reported when the diary technique was not associated with personal contact.

For two reasons the diary is not feasible for large-scale applications:

1. If the sample is not spatially (and temporally) concentrated but widely spread, the organization would be almost impossible and
2. The high cost of such a survey would inhibit its implementation on a large scale.

For small geographic areas, however, and as a control mechanism for large-scale surveys, it can been seen as an excellent technique.

Personal-Interview Technique

Problem Recognition

The personal-interview technique has been shown to be most appropriate when

1. Travel information to be gathered is limited to one sample day,
2. Geographic distribution of the population is not extremely great (i.e., does not extend over a whole country), and
3. Sufficient finances are available to expend considerably large amounts of money to obtain one entire household's travel behavior.

In addition, because of the presence of an interviewer in this technique, it is possible to incorporate certain methods of eliciting more comprehensive reporting of travel behavior than is the case with self-administered surveys.

General Description

The example to be used to describe the most recent advances in the personal-interview technique in the collection of travel data is a survey of about 25 000 households that took place in Sydney, Australia, in the last 6 months of 1981. In this survey, the 1981 Sydney Travel Survey, all persons 15 years of age and over were personally interviewed about their travel on one sample travel day. The same travel information was obtained for those 4-14 years old either personally or by proxy. The respondents were personally contacted before the travel day and interviewed as soon as possible after that day. The survey was carried out by the State Transport Study Group of New South Wales. The most important methodological aspects that contributed to the minimization of the systematic errors (described in the sampling section) for the Sydney study were as follows:

1. Two years of intensive planning were allocated to the research and design of the survey. An exploratory survey and three pilot tests formed part of this preparation.
2. The management of the survey was limited to the study group to allow maximum interface between methodological and operational needs.
3. Care in the preparation of the questionnaire included detailed testing of content, phrasing, and layout of the survey forms. The design and content of other travel surveys were examined and, where possible, the data were reviewed. All pilot surveys were conducted by experienced interviewers and concluded with one day of debriefing where all aspects of questionnaire design and administration were thoroughly debated.
4. Travel days, about which all information was obtained from respondents, were distributed evenly throughout the survey period. An equal amount of information was obtained for each of the seven days of the week.
5. The vital role played by the interviewer in ensuring that reliable results were obtained was recognized and reflected in the recruitment and training programs. Recruitment spanned 8 weeks and included extensive testing and interviewing of applicants. A four-day training session in groups of no more than 28 was designed to produce thorough, consistent interviewing techniques. Part of the training was an explanation of the purpose and use of all elements of data to be collected. This knowledge has been shown to foster good rapport with respondents and interviewer loyalty to the survey aims.
6. Systematic survey control for the duration of field operations included following up on initially noncontactable households to discover whether they were in the study area on the assigned travel day (i.e., eligible for the survey), periodic supervision of interviewers during an actual interview, and gathering basic demographic and car availability data wherever possible even if a household or a person refused to give travel information.

Underreporting of Trips

Since the trip or, more specifically, the travel movement that it represents is a very basic unit in transportation planning, the underreporting of trip data has received the attention of both transport researchers and modelers. Researchers cite examples from the United Kingdom where, even after adjustment, there were differences of up to 100 percent between home-based vehicle trips reported in home-interview surveys and those observed at external cordon points. Underenumeration was approached in two ways in the 1981 Sydney Travel Survey--by not allowing proxy interviews and by using a verbal activity-recall framework (i.e., asking respondents to verbally recall their travel in the framework of all out-of-house activities).

Nonproxy Interviews

An earlier Sydney study in 1971 had shown that whereas underreporting occurred throughout the day, it was most significant in the middle of the day off peak (i.e., between 9:00 a.m. and 4:00 p.m.). It was suspected that much of this discrepancy was attributable to the acceptance of proxy responses on trip data. Although household members were frequently aware of most household movements in the morning and evening, daytime trips (characterized by not having home as an origin or destination and general irregularity) were often not known to everyone.

In the 1981 survey, personal interviews were conducted with all members of the sampled households 15 years of age and over. It was hypothesized that because travel is reported directly by the traveler, results would more closely approximate reality and the number of reported trips would increase. Survey results supported this hypothesis.

Verbal Activity-Recall Framework

Many travel surveys have collected trip data by focusing on travel only, i.e., by asking the respondent what trips were made during the period of time under investigation. This technique neither ensures that all travel is recorded nor defines the researcher's notion of trip to the respondent. An activity-recall framework that uses activity rather than trip diaries has been shown to substantially increase trip reporting by using the self-administered questionnaire design. Indeed, increases of up to 13 percent have been reported between activity surveys and traditional travel surveys.

In order to apply this approach to the personal-interview survey, a technique was developed that combined the use of the activity-recall framework with the recording of trips in a relatively conventional manner. Quite simply, after establishing the location at which the respondent began the day, the interviewer asked, "What did you do next?" (activity) rather than "Where did you go next?" (trip). Non-travel-related responses (got dressed, had breakfast, etc.) were even recorded when they occurred at home, since they have proved to be the vital connections linking all activities and thereby enabling easy recall of all trips. It was expected that better recall would be reflected by an increased number of trips per person. This was found to be the case when an early pilot survey in which the normal trip-recall approach was used was compared with the later pilot surveys and the final results.

In addition, the significant increase in walk trips recorded in the survey when compared with earlier data gives definite support to the notion that the nonproxy personal interview and the activity framework are important tools in the accurate recording of travel behavior.

Response Rate

Low response rates are known to seriously affect the validity of survey results. Personal-interview methods, in particular, are susceptible to lower-than-average response rates, often due to the inappropriate times that the interviewer approaches the respondent. Two steps were taken to achieve high response rates. Contact prior to the actual interview was made first by letter and then in person to inform households about the survey and collect household information. Pilot testing showed significantly better response rates with this technique than with reliance on a letter precontact only. At precontact, all respondents were given a memory jogger on which to make notes about travel activities during the travel day. Each individual's name was written on the memory jogger, and each person was given a travel survey magnet so that these joggers could be attached to the refrigerator and thereby be less easily overlooked. The usefulness of this method was shown to be greatest when interviewing occurred more than one day after the travel day.

This example of a personal-interview survey method was very cost intensive due to the use of interviewers and due to the fact that at least six, and up to nine, callbacks were made at all sample households. The technique resulted in a response rate of 87.8 percent, however, which is unprecedented in survey methodologies of this kind.

Interviewer Bias

It is recognized that interviewers can easily bias the responses to travel behavior surveys. The structured questionnaire design and the extensive training and quality-control measures described above were implemented in order to minimize the interviewer effect. Detailed analysis of results is also instrumental in pointing to interviewer effects (e.g., significantly higher or lower trip rates or refusals) and can be dealt with to some degree by the application of correction factors.

Summary

The personal-interview technique as it currently exists is refined enough to deal with many of the problems that have been associated with this type of survey instrument in the past. Although it is costly and not suited to extremely large geographic areas, it is an extremely valid method of collecting travel data.

Self-Administered Questionnaire

Problem Recognition

Many researchers and practitioners believe that the self-administered questionnaire is the best technique for measuring individuals' travel behavior. When carefully designed and executed, it has many advantages in comparison with other techniques:

1. It can be completed at the leisure of the respondent and need not be filled in at the convenience of the interviewer;
2. Being written, it encourages the reporting of trips that may not be revealed to an interviewer;
3. It can be combined with interviewers in order to achieve a personal approach; and
4. It is much cheaper than similar personal-interview methods.

General Description

An example of the use of the written questionnaire for the collection of data in a travel survey can be seen from the German context. In 1975-1977, the Federal Ministry of Transport commissioned a countrywide study of travel behavior, which was undertaken by the firm Socialdata. The study, Kontinuerliche Erhebung zum Verkehrsverhalten (KONTIV), or continuous study of travel behavior, took place over a whole year (i.e., every day was a sample day), and information on all out-of-house activities was obtained from about 135 000 households in the Federal Republic of Germany. In the households selected in the survey, all of the German population 10 years old and older was surveyed and each person was asked about two days of activities. A multistage stratified sample was selected in three stages based on planning regions, municipalities, and households.

The survey instrument was a self-administered mail questionnaire. It was developed as a result of experiments in which travel diaries were adapted to large-scale use, i.e., without the necessity of using an interviewer. The questionnaire consisted of a household form, which collected sociodemographic and vehicle-ownership information on all persons 10 years old and older, and a person form, on which each person could complete details about his or her travel behavior.

The approach to the respondents consisted of an introductory letter, a mailed questionnaire, and three reminder notices, including a further questionnaire. The respondents were required to return the completed forms in a stamped envelope provided for this purpose.

The self-administered mail survey technique was shown to be ideal for the large-scale and extensive geographic area necessary for this exercise.

Problems with Self-Administered Mail Questionnaire

Interviewer Bias

Preliminary studies had shown that the influence of the interviewer in a personal-interview situation significantly affected both the response rate and the quality (validity) of results. The self-administered mail questionnaire does not have any interviewer effect.

Distribution of Sampling Days

Even though results are aggregated to monthly or annual values, the distribution of sampling days over the entire year can result in small daily sample sizes. This problem was approached by gathering out-of-house activity information for all persons on two successive days, thereby effectively doubling the sample size. Although only two days were sampled, a nonreported trip effect was already noticeable for the second day. This effect and measures that can be taken to address it are discussed later.

Exploratory research had also shown that seasonal variations existed due to the effect of holiday periods. In order to counteract these variations, a disproportionate sample was selected in which each quarterly period of the year was differently represented.

Finally, in order to compensate for the lower response rates that had been shown to exist for weekends, sampling-day pairs that included a weekend day were slightly oversampled.

Nonreported Trips

As noted in the section on personal interviews, the solution to the problem of unreported trips is central to the development of a successful survey instrument. In the case of the self-administered mail questionnaire, the recording of trips themselves is generally less of a problem than the recording of the mode used. In particular, when several modes are used for one trip, it has been observed that the respondent has difficulty in recording this information. In order to make this process easy for the respondent and at the same time valid for the researcher, pilot tests were conducted. Two methods were examined:

1. Changing the definition of a trip so that each trip leg was recorded instead of the overall trip; this method elicited many mistakes by the respondent, lengthened the time necessary to complete the form, and generally reduced the accuracy of reporting; and
2. Open questioning of the mode used; this resulted in entries that only referred to a small part of the trip.

There remained the technique in which respondents could check the box next to the mode or activity listed on the form. This presented a problem; preliminary tests showed that on the one hand respondents preferred the easiest solution (box checking) but on the other hand it was not easy to understand what activities fell within such categories as leisure. The solution was to opt for a semistructured approach in which boxes were supplied for the common, clearly understood modes and activities (e.g., car driver, school, work) and there was a category marked "Other, please describe" for the remaining alternatives.

With this technique and with the occasional help of street directories and maps of the public transport system, it was possible to reconstruct most trips even when only one mode was given. A postenumeration study reinforced the success of this technique.

Response Rate

In order to motivate respondents to take part in the survey and thereby to achieve a high response rate, several methods were used:

1. Approach letters had two return addresses: that of the Ministry of Transport and that of the research institute. The mention of the Ministry underlined the importance and the official character of the letter. The name of the institute, on the other hand, ensured the respondents anonymity with respect to the Ministry. In addition, special-issue stamps were used so that the letter itself was esthetically pleasing.
2. When the questionnaire was mailed, the envelope also had special-issue stamps on it. A letter of motivation from the Ministry was included for all respondents. It described the purpose and value of participation and assured the respondents of anonymity in addition to giving basic instructions as to how to fill out the form.
3. Information on government privacy regulations and on the citizens' rights in this respect was also included.
4. A reply-paid envelope was included to encourage return of the forms.
5. The reminder cards were prepared with equal care.

The response rate achieved (for households in which all persons responded) by using this example of a self-administered mail questionnaire was 72 percent over the whole year.

Mailing System

An important component of a mail survey based on sample days is the field operations exercise. An imprecise mailing system can result in imbalances in sampling days, the necessity for respondents to recall past behavior, or the nonresponse of the household.

It was therefore necessary to develop a mailing system that overcame these problems and therefore guaranteed a high response rate.

Initially, tests were made to discover the exact length of time taken for mail to reach all survey areas. The following system was then developed:

1. One week before the first sample day, the household received an approach letter. This had the advantage that genuine nonrespondents (e.g., because of vacant or demolished dwellings) were identified by the return of these letters. It was also a cost-saving method since these households did not have to be contacted in the future.

2. The forms for the household arrived two days before the first sample travel day.
3. At weekly intervals, all households that had not replied received first and then second reminders together with new sample dates; the same day of the week was maintained.
4. Those who had not responded one month after the original sample day received a new questionnaire as well as the notification of the new sample date.
5. One week after this, a third reminder was sent.

This process has the advantage that for each day (and date) of the year, there is a group of persons who answer immediately and a group who respond only after one reminder, two reminders, and so on. It thereby eliminates some of the important nonresponse effects, which are discussed in the next section.

Service to Respondents

Finally, in order to reduce negative reactions of those persons in the survey, a complete service to respondents was set up. All letters were answered and these as well as the letters of motivation were hand signed. A telephone service was also provided. Special telephone numbers were dedicated entirely to the survey, and respondents could use them at any time. Long-distance calls were returned to minimize costs to the survey participants. The project leader spent a considerable amount of time answering calls himself, thereby keeping himself in direct contact with any difficulties that could be avoided in the future.

Summary

The self-administered mail questionnaire technique has shown the current level of sophistication in this form of data collection. The survey instrument is a valid, reliable, and relatively cost-effective technique to use for gathering travel data. Recent adaptations of the original questionnaire form have shown that it is also suitable for persons whose language is not German. The degree of knowledge of many error sources and the experience at overcoming or correcting for them suggest that this method will form the basis for a growing number of travel surveys. The example illustrated has already become a methodological standard in countries outside the one for which it was originally designed.

CORRECTION AND WEIGHTING

Problem Definition

Since travel surveys have almost always been sample surveys, it has usually been recognized that the data do not represent the behavior of the whole population. Although the travel survey was primarily the domain of the engineer and the true unit of investigation was frequently the vehicle or the trip, the most common method of adjusting the sample to the population as a whole was expansion. This was often done simply on a geographic and household basis (e.g., if a 2 percent sample was selected from a certain area, all data elements were multiplied by 50). The very crude nature of this technique resulted in many data inadequacies, which were often the basis for arguing that increased sample sizes were necessary. The realization that simple expansion was less than adequate led to the application of some slightly more sophisticated methods, which included sociodemographic weighting to a greater or lesser degree.

The existence of a wide range of both secondary and primary data sources, however, has made it possible to consider much more extensive procedures, and it is these procedures that represent the state of the art in weighting and correction techniques. These procedures recognize that all empirical measurement is subject to errors of two kinds--those that can be attributed to the measurement technique and those that can be attributed to the subject being measured. In travel surveys, where the unit of observation is the individual, the second type of error (respondent-related) is particularly significant due to the large number of subjective errors and deficiencies. The new techniques are based on the assumption that it is possible to evaluate the degree and direction of the error to a large extent by

1. Identifying those variables that are particularly subject to error,
2. Studying the direction of the effect of these errors, and
3. Estimating the magnitude of these errors.

Even though the correction of these errors requires complex conceptual methods, the actual application of the weighting factors that correct the data set is a fairly simple mathematical procedure. It must be recognized, however, that although approximation to reality is improved, reality itself is never reached.

There are numerous examples of ways in which data can be corrected. Indicative of the wide range of possibilities are

1. Use of secondary data to correct for sample size and response rate,
2. Use of stratified sampling techniques for the correction of holiday behavior and the subsequent low response rates,
3. Correction with regard to the representation of foreign workers in the sample, and
4. Use of internal survey data to correct for nonresponse errors and for nonreported trips.

The ideal state of the art would be a methodology that allowed the correction of all these problems. In addition, it would include correction for the individual differences that have been observed for the perception of trips. Although the methodology of social science in this field has not yet reached this pinnacle, there are many known examples that attempt to mimimize sampling errors and errors attributable to interviewers' response. These will be discussed in the following sections.

Sample-Related Weighting

The type of correction necessary to adjust for errors in sample selection varies with the technique used for the sampling procedure. Stratified samples, which are an example of a disproportionate sampling technique and are not used frequently, have a well documented and relatively straightforward weighting methodology.

If the sample is based on addresses that are clustered along a random route to mimimize interviewer travel costs, many systematic errors are introduced into the data, particularly those related to land use characteristics. Since the magnitude of this type of error cannot be measured effectively after the survey, it has not been possible to develop correction or weighting measures to apply to these errors. Mailed questionnaires are generally considered the best way of overcoming this problem, although noncluster sampling has also been used in personal-interview surveys.

In contrast, the most commonly used sampling frame, a set of address files, presents a problem that can be rectified with simple correction methods. In general, this type of survey is household based, whereas the comparable data (e.g., age and sex) available from other official (secondary) sources is usually person based. In other words, the sampling unit (the household) and the unit of investigation (the individual) are not identical. This means that the behavior of persons from large households will be overrepresented and that of persons from small (in particular single-person) households will be underrepresented.

In order to correct for this error, the household size of the sample is compared with that of the population and the corresponding adjustments are made. In general, the result is that those in one- and two-person households are given factors greater than 1 and those in larger households are assigned factors less than 1. Research has shown that the effect of this type of weighting represents an overall change (decrease) in trip rate of about 5 percent per person. In addition it has the effect of changing the mode split by increasing the proportion of nonmotorized trips and those made with public transport and slightly decreasing the share of motorized travel.

Another aspect of sample-related weighting has been used to correct for day-of-week errors. Most samples used in the collection of travel data survey either only weekdays or both weekdays and weekends. In both cases the unit of analysis is usually the average day. It has been shown that the variation in travel behavior by day of the week is significant and for this reason correction for daily variations is an important part of eliminating errors in the sample. This principle has been extended to seasons of the year, since it has been shown that it cannot be assumed that any particular month or months are typical with respect to travel behavior.

The method of correction in this case is to check the distribution of the sample by day of week or by season and compare it with the distribution that would have occurred if the sample had been selected perfectly (i.e., one-seventh of the sample per weekday or one-quarter of the sample per season of the year).

Respondent-Related Weighting

The correction of respondent-related errors in travel survey data can be divided into three categories:

1. Sociodemographic correction: the correction for sociodemographic inequalities between the population and the sample from which it was chosen,
2. Correction for nonresponse: correction due to the total nonresponse of some individuals within the sample and in particular to the variation in travel behavior between respondents and nonrespondents, and
3. Correction for nonreported trips: correction for partial nonresponse by individuals and for inaccurate answers.

Sociodemographic Weighting

Sociodemographic weighting is the most common form of correction and has been applied to most data sets on travel behavior.

The data on age and sex that are available from secondary sources are usually available by geographic region (e.g., traffic zone). The sociodemographic weighting process is therefore most commonly done on a zonal basis. For example, if there are data for 7 age groups by sex, for 10 traffic zones there would be 340 (7 x 2 x 10) cells to be weighted. The survey data are analyzed on the basis of these cells. This distribution is the so-called "survey distribution" and its relationship to the actual distribution of secondary statistics produces the relevant correction factor for each cell.

An error made frequently in sociodemographic expansion has been to expand data only on the basis of households, disregarding the varying response rates for different-sized households. The effect is to produce a total population that in overrepresenting large households also generates between 10 and 20 percent too many trips. This type of error becomes particularly important if all sections of the population were not included in the original sample (e.g., foreigners).

Although secondary statistics usually represent the actual distribution of the variables being checked, it has been identified that in some cases the secondary data do not actually improve the survey results. If, for example, secondary data define two unmarried persons living together as two households, it would not be appropriate to correct survey data that defined them as one household, particularly in the light of the numerous studies that have shown the influence of other household members. In this case, household size would be best corrected by using nonresponse estimates, which are discussed below.

Correction for Nonresponse

Although sociodemographic weighting is not uncommon, correction for nonresponse errors is a much more recent phenomenon. Significant distorting effects occur in empirical surveys due to the fact that not all households or persons respond. In travel surveys, even when 75 percent of households respond, there is still no information on the remaining 25 percent. A series of basic studies has shown that there is a definite relationship between nonresponse and travel behavior and that the errors produced by it cannot be corrected completely by using sociodemographic weighting alone.

A technique that estimates both the direction and the degree of error has therefore been developed. The technique is based on studying trends with reference to the speed of response and the observation of the following variables: household size, share of out-of-house activities, mobility per mobile person (tripmaker), and a combination of mode and purpose.

The total sample is divided into five response categories according to the speed of response. For correction of written mail questionnaires the speed of response can be measured by the time elapsed since initial mailing. For personal-interview surveys, on the other hand, the number of contacts necessary to obtain an interview can be used.

The results of the nonresponse estimates are incorporated into the data as weighting factors. This usually takes place after the sociodemographic weighting has occurred. The importance of nonresponse correction has been highlighted by the facts that

1. Nonresponse estimates are not always in the same direction as the sociodemographic corrections and
2. Nonresponse estimates result in significant changes to the survey data.

Results of the KONTIV survey (mail questionnaire) and the Sydney personal-interview survey have clearly indicated differences in nonresponse for these two methods. Mail questionnaires result in an overrepresentation of trips and mobile persons, because the nonmobile persons tend not to understand the importance of their completing a travel survey. Personal-interview surveys, however, produce the opposite results, since mobile persons are often the most difficult to contact.

These factors become particularly important in surveys that, unlike the Sydney Travel Survey and KONTIV, have very low response rates.

Correction for Nonreported Trips

The correction for nonreported trips, like that for nonresponse, has also had limited, although important, application. The nonreporting of trips is particularly significant when the survey period is longer than one day (e.g., trip diaries). Willingness to respond and hence actual reporting of trips decline. Even over two consecutive days, trip reporting declines on the second day. Correction is therefore a necessary measure.

This phenomenon has been studied comprehensively only recently. It has been shown that it is necessary to differentiate among

1. Respondent errors that can be corrected with careful coding,
2. Respondent errors that can be identified by retrospective checking, and
3. Respondent errors that cannot be identified.

Although the methodology for estimating nonreported trips is still in its formative stages, analysis of trips identified by retrospective checking had been reported to result in about 14 percent additional trips. Most of these trips were short trips by nonmotorized modes for shopping or recreational purposes.

Summary

The correction and weighting methodology applicable to the data collected in travel surveys has only recently developed beyond straightforward expansion and sociodemographic techniques. Results of recent approaches that have included nonresponse estimates and correction for nonreported trips have indicated that important benefits to the data accrue from the use of these techniques, even though all of these methods are only estimates that improve the results but do reproduce reality.

INTERACTIVE-MEASUREMENT TECHNIQUES

Problem Definition

The examples of travel survey instruments that were discussed earlier described the way in which measurement techniques have been developed and adapted to meet the special problems and needs of travel surveys. The problems involved in providing a logical explanation of current behavior and at the same time giving a useful estimate of future behavior have always constituted the central theme in all areas of applied empirical research and particularly in the field of travel behavior. In this regard, the usual survey instruments are not able to deal with questions about

1. The relationship between behavior and its motivation,
2. Changes in behavior resulting from changes to individual variables within the individual's activity space, or
3. Changes in behavior when the activity space is substantially altered.

In seeking to find an acceptable solution, researchers in the field of travel data collection have therefore had to address the problems that existed in known survey techniques:

1. Straightforward questioning of behavior often measures subjective estimates of this behavior,
2. The explanation of travel behavior by individuals includes either intentional or unintentional deviations from reality,
3. Intended future (travel) behavior reported by respondents is rarely actually carried out, and
4. "What-if" techniques that elicit responses about situations not previously encountered by the respondent have minimal forecasting power.

As a response to these problems, interactive-measurement techniques of various forms are currently being practiced. These techniques consider the gathering of information as a special type of communication process. As such, the respondent and the interviewer play an equally important role. In other words, all elements of the well-known Lasswell formula are taken into consideration by the approach; i.e., who says what to whom using what medium with what effect? The interviewee is seen not only as a reacting and reporting element in the interview situation but as an active partner in the communication process. This approach is completely opposite to that adopted by those transport planners who use quantitative scaling techniques to measure attitudes.

Problems Addressed

Basically, there are four classic areas in which interactive-measurement techniques can be applied:

1. To obtain realistic information through interaction in the social context (e.g., in the household),
2. To overcome the problem that respondents verbalize perceptions other than those that they actually experience,
3. For the controlled reorganization of activity patterns, and
4. As a mechanism for collective decisionmaking.

The techniques are therefore particularly suited to dealing with problems associated with the measurement of attitudes and to examining complex behavioral determinants.

Problems in Measurement of Attitudes

Attitudes in this case refer to opinions and ways of thinking that are socially acquired. One problem with most existing methods of measuring attitudes is that they usually consider only the target person's account of his or her own attitudes. Traditional research has not commonly dealt with the fact that an individual's account of attitudes is subjective and not necessarily reliable. Other factors, such as the desire to conform to the perceived needs of the interviewer, also need to be considered.

Precise empirical explanation of the factors that influence mobility requires the use of the most appropriate survey instruments. The complex nature of mobility makes it necessary to ask a great number of questions, which makes face-to-face interviews essential. The survey instrument needs to deal with at least two problems:

1. It is difficult to make the interviewees aware of all aspects of their daily routine, some of which are performed or decided on almost unconsciously.
2. Decisions concerning manner, scope, and type

of transportation are not always individual decisions. It is important, therefore, that the interview take place in a real-life context, i.e., together with all household members.

When questions are aimed at the household as a whole, empirical methods that realistically depict the group's decisionmaking process must be used. Interactive-measurement techniques are designed to be used in the survey process in order to approach many of the problems associated with the measurement of attitudes.

Role in Total Survey Design

Interactive measurement has been found to fit easily within the framework of a comprehensive survey design, particularly when the object of investigation--for example, mobility--is relatively complex. An integrated approach to survey design in which each stage of data collection uses the most appropriate survey method usually includes several phases in which interactive measurement is appropriate. Examples of this integrated approach would be as follows:

1. Sociodemographic data, for which any form of direct questioning could be used;
2. Activity patterns, which would be recorded in a travel diary;
3. Data on the existing environment and the transport infrastructure, which could be obtained from official statistics or observation;
4. Data on subjective perceptions, which would be gathered by using personal interviews since the respondents do not realize that their view of reality is only their perception of it; in order to avoid undesirable feedback, a spontaneous survey technique is necessary;
5. Data on personality and psychological characteristics, which would also be gathered by using explorative personal interviews;
6. Data on the internal organization and structure within the household, which have been shown to be most reliable when an interactive discussion method is used; dominance of individuals, organizational details, and decisionmaking processes can be clearly established in this way; and
7. Data on dynamic aspects and behavioral sensitivities, which require the introduction of forecasting mechanisms into the technique, so that the relationships between a change in the objective situation and the corresponding behavior can be measured. (This is particularly difficult since the respondents themselves are often not clear on how their behavior would change nor do they understand the complex structure of all the variables that would influence the new situation. In this case it has been shown to be very successful to confront the household with the assumed situation and to allow them to react to it and to discuss possible decisions about behavioral changes. The result is a very good insight into the decisionmaking process, its constraints, extent, etc.)

Examples of Application

Two applications of interactive measurement will be used to show

1. The way in which the interaction between respondent and interviewer leads to increased precision in responses and
2. The way in which behavior can be realistically forecast by using controlled reorganization of activity patterns.

Interaction with Interviewer

In the example, respondents were asked to estimate total monthly expenditure on their cars. The cost estimates were divided into four successive stages, in each of which progressively more information was gained. The interactive-measurement technique used by the interviewers had the following sequence:

1. The respondent was requested to estimate monthly car costs as accurately as possible without the use of any documents;
2. Any comments made by the respondent on purchase, maintenance, use, and so on as self-support were used to revise the first estimate;
3. The interviewer listed all conceivable costs in order to gain another estimate; and
4. An estimate was made that took into consideration the household budget and any available accounts.

In this case the interaction with the interviewer not only made possible the nonverbal measurement of complex perceptual relations but also allowed the recording of cost sensitivities.

Controlled Reorganization

Interactive measurement has the advantage of requiring the household members to make a realistic and controlled reorganization of activity patterns. The actual activity patterns, determined from previous written surveys, are used as a basis for reorganization. The technique ensures that reorganization is realistic and the mutual interviewing of the group allows the interviewer to interrupt if contradictions occur.

An example illustrates the potential reorganization of the household's outdoor activity pattern. It can be useful for forecasting demand if changes in the urban public transit system are to be made.

The household is shown a set of information that includes data pertaining to actual activity patterns. While the interviewer explains how to change different constraints and options, the information that has been collected is checked, and it is then symbolically represented--visually--thus enabling the respondents to understand the implications of their decisions.

Those persons taking part in the exercise are told that the supply of the urban public transit system has been changed and that they must therefore try to reorganize their activity patterns (displayed in front of them) so that all trips are made by using an alternative mode. The alternatives are symbolized by new figures. It is the interviewer's responsibility to

1. Make sure that the interviewees give realistic answers concerning their options for reorganizing their activities,
2. Check to see whether the changed activity patterns of the individuals are mutually compatible within the given household structure,
3. Note the constraints that partly or totally influence the household's activity pattern,
4. Keep a protocol of the reorganized activity pattern, and
5. Explore the household's general alternatives for reorganization, e.g., substitute modes for the specific routes traveled.

Each respondent is therefore forced to consider the multiplicity of effects of each activity change. The method can be used to observe reactions to a wide range of both transport and nontransport measures.

SUMMARY

This paper has approached description of the state of the art in data collection for travel behavior by using examples that represent the most recent advances in several areas of measurement. Sampling methods, the design and implementation of different survey instruments, the correction of travel data, and the use of interactive-measurement techniques have been approached in this manner.

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Data Needs and Data Collection–State of the Practice

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In this paper, an attempt is made to examine the state of the practice in the area of data collection for travel forecasting, particularly that using behavioral travel-forecasting procedures and models. Because of similarities in data needs and data collection, the five planning areas of this conference have been grouped in this paper into three subsets: strategic and long-range planning, project and urban-microscale planning, and systems operations. The primary data-collection purposes considered are the need to calibrate, validate, and update models of the travel process and the need to provide information that can be used directly in planning or policy formulation without the intervention of a model. A secondary purpose is to provide data for improving or updating forecasts or for direct use in existing calibrated and validated models to predict current or future values. Although these are not exhaustive, they encompass the primary areas that motivate the majority of data collection and are adequate for discovering the state of the practice in data collection.

Before proceeding, it is appropriate to consider the reasons why there should be a workshop concerned with data issues and why there should be a paper on the state of the practice in data collection. First and foremost, data collection is one of the most seriously ignored areas of transportation planning. If one reviews past transportation study reports, there is rarely any mention of the data-collection procedures used as the basis of the forecasting and plan development. If there is any mention at all, it is usually as a footnote at best. There is no recognition in published transportation reports that data collection contains sampling error, nonresponse error, and the like, all of which will implicitly affect the quality of the forecasting models and the results obtainable from them. It seems that transportation planners have assumed that the clients for transportation planning cannot understand the fact that sampling errors and other measurement errors will exist and that such admission would compromise the acceptance of the planning. This may well be a correct perception, but correct or not, there has been a suppression of such information in technical reports. Although it is not clear which is cause and which is effect, there appears to be general ignorance of the effects of measurement and survey sampling error on planning and a simple formula is used that equates data quality to response rate. There is also a lack of understanding and attention to sampling and survey design issues.

Few transportation planners receive any formal training in survey sampling and survey design. Most transportation surveys are conducted by the transportation planners and technical people themselves; in very few instances are specialists used in data collection. Typically, a transportation survey is put together too hurriedly and based on someone else's design, which supposedly worked. In general, the entire attitude toward data collection is a cavalier one. Particularly in the context of the current penetration of new travel-forecasting techniques, issues of data collection have been raised in a totally new way. Transportation planners are being faced with decisions that they are unaccustomed to dealing with: questions of sample size, of special survey instruments that cannot be designed by borrowing from earlier surveys, and of models that are much more transparently dependent on high-quality data and are extremely sensitive to measurement errors. Only very recently have concerns been expressed about nonresponse bias (1,2) and the effects of this on model and general informational quality.

Another reason for a concern with data collection is that with a lapse of between 15 and 20 years since most of the major metropolitan areas in the United States undertook their original data collection for travel forecasting, there is increasing pressure to update both the data base and the models. This pressure arises both from the perception that 15-20 years without major data updates is too long a period for the original data to still be valid and from the fact that there are known to be major departures from trends clearly established in the 1950s and 1960s that implicitly affect travel behavior. The transportation professional finds it increasingly difficult to go to a hostile public hearing and defend his or her models and predictions on the basis of data this old and this far from current behavior. At the same time, there is clearly not the availability of funds for data collection that existed in the 1950s and 1960s, which made it so easy to collect large bodies of data with relatively little attention to data quality and sampling efficiency.

There is a somewhat tenuous line to be drawn between the state of the practice and the state of the art, particularly as to when one can consider that a procedure has entered into the state of the practice. In this paper, a somewhat generous interpretation--to the state of the practice, at least--is taken, so that a procedure is considered to be in the state of the practice if there is evidence of at least one use of the procedure in a practical transportation study.

As already mentioned, a difficulty arises with covering the state of the practice because there is relatively little accessible documentation of it. In the development of new procedures for data collection, documentation is provided in the research literature. Applications, on the other hand, are generally the subject of reports with limited circulation and with little publicity generated in connection with the specific project being undertaken. This paper relies, therefore, on my knowledge together with additional anecdotal information from colleagues.

DATA NEEDS

Before proceeding to discuss the individual areas of data needs, I must reemphasize a notion that should be well accepted by anyone engaged in data collection but is frequently overlooked. Data should always be collected for a purpose. Good instrument design and good methodology design can only follow from a clear statement of the purposes of data collection. In the context of planning issues, the primary generator of data needs is a modeling process or an analytical process. The data needs are therefore defined by the available models and analytical procedures. It is likely that in the following discussion, some readers will feel that there is an omission of the treatment of data needs for emerging planning areas such as strategic planning. This is unavoidable if no process exists yet for planning in such an area. Data support planning; they do not define it. Conversely, one cannot define data needs before the process that the data support has been defined.

Strategic and Long-Range Planning

The primary data needs in these context areas are for the calibration, validation, and operation of travel-forecasting models and the components of the planning process. The gradual penetration of travel-behavior models into practical planning has brought with it two significant changes in data needs: an emphasis on the collection of data about individuals instead of about zones or traffic facilities and a transparent sensitivity to errors in the data collection itself and therefore a need for much greater precision in measurement. Apart from this, the behavioral models have raised some unresolved issues and uncertainties in data needs rather than a clarification and a new, defined direction, as is discussed in the next few paragraphs. Principally, this has come about through the debate on reported versus network data and on assigning choice sets or determining reported or perceived choice sets.

In the event that one takes the position that behavioral models should be calibrated, validated, and operated on network and analyst-determined data, a position that is discussed at more length later in this paper, then the use of behavioral models does not change the basic data needs beyond the introduction of an emphasis on individuals and households and the reduction of the total data set size required. There is still the need to collect data on individual trips and to define the origin and destination in a way that permits geocoding to a zone system that relates to an existing network and also to define such items as mode or modes of travel, time of day, and trip purpose. Given current planning considerations, there is usually also a need to include occupancy of an automobile. In addition, there is some increase in the richness of the socioeconomic data collected and some difference in the definition of the specific values to be measured, such as the use of vehicle availability rather than car ownership. These changes are not due solely to the travel behavior influence; the concern with more careful conceptualization of the travel process that lies behind the behavioral models is also a primary reason for the improvement in the care and definition of socioeconomic variables. Beyond this, however, the data needs defined here are little different from those of the earliest comprehensive transportation studies undertaken in the 1950s.

If one takes the alternative position that behavioral models should be calibrated, validated, and possibly used with some elements, if not all, of reported or perceived data and with traveler-defined choice sets, then the data needs are changed quite significantly. Principally, this introduces the need to collect the type of data used in behavioral models from the individual traveler. These data are primarily the travel costs and the times of different components of the trip, such as walking, waiting, and time spent in the vehicle. In addition, the individual may be asked to identify alternative travel modes that could be used for the same trip and may also be asked to provide estimates of the values of the same cost and time variables that he or she was asked about for the chosen mode. Data on the trip purpose, the time of day, and the mode or modes of travel all remain the same as before. Although some instances exist in which joint mode and destination-choice models have been built for an ongoing transportation study (3), the major penetration of behavioral models is still into modal split only, and there is no change in the data needs generated by the destination-choice models. Indeed, one of the primary constraints often placed on the execution of a new model or models in the travel-forecasting process is that compatibility be retained with the existing data bases and with other components of the model stream, so that there is a definite limitation placed on the extent to which these models have introduced change into the data needs themselves.

Project and Urban-Microscale Planning

In many respects, the execution of project planning and urban-microscale planning still relies heavily on the same travel-forecasting models that are used for long-range planning or on parameters derived from them. For example, elasticity analysis or pivot-point procedures (4) use elasticities or coefficients from the travel-forecasting models used in long-range planning. Sketch-planning models, which may be used in the opening phase of project planning, are usually the same type or structure of model but are applied at a different level of geographic aggregation. In these respects, the data needs are the same as those described in the previous section of this paper for strategic and long-range planning.

The primary data need that has been added from awareness created by the behavioral travel models is that of attitudinal data. However, it is hard to say whether such data collection should be considered part of the state of the practice. It is true that a number of instances exist in which attitudinal data have been collected to support project or urban-microscale planning [a study of public opinion surveys by Stormes and Molinari (5), a survey by the Northeast Ohio Areawide Coordinating Agency (6), and a study by Tri-Met in Portland, Oregon (7), among others], but it is less clear whether in any of these instances the information gathered on attitudes, perceptions, or preferences has been used outside the research sphere. Nevertheless, it may be considered that the addition of attitudinal data to conventional measures of the quantity and location of travel is a change in the data needs that can be said to have derived largely from the behavioral approach to travel forecasting.

Systems Operations

In the area of systems operations, it is not clear that there has been any change in the data needs in the past two or three decades, and certainly it does not appear that any stem from the introduction of travel-behavior methodology. There are generally two components to such data needs: data on the operation of the system itself, such as speeds, delays, loadings, and capacity, and data on the manner in which the system is used by the individual traveler, although this latter component seems to have had much less importance in most studies. The major change that has occurred in the data needs for systems operations has been an increasing recognition of the need to obtain good data on the operation of existing rail and, more particularly, bus systems. These data include schedule adherence, maximum load points, load profiles by route segment and by time of day, boarding and alighting volumes, revenue generation and fare profiles, and use of transfers where available.

System use has largely been obtained by some form of intercept survey, such as roadside interviews for highway-based traffic and on-board surveys on buses. The state of the practice here seems to have changed little from the early studies and is influenced little by travel-behavior considerations. Roadside interviews still collect basically the origin, destination, purpose, time of day, and number of occupants in the vehicle. Similarly, onboard interviews have collected origin, destination, purpose, time of day, fare paid, and transfer use. Perhaps the one identifiable addition to the latter has been mode of access to the bus stop and mode of egress from the bus stop and some instances in which riders have been asked to report the time they spent waiting for a bus and the distance they traveled to get to the bus (8,9). Possibly these additional data components have arisen from an increased awareness of the behavior of people in traveling rather than from any other direct source and are needed to support the types of decisions that have become more people-oriented as a partial consequence of travel-behavior methodology.

As is discussed later in this paper, the major changes are more in the area of the sampling and survey instruments than in the data needs per se. The state of the practice in systems-operations data needs, then, has changed relatively little in the recent past and shows only a very minor influence from travel-behavior methodology.

Network or Reported Data

As mentioned previously, this is probably the major area that has affected data needs and is a direct outgrowth of travel-behavior models and procedures. Although there has been a considerable amount of discussion of the issue in various locations, it is worthwhile to review the arguments here, particularly because the controversy has not been resolved and this conference may be able to cast some further light on the issues.

Proponents of the use of network data support their position primarily from the argument that only network data will be available for forecasting, particularly for long-range forecasting, and that the lack of a systematic relationship between network and reported data, which prohibits the forecasting of reported-type data, also leads to differences in coefficient values between models based on reported and network data. Proponents of the use of reported data argue that such data are a better approximation to perceived data and are therefore behaviorally more sound. These data should give rise to more accurate and realistic coefficients, which in turn will yield more correct elasticities and pivot-point information for short-range planning applications. Furthermore, although it is recognized that the reported data cannot be forecast, the contention is that the forecasts with network data will be no more in error (and possibly less) than models using network data with network-derived coefficients.

Studies (10) based on comparisons between actual travel-time components and network-derived components have shown that network data approximate in-vehicle travel times fairly well but do not provide good measurements of other travel-time components. The extent to which in-vehicle travel times will be reasonably good approximations from network data also depends on the zoning of the region. The studies of comparisons of network and measured times are, however, incomplete, because they were based on a situation in which the zone systems in use were reasonably adequate for the size of the region. This is frequently not the case. A number of metropolitan regions have a far-from-adequate zone system. In such cases, there are serious deficiencies even in the network-generated line-haul times. Inadequate zones are defined here as ones that are too large and that therefore compromise the use of disaggregate-based models.

Specifically, when zones are too large, the approximations involved in using centroid-to-centroid travel times become large, so that many trips are allocated incorrect values of line-haul times or distances. Also, an increasingly large number of trips become intrazonal and so are removed from most of the travel-forecasting activity. An additional large number of trips will be provided with a path along one centroid connector to a common node on the highway or transit network and then along the next zone's centroid connector; thus they have no impact on the networks and also receive times estimated only from centroid connectors. I encountered problems of this nature in building models for the Oahu Metropolitan Planning Organization. The island of Oahu, which has a population of more than 850 000, is divided into 159 zones; some of these are as large as 15 $miles^2$ in area. Regionally, more than 20 percent of the trips are intrazonal. In addition, when the networks for highway and transit are built as independent networks, there are tremendous opportunities for severe inconsistencies to arise between the two networks, which may generate incompatible travel times from the two networks. This produces numerous outliers in the calibration data for the modal-choice models. In the same case, initial attempts to build disaggregate mode-choice models from network data produced counterintuitive positive signs for in-vehicle travel time, because the highway network (independent of the transit network) ran at too high a speed.

Although studies of the relationship between network and reported values do not appear to abound, those that have been undertaken do not provide evidence of a consistent, mathematical relationship. Rather, to the extent that relationships have been shown to exist, they indicate that there are both random and nonrandom elements to the relationships and that there are significant differences in the relationships for the travel mode used and travel modes not used and whether one is an automobile user or a transit rider; for example, values of variables like times and costs are underestimated on the mode used and overestimated on other modes (11). Such patterns of response will certainly give rise to differences in coefficient values between the use of reported data and either measured or network data. More seriously, however, network data have been shown to do a consistently poor job in providing estimates of variables such as walking and waiting times, parking costs, etc. Coefficients for such variables are likely to be severely compromised because of the lack of variance from zone-based data and the existence of large variances within the zones.

There has been no resolution of this controversy to date. Applications of behavioral models have used network and reported data with almost equal frequency. Proponents of each alternative remain unconvinced of the merits of the arguments in favor of the alternative approach. Empiricism has been unable to establish a clear direction in this area of data needs, and although theory provides direction, there are conflicting theories and they point in different directions. Nevertheless, empiricism may well hold the eventual answer to the dilemma. Given the disarray of theory on this issue, the resolution probably depends on a sufficient lapse of time to be able to test the goodness of forecasts from the alternative procedures. For this, careful design of comparable models is required for several study areas. Using both types of model in forecast situations and comparing the performance once the forecast time is reached would provide much useful information to resolve the issue. It is to be hoped that some metropolitan governments will have both the temerity and the unusual perspicacity to build models both ways and subject them to the test.

A similar situation exists with respect to choice-set definition. Two alternative procedures are considered--allocation of choice sets by the planner and reporting of the choice set by the traveler. To a large extent, the arguments for either approach are very similar to those raised for network versus reported data. In this case, the controversy concerns the definition of the modes available to a traveler for a disaggregate-choice model. The allocation method is usually executed by the analyst or planner, who allocates all modes to individuals in a given zone simply by whether the network indicates that there is a path available by the mode for the specific trip interchanges of individuals in the zone. The alternative is to ask individuals in a survey what modes they have available and to allocate accordingly. Thus, if an individual indicates that two-occupant and three-occupant automobiles are available but not one-occupant automobiles, even though he or she is from a household that has one or more cars and has a driver's license, only those two automobile alternatives would be assigned. The presence of one or more automobiles and the respondent's having a driver's license would lead the analyst to allocate all automobile modes. Two problems arise from this. The first is the danger of allocating alternatives to individuals who are in fact captive. The potential errors introduced by this have been described elsewhere (12). The second problem is simply that of identifying too many people as having certain alternatives available, which biases the model constants and potentially biases some coefficients, because an alternative that seems to the analyst to be widely available is not and therefore is chosen far less often than would appear warranted by the comparative level-of-service data.

As with the network and reported data, the controversy has not been resolved. Also, like that debate, much of the debate on allocated versus reported choice sets revolves around the issue of ability to forecast choice sets and the effects of using alternative definitions for calibration and forecasting, where the two definitions are likely to be inconsistent.

DATA COLLECTION

Strategic and Long-Range Planning

Probably the central data-collection activity involved in support of strategic and long-range planning is the survey of individuals and households to amass information on travel characteristics around the study region. As described in the section on data needs, the primary application of data in this context is for calibrating, validating, updating, and applying travel-forecasting procedures. Traditionally, the mechanism for such data collection has been the home-interview survey. Principally for reasons already discussed in this paper, there is a need to consider improvements to data collection in this area and to determine why some changes have begun to appear on a limited basis. Most instances of the collection of the standard 24-h travel data still rely on the same data-collection methodology that has been used since the 1950s. However, the amount of data collected for each trip is frequently too little for the purposes of current models and policy needs, the home-interview process is too expensive for the budgets available, the sample sizes used in the 1950s and 1960s also are too large for current budgets, and the methods produce too many errors that are no longer so easy to assume away or lose in the aggregation process. Concerns, too, with specific population subgroups in impact analysis have tended to show up deficiencies in much of the traditional data collection, so that the planner finds too little data available about key impact groups, such as the elderly, the handicapped, and the poor. Clearly, change is needed in the procedures, but too little change is evident in the practice.

Those changes that have occurred in this area of methodology are largely by nature of experimental applications of modified or different procedures, and there is as yet no consistent new methodology that has been applied. There are several areas in which such experimental changes have occurred, namely, sampling procedures, sample sizes, survey-instrument design, administration of the survey instrument, and reduction of data to machine-readable form. Although this may seem to embrace all possible areas of survey activity and to cover all areas of survey work, whether strategic, long-range, project, microscale, or operations, the specific applications of these different elements are extremely limited in occurrence and in context area. Those that have been applied in the specific context of strategic and long-range planning are described in this section of the paper, but somewhat briefly, with the idea of illustrating the types of changes that have come about.

The traditional home-interview survey was applied on a systematic or random sample, usually generated from some available list of households in the study region, or by a simple method of field sampling (13). Probably the advent of specialized sampling for the initial research activity in developing behavioral models was responsible for the discovery of alternative sampling methods. Many of the research studies used a technique that was subsequently labeled "choice-based" sampling and introduced sampling notions that departed radically from simple random samples. With this and the development of alternative administration procedures and instruments, as described later in this section, new methods, such as two-stage samples, stratified samples, and cluster samples, began to be used for transportation surveys (14-16). Increasingly, there seems to be a move away from straightforward simple random samples that has grown out of the realization that such samples are not very efficient, particularly if any supplementary information is available about the population from which the sample is to be drawn; this change has been coupled with another change, discussed below.

The second change that is beginning to percolate into transportation surveys is a change in the sample sizes. Several factors are coming together to produce a change in sample size. First, there are economic pressures to reduce sample sizes; it is no longer possible to contemplate undertaking household surveys on the sample sizes that were used in the first generation of long-range transportation-planning studies. It has been suggested that these sample sizes may well have been used simply because the money was available to pay for them and it seemed reasonable to spend the money that way. Now the money is no longer available, but there are perceived needs to gather new data. Therefore, smaller and more efficient samples are needed. Second, there has been a slow, possibly reluctant, recognition that the first generation of major transportation surveys provides supplementary information on which much smaller sample sizes can be calculated (17). This has required the recognition that the large sample sizes (2-6 percent) of the first-generation studies were defined at that size because of ignorance about the inherent variances in the variables of concern. Although model fit may not be the reason for choice of a sample size (which may be far more an issue of available budget), it is still the case that model fit is used to justify the use of a particular sample size. Thus, a frequent justification of the large samples of the 1950s and 1960s was that they were necessary to obtain nonzero estimates in most of the cells of a trip matrix that might contain 500 000 cells (700 by 700 zones). This was considered of paramount importance because it was mistakenly thought that the calibration of the models in the travel-forecasting procedure relied on this trip matrix. This is not the case, although it is still misperceived by most transportation planners. For example, the gravity model of trip distribution is not calibrated on the trip matrix but only on the trip-length distribution. Hence, there is a need to rethink the purposes of the data and to understand better the way in which calibration and forecasting make use of the data.

The third factor in sample-size change is that it has become clear that the disaggregate models do not need the large sample sizes of the aggregate models. Samples as small as 300 individual trips have been found to be very satisfactory for statistically good fits (18). In contrast to the first-generation samples of 20 000 and more households, which made as many as 140 000 trips in a 24-h period, these are indeed small samples. Fourth, it has been recognized that more sophisticated methods of sampling, such as stratified samples, are capable of producing as much information on regional travel as samples of considerably larger size that are based on simple random or systematic sampling (14). Thus, for a combination of reasons, smaller sample sizes are coming into use and there has been a concomitant improvement in understanding of the implications of sample size and recognition of the sampling error.

The third area of change is in the survey instrument designs themselves. Of particular note here is the increasing interest in a travel diary for collecting the traditional 24-h travel data (19). To my knowledge, travel diaries have been used in a few recent surveys, specifically in Broward County, Florida, in Southeast Michigan, and in Honolulu, Hawaii. Although the travel diary is by no means a new technique, there are design differences and differences in the method of administration in these instances that seem to have contributed to a marked change in the success of the travel diary. The primary issues raised by the travel diary are that of recall versus active completion and the question of whether the diary itself may modify travel behavior. A marked difference found in the three applications of the diary noted above is that the proportion of non-home-based trips is much higher than that recorded in recent surveys and is also much higher than would be expected just from the known travel adjustment of increased trip chaining. Traditional recall surveys were known to be low on non-home-based trips, and it was generally necessary to factor these trips upward by as much as 20-30 percent based on screen-line counts. Even after such factoring, it appears that the reporting of non-home-based trips may have been too low, perhaps because many of them are relatively short and would not be picked up by screen-line counts. Nevertheless, it still seems likely that people will omit a certain number of trips, either because they cannot be bothered to give a complete accounting of their trips or because they do not wish to reveal some trips.

Another change that has occurred in survey instrument designs, in a few cases, is the omission of coding blocks, which used to be very much in evidence on many of the traditional survey forms. There are two reasons for this. First, changes in administration, discussed in the next paragraph, have focused more and more on the self-report or self-administered survey. It has been recognized that the existence of coding blocks on such survey instruments is deleterious to response and has a strong negative impact on potential respondents. Second, changes in data-reduction methods, discussed in the succeeding paragraphs of this section, have eliminated the need for coding blocks as an interim measure in the transfer of data from the survey form to the computer. Indeed, it has become clear that a careful redesign of most survey instruments can accommodate the needs of data reduction as easily as they can increase the propensity of potential respondents to complete the survey form. There are some further changes in survey instrument designs that have arisen from increasing use of self-report procedures and that have been made easier by the increasing sophistication and flexibility of printing processes. This should not lead the reader to suppose that all survey instruments are now designed in such ways. It is rather the case that there are a few instances in which such instruments have been used. Unfortunately, there are still too many instances where good instrument design has not found its way into practice; the result is that response rates are often too low and that transportation surveys gain a bad reputation because of the difficulty of completing them and the adverse publicity that accompanies such poor designs.

The primary change in the administration of transportation surveys is in the use of procedures other than the home interview. This is not to say that there is anything inherently wrong in the home interview; it is more the case that the home interview has become too expensive for continued use in transportation surveys and is also an inefficient procedure for very small but widely scattered samples. Whereas early transportation studies for long-range or strategic planning relied totally on the home-interview survey for the major data base on person travel, more recent efforts have used a variety of alternative procedures.

Perhaps the most commonly used procedure that has been introduced more recently is the telephone interview. This may be used either on its own or in conjunction with some other form of survey. For the Bay Area Rapid Transit (BART) studies conducted by the University of California (20), telephone interviews formed the basis of the data collection. There are also some instances in which other types of survey administration have been used. In Southeast Michigan (16), a home interview was used to collect attitudinal and socioeconomic information, whereas a self-administered travel diary was left by the interviewer for subsequent pickup. In Honolulu County, a telephone survey was used as a sampling device and a means to gain cooperation from households and was followed by an extensive mail-out, mail-back survey, which achieved a high response rate of more than 60 percent usable responses (21).

The notion of a telephone survey as a sampling device deserves some elaboration. A random sample can be drawn very easily from a region by using random-digit dialing (RDD). This procedure uses a random-number generator to produce random four-digit numbers that are attached also at random to the three-digit exchange prefixes used by the telephone company in the study area. Various methods exist for making this procedure efficient while preserving randomness, but they are not germane to this discussion. Once these telephone numbers have been generated, each number is called until answered or up to a prespecified number of times. From an interview conducted at that time, details about the household contacted can be determined, and these details can be used to sample households by characteristics for a secondary survey. In the case of Honolulu, for example, an RDD telephone survey was used in which the telephone interview lasted for less than 5 min. The interview ascertained, among other things, the household size, vehicle availability, and mailing address. A mail survey was then sent to households in specific categories of household size and vehicle availability only. A similar administration procedure was used in Broward County, Florida, earlier but with somewhat less success in terms of response rate. Nevertheless, both telephone and mail-back surveys appear to be finding use in transportation surveys for primary data bases of person travel.

Again, these changes can be seen to be linked to a number of the earlier ones. One primary impetus to changing the administrative procedures is the same economic one that has helped to increase consideration of the smaller sample sizes. In turn, smaller sample sizes with a representative geographic distribution generate problems of efficiency with home-interview surveys. The extent to which behavioral travel-forecasting procedures have been the catalyst for these changes is not clear, but there definitely is some relationship, given the changing data needs of the behavioral models and the better understanding of the effects of sample size that have accompanied these models.

Finally, in the area of data reduction, the primary improvements that have come about are related to technological improvements in computer software ahd hardware, which have generally made the 80-column card obsolete as the data medium. Direct-to-disk data entry frees the data-entry task from the limitations of an 80-column format and the need to repeat person or household identifiers on each 80-column card. Instead, it is possible to produce data formats of varying lengths that can usually accommodate an entire survey form. Also, entry grids on CRT displays provide a means to reduce the keypunching error and remove the need to identify for the keypuncher the fields in which data are to be entered. These and similar improvements allow a careful designer to structure a survey form that can be keypunched directly, without any intervening coding step, either on the survey form or to coding sheets. As mentioned earlier, this has led to reducing the clutter of the survey form as well as to improving the accuracy of data recording by removing the coding and transfer steps, each of which adds error to the computer record.

Apart from these various changes, the state of the practice continues to rely on methods of data collection and design that have been in use for more than the past two decades, including such items as roadside interviews, spot counts, and transit patronage estimates derived usually from farebox revenue. As is noted in the next sections of this paper, many of the changes in other aspects of data collection that have been described here are not limited to long-range and strategic planning but are used in other planning applications as well.

Project and Urban-Microscale Planning

In many instances, short-range planning activities--project and urban-microscale planning activities--rely on data bases collected as part of the long-range or strategic planning effort. Relatively little data collection is undertaken directly for these activities unless it is to update an old data base or to provide some much finer detail than is available in the regional data base. In those cases in which some updating may occur, it is likely to take one of two forms--collection of data of an identical format to the long-range data collection but at a more detailed level and in a geographically concentrated area or collection of specialized data from the project area for specific analytical procedures to be used on the local area. In this second case, one is most likely to come across the collection of attitudinal data, as discussed in the section of this paper on data needs.

Similar to the long-range and strategic planning situations, the primary differences likely to be found in short-range planning reside in the sampling procedure, the sample size, the administration of the survey, and the design of the survey instrument. For reasons similar to those discussed in the preceding section, sample sizes are likely to be relatively small and the sampling procedure is unlikely to be a simple random sample. The reasons behind the selection of an alternative sampling strategy are more likely to reside in the unavailability of a suitable sampling frame, restricted to the geographic area of concern or the impact group of concern, and in the ease with which an alternative sampling procedure can be applied. For example, in dealing with a project that might involve changes in bus service, it may be of greatest interest to obtain attitudinal data from those using the existing bus service. Therefore, a sampling device, such as an intercept survey on the bus, is likely to be the sampling and administration mechanism. In another case, it may be desired to sample those people in a specific geographic area where a project is planned such as reserving a freeway lane or undertaking highway widening or upgrading. In such a case, a sampling mechanism might be the selection of those telephone exchange codes that correspond to the geographic area of concern and then an RDD procedure on the telephone numbers in those exchange codes.

Survey administration in such a case is much more likely to use mail, telephone, or other self-reporting techniques for the data collection. For example, in surveys in Florida concerning the impacts of service withdrawal of buses, residents of several localities were contacted by telephone by RDD and by a telephone interview, whereas current bus riders were sampled by using on-board, self-report survey instruments (22).

Other types of project or urban-microscale data collection include various forms of intercept surveys, such as roadside interviews, and interviews at parking locations, places of work, shopping centers, etc. For some of the planning activities for downtown people movers (DPMs), data have been collected from those most likely to use or be affected by the DPM by interviewing or distributing self-administered survey forms at downtown businesses. The state of the practice, therefore, includes a number of specialized data-collection activities that use a variety of administrative procedures. Sampling for these surveys has not changed much in the past decade; the sampling itself relies on random arrivals or simple random selection of sites. Frequently, the attitude is encountered that representativeness is not of great concern because of the specialized nature of the project for which data are being collected. This is a somewhat dangerous position to take and has led to something of a cavalier approach to most aspects of the sample design and sample-size determination for these surveys.

Systems Operations

Although there are a number of different aspects of data collection that may be encountered for systems operations, the principal one discussed in this paper is the collection of data from system users, which may be used to describe system operation or to diagnose problems with the system (23,24). In practice, two primary types of data collection are likely to be found. The first is an intercept survey of system users occasionally, but not usually, backed up by some type of survey of nonusers. The second is a purely observational survey, such as a street-corner bus-passenger count or a fare profile survey. The practice in such surveys has changed little in the past one or two decades. Sample-size determination has become a little more sophisticated; more attention is paid to the possibility that one may be able to expand full system data from a sample that does not cover, for example, all routes in a bus system. Nevertheless, much of the current state of the practice relies heavily on much larger samples than are justifiable from statistical grounds. Collection of data for Section 15 reporting to UMTA still specifies a far larger sample and far more extensive data collection than is warranted from any reasonable assessment of sampling errors and needed accuracy of reporting (25). The form of the survey has also changed very little. The primary method used is still either to hand out to riders a self-administered survey form to be returned on the bus or mailed back later or to use survey personnel to record specific data about the system operation. This is not so much to say that there is anything inherently wrong in these methods as it is to say that the state of the practice in these areas has changed little for some time, and there is no apparent use of some of the more interesting and exciting procedures that have appeared recently in the state of the art (Brög and Ampt in a paper in this Report).

NONRESPONSE

It is somewhat surprising that only very recently has any real concern been expressed by transportation professionals over the potential biases injected in any data-collection effort by nonresponse (1,2,26,27). In past documentation of transportation surveys, it is frequently very difficult, if not impossible, to determine what the nonresponse level was on any particular survey--it simply was not reported. Concerns that were raised with nonresponse were largely to defend a priori a specific choice of survey method, and the nonresponse to a home-interview survey, in particular, was frequently reported incorrectly and far too favorably to the home interview. As noted by Sheskin and Stopher (28), the home-interview survey rarely counted addresses that could not be found, vacant addresses, frequent no-answers, demolished residences, etc., as nonresponses, although all of these categories lead to a nonresponse count in mail-out surveys.

Much more important than this distortion between alternative surveys, however, is the fact that little attention has been paid to determining the extent of nonresponse in any executed survey and then establishing the degree to which there is evidence of a bias caused by nonresponse. Brög and Meyburg (1,2) have provided evidence that nonresponse exists in transportation surveys and that even a very small nonresponse percentage, which may have been dismissed as trivial, may have a profound biasing effect on the data. Stopher and Sheskin (28) have shown that some rather inexpensive designs can be employed in surveys to establish the potential existence of nonresponse bias and to allow some degree of correction for it. Slowly, these ideas are beginning to appear in practice. In Dade County, Florida, calculations were made of the nonresponse bias between two parts of a survey instrument--an on-board form and a mail-back form--and used to modify the expansion factors to expand the data to systemwide application (30). The fact remains, however, that nonresponse is of apparently little concern to most of those involved in transportation data collection, and overt procedures to minimize it and to compute the effects of nonresponse bias on the data are few.

PILOT SURVEYS

A second area that has been neglected in transportation surveys is that of the well-designed pilot survey (29). It has long been a mainstay of good data collection in the social sciences and in statistical survey activities, yet too frequently the agencies involved in transportation planning are in too much of a hurry to do their data collection to allow time for a comprehensive pilot survey and frequently will not allow adequate budget to undertake such an essential element in the design process. It is not the intent of this paper to explore and document the benefits to be gained from a pilot survey. These are well documented in much of the survey literature (29,30) and the specific benefits of some case studies in transportation have already been documented (31). Suffice to say that the interests of collecting the right data for a specific need, to ensure that concepts are being measured accurately and appropriately, to ensure that the profiles and analyses to be obtained are derivable from the data, and to explore the effects of design and questioning on response rate, understandability, etc., can only be served by an adequate pilot survey. In this sense, the pilot survey should be a complete rehearsal of the entire survey activity, not only in terms of administration of the survey instrument, but through the analysis and tabulation steps as well. The pilot survey should also be administered to a sample that is drawn from the same population as the main survey sample and should not be a simple test on people drawn from a totally different population.

Of course, such a pilot-survey effort as is described here requires a considerable amount of additional time and effort beyond that of the fielding of the primary survey. Yet there can be no certainty that the data collected are reasonable and meaningful without it. Therefore it is of the greatest importance to conduct such a pilot survey. Again, this is not the current state of the practice except in a very few instances. To my knowledge, such pilot surveys were conducted for the Dade County on-board bus survey; for the Southeast Michigan regional travel survey; for the surveys in Honolulu, Hawaii, in 1981; for the Baltimore disaggregate data set; and for the data collection in Broward County, Florida, in 1980. However, these appear to be most of the cases in which a careful effort has been undertaken to execute a pilot survey. In contrast, in the same time period, a larger number of transportation surveys have been undertaken in which either no pilot survey was undertaken or such a minimal pilot survey was done as not to warrant the name.

CENSUS DATA

A final area of concern that seems warranted in a paper of this nature is the use of and relationship of planning to the decennial census data. Lengthy treatments of this issue have appeared elsewhere, so only a brief treatment is offered here. First, the census offers an invaluable resource of socioeconomic data that is needed to complement much of the specialized data collected for planning. This is widely recognized and does not need elaboration. However, two recurrent problems arise: the timeliness with which census data are provided (often two or three years after collection for the most basic data and longer for the more intricate tabulations and cross-tabulations) and the suppression of data when the number of units in a census tract, or other unit, becomes small. In many urban areas, where traffic-analysis zones represent subdivisions of census tracts, the suppression of census data for reasons of confidentiality may rob the planner of much data of value.

Second, the transportation data collected in a sample are largely incompatible with traditional transportation planning data and models. This is so despite the repeated attempts of professional planners to inform the Bureau of the Census of the definitions and data items that would be of most value. For example, the census collects data only on the main mode of travel, whereas the transportation planner typically needs information on all modes used but also has a carefully constructed definition of main mode that does not correspond to the census definition. Also, the census collects data only on the average journey to work, whereas the transportation data base contains all journey-to-work data for a survey day. Thus data on second jobs and multiple trips to work are not available from the census. The census provides no information on other activities on the journey to work, such as dropping a child at school, and the census assumes that the journey to work is a home-based work trip. This will not be the case in a number of instances, so the data do not fit into the usual purpose categories used by the transportation-planning process. These are a few of the problems that arise with census data.

The problems with census data are not insolvable but do require a willingness to listen on the part of the designers of the census survey instruments. In the meantime, there is much scope for the creation of survey activities in a census year that can be used to augment the census data and correct some of their shortcomings. Specifically, collection of enriched samples from periodic highway counting programs, running on-board bus surveys, and some limited interview surveys provides the means to create a much richer resource out of census data. This is a direction that has been pursued by some agencies, for example, the Florida Department of Transportation. They mounted a Cenval Project for 1980, which sought to do exactly what has been described in this section. More work in this direction in the future would be highly productive.

CONCLUSIONS

The primary conclusion to be drawn from this paper is that there is an extremely large gap between the state of the practice and current knowledge in the area of data collection and that there has been only a very slow percolation of new procedures and information into transportation planning applications of data-collection procedures. This apart, the paper should serve to raise a number of issues.

First, there are some issues that have not been resolved with specific concern to behavioral models of travel demand. These issues are what data should be collected to support the calibration of such models--reported or network data--and how one should define and collect data on choice sets for these same models.

Second, there is a need to remove much of the complacency or indifference that exist with respect to data collection and the designs attendent on it. Data collection is essential to various aspects of transportation planning. Yet it is also an increasingly expensive activity that must compete for what has been for some time a steadily shrinking budget for planning. It is therefore more critical than ever that advantage be taken of reducing sample sizes by the use of different sampling schemes and by utilizing the information inherent in previous data collection.

Third, it is necessary to recognize that the best and most effective data collection is finely tuned to the principal purposes of that data collection. All-purpose surveys, frequently talked about by transportation professionals, are basically impossible to achieve but are capable of consuming vast amounts of money in the attempts to execute them.

Fourth, there needs to be an awakening to the problems and pitfalls of nonresponse. Transportation planners, in particular, need to recognize that the likely nonrespondent is the least mobile individual. As such, this is the person most likely to be affected by many transportation policies and activities but on whom the effects are unknown because no reasonable attempt was made to gain information from that individual. There are many methods available to deal with nonresponse, but too often the attitude holds that even a 30 percent nonresponse rate indicates nonexistence of nonresponse bias. Finally, there is too little effort accorded to the design and conduct of pilot surveys. Some of this, it is recognized, has arisen from rules and regulations promulgated by the U.S. Office of Management and Budget, where well-meaning rules to prevent repeated and unnecessary surveys also tend to prohibit a well-designed and executed pilot survey. But much still lies at the door of transportation planners who have failed to recognize the benefits to be gained from good pilot surveys and who also persist in viewing pilot surveys as having no purpose other than to test alternative survey instruments. Furthermore, there is too often a lack of adequate time to plan and design a survey. Surveys are undertaken in the context of requiring the entire effort to be concluded in five or six weeks. Such short time frames prohibit adequate design of samples and instruments, prevent the execution of pilot surveys, and do not allow high-quality printing and instrument presentation to be obtained. These are false economies. The effects on data quality of a good survey design are well documented in the survey literature but are studiously ignored by transportation professionals.

Perhaps the most important requirement for good data collection is for the transportation profession as a whole to recognize that there is an extensive discipline of survey design and execution and that undertaking a survey is neither a diversion nor a game. It is a serious concern that has wide-ranging impacts on policy and planning. Surveys also represent a point of contact between the transportation professional and the public at large. In this respect, bad surveys can do irreparable damage to relationships with the public. This, in turn, can undermine the acceptance of the products of planning.

In sum, there is a significant gap to be filled between theory and practice and solid and significant gains to be obtained in transportation planning by closing those gaps in data collection.

Before the conclusion of this paper, it is possibly worthwhile to raise one further issue. In the United States, it is no longer clear what the role of planning is likely to be. New federal approaches to planning seem likely to change that role significantly. If the decision to undertake transportation planning is left to the states and regions alone, it is not clear that there will be much transportation planning in the short-term future in many parts of the United States. In this case, of course, much that has been said here becomes academic. Alternatively, the reasons for planning and the way it is done may come under much closer scrutiny by those outside the profession. In this case, it will become even more important that many of the issues discussed here be dealt with effectively.

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Research Needs

1. Improved documentation of data-collection efforts

2. Forums for information exchange to assure data compatibility and professional understanding

3. Coordination among data collectors at various levels of government (at the federal level would include removal of barriers such as the OMB regulation that prohibits repeat surveys of the same individuals)

Workshop on Travel Behavior Characteristics and Analysis

Workshop Summary

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The Workshop on Travel Behavior Characteristics and Analysis was oriented to a review of alternative analytical approaches to the traditional planning and modeling process. The problems outlined in the planning sessions were approached from a different theoretical base: concepts, data-collection methods, and statistical techniques from the behavioral and social sciences were reviewed for their applicability to planning problems.

STATUS OF METHODS

Three papers were presented. Klausner described the development of the social sciences and highlighted their capability to expand the frame of reference for transportation analysis. He noted that in contrast to planning, the social and behavioral sciences provide rules of the social process to order data and a theoretical context for understanding the important relationships. The state of the art in five subject areas was summarized: activity-based approaches; approaches that used subjective variables, or attitudes; population segmentations; experimental approaches; and choice models. The first three involve the introduction of new concepts and require the planner to apply new analytical approaches. The cutting edge of the state of the art is activity analysis, which indicates a broadening of the frame of reference from a psychological to a social-psychological perspective.

As the workshop moved to an evaluation of tools, concepts, and procedures, the consensus emerged that most of the state of the art was sufficiently developed for application. However, some research needs were enumerated, as will be shown later.

Paaswell and Michaels reviewed the state of the practice. In juxtaposition to the wealth of the literature on the art, few planning applications were noted. Workshop members identified several areas where applications can be found: transit marketing studies; impact assessment, particularly socioenvironmental impacts; ridesharing agency reviews; and analysis of service for the elderly and handicapped. The planning levels that have benefitted most from these approaches are project and urban microscale. Survey strategies and market segmentation are reasonably well utilized in practice and attitudinal analyses have been performed in a few transit, carpool, and pedestrian planning studies.

The major impact on practice of social and behavioral methods has been an increase in understanding of the behavioral processes of individuals and households. The range of reactions to transportation system management actions and energy shortages can be identified and the implications of transportation options more readily defined. Furthermore, many new concepts and a process mode of thinking appear in planning reports. As Michaels suggested, although research has not necessarily changed the practice, it has changed the perceptions of planners.

PROMISING METHODS

The workshop determined that the methods that could be incorporated into planning practice with high short-term benefits are

1. Small-scale data-collection activities,
2. Simulations with small groups, and
3. Segmentation and activity concepts and derivative analytical techniques.

The first method emphasizes the developments over the last several years in reduced data requirements, updating prior travel surveys, or project-level planning. Statistical techniques (for example, multiple classification analysis for trip generation and logit analysis for demand estimation) are available to derive the maximum amount of information from these data.

Golob and Golob refer to the application of simulations with small groups to transportation problems. Controlled manipulation of one or two variables with sample sizes of 50 or so is often found in the psychological literature. The methods can be used in an exploratory situation to derive ranges of possible responses and outcomes, to determine elasticities for particular groups, and to generate information on new alternatives.

Market segmentation involves the analysis of subgroups within a population. It is based on the idea that although a population is not homogenous, individuals can be grouped based on a defining categorical variable. The concept of a differentiated market, or market segmentation, as already in use could be broadened for greater application. The defining variables in particular situations need to be documented.

Activity analysis shows promise as a conceptual framework for analyzing complex tripmaking behavior such as trip chaining and for analyzing transportation system management actions. The approaches provide an opportunity to define the impacts of service cuts, unemployment, spending, and destination patterns. Used in an experimental setting with small groups, techniques such as the Household Activity Travel Simulator (HATS) offer the planner a wealth of information without necessitating a large data-collection budget.

PLANNING LEVELS

The workshop participants concluded that the planning levels for which travel behavior analysis techniques are most suited are strategic planning and project planning. To some workshop participants, strategic planning necessarily involves the social and behavioral sciences. Planning for "what if" requires an understanding of the forces in the environment that impinge on transportation decisions. Strategic planning requires a different approach to data collection and more than any other planning activity requires greater understanding of travel behavioral processes. Goal definition, macrosystems analysis, and analysis of system linkages are integral to strategic planning. The testing of future scenarios, monitoring changing lifestyle and consumption patterns, and changes in the ordering of priorities provide part of the capability to perform strategic planning. Determining the direction of change can be accomplished through the use of monitoring techniques: mail and telephone panels, repeated focus groups, and cohort analysis of cross-sectional data. Experimental techniques and activity analysis can be used to define changes in societal objectives and to obtain more information about travel patterns. The identification of possible scenarios through use of the Delphi technique can provide expert opinion on possible futures.

Viewing transportation plans from the perspective of determining who benefits and who loses and broadening the perspective of statewide plans to incorporate impacts on state economies accompanies the shift in long-range planning to policy rather than facility planning. This policy aspect of long-term planning could be served by activity analysis and controlled simulation experiments. Project planning could benefit from use of all the approaches in grappling with outlining the implications of such plans. A focus on impact analysis suggests a more active policy analysis role for the planner. Such a perspective permeated the workshop discussion and formed the basis of the workshop recommendations. In order to do so, application of a greater number of tools and concepts in the planning environment is necessary.

BARRIERS TO IMPLEMENTATION

The workshop participants identified several barriers to the ready implementation of social and behavioral science techniques. The first is related to data needs. Activity, motivational, and attitudinal analysis require different types of data than are normally available or generally collected. Sample sizes can be small but the amount of information to be collected from individuals and households is greater than that collected in a typical travel survey. Related to this is the planners' lack of familiarity with detailed survey and interactional data-collection methods.

Second, the literature is not organized in such a way as to be helpful to the planner. Integrative essays are difficult to locate; studies and planning reports are often unpublished. When studies are published, rarely are the sampling and data-collection methods described in detail.

However, the most significant barrier is the lack of evidence that travel behavior approaches would lead to different results and therefore different decisions than more traditional approaches. Comparative analysis of approaches is a necessary prerequisite for diffusion of the techniques in the planning field.

TRANSFER POSSIBILITIES

Transfer possibilities identified in the workshop center on communication through greater use of NCHRP Synthesis of Highway Practice documents and the development and dissemination of procedural manuals and case studies. It was suggested that social and behavioral scientists should publish in the applied science journals and that planning courses incorporate information and techniques from the behavioral sciences. Universities could perform a major role in developing seminars for local planners and coordinating projects with metropolitan planning organization (MPO) staff. These avenues of communication have long been available, however. It is to be hoped that the conference, in focusing on the relationship between art and practice, will spur interest in relating the two.

CONCLUDING REMARKS

It is important to recognize that research affects practice in many more ways than merely through the transfer of technology. The knowledge base developed through a decade of research has greatly expanded the capability of the planner to meet new requirements. The challenges of the planning profession change and a major evaluation criterion for research is whether it helps us anticipate and adapt to such changes. Although it is essential to the transportation planning field to occasionally review the progress achieved in transferring research into practice, it is equally as important to establish new research horizons. A healthy discipline will always have a gap between research and applications, yet in a field oriented to implementation it is easy to lose sight of the benefits of research. The social and behavioral sciences, in providing a larger framework for understanding travel behavior, can be of assistance in providing information and tools for better performance of planning activities and in anticipating directions for future work.

Social Sciences as Conceptual Resource for Transportation Research

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My assignment is to brief members of the conference on potential contributions of the social sciences to transportation research. This assignment could be approached inductively from the bottom up, as it were. That would involve a case approach, commenting on the way social science theory and method might improve the accuracy or scope of application of specific examples of transportation research. Incrementalists, who anticipate that social scientific applications will evolve in transportation research as the sum of small adjustments, might prefer such a case approach.

Conversely, proceeding deductively from the top down, a conceptual map of the social sciences may be used to project some directions for transportation research by proposing alternative statements of transportation problems. The deductive approach, from theory to application, is chosen here for several reasons. Foremost is the fact that current transportation behavioral research is imprisoned by a physicalist frame of reference. This very frame of reference calls for revision. The conceptual frame is not physicalist in the literal sense that transportation systems are conceived as constituted solely by vehicles, motive power, and routes. Rather, the human actors in the system are treated as objects in a fluid medium, which is described by rates of flow in constrained boundaries subject to the action of valves and represented by such metaphors as "trip purposes" and "travel demand." The mathematical models preferred are those of operations research. Some of these models were originally designed to monitor physical flow processes such as inventory control. Others, models of population growth and mobility, are borrowed from demography and human ecology. These are specialized, and useful, forms of societal analysis that imagine a human population to be a set of objects arrayed in a spatial matrix.

Such models have immediate use in analyses of system problems of operating transit agencies. The power of social science, though, is hardly exploited in these applications. Market research in the motor vehicle industry, for instance, tends to break away from these spatial models and begins to draw on economical and psychological theories of consumer behavior. Were behavioral researchers called on to evaluate national transportation policy, to assess the interplay between characteristics of transportation systems and the regional distribution of industries, or to examine transportation in relation to defense strategy and tactics or in relation to health services or its impact on culture and education, the pressure would be to break away from the physicalist model in favor of a wider range of symbolist social science models.

In proceeding from a discussion of the nature of the social sciences to applied problems, we hope to reveal new possibilities for transportation research. Issues not high on the current agenda but of high national significance may be revealed. What resources may the social sciences, and sociology in particular, offer transportation planners and researchers?

As motivation, I begin with a series of comments on the way we think about transportation and offer general caveats (actually advice) about how not to think about transportation as a social phenomenon. In the second part of the paper, I examine problems of social prediction, particularly relevant to planning. I will close with a systematic, though brief and schematic, statement about the conceptual frameworks current in social science and the contributions to transportation research, particularly for planning and policy, possible within each framework.

HOW TO THINK AND NOT TO THINK ABOUT TRANSPORTATION

Five fallacies dog our thinking about transportation. They impede our research and planning.

1. Transportation refers to getting people and goods from here to there and in negating the space in between. Land use, contrasted to transportation, refers to a static commitment of territory to particular activities and facilities.

The error is to consider land use or human settlement, on the one hand, and transportation or mobility, on the other, as distinct social events. The basic analytic dimensions of transportation and of land use are similar rather than contrasting.

To specify these dimensions, let us begin with the idea of a social order. A social order consists of interrelated activities. The activities are accomplished by actors, the individual or collective agents of the activities, governed by social rules and goals and facilitated by material means such as technology and symbolic means such as language. A network of such activities constitutes a social structure. These activities may take place at locations distant from one another. This seeming condition of action may be modified by technical intervention.

Add to the idea of a social order the idea of a physical order of society, not to be confused with the physical order of nature. The physical order refers to the net of locations in which the activities reside. Human activity requires the articulation of the social and the physical orders. Transportation is itself a social activity, having both a social and a physical order among its components.

The function of transportation is to articulate the social and physical orders of the society. By mapping one on the other, society is transformed from a latent potential to an enacted reality. Transit between locations is one device by which social and spatial relations are articulated. Social interaction becomes possible despite physical separation. Speed is a mechanism that reduces the social significance of distance toward nothingness.

The social and spatial order may also be articulated by arranging activities within a limited set of locations. This we call land use. Land use is a way of ordering activities that does not negate space but makes creative use of it. The more-limited space becomes a stage for social action. The military, for instance, arranges fire power with respect to characteristics of a battleground, an element in tactics. Battleground characteristics are not passive but enter into the social, specifically the military, activity.

Transportation and land use are two ways of dealing with the same social problem, the patterning of human activities in space. Transportation might be distinguished from land use according to the distance between locations. The critical distance varies with the type of interaction and technology. The interaction of a net of satellite-tracking stations is a form of land use; the logistical support of those stations is a transportation problem.

2. The measure of the social benefit of a transportation system is the rate at which it processes people or goods through the system.

Why is this common assertion misguided? The benefit of a transportation system is its contribution to the ordering (i.e., articulating the social and physical orders) of other social institutions. A transportation system succeeds to the degree to which it facilitates the political, economic, or religious, among other, relations of a society. The measure is the extent to which it enhances the work of educational organizations or the functioning of hospitals, of medical services, or of manufacturing industry in American life.

These measures of effectiveness may be, but not necessarily, related to the economic efficiency of transportation itself. Striving for economic efficiency within the transportation system may reduce its ability to serve other social institutions. The proper evaluation of transportation is not based on its internal balance sheet alone but also on its contribution to the broader social system. The societal balance sheet may show profit for the transportation company and a deficit for social welfare, or vice versa.

3. Transportation is an industry.

Ways of thinking about manufacturing industries have been applied uncritically in thinking about transportation. Both transportation companies and manufacturing companies are profit-oriented firms. Both organize to accomplish their objectives through formally constituted bureaucracies. An industry, however, is a self-justifying social activity. Manufacturing, for example, involves the application of skill or craftsmanship in the production of a good or the offering of a service. Industries produce for consumption. Steel or rubber industries are characterized by the material resources around which their employees and activities are organized. Transportation is not an end in itself and its product is not a final item of consumption. Its role is infrastructural. We speak loosely of a health industry but stop short of speaking of a religion industry. Both of these are infrastructural services. The social role of transportation in facilitating other institutions of society is comparable with that of religion, health, and banking. None of these are ends in themselves. Banking facilitates exchange of labor and capital between households and industries. Trucking can be recognized as part of the social infrastructure because it takes on the meaning of the activities it facilitates. Trucking service to deliver groceries to sustain households is part of the social link between the family and the economy. Railroad cartage of coal is part of the coal industry, especially when the mining corporation owns the cars.

This semantic generalization from an industry to an infrastructure would not matter much for practical purposes but for the fact that policy tends to be generalized as a result. Economic policies for manufacturing industries are not equally valid for infrastructural services. Oligopoly controlling infrastructural service or, on the contrary, disorganized segmentation of control in that sector would be more of an impediment to society than either oligopoly or segmentation would be in manufacturing. A well-known historical example of such a lynch-pin role is the limitation that toll roads in 17th-century Europe or in the 19th-century Near East imposed on travel, cartage, and trade.

4. The enterprise of transportation is properly corporately proprietary.

Society's need for transportation is as intense as its need for the activities that transportation facilitates. The social contribution of transportation is not a product but is an increment of social order--in cybernetic terms, negative entropy. Governmental regulation emerges to chide the transportation system when it threatens to become selfish or behaves as if it were an end in itself. Competition among infrastructural organizations may not evoke Adam Smith's invisible hand as a source of social order. The invisible hand works in an economic free market. The less the direct economic relevance of social activities, the less likely is the invisible hand to emerge to govern them. The infrastructural organizations support numerous social activities that are not primarily market activities. They are familial, religious, etc.

Financial profitability for the individual transportation unit is desirable but not crucial for the existence of transportation as a system. It is a consequence of the way we finance transportation within our market system that, in practice, general profitability is accepted as a controlling norm. It is less important that profits show on the ledger of a specific company than that profits show on society's ledger. The shipper and the receiver are not the sole beneficiaries and therefore the only ones who need pay for the service. To hold this to be the case is again to treat an infrastructural service as if it were an industry. The fate of social organizations not primarily economic, such as small towns, should not hinge on economic exchanges between the trucking company and its shippers and receivers. Like health care and religion, transportation should resist total economic rationalization if it is to optimize its contribution to society.

Transportation ratemaking, for example, may be discussed as a choice between market and administered prices. All prices are administered to some extent. Every price may be negotiable in a Middle Eastern bazaar but not where prices are fixed by company policy. The issues are who administers the prices, the government or the board of a corporation; what criteria are considered; and what weight is given to each criterion. The so-called market price results from the decision of sellers to emphasize a revenue function based on cost functions and supply-and-demand relationships over, for example, political or military considerations.

Government responsibility for the general welfare is a license to administer prices for infrastructural services. Price administration may serve a variety of policies including population distribution, resource exploitation, sovereignty over territory, and military defense. Since government decisions are political, its policy also reflects constituent interests. This is a natural outcome of the fact that transportation is not an end in itself but designed to facilitate policy goals of other societal sectors.

5. Transportation is, in itself, politically and culturally neutral.

To say that transportation is neutral is to say that its influence on the shape of society does not derive from its intrinsic characteristics. It influences politics when it is exploited as a tool by the socially powerful. Indeed, political control of transportation influences the distribution of power among interest groups, ethnic groups, and regions. One reason governments have tended to nationalize and operate transportation systems is that strategic control may be exercised through them. Labor-management power struggles within transportation organizations are, for such reasons, of intense concern to the public. The reverse is also true. The distribution of social power affects transportation planning and programs, the establishing of routes, the acquisition of equipment, and the nature of service.

However, the social impact of transportation is not limited to its exploitation as a tool of the powerful. Transportation for reasons intrinsic to its character affects the balance of cultural power in the society. In this sense, it is not a neutral facility. Transportation strengthens economic and political institutions at the expense of other social institutions such as family and religion. This shift of institutional power changes the fundamental character of the society. Families, submerged in industrial society, increasingly incorporate norms and values that properly govern political and economic activities. This is in part what is meant by speaking of industrializing society as becoming modern and as becoming secular.

The cultural change occurs in part because of the nature of transportation technology and the way in which it serves society through an economic market. Transportation centers around complex technology and high energy. It is particularly promotive of those social activities based on the technical division of labor, the specialized occupations of production. Social activities aimed at acquiring and allocating resources and at shaping the physical environment and imposing the will of society on its members are aided by a powerful transportation system. Modern transportation does not promote to the same degree the more intimate and expressive social relationships in family, community, and religion.

SOCIOLOGICAL SCHEMAS

What Sociology Offers and What Is Missing from That Offer

The above fallacies do not occur simply because of insufficient rigor and precision in our thinking. They become apparent when transportation is conceived as institutionalized social activity functioning in a milieu of social organizations. General social science concepts have been brought to bear to achieve an understanding of the social system of transportation. This advantage must be balanced by a recognition of the limits of social scientific analysis, especially with reference to social planning in general and to transportation planning in particular. For illustrative purposes, the following discussion will deal with sociological knowledge rather than with all of the social sciences. A similar case may be made with respect to the knowledge produced through psychology, anthropology, economics, political science, the other generalizing social sciences, and history, a particularizing form of social scholarship.

Sociology, and even the social sciences taken together, offers some necessary but not sufficient knowledge for planning the empirical social system of transportation. The social sciences offer a narrow, specific, and perspective knowledge, a way of thinking about society that uses abstract general concepts. These concepts assemble seemingly disparate concrete events in an attribute "space." The coordinates assign to the events measures of the degrees to which they manifest the attributes defined by the spatial axes. Thus, the event may be living in a small town as compared with living in an urban center and the attributes may be distances traveled to school or proportion of households at various stages in the family life cycle.

Most American social science follows the positivist school of scientific philosophy. Taking a cue from the success of the physical and biological sciences, the method of choice derives from thinkers such as David Hume, Thomas Hobbes, Jeremy Bentham, or, more recently, Rudolf Carnap and Karl Wittgenstein. Approaches, no less scientific, derived from German idealism--the empiricism of Karl Marx, the economic sociology of Werner Sombart, and the comparative sociology of Max Weber--are less typical. The positivistic thrust implies the measurement of external variables to arrive at statements about social process from which a reconstruction of real events is attempted. To believe that the real, palpable world can be reconstituted from a collection of abstractions is a delusion.

As a result, four types of knowledge needed by planners are not provided by sociology. First, sociological knowledge is not technical knowledge. It is not knowledge designed for the manipulation of the social world. To draw an analogy, a sociologist is more like a physicist than like an engineer. Concern with particular concrete situations is rare. The establishment of probabilist or statistical relationships relating to a universalized process is the typical way of working. The practitioner needs statements relating to concrete means translatable into instrumental instructions for the social craftsman or engineer. The political scientist is not a politician. Politicians draw on political science but must know more about their specific constituencies than they could infer from generalizations about, say, social class and voting propensities. Social science provides some background for understanding instrumental knowledge. Theory offers an environment for the practitioners' understanding, perhaps reducing the likelihood of vain effort or sheer foolishness.

Second, sociology is not moral or religious knowledge. It provides no statement of the "oughts" or the "shoulds" of the world. Its descriptions, existential statements, are factual and carry no intrinsic implications for acting one way or the other. The moral actor, of course, has more of a chance of achieving moral ends when existing facts and possible facts are taken into consideration. The kind of world we would like to realize, given the facts, is defined by our collective moral or religious sensibilities. Philosophical ethics contemplate the options. Religions, or secular social philosophies, implement the values in action.

Third, sociology does not offer aesthetic knowledge, or knowledge of the patterns in which the social world organizes itself into an array of functionally related institutions. The arrangement of organized, competing, and cooperating groups that carry out the world's work manifests such a societal aesthetic. We rarely see the concrete social world. Partly, this is due to our positivistic attempt to infer that world from its secondary qualities, as philosophers call them, or attributes, as scientists term them. Idealist scientists, such as Max Weber, concentrated on the organized "historical individual" such as capitalism or feudalism or the German nation or the Catholic church. These take shape from an aesthetic or an organizational plan. One way to put it together is to go to literature or other more socially synthetic approaches. Such entities might well be our objects of research rather than simply the strategic research sites for measuring varying attributes.

Fourth, sociology is not a source of affective knowledge or emotional involvement in the activities. The social scientist aims for ethical neutrality, standing outside of the events and not judging them emotionally or morally, at least within the moment of scientific practice. Planners may never be ethically neutral, at least not in their active moments. In the preparatory moments, the planner may delay judgment but ultimately requires a commitment to action. The sociologist cannot provide the commitment, whether defined direction of development or the emotional thrust. At the same time, the sociologist is not alienated from the world. As Renée Fox, a medical sociologist, says in relation to the objectivity of the physician, the proper attitude is detached concern. Sociological work does not reflect the tone of the society. The reports are neither melancholy or slothful nor enthusiastic or triumphant. A social scientist who abandons such emotional and moral asceticism in his or her scholarly roles is not relying solely on the tools of social science.

Social planning is acting in society. It involves the scientific--that is, the cognitive--as well as the technical, the moral, the aesthetic, and the affective elements of action. Or, in the language of Alfred North Whitehead, philosopher of the natural sciences, the objects and entities ingress into, become part of, or qualify the developing concrescence of the real world as it emerges in the process that is reality. This cryptic sentence requires more elaboration than is possible within the confines of this paper. Allow it to stand as a signal that a more fruitful relation between science and policy planning and action may be achieved when both are reconceived within a framework of Whitehead's philosophy of organism.

Dilemma of Prediction

A plan delineates decisions for action in the future. Any present action predicates a future state of the system. The problem is that within the positivist scientific framework only "efficient cause," to use Aristotle's word for it, is legitimate. As a result we know only about completed events. We project these by extrapolating from an established mathematical model or by assuming a variety of scenarios. We work as if they were true. This fiction permits action in the present but does not avoid miscalculation.

Social scientists are pressured by agencies of the society to do "futurology." At the present state of the art, a conservative stance about futurological statements is prudent. Some social scientists are more courageous than others. A not-insignificant correlation exists between courage in this respect and being a publicist or a popularizer. Popularization is encouraged by the consumers of sociological knowledge because it offers them some sense of security.

The best predictor is an assessment of the current state of the system and a good theory of how it came to be the way it is. The future is always given in germ in the present, but this germ, and the program for its evolution, can only be recognized through some theory.

The discovery of such seeds and their evolutionary programs are at the heart of their empirical search of idealist social scientists. Thus, Marx' option of the inevitability of the shift from feudalism to capitalism and then to socialism is rooted in his theory of the evolving entities and their laws of change. This approach is not the prisoner of an analysis of the secondary qualities of the entity or the variable. The validity of the projection is not tied to past genetic causal relations. The model includes purposiveness, a sense of final cause, as part of the defining characteristic of the entity.

In the energy field, for instance, the Arab oil embargo of 1973 is treated as a surprise in energy scenarios based on the extrapolation of abstracted elements of past behavior. The embargo surprised only those who were not reading the purposive character of discussions in OPEC about the politicization of their economic power. Not predictable was the vote to implement that purpose at that particular meeting and in response to the particular political crisis. The decision was in the cards.

One statement, probably true but insufficiently appreciated, is that more general principles about society are known and available in the literature than are tapped by practitioners. In part this is a consequence of the social position of the transportation researchers mentioned in the opening of this paper. Researchers are, by and large, called on for immediate responses to organizationally defined problems. This precludes time for study and reduces the predictive validity of research.

Direct extrapolation on the basis of past data by using abstract variables is perhaps the most common predictive technique. Yet its level of predictive validity is not reassuring. Demographic projections illustrate the case. Census projections are not too inaccurate for computing intradecennial estimates. Like the economist who discovers that the best predictor of the price of gasoline in 1984 is that price lagged one year, so the demographer finds the 1960-1970 rate of change applied to the level of population in 1970 a good indicator of the 1980 population. Misprediction occurs for reasons outside of the demographic schema that do not enter computation of the rate. To extend such extrapolations far into the future is the butt of professional tongue-in-cheek comments. During the 1970s those fearful of world overpopulation could prophesy that by the year 3000 but a square foot per person of earth would remain and by the year 5000 the radius of the earth would be expanding, in flesh, at the speed of light. The exponential expression, untamed by any logistic curve-flattening considerations, dictates such outcomes. In real life, some Malthusian positive or moral check would save some members of the population.

A 1948 prediction of the population of the United States in 1980 is illustrative. In 1948, observing post-World War II fertility rate increases, the Bureau of the Census anticipated a United States population of 165 million for 1980. The population for that year was nearly 230 million, an error of the order of 300 percent in a 32-year projection. Lawrence Klein, founder of Wharton Economic Forecasting, says he is comfortable predicting the next two months or the next quarter.

The Meadows' Limits to Growth perceived "overshoot and collapse" of our physical environment. The Meadows' models occupy the attention of political leaders more than scientific leaders. These models connect a number of exponential functions based on the growth of physical variables. Economists were quick to point out that little attention was given to economic variables that would control the rate of consumption, of production, and so of pollution, for example. Nothing in the models refers to the social institutional context. The original Limits to Growth, about 10 years old now, shows a curve representing the increase of gross national product (GNP) per capita over successive years. That function should be increasing exponentially according to the graph.

Transportation planners certainly must look ahead a few years. In fact, in planning a rapid transit system, estimates of ridership a half-century hence would be most useful. Responsible projecting from planning requires that one be theoretically informed. The work of William F. Ogburn offers an example of theoretically informed projecting. Ogburn was a sociologist at the University of Chicago in the 1920s and 1930s, the author of the theory of social lag and among the first of the social science fraternity to commute between university and government. Herbert Hoover brought him to Washington along with Charles Merriam, the political scientist, to establish a Commission on Social Trends. At that moment in history social scientists were more prominent than natural scientists in advising government. The Commission's report, Recent Social Trends, published in the first year of the Roosevelt administration, contributed to New Deal planning.

William F. Ogburn thought about the impact of technology on society. He erred in some specific technological predictions. For example, he anticipated that in the years following World War II a "roadable" helicopter would became a choice mode of travel. This hybrid helicopter and automobile, demonstrated around 1945, could fold its rotors and proceed along a road or deploy its rotors to fly over to the next road. The roadable helicopter did not become the family car because of the availability of functional alternatives.

A 1948 article by William F. Ogburn from the New York Times Magazine was entitled "Who Will Be Who in 1980?" This 34-year-old prediction is, in many respects, an accurate one. He interpreted an excess of marriages in 1947 as postwar deferred marriages. A blip in the fertility rates was anticipated. This demographic fact, in its social context, led him to infer impact on the school system, first an increased need for classrooms and then a drop in that demand. The anticipated pattern pretty much happened.

He observed that women were drawn into the labor force during World War II. To interpret the meaning of this, he refers back to models from 1918 when the proportion of women in the labor force had also increased. He anticipated a stimulation of the women's movement and a change in sexual mores. Very perceptive.

For another prediction, he calculated a future decline in the birth rate following completion of the deferred births. This would not indicate a real change in family styles but would, by itself, produce a shrinkage in certain markets. However, the introduction of new inventions would balance that effect. Businesses would be founded around these new inventions. Among the inventions that would make a difference, he did not mention the roadable helicopter. New businesses, he wrote, will be built on television, the helicopter, the magnetic wire recorder, and the electronic tube. Solid-state electronics and computer chips were not yet obvious to him. The University of Pennsylvania prototype computer at this time was operating on vacuum tubes. He further predicted businesses dealing in facsimile transmission, plastics, alloys, and atomic fission. He erred in his expectations of atomic fission. At a time when leaders spoke of atomic power producing electricity too cheap to meter he did not appreciate some real costs associated with a changeover of nuclear plant construction or waste disposal nor did he grasp the evolving public resistance to atomic development and its effect on the availability of capital to fund nuclear plants.

What enabled Ogburn to score so highly? He could see reality because he did not stay within any of the confined abstract frames of reference. He was a sociologist who was able to look at several components of the picture and to integrate these forces. He was well grounded in social theory.

A last example is taken from the writings of one of the finest institutional economists and sociologists. In 1942, Joseph A. Schumpeter, then a professor at Harvard, wrote Capitalism, Socialism and Democracy. Posing the question, "Can capitalism survive?" he responds "No." The breakdown of capitalism will not be due to its economic failure. Marx had predicted the breakdown of capitalism following a series of economic crises, the inevitable capitalist business cycle. Schumpeter predicted that its successes doomed capitalism. Consistent with the German idealist tradition, capitalism is treated as an historical individual with its own developmental laws. It is not characterized in terms of attributes, as in a contemporary econometric analysis. A process of creative destruction is built into the capitalist system. The system tends to mutate with the introduction of associated kinds of technology and their new forms of industrial organization. He predicted corporate concentration not unlike the current merger contest of Bendix and Martin Marietta. Negotiating for someone's stock becomes more profitable than building a new factory.

Schumpeter perceived the role of the entrepreneur, or risk-taking behavior, as a key to capitalist growth. Observing the development of bureaucratic structures, he writes that "everything is becoming routinized." Rationalization will rob us of the entrepreneurs and this will deprive capitalism of its dynamic. The large bureaucratic structures that are a mark of capitalist success will destroy the system. After the problem is presented by the elite that enters government through capitalist success as a routinized bourgeoisie, these persons are not heroic and therefore at a disadvantage in managing international relations.

Schumpeter's success in prediction is due to his ability to move between economic and sociological categories and not become lost in a jungle of abstract variables. Transportation planners need their Ogburn and their Schumpeter.

The last section of this paper suggests some directions in which travel behavior research may escape its physicalist models. The following pages survey the various areas of sociology and suggest issues for transportation research. Beyond travel behavior and problems in the prediction of public bus ridership or of community opposition to thruway construction, social research has a place in proposing and evaluating national transportation policy.

MAPPING SOCIOLOGY: ILLUSTRATIVE RESOURCES FOR TRANSPORTATION SOCIAL RESEARCH

Roots of Sociologies

The social sciences do not constitute a single discipline nor is the subject matter of any one of them ordered in the logic of a discipline. The reasons are historical. American university departments of sociology were, in some cases, a product of American social welfare practice, established at the turn of the century by sons of Midwestern ministers. In other cases, departments emerged from the more global and ethically neutral thinking of European scholars who migrated here or who influenced American thinkers studying abroad. Sociology reflects a number of traditions.

This section organizes some of the materials of sociology in terms of several frames of reference and suggests questions, especially transportation questions, that may be asked within each framework. The presentational principle will be to move from the conceptually simplest form to the conceptually more complex forms of social science thinking.

A frame of reference refers to background rules, hermeneutic principles, which define the types of concepts and therefore of propositions and theories that are legitimate and the types of interpretation that make sense. Sociology, as our illustrative social science, may be examined as a series of interfaces between sociology and the other sciences. Sociology borrows its styles of thinking from the natural sciences and the humanities as well as from such social sciences as political science, psychology, economics, and anthropology. At each interface sociology uses a definable net of concepts to grasp social reality and tends to select a particular range of substantive problems.

Interface with Natural Science

The conceptually simplest sociology borrows its style of thinking from the natural sciences. Following Newtonian physics, the space-time frame of reference is adopted. The real world, now the social world, is taken to consist of objects distributed in a spatial matrix. Demography dominates this kind of study of society. The demographic population, which may be a population of any type of independent units, is to be enumerated. Ordinarily, nondemographic factors establish the boundaries of the population. The basic mathematical models of demography apply as well for measuring the growth of fish in a stream as for human beings. The growth exponential Ce^x, where x refers to a rate of change, may be applied to people, to microbes, or to social attitudes. Whatever the units are in their totality is unimportant. Their characterization as objects dispersed in a boundary is abstracted from any other reality they possess.

Three basic concepts are fundamental to the field. These are fertility, mortality, and migration. All the other concepts, such as population ratios and rates, are derivative. Human population studies are reduced to an analogy to the probability that red balls and white balls will be found in an urn. The rate at which balls accrete to the urn (fertility), the rate at which they are removed (mortality), and the rate at which they might move from one urn to another (migration) are the central ideas. The advantage of this approach is remarkable clarity and often highly precise measurement.

Asserting that this is the most abstract form of societal study may seem to be a paradox since enumerated people seem quite visible and concrete. The method abstracts simple existence and the physical location from the total qualities of the subjects. Everything except their movement into locations is ignored. This highly abstract thinking allows analysis of certain kinds of useful questions.

Aside from the obvious question of the number of people within a particular boundary at a particular time or its rate of change over time, demographic data may be used to estimate social data. Demographic data predict social data best when the correlation between the number of people in an area and social activities is governed by some law of nature. Until it is questioned, the constitutional principle for apportioning congressional representatives simulates a law of nature. For every given number of people resident in a particular area (the number having been established following the decennial census), one representative is to be sent to Congress. The demographic facts are less helpful when the law relating them to social events is not quite so specific or binding as a natural law or as a constitutional principle. The use of demographic enumerations to plan school services is an example. When birth rates increase, a need for more schoolrooms may be anticipated. However, the ratio is conditioned by residential preferences, racial attitudes, the attitude toward education, and so forth. The prediction of transit ridership from demographic data encounters similar difficulties. Good rules of thumb come into use to assist transportation planners under such circumstances.

Demographic data are a good first approximation for Malthusian problems relating population size and resource consumption. Malthus theorized about food supply but his models apply to any natural resource. Purely demographic treatment becomes inaccurate to the extent that the relationship between population and resources is mediated by the organization of the population, its social order, and the technology at its disposal and its location--the physical order. Demographic data are weaker still for market predictions. If baby products are to be marketed, knowledge of birth rates, rates of marriage, family formation, etc., cannot be unhelpful. Yet extrademographic factors affect these rates and the character of the demand.

The field of human ecology also conceives of society in a natural science frame of reference. In this case, the biological organism and biotic communities, rather than Newtonian physics, are the model. Human ecology adds the concept of organization among the units to the basic ideas of demography. The arrangement of a population in a territory or the relationship among communities in several territories may be introduced along with its processes of growth and structuring, such as the social division of labor or its patterning with respect to resource or geographic features. The issue of land use and transportation, as described in the opening section, may now be raised. Questions about transportation demand may be framed with respect to the ecological interdependence of communities. The human ecological format allows one to raise environmental problems such as those around the relationship among human, plant, and animal populations.

Problems of crowding in urban centers can be approached in these terms. However, here again the theory becomes weak. Crowding is not simply a question of physical density of population or even a simple function of the organization of that population. We studied households, for example, that were accepting evacuees from a flood disaster. How crowded the host household appeared to its occupants depended on the organization of that household and whether or not mass feeding was instituted, the kitchen allocated to families on a hourly schedule, or the evacuee family was absorbed into the routine of the host family. Certain forms of social organization could absorb more people with more or less experienced stress.

A society cast as a theory of distributed objects organized in a spatial matrix restricts analysis to external characteristics of the units. Demography and human ecology are concerned with populations and communities. The rule for deriving these from the original objects of observation is arithmetic, the aggregate being the exact sum of the enumerated units. The following paragraphs will suggest additional concepts necessary for accounting for the behavior of the units such as mind, norms, values--i.e., concepts of symbolic processes. However, the image of objects distributed in a spatial matrix will hover over the analysis as a rule for admitting cases to the set to be considered, the selection of units of analysis. A population of attitudes may be studied through a sampling of persons having the attitudes. The units may be conceived as independent of one another and selected by probabilistic methods. The assumption of independence refers to the occurrence of the attribute of a particular object, not to the distribution of objects. Thus, the likelihood of mortality of a particular unit may depend on prior mortalities. This is handled by conditional probabilities. In the case of attitudes, each attitude may change the others much as a spot of color on a painting changes the whole picture.

The demographic and human ecological approaches do deal with certain characteristics of the objects. These include the length of time they have been in a particular location in the matrix (age) or whether they are new entrants (birth) to the set. One may take other attributes of the units and treat them under the same assumptions. This draws the natural science approach into the measurement of attributes even when those attributes are not inherently space/time attributes. In the above paragraph, we discussed the occurrence of attitudes. Now, the very content of attitudes may be analyzed with reference to an attribute space. Attitudes may form the axes of such a space and scores or values of the attitude variables may be used to locate a person within the space. Each location, again, may be considered as independent and the distribution of attitude scores treated by probabilistic methods. The common statistical techniques such as correlation and regression or analysis of variance are tied to these types of assumptions.

Most of the social attributes that form the meat of sociological analysis are not directly observable, not in the protocol language, as the philosopher of social science would say. This applies to the idea of the population of Philadelphia as well as to the idea of a religious cult or a militant attitude. Indicators are used to attest to the presence of these attributes. For instance, responses to questions may be taken to indicate underlying attitudes. The questions taken to evoke the response are but a sample of a universe of items that might have been selected to measure the underlying attitude. Here again, the natural science frame of reference holds sway and, again, not in the substance of the concepts but in the methods for manipulating them. The questionnaire items may be considered as distributed in a spatial matrix, located at independent points, and treated as objects for enumeration and measurement of their joint occurrence. Methods of factor analysis and Guttman scaling may be used to affirm that some small number of such items is an adequate sample of the universe of items that might have been used to measure the latent attributes. The method of treating the observation, if not that of establishing the concepts, is that of the natural sciences. This is what Emile Durkheim, the French sociologist, had in mind when he wrote of treating social facts as things.

Interface with Economics

To explain social action by using only the concepts of demography and human ecology is to give primary weight to situational factors, changes in the environment. In Darwinian theory, for instance, adaptation to a niche is discussed in terms of established characteristics of a species, including mutants, in the face of environmental conditions. To posit a mind is to allow the objects and internal structure to account for choices in the face of environmental conditions. In social analysis, it is common to observe several people or groups responding in different ways to the same environment. Positing a concept of mind is a way of dealing with these behavioral variations. The simplest concepts of mind allow but one rule of mental functioning, a rational rule. Adam Smith and other 19th-century economists entertained such a concept of choice based on a rational assessment of pleasure and pain. Some current microeconomic theories of consumer behavior are still of this character, conceiving of a decisionmaker attempting to optimize utility. The economic behavior theories that rest on such a concept of mind presume that it is already in place. To explain the emergence of mind, one would turn to psychological investigations.

Pure market analyses are pursued by using the idea of the rational mind. When the object of the analysis is a capitalist firm, defined as a rational profit-maximizing entity, this assumption is a good approximation of empirical findings. If the object of analysis is a household, the empirical observation of behavior tends to be further from what the model would lead one to expect. The household as an economic unit is not a rational profit maximizer subject to formal rationality but is, in the language of some economists, a budgetary unit subject to substantive rationality. Its aim is to optimize a relation between consumption and cost rather than to maximize profit. This point is important for travel demand studies since most travelers are delegates of households as they engage in work, pleasure, or family visiting trips.

Institutional economics, in reality the sociology of economic organizations, extends simple market analyses to other social institutional factors. The rational decision taken by the firm may be examined in the light of considerations properly called political (as in planning in the face of a trade embargo) or psychological (as in framing a proposal to appeal to the sentiments of the chairman of the board or to navigate its way around two competing vice presidents of the corporation). One may view economic systems in relation to religious institutions, as for instance in Weber's classical analysis in The Protestant Ethic and the Spirit of Capitalism. The value context under which a particular economic system can emerge becomes salient. This requires the introduction of yet another class of concepts, those referring to value standards and nonrational rules for the working of the mind. Such added theoretical complexity will be treated below as we discuss the interface between sociology and anthropology.

Economic concepts are borrowed for analyzing behavior in noneconomic settings. This is another aspect of the interface. The family may be studied with respect to the way a transportation system links it to, say, educational or commercial organizations. The travel behavior of the family may be expressed in terms of an exchange model. Traveling to shop is a role delegated by the household that involves a payment in time and effort by the delegate. What, following this model, is the quid pro quo of another member of the family? Family relations are not fully represented in an exchange theory. It is, however, a good way of locating those reciprocities that exist in family life. Families in industrial society approach the exchange model more closely than families in traditional societies.

Interface with Political Science

Human ecology deals with the organization of population. The principle of organization, in that framework, is largely organization in space. An interesting borderline case is that of the ecological food chain. Although, true to the frame of reference, the relation of hunter and prey is one of spatial incorporation, as in digestion, the metaphor carries the idea of power, of dominance, of control. At the social level, one population becomes subject to the will of another under threat of coercion. Social dominance requires symbolic social influence. The mediation of social relations by symbolism adds one type of concept to social analysis. Hierarchies of power, based on potential coerciveness, extend to relationships among groups, such as nations. The symbolizing of power presupposes a concept of mind but of a mind that operates by other than rules of rationality. Power involves a nonrational element in social relations.

Power is a central problem of political science. Systems of social stratification may be understood with respect to the idea of power, of classes of people with a common relation to the power hierarchy. Power relationships are routinized in bureaucratic organization. Such an organizational concept of power can be used to study government, industrial or infrastructural planning, and transportation bureaucracies. Questions may emerge, for example, about the relation of formal to informal organization. How does this relation affect organizational output? How does a bureaucracy meet sudden social change? Planning tends to assume surprise-free scenarios.

Informal processes of redistributing power are studied under the heading of collective behavior. Recently, we studied a New York power blackout and the accompanying looting as spontaneous collective behavior. Here one needs not only a concept of power but also one of play. Play, highly symbolic activity, requires concepts referring to a broad range of social meanings, in fact, the cultural meanings of the anthropologist.

Interface with Anthropology

We have assumed one-dimensional, rational minds in traditional economics and one-dimensional, social hierarchies based on power in traditional political science. Much of what people do during a day makes sense only if we assume a variety of standards for making decisions. The concept of values meets this need and rescues mind and society from simple rationality, physical coercion, and a single-dimensioned hierarchy. The explanation of religious and artistic behavior, for example, demands such additional conceptual complexity.

Societies may be compared on the basis of broad cultural themes or value patterns, the goals they set, their moral judgments, and their tastes for pleasure and beauty. The theme or spirit of the society conditions all levels of social activity. Militarist Sparta may be compared with civic Athens. One would expect the transportation policy of a military to differ from that of a civic society.

The anthropological notions of culture facilitate analysis of the interaction of social institutions, the relationship between economic and political culture and between family and religious culture, and the interrelation of all these to health and to education and transportation. Ultimately, the study of transportation is the study of linkages among social institutional activities.

The development of a society may be conceptualized as change in its institutional forms, say from traditional to modernizing. Transportation and communication practices are key to processes of inclusion and exclusion with an evolving culture.

Interface with Psychology

Mind develops in interaction with society and can be as many sided. The subfield of social psychology asks how the individual becomes a member of society and what the role of the family and of the school is in socialization. From the societal perspective, social psychology, or perhaps psychological sociology, studies recruitment to society's statuses and may trace the displacement of family by community as a socializing agency. The confrontation between these two forms of social organization, community and family, is manifest in current conservative/liberal issues on science and Genesis or prayer in the schools or the changing status of women. These issues arise as the traditional patriarchal family relinquishes control over socialization to the community, a social system transcending the family. The question of the control of transportation may be framed as a matter of the level of society to which it is assigned. At one extreme, households control the private automobile. At the other extreme, governments control nationalized systems. In each event, the controlling institution will use transportation for the attainment of its ends.

The personality basis for social attitudes is another issue arising at the interface of psychology and sociology. In transportation research on attitudes toward attributes of transportation systems, one wants to distinguish the aspects of responses due to personality from those due to attributes of the system. Planners can adjust the latter after a study and still not affect predispositions to travel.

Attitudes are relatively permanent orientations to a set of objects. Opinions are more volatile reactions to particular concrete situations. This distinction, of course, is significant for market research as well as for political mobilization. Intergroup attitudes, prejudice and discrimination, are a meaningful factor in the use of shared public transportation facilities. Does the subway become the turf of a particular sector of society, socially excluding other travelers?

Problems of mental health and mental healing, disturbances of socialization, also arise at this interface. Personality requirements for role performance and studies of worker performance and of man-machine systems are relevant to the behavior of the transportation labor force.

Interface with Humanistic Studies

The scientific method is carried into the study of fields usually considered humanistic. The sociology of religion, for example, is closely aligned with the history of religions but tries to offer general statements about religious organizations and religious leadership. Under the influence of the humanities, concern with the substance, the concreteness, and particularity of the subject matter makes it difficult to resist judgments of value and desirability.

The sociology of knowledge, growing out of philosophical epistemology, is another example. The classifications of knowledge are not those of the philosopher but rather those relevant to social ordering. To critique transportation policies in the light of the social attributes of their proponents is an application of the sociology of knowledge. Such ad hominem examination is not relevant to the truth of a position but is relevant to an assessment of which policy will prevail.

Both the sociologies of religion and of knowledge illustrate applied sociology. General sociological concepts are particularized for a designated institutional setting. The general concept of leadership, or executive role, for instance, appears in the sociology of religion as the study of the role of the minister or the priest or the magician.

Sociology may also be a humanistic field aiming for a clarification of values. Such work borders on social philosophy. Unlike social philosophy itself, this type of humanistic sociology deals with the factual rather than utopian basis for judgments.

Idealist social science is a humanistic study, an empirically based humanism. Its concepts tend to be realistic, that is, to mirror the concrete world instead of merely classifying it in terms of abstract attributes. Marxist praxis and Marxist theory can, for this reason, join in proposing a practical social agenda.

Practical Intersect of Sociologies

The realistic symbolism of humanistic sociology relates it to social technique and to the craft of social living. In the framework of positivistic social science, each interface introduces abstract concepts. The sociology of social conduct transcends the abstractions to fix on social problems. A social problem definition does not emerge out of disciplinary questions. It is an interpretation by members of a society of a point of strain in the society.

The study of group relations or race relations is an instance of the sociology of social conduct. The analyst draws on all of the relevant social sciences to understand problems of group formation, group conflict, group competition, and attitudes such as prejudice.

Functional analyses help us appreciate the ordering of groups in relation to the operating of society as a whole. In criminology, although the definition of crime is socially generated, theories concern the emergence of deviant social acts, criminal or not, and the manner in which they may engage the formal judicial system or the informal sanctioning system.

The sociology of a particular organization, the sociology of industry, and the sociology of the military or of religious organizations, as contrasted with religious institutions, mentioned above, are studies of concrete social conduct. Social conduct is particularized. A study of an operating transportation organization, say the Chicago Transit Authority, would have this character. Positivistic social science provides statements probabilistically related to these particular situations. The policymaker may do well with such probabilistic statements.

Analytic Intersect of Sociologies

The positivistic social scientist is faced with abstractions of the various social sciences, each offering a perspectival view of society. Reductionist approaches to integrating these several sets of abstract concepts may seek to translate all into the concepts of a single social science. All of life, it may be argued, is reducible to intrapsychic phenomena. Culture is psychic, carried in people's heads, and therefore mental processes are the basic subject of discussion. Orthodox psychoanalysis would proceed in this way. As soon as two people are together, however, a new emergent level of reality, their relationship, appears with, as Durkheim says, a sui generis existence.

An impediment to the nonreductionist integration of the theories is that different traditions of theorizing have arisen at each of the interfaces. It is difficult to have a social psychology based on concepts of social structure developed in a Marxian frame of reference and the concepts of psychology in a Skinnerian frame of reference. Talcott Parsons' general theory of action meets this problem through a set of generic social science concepts. These are general concepts that are individually specified within psychology, sociology, or anthropology. For example, the concept of performance and sanction expresses the interaction between two actors at a generic level, one initiating an action and the other responding in some way meaningful to the first actor. Reinforcement theory in psychology may have its analog in stimulus and response. Role relations in sociology may be said to involve binary elements of proaction and reaction. The concepts of supply and demand in market economics are a specification of performance and sanction in that context, the demand being the sanction that influences the future rate of production. The social science disciplines, thus, with a common language, examine exchanges among the social, personality, and cultural systems.

Another approach is to argue, as does Charles Morris in his theory of semiotics, that all scientific knowledge is a symbolism. Semiotics is offered as the metalanguage for integrating the sciences.

CONCLUSION

Transportation research may be conducted with the concepts proposed at each of the interfaces discussed above. Transportation planning is a problem of the practical intersect of the sciences of man. Studies at any intersect contribute to the understanding needed for planning. The caveats above about what sociology offers and what is missing from that offer should be recalled here.

Transportation research may expand from travel behavior to matters of economic and political national policy. Social science will contribute only the cognitive element to the knowledge. The planner must look elsewhere for moral guidelines and affective commitment to action. The analyst may then introduce the familiar models of operations research, such as linear programming, or of econometrics, such as production functions. These are, by and large, rationalistic models designed to aid us in drawing the implication of what we know. They tend not to be in themselves methods of discovery of new knowledge. New knowledge will become available through the conceptual resources of the social sciences and their associated empirical methods.

Classification of Approaches to Travel-Behavior Analysis

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This is intended to be a review of approaches to the analysis of travel behavior. We attempt to make it different from previous reviews by categorizing each approach discussed. Clearly, in reality such complex studies do not fit into a few rigid categories. Nevertheless, we have found the categorization to be useful in our own attempts to understand the similarities and differences among the known approaches. It serves to organize comparisons and might possibly help identify areas for further study.

The categorization is based on a cross-classification according to five subjects. They are (together with their simplified labels)

1. Activity-based approaches (Activities),
2. Approaches using subjective variables (Attitudes),
3. Approaches using population segmentations (Segmentations),
4. Approaches using controlled experiments (Experiments), and
5. Approaches directly involving choice models (Choices).

A full matrix cross-classification scheme is used (Figure 1). The rows of the matrix represent the primary subjects, and the columns represent the secondary subjects. The subsections of the paper are organized in the same order as the cells of the matrix. The only category of approaches not covered in this review is that for the mainstream of discrete-choice models that are now standard travel-behavior techniques.

A substantial number of references are cited in this review. This was the result of the desire for proper credit for different approaches and of the specific motivation associated with searches for missing links in the categorization scheme. However, another reason for including so many references is in response to a major conclusion of this review: researchers in the field of travel-behavior analysis are continuing to reinvent old concerns and approaches. The body of literature is building up dramatically without a corresponding increase in insight and analysis capability. This review is a modest attempt at compiling results in a way that might prove useful in continuing research.

Wherever possible, references from outside the field of transportation research were suppressed if a transportation research reference was found that conveyed the appropriate information. Consequently, this review is not a good place to look for background material from fields such as psychology, economics, geography, or marketing research. Also, wherever possible, citations were made to readily available sources, particularly journals; reports of research organizations were only included where no corresponding journal article could be located.

Finally, discussions of methodology and data collection were minimized. These subjects are perceived to be covered in other, complementary reviews.

ACTIVITIES

Activity approaches have been emerging in recent years as a challenge to the orthodoxy of the established travel-demand modeling techniques. The proponents of activity research have discussed extensively the weaknesses and limitations of current disaggregate demand models. They have advocated the replacement of trips by better measures of activity patterns. This is considered to be central to predictions based on an understanding of the underlying causes of travel behavior (1-3).

The approaches adopted vary enormously. Nevertheless, they can be characterized as concentrating on the types of things people do outside and inside their homes in the setting of their physical and social environment. The most ambitious goal of these approaches is the understanding of what has been termed complex travel behavior. This requires an understanding not only of individual behavior,

Figure 1. Matrix cross-classification scheme.

	SECONDARY FOCUS				
PRIMARY FOCUS	ACTIVITIES	ATTITUDES	SEGMENTATIONS	EXPERIMENTS	CHOICES
ACTIVITIES	1.1	1.2	1.3	1.4	1.5
ATTITUDES	2.1	2.2	2.3	2.4	2.5
SEGMENTATIONS	3.1	3.2	3.3	3.4	3.5
EXPERIMENTS	4.1	4.2	4.3	4.4	4.5
CHOICES	5.1	5.2	5.3	5.4	

but also of household interactions as a means of explaining and predicting responses to a host of activity influences.

What the activity approaches lack in terms of cohesive theory is compensated for by a profusion of concepts and methods (and an accompanying profusion of new travel-behavior nomenclature). This reflects the diversity and interdisciplinary nature of the research. Overviews, with the exception of those by Root and others (4) and by Damm (5), tend to be partial rather than comprehensive. However, a good understanding of the extent of work in the field can be gained from these two sources and from studies by Damm (6), Jones and others (7), Wigan and Morris (8), Allaman (9), Pickup and Town (10), Carpenter and Jones (11), Morris (12), and Root and Recker (13).

The potential advantages of activity-based approaches would appear to be considerable. Intuitively, it seems appropriate that travel be viewed as arising out of activity needs and desires. For policy evaluation purposes, the approaches are attractive because of their suitability in considering policies in which effects might be indirect (for example, changes in working hours). Also, policy initiatives can be studied in terms of their influence on the extension, contraction, or substitution of activities. This goes beyond the evaluation of policies in terms of conventional economic costs and benefits.

Views appear to be divided with regard to the immediate applicability of the approaches. Those whose objectives are comprehensive activity-based demand models typically feel that there is still some work to be done before replacements can be offered for conventional models (5). Others have argued that despite the lack of a cohesive theory, elements within the activity framework can be used together with existing models and indeed should be used to adapt and improve them (14,15).

In stressing the importance of new or previously overlooked topics (such as spatial and temporal constraints on choices and influences of life cycle), activity approaches risk neglecting some of the traditional and still important explanators of travel behavior (12). Moreover, activity analyses often require extremely detailed data. Lack of these data has inhibited development. More attention might usefully be directed toward adapting existing data sets, and Knapp (16) offers an initial attempt at this. Also, activity approaches might be tested on limited data by relying on simulation and artificial sampling techniques to expand the data base; these issues have received little attention.

It is our premise that activity approaches can benefit in this early stage of development from systematic comparisons with other types of approaches. Such comparisons are attempted in this review.

Activities

Following the scheme the matrix described earlier (Figure 1), the travel-behavior studies in this category are those that deal with relationships among components of activities. In many cases, these studies have served as foundations for later developments that employ segmentation analyses, experimental methods, or choice modeling. In other cases, the studies are relatively independent of the efforts described in other sections of this review, but they do not fit into one of the categories that cross-classifies activity approaches with other subjects. These include approaches that use simulation techniques.

One of the most important features of activity-based approaches has been the explicit recognition of the joint constraints on travel behavior of time and space. Foundations for this concept were provided by Hägerstrand and his colleagues, who greatly advanced the field known as time-space geography, or simply time geography (17). Time-space geography offered a unified paradigm for the study of complex travel behavior. The paradigm complemented the perspective on activities as satisfactions of human needs and desires provided by Chapin (18,19) and his colleagues. Thus, researchers by the early 1970s had comprehensive constructs on which to formulate and test hypotheses of activity behavior.

Activity studies based on simulation models were the first to emerge. Early efforts were those of Nystuen (20), Brail (21), Ginn (22), and Hemmens (23). Nystuen related the structure of shopping tours (round trips from home and back) to spatial factors by using stochastic processes, whereas Ginn employed dynamic programming methods in a seminal study of spatial influences on multiple-stop tours (often called trip chaining). Hemmens related trip-chaining events to household socioeconomic characteristics by using a Markov model.

The foundations provided by Hägerstrand and Chapin began to appear in a second group of simulation models by Tomlinson and others (24), Westelius (25), and Vidakovic (26,27). Tomlinson developed an entropy-maximizing model that allocated urban area population to the most probable spatial activity location for successive time periods. This approach has been further developed by Vidakovic within a choice framework. The work of Westelius (25) and Vidakovic (26) continued earlier investigations concerning the lengths and number of stops on a tour by using stochastic simulations and probability distributions, respectively. Vidakovic (27) represents an early attempt at placing trip-chaining phenomena in a broad behavioral context.

Direct applications of the concepts advanced by Hägerstrand and Chapin are to be found in the next group of studies. Concepts from the latter source were operationalized by Kobayashi (28,29) in a queueing model that maximized a cost-effectiveness function to estimate the distribution of trips in the satisfaction of activities. The model dealt specifically with relationships between the number of tours and the number of stops on the tours under various conditions. Building directly on the paradigm provided by the time geographers, Lenntorp (30) developed a simulation model that computed the potential number of time-space paths that an individual could follow in executing a particular activity program. This model was used for exploring the implications of transport network and land use changes, but it has no predictive capability. Going a step further, Burns (31) used these constructs in a theoretical study that traced the effects on accessibility of possible policies affecting spatial and temporal constraints on travel. In the latest and most advanced work in this area, Kitamura and others (32) and Kostyniuk and Kitamura (33) combined a theoretical model with regressions and contingency-table analyses to investigate the properties of time-space paths as reflected in trip-chaining behavior.

Considerable insight into activity behavior has also been gained by using more descriptive analysis techniques. Cullen and Godson (34,35) conducted a series of multivariate statistical analyses aimed at identifying salient features of activity patterns (which included subjective variables). Bentley and others (36) fitted probability distributions in studying frequencies of return trips to home by tour (or journey) stages, whereas Shapcott and Wilson (37) were able to infer trade-offs made in time allocations by comparing observed correlations among activities with theoretical correlations that would result from certain types of behavior. Oster (38,39) and Hanson (40) identified important behavioral implications by isolating trip-chaining effects related to the work trip. (Hanson, in a study apparently performed independent of the related earlier efforts by Cullen and Godson, employed an effective statistical-analysis technique by using data on linkages among activities, which is related to the focus of some of the analyses discussed in later sections of this paper.)

Descriptive analyses were also included in the extensive study reported by Jones and others (41), which also involved further developments of a method of the type discussed later. These analyses appear to have led to the formulation of a combinatorial algorithm to generate the feasible responses that an individual could adopt for rescheduling activities when faced with a change affecting existing activity patterns. The algorithm is based on heuristic rules to reduce the number of potential permutations and has been used in the generation of choice sets (42).

Further descriptive statistical analyses have been performed by Adiv (43), Godard (44), Herz (45), Kitamura (32), and others. These studies are particularly important in that they demonstrate how readily available statistical techniques can be used to identify salient features of activity patterns from data sets collected in support of conventional trip-based travel-demand models.

Activities/Attitudes

In this section we are concerned with approaches that relate activities to attitudes and other subjective variables. Much of the conceptual work along these lines can be traced to that of Chapin (19,46), in which relationships were examined between needs and the creation of activity patterns. This work focuses on role structure, which was defined as a combination of sex, family responsibilities, and employment status. The work contrasts with that of the time-space geographers (reviewed in the previous section) in that it deals with preferences rather than constraints (47).

Kutter (48-50) has integrated the concept of roles with time and space constraints and has recommended using segmentation methods to investigate relationships between activity patterns and a variety of socioeconomic variables aimed at depicting role structures. By using a related but more sociological approach, Fried, Havens, and Thall (51) developed a conceptual model of travel choice based on adaptation processes. This model incorporates a number of subjective variables, particularly role indicators, and several of the model hypotheses were tested by Allaman and others (52). Also, Cullen and Godson (34,35) and Stephens (53) included subjective measures of commitment to activities (measurements of the degree to which an activity is compulsory versus discretionary) in their empirical work on activity structure.

There appears to be very little recent work focusing on perceptions and beliefs about activities. An exception is the situational approach reviewed later, which attempts to account for a variety of factors affecting activity choices through the use of interactive surveys and segmentation concepts. Among the factors demonstrated to restrict activity choices are prejudice and familiarity (54). In addition, experimental approaches involving gaming simulations have been developed for exploring subjective influences on activity patterns, and these methods are reviewed in the section Activities/Experiments.

Activities/Segmentations

Three types of approaches appear to fall within this category. The first type involves the use of segmentations based on household socioeconomic and demographic characteristics. Chapin (19) and his colleagues pioneered the use of such segmentations in understanding differences in activity patterns. In particular, Chapin proposed the use of stage in the family life cycle (now usually called simply life cycle), which incorporates marital status, the number and age distribution of any children, and whether children live at home. This concept has been used effectively in a number of travel-behavior studies. In the realm of activity analyses, it was developed by Reichman (55) and has been employed extensively by Jones and others (7) and Allaman and others (56). Examples of the use of other important segmentation bases for specific analyses of differences in activity patterns are found in studies by Hanson (57) (age) and by Hanson and Hanson (58) (sex).

The second type of segmentation involves using activity patterns themselves as the segmentation basis. Recker and others (59,60) and Pas (61,62) have shown that the myriad of daily activity patterns typically reported in a sample of activity diaries can be grouped into a relatively small number of categories (10 or less) without significant loss of statistical information. This represents a population segmentation as well as one of activity patterns, because an individual and a household are associated with each pattern.

In the approach of Recker and others the homogeneous groups of activity patterns are determined by using pattern-recognition techniques. They are later employed in an activity-pattern choice model. In the approach of Pas (61,62), the groups are found by using multivariate statistical methods like those commonly used in population segmentation. An investigation was then conducted in which differences among the activity-pattern groups were described in terms of the socioeconomic characteristics of the household segments. This appears to be a particularly effective approach to exploratory activity analyses, which could be extended and applied in different situations.

Finally, a third type of segmentation approach underlies the simulation model developed by Zahavi and others (63-65). This model interrelates household travel by various modes with residential location, car ownership, and transportation systems supply. It takes advantage of certain regularities found in the distribution of travel expenditures by household segments. Both time and money expeditures are included (66,67).

Segmentation structure in the context of aggregate activity patterns is a key to the Zahavi model, because expenditure distributions have been demonstrated to be stable over time and across cities only for segments defined on the basis of certain household characteristics. Moreover, the segmentation structure is dynamic; households are reassigned among segments in the course of the simulation as conditions change and feedback occurs. As with a few other analysis approaches reviewed earlier, the model uses total travel distance in place of trips as a measure of total activity satisfaction. Such an aggregate measure is consistent with the intended application of the model in forecasting changes in total intraurban travel and population distributions. An important issue for future research is to compare the performance of this model with alternative forecasting techniques based on more conventional definitions and assumptions.

Activities/Experiments

In this section we are concerned with experimental methods for studying the relationship between activities and travel patterns and for exploring and estimating responses to policy affecting the location and scheduling of activities.

The use of gaming as an experimental technique for investigating decisionmaking has been proposed and tested by Hoinville (68), Biel (69), and Burnett (70). Previously, Chapin (18,19) had reviewed gaming simulation techniques in the context of activities and travel.

The best-known example of such games is the Household Activity Travel Simulator (HATS) (71). This is an interactive device that uses visual-display boards in in-depth group-interview situations. With previously recorded personal activity data, each household member is asked to construct his or her activity pattern on the board by using colored blocks for time periods that represent the 24-h day. Locations of activities are also recorded and marked on maps on the upper section of the board. Respondents are then presented with a change in the level of public transport services or some other aspect of the environment and are asked to rearrange their activity schedules. Discussions are encouraged between household members and with the interviewer to test out feasible options and to reach decisions as to which alternative they would adopt.

The technique allows the study of constraints and adaptive strategies and their likely effects on travel patterns. Also, through the use of group interviews, interpersonal linkages can be fully explored. This is most useful for small-scale exploratory studies. Among the applications reported are evaluations of changing school hours and changing levels of public transport services in rural and urban areas (7,72). A similar gaming technique (called REACT) has been applied to the investigation of energy restrictions on travel by Phifer, Neveu, and Hartgen (73).

Extended possibilities for structuring such interactive gaming techniques have been proposed by Brög, Heuwinkel, and Neumann (54). Many of these possibilities have direct application in the situational approach discussed in the section Segmentations/Activities, but others are relevant to a broader set of applications. In addition, Burnett and Hanson (74) used a variation of previous gaming techniques to explore spatial choice behavior in the context of constraints. This work is partly related to the concepts of mental maps and learning theory reviewed in the section Attitudes/Activities.

Activities/Choices

Travel-behavior analyses that focus on choices among alternative activity patterns have begun to emerge in the last five years or so, building on the foundations provided by the studies reviewed so far. In general, these analyses appear to have as a long-range goal the development of travel-demand forecasting techniques that would replace conventional trip-based techniques. A complementary set of analyses, reviewed in the section Choices/Activities, appears to be aimed at incorporating activity-pattern components in conventional forecasting techniques.

The initial efforts in this category focused on choice of activity duration. Bain (75) used an econometric approach to structure individuals' choices of out-of-home activity durations but did not account for interactions among activity sequences. Such interactions were subsequently addressed in a simultaneous equation model developed by Jacobson (76). In this model, a two-stage choice process was defined that involved choice of activity duration followed by choice of travel pattern. Importantly, household interactions were considered. Later, Allaman and others (52) formulated a constrained simultaneous equation system that attempted to capture allocation of time among many different activities for life-cycle segments. This represents an important application of life-cycle segmentation, but difficulties were encountered in explaining choices of activity duration.

Damm (77,78) and Damm and Lerman (79) developed a model that described the joint choice of whether to participate in an activity and the duration of the activity. Choice models were estimated for activities in five daily time periods defined around the work trip and for various population segments. In each model, variables were constructed to capture interactions with choice in previous time periods. The results were found to be consistent with the concept of discretionary and compulsory activities and with expected strong relationships between household characteristics and activities involving trips to and from home.

A different approach was pursued by Van der Hoorn (80,81). Choice models were specified for activity type and location; location was confined to home, in town, or out of town. By using population segmentations of the type reviewed in the section Choices/Segmentations, populations were then assigned to the three locations by quarter-hour time periods based on the results of the choice model estimations. This extends the simulation approach developed by Tomlinson and others (24) into the realm of choice. It is reported that the Van der Hoorn model is being used to explore the impacts of policies involving variable working hours, income reduction, and reduction in working hours according to various schemes.

A new type of trip-generation model was developed by Landau, Prashkar, and Kirsh (82) in which many of the same concepts of household interactions and compulsory versus discretionary activities were taken into account. A multistage choice process was specified. It involved the choice as to whether or not to engage in a specific activity, the conditional choice of executing a chosen activity during a specific time period, and the conditional choice as to the specific household member who would make the trip.

Possibly the most ambitious choice-modeling study in the field of activity analyses is that of McNally and Recker (83). A five-stage simulation model has been developed to model directly the choice of complex activity patterns. The stages are (a) specification of activity programs for each household member, considered within the context of heuristic rules concerning interactions and constraints; (b) generation of a full set of feasible activity patterns to meet these programs; (c) reduction of the set of feasible activity patterns by eliminating inferior patterns with a multiobjective programming algorithm; (d) specification of a representative set of activity pattern alternatives by using pattern recognition and classification techniques; and (e) a choice model of the usual travel-behavior type with the representative patterns as choice alternatives. The theoretical underpinnings of this simulation model [discussed by Root and Recker (84)] are related to the utility theory models proposed by Burns (85) and by Golob and others (86). These models focus on travel distance and the roles of choice constraints. The fourth-stage algorithm is founded on the segmentation approach discussed earlier.

Finally, it appears that some of the ongoing studies that have been reviewed might soon evolve into choice models of one type or another. For example, Vidaković (87) reports progress toward a choice model system employing the concept of disposable time intervals for structuring choice probabilities for the execution of discretionary activities. Likewise, Beckmann, Golob, and Zahavi (88) document a conceptual approach aimed at linking spatial distributions of populations and activity sites with activity patterns. Many other types of approaches can be expected in this particularly fruitful research area.

ATTITUDES

In this section, we cover travel-behavior analyses that focus on subjective variables such as perceptions, evaluations, and judgments. In transportation research, these subjective variables are generally referred to as attitudes. In keeping with the theme of this review, an attempt is made here to relate analyses dealing with attitudes to other types of analyses, namely, those dealing with activities, segmentations, simulations, and choices. In this way this review is meant to differ from previous ones. Many such reviews are available: those by Hartgen (89), Golob (90), Golob and Dobson (91), McFadgen (92), McLeod (93), Michaels (94), Spear (95), Hensher and McLeod (96), Hartgen (97), Levin (98), Louviere (99), Louviere and others (100), Dix (101), Held (102), Michon and Benwell (103), Tischer (104), Johnson (105), Stearns (106), and Dobson (107).

This review fails to consider in any detail the theoretical bases for attitude measurements and modeling. These bases are found primarily in psychology and have been covered in reviews such as those of Golob (90), Michaels (94), Johnson (105), Levin (98), and Held (102). Nor does this review deal with details of methodology and data collection. These issues are also covered in comprehensive fashion in previous reviews, such as those of Golob and Dobson (91), Dobson (107), Spear (95), Louviere and others (100), and Tischer (104). These reviews contain numerous references to prior applications of many techniques in marketing research.

Semantic confusion has accompanied application of attitude measurement and modeling in transportation research. Levin (98) observed that there are almost as many definitions of attitudes as there are researchers working in the field. Four contemporary reviews [those by Held (102), Levin (108), Michaels and Allaman (109), and Michon and Benwell (103)] specified four incompatible sets of definitions for subjective variables. This review attempts to avoid nomenclature problems by simply ignoring distinctions among types of subjective variables except where such distinctions are necessary to distinguish alternative research approaches. Where distinctions are necessary, we adopt the rather arbitrary but useful separation of subjective variables into perceptions, beliefs (including satisfactions and preferences), and behavioral intentions.

Attitudes/Activities

It is useful to classify in this category studies that have been concerned with individuals' perceptions of the space around them. These perceptions and associated beliefs can be regarded as attitudes about the opportunities and constraints affecting activity patterns.

Early efforts appear to have been directed in four ways: (a) development of the concept of mental maps; (b) scaling of spatial preference functions; (c) specific perceptions of travel distance, time, and cost; and (d) application of learning theory to spatial cognition. First, mental maps attempt to capture individuals' perceptions of spatial opportunities within a given geographical area. Gould and White (110) and Morris (111) demonstrated that such perceptions depend on familiarity as measured by proximity of residence to the area in question, length of time at residence, visits previously made to the area, and certain socioeconomic and demographic characteristics. Horton and Reynolds (112) demonstrated how such a concept could be used in travel-behavior analyses. MacKay and others (113) and Young and Richardson (114) used mental-map principles in models of spatial choice behavior. Young and Richardson used the method of trend surface analysis (115) to quantify spatial perceptions.

Spatial preference functions have been studied by Rushton (116,117) by using multidimensional scaling methods of the type used in several nonspatial studies. This work serves as a foundation for more direct applications to travel-behavior analysis, but follow-up studies have not emerged. Only a few studies, such as that by Koppelmen and others (118), have taken up the objective of determining spatial preference structures, but these studies have been largely independent of the original work by Rushton.

Distance perceptions have been studied by Golledge and others (119), Briggs (120), Canter (121), and others and time perceptions by Young (122), Young and Morris (123), Clark (124), and others. In addition, Lansing and Hendricks (125), O'Farrel and Markham (126), Dix and Goodwin (127), Henley and others (128), Adiv (129), and Brög (130) studied drivers' perceptions of car costs. These studies provide psychophysical foundations for transformations of variables in conventional travel-demand models. In particular, they demonstrate that perceived and objectively measured variables differ systematically, and the relationships are not generally linear. Unfortunately, very few demand modelers appear to be aware of such results (109).

Finally, learning theory has been applied to spatial perceptions by Golledge and Brown (131), Golledge (132), and Burnett (133,134). Typically, these studies combined learning theory with psychometric scaling of perceptions and demonstrated how stereotypes can be formulated depicting individuals' evolving activity patterns (135). They demonstrated how multiple-activity patterns could be chosen by the same person over time.

More recently, Swiderski (136) developed a model of destination choice that incorporated concepts of mental maps and learning theory. However, the approach is limited by the simplistic assumptions required in Markov process models (135). Finally, Burnett (137) proposed measuring spatial perceptions in terms of both the physical and the social environment; the social environment might include components of territoriality, desires for interactions with friends, or favorite locations.

Associated attitudinal issues are discussed in the section Activities/Segmentations, which concerns segmentations related to household roles and responsibilities and perceptions of constraints on choice. Related issues are also discussed in the section Segmentations/Activities, which concerns segmentations based on perceptions of time, costs, and environmental constraints.

Apparently there have been no applications to activity-pattern choice of full-blown attitude-behavior models of the type reviewed in the section Choices/Attitudes. Given the development of methods to identify typical feasible patterns, this might be an area for fruitful research, particularly in light of observations by psychological theorists that attitudes correlate well with a complex of related behavior but not with a single choice event alone (138).

Attitudes

No studies have been classified in this category. For the purposes of this review, studies dealing primarily with attitude structure are not interesting unless such structure is related to one of the other subject areas represented in Figure 1.

Attitudes/Segmentations

A number of studies have compared attitudes among population segments. Some of these were concerned with attitudes about proposed hypothetical transportation systems; they will be discussed in the section Segmentations/Experiments. Other studies involved attitudes on a segmentation basis as well; they are discussed in the section Segmentations/Attitudes. The remaining studies comparing attitudes among population segments are the subject of this section.

The most important of the attitude-comparison studies are deemed to be those that investigated differences between users and nonusers of particular travel modes. They are important because evidence was uncovered that was later used in improving attitude-behavior models. Also, the results might have an impact on certain types of sampling techniques used in disaggregate demand models.

Comparisons of perceptions and preferences between users and nonusers were conducted by Gustafson and Navin (139), Lovelock (140), Byrd (141), and Dobson and Tischer (142), among others. Significant differences were noted. In particular, Dobson and Tischer observed that, in general, individuals who use a mode view that mode more favorably than those who do not. This might be the consequence of any of several behavioral processes; Horowitz (143), Golob and others (144), and Tischer and Phillips (145) all tested one particular hypothesis. This was that individuals with choices tend to upgrade their feeling about their chosen alternative and downgrade those about the rejected ones after a choice has been made. Results of these tests were positive and have been elaborated by further studies. Furthermore, such a hypothesis is consistent with psychological theories such as cognitive dissonance (146) and self-perception (147), both of which are related to the common notion of rationalization. These studies demonstrate the effective use of segmentation to test travel-behavior hypotheses.

Attitudes/Experiments

In this section, studies are discussed that measure attitudes toward proposed new transportation modes or other hypothetical situations by using the simplest types of experiments. These experiments involve the presentation to respondents of attributes of the hypothetical situations. The attributes are presented singly or in pairwise combinations, and reactions are assessed by using various survey-scaling devices. (Surveys of this type are usually accomplished through mail-back or home-interview questionnaires.) Travel-behavior analyses in which experimental designs are more closely linked to the analysis method itself are the subjects of the section Experiments/Attitudes. (In the terminology of conjoint measurement, this section deals with two-factor-at-a-time approaches and with simple disjoint measurements; in a later section, full-profile approaches will be discussed.)

An early approach is that of Golob and others (148). Thurstone's model of comparative judgment was used to estimate scale values for various attributes of dial-a-ride services based on survey paired-comparison judgments. Unidimensional semantic differential scales were also analyzed. The effort led to useful insights into consumer preferences, but the methodology has since been supplanted by more powerful multivariate measurement approaches [for example, that of Gensch and Golob (149), where comparisons were made among preference structures regarding different types of proposed new modes]. Benjamin and Sen (150) demonstrated how multivariate approaches can lead to improved insights when compared to unidimensional scales.

A two-factor-at-a-time conjoint-measurement approach that has seen application in transportation research is trade-off analysis. It was developed by Johnson (151) and involves respondent's rankings of combinations of the levels of two attributes. The rankings are repeated for different pairwise combinations, and the values or utility weights for the levels of each attribute are estimated from the ranking data for a sample of respondents by using a special scaling algorithm. The use of the approach in travel-behavior analysis is described by Ross (152) and by Donnelly and others (153). It has been successfully applied in assessing the impacts of public transit fare changes (154), in assessing public opinions about public transit operating-assistance programs (155), in establishing preferences for rural transit services (156), and in forecasting the effects of proposed changes in work schedules (157). In this last study, a before-and-after survey showed that the approach based on "before" data produced aggregate predictions that coincided well with actual behavior but that specific attribute utility weight estimates were less adequately reproduced. Such a before-and-after test is called for in evaluating other approaches as well.

Attitudes/Choices

One of the major objectives of attitudinal studies in travel-behavior research has been to explain travel choices in terms of subjective variables. If a strong link were to be found, predictions could be made in transportation planning and marketing regarding the effects of decisions influencing such things as travel comfort, convenience, safety, or even style. This objective has been sufficient to motivate a continuous stream of research for the last 25 years or so.

Early studies aimed at linking attitudes and travel choice can be divided into two types based on model specification: those in which the explanatory variables consisted entirely or almost entirely of subjective variables and those in which the explanatory variables consisted of objectively measured travel times and costs together with one or more subjective variables. Both types of early studies predominantly focused on choice of mode, usually for the home-to-work trip, which was consistent with contemporary studies on other topics in travel-behavior research.

The former type of early study typically used as explanatory variables individuals' ratings of their perceived alternative choices on a series of semantic differential scales. These ratings were designed to capture satisfactions or other perceptions and beliefs concerning modal characteristics. Statistical correlations between the explanatory variables and a dependent choice variable were then estimated by using the disaggregate demand model methodologies fashionable at the time. The approaches were largely based on developments in psychology and marketing research. Important among these early studies are those by Sommers (158);

Golob (159); Hartgen and Tanner (160,161); Allen and Isserman (162); Demetsky and Hoel (163); Wallace and Sherret (164); Ewing (165); and Hensher, McLeod, and Stanley (166). Hartgen (167) and Westin and Watson (168) provided comparisons of explanatory power between models based on attitude and objective variables, with mixed results.

There is disagreement among reviewers concerning the overall success of these studies. It is safe to say that results depended on the specific nature of the choice situation and the techniques used for data collection and analysis. Success was pervasive enough to encourage refinements of the approach. Thomas (169), Dobson and Tischer (170), and Hensher and McLeod (96) introduced different types of subjective variables; Recker and Golob (171) and Recker and Stevens (172) introduced choice constraints. Models were also extended to other choice situations: Cadwallader (173) and McKay and others (174) studied spatial choice; Costantino, Golob, and Stopher (175) studied choice among hypothetical new transport modes. Generally, the links found between attitudes and travel choices were stronger than in previous studies. This was encouraging (159,176), but many questions remained unanswered.

The second type of early attitude-choice study was concerned with the introduction of one or a few subjective variables in models based on time and cost variables. As noted by Dix (101), these studies were aimed at accounting for biases in travel choice not explained by time and cost variables (177-179). Efforts were focused on methods to capture a complex of subjective variables in a single index that could be included in conventional models. The subjects were comfort (180), convenience (181), reliability (182), and these three factors taken together (183). The methods generally used techniques of multidimensional scaling developed in psychometrics and applied previously in marketing research. Although considerable insight was gained concerning how travelers' beliefs and perceptions on these subjects are influenced by specific characteristics of travel modes, the methods have proved to be rather complicated and expensive to apply in practice.

Second-generation studies of links between attitudes and choices can be distinguished by the abandonment of the assumption of one-way causality. These studies recognize that attitudes can influence choice, but choice in turn can influence attitudes. The effect of choice on attitudes was first detected in the segmentation studies discussed earlier. There is strong support for the concept in psychological theories. Moreover, transportation researchers have proposed that feedback from choice behavior to attitudes might result from ex post facto rationalizations motivated by a questionnaire (184) or from habit formulation (185,186). [Voltenauer (187) goes so far as to contend that the direction of causality is essentially only from behavior to attitudes, a minority view among researchers.]

Empirical evidence supporting two-way causality between attitudes and travel-choice behavior has been supplied by Foerster and others (187a), Tardiff (184), Dobson and others (188), Horowitz (143), Dumas and Dobson (189), Golob and others (144), Tischer and Phillips (190), Reibstein and others (191), and Kroes (192). Foerster and others and Tischer and Phillips (190) based their conclusions of attitude-choice interdependency on longitudinal analyses of survey data at two points in time. Horowitz and Golob and others tested hypotheses of cognitive dissonance through reanalyses of four separate attitudinal surveys. Tardiff (184), Dobson and others (188), Reibstein and others (191), and Kroes estimated parameters in simultaneous-equation systems by using standard econometric methods.

The simultaneous-equation systems used in analyzing causality provide convenient structures for flow diagrams depicting the roles of subjective and objective variables in behavioral processes. As noted by Dobson and others (188), for every simultaneous-equation system there exists a flow diagram that unambiguously shows the linkages among the exogenous and the dependent variables. Such diagrams have been used by Dobson and others, Golob and others (144), Young and Richardson (114), Kroes (192), Levin (108), and others to contrast alternative modeling approaches. (However, not all recent attitude-behavior depictions subscribe to the generally accepted causal link from choice to attitudes). It is quite possible that further contrast of approaches using both simultaneous equations and flow diagrams would serve to resolve cosmetic differences and identify fruitful areas for further research.

The state of the art with regard to our understanding of attitude/choice relationships, although still imperfect, nevertheless has certain clear applications. In particular these techniques are potentially useful for examining the possible effectiveness of certain policy instruments and/or strategies for achieving certain transport policy objectives. In instances in which it is considered desirable to change or influence existing habits or travel patterns, such studies can help to indicate the methods most likely to bring about the desired effect. These methods may not, given the complex relationship between attitude and behavior, always be the most obvious or the most direct. An example offered by Kroes (192) is that of trying to increase train use at the expense of car use. It is suggested that changing the objective parking situation by limiting parking space or increasing charges is likely to be more effective than seeking to improve traveler satisfaction with the quality of train travel. Other likely policy applications could be studies on increased use of park-and-ride stations, the adoption of energy-saving driving habits, the use of seatbelts, and mode changes.

SEGMENTATIONS

In this section, analyses that focus on population or consumer segmentation are covered. Here it is assumed that segmentation refers to any systematic classification of population relevant to analyses of travel behavior and values. As in the case of attitudes, an attempt is made to avoid semantic problems by using simple nomenclature. Readers interested in such problems are referred to the review by Tye (193), in which the issue of market versus consumer segmentation is addressed. Additional, comprehensive overviews of segmentation approaches in travel-behavior research are provided by Reed (194), Lovelock (195), Hensher (196,197), Louviere and others (198), and Dobson (199).

As is generally the case in this review, this discussion does not concentrate on foundations for segmentation analyses that are outside the field of transportation research. These foundations are generally traced to previous applications of segmentation analyses in marketing research. They are discussed in previous reviews, particularly that by Dobson (199).

Segmentations/Activities

The major approach classified within this category stands somewhat alone. This situational approach has been described by Brög (200,201), and the interactive interviewing methods that support it have been explained by Brög and Erl (202).

The approach begins with the identification in detail of the decisionmaking situation of each individual, including his or her activity patterns. The potential for the individual to change behavior given an alteration in external conditions is then examined. The framework of the analysis is the identification of constraints that will rule out certain courses of action. These procedures allow the segmentation of individuals into groups with and without the potential to change their behavior. Constraints on actions are very broadly considered and may include lack of information as well as negative attitudes toward possible options. Individuals are further segmented by the nature of their potential responses, which may include nontravel responses. Through these selective means, small behaviorally homogenous groups are identified. These form the base on which forecasts are made of likely responses to policy changes.

The approach has been applied to a variety of policy questions. These include estimating reactions to public transit fare increases (203), investigation of the long-distance travel market and its further development in Germany (204), the acceptance of policies to encourage bicycle travel (205), and the testing of alternative rapid-transit scenarios (15).

The situational approach is data intensive and requires the use of skilled interviewers and trained analysts. This is an example of a method that requires specially collected data. There do not appear to be any examples of such data being reused to test policies not included in the original survey design. Nevertheless, the approach is unique and an important research topic would be to test it against several of the approaches discussed in the sections Activities/Segmentations and Activities/Choices and the approach proposed in the section Experiments/Activities.

Segmentations/Attitudes

Classified here are travel-behavior analyses that employ attitudinal segmentation bases. The usual objective of these analyses is a better understanding of how the underlying dimensions of perceptions and beliefs differ among population segments. The usual approach is to determine segments with homogeneous profiles of subjective variables, to assess the nature of the differences among the profiles, and to relate the segmentations to socioeconomic and travel pattern characteristics. Golob and Dobson (91) were early advocates of such approaches, and the theme was subsequently taken up in several of the overviews cited in the introduction to the sections on segmentations.

Many of the initial studies along these lines were concerned with understanding the underlying dimensions of perceptions and beliefs about proposed new transportation modes. These studies are reviewed in the section Segmentations/Experiments because they involve responses to hypothetical situations. Some of the methods used in these initial studies are compared by Nicolaidis and Dobson (206). The approaches were extended into the realm of attitudes about existing modes by Neveu, Koppelman, and Stopher (183), among others, and attitudes about destination-choice alternative by Stopher (207).

A negative note was interjected by Nicolaidis and others (208), who found that subjective variables in general performed poorly as segmentation bases when compared with other types of variables. These results were supportive of the approaches reviewed under Segmentations/Choices, which used perceptions of constraints on choice as segmentation bases. They also motivated Golob and Recker (176) to propose an analysis procedure for attitudinal data based on segmentations by perceived choice constraints (but which failed to account for causal feedback from behavior to attitudes). A further negative note is associated with the analyses of data based on respondents' similarity judgments. Such data uses have been shown to be susceptible to methodological problems (209,210) and data-collection biases (211).

Refined approaches have led to useful insights: Dobson and Tischer (212) found strong and interpretable relationships between choices and segmentations based on beliefs about modes, as did Gensch and Torres (213) in a segmentation study aimed more at target markets for public transit. Stopher and Ergün (214) found interpretable differences among attitudes related to attributes of recreational activities. Benjamin and Sen (215) demonstrated how segmentation based on multidimensional scaling of subjective variables can be used to identify specific transit improvements, and Tardiff (216) developed a comprehensive segmentation approach based on general attitudes toward car, public transit, and public transit improvements.

Another subject area for potential applications of attitudinal segmentations is that of roles and their relationships to travel behavior. The definitions of roles proposed by Fried (217), Koppelman and others (218), Havens (219), and others involve subjective variables as well as objective variables of the types discussed in the next section. Similarly, life-style has many subjectively measurable components when taken in its full meaning in marketing research. Segmentations based on psychographic variables might be useful first steps in addressing role, life-style, and personality in the travel-behavior context, and some progress has been reported here by Davis (220).

Finally, one segmentation concept from marketing research that has seen little apparent application to travel-behavior analyses is benefit segmentation (221). This refers to segmentations based on the benefits people are seeking in consuming a product or service. It is related to the notion of valence in psychology (222). The concept has been partly adapted in one approach discussed in the section Experiments/Segmentations, but it might usefully be extended in a segmentation by benefits and disbenefits of transportation investments. In this way the extensive methodology of segmentation (including advanced techniques of psychometric scaling and multivariate statistical analyses) would be brought to bear on the difficult measurement problem of distinguishing effects among population groups. For purposes of the evaluation of transport policies, this could be seen as a supplement to the procedures more commonly adopted in social cost/benefit analysis.

Segmentations

In this section, studies concerning the general uses of segmentations in travel-behavior analyses and comparisons of alternative types of segmentation bases are discussed. Also discussed here are segmentation approaches that use socioeconomic and demographic variables as bases, including those that combine such variables in innovative ways.

Lovelock (140), Hensher (196), and Dobson (223) discuss the similarities and differences between uses of segmentation in transportation planning and management and uses in the general field of marketing. Topics include contrasts of the service-provision and profit-maximization motives of the two fields, respectively, and identification of situations where resolution of differences is possible. These are judged to be important discussions because of the potential for the application of results from extensive research efforts in marketing [for example, those by Johnson (224) and Kotler (225)] to problems in travel-behavior analyses. Rubin and others (226) document one such application.

For comparisons of alternative segmentation bases, Tye (193) listed six types of bases: (a) subjective judgments, (b) sociodemographics, (c) relevant choice sets, (d) attributes of choice, (e) use and observed choice, and (f) geography. Segmentation bases types b and f are discussed in this section.

An empirical comparison of segmentation bases representing each of the first four types was conducted by Nicolaidis and others (208). The bases were compared with respect to five criteria: measureability, substantiality (relative sizes of the population groups represented by the segments), statistical robustness of the results, relationship with planning of service options, and relationship with travel behavior. [Gensch and Torres (213) also used these five criteria in an evaluation of a segmentation approach reviewed earlier; a sixth criterion was introduced: accessibility to the segments for purposes of the marketing promotion of transportation services.] Nicolaidis and others (208) reported that segmentations based on choice constraints (relevant choice sets) performed best.

Segmentations based on socioeconomic and demographic variables have been common in travel-behavior analyses. These segmentations have evolved from the use of single variables [for example, focus on income effects by Stopher and Lavender (227)] to the use of complexes of variables. A particularly useful complex has been life-cycle. Segmentations based on life-cycle have been important for years in marketing research (228), and pioneering applications in transportation can be attributed to Aldana and others (229) and Chapin (19). More recently, the concept has been explored in the travel-behavior analyses of Bourgin and Godard (230), Stopher and Ergün (213), Downes (232), Allaman and others (56), Bourgin and Godard (233), Collin (234), Knapp (235), Salomon and Ben-Akiva (236), Wigan (237), and Zimmerman (238). Clarke and Dix (239) have developed an analysis procedure based on the work of Jones and others (7), which focuses on the dynamic aspects of life-cycle; individuals and households evolve from one stage in the family life-cycle to another over time (or move from segment to segment). Life-cycle has proved to be an important segmentation basis in studies of activity patterns.

Life-cycle segmentations have rapidly acquired considerable popularity. Their influence is to be found in both data-collection and analysis procedures. It can also be extended as a framework for considering the implications of policies for the different life-cycle groups. However, reservations have been expressed by Brög (240) and Morris (241) about a possible overreliance on a concept such as life-cycle in explaining patterns in travel behavior to the exclusion of other important explanatory variables. Moreover, nonconforming households, which have increasing relevance, are not usually adequately accounted for in such approaches.

Life-style is another variable complex that has been effectively used as a segmentation base in marketing research (242). However, this concept is more difficult to implement because of ambiguities in definition and because of data requirements (243). In its most ambitious form, life-style incorporates the concepts of social class and basic selections among alternative living arrangements and types of leisure-time activities. Life-style components have been used in travel-behavior analyses by Reed (244), Wachs (245) and his colleagues, Fried and others (246), Reichman (247), Kelly (248), and Salomon and Ben-Akiva (236). The results of these studies are encouraging. When the differences in the approaches are reconciled and combined with results from life-cycle analyses and analyses dealing with subjective components of life-style, this segmentation base should provide a useful foundation for applications in transportation planning.

Segmentations/Experiments

This category is modest in scope. Included are studies dealing with the development of segments that differentiate perceptions and beliefs about hypothetical new transportation products or services. These studies have been separated from the studies reviewed in the section Attitudes/Experiments in order to highlight the segmentation aspects of the approaches. The studies represent a merging of the subjects in the sections Attitudes/Simulations and Segmentations/Attitudes because the studies are attitudinally based.

It has long been demonstrated that segmentations based on behavioral intention are often related to differences in actual future consumer demand (249). At least two studies have used behavioral intention concerning use of a new or modified transportation mode as a segmentation criterion: Alpert and Davies (250) were unable to find distinct segments based on perception and belief data that explained differences in behavioral intention, but Tischer and Dobson (251) did find significant relationships. Dobson (223) attributes this difference in results to use of a single-response scoring of intention (250) and a multiple-response scoring (251).

Costantino and others (252) segmented populations on the basis of both socioeconomic characteristics and subjective beliefs; their objective was to explain differences in choices among hypothetical new transportation modes. Both segmentation bases produced significant improvements in the choice models. And in a series of studies testing different segmentation methodologies, Dobson and others (253), Dobson and Nicolaidis (254), and Dobson and Kehoe (255) analyzed beliefs about proposed new modes. In each study, segments were found with homogeneous profiles of preference, and the segments were interpretable in terms of differences in socioeconomic and activity-pattern characteristics. The major criticism of these approaches is the complexity of their methodologies and possible problems with the required data. Applications of simplified versions of these methodologies could be quite useful in assessing reactions to alternative transportation plans of many types, particularly if the segmentation methodologies were coupled with simulations of the type to be discussed in the introduction to the sections on experiments.

Segmentations/Choices

A number of studies have focused on segmentations based on choice constraints. Many of these studies are in the realm of time and space constraints or activity patterns and are discussed in the introduction to the sections on activities and in the section Segmentations/Activities. In the relatively over-studied realm of mode choice, choice constraint segmentations based on variables such as car ownership are common. Recker and Golob (256,171) and Recker and Stevens (172) proposed segmentations based on the perceived availability of each mode. The choice models estimated on the segments exhibited significantly greater explanatory power than the models estimated on the total samples. Only limited comparisons were made between perceived and objectively measured constraints. This is a useful area for further study.

A completely different approach is to base segmentations on estimations of the probabilities that individuals will make certain choices. If such probability estimates are made in concordance with individual choice of the logit and probit genre, this translates into segmenting individuals on the basis of their calculated utility levels. This was proposed by Reid (257) and later carried out by Gensch (258). Gensch used standardized differences in logit-model utilities as a means of identifying a segment most likely to switch to public transit. The overall goal of the study was to develop an improved technique for use in transit marketing promotion. Further efforts along this direction appear to be warranted.

It is also possible to segment individuals directly on the basis of their observed choices. Such an approach was taken by Hensher (259): shoppers were segmented on the basis of their trip frequencies, and the resulting segments were found to be consistent with differences in socioeconomic characteristics. This represents an extension of the concept of behavioral-intention segmentation to the realm of actual choice. The most effective, unexplored use of this approach might be in interrelating different types of travel choices. That is, it might be used in exploring how segments representing differences in one type of travel behavior (say, trip frequency) are related to variances in another behavior (say, total time spent on travel).

Finally, Hauser and Urban (260) have provided perhaps the strongest methodological link between segmentation and choice. Their approach is experimental and is discussed in the section Experiments/Segmentations.

EXPERIMENTS

Approaches based on the collection and analysis of subjective judgments according to experimental designs are dealt with here. These approaches are variously called controlled simulations, controlled experiments, or laboratory simulations. The term "laboratory" is used figuratively, because data to support the approaches have been collected by using a variety of formats (such as home interviews and on-board surveys as well as questionnaires administered to respondents gathered at a central location or laboratory). Experimental approaches were developed by psychologists and have been used extensively in marketing research. Their use in travel-behavior analysis is just emerging.

Data collections involve judgments by respondents about alternatives that are defined within a predetermined set of hypothetical situations. These situations are generated by a design-of-experiments plan in which the variables of interest are systematically manipulated. [The theory of design of experiments is described in detail in texts by Cochran and Cox (261) and Winer (262); uses in marketing research have been described by Green (263).] In travel-behavior analysis, the variables of interest are typically the characteristics (attributes) of travel modes, destinations, etc. The specific nature of the survey task depends on the data analysis method being used. A comprehensive overview of alternative methods is provided by Green and Srinivasan (264). In the field of travel-behavior analysis, overviews are provided by Hensher and Louviere (265), Levin (98,108), and Louviere and others (100,266) in the course of describing the use of a particular method.

The experimental approach is one of stated preference rather than revealed preference because no direct observations of real-world behavior are used in estimating the models. Consequently, debates regarding the relevance of experimental approaches are often on the level of dogmatic beliefs in the value of stated versus revealed preferences. This might be fortunate or unfortunate, depending on one's view of scientific progress, but it has surely led to rather sweeping statements on the issue. From the point of view of proponents of experimental approaches, Louviere and others write (266):

> We regard it as unfortunate that, despite five years of highly successful validity tests, simulation methods remain generally unaccepted and are forced to take a back seat to more traditional econometric methods. Although paradigms are slow to change, it is hard to understand the resistance to methods that have a good record in numerous validity tests over an extended period of time. Simulation models are at least as accurate as revealed-behavior models, offer greater flexibility in both data collection and analysis, and allow stronger model tests.

If this statement holds up only partly under cross-examination, the current approaches deserve careful consideration.

There is no precise criterion with which to classify specific methods under the broad heading Experiments. The decision here is to discuss within these sections methods that typically involve presenting respondents with full combinations of variables. Methods that involve presenting respondents with comparisons between pairs of variables (attributes of choice alternatives) are dealt with in the section Attitudes/Experiments.

Experiments/Activities

There do not appear to be any studies that fit into this category. It is useful to ask why this is so. One answer might be that activity approaches have only recently become popular. Consequently, the attention of the experimentalists, another segment of the research community, has not yet been drawn in the activity direction. Rather, their attention remains largely drawn in the direction of mode choice, an overemphasis that has plagued travel-behavior analysis throughout its history.

There is every reason to believe that studies applying experimental approaches to activity preferences and choice behavior would be quite useful. It is possible to imagine studies in which respondents are presented with situations involving choices among alternative activity patterns under varying conditions in accordance with a design-of-experiments plan. Much might be learned about the structure of activity preferences. As is discussed in Experiments/Attitudes, experimental approaches have proved to be particularly effective in identifying nonlinearities in preference structures. Experimental approaches thus appear to be ideally suited for activity applications because a substantial degree of nonlinearity can be expected in activity preferences. These nonlinearities might include noncompensatory decision rules, interactions between variables, and threshold effects (particularly related to satisfactions of compulsory activities).

Experiments/Attitudes

It is a basic premise in the experimental approaches reviewed in this section that the most valid subjective responses are those that are elicited when respondents view variables taken together in various combinations, not alone or in pairwise comparisons. Such approaches are known as full-profile approaches (264) and at least three types have been applied in analyzing travel behavior: functional measurement, conjoint measurement, and magnitude estimation. These methods are ordered in terms of apparent number of published studies in the field of transportation research. (The second category of experimental approaches, two-factor-at-a-time methods, is discussed in the section Attitudes/Experiments.)

Functional measurement, also called information-integration theory (267), uses analysis-of-variance techniques to estimate the values (or utility weights) for levels of the attributes under study. Typically, respondents are asked to provide preference ratings for hypothetical alternatives on a bad-to-good scale of 1 to 20 or 1 to 100. As in the other full-profile approaches, the hypothetical alternatives are specified in terms of a design-of-experiments plan. Important aspects of the approach include the ability to detect interaction effects and noncompensatory combinations of attributes and the ability to rigorously test alternative model hypotheses. (Methodological comparisons between functional measurement and other approaches are provided in many of the overviews cited in the introduction to the sections on experiments.)

Functional measurement has been applied to mode choice for home-to-work trips and long-distance travel, destination choice, residential location choice, and a variety of other choices in a series of separate studies: those by Levin and others (268), Meyer and others (269), Louviere and Meyer (270), and Levin and Herring (271), among others. Benjamin and Sen (272) compared functional measurement with conjoint measurement trade-off analysis and unidimensional scaling and concluded that functional measurement was most effective. Many of these studies have involved checks of functional-measurement results against revealed choices; the outcomes have been encouraging. Stated preferences were found to be related to choices but not in a linear manner. The researchers failed to follow up in assessing the influence of this nonlinear relationship on estimations of choice-based attribute values, but steps were taken to relate function-measurement results directly to choice through use of a conventional logit model (273). More recently, Louviere and others (266) compared predictions of mode choice by using functional-measurement results against those of a logit model based on revealed-choice data for the same subjects; the two approaches performed about equally well, but functional measurement supplied more information about attribute elasticities.

The second approach, conjoint measurement (274), has had only a few applications in travel-behavior analysis. It is similar to functional measurement but requires only rank-order preferences from respondents, which is an easier survey task. The methodology involves a type of scaling algorithm that is similar to the algorithms tested in the travel-behavior field by Dobson and others (253) and by Dobson and Kehoe (255). Because there is less information in the survey data, conjoint measurement is more restricted in its ability to test for alternative rules of attribute combinations and to detect interaction and threshold effects. However, recent methodological developments that have not yet found their way into transportation applications appear to have alleviated some of the shortcomings [Green and Srinivasan (264) review early stages in some of these developments.]

Conjoint measurement has been used by Davidson (275) to forecast demand for alternative configurations of proposed new forms of air travel. It has also been used by Steer and Willumsen (276) to forecast the effects of alternative modifications in rail timetables. There are numerous other applications in marketing research.

The third approach is called magnitude estimation (277). Respondents are asked to provide scale judgments about the ratio of preferences between two hypothetical alternatives. Because this survey task might prove difficult in complicated choice situations, the approach has typically been applied to choices among familiar alternatives. The analysis methodology is based on generalized least-squares regression and is extremely effective in detecting and testing threshold and interaction effects. It is closely related to the approach known as clinical judgment analysis (278). Magnitude estimation has been successfully applied by Horowitz (279,280) in estimating relative weights for the components of bus travel--travel, waiting, walking, and transfer time--under various conditions of weather, seating availability, etc. The approach was also used by Pullian and others (281) in a less extensive investigation of relative weights among trip components.

There are a number of other full-profile approaches described in the psychological and marketing research literature. One approach, involving segmentation, is discussed in the section Experiments/Segmentations. Some other approaches are discussed in the references cited in the introduction to the sections on experiments. We are not aware of any major applications of them in travel-behavior analysis. Nor would such applications be expected to be unusually productive. The three approaches already available have each been shown to be robust, so variations on the theme should not be needed. Instead, tests similar to that conducted by Benjamin and Sen (272) might be conducted to compare the three approaches in different behavioral contexts.

Indeed, there seems to be a dearth of effort to resolve minor differences among approaches in the transportations applications of these methods. Green and Srinivasan report that studies in marketing research aimed at comparing alternative approaches have revealed that the approaches yield similar predictions. Results seem to be most sensitive to the structure of the survey task and the choice context. Comparisons of alternative survey tasks should be conducted in the realm of travel behavior.

Experiments/Segmentations

Population segmentations are easily incorporated into experimental approaches of the type discussed earlier. This is one of the advantages of experimental designs: to be able to test differences among respondents within the same methodology used for estimation of variable effects. In addition, many of the multivariate statistical techniques used in the studies reviewed in the introduction to the sections on segmentations can also be used to explore differences among response profiles in experimental data.

However, only a few experimental studies have included segmentations. This is probably due to the nature of the data: Often, either a homogeneous sample of convenience (students) is used in testing and refining an approach or an application calls for a study of the behavior of a predefined segment. Fortunately, examples are available, and these include the functional measurement study by Meyer and others (269) and the trade-off analysis study by Donnelly (282). In a study of mode choice between car and bus, Meyer and others found that their sample could be effectively divided into three segments on the basis of preference profiles; these were a car-based segment, a bus-based segment, and an unbiased segment. These results are similar to ones found by using nonexperimental approaches [see study by Dobson and Tischer (212), for example].

A different type of experimental approach involving segmentation was developed by Hauser and Urban (283). It is based on axiomatic utility theory (284), in which the structure of preferences is derived deductively from a set of assumptions. In the Hauser and Urban approach, individuals are segmented on the basis of criteria similar to the benefit segmentation discussed earlier. Parameters of the preference structures are then estimated from responses to prespecified lotteries. This approach has not been widely adopted in travel-behavior analysis.

Methodologically, there have been some new developments in marketing research that hold forth the promise of more effective segmentations in experimental approaches. These new developments do not appear to have reached the field of travel-behavior analysis. Specifically, a technique called componential segmentation (285) is aimed at predicting individual preferences from joint analyses of respondent profiles and the attribute profiles typically used in experimental approaches. Tests of travel-behavior applications of such new marketing research techniques are likely to yield useful results.

Experiments

We know of no studies that qualify for this category. According to the definitions employed in this review, studies in this category would represent the ultimate in travel-behavior analyses. These would be approaches in which experimental designs were used to specify combinations of levels of objectively measured variables, such as travel times, walking distances, costs, and physical vehicle designs in the mode-choice context. Then respondents would be presented with actual real-world choice alternatives representing these combinations, and choice would be monitored. Viewed another way, these approaches would extend the subjective survey tasks of the types described in the sections dealing with experiments and attitudes to real-world situations. Such experiments are expensive but not infeasible.

Demonstration projects of the kind undertaken to evaluate new transportation hardware and operating strategies might serve as a basis for true behavior experiments. But such demonstration projects have not generally been structured in such a way as to allow determination of underlying causes in changes in travel behavior. Needed are careful experimental designs and before-and-after surveys to monitor behavioral changes. Simpler experimental designs of the type used in trade-off analysis might be envisioned as a starting point in using demonstrations in this way.

Experiments/Choices

Recently, it has been demonstrated that experimental approaches can be used to estimate discrete-choice models such as the multinomial logit model. This is potentially an important development, because it marries two previously different philosophies of travel-demand analysis and opens up possibilities for extensions of choice modeling.

The development of experimental approaches to choice modeling has proceeded along two paths. One approach is based on a level of data aggregation that is analogous to that used in conventional disaggregate travel-demand models (this is referred to here as the group-level approach). The second approach operates on the individual level; a separate choice model is estimated for each respondent. This level is more consistent with that used in the descriptive techniques that have explored the role of time and space constraints on travel behavior: The focus is on representative travelers rather than on the average across groups of travelers. These two experimental approaches to choice modeling share many methodological considerations.

In both approaches, a design-of-experiments plan is used in which the levels of the independent variables and choice set compositions are systematically manipulated. Respondents are thus presented with predetermined choice situations and asked to choose among the alternatives specified as being available, where these available alternatives are characterized by different levels of the independent variables (such as times and costs). The experimental design makes it possible to control the intercorrelations among the variables and between the variables and choice set compositions. This allows precise satisfaction of some of the assumptions underlying discrete-choice models (286) and it allows rigorous testing of independent and interactive variable effects. Both approaches then use a generalized (weighted) least-squares estimation technique to estimate multinomial logit models from the experimental data. [The estimation method was developed by McGuire and others (287) and Grizzle and others (288) and involves a specific set of dummy regression variables required by the transformation of the logit model to a linear system; these variables are explained by Batsell and Krieger (289) and are illustrated by Louviere and Hensher (290).]

The group-level approach was introduced into travel-behavior analysis by Louviere and Hensher (290). These authors document several applications, many of which involved successful validations of results with external evidence of real-world choice behavior. The approach provides the same type of information that is provided by choice-model estimations by using revealed-choice data: variable coefficients and associated standard errors for the sample being studied. The approach translates into the realm of experiments the method of estimating logit models from contingency tables. This estimation method has been developed in marketing research by Green and others (291), Flath and Leonard (292), and others and has been used in analyzing travel behavior by Segal (293). It is in turn related to log-linear analyses of contingency tables commonly used in social science research (294,295).

The individual-level approach was developed in marketing research by Batsell (296) [also by Batsell and Lodish (297)]. In this approach a separate logit model is estimated for each respondent based only on his or her choices. Respondents are then segmented according to similarities and differences in model structure. Apparently, this approach has not yet been applied in travel-behavior analysis.

The two approaches are complementary. They each impose a slightly different requirement on experimental design. The group-level approach might be envisioned in choice situations in which there are quite a few candidate independent variables. Fractional experimental designs can be used to reduce the number and still secure information regarding most of the effects of the variables. The individual-level approach might be envisioned as a segmentation technique, where the objective is to explore structures in previously unmodeled choice contexts. The activity-based analyses discussed in the section Activities appear to have identified a number of such contexts. Small experimental individual-level choice studies might be usefully commissioned there. In any event, either of the current approaches provides a low-cost alternative to the estimation of choice models by using revealed-choice data.

CHOICES

In this last major section, we review approaches that focus primarily on models of individuals' choices. Our objective is, as before, to compare alternative travel-behavior approaches by cross-classifying this subject area with the other four subject areas. However, this section is limited by the omission of the section that would have reviewed developments in the area of travel behavior that has come to be regarded as standard methodology: probabilistic models of choice of mode trip, frequency, car ownership, or residential location (nested or otherwise) based on objectively measured variables and using revealed-choice estimation procedures. It would obviously need to be a very large section.

This exclusion does not represent a judgment about the value of these approaches. Rather, it represents a division of labor between the current review and others. (It also represents our inability to fully appreciate the important nuances of the choice-modeling approaches.) Reviews that focus on studies of that type, but that also cover some of the research classified into the following sections are provided by Daganzo (298), Daly (299), Hensher and Johnson (300), Manski (301), Horowitz (paper in this Report), and Lerman (paper in this Report). These reviews are all quite comprehensive and are considered to be complementary to this one.

Choices/Activities

This category covers travel-behavior studies that focus on modeling activity-related choices. There is a gray area between the coverage of this section and that of the section Activities/Choices. The intention in the latter was to review studies that focus mainly on simultaneous choices among a complex of activity components with correspondingly less detailed specifications of choice related to any particular travel component. This section deals with choice models for particular components of activity patterns, often trip chains or tours. This is recognized as a rather arbitrary distinction. Indeed, some studies [such as the one documented by Adler and Ben-Akiva (302)] span both sections. Nevertheless, each study is reviewed either in one section or in the other, not in both.

Important early activity-choice studies were those of MacKay (303) and Maw (304). MacKay developed and tested a three-stage model involving (a) the decision to generate a shopping trip during a specific time period, (b) the number of stops to be made, and (c) which type of establishment would be visited at each stop. Maw developed a conceptual model of recreation activity choice based on the concept of variable blocks of free time during a day. The model incorporated several other types of choice constraints as well (which represents an extension of some of the concepts described in the section Segmentations/Choices). Time of day of travel was also modeled for the journey-to-work choices by Abkowitz (305,306).

The modeling of certain aspects of activities through the definition of trip tours (round-trip journeys) rather than trips as choice alternatives was pursued in a study documented by Daly (307), Weisbrod and Daly (308), and Daly and van Zwam (309). This study demonstrated how the realm of disaggregate travel-demand models involving choice of travel frequency, destination, mode, and time of day can be extended from trips to trip tours. In another study exploring the possibilities and limitations of existing choice models, Ben-Akiva and others (310) developed a model for non-home-based travel, which focused on the choice of whether to return home from a given location.

In a series of choice studies, Horowitz (311-314) explored travel behavior involving multiple-destination trips. The first study was concerned with the frequency and destination characteristics of nonwork car travel. This was extended in the second study to a nonwork disaggregate demand model, which related trip-tour frequency, destination choice, and choice of the number of stops to household characteristics, destination characteristics, and transportation level of service. Finally, Horowitz (314) specified a similar modeling system that includes both work and nonwork travel and is used to assess the impacts of alternative fuel-allocation policies.

Other approaches to modeling interrelated, activity-based travel choices are reported by Lerman (315), Lerman and others (316), and Adler and Ben-Akiva (302). Lerman (315) developed a joint mode-destination choice model for nonwork travel by merging a logit model with a model of semi-Markov processes. The model uses probability distributions of dwell times at home and nonhome destinations to determine trip departure times. Taking a different approach, Adler and Ben-Akiva developed a model that included trade-offs between single- and multiple--destination trips and, importantly, covered travel over an entire day. The model was based on a theoretical derivation of a household's desires for nonhome activities, taking into account household resources and travel expenditure functions. It extends the type of theoretical arguments fashioned by Burns and Golob (317) in developing the concept of accessibility.

Choices/Attitudes

An important merging of choice modeling and attitude analyses has been the application in choice models of alternative decision rules. It is well known that virtually all disaggregate travel-demand models are based on utility maximization. There are reasons to believe that this decision rule might not apply in all choice circumstances (318-320). Different decision rules have been developed by referring to psychological theories. These same and related theories underlie many of the attitudinal studies discussed in the introduction to the sections on attitudes in this review. Moreover, the different decision rules have been typically applied through the use of subjective variables. Application by using only objectively measured time and cost variables remains a subject largely for future research.

As an alternative to the development of different decision rules, several studies have focused on modifications to conventional utility-maximizing models in order to make the models more consistent with known perception phenomena. Researchers such as Sen (321), Hensher and Johnson (320,322), Lerman and Louviere (323), Koppelman (324), and Daly (325) have explored nonlinear variable combinations in utility-maximization models with encouraging results. Such transformations are consistent with nonlinear perceptions of time and space uncovered in the studies discussed in the section Attitudes/Activities and with results found in the simulation studies discussed in the section Attitudes/Experiments. Using a different approach, Krishnan (326) improved the explanatory power of a conventional mode-choice logit model by introducing the psychological concept of just-noticeable differences to utility comparisons. Other approaches have been to introduce concepts of habit or choice inertia (327-330), search processes (331,332), and other types of threshold effects (333) into utility-maximization models.

Choice models in the field of travel behavior based on non-utility-maximizing rules have been developed by Foerster (334), Recker and Golob (335), Gensch and Svestka (336), and Young and Richardson (337). These studies all postulated noncompensatory choice models in which no direct trade-offs are assumed between characteristics of the choice alternatives. Characteristics are assumed to be considered one at a time by decisionmakers, which reflects constraints on human decisionmaking capacity (338) and a hierarchy of importances.

Foerster (334) compared different noncompensatory and compensatory decision rules for mode choice; the alternative models were estimated by numerical methods. Recker and Golob (335) implemented a choice model based on the concept of elimination by aspects (339), and Gensch and Svestka (336) used the same concept in a different, more pragmatic way. Finally, Young and Richardson (337) developed a probabilistic elimination-by-aspects model of residential choice. All of the models were compared with conventional logit models estimated by using the same survey data. It was unanimously concluded that the noncompensatory and compensatory (logit) models led to fundamentally different policy recommendations. This is an important result because it points out the need to question the basic assumptions underlying logit and probit choice models. These assumptions might be inappropriate in many contexts of travel behavior.

Choices/Segmentations

Segmentations typically underlie applications of travel-demand models. However, their use is often implicit, as in cross-classifications for trip generation, identifications of captive mode users, and aggregations of households by spatial zone. Indeed, spatial segmentations are fundamental to travel-behavior analyses. Examples of more explicit spatial segmentations are provided by Goddard (340), Simmons (341), Hanson and Marble (342), Wheeler (343), and Golob and others (344). In each of these studies, functional regions of homogeneous spatial interactions were determined by analyzing origin-destination flow matrices by using different multivariate statistical techniques. These regions (spatial segments) can be used in defining service areas for dial-a-ride systems or carpool matching assistance programs or for route-location studies.

The introduction of disaggregate demand models has called for the use of segmentations in aggregation procedures (298,345-348). For example, Dunbar (346) specified an aggregation procedure for mode-choice models that involved four steps (193): (a) defining segments with similar socioeconomic characteristics and levels of service, (b) determining the relative frequencies of each segment within the total population, (c) forecasting behavior for each segment by using average attribute values, and (d) aggregating by using steps b and c.

Finally, choice-based sampling, now a statistically well-understood means of estimating disaggregate models (349,350), can be considered a segmentation method. A potentially inherent problem with choice-based sampling becomes apparent when the technique is viewed in the segmentation context. This potential problem is a result of the phenomenon of differential perceptions and beliefs between users and nonusers of a given mode or in general between those who choose and those who do not choose an alternative. Studies reviewed in the section Attitudes/Segmentations have shown these differences to be measurable and pervasive. This might suggest the likelihood of certain biases in choice-based estimations and indicates the need for further research.

Choices/Experiments

In this category, the focus is primarily on choices, with a secondary focus on hypothetical choice situations. This characterizes those travel-behavior studies that use the approach referred to as transfer pricing or diversion pricing. These are of English and Australian origin. They involve asking respondents themselves to identify the amount of change in an attribute on their chosen alternative that would have to occur for them to consider another alternative.

This work was pioneered in the field of travel-behavior analysis by Lee and Dalvi (351). It was later adopted and expanded by Hensher (352,353). Most studies have been in the context of choice of mode for the journey to work. Although considerable insight has been gained into time and cost trade-offs by using this approach, there are certain inherent difficulties that have inhibited its wider application. Dalvi and Lee (354), Dalvi and Daly (355), and Bruzelius (356) discuss these difficulties from the point of view of value-of-time estimations.

Four difficulties can be readily identified. First, the approach is subject to the problems associated with attitude-behavior relationships in general and use of behavioral intention in particular; in addition, there is the problem of differentiating responses that imply considering behavioral changes from those that imply intending such changes. Second, results appear to be sensitive to the specific wording of the survey questions, including minor changes in the specification of the choice context (354,356). Fortunately, certain biases in responses are understood (357), and studies have been conducted to compare survey presentations (358,359). Third, there is the danger of attributing all of the differences between choice alternatives to differences in one or two characteristics for which transfer price responses are sought. And fourth, there are certain methodological problems involved in estimation (354,355).

More recent applications of the approach have involved its use as one part of a demand-forecasting study for Tehran (360) and its use in forecasting demand for proposed new modes (361). This latter study was concerned with the assessment of alternative strategies for carpooling incentives. It is of particular interest because it demonstrates how the approach might be applied in a broader context and relates transfer pricing to the approaches discussed in the section Experiments. It would be highly desirable to include transfer pricing in the research aimed at directly comparing alternative methods called for in that section's discussion.

CONCLUSIONS

A number of conclusions have emerged from this classification of analysis approaches. These conclusions have emerged through observations concerning the relative scarcity of approaches in particular cells of the classification matrix and from comparisons among the approaches in different cells. These comparisons were primarily among cells in the same rows or columns of the matrix. The conclusions are organized according to the anticipated research time frame.

In the short term, it might be fruitful to apply some of the results determined in the research classified into cell 2.1 (reviewed in the section Attitudes/Activities) in existing choice models of the cell-5.1 type. That is, known biases in perceptions of distance, time, and cost could be used to improve models involving trip tours, trip chains, and activity durations. Some nonlinear perception functions have been introduced in mode-choice models (Choices/Attitudes), but this work has not extended to the more activity-based choice models (Choices/Activities). There appears to be a wealth of information in the studies reviewed in Attitudes/Activities. In general, this information has not been consulted by choice modelers.

Next, it appears to be useful in the short term to continue efforts along the lines of the studies reviewed in the section Experiments/Choices. The estimation of logit-type choice models by using controlled simulations represents a cost-effective alternative to revealed-preference estimations. It is important to compare the results of the two approaches (that is, to compare approaches of the cell-4.5 and cell-5.5 types).

Finally, in the short term, there appears to be a possible problem with choice-based sampling techniques. This was revealed by consulting the studies reviewed in the section Attitudes/Segmentations in comparison to the choice-based sampling technique reviewed in the section Choices/Segmentations. A number of the cell-2.3 studies have concluded that there is a distinct difference in perceptions of chosen and nonchosen alternatives. This might affect choice models in general and choice models estimated by choice-based samples in particular.

In the longer term, further development of models of the type reviewed in the section Activities/Choices is deemed to be important. These models of activity-pattern choice are particularly relevant for many modern policy questions. It might be useful to apply some of the results from the segmentation studies reviewed in the section Activities/Segmentations in making the task more manageable.

Finally, the attention in laboratory-experiment studies of the functional-measurement or conjoint-measurement type could usefully be directed away from mode choice and related decisions and toward activity-pattern choice. This is viewed as both a short- and a long-term objective.

SUMMARY

In order to compare approaches to travel-behavior analysis, this review has attempted to cross-classify alternative approaches according to primary and secondary focus. Five primary-focus subjects have been used: activity-based approaches (Activities), approaches using subjective variables (Attitudes), approaches using population segmentations (Segmentations), approaches using controlled experiments (Experiments), and approaches directly involving choice models (Choices).

The resulting cross-classification can be depicted by a five-by-five matrix in which the rows represent the primary subjects and the columns the secondary subjects. Each cell in this matrix (except one) corresponds to a section in the review.

The following list summarizes the types of approaches to travel-behavior analysis that were judged to fall within each cell in the matrix. These types are listed here by their commonly used names. They are discussed in detail in the main body of the review, and references are provided.

1. Activities

a. Activities (sole focus): quantification of time/space constraints; simulation models of activity duration; statistical analyses of activity patterns

b. Activities/Attitudes: measures of activity commitment; role structures in activity programs

c. Activities/Segmentations: analyses of activity-pattern differences by life-cycle segment; grouping of activity-pattern types; segmentations by travel time and money expenditures

d. Activities/Experiments: HATS and other survey-simulation methods

e. Activities/Choices: models of activity-pattern choice

2. Attitudes

a. Attitudes/Activities: mental maps; perceptions of distance and time; use of learning theory

b. Attitudes

c. Attitudes/Segmentations: differences in attitudes among population groups; tests of cognitive dissonance

d. Attitudes/Experiments: trade-off analysis; scaling of responses to hypothetical concepts

e. Attitudes/Choices: attitude-behavior models; quantification of variable in choice models

3. Segmentations

a. Segmentations/Activities: situational approach

b. Segmentations/Attitudes: segments based on differences in preferences and perceptions

c. Segmentations: segments based on life-cycle and life-style; comparisons of segmentation bases

d. Segmentations/Experiments: segments based on behavioral intention

e. Segmentations/Choices: choice-constraint segments; segments based on utility levels

4. Experiments

a. Experiments/Activities

b. Experiments/Attitudes: functional measurement; conjoint measurement; magnitude estimation

c. Experiments/Segmentations: axiomatic utility theory; segments based on functional-measurement results

d. Experiments

e. Experiments/Choices: controlled simulations of logit models

5. Choices

a. Choices/Activities: choice models with trip tours, trip chains, and trip timing

b. Choices/Attitudes: non-compensatory choice models; choice models with nonlinear variable combinations

c. Choices/Segmentations: segments used in choice-model aggregation; choice-based sampling

d. Choices/Experiments: transfer-pricing approach

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Travel Behavior Models: State of the Practice

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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 disaggregate 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 methods 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 performance 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

Workshop on Mathematical Structures and Uncertainty

Workshop Summary

FRANK S. KOPPELMAN, Northwestern University

The focus of this workshop was various mathematical choice models representing travel behavior, based primarily on individual-choice theory. In conjunction with other methods, these tools produce information on travel flows on proposed transportation systems and other related alternatives. These techniques possess many advantages over existing procedures (covered extensively in the Workshop on Long-Range and Strategic Planning Methods) but are sometimes cumbersome to use and contain unknown errors. The state of the art was assessed, relating methods to practical and institutional problems. In background papers, Steven R. Lerman and Joel L. Horowitz summarized the state of the art and the state of the practice.

The workshop participants found that methods currently available can generally support decision-making for a wide range of planning problems. However, many planners and decisionmakers view these methods as unnecessarily cumbersome and irrelevant to their concerns in their current form. In addition, current models are deficient in ability to represent or predict travel behavior accurately for many options. Thus, two different areas were addressed:

1. Overcoming barriers to current use of the best available techniques for specific purposes and
2. Improving the behavioral content and accuracy of existing techniques.

A number of reasons were identified for failure to move techniques into practice. These are

1. Heavily technical descriptions of methods,
2. Excessive claims about unrealized advantages,
3. Lack of clarity of ways in which techniques respond to planner-identified problems,
4. Inadequate priority or time given to learning new techniques,
5. Failure to acknowledge the source of improved capabilities, and
6. Inadequate definition of current and future issues.

To deal with these concerns, it was suggested that gap-closing materials, such as methodological manuals, software support, instructional programs, and documentation of successful applications, be developed. Issues and planning areas most appropriate for analysis should also be identified. Numerous short-range projects, operating procedures, and pricing decisions are sample cases where simple applications of advanced models can be described. Selected regional-scale problems should also be studied through upgrading of current large-scale model systems. Emphasis should be on issues that cannot be addressed by current (traditional) methods and issues that can be addressed more efficiently by new methods. Planners' criteria for selecting and using models and procedures can be satisfied by new methods, which should be described. This includes simplified applications (such as pivot-point methods), improved (or new) issue sensitivity, higher levels of precision than traditional models (reduced uncertainty), and ability to apply model systems at different levels of complexity.

Options for adopting new models should be developed, varying according to level of sophistication, range of problems, and development of a new model or adoption of one from another environment.

Mathematical Models of Travel Demand: A State-of-the-Art Review

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The state of the art in modeling transportation systems has evolved at an extraordinarily rapid pace since the early highway studies of the 1950s. This rapid evolution has been the result of the confluence of several major factors, including

1. The growth of the federal government's involvement in the transportation sector and the government's willingness to fund both research and planning activities;
2. The extensive fertilization of transportation systems analysis from other fields, notably economics, statistics, and operations research;
3. The technological advances made in digital computers; and
4. The perceived demand for a rational decision process in making capital investment and operating decisions in the transportation sector.

These and other forces have all acted to produce major innovations in the field of travel demand analysis, which forms a large part of what has constituted transportation systems analysis. I intend to examine the various components of travel-demand modeling and describe what I believe to be the major changes in the state of the art. I will particularly emphasize innovations in the last few years in order to focus the attention of workshop participants on the progress we in the research community have collectively made since the last major international conference on travel demand, held in Eisbee, West Germany, in 1979. I will also present my personal evaluation as to whether the state of the art in different areas has advanced as rapidly in recent years as it has in the past and why any observed rate of change has shifted.

This review is restricted to what I term mathematical behavioral models, i.e., abstract, mathematical representations that purport to approximate in some way the processes underlying travel demand.

This eliminates other, more qualitative approaches such as focus groups, simulation games, and various exploratory data-analysis methods from the scope of the review. In addition, it eliminates models designed with the objectives of predicting travel demand as a function of a few aggregate correlates.

In reviewing the state of the art, I have intentionally adopted a very broad view of mathematical demand modeling. This view is intended to include far more than the technical aspects of the model structure and statistical inference.

In adopting a broad view, I hope to demonstrate that although the state of the art has made great progress along some dimensions, it has left a greater number of potentially fruitful avenues of research almost untouched. I will also propose the thesis that further efforts in the areas that we have historically emphasized will, in all probability, yield smaller returns than comparable efforts directed at some of these unexplored possibilities.

The remainder of this paper is organized as follows. The next section presents a subdivision of the travel demand modeling process into five distinct components. These are behavioral theory, measurement, statistical model structure, estimation, and forecasting. An assessment of the state of the art in each of these five areas is presented next. Finally, the progress made to date is summarized and some rough priorities for future research are suggested.

COMPONENTS OF TRAVEL DEMAND MODELING PROCESS

There are obviously a virtually infinite number of ways in which the process of travel demand modeling can be divided. However, for the purposes of this review, I have found it useful to divide the field into five distinct areas.

The first area is behavioral theory. This is intended to encompass all aspects of the behavioral theory underlying any particular travel demand model. It includes areas such as

1. The attributes considered by individuals making demand choices;
2. The particular choices represented in a model, including the type of choice (mode, destination, etc.), the period over which the decision is made (day, month, year, etc.), and the nature of the set of possible choices (continuous, discrete, or mixed);
3. The decision rule (compensatory, elimination by aspects, lexicographical, etc.); and
4. The assumption about the information available to the decisionmaker, including how information is acquired and used.

It is important to emphasize that the area I define as behavioral theory is quite distinct from the problems of how to make that theory operational. One can easily imagine an entirely reasonable theory of travel behavior for which there exist no corresponding data, statistical model, or estimation technique. For example, a theory of behavior in which travel decisions at any time depend structurally on all previous travel decisions might be entirely plausible but impractical to make operational.

The second area is what I term measurement. This includes all aspects of data collection such as how and which attributes are measured, how travel decisions are observed, how samples are taken, and whether data are cross-sectional or longitudinal. In addition, issues of whether so-called attitudinal or perceptual data are collected come under the general heading of measurement. Finally, whether the analyst measures actual choices (revealed preferences) or stated preferences to hypothetical choices is part of measurement.

The third area is model structure. This broad category incorporates the methods through which behavioral theory and data are combined to produce a statistical model of travel demand. For example, virtually all discrete-choice models have the assumptions of utility maximization as their underlying behavioral theory. Moreover, as commonly used, the measurement process is typically a cross section of individuals drawn at random and observed for some fixed period (usually 24 h); each observation consists of the actual travel choices and physically measured attributes such as time, cost, etc. In this subset of the field of travel demand analysis, the statistical model structure is usually some variant of the multinomial logit model, in which the analyst treats utilities as a vector of independent and identically distributed random variables, each Type I Extreme Value (or Gumbel) distributed. These assumptions, when combined with the theory and a set of observed attributes, provide the basis for specifying the probability distribution over the set of possible choices.

The fourth area is estimation. Conditional on the set of measurements taken and an assumed statistical process that generated them, estimation is the technique by which unknown parameters of the model are inferred. This area has been dominated in travel demand analysis by classical statistical inference by using the methods of least squares and maximum likelihood.

The final area is what I have loosely termed forecasting. Under this general heading I include all of the following:

1. Prediction of the values of independent variables;
2. Aggregation and/or disaggregation of demand forecasts;
3. Representation of policy changes in the models; and
4. Integration of demand forecasts with other components of the transportation systems analysis, including equilibration with other models in which demand is an independent variable.

Each of these five different components is reviewed in the following sections.

BEHAVIORAL THEORY

Despite the objections of innumerable critics, the vast majority of the literature in the field of travel demand analysis has been either implicitly or explicitly derived from the hypothesis of individual utility maximization. This class of models encompasses the entire spectrum of neoclassical economic models of consumer behavior, choice models, and large segments of the transportation-related research in marketing and psychology.

There are two reasons for the dominance of utility maximization as an underlying behavioral theory in travel demand models. First, there has been a strong influence of economics on the research community on travel demand forecasting dating from early work by Meyer, Kain, and Wohl (1). The second and more relevant reason has been the ease with which tractable, analytic results can be derived when one assumes that decisions on multiattribute services such as transportation can be reduced to the optimization of a scalar index of worth.

Many of the objections to utility maximization as a behavioral theory can be dealt with by modifying other assumptions of the neoclassical economic model. For example, psychologists have often argued that subjects tend to rely on satisficing rules when they choose among many alternatives. Thus, individuals select alternatives that meet certain upper and lower thresholds along their various attributes rather than combining the attributes in some compensatory fashion [see, for example, a study by Golob and Richardson (2)]. This type of behavior, in which a decisionmaker behaves as though he or she possessed fixed levels of aspiration, can be approximated by a utility-maximizing individual who faces alternatives one at a time, where each alternative examined has associated with it some search cost. The resulting models, although based on the assumption of utility maximization, produce a behavior in which individuals examine alternatives until they find one with attributes leading to a utility level exceeding some fixed value. Examples of such models appear widely in the literature in statistical decision theory (3) and have more recently been extended in numerous works such as those by Weibull (4) and Hall (5).

Given the tractability of behavioral theories rooted in the assumption of utility maximization, it is not surprising that the state of the art in travel demand analysis has tended to move by extending that theory rather than by abandoning it altogether. These extensions can be viewed along the following dimensions.

Extension of Choice Sets

Travel demand models have moved steadily to encompass an ever-increasing range of potential choices. The earliest demand models that had any real underlying behavioral theory were exclusively models of mode choice [e.g., see early work by Lisco (6), Warner (7), Watson (8), Quarmby (9), Stopher (10), and Lave (11)]. Since those early discrete-choice models, work has been done on choice of destination, mode, automobile ownership, time of day of travel, frequency, activity duration, automobile type, housing, residential location, and workplace location. Much of this body of research, however, has added little to the area of behavioral theory; rather it has tended to focus on utilizing existing assumptions on different empirical problems. This is particularly true in much of the discrete-choice literature, where the emphasis on extending models to new empirical contexts has been on issues of specification of the statistical model structure.

Extension of Assumptions About Information

The simplest models of traveler behavior assume the existence of a perfectly informed decisionmaker who is aware of all of the available alternatives and who knows all the alternatives' attributes with certainty. Particularly when one is dealing with very large sets of feasible alternatives or travel behavior that is not routine, this assumption has been questioned. Recent work has explored the consequences of relaxing these assumptions in a number of different ways. For example, Lerman and Manski (12) have explicitly considered how the process of information acquisition can be incorporated into discrete-choice behavior. Their work treats information as obtained from three generic types of sources:

1. Direct experience,
2. Word-of-mouth communication from other informed members of the population, and
3. Media coverage transmitted through one or more mechanisms.

Other efforts have been directed toward relaxing the assumptions regarding the cost of obtaining information about alternatives. Hall (5), for example, considers the case of an active search for housing, where the decisionmaker must decide whether to accept a given alternative from the set he or she knows about or to incur some actual (or psychological) expense to obtain further alternatives. The resulting models are similar to those developed by Weibull (4) in the context of destination search.

Linking Travel Behavior to Activity Demand

Despite the consensus that transportation is a derived demand, it is only relatively recently that travel demand modelers have attempted to derive models of transportation choices from an underlying theory of the demand for activities in which individuals choose to participate. The early qualitative work by Hagerstrand (13), Lenntorp (14), and Chapin (15) produced a great deal of behavioral insight but virtually no mathematically structured theory. More recently, efforts to model time allocation by Bain (16), Jacobson (17), and others have produced models of the duration of activities but not how those activity decisions result in specific travel choices. Damm and Lerman (18) have modeled the choice of whether to participate in an activity at a given period of time during the day for workers jointly with the choice of the duration of the activity. However, there is still no single integrated theory that directly links choice of activities with tripmaking.

Interactions Among Household Members

Virtually the entire body of behavioral theory deals with the choices of a single decisionmaker, defined either as an individual or as a household. More realistically, there are many household decisions that result from interactions among household members, each of whom may have different objectives. To date, there has been almost no analytic theory of intrahousehold interactions, with the notable exception of empirical work by Jacobson (17) on the allocation of shopping activities between adults in the household. Such interactions are probably becoming increasingly important in determining certain types of travel behavior as traditional roles in households become less and less significant determinants of the allocation of household tasks between members of a married couple.

Choice-Set Determination

The existing theory has generally assumed that the choice set available to an individual is relatively large, limited in most cases only by resource constraints (e.g., budget constraints or time constraints) or physical availability (such as the unavailability of an automobile). The more qualitative literature of traveler behavior suggests that there may be other constraints operating, including some that may be attributed to issues such as lack of information.

Perhaps the best examples of constraints that we do not currently represent in existing theories is what Hagerstrand (13) terms "coupling constraints." Basically, these constraints arise when the decisions of two or more individuals must be coordinated for either one to make a trip. Most carpooling choices, which we now model as independent decisions of separate actors, are in reality constrained by the need for the members of the carpool to have matching schedules.

Development of Intermediate Constructs

The original behavioral theories typically treated utility as a function of a vector of observed, physically measured attributes. This approach was widely criticized as ignoring the process by which physically measured attributes are perceived and acted on by individual decisionmakers. It has been proposed that individuals assess alternatives by first constructing some intermediate variables and then evaluate their alternatives based on these intermediate constructs. Most of the efforts to explicitly capture these intermediate processes in explaining traveler behavior are the result of cross-fertilization of travel demand analysis by marketing research. Examples include the use of multistage models [such as the Lens model first proposed by Brunswik (19) in the marketing context] to study choice of a shopping center by Koppelman, Hauser, and Tybout (20).

In the Lens model, physically measurable attributes are translated into actual decisions in a sequence of steps. First, physical attributes of both an alternative and a decisionmaker produce perceptual attributes of the alternative. (These perceptions may be on a considerably smaller number of dimensions than the original attributes.) The perceived attributes then induce a set of preferences for the set of alternatives. These preferences are then further modified by situational constraints that limit the actual choice made.

Obviously, the Lens model is only one possible way in which intermediate constructs can be introduced into a behavioral theory. The important issue in developing such constructs is whether one can use them as a basis for an operational model. In particular, does the theory impose useful restrictions on the relationship between observable variables and the hypothesized constructs that help in developing more reasonable models?

The above review suggests that even within the paradigm of the utility-maximizing traveler there exist an enormous number of relevant areas for the extension of behavioral theory. Overall, one can probably substantiate the argument that in the area of behavioral theory, the field of travel demand analysis has evolved extremely slowly. This lack of progress is probably due to the great emphasis we as analysts have placed on models that are operational. Funding for research that has improvements in behavioral theory has been confined to just a few studies [notably NCHRP Project 8-13 (21)], and most of the progress in formulating better theories of behavior has come as a by-product of studies with more immediate objectives. This emphasis on developing behavioral theories that are simple enough to lead to tractable, immediately operational models that can be estimated and applied has produced a disinclination to explore behavioral theory for its own sake. Moreover, it has encouraged criticism of the basic paradigm of utility maximization as inadequately reflecting what many view as demonstrably nonmaximizing behavior. Without a judgment as to whether such criticism is in fact merited, it is probably safe to argue that those of us working with such models have failed to fully exploit their potential for explaining or approximating behavior that on the surface appears contrary to the hypothesis of utility maximization.

Measurement

Measurement includes an extremely wide range of subjects of relevance in travel demand modeling. In this section, I will restrict my comments to those measurement problems that relate directly to the development of mathematical models of tripmaking and ignore the issues that must be considered in more qualitative or exploratory travel demand analysis. This to some extent restricts the scope of the review, since many travel demand models are developed from data that were intended for other purposes.

For the purposes of exposition, the work in this area will be divided into four subareas. Each is considered below.

Attributes Collected

Data-collection efforts in travel demand studies have been dominated by the use of 24-h trip diaries, which are usually augmented by socioeconomic information about respondents and network-based data on the level of service provided by alternative modes. De facto, this domination has resulted in an emphasis on the use of a relatively limited subset of possible attributes and has traded off large samples for high levels of reliability in the data base.

Efforts to extend the range of attributes measured in travel demand analysis have been directed toward either generating data on different, physically measured attributes or measuring what have loosely come to be called perceptual or attitudinal data. Examples of the former include efforts by Small (22), Lerman and others (23), Abkowitz (24), and others to measure the reliability of modes, either by inferring the higher moments of the travel-time distribution from repeated observed trips or by associating distributions of travel times on links in the network and deriving network travel-time variances. Other extensions of the types of attributes used appear in the literature on destination choice (notably for shopping trips) where the typical land use measure such as employment by type and zonal areas devoted to different uses has been enhanced by measures of the number and variety of stores, parking spaces, mean walking times to parking, and measures of physical amenities such as enclosure of malls. One good example of this type of work is that of Kern and Parcells (25), where the Census of Retailing is used to measure a large number of attributes of different retailing centers.

The measurement of that which is not physically measurable, such as perceptions of quality, convenience, etc., has probably received somewhat greater attention. The early research results in this area by Spear (26) in the context of mode choice and by Kostyniuk (27) in the context of destination choice were somewhat mixed, particularly when these measures were used along with the physically measured attributes. Although these ambiguous results could be attributable to many causes, one might speculate that the most crucial problem was lack of a clear theory about how to use this type of data appropriately. The measures used were often the result of questions in which respondents imposed their own views on what the attributes labeled comfort or convenience were measuring. What is needed is a clearer structural theory of the process by which physically measured attributes and socioeconomic characteristics interact to form these intermediate constructs and a clearer theory of how the available psychometric techniques that purport to measure these constructs work. This more structural model would then provide some guidance as to how we should and should not use these types of variables and how the values of these variables can be modeled as functions of other attributes. This is apparently an active area of research in the marketing field (28) and may yield some useful results for building travel demand models that rely on these nonphysical attributes.

Sample Sizes and Sampling Strategies

With the development of statistical techniques for utilizing disaggregate data for modeling qualitative responses (notably the multinomial logit model) the research community consistently endorsed the collection of smaller samples that were broader in terms of the information collected from each respondent and better verified. The emphasis on using smaller, more reliable samples was reflected in early disaggregate demand studies (29-31). Recent data-collection efforts have followed these recommendations but have largely used the same sampling strategies as earlier studies.

Advances in the analysis of sampling techniques such as stratified sampling, choice-based sampling, and various hybrid strategies have provided a much richer set of alternative sample designs. Most of this literature, however, has focused on how these different sampling strategies can be used to estimate a model and not on how one should choose a sampling method.

Work by Lerman and Manski (32) opened up this issue without providing a great deal of specific practical results. Indeed, their key result was largely negative; i.e., the optimal sampling strategy for even simple problems cannot be determined without prior knowledge of the unknown parameters of the model to be estimated. Daganzo (33,34) noted this result and formulated the sample design problem as a nonlinear programming problem in which the parameters of the model were treated as known. In this model, the fractions of the sample taken from each of a finite set of possible sampling strategies are the decision variables; the objective function is a measure of the efficiency of the estimated parameters such as the trace or largest eigenvalue of the variance-covariance matrix of the estimator.

Subsequent empirical experiments by Sheffi and Tarem (35) have applied Daganzo's basic technique to sample design for logit model estimation. In their work, initial parameter estimates are obtained from a small, randomly drawn sample, and the resulting estimates are used to optimize a second-stage sample. Their results on both simulated and actual data suggest that substantial gains in efficiency are possible from use of this two-stage technique and that these gains are not particularly sensitive to the size of the first sample so long as it is greater in size than some minimal fraction of the total sample. Their work applies only to designing samples that are stratified on exogenous variables, leaving the optimal design of endogenously designed stratified samples almost entirely unresolved.

A sample design question that remains essentially unexplored is the development of optimal sample designs when the parameters are not viewed as known with certainty. (Daganzo's technique is derived by treating the parameters as fixed.) Potentially, one could treat the parameters as uncertain either because only estimates inferred from small samples are available or because the parameters are assessed subjectively from expert judgment. This would complicate the optimization problem substantially, and it is unclear whether the optimal strategies that would be derived would be significantly different from those based on deterministic a priori parameters.

Preference Data

For largely the same reasons that travel demand research has been dominated by the use of a limited number of physically measured attributes, we have historically relied on data on revealed preferences. Indeed, the issue of whether travel demand analysis should use data other than revealed preferences has been the focus of many of the longer debates in previous travel demand conferences. Most of this debate, unfortunately, has centered on the simple questions of what type of data should be used and not on what I perceive to be the most meaningful question of how to use different forms of data.

The types of alternative data on preferences that have been used include stated preferences (or rankings) of hypothetical alternatives, scaled measures of intensity of preference for either actual or hypothetical alternatives, and questions about trade-offs that individuals would be willing to make on particular attributes. Each of the above types of preference data has within it a myriad of distinct options, some of which involve detailed procedures such as the allocation of a fixed number of chips by a respondent in which the number of chips given to any alternative reflects the intensity of preference (36).

Proponents of these methods argue that they allow the analyst to extract vastly more information from each respondent, including multiple responses to different choice situations and reactions to combinations of attributes that are simply unobserved in revealed-preference data. These features of this type of data make it possible to model demand for new alternatives without making the strong assumptions on model structure and genericity of attributes that are required when revealed preferences for existing alternatives are used. In addition, because responses for a variety of choice situations can be elicited in collecting this type of data, it is possible to estimate demand models separately for any given individual in the sample. As demonstrated in a relatively simple case study by Fischer and Nagin (37), this greatly facilitates the diagnosis of the structure and causes of random taste variation in the population being modeled. Finally, the ability to construct a very wide range of attributes in the data makes it considerably easier to determine the appropriate functional form for demand models [see paper by Lerman and Louviere (38) for an example].

Those who argue for the exclusive use of revealed preference note that people often do not actually do what they say they would do under hypothetical circumstances. Thus, there may be a tendency to overcommit to hypothetical new alternatives in response to questionnaires, misleading the travel demand analyst into erroneous and often overoptimistic forecasts of the demand for such innovations. Given the uncertainty that exists about how people respond to hypothetical questions, revealed preferences provide the best basis for modeling demand.

Both the above arguments reflect extreme views. A more centrist (and in my view more reasonable) position is that although responses to hypothetical questions do indeed incorporate sources of error in the prediction of actual behavior, they do provide potentially valuable information about how people will actually behave. The key is to structure an explicit theory about how stated preferences map into actual behavior. This theory would allow us to use both revealed and hypothetical preferences within the same model; the model structure would be used to control for the fact that two distinctly different types of information are represented. One conceptual basis for such a theory has already been described by Koppelman, Hauser, and Tybout (20), who have adapted some of the work in the marketing field to the transportation context. However, there is a major, and to my knowledge still unfilled, gap between the conceptual theory and an operational model that allows a synthesis of revealed and hypothetical preferences in a single model.

Choice-Set Availability

The FHWA-funded study of data-collection methods piloted in the Baltimore disaggregate data-collection effort had as one of its goals to measure the set of transportation alternatives available to a subset of the respondents for one trip. The results of this portion of the data collected showed that respondents reported having very few alternatives to their chosen travel mode and destination. This is in direct contrast to the assumptions made in many discrete-choice models of traveler behavior, where it is often assumed that the set of feasible alternatives is quite large. The question remains whether in fact the choice set actively examined by an individual is quite small or whether respondents chose to screen out many alternatives that they knew were available but were so decidedly inferior that they were ignored. In addition, the survey instrument used in this study was extremely lengthy, and it is conceivable that many respondents intentionally truncated their list of alternatives in an effort to shorten their interview.

The question remains, therefore, how the choices perceived by an individual can be measured. Part of the problem in addressing this question in any meaningful way is that we lack an operational definition of what really constitutes the availability of an alternative. Most of the models we now use treat availability as a binary issue; either an alternative is available to an individual or it is not. A more realistic model would recognize that there are degrees of availability, which range from alternatives that are used every day to those that are simply infeasible. In the middle of this spectrum lie alternatives about which the individual has only incomplete and potentially out-of-date information. This information may be so incomplete or hazy that the individual responds to questions about its availability by telling the interviewer that it is unavailable. In fact, circumstances such as the need to travel by modes other than those customarily used (as in the case of a breakdown of the family's private automobile) may trigger a process of active search for better information and subsequent use of the alternative.

STATISTICAL MODEL STRUCTURE

The field of model structure, particularly for discrete-choice models, has undergone major expansion since the development of the multinomial logit model by McFadden (39). Some of this expansion was the result of entirely new model structures, whereas other developments were the operationalization of models that had existed in theory for some time but were considered impractical due to what appeared to be insurmountable computational difficulties. As we shall discuss further in a comment below, the major area of progress has been the derivation of new models by altering the assumptions about the specification of the disturbances in random utility models. There has been considerably less active research in passenger demand analysis on new structural forms for continuous dependent variables. Each of the major research subareas is discussed below.

Logit-Based Extensions

Given the computational tractability of the conditional logit model and its extraordinary statistical properties when used to estimate different samples and subsets of alternatives, it is not surprising that there has been significant research activity directed toward generalizing the logit model while still attempting to preserve some or all of its most salient features. The earliest such work is due to Ben-Akiva (31), who first proposed what has come to be termed the nested logit model. His work led to both a practical extension of the logit model to allow for a limited class of nonindependent disturbances and a computationally tractable but not fully efficient estimation technique for that model. Efficient estimation via full information maximum-likelihood estimation has now been accomplished by Brownstone (40) and by Ben-Akiva and Lerman (41).

In subsequent work, McFadden (42) has shown that the now-standard conditional logit model and various forms of the nested logit model are both members of a large class of what he termed generalized-extreme-value (GEV) models. Members of this class can be derived straightforwardly by using McFadden's theoretical results that characterize the GEV model. However, to date there have been no new special cases of any great interest.

Another generalization of the logit model was derived by Sheffi (43). In this variant of the logit model, the probability of any given choice is represented as the product of a sequence of binary logit probabilities. In still another variant, Small (44) has derived what he calls a serial logit model with potential applicability to modeling cases where the choice set is logically ordered (e.g., integer outcomes).

Another area of logit extensions has been the evolution of the continuous logit model. In this work, the set of alternatives is treated as continuous, and the logit model is modified so that the denominator is the integral (rather than the sum) over the entire set of feasible choices. This model was first proposed without any formal derivation by Watanatada (45) and subsequently derived by assuming that the IIA property holds with respect to subsets of continuous alternatives (46). A formal derivation from random utility theory was constructed by Litinas (47), who also derived a variety of interesting and tractable analytic cases where the model could be applied. In particular, by assuming that the set of destination is a continuous plane and making specific assumptions about the distribution of level of service and potential destination over that plane, Litinas was able to derive closed-form expressions for vehicle miles of travel, mean trip length, and other travel summaries directly (48).

This underlying model was also used by Litinas and others (49) to model trip generation. In this work, the mean trip rate for an individual was represented by a continuous logit model defined over the nonnegative real numbers. In any given day, the number of trips made was represented as a stochastic process with integer outcomes conditional on the mean trip rate. For the case where the daily trips are Poisson distributed, they showed that the observed trips are negative binomial distributed.

Probit Models

The late 1970s were characterized by a significant growth in interest in forms of the multinomial probit model. Researchers had long been aware of the potential generality of multinomial probit; one can construct probit models that allow for random coefficients and disturbances with any arbitrary covariance structure (50). The key obstacle to the exploitation of the multinomial probit model had been the enormous computational burden associated with computing multinormal probabilities.

These problems are addressed by three distinct computational approaches. The first was a method used by Clark (51) and applied by Daganzo, Sheffi, and others in a series of papers [e.g., one by Daganzo, Bouthelier, and Sheffi (52)]. The key to this method was the approximation that the maximum of two normally distributed random variables is normally distributed. (The reader can verify that this is in fact not true by considering the distribution of any two normally distributed random variables that are perfectly negatively correlated.) Early empirical experiments suggested that this approximation is relatively accurate for a large class of normal distributions, particularly if the normal variates did not have extremely different variances and were positively rather than negatively correlated [see study by Lerman and Manski (53)]. Moreover, the computational experience demonstrated that the method was easy to code, rapid to execute, and did not exhibit the exponential growth of computation times with increasing choice-set size that characterized many of the other approaches, particularly forms of numerical integration.

More recent evidence accumulated in extensive numerical experiments reported by Horowitz, Sparmann, and Daganzo (54) has generated the basis for some reconsideration of the early optimism about the value of the Clark approximation. Their work suggests that there are many instances where the approximation is unacceptably erroneous, particularly for problems with relatively high taste variation.

The second approach used has been the application of various types of series expansion (55). This approach led to the first actual empirical application of trinomial probit that allowed for non-IID disturbances [Hausman and Wise (56)]. Although quite accurate, the computational burden associated with series-expansion methods makes their use in choice problems with more than five or six alternatives infeasible for most purposes.

The third approach is a variant of Monte Carlo integration proposed by Lerman and Manski (53). In their work, the choice probabilities are computed by drawing realizations of the disturbances and exploiting the relative ease with which random number generators can be used to simulate normally distributed random variables. The fraction of drawings for which any alternative has the highest simulated utility is used as the basis for an estimate of the choice probability. Unfortunately, Lerman and Manski's simulation experiments suggest that multinomial probit models estimated in this way will require perhaps an order of magnitude more computational resources than comparable logit models.

At this point, it appears that trinomial probit models are the one case in which the computational requirements of model estimation have been reduced to what most researchers would judge to be reasonable levels. Sparmann (57) has developed a clever tabling scheme for the trinomial probit function that is parameterized in a way that reduces estimation costs significantly. Work with larger choice sets will require either acceptance of the Clark approximation (58), further work on faster codes (using any of the above techniques), the use of less general probit model forms that decrease the number of parameters to be estimated (59), and the complexity of the choice probability evaluation or simply larger computer budgets.

Truncated Dependent-Variable Models

There are certain instances in which the dependent variable either is restricted to a limited set of discrete outcomes or takes on some range of continuous values. The most common such instance in transportation is when activity duration is the dependent variable. Over the usual period of observation, the amount of time any individual spends is either zero (i.e., he or she does not participate in the activity) or a positive, real number. The methods used to deal with such problems have been generally adapted directly from the econometrics literature initiated by Tobin (60). Application of this method and more recent extensions to allow for simultaneous systems of truncated dependent variables appear in work by Bain (16) and Jacobson (17).

Models with Mixed Continuous and Discrete Variables

There are some travel problems for which the dependent variables are both continuous and discrete. For example, one might view a commuter's work trip choice as consisting of a decision on when to depart from home to work (a continuous dependent variable) and a decision on what mode of travel to use (a discrete choice). This type of problem was first explored in a travel demand context by Westin and Gillen (61). Their approach requires that the disturbances for both the continuous and the discrete decisions be normally distributed and that the utility of the discrete alternatives be linear in the continuous dependent variable. They derived a multistep estimation method based on work in the field of labor-force participation pioneered by Heckman (62). This method iterates between estimation of the continuous equation and the discrete equation, eventually leading to a consistent, although not fully efficient, set of parameter estimates. This was the basic approach adopted by Damm and Lerman (18) to model the decision of workers to participate in a nonwork activity during each of five periods during the day and, if the decision is to participate, for how long.

Variants of these types of models have been developed outside the transportation field by Dubin and McFadden (63), who use the multinomial logit model for the discrete choice. In other work, McFadden and Winston (64) have used full information maximum likelihood and estimated mixed continuous and discrete models of freight demand.

Time-Series Analysis

Because most of the data available to transportation analysts has been cross-sectional, the use of time-series approaches has not been emphasized in travel demand modeling. Most of the time-series methods used in travel demand analysis have been applications of well-known methods developed for the analysis of aggregate economic models, in which the dependent variable is continuous. These methods are considerably less applicable to microlevel transportation data, in which most of the observations will be a sequence of discrete trip choices. One approach used by Jacobson (65) in analyzing trip generation for a panel data set is to aggregate the data temporarily and to treat the resulting dependent variable as continuous.

The new methodological contributions in terms of modeling time series of discrete decisions have been largely developed by econometricians working on problems outside of transportation, particularly theoretical work in labor economics by Heckman (66). In the transportation literature, Daganzo and Sheffi (67) have developed a computational technique for applying probit analysis to a time series of discrete decisions. Their technique reduces the computational burden from exponential in the product of the number of time periods and alternatives to linear in the same product.

Lerman and Manski (12) have explored a time series of discrete decisions in which members of the population are acquiring information about a change in the transportation system. Their model structure, however, leads to quite complicated expressions for the probability of observing a given sequence of choices.

Stochastic Choice Sets

Another extension to the standard discrete-choice model is derived from the assumption that the analyst no longer knows the decisionmaker's true choice set. In this case, a probabilistic model of choice-set generation can be hypothesized. This model typically has unknown parameters that must be estimated along with the parameters of the utility function.

Manski (68,69) has laid the theoretical foundation for this process. Particular cases have been explored by Pitschke (70), Pitschke and Lerman (71), and Ben-Akiva (72). Ben-Akiva has demonstrated that the Dogit model proposed by Gaudry and Dagenais (73) can be reinterpreted as a model where each individual has two possible choice sets. The decisionmaker is either captive to his or her chosen alternative or has the full choice set. A parameter in the Dogit model, when normalized, is the probability of captivity.

ESTIMATION

Of all the five areas covered in this review, there is perhaps the least to discuss in the field of estimation that is specific to travel demand analysis. Given the universality of the problem of inferring unknown parameters of statistical models, it is not surprising that most of the advances in methods used by travel demand analysts are in fact the result of advances in statistics and econometrics in general.

These more general advances, however, have had a significant impact on the state of the art in travel demand modeling. For the purposes of discussion, it is useful to divide the progress made in this area into three distinct subareas.

Maximum-Likelihood Estimation Under Alternative Sampling Strategies

The statistical theory of estimating a wide range of models under a host of alternative sampling strategies is now extremely well developed. The evolution of this theory is the result of a few key studies, each building on earlier developments. This literature began with the thorough exposition of maximum-likelihood estimation by McFadden (39). His work provided the basis for virtually all of the applications of discrete-choice analysis in the 1970s. Ben-Akiva (31) then extended the available estimators in developing a sequential, maximum-likelihood method for the nested logit model.

The first theoretical inquiry into the effects of endogenous sampling strategies on the estimation of discrete-choice models was by Manski and Lerman (74) for the case of pure, choice-based samples. Their work produced a computationally simple though not fully efficient estimator in which observations were weighted and then treated as exogenously drawn from the population. This weighting technique was appropriately termed weighted exogenous sample maximum-likelihood (WESML) estimation. Manski and Lerman also presented a proof originally due to McFadden that for the multinomial logit model with a full set of alternative-specific constants, choice-based samples can be treated as exogenously drawn without affecting the statistical properties of any of the coefficients except the constants; moreover, the constants can be consistently estimated by a simple correction to the exogenously estimated constants if one knows a priori the shares in the population choosing each of the alternatives.

Manski and McFadden (75) developed a number of estimation methods for what they term general-stratified samples, a very general class of sampling techniques that encompasses exogenous samples, choice-based samples, and various possible hybrid methods. Their work also considers how different forms of a priori information (such as knowledge of the distribution of exogenous variables and the population shares choosing the alternatives) can be used directly to increase the efficiency of parameter estimates.

A more recent contribution to this literature is that due to Cosslett (76). He extends the range of sampling strategies considered to include cases where choice-based and exogenously drawn samples are pooled (to form what he terms enriched samples) and where a usual sample is augmented by data that provide information about the distribution of attributes in the sample but not the observed choices (to form what he terms supplemental samples). Cosslett has also succeeded in unifying some of the earlier work by showing that the special results for the use of choice-based samples in the logit models not only yield consistent estimates but also provide asymptotically efficient parameters. Moreover, he has demonstrated the further property of the logit model that enriched samples can, for the purposes of estimation, be treated as exogenously drawn as long as the model has a full set of alternative-specific constants.

Lerman and Gonzalez (77) have analyzed a special class of endogenous sampling methods appropriate for the analysis of cases in which the choices take on integer values. Their specific example is where trip generation is represented as a Poisson process in which the mean is a function of attributes of the individual and the transportation system and the data are drawn so that the probability that any given individual appears in the sample is a linear function of the number of trips the individual made. They term this a proportionate endogenous sample (PES) and derive an extremely simple estimator for the case of Poisson-distributed dependent variables. Their work was generalized by Litinas and others (49) and by Lerman (78) to include cases where both the underlying process is not Poisson and the sample is drawn so that the probability of an observation is a general, not necessarily linear function of the dependent variable. Lerman's work also allows for the possibility that the function describing the sampling likelihood itself contains unknown parameters to be estimated.

It is important to note that although there is now a rich theoretical literature on how one can use data drawn by a host of sampling strategies to estimate discrete-choice models, many of the resulting methods have never been implemented. There is good reason to believe that for many of the estimation methods, major computational difficulties will be encountered as researchers attempt to write practical computer codes. For this reason, most of the empirical work with endogenous samples has relied on the tremendous simplifications that result when the underlying model is assumed to be multinomial logit. In cases where other model forms have been used, the less efficient but computationally convenient WESML estimator has been used (79).

Statistical Tests

A second major area in which substantial progress has been made is the development of statistical tests that help diagnose failures of assumptions made in specific model form. This work has focused intensively on methods to test the validity of the multinomial logit model. McFadden, Tye, and Train (80) proposed a large number of tests in which the multinomial logit assumptions (particularly the property of independence of irrelevant alternatives) was treated as the null hypothesis. These various statistical methods were unfortunately often somewhat ad hoc, and serious questions were raised about the power of many of them. More recently, Horowitz (81) derived a form of Lagrange multiplier test in which a probit model with independent and identically distributed disturbances serves as an approximation to the null hypothesis of a logit model and the full spectrum of possible non-IID multinomial probit models is the alternative hypothesis. Although this method requires some reprogramming of existing software to obtain the test statistic's value, the added computational burden is quite small.

The most recent IIA test was derived by McFadden and Hausman as a special case of a powerful class of specification tests developed by Hausman (82). This test requires that the analyst reestimate a model by omitting one or more of the alternatives (as well as all the observations choosing the omitted alternative and the coefficients that cannot be estimated without data on the omitted alternative). The test statistic, which is chi-squared distributed, can then be computed solely as a quadratic function of the estimated parameters from the model estimated from the full and the restricted choice sets and the variance-covariance matrices of these two-parameter estimates. Analysis of the power of this test by McFadden suggests that this simple method is quite powerful, and recent empirical work has tended to use the method with increasing frequency.

Another distinct area of statistical tests has been developed by Horowitz (83). He notes that virtually all the tests developed and applied to data require that the null hypothesis be a restricted form of the alternative hypothesis. This had made it impossible to test whether different models were statistically better or worse than others unless one of them could be written as a restricted version of others. Horowitz's results testing a number of statistics indicates that one of the simplest, most widely used statistics for maximum-likelihood estimation, called the rho-squared statistic (39), when appropriately corrected for degrees of freedom is the basis for an extremely powerful test of nonnested hypotheses.

Robust Estimation

As noted above, most of the available estimation methods are based on either maximum-likelihood procedures or some variant that uses either a partial likelihood or what might, in the case of the WESML method, be appropriately termed quasilikelihood. Although maximum likelihood has the general advantage of being computationally tractable for many specific cases and can be shown to yield consistent and asymptotically efficient estimators for a very broad class of combinations of model form and sampling strategy, it has the distinct disadvantage of requiring that the distribution of observations be known as a finite vector of unknown parameters. Moreover, there is no reason to believe that maximum-likelihood methods are particularly robust with respect to either measurement errors or failures of the assumptions of the models to which they are applied. I and others have made simple numerical experiments that in fact suggest that for certain types of errors, maximum likelihood can in fact produce estimates that are extremely sensitive to just a few erroneous observations. (These cases are characterized by the miscoding of the observed choice, so that a few of the alternatives chosen in the sample have very low choice probabilities when evaluated at the true parameters.) Somewhat less empirical sensitivity has been shown for special cases in which the logit model is used even though the disturbances are not independent or homoskedastic. These experiments, reported by Horowitz (84), suggest that maximum likelihood is empirically (though not theoretically) robust to certain types of specification errors but sensitive to others.

Given the potential difficulties in using maximum-likelihood-based methods, there have been attempts to construct estimators that are more robust, i.e., that require less stringent assumptions yet still provide estimates with desirable statistical properties. Manski's maximum score estimator (85) is perhaps the first example of such a technique. In this method, the exact distribution of the disturbances need not be known; all that is required is that they have a set of general properties. This method results in consistent, though not fully efficient, estimates. More recently, Cosslett (86) has been exploring still more robust estimates for the case of binary discrete-choice models. His only key restriction is that the choice function be monotonic in the difference in the systematic utilities of the two alternatives. [As an interesting aside, Ben-Akiva and Lerman (87) present an example of a probit model that allows random taste variations in which this monotonicity property is violated.]

FORECASTING

The last area explored in this review covers the entire process through which a particular estimated model is used as part of a transportation systems analysis to make forecasts that are, it is hoped, of some use in assisting the parties involved in transportation decisions in making better choices among alternative policies. This area has received very little rigorous, theoretical treatment; in fact, many travel demand researchers have tended to treat the model rather than the uses to which it is put as the goal of demand analysis. This limited view may be acceptable in certain instances, such as when the objective is estimates of an individual's willingness to pay for the attributes of a transportation service (as in the value of time studies that were conducted both in the United States and abroad during the interval of large-scale cost-benefit analyses). It is, however, far too narrow a view for the entire profession to adopt. In this section, I attempt to summarize the research results in this broad field, with particular emphasis on recent advances made in equilibrating demand forecasts with other models of the transportation system.

Aggregation Across Alternatives

The one area of forecasting that has been heavily emphasized in the demand research community has been how models of individual behavior can be aggregated to obtain useful forecasts of population tripmaking. This problem arises because most of the disaggregate models are nonlinear in attributes that vary across the population; merely substituting the means of the population attributes into the model estimated for a sample of individuals produces incorrect aggregate forecasts; in some instances, the resulting errors can be substantial.

The most comprehensive study of this problem is that by Koppelman (88), who divides possible procedures for aggregating across individuals into five categories.

1. Naive procedure: The analyst simply ignores the problem and hopes for the best. This works well if the population being studied is relatively homogeneous in their choice of relevant attributes and if the model is nearly linear in the area where most of the population falls.
2. Classification: The population is first divided into mutually exclusive, collectively exhaustive groups, and the naive procedure is applied within each group. The resulting group forecasts are then summed to contain the forecast for the entire population. The classification procedure works extremely well as long as the groups are chosen intelligently (i.e., so that within each group, the conditions for the accuracy of the naive procedure are approximated). The empirical evidence suggests that one can work with relatively few groups as long as the set of travel alternatives is the same within each group.
3. Statistical differentials: A Taylor-series expansion of the disaggregate model is used. Unfortunately, even though the expansion for the individual model may be accurate, when the series expansion is then used to aggregate across the population, the resulting forecasts can still have serious errors. This method is therefore not used in practice.
4. Explicit integration: If one assumes that the distribution of the attributes can be reasonably approximated by some tractable, known probability density function, there are certain instances in which a closed-form solution for the aggregation across individuals can be derived. Unfortunately, the combinations of model form and distribution of attributes that work out are quite small, making the available explicit integration methods of little practical use to date.
5. Sample enumeration: A sample from the population (appropriately weighted to reflect how it was drawn) is used to represent the complete distribution of the attribute within the entire population. Forecasts for the sample are summed (by using the sample weights), and the resulting estimate is used as the aggregate forecast. This method works well if the values to be forecast are for large population groups that are reasonably well represented in the available samples. It is inappropriate for forecasting values such as origin-destination modal splits, where the number of separate population groups for which forecasts must be obtained may greatly exceed the size of the sample.

As a summary note, it is worth mentioning that the problem of aggregation across individuals is viewed by most as largely solved. By this, I mean that the available techniques reduce the error associated with aggregating across individuals to levels that are sufficiently small so that research efforts are better directed toward other modeling problems. Very little new research has been done since Koppelman's comprehensive study, and few analysts are deeply concerned with the issue.

Network Analysis

Because the early work in the field on network equilibration was derived under the assumptions that total demand was known and inelastic with respect to level-of-service attributes, much of the research on equilibration was outside the travel demand field. These historical antecedents produced a separation of the two fields of research even after the relatively strong assumptions on demand were relaxed. As this point, significant progress has been made in establishing both the conditions for network equilibration and computationally practical algorithms for solving for equilibrium.

The early work in this area is derived from an hypothesis proposed by Wardrop (89). He postulated what is essentially a deterministic path-choice model; his rule for establishing an equilibrium in traffic networks was that one should always choose the path with the least time in a network and that all paths with travel times greater than the minimum available will never be chosen. This rule is the basis for a class of powerful computational algorithms in which the conditions for network equilibrium are achieved at a set of link volumes that maximize a convex, nonlinear program (90).

Extensions of this basic approach allowed for the use of origin-destination demand functions that were elastic with respect to level of service (91); however, these models still required the use of a deterministic rule for individuals' choice of path through the network. Other extensions allowed for multimodal networks, including the possibility that links in the network served more than a single mode (e.g., instances in which a street is used for both buses and private automobiles).

From the perspective of travel demand analysis, the more relevant work in this area is what has come to be termed stochastic user equilibrium. Basically, this work assumes that the choice of path through a network is explained by some known choice model, in which each path meeting some criterion is a feasible choice. Dial (92) developed the first computationally efficient algorithms for solving for such equilibria under the assumption of fixed link times and costs. More recently, there has been a rapidly expanding literature that includes the use of probit models for path choice (93,94). This class of models typically requires some restrictions on the choice models (particularly the restriction that there is no taste variation) but has led to some important proofs of the existence and uniqueness of equilibrium and to some efficient computational algorithms.

Nonnetwork Equilibration

In addition to the large body of work on establishing equilibrium in networks, there have been a few efforts at developing model systems outside the network context in which one or more attributes of the demand models are endogenous. Manski and Sherman (95,96) developed a model of the U.S. automobile market in which equilibrium in any given model year depends on a vector of endogenously determined prices for used cars. In the model, the market for each make, model, and year combination is a function of the prices for that automobile class; although new-car prices are assumed to be set exogenously by the manufacturers, used-car prices (and scrappage rates) are determined in a equilibrium framework.

A more general, theoretical treatment of this problem is given by Sheffi (97), who applies much of the methodology originally developed in the network context to equilibration without networks. He demonstrates that the equilibrium conditions can be formulated as a fixed-point problem and that there exists a convex, nonlinear program that, when solved, yields a solution to the fixed-point equations.

CONCLUSION

As discussed in the introduction, no review paper can be entirely comprehensive. In this work, I have focused my attention on what I believe to be the most important developments in the state of the art in mathematical modeling of travel demand.

The state of the art has moved quite rapidly in certain aspects and quite slowly in others. In my view, the progress has been greatest in the fields of estimation methods and model structure. At this time, the theory in these areas is quite rich, and most of the new developments are coming from non-transportation research. Although it is difficult to project how quickly new developments of relevance to travel demand analysis will occur, there is an often-voiced suspicion by many in this field that further revolutionary results such as the early developments in discrete-choice theory and the use of alternative sampling strategies are not particularly likely. It is more probable that we will see a period in which many of the theoretical achievements in previous years will be translated into operational tools. For example, it is likely that practical estimation codes for the use of different model structures and samples will become widely available, significantly reducing the costs of travel demand analyses.

In contrast to the rapid progress made in estimation and model structure, there has been very little shift in the state of what I have called behavioral theory. In part, this is probably due to the fact that travel behavior is extraordinarily complex and is therefore difficult to model. However, as discussed in the section on model structure, it is also attributable to the low emphasis the profession and funding sources have placed on this area.

The progress in measurement has been somewhat mixed. Certainly major contributions in the areas of sample strategies and optimal sample design have been made. However, there are still a vast array of psychometric measurement methods that we still do not know how to effectively integrate into the mainstream of the analysis of revealed-preference data. Given the potential benefits of being able to use data on actual and hypothetical choices within a single model structure that accounts for the underlying processes by which these types of data are generated, further research in this area would appear to have extremely high potential payoff.

In the area of forecasting, it is probably safe to argue that the problem of aggregating demand models across individuals is probably a major concern. However, there is a need to better draw together the work on equilibration with the mainstream of travel demand research. In particular, the questions regarding which of the assumptions now implicit in existing equilibrium formulations can and should be relaxed so that new demand model structures can be incorporated in more complete model systems remain open. For example, travel demand models typically include variables in which level-of-service attributes (e.g., time and cost) interact with socioeconomic attributes (e.g., income). In such cases, the contribution of link times and costs to the total utility of a given travel route through a network will vary across the population; in a sense, each traveler from a given origin to a given destination faces a different set of link times and costs depending on their individual attributes. Such situations are not represented in most of the equilibration techniques that have been developed to date.

As a final note, there remain serious questions regarding whether travel demand analysis as a field has lost much of the momentum that characterized it in the 1970s. These concerns arise from both the research community, where progress in the areas of model structure and estimation appears to be increasingly at the fringe of what is potentially applicable in the near term, and from the users of new methods who find recent results increasingly arcane. As a personal view, I believe that to some extent both views are justified, but both views miss a more central point. Research into model structure and estimation is only a small part of what constitutes travel demand analysis, and major innovations outside this area are not only possible but quite likely.

In order to perform this research, a continued commitment by funding agencies will be required. Obtaining this commitment will require that the research community better explain the value of the contributions of the research to date and better articulate the potential payoff of future research and development activities.

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Evaluation of Discrete-Choice Random-Utility Models as Practical Tools of Transportation Systems Analysis

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Travel decisions frequently entail choices among discrete sets of alternatives, such as frequencies, destinations, modes, and routes of travel, and a large proportion of travel behavior research and practical travel demand analysis is oriented toward predicting the outcomes of such choices. A convenient behavioral and mathematical framework for modeling these choices is provided by a class of mathematical models called discrete-choice random-utility models. These models are based on the assumption that an individual's preferences among the available alternatives can be described with a utility function and that the individual selects the alternative with the greatest utility. The utility of an alternative is represented as the sum of two components: a deterministic component that accounts for systematic effects of observed factors that influence choice and a random component that accounts for the effects of unobserved factors. The random-utility model then predicts the probability that a randomly selected individual with given values of the observed factors will choose a particular alternative (i.e., the probability that the utility of the particular alternative is greater than the utilities of all other alternatives). The multinomial logit (1,2), multinomial probit (3-5), and generalized-extreme-value (6,7) models are three well-known examples of discrete-choice random-utility models. [See the work of Domencich and McFadden (1) and Hensher and Johnson (8) for discussions of the behavioral foundations of these models in the context of travel analysis.]

Many of the fundamental concepts of random-utility modeling have been known for more than 50 years (9), and some of these concepts were used in travel demand analysis as early as 1962 (10). However, the development of random-utility modeling as a practical analytic technique did not begin until the late 1960s, and random-utility models were not brought forcefully to the attention of the transportation community until the early 1970s. It was argued then that random-utility models had several important theoretical and practical advantages over other available travel demand modeling approaches such as the well-known four-step process. The main advantages claimed for random-utility models were as follows:

1. They are based on an explicit principle of human behavior, whereas other available models are not;
2. They can treat a wider range of travel choices, interactions among travel choices, and policy variables than can other available models; and
3. They make more efficient use of data than do other available models.

It was argued that these advantages enable random-utility models to forecast travel demand more accurately and less expensively than do other models.

Since the early 1970s, there has been much research on theory and methods of random-utility modeling, and random-utility models have been used in a wide variety of practical travel demand analyses. As a result, the random-utility approach to travel demand modeling is understood much better now than it was 10 years ago. The purpose of this paper is to review current knowledge of random-utility modeling that affects practical travel demand analysis and to identify the implications of this knowledge for practice. Three broad questions related to this objective are addressed:

1. Do the initially claimed advantages of random-utility models still appear to be advantages and, if so, to what extent are these advantages being exploited in practice?
2. What additional issues affecting the use of random-utility models have arisen since the early 1970s, and what are their implications for practical travel demand analysis?
3. What important problems concerning the practical application of random-utility models remain unsolved?

The remainder of the paper is organized as follows. The next section reviews the main concepts underlying random-utility models and summarizes the methods normally used for developing empirical models; this section provides a basis for the subsequent discussion. The third section evaluates the initially claimed advantages of random-utility models, and the fourth discusses additional issues that have arisen during the subsequent 10 years. Concluding comments are also presented.

BASIC CONCEPTS AND METHODS

Let an individual face a set of J mutually exclusive alternatives, one of which must be chosen. Let C denote the set of all available alternatives, and for each $j \epsilon C$ let $\underline{Z}_j$ denote the vector of attributes of the individual and alternative j relevant to choice among the alternatives in C. The fundamental premise of random-utility modeling (as well as of many of other models of human behavior) is that there exists a function U of the attributes with the property that for any two distinct alternatives i and j in C, $U(\underline{Z}_j) > U(\underline{Z}_i)$ if and only if the individual prefers j to i. U is called a utility function.

It is generally recognized that the attributes of individuals and alternatives that are relevant to choices among travel options are not all known to analysts and that it is usually not feasible to observe (or measure) the values of all the known attributes. In random-utility models, this inherent uncertainty as to the identities and values of a potentially large set of attributes is dealt with by dividing the utility function into deterministic and random components. The deterministic component is a function of the observed attributes of individuals and alternatives and accounts for the systematic effects of these attributes on choice. The random component accounts for the effects of the unobserved attributes. Mathematically, the utility U_j of an alternative j is written as follows:

$$U_j = V(\underline{X}_j, \underline{\theta}) + \epsilon j(\underline{X}_j, \underline{\theta}) \tag{1}$$

where

- $\underline{X}_j$ = vector of observed attributes of the individual and alternative j,
- $\underline{\theta}$ = vector of constant parameters,
- V = deterministic function, and
- ϵ_j = random variable.

The notation $\epsilon_j(\underline{X}_j, \underline{\theta})$ signifies that the probability distribution of ϵ_j may depend on $\underline{X}_j$ and $\underline{\theta}$. In typical transportation applications, observed attributes of individuals might include income, automobile ownership, and household size. Unobserved attributes might include health, social status (except as indicated by income), occupation, and schedule commitments that affect travel choices. Observed attributes of alternatives typically include travel times and costs and, if the alternatives are locations, employment and population levels. Unobserved attributes of alternatives usually include reliability and comfort if the alternatives are modes and prices, quality, and variety of available goods and services (except as indicated by employment and population levels) if the alternatives are locations.

An individual chooses alternative $j \epsilon C$ if $U_j > U_i$ for all $i \epsilon C$ such that $i = j$ (i.e., if j is preferred to all other available alternatives). In random-utility models, choice cannot be predicted deterministically because the utilities are random (or, more fundamentally, because of the dependence of the utilities on unobserved attributes of individuals and alternatives). Rather, random-utility models give the probabilities that each of the available alternatives is chosen. Let $\underline{X}$ denote the matrix $(\underline{X}_1,\ldots,\underline{X}_j)$. Then the probability that a randomly selected individual chooses alternative j ϵ C is

$$P(j|\underline{X}, \underline{\theta}, C) = \Pr(U_j > U_i \text{ for all } i \epsilon C, i \neq j) \tag{2}$$

or

$$P(j|\underline{X}, \underline{\theta}, C) = \Pr[V(\underline{X}_j, \underline{\theta}) + \epsilon j > V(\underline{X}_i, \theta) + \epsilon i \text{ for all } i \epsilon C, i \neq j] \tag{3}$$

An explicit functional relation between the choice probabilities and the deterministic components of utility can be obtained if the probability distributions of the random-utility components are known or assumed. The simplest assumption that leads to useful models is that the random variables ϵ_i $(i = 1,2,\ldots,J)$ are independently and identically distributed (IID) with the following distribution function (the Gumbel Type I extreme-value distribution):

$$F(\epsilon) = \exp[-\exp(-\epsilon)] \tag{4}$$

The choice probabilities are then related to the deterministic components of utility through the well-known multinomial logit model:

$$P(j|\underline{X}, \underline{\theta}, C) = \exp[V(\underline{X}_j, \underline{\theta})] / \sum_{i \epsilon C} \exp[V(\underline{X}_i, \underline{\theta})] \tag{5}$$

Other distributional assumptions that yield useful choice models are that the ϵ's are multivariate normally distributed, thereby leading to the multinomial probit model (3-5), and that the ϵ's have a generalized extreme value (GEV) distribution, thereby leading to the GEV model (6,7). The sequential or nested logit model can be obtained as a special case of the GEV model by choosing appropriate values of the parameters of the GEV distribution.

The values of the constant parameters $\underline{\theta}$ rarely are known a priori in practice. They must be estimated by fitting the model to data consisting of observations of the choices and values of the attributes (or explanatory variables) for a random sample of individuals. The method of maximum likelihood usually is used for this purpose. [Discussions of the technical aspects of maximum-likelihood estimation of random-utility models may be found elsewhere (2,3,7,11).]

If the estimation data set contains observations of large numbers of independent choices corresponding to each set of values of the explanatory variables (i.e., independent repetitions of the observations), it is possible to use regression techniques to estimate the values of the parameters $\underline{\theta}$. The Berkson-Theil method for logit models (1,2, 12) is a well-known example of this estimation technique. Berkson-Theil and other regression-based estimation methods usually cannot be used when the estimation data consist of observations of real choices among real travel options since the necessary repetitions of observations rarely are available. However, the methods can be useful when the data are generated by design in laboratory environments, where repetitions can be incorporated into the experimental design, simulated by asking respondents to indicate the percentages of the time they would make various choices, or avoided entirely by asking respondents to assign cardinal rankings to their preferences among the alternatives. [See the paper by Louviere and others (13) for examples of the use of the BerksonTheil method to estimate logit mode-choice models from laboratory-generated data.]

Regardless of the estimation technique used, the computations associated with parameter estimation are simplified greatly when the deterministic component of the utility function is linear in the parameters, i.e., when

$$V(\underline{X}_j, \underline{\theta}) = \underline{\theta}' \underline{f}(\underline{X}_j) \tag{6}$$

where $\underline{f}$ is a known, vector-valued function. Accordingly, most practical applications of random-utility models are based on the assumption that V has this form. Note that linearity in parameters does not imply linearity in the explanatory variables $\underline{X}_j$ since the components of $\underline{f}$ can be, and in practice often are, nonlinear. There is no behavioral justification for the linearity-in-parameter assumption, but the assumption can be justified mathematically by the observation that any function satisfying certain broad regularity conditions can be approximated arbitrarily well by a polynomial, which is a linear-in-parameter form. In principle, this observation implies that only linear-in-parameter forms need to be considered in developing specifications for the utility functions of random-utility models. However, in practice an inconveniently large number of polynomial terms may be needed to achieve satisfactory approximations to functional forms that psychological theory or other considerations may suggest are useful. Accordingly, the specifications of the function $\underline{f}$ that are used in practice often include nonpolynomial components (e.g., logarithms or quotients of explanatory variables). There also are situations in which theoretical or empirical considerations may suggest the desirability of using nonlinear-in-parameter utility functions. Although parameter estimation with nonlinear-in-parameter utility functions is more difficult than parameter estimation in the linear-in-parameter case, it is by no means impossible. [For examples of random-utility models with nonlinear-in-parameter utility functions, see studies by Lerman and Louviere (14), Daly (15), and Koppelman (16).]

INITIALLY CLAIMED ADVANTAGES

Behavioral Basis

If there were convincing empirical evidence that the utility-maximization principle provides a correct description of travel behavior, random-utility models clearly would be superior to other models in both theoretical and practical terms. The use of other models would be justified, if at all, only if they were good approximations to random-utility models. Unfortunately, there is no empirical evidence either for or against the validity of utility maximization as a principle of travel behavior. It is worth noting, however, that in certain situations not related to travel it has been found empirically that some individuals' preferences are intransitive and therefore inconsistent with utility maximization (17,18). Although this finding has no immediate application to travel analysis, it does demonstrate that the utility-maximization principle is neither tautological nor unchallengeable, and it suggests the possibility that the principle may be testable empirically in travel-related contexts.

Since there is at present no empirical evidence concerning the validity of utility maximization as a principle of travel behavior, it is necessary to find other grounds for evaluating the principle as a basis for travel demand analysis. One possibility is to examine its intuitive plausibility. Some investigators have suggested that utility maximization lacks plausibility for reasons such as the following:

1. Utility maximization seems to preclude noncompensatory decision rules, although such decision rules may be used in some circumstances. For example, an individual may refuse to use a mode that is perceived as being unsafe, regardless of how attractive the mode is in other respects.
2. Utility maximization seems to ignore the possibility that some individuals' travel decisions may be constrained by schedule commitments or other factors, thereby precluding choice of certain seemingly attractive alternatives.
3. The utility-maximization principle seems to imply that individuals have knowledge of and evaluate all alternatives independently and simultaneously. However, in cases where there are large numbers of alternatives, some may be unknown to any given individual and others may be evaluated by using a sequential decisionmaking process. Sequential processes also may be used if the alternatives are perceived as belonging to groups such that the members of each group are similar to one another and the members of different groups are dissimilar.

Although these criticisms usually are directed at random-utility models as a whole, they are more appropriately applied to the particular forms of models that are in current use. It is not difficult to construct random-utility models that incorporate noncompensatory decision rules [e.g., the elimination-by-aspects model (19-21)]. Lack of knowledge of alternatives and constraints precluding the choice of certain alternatives can be dealt with by excluding unknown or precluded alternatives from an individual's choice set. Simple models of choice-set generation have been proposed by several investigators (22-24), and additional research may make it possible to relate choice sets to observed attributes of individuals and alternatives. [See paper by Landau, Prashkar, and Alpern (25) for some initial efforts in this area.] Finally, the elimination-by-aspects and sequential logit models are examples of sequential decision models that are consistent with utility maximization. With the exception of the sequential logit model, which is used relatively frequently (7,26), these variants of random-utility models have not entered practice, and most require further developmental work before they will be ready for practical application. Until this developmental work occurs, it will not be possible for practical random-utility models to exploit the ability of the utility-maximization principle to accommodate a wide variety of seemingly different and, in some circumstances, highly plausible behavioral principles and decision processes.

If utility maximization is a correct or approximately correct principle of travel behavior, one might hope that its use would bring certain practical benefits in addition to increased realism and accuracy of models. Examples of such benefits are

1. Guidance regarding the correct functional specifications of travel-demand models,
2. Transferability of models among geographical areas, and
3. Ability to forecast demand for alternatives not present in the estimation data set (e.g., new modes).

With regard to the first of these benefits, adherence to the utility-maximization principle does not prevent models from being misspecified. (Specification errors in random-utility models are discussed in greater detail in a later section of this paper.) However, the principle provides modest guidance on specification by excluding models that are clearly inconsistent with it (e.g., models that permit intransitive preferences). Depending on the tastes of the analyst, models whose consistency with utility maximization is questionable (e.g., sequential logit models in which the coefficient of the inclusive price term lies outside of the interval [0, 1]) also may be excluded. In addition, the utility-maximization principle provides analysts with a useful conceptual framework for thinking about how models should be specified.

The situation regarding geographical transferability and predicting demand for new alternatives is less encouraging. Among the few reported investigations of geographical transferability, two resulted in acceptance of the hypothesis that the models being considered could be transferred without changing their functional specifications or the values of their utility function coefficients (27,28). However, most investigations have resulted in rejection of the hypothesis of geographical transferability (29-32). In addition, the two available empirical studies of the ability of random-utility models to predict the demand for a new mode (both of which used the same data) suggest that at present such predictions cannot be made reliably (29,33).

There are many possible reasons for the failure of random-utility models to be transferable among geographical areas or to give reliable predictions of demand for new modes (34,35). Three particularly likely ones are as follows:

1. The probability distributions of the random components of models' utility functions may be different in different geographical areas.
2. Knowledge of the distributions of the random-utility components for existing modes may provide little information on the distribution of the random-utility component for a new mode, making it necessary to guess (perhaps erroneously) the new distribution.
3. Errors in measurements of explanatory variables (especially level-of-service variables) and the use of zonal aggregate or proxy variables (e.g., to represent the attractiveness of alternative destinations) may bias models in ways that differ among geographical areas and modes (31,33).

The first of these reasons may explain the observation that a model's geographical transferability sometimes can be improved greatly by using data from the new area to reestimate the values of any alternative-specific constants in the utility function (32). Reestimation of alternative-specific constants is equivalent to reestimating the means of the distributions of the random components of utility. Further improvements in geographical transferability may be achievable by using the data from the new area to rescale the remaining utility function coefficients (36). This is equivalent to reestimating the variances of the distributions of the random-utility components. Koppelman and Wilmot (104) have reported promising results with this procedure. Since reestimating alternative-specific constants and rescaling other utility function coefficients requires a smaller analytic and computational effort than does development of a completely new model, reestimation and rescaling may provide a practical method for obtaining satisfactory models in geographical areas where development of new models is not feasible. However, additional research is needed to determine the types of models to which this procedure is likely to be applicable (e.g., work-trip mode choice, nonwork destination choice) and the extent of the improvements in transferability that can be achieved.

Range of Choices, Interactions, and Policy Variables That Can Be Treated

Travel and travel-related choices that have been treated with random-utility models include choices of mode (1,26,37-50,52,56,67), destination (1,28,31,37,43,45,48-50), travel frequency (1,28,31,40,47,48,50), multidestination travel or trip chaining (28,31,48-50,63), time of day of travel (1,44,51), residential location (52,53), retail location (i.e., a retail store owner's choice of where to locate) (54,55), number of automobiles owned (39,43,52,53,56), types of automobiles owned (57,59), and gap acceptance at intersections (60,62). Interactions among choices or joint choices that have been treated include mode and destination (37,40,43,45); mode, destination, and frequency (1,47); mode, destination, frequency, and trip chaining (48); destination and frequency (28); destination, frequency, and trip chaining (31); mode, destination, and trip chaining (49,50); automobile ownership and work-trip mode (39,56); residential location, automobile ownership, and work-trip mode (52,53); and work-trip mode and time of day of travel (44). Transportation policy variables that have been included in random-utility models include a wide variety of travel-time and cost components; various indicators of transit comfort, convenience, and reliability (44,51,64,67); carpool incentives (42,43,65,66); and households' gasoline allocations in a fuel-rationing program (68). (The foregoing reference citations are illustrative, not exhaustive. An exhaustive listing of transportation applications of random-utility models is beyond the scope of this paper.)

Many of the foregoing choices and some of the policy variables can be treated with models other than random-utility models. For example, the standard four-step travel demand modeling process treats choices of trip frequency, destination, and mode; and the destination and mode models used in the four-step process (and occasionally the trip-frequency model) normally include indicators of travel times and costs. However, no other class of models currently in use permits treatment of the variety and complexity of choices, interactions among choices, and policy variables that have been treated with random-utility models.

With the exception of mode-choice modeling, for which random-utility models now are widely used, most transportation applications of these models have been carried out by individuals who are either engaged mainly in research in travel behavior analysis or closely associated with such research. The ability of random-utility models to represent unusually broad ranges of travel choices and policies is not being exploited by wider applications in the community.

One aspect of travel demand analysis that has not yet been treated satisfactorily with random-utility models is equilibration of transportation system performance with such travel choices as frequency, destination, mode, and time of day of travel. Equilibration is important in practice because traffic engineering and other measures to improve transportation system performance may, through their effects on travel times and costs, induce significant changes in travel frequencies and the other choice dimensions. Because travel times and costs are determined jointly by the physical capabilities of transportation facilities and the choices of individual travelers, the effects of system improvement measures on travel times and costs cannot be determined independently of their effects on travel demand. This problem is difficult to treat with random-utility models for two reasons. First, depending on the models being used, it may be necessary to enumerate the routes between each origin and destination. This can be a task of substantial computational magnitude. Second, existing network-equilibration techniques operate with aggregate measures of travel demand (e.g., trip tables), whereas random-utility models produce disaggregate demand estimates. Although numerical procedures for aggregating random-utility models are well known (69), their use in connection with existing equilibration techniques entails substantial computational difficulty and expense. Analytic aggregation procedures are available for multinomial probit models (70), but the use of probit models is not feasible in many situations because of their complexity. When probit modeling is feasible, its use may help to reduce the computational magnitude of the equilibration problem. The use of probit models for equilibrating travel demand and transportation system performance has been discussed by Sheffi and Daganzo (71,72).

Efficiency of Data Use

Econometric estimation and forecasting with random-utility models typically require data sets containing observations on several hundred individuals compared with the several tens of thousands of observations that can be required by other modeling approaches. The ability of random-utility models to operate with relatively small data sets makes these models particularly well suited to small-area studies, studies involving observations of travel behavior in several different time periods, and other applications in which acquisition or manipulation of large data sets is not possible.

Depending on the circumstances, additional economies in data acquisition and use may be available through use of choice-based sampling and estimation techniques (73,77). In choice-based sampling, the observations are stratified on the choice variable. For example, the estimation data for a mode-choice model might be obtained from roadside interviews of automobile travelers and on-board surveys of transit users. In binary choice situations, choice-based sampling yields considerably greater estimation efficiency than does simple random sampling when one of the alternatives is chosen by less than 5-10 percent of the population (77). The relative efficiency of choice-based and simple random sampling when there are more than two alternatives and the relative efficiency of choice-based and exogenous stratified sampling (i.e., stratification on the explanatory variables and not the choice variable) have not yet been investigated. The relative costs of data acquisition through choice-based sampling and other methods also have not been investigated, although it seems certain that some choice-based methods (e.g., roadside and on-board surveys for acquisition of mode-choice data) are less costly than some conventional methods (e.g., home-interview surveys). Choice-based sampling and estimation methods are not yet being used in practice for the development of random-utility models, possibly because these methods are relatively new and their merits in comparison with conventional methods are not yet well understood.

Another method that has the potential for greatly improving the efficiency of data acquisition and use is the collection of data through designed-choice experiments. In these experiments, individuals are asked to choose among alternatives whose attributes are specified by design. The main advantage of this method is that since the alternatives and attribute values are controlled, the experiments can be designed to include alternatives that do not yet exist, span wide ranges of attribute values, and achieve high levels of estimation efficiency. An important issue that must be resolved before this method can be applied with confidence is the extent to which models developed from designed-choice experiments can be used to forecast real choices among real transportation options. [Examples of the use of designed-choice experiments for developing models of travel and travel-related choices are described elsewhere (13,14,78-83).]

ADDITIONAL ISSUES

Specification Errors and Specification Testing

Random-utility models, particularly logit models, are subject to a large number of specification errors. Errors that can arise in logit models include

1. Misspecification of the choice set;
2. Use of an incorrect functional form for the deterministic component of the utility function (this includes as a special case the use of an incorrect set of explanatory variables);
3. Correlated deterministic and random components of utility;
4. Random taste variation, i.e., the parameters of the deterministic component of the utility function are not the same for all individuals;
5. Nonidentically distributed random components of utility; and
6. Correlated random components of utility.

There have been several theoretical studies of the magnitude of the errors in forecasts of choice probabilities that can be caused by specification errors (23,84-86). Although it is risky to attempt to draw general conclusions from this limited group of studies, the results seem to suggest that errors 2, 3, and 4 above are particularly serious. These can cause errors of more than 100 percent in forecasts of choice probabilities and thus are clearly capable of destroying a model's practical value. The remaining errors appear to be less serious, although they too can impair a model's usefulness. Errors of up to 50 percent in forecasts of choice probabilities have been reported from these causes. The limited empirical evidence that is available seems to confirm that specification errors can cause forecasting errors of these magnitudes (5,87).

The variety and severity of specification errors that can occur in random-utility models make it important to carry out specification testing as part of the development of empirical models. One group of specification tests that is used routinely in practice consists of examining the signs, t-statistics, and possibly ratios of the estimated utility function parameters for consistency with a priori expectations. These tests have the virtue of being very easy to carry out, and they can be useful for ruling out models with clearly unreasonable properties. However, the tests lack power. Models with specification errors that cause large errors in the choice probabilities can have parameters with satisfactory signs, t-statistics, and ratios and therefore escape detection with these tests (88).

A more powerful class of specification tests consists of formal statistical comparisons of models with different specifications (88-92). Depending on the models being compared, these comparisons usually are carried out by means of likelihood-ratio tests, Lagrangian-multiplier tests, or the likelihood-ratio index goodness-of-fit statistic. The limited evidence that is available suggests that many of these tests have high probabilities of detecting incorrectly specified models when the resulting errors in the choice probabilities exceed 10-20 percent (86,88,92). Moreover, the computational effort involved in carrying out these tests is modest. However, the tests are not yet in widespread use, possibly owing to their newness, the statistical formalism associated with them, and the lack of generally available computer software for implementing them. [Examples of applications of specification tests based on formal statistical comparisons may be found elsewhere (5,28,29,31,33,51,89).]

The probability of identifying an erroneously specified model when it is compared with one or more alternative models depends on the specifications of the alternatives. Hence, it is possible that comparison tests may fail to identify a highly erroneous model due to inadequacy of the alternatives. In addition, comparison tests do not provide direct indications of the forecasting errors that would be caused by use of an erroneously specified model. The possibility of inadequate alternatives can be avoided and direct measures of forecasting accuracy obtained by comparing a model's forecasts of aggregate-choice shares with observations of these shares (93). This method of testing models has obvious intuitive appeal in addition to avoiding complicated statistical formalism, and these characteristics may account for its relatively widespread use. However, the method also has some important difficulties. One difficulty is that predicted and observed aggregate shares both are subject to random-sampling errors. Depending on the sample sizes used in parameter estimation and aggregation and the magnitudes of the true (but unknown) choice probabilities, the sampling errors may be very large. Although most of the statistical theory required to estimate the magnitudes of these errors exists, software for carrying out the necessary computations does not. Thus, in practice it can be difficult to determine whether differences between predictions and observations should be attributed to random-sampling errors or treated as evidence that the model in question is misspecified.

A more serious difficulty is that it is not clear what population groups should be used for computing aggregate shares. For example, the population might be grouped according to income, location of residence, trip length, or location of workplace, among other criteria. The choice of group affects the differences between predicted and observed aggregate shares and the magnitudes of the sampling errors in these differences, and it can cause the differences to be irrelevant to the question of whether a model is correctly specified. For example, suppose a model is estimated from observations on individuals living in the northern suburbs of a city and is tested by comparing predicted and observed aggregate-choice shares of individuals living in the southern suburbs. Then large differences between the predictions and observations would indicate that the model transfers poorly to the new (i.e., southern) population, assuming that the effects of random-sampling errors are known to be small, but would not necessarily imply that the model is erroneously specified relative to the population from which it was estimated. (Of course, knowledge that a model transfers poorly to a new population can be of great practical importance, depending on the intended applications of the model, even if it is irrelevant to the question of whether the model is correctly specified.)

Because of these difficulties, comparisons of predicted and observed aggregate shares do not now provide as firm a basis for identifying erroneously specified models as do formal statistical comparisons of alternative models. [Examples of applications of the method of comparing predicted and observed shares may be found elsewhere (27,30,32,65,66,87,93-95).]

Data Adequacy

Erroneous measurements of the explanatory variables are well-known causes of error in econometric models. In travel demand analysis this problem is particularly apparent in random-utility models, since these models typically include more explanatory variables than do other models.

There is evidence that the transportation level-of-service data contained in standard transportation data sets may be highly erroneous. These data typically are obtained from network models and represent, at best, average values for traffic zones. In an analysis of level-of-service data obtained in the San Francisco area, it was found that network-based data gave particularly poor estimates of the out-of-vehicle components of transit travel time (96). The network estimates were found to be biased, and the root-mean-square (RMS) differences between the observed and network values were comparable in magnitude to the mean observed values. The RMS errors in the network-based estimates of transit and automobile in-vehicle travel times varied from 25 to 50 percent of the mean observed values, depending on the mode.

Not surprisingly, erroneous measurements of level-of-service variables cause the estimated values of the parameters of travel demand models to be biased and can lead to highly erroneous forecasts (38,96). For example, in the analysis of the San Francisco data it was found that use of zonally averaged values of observed level-of-service data instead of network-based data reduced the error in a logit mode-choice model's prediction of Bay Area Rapid Transit (BART) patronage from 92 to 23 percent. The remaining 23 percent error is mainly the result of zonal averaging of the observations. Theoretical analyses have shown that zonal averaging of level-of-service or other explanatory variables can induce errors of roughly 100 percent in models' predictions of choice probabilities (85).

The large estimation and forecasting errors that can result from use of network-based level-of-service data suggest that in the future increased emphasis should be placed on measuring the values of level-of-service variables. The relatively small data sets required by random-utility models make this a considerably less onerous undertaking than it would be if data had to be obtained for a model requiring observations on tens of thousands of individuals.

Another aspect of conventional data sets that is deficient is their representation of locational attraction variables. These variables usually are limited to indicators of the population, employment, and geographical size of traffic zones. Population, employment, and size are, at best, crude proxies for the characteristics of locations travelers actually consider when making destination choices. Empirical evidence for the inadequacy of these variables, including the possibility that they may cause large errors in forecasts of destination choice, has been presented by several investigators (31,97,98). In the future, efforts should be made to acquire data on locational attributes more closely related to travelers' decision processes.

Simplified Methods

Although random-utility models usually are presented in a context of elaborate mathematics and large computer systems, they also are amenable to simplified applications. Useful estimates of the effects of transportation policy measures on aggregate choice shares, fuel consumption, emissions of air pollutants, and costs of transportation services, among other impact variables, often can be obtained by hand with the aid of a desk calculator (99-101). In addition, the small data sets required by random-utility models make it possible to carry out more elaborate computations, such as parameter estimation, on microcomputers. Software packages for performing these computations are likely to become generally available in the near future.

Interval Forecasts and Sensitivity Analysis

Most forecasts of travel demand are made in the form of point estimates with few or no quantitative indications of the potential magnitude of the errors that may be associated with them. However, it is generally agreed that these errors can be large and that it would be useful to have information on their potential magnitude.

There are three basic causes of error in travel demand forecasts:

1. Random-sampling errors that arise in the processes of parameter estimation and model aggregation,
2. Errors in forecasts of model's explanatory variables, and
3. Model-specification errors.

The effects of random-sampling errors on forecasts can be treated by using standard statistical methods, and confidence intervals for the forecasts can be obtained. Procedures for doing this have been described by several investigators (4,93,102,103). Many of these procedures require relatively modest computational resources. However, the mathematics associated with the procedures is relatively complex, the required computations usually cannot be performed by hand, and computer software for performing the computations is not generally available. Consequently, the procedures have been used only in a small number of illustrative applications (4,103). The results of these applications suggest that when logit models are estimated from data sets containing several hundred observations, the half-widths of the 95 percent confidence intervals for individual choice probabilities are roughly 15-30 percent of the estimated values of these probabilities. These results reflect only sampling errors in the values of the estimated parameters. Confidence intervals for aggregate shares, which also include sampling errors due to aggregation, are likely to be somewhat larger.

The errors in models' forecasts caused by erroneous forecasts of the explanatory variables and by specification errors can be considerably larger than those caused by random-sampling errors (85) but are, unfortunately, more difficult to evaluate. This is because there are no objective methods for estimating the magnitude of errors in forecasts of explanatory variables or model specification. Consequently, it is not possible to develop statistically meaningful confidence intervals for the effects of these errors. However, it is possible to evaluate the sensitivity of models' forecasts to judgmentally specified changes in the values of explanatory variables and specifications. The results of such sensitivity analyses provide qualitative indicators of the robustness of models' forecasts in the presence of errors in the values of explanatory variables and specifications.

There are two methods for carrying out sensitivity analyses of the effects of errors in forecasts of a model's explanatory variables. One method consists of varying the values of the explanatory variables singly or in groups over judgmentally determined ranges and observing the effects on the model's output variables. The other method consists of assuming a probability distribution over one or more explanatory variables and computing the resulting distributions of the outputs (4,93). The first method is simpler conceptually and easier to implement than the second, and it is used occasionally in practice. For example, travel demand forecasts sometimes are made for several different forecasts of a region's population or land use patterns. However, the first method can exaggerate the uncertainties in a model's output variables. For example, assigning all of the explanatory variables' values on the boundaries of their assumed ranges of uncertainty may produce large changes in the output variables, but it may be highly unlikely that the true (but unknown) errors in the values of the explanatory variables all would have their assumed maximum values simultaneously. The second method creates at least the appearance of avoiding this difficulty, since the assumed probability distributions of the explanatory variables can be specified so as to make the simultaneous occurrence of large errors in several variables unlikely. However, the results thus obtained depend on the assumed distributions and can be misleading if these distributions are not specified carefully.

To estimate the effects of specification errors on forecasts, it is necessary first to find a means of simulating these errors (i.e., of changing the model under consideration to represent the occurrence of specification errors). It is not clear at present how this can best be done, since the model adopted for use in forecasting presumably has the best of the specifications considered during the model development process. One possibility is to compute the range of forecasts resulting from the use of several differently specified models. This method may be particularly useful if it is possible to identify several models that fit the estimation data set roughly equally well but that give different forecasts of choice when the explanatory variables are assigned particular values of interest. However, the method may tend to exaggerate the consequences of specification error if the model adopted for use in forecasting provides a substantially better fit to the estimation data than do the other models used in the sensitivity analysis.

Another possible way of representing the effects of specification error is by varying the values of one or more parameters of the model in question. This method may be useful for estimating the effects of forecasting errors arising from random taste variations (assuming that this is not already accounted for in the model) or changes in individuals' tastes that may occur during the time period to which the forecast applies. It also may be useful in cases where a model's forecasts are determined mainly by a small set of parameters whose values are sensitive to specification. For example, the value of travelers' time implied by a model is likely to be sensitive to the specifications of the travel time and cost terms of the utility function. Thus, the effects of specification error on a forecast that depends mainly on the value of time might be investigated by varying the values of the parameters that determine the value of time.

[Examples of sensitivity analyses of the forecasts obtained from a set of random-utility models may be found elsewhere (68).]

CONCLUSIONS

The main advantages claimed for random-utility models in the early 1970s when these models were first brought to the attention of the general transportation community were their basis in an explicit behavioral principle, their ability to treat a wide range of travel choices and transportation policy options, and their ability to make efficient use of data. In retrospect, the behavioral basis of random-utility models and the practical benefits associated with it seem to have been exaggerated. The utility-maximization principle is clearly useful for model development, but its validity remains uncertain, and even if it is valid, it does not guarantee that models will be behavioral, causal, or free of potentially serious specification errors. The other initially claimed advantages of random-utility models appear to be real and, quite possibly, even more important now than they were 10 years ago. In a period of limited resources and increased demands for nontraditional outputs from the transportation analysis process, the flexibility and efficiency of random-utility models are particularly valuable attributes. However, they remain largely unexploited by practitioners.

Several relatively recent improvements in random-utility modeling will be ready for widespread practical application as soon as computer software for implementing them becomes available. Examples of these are specification tests based on statistical comparisons of differently specified models and procedures for developing statistical confidence intervals for forecasts. The availability of the necessary software would make random-utility models the only class of operational travel demand models with systematic, easy-to-use procedures for specification testing and error analysis. Another attribute of random-utility models that may be of considerable practical value is their adaptability for use in simplified analyses.

There also are a variety of unsolved problems affecting the practical application of random-utility models. These involve such matters as alternative decision processes, geographical transferability, prediction of demand for new alternatives, computational procedures for equilibrating travel demand and transportation system performance, and the relative merits of choice-based and exogenous sample designs, among others. Further research on these problems would be highly desirable and could significantly enhance the already substantial practical advantages of random-utility models.

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Research Needs

1. Dynamic aspects of travel behavior (adjustment time, daily variability of travel, and trends versus turning points)

2. Preference characteristics of the population

   a. Whether the preference intensity among alternatives is so great as to require that changes in service be very large to cause substantial behavior shifts
   b. Whether we can identify the attributes of services to which behavior is most sensitive

3. Application of model estimates in different contexts

4. Improvement of linkage with application programs

5. Incorporation of aggregate flow information in model-calibration process

6. Improvements in data measurement

7. Definition of confidence limits in prediction

Workshop on Long-Range and Strategic Forecasting Techniques

Workshop Summary

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Conferees at the Conference on Urban Transportation Planning in the 1980s (Airlie House, 1981) concluded that there will continue to be a need for systemwide transportation facilities planning. Long-range planning will be strategic rather than facilities oriented, and new methodologies may be required. The overall goal of this workshop was to identify travel-forecasting methods that could be applied to reach long-range planning solutions and to discuss the relationship between strategic and facilities planning methods.

More specifically, the issues relating to long-range and strategic planning identified in the initial context workshops were to be discussed in terms of the availability of methods to deal with the issues and research needed to close identified gaps between the state of the art and the state of the practice.

The papers presented by Creighton and Stuart were intended to spur discussion on the state of the art and the state of the practice. The discussion that followed covered a broad range of ideas and issues stimulated by the papers and the experience of those present. Although the discussion began within a rather broad framework of approaches to strategic and long-range planning, methods to accomplish this type of planning soon began to emerge.

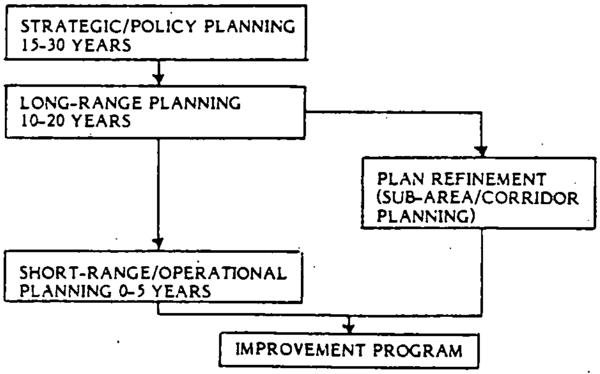
The many methods that were discussed were summarized and matched against a summary of the almost 30 issues from the context workshops that the participants felt were relevant to strategic and long-range planning. Through this matching process, a consensus was developed of which of the methods were relevant or useful in dealing with the issues and finally of which issue-method pairs contained gaps between art and practice. These issue-method pairs were grouped into logical research areas for later detailing by workshop participants. The issue-method matrix was carried back to the context workshops as a vehicle for further discussion on how to close the gaps between art and practice.

A constant theme that was woven throughout the workshop was how to communicate better with decisionmakers and within the planning community. Better information for decisionmakers and better technology sharing were consistently recognized as vital ingredients in effective strategic and long-range planning. This is perhaps more critical in these planning functions than in short-range and operations planning since the policymakers can relate better and have a greater interest in near-term alternative improvements.

A second major discussion centered on the definition of strategic planning and how it and long-range planning relate to each other and to other functional planning areas. Although no firm definition was developed, a consensus did evolve out of the experiences shared by the workshop attendees. The following provides a useful framework for relating the methods discussed in this workshop to the planning areas discussed in other workshops:

1. Strategic planning should identify preferable transportation improvement strategies or policies (e.g., low capital versus capital intensive, alternative service levels desired, capital and subsidy limitations) as an input to plan development.
2. Long-range planning should identify corridors or subareas that are deficient, identify priorities, and outline a range of feasible candidate improvements in those areas.
3. The long-range regional land use and transportation plan provides a background or framework for subsequent corridor or subarea-level refinement through such techniques as windowing or focusing.
4. The planning process provides base-year data, models, and relationships useful in corridor or subarea planning.
5. The long-range data base (e.g., land use forecasts, trip tables, modal splits) provides back-

Figure 1. Relationship of methods and planning areas.



ground input or can be used directly within the corridor or subarea.

6. The programming implementation and process depends on a project-level assessment of impacts and design detail that cannot be accomplished at the regional system level. The long-range plan will continually be modified through the subarea and corridor-level planning. Impacts of short-range actions on the long-range plan need to be assessed, since their implementation could change the need for, or extent of, the proposed improvements in the long-range plan.

Conceptually, the framework might look like that shown in Figure 1.

Initial discussion on methods culminated in four approaches to conducting strategic and long-range planning. These approaches, with important features of each that evolved from the discussions, are summarized below:

1. Traditional forecasting process: long-range plan as a product

2. Alternative scenarios

   a. Traditional long-range models
   b. Product is plan tested against range of alternative land use patterns and growth assumptions
   c. Process reflects need to input wide range of local interests
   d. High degree of communication with decisionmakers throughout
   e. Relatively high level of effort required

3. Sketch planning

   a. Some traditional methods used with variations--often manual rather than computerized
   b. Quick turnaround at lesser level of detail than traditional systems planning
   c. Provides flexibility for decisionmakers and analysts to ask what-if questions and screen out infeasible alternatives from further analysis
   d. Less detailed product, often range of alternatives requiring further analysis

4. Management planning

   a. Agency management
      (1) Internal to agency
      (2) Management strategies
      (3) Policy direction
      (4) Decision process, not plan
   b. Regional or statewide policy planning: output is typically broad set of policies to guide state's growth and development

These approaches to strategic and long-range planning served as a benchmark for the workshop discussion on methods. Within the context of the four planning approaches, a broad array of methods was developed. These were considered in terms of the relevant issues that came out of the context workshops.

Almost 30 issues were identified initially as having potential relevance to strategic and long-range planning. These issues were categorized into the four broad areas below:

1. Planning and forecasting process

   a. Uncertainty and reliability (this broad area includes issues related to the quality of input data, range of forecasts, and technology transfer among planners and staff)
      (1) Accuracy of forecasts, input data, etc.
      (2) How to incorporate uncertainty into planning process
      (3) Ability to anticipate change
         (a) Changes in trends and approaches to critical thresholds
         (b) Impact assessment and analysis of effects
   b. Communication with decisionmakers
      (1) Education--to assist decisionmakers in using planning output and evaluation of impacts of alternative actions
      (2) Understanding--to enhance decisionmakers' understanding of what planner is able to provide to assist in policy decisions

2. Forecasting products

   a. Equity and distribution of impacts
      (1) Who benefits and who loses from alternative improvements or transit service packages
      (2) Transit effectiveness in meeting social goals
      (3) Accessibility and mobility
      (4) Market segmentation for service development and impact assessment
   b. System effectiveness and efficiency
      (1) Monitoring--knowing what travel is taking place and what systems are in place--also whether there is improvement in trends over time
      (2) Evaluation of past assumptions
      (3) Feasibility of proposed projects (benefit/cost)

3. Ability to analyze current policy options

   a. User-side subsidies--impacts on transit patronage and revenues
   b. Demand response to service changes
   c. Technology
      (1) Upgrades to existing models
      (2) Better use of existing models
      (3) New models
   d. Impacts of deregulation on
      (1) Economy
      (2) Finance
      (3) New ridership market

4. External factors

   a. Economy
   b. Family life-style
   c. Resource allocation

These issues were matched with a list of 15 meth-

Table 1. Issue-method relationships.

Method	Issue 1a. Uncertainty	1b. Communication	2a. Equity	2b. Effectiveness	3. Policy Options	4. External Factors
Data and inventories						
Socioeconomic and demographic forecasts	⊕	⊕	⊕		+	⊕
Data-base management		⊕	⊕	+		+
Performance monitoring (system use, quality of service, pavement management)		⊕		⊕		
Planning process						
Traditional process (regional and subarea)	⊕	⊕	+	+	⊕	
Alternative scenarios	⊕	⊕	+	+	⊕	⊕
Sketch planning (system and corridor policy assessment and facility options)	⊕	⊕	+	+	⊕	
Policy planning						
Agency management and policy direction (internal efficiency)		⊕		+	+	+
Regional or statewide	+	⊕	+		+	+
Freight and goods movement						
Freight study (state)	+		+	+	⊕	⊕
Goods movement (urban)	+		+	+	⊕	⊕
Revenue forecasting	⊕	⊕	+		⊕	⊕
Impact assessment						
Short-range planning or project on long-range plan	+	⊕	+	+	+	
External	+	⊕	+	+	+	+
Behavioral and market segmentation						
Behavioral demand modeling (demand modification)	⊕	⊕	⊕		⊕	⊕
Market segmentation (socioeconomic, geographic, attitudinal)	⊕	⊕	⊕		+	⊕

ods that evolved from the workshop discussion. The result was the matrix shown in Table 1. The plus sign indicates those methods that the workshop participants felt were relevant or useful in dealing with the general categories of issues. The circled plus sign indicates the issue-method pairs where research is needed to close the gap between art and practice.

Seven general areas of research needs were carved out of the more than 30 issue-method pairs that were identified as needing work to close the art-practice gap. In many of these cases it was felt that the methodology existed but that there was a great need to transfer the information and make it known to the practitioners through applications research or synthesis studies. The general research areas needed with the relevant issue-method pairs are shown below (numbers in parentheses in Issue column refer to list of issues above and in Table 1):

Issue	Method
Dealing with uncertainty and communicating uncertainty to decisionmakers (1a, 1b)	Socioeconomic and demographic forecasts and planning process
Ability to analyze alternative policy options (3) under uncertainty (1a) and the impact of external factors (4)	Revenue forecasting
Uncertainty and reliability (1a), equity and distribution impacts (2a), policy options (3), and external factors (4)	Behavioral demand modeling and market segmentation
Dealing with uncertainty in travel-forecasting process (1a)	Socioeconomic and demographic forecasts, planning process
Better use of existing communication procedures (1b)	All methods as appropriate
Ability to deal with policy options (3) and external factors (4)	Freight study and goods movement
Equity and distributional impacts of accessibility and market segmentation (2a)	Socioeconomic forecasts and data-base management

Long-Range Strategic Planning and Forecasting Techniques: The State of the Art

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The charge of this paper is to discuss methods and techniques for long-range strategic planning and forecasting--methods and techniques that are at the frontier of current knowledge and that will give us clues to the direction in which transportation planning will proceed in the future.

At the Conference on Urban Transportation Planning in the 1980s, held at Airlie House in 1981, it was declared that there would continue to be a need for systemwide transportation facilities planning. That need stems first from the long lead times that it takes to plan and build new transportation facilities but also from the need to have a sound framework within which short-range project plans can be evaluated.

However, in the program for this conference, this workshop was asked to be strategic rather than facilities oriented, and hence it seemed reasonable to downplay the idea of systems. We shall not get totally away from systems, however, because some strategic-planning techniques are inherently systems oriented and because we have also been asked to look at the relationships between strategic and facilities planning methods--in effect, to build linkages between the two activities.

In this paper I will concentrate on strategic planning and forecasting at the state level. Darwin Stuart, in the companion paper on the state of the practice, concentrates on planning at the regional and metropolitan levels.

As we go up the scale into longer time frames and become concerned with larger regions (both of these are essential characteristics of strategy as opposed to tactics), travel behavior becomes of interest primarily as an aggregate phenomenon. In effect, we must focus not on individual trips or origin-destination patterns or temporal patterns, but on vehicle miles of travel, person miles of travel by public transportation, and ton miles of freight. In strategic planning and forecasting, travel is only one of a number of large and important factors such as the condition of physical facilities, the availability of financial resources, the state of the economy, the price of energy, the prosperity of private transportation companies, the application of new technology, the quality of the environment, and the quality of life. In this kind of setting, travel behavior and its forecasting are only important in aggregate terms.

The evidence on which this paper is based is drawn almost exclusively from my research work on NCHRP Project 20-5, which was the development of a synthesis report, Statewide Transportation Planning (1).

CONTEXT

Methods and techniques play their proper roles in the context of large work programs and government organizations. Without the support of a dynamic departmental program that assigns problems to transportation planners and uses their forecasts, evaluations, and plans for actual decisionmaking, the methods and techniques may become only toys.

To develop a dynamic program, any department needs an appraisal of where it stands. As an example of such an appraisal and its impact on a statewide planning program, an inspection of Figure 1 (1) is suggested. The last column in that figure is particularly relevant.

The following conclusions may be drawn regarding strategic transportation planning at the state level (1). Many of the same conclusions apply at the regional or metropolitan level, except that in those areas the structure of government is less unified and the needs for freight transportation planning are generally less.

1. There will be a need for more staff work in financial policy planning, programming, and critical examination of year-to-year performance of all modes.
2. Less attention will be paid to system planning, at least in the classical comprehensive, continuing, and cooperative (3C) approach.
3. Planning will become more multimodal rather than being restricted to traditional modes.
4. There is a need for better, more responsive tools in most of the modal planning areas.
5. Work with private transportation systems will continue, both for person and goods movement. This will require greater understanding of these modes and of the way they affect the economy of a state. Public investments will continue to be needed to cushion the impacts of changes and to improve or coordinate the operations of all systems, but these investments will have to be made with more careful attention to their economic worth. This planning will continue to be an intermodal activity; engineering economics will play a major role.
6. Planning will become more sensitive to the impact of transportation (all modes) on the economy of each state.

Clearly, we must look for methods and techniques that will address critical issues and respond to the requirements that top management in a transportation agency will place on its planning staff.

In this regard, it is helpful to look at the framework for statewide transportation planning that was proposed in the NCHRP synthesis report. This framework is responsive to the increasing management orientation of transportation planning and organizes statewide transportation planning into two parts:

1. The substantive part, that which is concerned with the substance of transportation: the different modes, their physical and service properties, and travel behavior (persons and goods). Substance involves systems planning, corridor planning, and project planning.
2. The management part, that which deals broadly with all implementation procedures from decisions on policy and strategy to communications with legislature and the public, programming, and the monitoring of system performance.

This recommended framework is shown in Table 1. Note that strategic planning or policy analysis has a key place at the top of the management column. Such a position, however, does not make strategic planning independent of systems planning or modal planning in the substantive column or of communications, programming, or performance monitoring in the management column. All of these activities are interdependent.

TECHNIQUES

Given this background and context, what techniques are available? What is the state of the art? In what direction is transportation planning going?

As it turns out, there are a large number of methods and techniques that are new, exciting, and worthy of being labeled state of the art.

NCHRP 20-5 identified 27 techniques that were called examples of good practice. Clearly, we can only present a few here and then only briefly. These are of two types: (a) individual techniques, which repond to specific problems; and (b) integrative techniques, which help to coordinate results.

The presentations describe the problem or problems faced, the method in brief, and then attempt to identify the key characteristics that make each technique worthy of being called the state of the art. At the conclusion, I shall try to pull these characteristics together to see whether they give any clues as to the future of transportation planning.

Individual Techniques

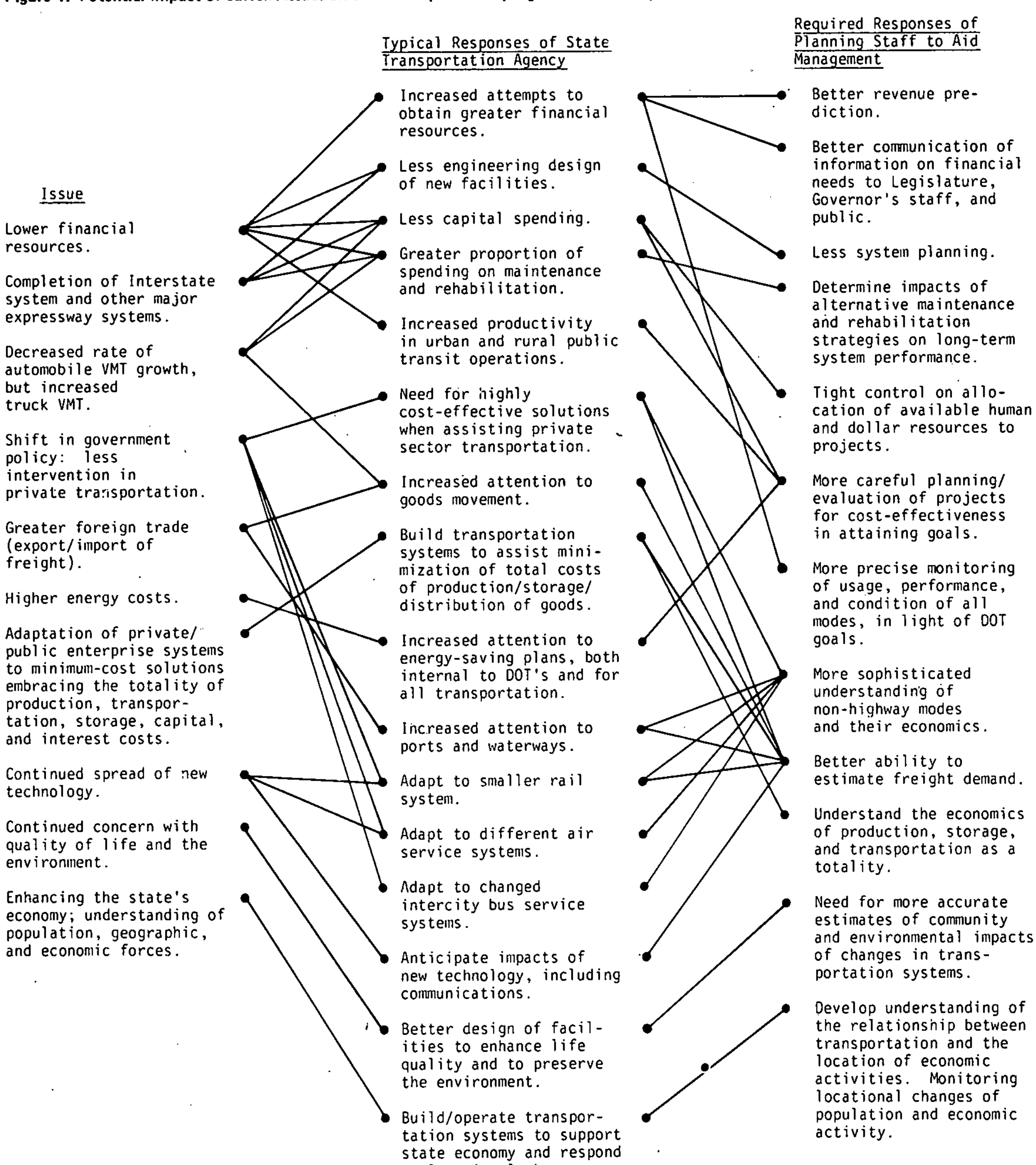
Group A: Estimation of Financial Resources

Estimation of financial resources is one of the critical elements in long-range strategic forecasting for the simple reason that financial resources establish the boundaries of the capital and operating plans and programs of a transportation agency.

Travel forecasting in turn is an important component of financial forecasting because fuel, vehicle ownership, and other travel-related items are major components of the tax base that is traditionally available for or dedicated to transportation improvements.

There are a number of financial forecasting models that states are using (2,3). However, the California package of models, including FINPLAN (4),

Figure 1. Potential impact of current issues on state transportation programs and on requirements for planning.



seems to me to be at the leading edge. FINPLAN is a multiyear computerized model that estimates financial resources for highways; it takes into account all the factors that contribute resources (taxes, fees, and miscellaneous sources) and also that subtract from resources (apportionments and transfers). FINPLAN is a highly disaggregated model, with eight main modules (see Figure 2).

What particularly about the California package makes it so timely? There are, I suggest, several reasons.

Table 1. Framework for statewide transportation planning.

Substantive Content	Management Content
Mode	Strategic planning or policy analysis
Highway (automobile or truck)	Financial
Rail	Regulation
Air	Shared policies (e.g., with land use, energy, and the environment)
Port or waterway	Communications
Pipeline	With state administration
Bicycle or moped	With legislature
Bus (intercity, rural)	With public
Urban transit[a]	With regional transportation planing agencies
Level of planning	With local governments
Systems planning	Programming
Corridor planning	Projects
Project planning	Resources (including staff time)
Preliminary engineering[b]	Performance monitoring
Engineering design[b]	Of systems and services
Planning for operations of existing systems or services[b]	Evaluated in terms of goods and standards)
Assistance to local, county, or regional transportation planners	Miscellaneous
As a process	Operations management studies
Data collection	
Forecasts	
Goal specification	
Preparation of alternative plans	
Testing	
Evaluation	
Decision	

[a] In some states, urban transit may be a function of a statewide transportation planning staff, but in most states only the funding levels are critical issues in statewide transportation planning.
[b] Not functions of transportation agency's planning staff, but part of the total process leading to construction or project implementation.

1. The components of the package are regularly run and rerun. This can be done because they are programmed for computer operation. Thus analysts can concentrate on a critical analysis of the input variables and use alternative inputs. Most of us are skeptical about long-range forecasts (which, however, are essential to strategic planning), and it is only when we can see how the future will look under a range of alternative assumptions that we believe the results.

2. FINPLAN is comprehensive; that is, it is internally structured so that it not only estimates revenue but predicts where the funds will be allocated through the various fund accounts and apportionment to local government.

3. A related California model estimates escalation of capital costs as a result of inflation (5). What makes that model interesting from the point of view of the state of the art is that it has a tie-in to an external forecasting source on a regular basis. In this case, the source is Chase Econometrics. The strategic forecasting operation benefits from this linkage to an external forecast that deals with the national economy.

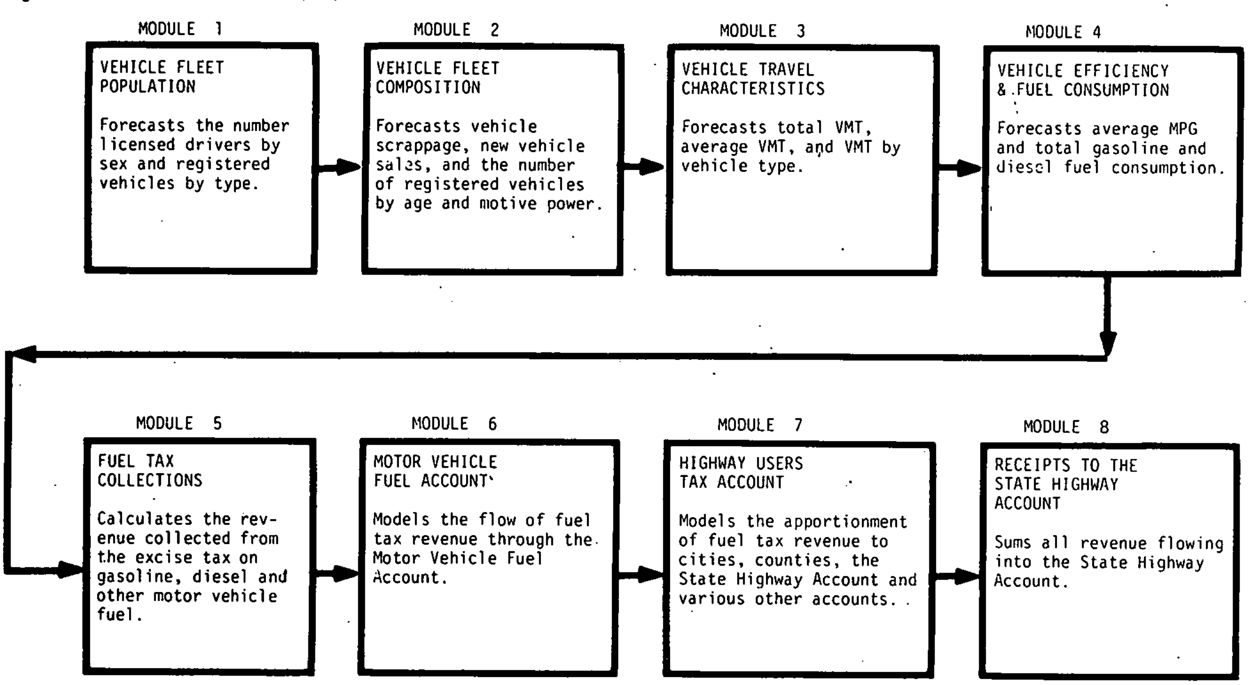
Group B: Freight Modal Study

Strategic planning at the state level (or at the multistate or regional level) must, from time to time, deal with a variety of modes, and for each mode (or modal problem) a different technique may have to be applied or developed. Here an analytical technique is described.

Proposals had been advanced to build an all-American canal linking the Great Lakes with the Atlantic Seaboard. Twelve improvement plans were to be evaluated, consisting of different route locations and channel sizes. The problem was to estimate the economic benefits that would accrue to shippers if each of the proposed navigation systems was built.

The technical problem required estimation of commodity flows by major commodity type for origin-destination pairs that included the 19-state Great

Figure 2. Schematic of FINPLAN model.



Lakes region plus other domestic, Canadian, and foreign origins and destination. Transportation costs had to be calculated for alternative combinations of modes and routes, including rail and truck routings. Costs included transshipment costs and costs as a function of barge and vessel sizes. An accounting model [Transport Cost Calculation System (TCCS)] was developed to summarize costs and thereby savings over present routings (6).

What is unusual about this procedure is that it employed the computer not as a travel-forecasting tool, but as an accounting tool. In the realm of freight transportation, we must deal with extremely disaggregated conditions--different commodity types, different vehicle requirements, different transshipment costs, different perishability rates, and different origin-destination types. To handle these successfully over the range of commodity types and other conditions that exist the computer has to be employed as a clever adding machine, given a large number of rules to work with. The strategic plan is developed not so much as a response to forecast conditions (which are so hard to predict) but as an evaluation of how alternatives will perform under present travel demands.

Group C: Highway Pavement Management

A number of states (California, Arizona, Washington, and North Dakota, for example) have developed pavement-management systems (7-11). These systems have been brought into being at a time when diminished fiscal resources and inflation have reduced states' abilities to build and maintain highways and when, therefore, greater care has had to be taken in the allocation of funds to pavement management.

The essence of these systems is contained in three elements:

1. A complete inventory or an adequate sample of all miles (or preferably lane miles) of a state's highway system, containing condition indicators that are regularly updated;
2. A set of criteria that define the conditions when lanes need maintenance or rehabilitation; and
3. Equations based on historical data that will estimate the need for, and cost of, maintenance and rehabilitation under alternative investment strategies. These equations should take traffic volume data into account.

What is it that makes such techniques timely and that will lead other states to use them? Basically, there are two characteristics that count:

1. The ability to predict the rate of deterioration of pavements, and hence physical maintenance or rehabilitation needs and their costs, is important to the development of long-term strategies for state transportation agencies; and
2. The technique requires a good data base and that data base needs to be stored in a computer in a fashion so that updating can be done inexpensively.

Integrative Techniques

One of the problems with long-range analysis and forecasting techniques is that they tend to become highly specialized. Inevitably, the more advanced they become, the more specialized they will be. Therefore, some integrative techniques are needed.

What are the state-of-the-art integrative techniques? There are two that I would like to discuss briefly.

Group D: Published Master Plan

At least 13 states have published statewide transportation plans since 1975, according to data received during NCHRP Project 20-5 research work, and most of these plans were actually published in the period 1978-1981.

One of the reasons for preparing a statewide multimodal transportation plan is to force coordination between (or integration of) separate modal plans; decisions made on finances; regulation; and relationships with the nontransportation dimensions or sectors of a state or region. Requiring statewide transportation plans to be prepared is, in many cases, part of the directive given to state departments of transportation by their legislatures, and this makes sense because a lack of coordination between the modes has often been one of the prime reasons justifying creation of state departments of transportation.

Actually, there are few better ways of finding inconsistencies between single-mode plans or between plans and financial policies than through combining them in a report with its maps, text, and tables and then critically reviewing the results within the transportation agency and with the public. All kinds of problems can remain undiscovered when different plan elements are lying around in different bureaus or offices. Forcing them together in a report will reveal most of these inconsistencies.

Group E: Performance Monitoring

Performance monitoring is the regular measurement and evaluation of the use and quality of service provided by all the transportation systems of a state or an urban or metropolitan area. The concept of monitoring transportation systems has been around for many years and is implicit in activities such as highway sufficiency ratings and the monitoring of activities on rehabilitated railroad branch lines (12).

In what way is performance monitoring relevant to long-range strategic forecasting or to travel behavior? Or in what way is it an integrative technique?

The answer to these questions lies in the fact that long-range forecasts are notoriously prone to error because travel, among other subjects (such as the economy, population, technology, and energy supplies or prices), is subject to so many external forces. Given this condition but still accepting the necessity of very careful forecasting of future conditions, it is important to obtain regular indicators of changes that are taking place now. Transportation needs indicators just as much as economists, businessman, and governors need data on unemployment, money supply, prices, and bankruptcies.

At present the state of the art of monitoring is not highly developed, although in certain subject areas [e.g., pavement management systems (7,13,14)] it has galloped ahead. I expect that this trend will continue strongly in the future.

ESTABLISHING LINKAGES BETWEEN STRATEGIC TECHNIQUES AND FACILITIES PLANNING

As suggested in the workshop directive, relationships between strategic and facilities planning methods are to be discussed. We do need to build linkages between strategic planning and the world of physical systems and project plans. This is important because without adequate relationships, strategic planning can become irrelevant to decision-making, whereas, on the other hand, facilities planning can become detached from the future unless it is based on a sound, long-range strategy.

As it turns out, there are a number of linkages that can be quite effective:

1. Where the strategic plans are modal, as in the case of the all-American navigation system cited earlier, the strategic plan is the facilities plan.
2. Where a modal planning operation predicts future conditions and the needs that derive from those conditions, as in the case of a highway pavement management system, strategy can be developed by means of an upward link from the modal plan to the strategic plan.
3. The fiscal constraints imposed by estimates of financial resources provide an important linkage, which should be administered through the programming process.
4. Monitoring of travel and transportation facilities and services provides a regular means for evaluating whether system performance at particular places in a state or urban area is actually improving toward strategic goals or is declining in quality.

DIRECTION OF FUTURE TECHNIQUES

In the long run, our work in transportation must be directed toward a vision of a desired future condition. That vision will be expressed both in qualitative terms (such as low accident rates, reduced noise, and low-cost travel) and in physical terms. The physical terms will be important because so much of what will be in fact exists today.

Strategy is the means by which the vision is achieved. Developing that vision, which realistically is an adaptive target, calls for multiple planning and forecasting techniques. There is no single, preferred technique nor any likelihood that an all-embracing technique will be developed. The bigger the planning area and the longer the range, the more techniques there will be. The fact that we must employ a flock of them does not, however, diminish their individual importance. Each technique is just as important to planning as a technological improvement (like the wide-bodied jet or the container ship) is to transportation itself.

If we look at the state-of-the-art example given in this paper, we can discern certain qualities that indicate the direction future techniques will take. There are six of these qualities:

1. Repetitive computer operation: The techniques will be repeated year after year or even more frequently as integral parts of a transportation agency's planning, forecasting, and evaluation program.
2. Internally comprehensive: The techniques will deal with a variety of closely related phenomena in the general subject area of concern.
3. Externally linked: The techniques will have, where appropriate, one or more links to the non-transportation world as a means of verification or to study impacts.
4. Process orientation: The new forecasting and planning techniques will be more process or accounting oriented than theoretically oriented. Theories and models will be employed, but they will play secondary rather than primary roles.
5. Data base: The techniques will depend on data bases that are much more extensive, well maintained, and accessible than anything we now know. Michigan's data base is a forerunner (14,15).
6. Retroactively checked: Planning and forecasting techniques will have their predictions constantly checked through programs of monitoring.

Finally, there is one dominant thought. Success, usefulness, and innovation will occur wherever there is a transportation agency that has the wit to nurture technique and the strength to submerge technique as a utilitarian part of a dynamic program.

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State of the Practice: Travel Analysis Methods in Long-Range and Strategic Planning

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In response to the shifting issues and context for urban transportation planning, particularly the reduced capability of most regions to finance major highway and transit capital improvements, less emphasis is now being given to long-range planning than in the 1970s. Long-range planning, to be sure, will continue, and past plans will be refined and updated. However, the greater priorities are now being placed on shorter-range questions of transportation systems management and efficiency--obtaining increased capacity and service from existing facilities. Without the prospect of major capital investment as a tool for guiding urban growth, development, and redevelopment, less interest also is currently being shown in strategic or policy planning, with even longer time frames (beyond 20 years) than traditional long-range transportation planning.

In this paper, two case studies--Milwaukee and Dallas-Fort Worth--are used to examine travel analysis and long-range and strategic planning methods now in use within this context of changing planning requirements.

In general, current work of the North Central Texas Council of Governments (NCTCOG) is regarded as representative of most medium-sized and larger urban regions (1,2). NCTCOG is updating its 1975 regional transportation plan with only modest technical effort and with relatively little innovation in the application of travel-demand models or the analysis of strategic planning options. State-of-the-art disaggregate demand-analysis models were installed in 1979 and offer considerable flexibility in application at regional or subarea levels. However, these models are not being used in any extensive or thorough way to explore a wide range of regional transportation alternatives nor are multiple scenarios or alternative futures for the region being examined. This, in turn, is consistent with the perceptions of the COG Regional Transportation Council with regard to transportation planning and programming priorities in the region.

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) has been one of the stronger metropolitan planning organizations (MPOs) for a number of years in terms of both local political support and technical capability. Staff of the agency has been given sufficient freedom to test new analytic methods and has recently completed an update of the transit component of the 1974 regional transportation and land use plan, which offers some measure of leadership and innovation in long-range and strategic transportation planning (3,4). Both alternative socioeconomic futures and accompanying land use plans were explored. A wide range of alternative transportation systems (highway and transit), which support each of these alternative futures, was also defined and analyzed in detail by applying state-of-the-art demand-modeling methods. This example consequently provides something of a benchmark or target for improved analytic support of long-range and strategic planning but not without important technical difficulties.

In the remainder of the paper, these two case studies are contrasted in three ways:

1. Evolving methods for strategic planning (or at least the forecasting, assumption setting, or both associated with socioeconomic or land use contexts for travel demand analysis) as well as long-range transportation planning and demand modeling are briefly reviewed. Seven different methodological topics are investigated, covering such aspects as the role of alternative land use plans, the management of information overload for participating decisionmakers, or the importance of corridor or subarea planning to regional-level decisionmaking.
2. In support of the overall conclusion that the state of the practice in this area is relatively weak, reasons for this lack of attention or focus are given. Several different reasons are suggested, ranging from the information absorption limits of decisionmakers to the technical and communication difficulties associated with delineating complex socioeconomic and environmental scenarios and the increasing short-range implementation focus of many decisionmakers.
3. Several suggestions are outlined for closing the apparent gap between the state of the art and the state of the practice in travel analysis methods that support long-range and strategic planning.

EVOLVING METHODS

Several general areas of transportation and land use planning strategy and travel analysis methodology merit examination. These include the extent to which alternative futures are utilized; the extent to which travel demand models are employed (and their associated degree of complexity) in relation to alternative futures and in general; the extent to which corridor or subarea transportation planning and travel analyses are conducted or required to make decisions; and the extent to which the often extensive information output of travel analysis is effectively managed.

The evolving methods investigated here and their treatment by the two case-study areas, Milwaukee (SEWRPC) and Dallas-Fort Worth (NCTCOG), are summarized in Table 1.

Table 1. Summary of evolving methods: SEWRPC and NCTCOG.

	Case-Study Treatment	
Evolving Method	SEWRPC	NCTCOG
Alternative futures and scenarios	Two socioeconomic scenarios	Concept not used
Alternative land use plans	Two land use plans for each scenario	Urban development model used for single projection
Long-range transportation alternatives	Six modal options matched against four scenario and land use plan combinations to yield 24 basic alternatives	Eleven modal options matched against single, eight-corridor transportation and land use system
Travel-demand analysis	UTPS-based computerized demand modeling	Manual sensitivity analyses
Policy and strategic options	Focus on intangible benefits of rail alternatives	Focus on influencing future land development patterns
Management of evaluative information	Three-stage, narrowing down evaluation process	Not an issue
Decisionmaker informational needs	Ten; 40 summary measures used	Five; 10 key indices desired

Alternative Futures or Scenarios

Few regions have successfully employed the notion of alternative futures as a background for regional transportation and land use planning. One of the immediate dangers is, of course, doubling or quadrupling (or worse) the amount of work necessary to carry forward any competent analysis of alternatives, given the time and budget constraints associated with typical planning agency staffs. Keeping the number of alternatives under control and structuring them so that they represent a high or low assumption along key parameters are important guidelines.

SEWRPC defined two basic alternative futures for updating its regional transportation and land use plan--a moderate-growth scenario and a stable or declining-growth scenario (3). As indicated in Figure 1 (3, p. 155), each scenario was tied to a series of assumptions regarding basic external factors affecting regional growth, such as energy availability and price, automobile fuel efficiency, household size, female labor force participation, household income growth (real dollars), and population and employment growth. Figure 2 (3, p. 141) indicates how each scenario was assumed to follow a high or low growth rate through the year 2000 for the various key factors. The scenarios are consequently used as a way to bound the future of the region in terms of pessimistic or optimistic growth and economic prospects.

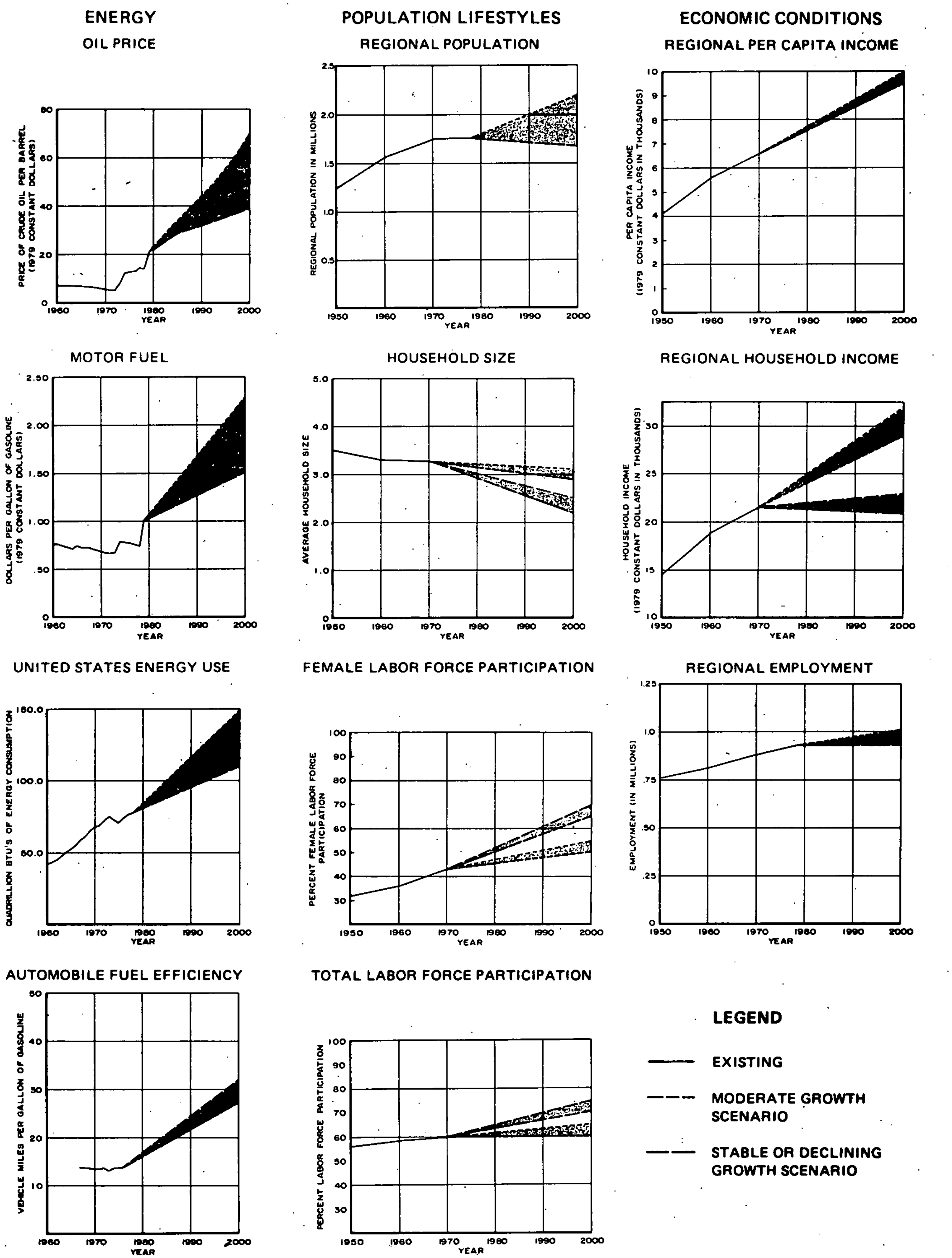
In updating its regional transportation and land

Figure 1. Alternative futures.

Key External Factor	Moderate Growth Scenario	Stable or Declining Growth Scenario
Energy The future cost and availability of energy, particularly of petroleum	Oil price to converge with world oil price, which will increase at 5 percent annual rate to $72 per barrel in the year 2000 (1979 dollars) Petroleum-based motor fuel to increase to $2.30 per gallon by the year 2000 (1979 dollars) Assumes some potential for major and continuing disruptions in oil supply	Oil price to converge with world oil price, which will increase at 2 percent annual rate to $39 per barrel in the year 2000 (1979 dollars) Petroleum-based motor fuel to increase to $1.50 per gallon by the year 2000 (1979 dollars) Assumes no major or continued disruptions in oil supply
The degree to which energy conservation measures are implemented, particularly with respect to the automobile	Low degree of conservation in all sectors, resulting in increase in energy use of 3 percent Automobile fuel efficiency of 27.5 miles per gallon	High degree of conservation in all sectors, resulting in increase in energy use of 2 percent or less Automobile fuel efficiency of 32 miles per gallon
Population Lifestyles The degree to which the changing role of women affects the composition of the labor force	Female labor force increases to 50 to 55 percent and total labor force participation is 60 to 65 percent	Female labor force increases to 65 to 70 percent and total labor force participation is 70 to 75 percent
The future change in fertility rates	A continuation of below-replacement-level fertility rates during the next decade, followed by an increase to replacement level by the year 2000	A continuation of below-replacement-level fertility rates to the year 2000
The future change in household sizes	Average household size stabilizes	Average household size continues to decline
Economic Conditions The degree to which the Region will be able to compete with other areas of the nation for the preservation and expansion of its economic base	Region is considered to have relatively high attractiveness and competitiveness	Region is considered to have relatively low attractiveness and competitiveness
The future change of real income	Per capita and household income increase envisioned as a result of the attractiveness and competitiveness of Region, an increased proportion of the population being of work force age, and increased population labor force participation	Per capita increase likely but no household income increase envisioned as a result of the lack of attractiveness and competitiveness of Region, but increased proportion of the population is of work force age, and there is increased population labor force participation

Attendant Regional Change	Moderate Growth Scenario	Stable or Declining Growth Scenario
Population of the Region in Year 2000 Size	2,219,300 persons	1,688,400 persons
Age Distribution	29.2 percent—0-19 years of age 58.5 percent—20-64 years of age 12.3 percent—65 years of age or older	26.8 percent—0-19 years of age 60.6 percent—20-64 years of age 12.6 percent—65 years of age or older
Number of Households	681,100 to 739,400	673,600 to 750,600
Household Size	Average of 2.9 to 3.1 persons	Average of 2.2 to 2.5 persons
Economic Activity of Region in Year 2000 Employment	1,016,000 jobs	887,000 jobs
Structure	Manufacturing. . . . 32 percent Services. . . . . 40 percent Other . . . . 28 percent	Manufacturing. . . . 30 percent Services. . . . . 41 percent Other . . . . 29 percent
Personal Income	$29,600 to $32,000 per household in 1979 dollars (38 to 50 percent increase over 1970, or a 1.1 to 1.4 percent annual rate of increase) $10,000 per capita in 1979 dollars (54 percent increase over 1970, or a 1.4 percent annual rate of increase)	$21,400 to $23,700 per household in 1979 dollars (0 to 11 percent increase over 1970, or a 0.0 to 0.3 percent annual rate of increase) $9,500 per capita in 1979 dollars (46 percent increase over 1970, or a 1.3 percent annual rate of increase)

Figure 2. Ranges of external factors considered in alternative-future scenarios.



use plan, NCTCOG has followed a more traditional approach of single-valued forecasts of demographic, employment, and development characteristics of the region, based on an examination of past trends in the region and in other regions across the country (2,5). Conventional population and employment forecasting models were utilized to derive single-valued year-2000 forecasts. In deriving these forecasts, however, extensive consideration also was given, as in the Milwaukee region, to the availability and price of transportation energy and to socioeconomic trends regarding age distribution, residential density, sunbelt-snowbelt population shifts, and central city versus suburban population and employment shifts.

Alternative Land Use Plans

Each of the SEWRPC growth scenarios was accompanied by two corresponding land use plans. These land use development assumptions also tend to represent density and distributional extremes. The centralized land use plan assumed that virtually all new urban development would occur at medium residential densities adjacent to existing urban centers [see Figure 3 (3, p. 145)]. Considerably less land would be consumed for urban uses compared with the decentralized land use plan, which reflects historic development trends in the region since 1963--low densities, urban scatteration, and inefficient provision of accompanying urban services [Figure 4 (3, p. 147)]. For both scenarios, distributional assumptions by land use category and location were made for the two land use plans accompanying each scenario. A total of four basic alternatives (two scenarios and two land use plans each) resulted as the framework for defining transportation alternatives.

In contrast, NCTCOG exercised an urban development model to project a single-valued allocation of urban land uses among the region's subareas. This model requires as input the accessibility provided by assumed highway service levels, since accessibility is one of the factors influencing the distribution of residential population. The land use allocation is also constrained by local zoning policies and holding capacity. Since only a relatively small number of regions have opted for the utilization of computerized urban development models, this use in Dallas-Fort Worth may be atypical. (No land use model was employed in Milwaukee.) There has been pressure from some rapidly growing suburbs in Dallas to consider the effect of increased growth rates for their jurisdictions on area transportation alternatives, which represents, in effect, a higher-growth scenario.

Matching Long-Range Transportation Alternatives to Alternative Futures

It is at this stage of a long-range transportation planning process that the dangers of information overload become evident. In Milwaukee, it was felt that a thorough analysis required five modal options in addition to a base-case plan. These options included express bus-on-freeway (base case), expanded bus-on-freeway, busway, commuter rail, light rail, and heavy rail rapid transit. As a first cut, so-called maximum extent systems for each of these modes were matched against each of the four scenario and land use combinations, which resulted in 24 basic alternatives. A three-level process of evaluation involved an initial testing of these 24 alternatives, a truncating of the five primary transit systems to their highest performance corridor components (followed by a subsequent round of analysis and evaluation), and a more detailed evaluation of two finalist, composite alternatives.

In Dallas-Fort Worth, a less structured planning process has been followed, and emphasis has been given to the relatively rapid definition and analysis of express transit alternatives for the Dallas portion of the region. For the single population/employment land use projection, a series of 11 different modal systems alternatives was defined for Dallas at a sketch-planning level of detail. For ease of analysis, the same basic eight-corridor network was assumed for each alternative, and levels of service (average speed, station spacing, headway, etc.) were assumed to vary for each mode (6). In effect, the selection of a single land use plan permitted a larger number of modes to be analyzed, although the total number of alternative transportation systems examined was still considerably less (about one-half) than in Milwaukee.

Extent of Travel Demand Analysis

Major differences between SEWRPC and NCTCOG emerge here, reflecting in large part the time frame and budget allocated for analysis. The SEWRPC long-range plan update was set within a multiyear regional transportation planning program and accomplished within a well-thought-out planning process. Computer-based travel demand modeling was applied to each of the 24 maximum extent alternatives as well as to the most promising of the remaining truncated alternatives; this involved a major expenditure of funding and staff effort.

In the Dallas region, on the other hand, analysis of express transit alternatives was initially conducted for the Interim Regional Transportation Authority (IRTA), established within a relatively short time frame and modest budget to select a viable transit alternative for the region with a mandate not fully integrated with the ongoing regional transportation planning program. While NCTCOG staff participated in the resultant planning effort, it was not possible to fully utilize the recently developed and improved travel demand modeling package (6). Preliminary travel demand analyses for the express transit alternatives were consequently derived by using manual sensitivity analyses of demand forecasts before 1975, in turn based on the somewhat outdated demand modeling package of that time. Much less effort was devoted to travel demand analysis in Dallas-Fort Worth than in Milwaukee. NCTCOG does plan to apply its computerized travel demand modeling package to a single selected express transit alternative or service plan, to more completely detail its operational and demand characteristics. This transit plan will then be combined with a companion, separately developed highway plan to form the overall updated regional transportation plan.

Policy and Strategic Options Versus Facility-Oriented Options

Although one of the conclusions of a recent conference on urban transportation planning involves the reorientation of long-range transportation planning more toward policy and strategic options and less toward facility-oriented options (7), this dimension is a difficult one to characterize for the two case studies.

In general, the SEWRPC planning process was quite specifically facility oriented in the sense of detailed definition of transit alternatives regarding route alignment and station location and corridor-by-corridor service-level differences (all required as input to the computerized travel demand model-

Figure 3. Existing and proposed land use in region: 1970 and 2000 centralized land use plan for moderate-growth scenario.

Land Use Category	Existing 1970		Planned Increment		Total 2000	
	Acres	Percent of Major Category	Acres	Percent Change	Acres	Percent of Major Category
Urban Land Use						
Residential						
Urban High Density.	24,389	7.4	371	1.5	24,760	6.2
Urban Medium Density.	37,092	11.3	41,046	110.7	78,138	19.5
Urban Low Density.	72,701	22.2	- 7,689	- 10.6	65,012	16.2
Suburban Density.	22,079	6.7	4,862	22.0	26,941	6.7
Subtotal	156,261	47.6	38,590	24.7	194,851	48.6
Commercial.	6,517	2.0	698	10.7	7,215	1.8
Industrial	10,038	3.1	6,672	66.5	16,710	4.2
Governmental and Institutional	16,628	5.1	951	5.7	17,579	4.4
Transportation, Communication, and Utilities[a]	109,430	33.4	21,441	19.6	130,871	32.7
Recreation	28,982[b]	8.8	4,166[c]	14.4	33,148	8.3
Urban Land Use Subtotal	327,856	100.0	72,518	22.1	400,374	100.0
Rural Land Use						
Residential	- -[d]	- -	22,306	- -	22,306	1.7
Agriculture	1,040,119	74.7	- 79,779	- 7.7	960,340	72.7
Other Open Lands[e]	353,125	25.3	- 15,045	- 4.3	338,080	25.6
Rural Land Use Subtotal	1,393,244	100.0	- 72,518	- 5.2	1,320,726	100.0
Total	1,721,100	- -	- -	- -	1,721,100	- -

[a] *Includes off-street parking uses.*

[b] *Includes net site area of public and nonpublic recreation sites.*

[c] *Includes only that net site area recommended for public recreation use.*

[d] *Included in land use inventory as part of urban residential land use.*

[e] *Includes woodlands, water, wetlands, unused lands, and quarries.*

Figure 4. Existing and proposed land use in region: 1970 and 2000 decentralized land use plan for moderate-growth scenario.

Land Use Category	Existing 1970		Planned Increment		Total 2000	
	Acres	Percent of Major Category	Acres	Percent Change	Acres	Percent of Major Category
Urban Land Use						
Residential						
Urban High Density.	24,389	7.4	- 2,548	- 10.4	21,841	4.6
Urban Medium Density.	37,092	11.3	43,888	118.3	80,980	16.9
Urban Low Density.	72,701	22.2	- 2,423	- 3.3	70,278	14.7
Suburban Density.	22,084	6.7	64,889	293.8	86,973	18.2
Subtotal	156,266	47.6	103,806	66.4	260,072	54.4
Commercial.	6,517	2.0	385	5.9	6,902	1.4
Industrial	10,039	3.1	3,847	38.3	13,886	2.9
Governmental and Institutional	16,617	5.1	2,735	16.5	19,352	4.0
Transportation, Communication, and Utilities[a]	109,407	33.4	33,788	30.9	143,195	30.0
Recreation	28,996[b]	8.8	5,738[c]	19.8	34,734	7.3
Urban Land Use Subtotal	327,842	100.0	150,299	45.8	478,141	100.0
Rural Land Use						
Residential	- -[d]	- -	4,782	- -	4,782	0.4
Agriculture	1,040,122	74.7	- 141,070	- 13.6	899,052	72.3
Other Open Lands[e]	353,136	25.3	- 14,011	- 4.0	339,125	27.3
Rural Land Use Subtotal	1,393,258	100.0	- 150,299	- 10.8	1,242,959	100.0
Total	1,721,100	- -	- -	- -	1,721,100	- -

[a] *Includes off-street parking uses.*

[b] *Includes net site area of public and nonpublic recreation sites.*

[c] *Includes only that net site area recommended for public recreation use.*

[d] *Included in land use inventory as part of urban residential land use.*

[e] *Includes woodlands, water, wetlands, unused lands, and quarries.*

ing). Key policy issues were, however, also addressed as a part of the overall evaluation of alternatives. A basic policy issue raised by the Commission was the judgmental trade-off regarding the measureable and more certain advantages of the bus-on-metered freeway alternative and the intangible advantages of the light rail transit alternative and of commuter rail facilities and services. A detailed and thorough technological and policy evaluation of modal alternatives was also prepared as background material for the Commission, again reflecting a significant expenditure of staff and budget resources.

At NCTCOG, on the other hand, although it would appear that the comparative lack of modal specificity would allow a greater focus on policy issues--specific alignments and station locations were not a part of the express transit alternatives defined--there was also a danger that too many policy issues might in the end be only superficially addressed. One major issue raised by IRTA broad members involved the extent to which investment in high-capacity, grade-separated rail transit could or could not significantly influence future land use development in the long term. The extent to which this should be a desired regional objective, addressed by land use policies and controls as well, was also raised. Insufficient time and budget were available to adequately examine such weighty policy issues as these.

Management of Evaluative Information

As indicated above, the SEWRPC alternative-scenarios planning process generated a considerable amount of information regarding 24 basic maximum-extent transportation alternatives. In order to sift through the information generated on these initial alternatives as well as on subsequent versions of them, it was necessary to devise a three-stage evaluation process for narrowing down to the final two alternatives, which were more carefully compared.

Following review of the maximum-extent alternatives, a series of truncated alternatives was also defined, with a reduction of the total number of alternatives under consideration to 10 (some alternatives were assumed to appropriately serve two or more of the scenario and land use combinations). Under the third evaluation stage, the two most promising alternatives--bus-on-metered freeway and a two-tier or two-stage light rail system--were more fully evaluated, including a more careful consideration of intangible or indirect impacts.

In Figures 5, 6, and 7 a partial summarization of this sequence of evaluative efforts is given, and some idea of the volume of evaluative information that required the concentrated attention of Commission members as they proceeded through the process is indicated. This information flow was regarded as unwieldy and cumbersome by some participants (8).

Decisionmaker Informational Needs

The NCTCOG planning process was not so thoroughly structured as that followed in Milwaukee, so that the dangers of information overload were much less. It simply was not possible to generate the quantity of network performance and cost data, at a considerable level of detail, as that carried forward in Milwaukee. Emphasis in the evaluative stages of the planning process consequently shifted from management of potential information overloads to meeting the key informational needs of decisionmakers. This, in effect, involved zeroing in on 5-10 key indices for assessing express transit alternatives without devoting time and effort to additional supporting information, which, although valuable in providing a more thorough understanding and background on important similarities and differences among transit alternatives, is only supportive.

The bottom-line indices--peak-link, peak-hour, and peak-direction passenger volume; daily ridership volume; capital cost per passenger; operating and maintenance cost per passenger; total capital cost; operating subsidy per passenger required; and related effectiveness or efficiency measures--remain the key desired outputs of the planning process. In the Dallas-Fort Worth example, however, additional information was desired by IRTA members regarding the related scenario-type variables that might affect potential transit demand--energy cost, residential density, highway congestion levels, etc. In fact, although these key requested sensitivity analyses could perhaps have been better addressed by a more thorough alternative-futures component of the planning process, such an approach was precluded by the short time frame under which the IRTA transit planning process was inaugurated (six months).

LIMITED STATE OF THE PRACTICE

A number of important contrasts between the SEWRPC and NCTCOG examples are now evident--prior commitment to thorough and systematic regional planning processes (SEWRPC), political mandate for and urgency of reaching express transit investment decisions in a short time frame (NCTCOG), major differences in the level of staff effort and funding devoted to the long-range and strategic planning process, associated time and funding availability for the exercising of computerized travel demand models, and the extent to which varying assumptions (high versus low) regarding key external factors have been reflected in travel demand and supply relationships for different modal alternatives. In general, although several aspects of the SEWRPC case study are both noteworthy and commendable, the NCTCOG case study is nevertheless representative of the majority of the MPOs across the country. It is consequently necessary to use both case studies to investigate a number of reasons for the relatively limited state of the practice in long-range and strategic planning and supporting travel analysis methodology.

The following preliminary reasons are offered.

Decisionmakers Have Information Limits

The NCTCOG example in particular illustrates how the underlying decisionmaking and political or community context can place real limits on the ability (and even desire) of decisionmakers to absorb extensive evaluative information regarding transportation alternatives.

In general, at least two levels of decision can be distinguished, and many decisionmakers focus on the simpler, less demanding level, namely, can any sort of capital-intensive transportation investment (such as fixed guideway, grade-separated transit) be justified and in how many corridors? Given this go or no-go decision, the additional information required to discriminate among technology options calls for a second decisionmaking level and places greater demands on decisionmakers for the understanding of impact differences and trade-offs among them. As experience in most other regions shows (and certainly in Milwaukee as well), many decisionmakers at either level search for those 5-10 key criteria for which a straightforward choice among alternatives can be made. This desire for simplicity reflects limited time available for in-depth analysis as well as a pragmatic search for the essentials (9).

Figure 5. Summary of evaluation of base system plan and alternative maximum-extent primary transit system plans under each scenario land use plan.

	Alternative					
Scenario	Base Plan	Bus-on-Freeway Plan	Commuter Rail Plan	Light Rail Transit Plan	Busway Plan	Heavy Rail Rapid Transit Plan
Moderate Growth Scenario-Centralized Land Use Plan						
Public Transit Ridership						
Passenger Trips per Average Weekday	326,800	387,900	372,100	357,800	353,500	346,600
Cost						
Total Cost						
Total Cost to Design Year	$579,742,000	$832,269,800	$868,415,300	$1,120,900,000	$938,394,490	$2,048,414,900
Capital Cost						
Total Capital Cost to Design Year	148,842,000	221,249,800	210,245,300	628,160,000	442,054,490	1,572,378,300
Total Capital Investment to Design Year	233,328,700	356,443,700	401,852,100	1,231,138,000	771,162,200	2,930,538,000
Net Operating and Maintenance Cost (deficit)						
Total Deficit in Design Year	23,198,300	45,713,000	51,607,600	30,928,100	31,378,700	28,840,500
Total Deficit to Design Year	430,900,000	611,020,000	658,170,000	492,740,000	496,340,000	476,036,600
Cost-Effectiveness						
Cost to Design Year per Passenger						
Total Cost to Design Year per Passenger	0.39	0.52	0.54	0.73	0.62	1.35
Capital Cost to Design Year per Passenger	0.10	0.14	0.13	0.41	0.29	1.04
Operating Deficit to Design Year per Passenger	0.29	0.38	0.41	0.32	0.33	0.31
Percent of Operating and Maintenance Cost Met by Farebox Revenue in the Design Year						
Total Transit System	62	53	49	59	58	60
Primary Element	56	54	41	88	86	74
Moderate Growth Scenario-Decentralized Land Use Plan						
Public Transit Ridership						
Passenger Trips per Average Weekday	217,400	256,700	245,100	234,700	231,600	--
Cost						
Total Cost						
Total Cost to Design Year	$542,926,370	$770,816,100	$785,265,880	$1,040,607,700	$ 900,128,990	--
Capital Cost						
Total Capital Cost to Design Year	124,606,570	180,135,500	182,522,880	583,822,300	407,051,590	--
Total Capital Investment to Design Year	186,198,500	286,385,500	334,665,700	1,127,632,600	733,648,700	--
Net Operating and Maintenance Cost (deficit)						
Total Deficit in Design Year	21,625,900	43,171,000	44,678,800	26,434,100	30,970,600	--
Total Deficit to Design Year	418,319,800	590,680,600	602,743,000	456,785,400	493,077,400	--
Cost-Effectiveness						
Cost to Design Year per Passenger						
Total Cost to Design Year per Passenger	0.44	0.59	0.60	0.84	0.73	--
Capital Cost to Design Year per Passenger	0.10	0.14	0.14	0.47	0.33	--
Operating Deficit to Design Year per Passenger	0.34	0.45	0.46	0.37	0.40	--
Percent of Operating and Maintenance Cost Met by Farebox Revenue in the Design Year						
Total Transit System	53	43	42	56	48	--
Primary Element	45	48	35	82	80	--
Stable or Declining Growth Scenario-Centralized Land Use Plan						
Public Transit Ridership						
Passenger Trips per Average Weekday	215,900	241,700	230,500	227,200	224,800	--
Cost						
Total Cost						
Total Cost to Design Year	$493,042,100	$708,108,800	$777,644,100	$1,019,763,000	$ 845,224,700	--
Capital Cost						
Total Capital Cost to Design Year	119,819,100	173,830,600	260,209,900	577,865,600	399,377,700	--
Total Capital Investment to Design Year	180,851,300	273,722,800	305,467,100	1,106,884,700	719,773,600	--
Net Operating and Maintenance Cost (deficit)						
Total Deficit in Design Year	15,988,800	36,120,700	34,015,200	24,573,100	25,066,800	--
Total Deficit to Design Year	373,223,000	534,278,200	517,434,200	441,897,400	445,847,000	--
Cost-Effectiveness						
Cost to Design Year per Passenger						
Total Cost to Design Year per Passenger	0.40	0.56	0.62	0.83	0.68	--
Capital Cost to Design Year per Passenger	0.10	0.14	0.21	0.47	0.32	--
Operating Deficit to Design Year per Passenger	0.30	0.42	0.41	0.36	0.36	--
Percent of Operating and Maintenance Cost Met by Farebox Revenue in the Design Year						
Total Transit System	61	45	45	53	52	--
Primary Element	49	35	22	82	77	--
Stable or Declining Growth Scenario-Decentralized Land Use Plan						
Public Transit Ridership						
Passenger Trips per Average Weekday	169,400	193,100	183,200	180,000	178,300	--
Cost						
Total Cost						
Total Cost to Design Year	$483,703,200	$688,398,600	$679,440,000	$1,016,911,000	$ 855,484,300	--
Capital Cost						
Total Capital Cost to Design Year	107,761,000	155,958,000	158,285,100	563,200,000	393,968,500	--
Total Capital Investment to Design Year	161,597,700	252,706,300	284,576,100	1,080,881,200	709,158,500	--
Net Operating and Maintenance Cost (deficit)						
Total Deficit in Design Year	16,328,700	35,891,000	34,480,300	26,049,800	27,025,400	--
Total Deficit to Design Year	375,942,200	532,440,600	521,155,000	453,711,000	461,515,800	--
Cost-Effectiveness						
Cost to Design Year per Passenger						
Total Cost to Design Year per Passenger	0.43	0.58	0.59	0.90	0.76	--
Capital Cost to Design Year per Passenger	0.10	0.13	0.14	0.50	0.35	--
Operating Deficit to Design Year per Passenger	0.33	0.45	0.45	0.40	0.41	--
Percent of Operating and Maintenance Cost Met by Farebox Revenue in the Design Year						
Total Transit System	54	45	39	45	44	--
Primary Element	49	27	19	79	67	--

Figure 6. Summary of evaluation of base system plan and truncated and composite primary transit system plans under moderate-growth scenario centralized land use plan.

Evaluative Measure	Alternative				
	Base Plan	Truncated Bus-on-Freeway Plan	Composite Commuter Rail Plan	Composite Light Rail Transit Plan	Composite Busway Plan
Objective No. 1—Serve Land Use					
Accessibility					
Average Overall Travel Time of Transit Trips to the Milwaukee Central Business District (minutes)	35	34	36	35	37
Objective No. 2—Minimize Cost and Energy Use					
Cost					
Total Public Cost to Design Year (capital cost and operating and maintenance cost deficit)	$579,742,000	$774,474,000	$781,156,400	$964,264,000	$883,375,000
Average Annual Total Public Cost	27,606,600	36,879,700	37,197,900	45,917,000	42,066,200
Capital Cost[a] and Investment					
Capital Cost to Design Year	148,840,000	222,980,000	214,551,000	435,845,000	347,468,000
Average Annual Capital Cost	7,087,600	10,618,100	10,216,700	20,754,500	16,546,100
Capital Investment to Design Year	233,328,700	341,200,000	374,573,200	833,951,200	626,992,700
Average Annual Capital Investment	11,110,900	16,333,700	17,836,800	39,711,900	29,856,800
Operating and Maintenance Cost Deficit (net cost)					
Deficit in Design Year	23,198,300	38,272,600	40,161,600	35,388,300	36,324,300
Deficit to Design Year	430,900,000	551,494,000	566,605,400	528,419,000	535,907,000
Average Annual Deficit	20,519,000	26,261,600	26,981,200	25,162,800	25,519,400
Cost-Effectiveness					
Total Cost to Design Year per Passenger	0.39	0.47	0.50	0.62	0.57
Capital Cost to Design Year per Passenger	0.10	0.14	0.14	0.28	0.22
Operating Deficit to Design Year per Passenger	0.29	0.34	0.36	0.34	0.35
Percent of Operating and Maintenance Cost Met by Farebox Revenue in the Design Year[b]					
Total Transit System	62	56	54	59	59
Primary Element	56	60	52	76	76
Energy					
Total Transit System Energy Use to Design Year (million (BTU's)	20,278,020	24,749,880	24,560,460	26,987,880	25,364,600
Total Transit Construction Energy Use to Design Year (million (BTU's)	1,498,400	1,914,560	2,414,100	3,940,730	3,321,680
Total Transit Operating and Maintenance Energy Use to Design Year (million BTU's)	18,779,620	22,835,320	22,146,360	23,047,150	22,042,920
Total Transit Energy Use per Passenger Mile to Design Year (BTU's)	3,329	3,007	3,229	3,376	3,172
Total Transit Passenger Miles per Gallon of Diesel Fuel to Design Year (BTU's)	40.9	45.2	42.1	40.2	42.9
Dependence on Petroleum-Based Fuel	All trips dependent	All trips dependent	All trips dependent	27 percent of transit trips not dependent	All trips dependent
Petroleum-Based Fuel Use by Transit to Design Year (gallons of diesel fuel)	134,355,000	161,649,000	158,861,000	143,383,000	155,551,000
Automobile Propulsion Energy Use in Design Year (gallons of gasoline)	404,800,000	388,800,000	397,600,000	395,200,000	396,000,000
Objective Nos. 3 and 5—Provide Appropriate Service and Quick Travel					
Average Weekday Transit Trips					
Total Transit System	326,800	378,600	366,100	374,600	372,900
Primary Element	15,000	75,100	46,300	145,100	134,900
Percent of Transit Trips Using Primary Element	4	20	13	39	36
Service Coverage					
Population Served Within a One-Half-Mile Walking Distance of Primary Transit Service	257,100	373,500	190,500	550,900	550,900
Population Served Within a Three-Mile Driving Distance of Primary Transit Service	1,012,400	1,620,700	1,428,200	1,685,600	1,685,600
Jobs Served Within a One-Half-Mile Walking Distance of Primary Transit Service	237,000	293,600	221,300	441,200	441,200
Average Speed of Transit Vehicle (mph)					
Primary Element	19	29	29	26	25
Total System	14	18	16	18	18
Average Speed of Passenger Travel on Vehicle (mph)					
Primary Element	25	34	30	27	26
Total System	15	21	18	20	20
Objective No. 4—Minimize Environmental Impacts					
Community Disruption					
Homes, Businesses, or Industries Taken	None	None	None	None	None
Land Required (acres)	12	70	90	210	200
Air Pollutant Emissions—Total Transportation System (Highway and Transit) in Design Year (tons per year)					
Carbon Monoxide	171,193	167,368	168,440	167,055	167,508
Hydrocarbons	17,361	16,887	17,025	16,853	16,905
Nitrogen Oxides	30,693	29,988	30,371	30,000	30,015
Sulfur Oxides	2,514	2,502	2,533	2,754	2,499
Particulates	4,086	4,018	4,046	4,032	4,019
Objective No. 6—Maximize Safety					
Proportion of Total Person Trips Made on Transit	0.074	0.086	0.083	0.085	0.084

[a] *The capital cost of a composite plan is equal to the plan's required capital investment, or total capital outlays necessary over the plan design period, less the value of that investment beyond the plan design period.*

[b] *Transit revenues were assigned entirely to the primary transit element for primary transit trips which used, through transfers, local or express transit as a feeder or distributor to the primary transit element. The proportion of trips using primary transit which transfers to or from local and express services was found to be highest under the commuter rail plan—1.2 transfers per primary trip—and lowest under the light rail transit and busway plans—0.4 transfer per primary trip. Under the bus-on-freeway plan, 0.7 transfer was made per primary trip. Consequently, to some extent a disproportionate share of transit revenues was assigned to each plans's primary element, this disproportionate share being the highest under the commuter rail plan and the lowest under the light rail transit and busway plans.*

Policy or Strategy Planning Is Difficult to Structure

Too often, the long-range, multiple-variable approach to alternative futures or scenarios, as carried forward in Milwaukee, becomes sufficiently complex to tax the comprehension of the typical political decisionmaker, if not the engineers and planners involved as well. The interrelationships of socioeconomic variables are intricate and not well understood, and their intermingling makes them difficult to analyze or discuss clearly (10). Because of this elusiveness and because of the diffi-

Figure 7. Summary of evaluation of base system plan, bus-on-metered freeway system plan, and lower tier of two-tier system plan under moderate-growth scenario centralized land use plan and stable or declining-growth scenario decentralized land use plan.

	Alternative					
	Base Plan		Bus-on-Metered Freeway Plan		Lower Tier of the Two-Tier System Plan	
	Optimistic Scenario	Pessimistic Scenario	Optimistic Scenario	Pessimistic Scenario	Optimistic Scenario	Pessimistic Scenario
Evaluative Measure	Moderate Growth-Centralized Land Use Plan	Stable or Declining Growth-Decentralized Land Use Plan	Moderate Growth-Centralized Land Use Plan	Stable or Declining Growth-Decentralized Land Use Plan	Moderate Growth-Centralized Land Use Plan	Stable or Declining Growth-Decentralized Land Use Plan
Objective No. 1—Serve Land Use						
Accessibility						
Average Overall Travel Time of Transit Trips to the Milwaukee Central Business District (minutes)	35	35	34	34	34	34
Objective No. 2—Minimize Cost and Energy Use						
Cost						
Total Public Cost to Design Year (capital cost and operating and maintenance deficit)	$579,742,000	$483,703,200	$722,873,900	$567,486,900	$812,880,000	$619,931,500
Average Annual Total Public Cost	27,606,600	23,033,500	34,422,600	27,023,100	38,708,600	29,520,500
Capital Cost						
Capital Cost to Design Year	148,840,000	107,761,000	214,323,900	160,906,900	306,300,000	217,931,500
Average Annual Capital Cost	7,087,600	5,131,500	10,205,900	7,662,200	14,585,700	10,377,700
Capital Investment to Design Year	233,328,700	161,597,700	329,729,600	229,867,300	470,700,000	364,526,300
Average Annual Capital Investment	11,110,900	7,695,100	15,701,400	10,946,000	22,414,300	17,358,400
Operating and Maintenance Deficit (net cost)						
Deficit in Design Year	23,198,300	16,328,700	32,904,700	20,158,500	32,658,400	19,481,200
Deficit to Design Year	430,900,000	375,942,200	508,550,000	406,580,000	506,580,000	402,000,000
Average Annual Deficit	20,519,000	17,902,000	24,216,700	19,360,900	24,122,900	19,142,900
Cost-Effectiveness						
Total Public Cost to Design Year per Passenger	0.39	0.43	0.46	0.50	0.52	0.54
Capital Cost to Design Year per Passenger	0.10	0.10	0.14	0.14	0.20	0.19
Operating Deficit to Design Year per Passenger	0.29	0.33	0.32	0.36	0.32	0.35
Total Public Cost to Design Year per Passenger Mile	0.10	0.11	0.09	0.12	0.10	0.13
Capital Cost to Design Year per Passenger Mile	0.03	0.03	0.03	0.03	0.04	0.05
Operating Deficit to Design Year per Passenger Mile	0.07	0.08	0.06	0.09	0.06	0.08
Percent of Operating and Maintenance Cost Met by Farebox Revenue in the Design Year						
Total Transit System	62	53	61	52	61	52
Primary Element	56	49	60	45	63	47
Energy						
Total Transit System Energy Use to Design Year (million BTU's)	20,278,020	15,037,280	22,305,100	16,120,900	23,213,700	16,551,300
Total Transit Construction Energy Use to Design Year (million BTU's)	1,498,400	1,044,480	1,840,100	1,335,200	2,414,700	1,875,800
Total Transit Operating and Maintenance Energy Use to Design Year (million BTU's)	18,779,620	13,992,800	20,465,000	14,785,700	20,799,000	14,675,500
Total Transit System Energy Use per Passenger Mile Traveled to Design Year (BTU's)	3,330	3,530	2,730	3,380	2,830	3,540
Total Transit Passenger Miles per Gallon of Diesel Fuel to Design Year (BTU's)	40.9	38.5	49.8	40.1	48.1	39.4
Dependence on Petroleum-Based Fuel	All trips dependent	All trips dependent	All trips dependent	All trips dependent	8 percent of transit trips not dependent	8 percent of transit trips not dependent
Petroleum-Based Fuel Use by Transit to Design Year (gallons of diesel fuel)	134,355,000	100,744,850	144,697,000	114,936,000	124,502,200	112,450,000
Automobile Propulsion Energy Use in Design Year (gallons of gasoline)	404,800,000	338,400,000	395,200,000	332,800,000	395,200,000	332,800,000
Objective Nos. 3 and 5—Provide Appropriate Service and Quick Travel						
Average Weekday Transit Trips in Design Year						
Total Transit System	326,800	169,400	371,300	176,000	372,900	176,300
Primary Element	15,000	9,500	75,100	22,500	96,300	34,200
Percent of Transit Trips Using Primary Element	4	6	20	12	26	19
Service Coverage						
Population Served Within a One-Half-Mile Walking Distance of Primary Transit Service	257,100	181,500	373,500	250,100	392,200	260,100
Population Served Within a Three-Mile Driving Distance of Primary Transit Service	1,012,400	698,800	1,620,700	933,167	1,300,000	930,600
Jobs Served Within One-Half-Mile Walking Distance of Primary Transit Service	237,000	194,600	293,600	253,100	309,300	260,200
Average Speed of Transit Vehicle (mph)						
Primary Element	19	24	29	27	29	27
Total System	14	15	18	17	18	17
Average Speed of Passenger Travel on Vehicle (mph)						
Primary Element	25	25	34	32	32	30
Total System	15	15	20	18	21	19
Objective No. 4—Minimize Environmental Impacts						
Community Disruption						
Homes, Businesses, or Industries Taken	None	None	None	None	None	None
Land Required (acres)	12	10	70	20	120	60
Air Pollutant Emissions—Total Transportation System (Highway and Transit) in Design Year (tons per year)						
Carbon Monoxide	171,200	165,800	167,400	163,100	167,300	163,100
Hydrocarbons	17,400	16,700	16,900	16,400	16,900	16,400
Nitrogen Oxides	30,700	30,100	30,000	29,200	30,000	29,200
Sulfur Oxides	2,500	2,400	2,500	2,400	2,600	2,400
Particulates	4,100	4,000	4,000	3,900	4,000	3,900
Objective No. 6—Maximize Safety						
Proportion of Total Person Trips Made on Transit	0.074	0.047	0.084	0.050	0.084	0.050

culty in showing direct ties to the specifics of choosing alternative transportation projects in a real-world, short-term setting, this policy or strategy approach to planning is difficult to integrate into the ongoing urban planning process. Though many can agree that high or low values for some of these key external factors certainly ought to be significant, it is difficult to show just how significant they are in comparing transportation alternatives.

Realities of Fiscal Constraints Now Dominate Planning

From all appearances, the 1980s will represent an era of austerity in urban transportation system investment, at least in comparison with the 1960s and 1970s. The well-known spiral of increasing costs and decreasing gasoline-tax-based revenues coupled with resistance on the part of the general public to increased taxation indicates that capital-intensive highway and transit plan alternatives now have less relevance. In many regions, consequently, more emphasis is now being placed on short-range, low-capital improvement alternatives. The differences among these alternatives in terms of potential service levels are less, and more interest is focused on cost and implementation and operational details.

Fiscal problems over the last few years in many regions have placed the solution of present volume and capacity problems via TSM-type measures in highest priority and urgency, with a consequent waning of interest in the distant long-range plan (11). Evaluation of alternative projects within transportation improvement programs (TIPs) has drawn increasing attention from decisionmakers in many regions (9).

Subarea or Corridor Planning Has Increased Emphasis

In the Dallas example, considerable interest in the definition of community-oriented service areas or corridors was shown by local decisionmakers. This reflected, in turn, their political affiliation with different communities and subareas within the region. Major local community interest in the potential of a regional transit system lay simply in the question, "What's in it for us?" Analyses of the different modal alternatives were consequently conducted on a corridor-by-corridor basis. Corridor travel needs were distinguished according to central-business-district, intracorridor, and between-corridor travel linkages. In general, such subarea planning emphases tend to become both facility oriented and shorter range in focus, further limiting the state of the practice for long-range planning.

Quick-Response Issue and Problem-Oriented Models are Needed

Partly as a result of this subarea emphasis and the fact that a fair number (5-15) of subareas are likely to emerge in any given region, travel analysis capabilities should offer quick turnaround features. The recent development of a number of such techniques has in fact addressed a continuing and perhaps growing need in the urban transportation planning process. However, the application of such techniques appears of less value in a long-range, regional planning sense than in a medium-range, corridor planning sense.

Focus on Transportation Systems Management Continues

The need to make more efficient use of existing facilities, mentioned above, will be important throughout the 1980s, particularly in slow-growth, stable, or declining regions. Even in growing sunbelt regions, the realities of fiscal constraint place equal emphasis on maximizing use of the current transportation systems (11,12). Better understanding of operating and maintenance costs, financing strategies, alternative revenue-generation techniques, and related fiscal matters all have a short-range character about them and are clearly management oriented in nature. They correspondingly call for less capability in travel analysis than may already be available in many regions. In this case, the current state of the art is adequate, and the state of the practice must now catch up.

SUGGESTIONS FOR CLOSING GAPS IN PRACTICE

How can practitioners make better use of travel-analysis technical capabilities that already appear methodologically adequate? A number of possible actions to be taken at federal, state, and/or regional or local levels include the following:

1. Reduce analyst and decisionmaker communication barriers: In too many cases, the breadth of content as well as technical complexity of long-range plan alternatives analyses are overwhelming to decisionmakers. Whether the latter are elected officials, appointed lay citizens, or staff representatives from local public agencies, too often the results of alternatives analyses are simply poorly communicated. A dual educational process may be needed, involving provision of both rudimentary background for decisionmakers and improved communication skills (oral, written, graphic) for planners and engineers.
2. Address inadequate funding problems: As transportation planning work programs for many regions respond to stable or possibly reduced budgets, the shifting priorities reviewed previously indicate that short-range planning activities are likely to receive increasing emphasis; reduced budgets will then remain for long-range planning (including many travel analysis activities). [NCTCOG now allocates only 10 percent of its budget to long-range planning (1).] These potential funding problems provide a basic real-world constraint, indicating that long-range or strategic planning must prove its value.
3. Short-range planning issues have long-range planning implications: One of the important components of current NCTCOG planning efforts involves an exploration of the long-range planning consequences of short-range, TSM-oriented low-capital solutions (2). Although such solutions are designed to solve immediate problems, particularly in growth regions, these problems ultimately often have serious long-range dimensions. Continuing short-range, interim-type solutions may prove inadequate, and such consequences must be more thoroughly addressed.
4. Stress quick-response, simpler travel analysis methods: This emerging environment for long-range and strategy planning suggests that those state-of-the-art capabilities that involve sketch-planning activities, oriented toward corridor or subarea geography and permitting the relatively rapid analysis of many potential transportation alternatives, will have carryover into short-range transportation planning as well. These more flexible travel analysis methods consequently can be of service across the board and should be emphasized.

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Research Needs

1. Freight study and goods movement (develop a reporting procedure for intercounty and intracounty motor carrier data consistent with Interstate data)

a. Specification of intercounty and intracounty data set
b. Contact of government and regulatory agencies to identify data currently being collected
c. Modification of existing procedures or development of new collection methods to obtain specified data

2. Addressing uncertainty in travel simulation models

a. Investigation of input forecasts
b. Quantitative study of uncertainty

3. Synthesis of techniques for planner communications

a. Survey that includes list and description of various techniques
b. Case studies and examples of each technique
c. Step-by-step discussion of how to use the techniques

4. Revenue forecasting

a. Examination of existing revenue-forecasting models, such as California's PYPSCAN
b. Examination of existing procedures for estimating local government revenue and expenditure patterns for transportation
c. Development of logic for multimodule forecasting model capable of accepting a range of exogenous inputs (national and international) and capable of allocating revenues to programs, agencies, and local governments under alternative allocation or apportionment formulas
d. Preparation of manuals and review with sample of states to ensure workability
e. Preparation of microcomputer programs to perform the calculations
f. Deal with uncertainty by multiple runs of programs under alternative assumptions and by regular (every quarter-year) rerunning of programs

5. Communication with decisionmakers

a. Uncertainties: interview of decisionmakers to identify areas of dissatisfaction in transportation planning with emphasis on
(1) Understanding techniques used by planners
(2) Determining whether planners provide useful information
(3) Determining whether there are any concerns not addressed by planning staff
b. Communication techniques: improved techniques, especially
(1) How to describe the interaction of various factors, their impact on transportation, and the decision points and risks
(2) Effective ways to present relevant data
(3) Effective ways to measure and explain performance

Workshop on Quick-Response and Sketch-Planning Methods

Workshop Summary

GRANVILLE E. PAULES, Federal Highway Administration

This workshop covered planning methods that can be applied in a quick response to decisionmaking. Such procedures are also called sketch-planning techniques. Background papers by Arthur Sosslau and George Schoener summarized the state of the art and the state of the practice, respectively.

Quick-response techniques were defined as those techniques that support the required decisionmaking time frame within the given cost and staff resource constraints. These techniques may be manual, stand-alone, microcomputer based, or subsets of larger computer systems (e.g., UTPS). As such, these techniques represent more than just those documented in NCHRP Report 187, Quick Response Urban Travel Estimation Procedure and Transferable Parameters. Table 1 provides an overview.

Table 1. Techniques and applications areas.

Technique	Application Area: Regional	Corridor or Subarea	Project
Computerized			
Conventional models			
UTPS	X	X	X
PLANPAC/BACKPAC	X	X	X
NAG (network aggregation)	X	X	
CAPM (sketch planning)	X		
SCAGM (small city gravity model)	X		
DRAM/EMPAL (land use)	X		
Windowing or focusing	X	X	
Air-quality analysis	X		
FREQ (freeway operations)	X	X	
Carpool-matching programs	X		
Noncomputerized			
NCHRP Rept. 187			
Four-step (quick response)	X	X	X
Site impact		X	X
Corridor diversion		X	
Energy-conservation estimation	X	X	X
Air-quality analysis	X	X	X
Manual of planning for your community	X	X	X
AASHTO Red Book (user-benefit analysis)			X
Pivot point (corridor mode choice and route diversion)		X	
Land use and arterial spacing		X	
Planner-aids case studies	X	X	
Macrolevel manual		X	
Parking-management handbook	X	X	
Sampling			
Ground-count factoring	X	X	X
Design of small-sample home-interview travel surveys	X		
Statewide manual (sampling techniques)	X		
Automobile on-board surveys	X	X	
Transit on-board surveys	X	X	
External cordon (O-D manual)	X	X	
1980 Census	X	X	
VMT or PMT sampling	X	X	
Reasonableness checking			
Characteristics of Urban Transportation Systems (CUTS)	X	X	X
Characteristics of Urban Travel Demand (CUTD)	X	X	X
Traveler response to transportation system changes	X	X	X
NCHRP Report 187 (defaults)	X	X	X
ITE trip generation	X	X	X
FHWA trip-generation analysis manual, 1975 (Appendix E)	X	X	
Friction factors	X		

Quick response does not necessarily imply less detail. That is, the techniques may be applied across all the various planning contexts (i.e., strategic, project, urban, microscale, and system operations); the level of detail increases when a change is made from strategic to system operations. Also, quick-response procedures may be applied as part of an on-line planning effort or may be used to evaluate the reasonableness of previously conducted studies. These procedures may be viewed as giving planners relative control of the planning environment. In the ultimate, for computerized approaches, the planner interacts directly with the computer and receives a response to an inquiry almost immediately. The output is generally provided in a format that may be easily interpreted by decisionmakers. The quick-response concept generally applies in sketch-planning situations but may apply as well in situations normally viewed as requiring many variables and detailed data.

Sketch-planning techniques are defined as those techniques useful in screening a large number of alternatives. They may involve but are not limited to quick-response procedures. In these techniques, the number of variables and the precision involved are adequate to eliminate most alternatives that are not cost-effective. The remaining alternatives require more refined analysis.

Methods are structured to permit parametric sensitivity analyses and thus test the importance of modeling assumptions and data quality and aid in establishing bounding values for major decision variables. In addition, such methods often exploit common data bases.

Besides the objective of screening out impractical alternatives, the techniques should provide insights into the following areas:

1. The interaction among variables in single-objective scenarios,
2. The interaction among objectives in multiple-objective scenarios,
3. The definition of alternatives for more detailed study,
4. The identification of other data needs, and
5. The assumptions where uncertainty must be reduced.

Sketch-planning techniques may also be manual, stand-alone, microcomputer, or subsets of larger computer systems, e.g., UTPS.

The workshop reviewed the use and applications of quick-response techniques to each of the five levels of planning. Their findings are as follows.

Strategic and long-range systems planning are intended to monitor surveillance and trend analysis, anticipating problems. Planning at this level reviews objectives and broad priorities, develops measures and indicators of success, responds to unexpected changes in the environment, retains close-out future options, and reviews major policy alternatives. It is generally large in geographic area and comprehensive in scope; it extracts essential factors from relevant areas. These include demographics, economics, urban development, transportation and land use, travel demand, technology, and institutional or intergovernmental structure. Long-range planning also provides information to support project planning, such as interaction effects between projects.

Quick-response methods applicable to long-range and strategic planning include what-if scenario testing and pivot-point methods. NCHRP Report 187 on land use and arterial spacing and transit corridor analysis are other examples. These are commonly used by planning agencies, MPOs, operating agencies, and transportation and/or land use planners.

The status of quick-response methods is quite advanced. Sound conceptual basis exists for the methods, and demonstrated examples are available. However, packages are not available for general use, although some demand-oriented information has been disseminated.

Project planning focuses on major capital-intensive transportation proposals analyzed in comparison with alternatives involving less capital investment or no action at all. The scale is generally travel corridors or subareas; the planning process is oriented to making a final decision on a transportation action rather than studying long-range strategies and/or plan development.

The time horizon depends on useful life of the major capital investment alternatives and is usually quite short. Land use and demographics are generally prespecified rather than a consideration of options, and cost and evaluation methods are needed as well as demand-estimation techniques.

Quick-response methods (see paper by Sosslau in this Report) are more applicable to project planning than to the other context areas. Strong conceptual basis exists and demonstrated examples are readily available, although more are needed. Some packages are available for general use, and information has been partly disseminated.

Urban-microscale planning focuses on subareas. The planning process may appear as project planning, which has capital investment components, or may focus on system operations. Though land use decisions may be involved, the change in land use in the subarea is presumed to have little impact on the overall region. Institutional and jurisdictional interactions may require resolution. Some microscale planning is done by state departments of transportation or regional agencies, although more likely by a local agency most directly affected by the outcome.

The status of quick-reponse techniques is quite limited. Although conceptually such methods are possible, very few have been demonstrated and fewer still have been packaged for general use. Research needs identify concerns for development.

In system operations, studies usually have a non-capital-intensive outcome, although many affect a variety of local rules, regulations, and procedures. These studies may involve a number of jurisdictional units and institutions, and results often appear in the implementing agency's operating budget for the year. Procedures normally involve considerable detail.

The status of quick-response methods is similar to that of microscale planning.

Quick-Response and Sketch-Planning Techniques: State of the Art

ARTHUR B. SOSSLAU, Comsis Corporation

Urban travel analysis procedures historically have been designed to evaluate regional transportation systems and to provide design volumes. These activities, being broad in scope and involving many steps, usually did not require what might be referred to today as quick-response analysis time frames. As a matter of fact, the use of the computer along with the tools developed resulted in what might be considered quick response for activities such as regional systems analysis for freeway systems.

Times change, however, and emphasis in transportation planning has been changing. Use of regional methods, modifications to these, or adaptation of computer approaches to a myriad of applications usually does not result in quick response or the most appropriate approach. Today more than ever there is a need for methods designed to aid in making quick-decision trade-offs on projects. There is also a need to screen alternatives quickly and efficiently so that more detailed analysis can be more effectively concentrated on the most feasible transportation improvement proposals. Local planners need to analyze the transportation impacts of new developments (site-impact analysis). Interest is being centered more often on corridors and subareas rather than on a regional level. The effects of development and growth on the arterial system must now be evaluated by transportation planners.

I will try to address the state of the art as it pertains to quick-response planning techniques. This will cover planning methods that can be applied in a quick-response manner to the decisionmaking process. The remainder of the paper will address

1. What quick response is,
2. What some examples of currently available methods are,
3. Taking advantage of current technology, and
4. Conclusions and recommendations.

WHAT IS QUICK RESPONSE?

From my perspective, quick response is a frame of mind. One needs to take one's head out of the sand, the sand being represented by the large mainframe computer and travel-forecasting models that have been applied in regional analysis. UTPS and PLANPAC have their place and for some work offer quick response. However, the quickest response to a project is not always a model and a computer. The range of quick response includes, on the one hand, the planner, who, based on years of experience and know-how, can judge pretty reasonably the consequences of a proposal. The World Bank, as an example, has developed and will continue to develop decisions on a multi-million-dollar public work project based on experienced judgment. At the other end of the scale, a two-year, computer-based modeling process may be the quick response to a project such as the analysis of alternatives for a multi-billion-dollar subway system in Washington, D.C.

Quick response and sketch planning have also been used interchangeably by many. Sketch planning usually connotes quick first evaluations of urban transportation proposals and as such is quick response. However, a quick-response technique may well be the only tool used in a planning activity since it turns out to be the appropriate tool for a given need. The idea that quick response is a frame of mind has a lot of aspects to it. Some wish to study everything with a degree of detail that reduces error and increases accuracy. The interest no doubt is to reduce risk to the lowest possible level that can be provided by available methods and technology, regardless of the type of project, time available, or appropriate expenditure of planning funds.

A major impediment, I believe, to the changing of the frame of mind is the long-term institutionalized, prepackaged, well-documented and marketed transportation analysis packages made available to the profession (PLANPAC, UTPS). Such institutionalization of capabilities takes time to overcome. In addition to the effect of this on the professional planner, the decisionmaker and the public have been sold on the traditional model process exemplified by computer printout. They equate credible analysis with traditional model output. The current emphasis by UMTA and FHWA to use the method best suited for a study and to simplify planning approaches will take time to be fully accepted. Training courses, users' guides, and other material should help in this process.

It is quite evident that historically used planning procedures are often inappropriate to permit an analytical response to decisionmakers within desirable time and cost constraints. What is needed are simplified planning methodologies that are easy to understand, relatively inexpensive to apply, and, above all, responsive to the policy issues of the day. Typical improvements to conventional planning procedures might include the following:

1. Avoiding total dependence on complex multipurpose computerized models and instead using manual estimation techniques;
2. Reducing or even eliminating large-scale data-collection and forecasting efforts by utilizing readily available data, transferable parameters, or synthetic models;
3. Improving data-collection procedures to reduce the time and costs to obtain the information desired;
4. Analyzing regional plans at the district level rather then the zonal level and/or focusing planning efforts to corridors and subareas;
5. Using shorter-range forecasts; and
6. Utilizing available technology, such as microcomputers and digitizing and plotting capabilities, to best advantage.

It is difficult to arrive at a distinct and unambiguous definition of quick-response travel estimation techniques. For discussion purposes, quick-response techniques may be defined as those that can provide transportation-related outputs with the minimum of input resource requirements within a short time as compared with standard urban transportation-planning batteries such as UTPS and PLANPAC.

In general, techniques in which extremely detailed networks, large numbers of zones, and calibration of trip-generation, trip-distribution, mode-choice, and trip-assignment steps are required are not considered to meet the quick-response criteria, whereas techniques requiring less detail do qualify. It is of course recognized that UTPS and PLANPAC can be employed to provide quick response under proper use for certain applications.

QUICK-RESPONSE TOOLS

A summary of some available methods will help define appropriate applications, the approach taken, and perhaps indicate needed advancements. The approaches to be described include

1. Manual methods and transferable parameters [NCHRP Report 187 (1)],
2. Pivot-point methods developed by Cambridge Systematics (2),
3. Land use and arterial-spacing methods originally developed by Gruen Associates (3),
4. Critical movement summation (CMS) for intersection capacity analysis (4),
5. Transit corridor analysis (5), and
6. Automobile use studies as alternatives to home-interview surveys.

Table 1 summarizes this information.

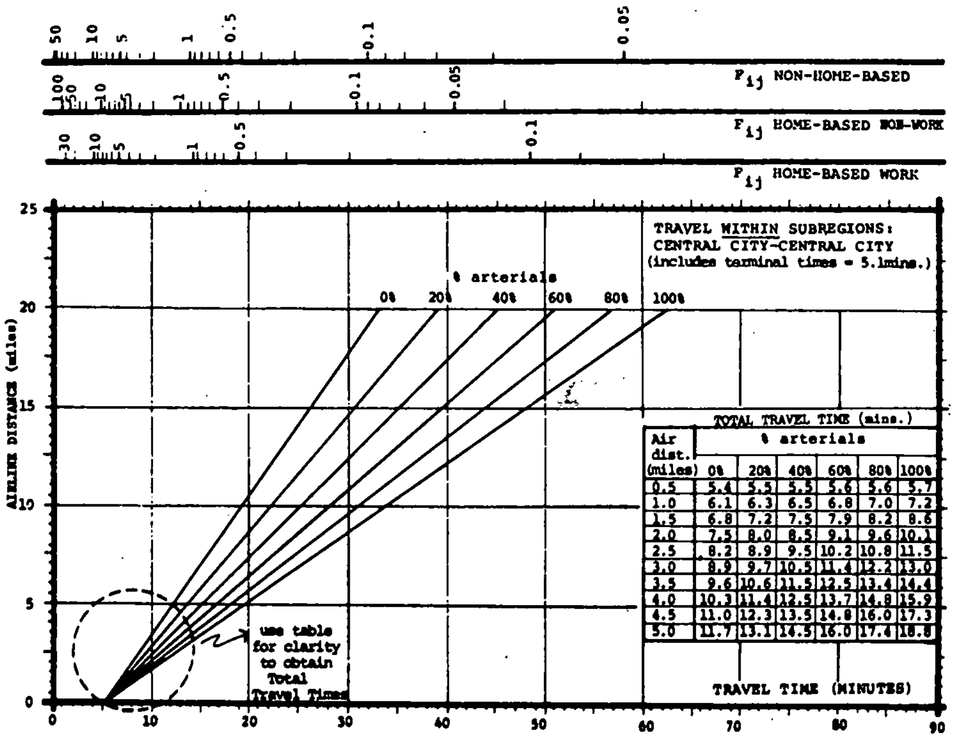
Manual Methods and Transferable Parameters

NCHRP Report 187 (1) was published in 1978 and has

Table 1. Application areas for quick-response tools.

	Area				
Tool	Strategic Planning	Long-Range Systems Planning	Project Planning	Urban-Microscale Planning	Systems Operations
NCHRP Rept. 187 (1)	X	X	X	X	
Pivot-point method (2)		X	X		
Land use and arterial-spacing method (3)	X	X			
Critical movement summation (4)					X
Transit corridor analysis (5)		X	X		
Automobile use survey			X		
Downtown circulation (6)			X		
Small-urban-planning manual (7)	X	X	X	X	X
RIDE computer program (8)			X		
Transit options for small communities (9)			X		
Dual-mode sketch			X		
Transportation Network Evaluation System (10)			X	X	X
Microcomputer programs for transit operations			X		X
Simplified Aids for Transportation Analysis (11)	X		X		
North Central Texas Council of Governments TSM planning document (12)			X	X	X
Massachusetts Institute of Technology hand-held calculator methods (13)				X	X

Figure 1. Examples of quick-response nomographs.



TOTAL TRAVEL TIME (mins.)

Air dist. (miles)	% arterials 0%	20%	40%	60%	80%	100%
0.5	5.4	5.5	5.5	5.6	5.6	5.7
1.0	6.1	6.3	6.5	6.8	7.0	7.2
1.5	6.8	7.2	7.5	7.9	8.2	8.6
2.0	7.5	8.0	8.5	9.1	9.6	10.1
2.5	8.2	8.9	9.5	10.2	10.8	11.5
3.0	8.9	9.7	10.5	11.4	12.2	13.0
3.5	9.6	10.6	11.5	12.5	13.4	14.4
4.0	10.3	11.4	12.5	13.7	14.8	15.9
4.5	11.0	12.3	13.5	14.8	16.0	17.3
5.0	11.7	13.1	14.5	16.0	17.4	18.8

Figure 8. Airline distance vs travel time vs distribution factors, by trip purpose (central city to central city), in urban area of 50,000-100,000 population.

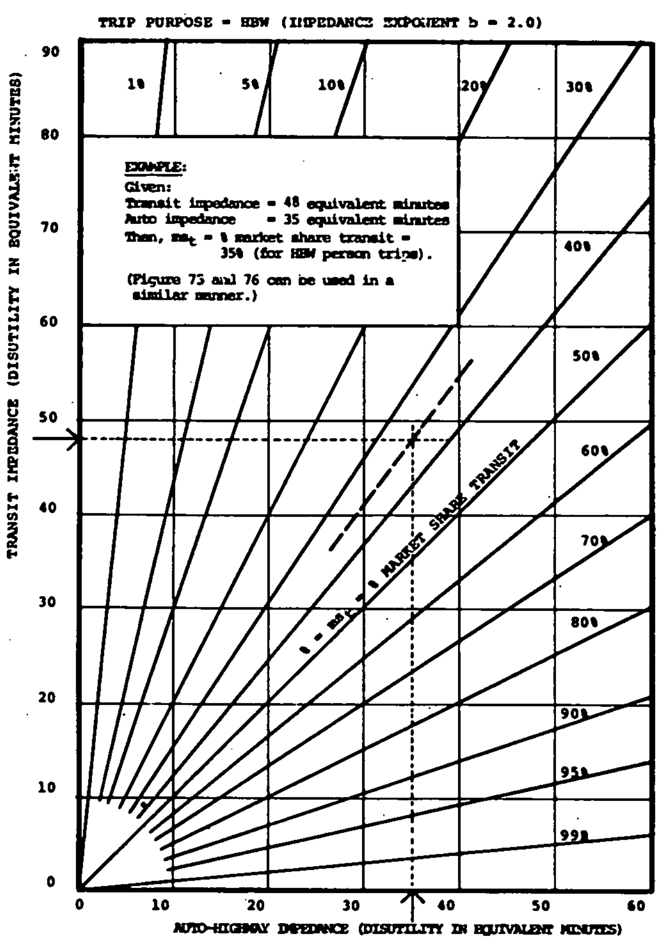


Figure 74. Mode-choice model nomograph: trip purpose, HBW.

received wide acceptance in the United States. A large number of reports have been distributed, some 6300 copies, and close to 1000 persons have been trained in FHWA-sponsored workshops.

This approach parallels the standard four-step transportation-planning elements of trip generation, trip distribution, mode choice, and trip assignment. The manual elements are very similar to procedures used by most transportation planners. Several shortcuts are included, however. To cite a few, networks are not coded, calibrations are eliminated through use of selected parameters from past studies, input data are minimized by providing estimates from nomographs [see examples in Figure 1 (1)], and the level of application effort has been minimized through the provision of step-by-step instructions and simplified work sheets. In addition to the four-step components, transferable parameters are provided for the analysis of automobile occupancy, the determination of directional distribution of traffic by time of day, and the analysis of highway volume and capacity.

All these techniques were developed in such a manner that each would be applied independently of the others, yet the techniques could be combined to operate interdependently. Except for the typical demographic and socioeconomic input data, such as population and household income and general transportation system descriptions on a map, the user can operate these procedures without reference to other sources and with nothing more sophisticated than a hand-held electronic calculator.

It is intended that a transportation planner or analyst with a 2- to 3-year level of experience be able to apply the techniques contained in the User's Guide. It is possible to train a technician to use portions or all of the methods. Ideally, the procedures are most suitable for small-scale transportation projects or localized land use impacts. Specific projects might include the evaluation of system needs within a single corridor, the assessment of impacts of a transit route extension, or increased frequency of transit service. The manual techniques have been designed to also adequately address the traffic impacts of a proposed major development on the surrounding street system.

The techniques also provide the capacity to conduct transportation analysis at the regional level. If a regional analysis is contemplated, it is recommended that the number of analysis areas (zones) be limited to allow application within a reasonable time frame.

The manual methods have proved to be manageable in application, and it is possible to produce reasonable results quite rapidly for many applications, as will be described by George Schoener in his state-of-the-practice paper. To exemplify, the transit demand potential on a single route was estimated in a few hours; spacing requirements based on alternate land development policies were determined within 2-3 days. Further, the transportation impacts of a major residential site were calculated within a week, and a proposed improvement in a corridor was evaluated in about the same time. These findings confirm the quick-response capabilities of the manual procedures developed.

In order to fully realize the potential of the manual techniques, it is necessary that the user or planner modify conventional ideas about the planning process. First, it must be understood that since the manual methods provided are quick and simple, clerical and technical help can be substituted for the computer and computer specialist. Therefore, manual analysis can be very cost-effective. Also, it is anticipated that in most cases, through application of the methods, the user would acquire a deeper understanding of the circumstances surrounding the problems than if all comparable work was done by computer. Consequently, his or her ability to present the process and results clearly to elected officials and the public would be enhanced. Finally, and most importantly, the manual approach stresses simplicity rather than precision in its application and output. This in turn renders manual techniques flexible and versatile, which is a positive benefit over the rigidity and complexities of computerized transportation planning. The manual methods, however, are not offered as a replacement for the computer models but rather as an extension of existing analysis techniques.

Pivot-Point Methods

A set of guidelines for travel demand analyses of programs promoting carpools and the like (2) was developed by Cambridge Systematics for the Federal Energy Administration.

Based on travel behavior and observed responses in demand, the procedures provided forecast likely changes in travel patterns that would occur in an area and take into account both the attractiveness of alternative travel possibilities and the household and travel characteristics of potentially affected travelers. Specifically, estimates are produced of revised modal shares for driving alone, shared ride, and transit; changes in carpool size and automobile occupancy; and reduction in vehicle miles of travel for alternatives defined. The estimates are made relative to a known set of modal shares based on either measured current conditions or a forecast, hence the term pivot-point method.

The procedures have been designed to satisfy the following criteria:

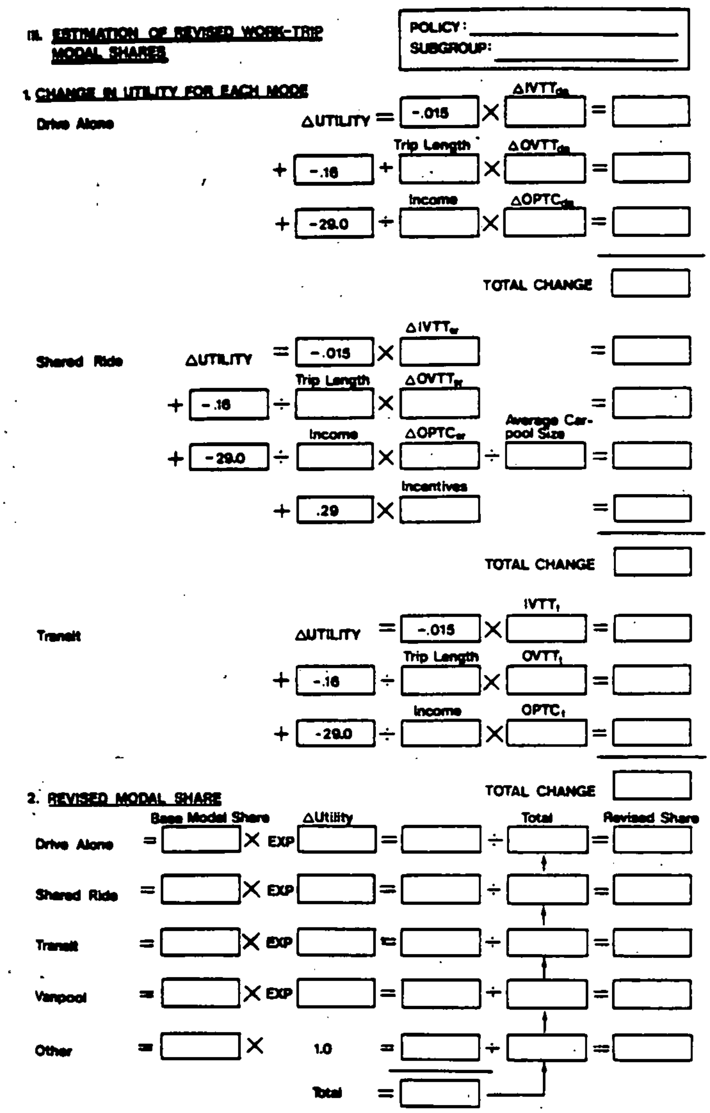
1. To provide a reasonably accurate estimate of changes in travel demand;
2. To require modest data requirements;
3. To involve low set-up and analysis costs;
4. To be adaptable to alternative levels of data, time, and funding availability;
5. To not require a computer;
6. To be adaptable to a wide range of urbanized areas and policy types;
7. To be capable of application to different geographic scales of interest (e.g., facility, corridor, areawide); and
8. To be able to analyze differential effects of program measures on various population groups.

Utilization of the work sheets normally requires only a few hours of data collection and calculation; information on travel patterns and socioeconomic characteristics readily available in most urban areas is used.

The approach achieves its simplicity by predicting revised travel behavior (e.g., a shift from drive alone to shared ride) based on data describing both existing travel behavior and changes in transportation level of service rather than employing a full set of travel demand models to recalculate modal shares based on detailed household, traffic-zone, and level-of-service data. By employing an incremental approach in which travel-demand coefficients are used to pivot about an existing situation, data requirements are greatly reduced, detailed socioeconomic and level-of-service data for each traffic zone or household are not required, and costly model development and validation are eliminated. Only estimates of existing modal shares and proposed changes in the transportation level of service for any given program are necessary.

To account for potential differential character-

Figure 2. Work sheet for pivot-point method.



istics of program measures, the relevant analysis population can be divided into a number of discrete classes or subgroups in order to achieve a higher degree of homogeneity within each group analyzed. For each classification, estimates of revised travel patterns are made by using estimated base modal shares and level-of-service changes for that particular group. A sample work sheet is shown in Figure 2 (2).

The pivot-point approach uses a logit mode-choice model to examine incremental changes in modal shares as a function of changes in modal levels of service from an existing or base condition (pivot point). The model is based on a logit mode-choice model calibrated on Washington, D.C., data.

Comsis Corporation recently accomplished some work for the Puget Sound Council of Governments (PSCOG) to evaluate transportation control measures for the Puget Sound region. The pivot-point method was used to evaluate some 138 possible control measures in a quick-response environment. This study used a pivot-point procedure developed from the PSCOG logit model (transferred from Twin Cities).

Land Use and Arterial Spacing

A technique developed by Gruen Associates has proved useful in evaluating the impact of a proposed traffic generator (e.g., shopping center, industrial park, airport) on the highway system surrounding the development (3). The procedure can also be used to estimate arterial requirements in developing suburban sections of metropolitan regions where growth potentials offer a broad range of planning opportunities.

Figure 3 (1) shows the first step, an initial approximation of average traffic volumes, which is item adjusted by factors [Figure 4 (1)] based on

1. Density and project size,
2. Level of service,
3. Automobile ownership,
4. Transit utilization,
5. Project and nonresidential and residential mix, and
6. Freeway diversion.

The average number of lanes and the spacing required are obtained from an estimate of gross subregional density in residents per square mile.

Intersection Capacity Analysis

A planning technique that has found good acceptance

Figure 3. Chart for subregional density versus average volumes and lane requirements for arterials.

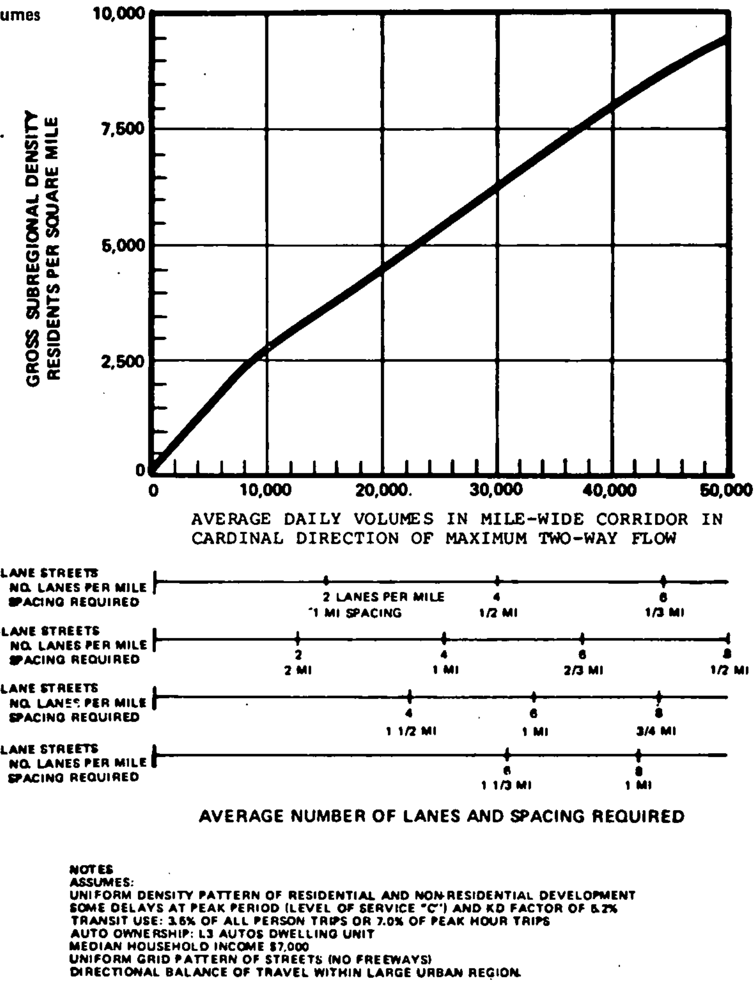


Figure 103. Chart for subregional density vs average volumes and lane requirements for arterials (1).

is the CMS technique developed by McInerney and Peterson (4). This method is used to accomplish intersection capacity analysis quicker and more appropriately for planning purposes than those more detailed procedures appropriately used for design and analysis by traffic engineers. The procedure is a good one for determining which intersections pose a capacity problem and should perhaps be studied by more detailed methods. The technique has been adopted by many local and regional planning agencies for use in development impact studies and to review traffic assignment results at major intersections. The technique does not actually calculate intersection capacity but instead calculates a critical intersection volume and compares that volume against a benchmark intersection capacity that is stratified by level of service.

This technique defines the critical movement volume as (1) "the volume of travel represented by the highest lane volumes of opposing travel (through and left turn) from both the north-south and the east-west directions that occurs during the peak-hours." Figure 5 (1) shows the procedure.

Transit Corridor Analysis

The UMTA manual Transit Corridor Analysis: A Manual Sketch Planning Technique (5) describes a sketch-planning technique for quick first evaluation of urban transportation planning proposals that is accomplished manually (without computer use). It presents the computational steps, which rely heavily on graphic aids. The technique is useful in the analysis of short- and long-range plans for urban line-haul transit systems.

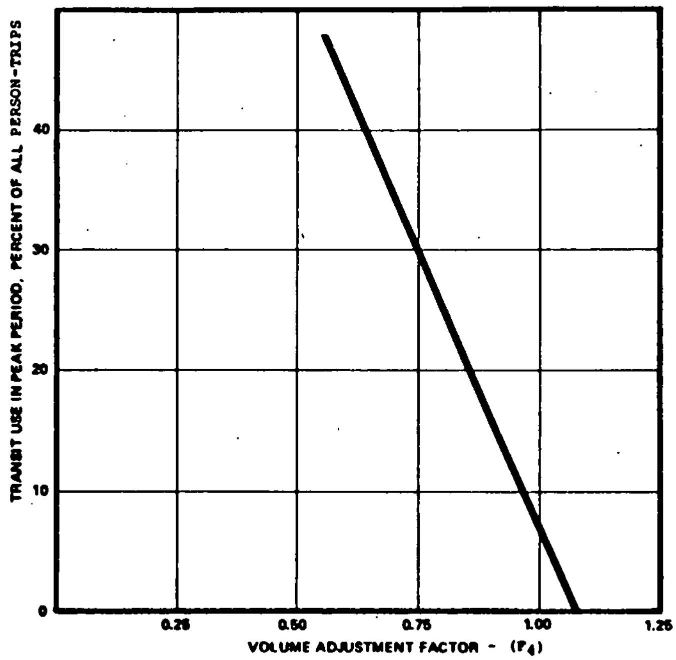
The technique's three modular phases include demand estimate, cost analysis, and impact analysis. The procedure estimates corridor transit trips only. If intercorridor transit trips are a large portion of total regional travel, special attention is required in the trip-distribution phase. The manual technique is used to analyze line-haul modes, including local or express bus, bus rapid transit, light rail transit, rail rapid transit, and commuter rail.

After the identification of the transportation issues and objectives, the first task for the user is to subdivide the region of interest into appropriate travel corridors and districts reflecting homogeneous land uses and predominant desired lines of travel.

The number of districts (about 50-100 regionally) to be used will depend on the level of aggregation of existing data, the number and configuration of travel corridors, and the constraints imposed by the computational effort required. Data assembly, to proceed concurrently with corridor and district delineation, should be relatively simple and should take no longer than a few days.

Following the first two tasks is the estimate of travel demand for the region as a whole and for each district. Subsequently, mode-choice and travel-allocation procedures produce comparative estimates of peak ridership volumes by transit facility.

Figure 4. Adjustment factors for land use: arterial spacing procedure.



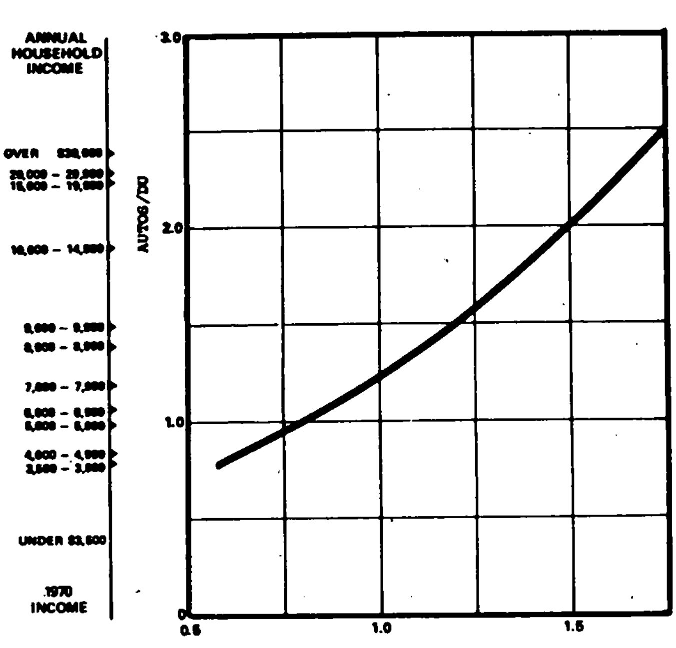
NOTES:

Assumes peak-period transit use of 7% for base condition.

Peak-period transit use of 7% is equivalent to 3.5% of all daily person-trips.

If any adjustment factor of under 0.85 is obtained from above, do not apply an adjustment factor from Figure 107 unless factors are determined to be independent.

Figure 106. Chart for adjustment factor, F_4, for transit utilization (1).



NOTES:

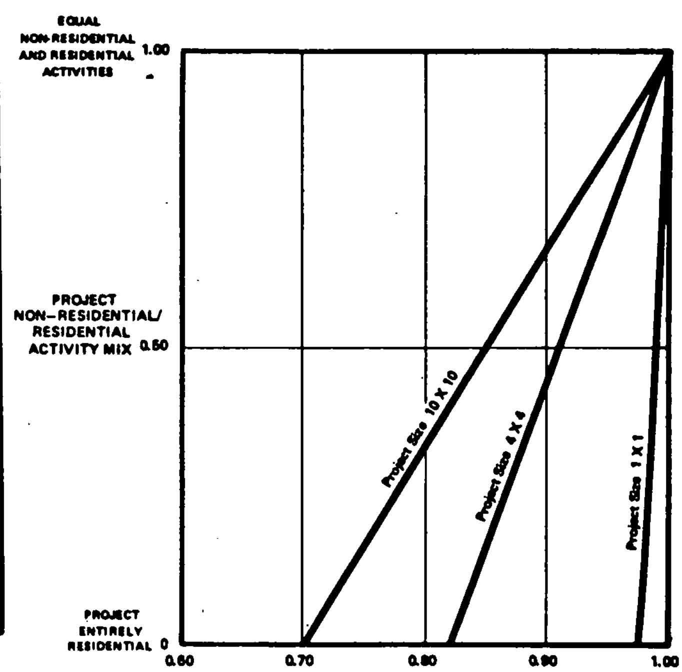
Use autos/DU as the primary parameter for volume adjustments.

Use income scale for approximation only if autos/DU data not available.

Income scale is non-linear.

See Figure 106 note concerning combined use of Figures 106 and 107.

Figure 107. Chart for adjustment factor, F_5, for auto ownership and household income (1).



NOTES:

Assumes uniform density pattern of residential development and project containing residential plus nonresidential development.

Assumes uniform grid pattern of streets (no freeways).

Assumes directional balance of travel in large urban region.

Project nonresidential/residential activity mix is defined as the number of jobs provided within project, divided by labor force within project.

For predominantly nonresidential projects (i.e., activity mix greater than 1), use of trip generation tables in Chapter 2 are recommended instead of Figure 108.

Figure 108. Chart for adjustment factor, F_6, for project nonresidential/residential activity mix (1).

Figure 5. Example of critical movement summation.

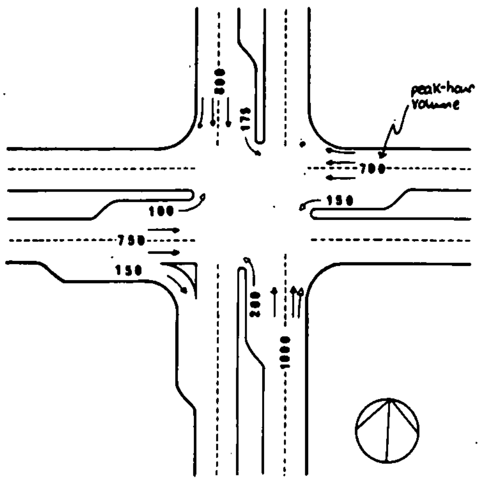


Figure 116. Traffic data for intersection capacity analysis.

1. Determine the net approach volume (through volume) and multiply by the appropriate lane-use factor to obtain lane volume. (If lane volumes are available this step is not necessary.) Thus, with reference to Figure 116, this step would yield the following results:

DIRECTION	NET APPROACH VOL.	LANE-USE FACTOR	LANE VOLUME
Northbound	1,000	0.55	550
Southbound	800	0.55	440
Eastbound	750	0.55	413
Westbound	700	0.55	385

2. Determine the critical lane volume for each approach as follows:

	N-BOUND	S-BOUND	E-BOUND	W-BOUND
Through volume	550	440	413	385
Opposing left-turn volume	175	200	150	100
Total	725	640	563	485

3. Select maximum of N-S volumes and E-W volumes and sum to determine Critical Movement Summation (CMS).

CMS = Northbound + Eastbound
CMS = 725 + 563
CMS = 1,288 vehicles

4. Compare CMS to volume ranges given in Table 49 to determine intersection operating service level.

Thus, from Table 49, the user can conclude that the intersection described by Figure 116 is operating at level-of-service "D."

TABLE 49

INTERSECTION CAPACITY BY LEVEL OF SERVICE

LEVEL OF SERVICE	RANGE OF CAPACITY (VPH) LOW	HIGH
A	0	900
B	901	1,050
C	1,051	1,200
D	1,201	1,350
E	1,351	1,500
F	(Special case)	1,500

Having obtained appropriate line volumes for each transit line, the user then proceeds to the physical and annualized cost analysis and environmental-impact phases. These parts of the analysis are performed on a facility-by-facility basis; however, the interaction between each facility and the entire transit system is considered at the same time.

After the initial estimate of physical parameters and costs of the proposed system, the graphic techniques employed permit simple use in a backward-seeking mode. This supplies design guidance in dealing with such questions as the impact of changes in operational costs or the adjustment of fleet size requirements. In addition, the nomographs facilitate the performance of rough sensitivity analyses.

Finally, the modular design of the technique is meant to allow the user flexibility in the evaluation of the alternatives. The flexibility is reflected in the user's freedom to substitute his or her own data and techniques at various steps. The user might already have reliable demand estimates, in which case he or she can proceed directly to the physical and cost analysis in the evaluation phases. Or, at a level of finer detail, the user might provide his or her own values for certain parameters rather than the default values of the technique. Sensitivity tests, as for the effects of increased fares or travel speeds on transit patronage, can easily be made through the modular structure of this technique. Additional testing can explore the impact of uncertainties in assumed performance or cost estimates.

Automobile Use Study

The idea of quick response and more timely and cost-effective procedures reaches into the area of data collection also. We are generally tied by tradition, experience, and institutions to procedures of the past. This is true to a large degree for home-interview origin-destination studies. Few have been conducted lately due to the high cost and the time to complete. Those that have usually are of a small sample size and still take a long time to complete.

An alternative to the home-interview survey that is less costly and more timely (quick response) has been successfully implemented in several areas, including Atlanta and Washington. This has been termed an on-board automobile survey (automobile use survey). The on-board automobile survey is appropriate to determine trip-generation characteristics, trip-length frequencies, trip purposes, and so on. Coupled with an on-board transit survey, it provides required information for mode-choice analysis. In addition to information on trip characteristics, the on-board automobile survey measures vehicle use.

The on-board automobile survey combines telephone interviews with a vehicle trip log for each automobile in a selected sample. The telephone inquiry solicits household participation and gathers basic socioeconomic information. Sampling is by household; all vehicles in a selected household are part of the survey.

For automobile trip data, a vehicle log should be sent for each automobile owned or garaged at the household and for each truck used for personal travel. The vehicle log should be completed for a given 24-h survey day. The survey day and date should be entered on the forms sent as well as the household address. Also, if vehicle information (make, model, year, etc.) is requested in the telephone interview, this should be entered on each form sent to the household.

The log data for each vehicle in the survey should be limited to the following basic trip information:

1. Starting and ending odometer reading for each trip,
2. Starting and ending time of each trip,
3. Purpose of each trip (plus home-based or non-home-based identifier), and
4. Number of people in vehicle (household members and non-household-member passengers) for each trip.

A trip for the purpose of the survey is defined as the movement of the vehicle between two points, in which a driver or passenger enters or leaves the vehicle at one of the points.

As may be noted, information is not obtained with regard to the location of the origin or destination of the trip. This attribute of the technique as well as the minimal interviewer time involved are the major contributors to the low cost per survey. Since the primary focus of the procedure is model improvement or monitoring of trip length and trip rates, geocoding of the observed trips is not necessary. It is suggested, however, that the household address be coded to some geographic system.

Other Quick-Response Tools

There are numerous other examples of what might be referred to as quick-response methods. These will be listed with only a fleeting description for reference purposes:

1. Procedures for planning downtown circulation systems are contained in a three-volume report that provides a work-sheet approach to estimating demand, cost, revenue, and impacts (6).
2. Small-urban-area planning manuals such as Transportation Planning for Your Community (7) provide methods for the level of analysis appropriate in areas with less than 200 000 population. This document consists of a series of manuals for the decisionmaker and the manager of the planning effort, as well as technical manuals on traffic planning, programming projects, systems planning, transit planning, and monitoring and forecasting.
3. The RIDE program in UTPS (8) estimates patronage cost and productivity of different levels of bus transit and carpool priority. Networks are not used; rather, service is described by frequency of service and spacing between routes.
4. Analyzing Transit Options for Small Urban Communities (9) provides analysis methods based on tables and graphs for estimating patronage, cost, and revenue implications of transit service operation.
5. The Transportation Network Evaluation System (TRANES) (10) is a data-retrieval technique that allows the user to access socioeconomic information. It permits the user to specify existing or planned transit lines and stops and then retrieve information on the number and types of present or potential transit users within specified access limits of the closest or most convenient transit facility.
6. Procedures for transit applications that are microcomputer based are available, for example, for analysis of vehicle rehabilitation and replacement plans, fare-revenue projections, route performance and cost analysis, ridership reporting, ridership and revenue projections, Section 15 ridership survey processing, information systems for bus maintenance and operations, five-year cost projections, computerized driver selection system, impact of transit fare changes, bus-schedule timing.
7. Simplified Aids for Transportation Analysis (11) includes individual manuals for transit-route evaluation, estimating ridership and cost, estimating parking accumulation, and forecasting automobile availability and travel.
8. Interactive-graphics work for network editing and display has been developed for the Apple II computer by Robert Dial of UMTA.

TAKING ADVANTAGE OF CURRENT TECHNOLOGIES

As can be seen from the discussion so far, the quick-response methods have generally been based on models and methods that have been developed for long-range systems planning, project planning, system operation, and so on. As a profession we should continuously review emerging methods for their appropriate adaptation to quick-response application. However, research funding for quick-response methods that are unique, and not adaptations, has not occurred. What is needed is a clear idea of those issues for which some quick-response methodology is the appropriate level of analysis and an expression of research needs in such development.

The microcomputer as a tool offers some unique capabilities that in themselves provide quick response. One such capability is computer graphics. Once purchased (cost is low), the computer is used virtually free; amount of time used is of little consequence. The user interacts with the computer so that the answers are available at the terminal. (One does not have to wait for the machine room to schedule the run and return the output.) Most programs are user friendly, which reduces the time required to learn the system. The microcomputer will be a key element in developing quick-response methods.

Likewise, digitizing and plotting capabilities offer some unique capabilities for quick response. As a possibility, consider the use of census data by tract or block allocated to some geographic grid unit such as a quarter square mile. The data would include population, income, cars owned, employment, etc. With this grid over laid on a sheet or route map, a potential transit route could be defined by grids passed through or by being digitized. Data for a mode-choice analysis such as population within 0.25 mile of transit, employment density, and income automatically accessed along with appropriately coded system data would allow a rapid calculation of ridership based on an internal mode-choice model. Many alternative routings could be tested in a quick-response mode with this approach.

CONCLUSIONS AND RECOMMENDATIONS

In summary, I believe that quick-response method development and use are greatly dependent on acceptance of the approach for those applications in which such methods are most appropriate. At one end of the scale, quick response is as simple as taking known methods and converting them to quick-response methods, giving up as little as possible in accuracy in the process. Many of the models used by urban studies today are easily converted to quick-response (perhaps manual) methods. These are appropriate for many site-impact, project, and corridor-level analyses.

I would recommend additional attention to institutionalizing the idea of quick response through user manuals, training seminars, case studies, and the like.

Quicker adoption of modern technology, including emerging transportation techniques, microcomputers, and digitizing and plotting capabilities, should be fostered.

Finally, research funding should be provided for projects to develop quick-response techniques in data collection, travel estimation, use of new technologies, and others.

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Quick-Response and Sketch-Planning Techniques: State of the Practice

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Following the publication of NCHRP Report 187 (1) in 1978, the term "quick response" became an often-used expression in the urban transportation planning field. By virtue of the implication of being able to provide information to decisionmakers in a relatively short time frame, quick-response procedures have been widely embraced by the transportation planning profession. Managers and decisionmakers, in particular, are enamored with the prospect of the urban planning process actually being able to provide timely inputs to the decisionmaking process. This infatuation with the quick-response procedures is in part due to the frustration that developed with the cumbersome, data-intensive technical process that emerged from the 1960s. Too often, decisions were made before the urban planning process was able to provide useful information.

Unfortunately, the quick-response procedures are viewed by some as the panacea to all the previous problems associated with the technical procedures used in urban transportation planning. This perception has created an environment where quick-response procedures are recommended as the analysis tools for evaluating all urban transportation problems. In some instances, this has resulted in unsuccessful attempts to apply the quick-response techniques; the lack of success has resulted primarily from an inappropriate application of the procedures. Therefore, I think it is extremely important that we carefully define the quick-response procedures as they currently exist and highlight the limitations associated with them. To initiate the discussion, I will provide some illustrations on how the procedures have been successfully applied to contemporary urban transportation problems.

For the purposes of this presentation, I will restrict my discussion to the applications of the quick-response procedures documented in NCHRP Report 187, realizing that uses of other sketch-planning procedures will surface during the workshop discussions. In addition, I will highlight the limitations of the procedures and problems encountered in applying the procedures. To do this, I will rely heavily on the results of two surveys conducted by the Federal Highway Administration (FHWA) on the use of the quick-response procedures.

APPLICATIONS OF QUICK-RESPONSE PROCEDURES

In April 1980 and November 1981, the Urban Planning and Transportation Management Division of FHWA conducted a survey to determine the applications of the quick-response procedures. Those surveyed represented some 721 persons trained in the 21 National Highway Institute-sponsored workshops on quick-response procedures. Some 66 of these persons represented federal agencies; 307, state departments of transportation; and the remaining 348, city, county, and regional planning agencies.

In the first survey conducted, in April 1980, the questionnaire solicited information on the type of problems addressed with the quick-response techniques, the specific procedures used, problems encountered, and the level of effort expended. The applications described in the responses were summarized into the following categories:

1. Long-range systems analysis,

2. Corridor or subarea analysis, and
3. Site-impact analysis.

These categories correspond roughly to the following three levels of planning described in the draft conference material: long-range system planning, project planning, and urban-microscale planning.

To get an idea of the type of problems being evaluated with the quick-response techniques, several examples within each of these three categories are listed below:

1. Long-range systems analysis

a. Santa Fe, New Mexico: To evaluate the performance of the highway system in a long-range planning context, it was necessary to develop an estimate of travel patterns for the forecast year. This was accomplished by using a computerized version of the quick-response trip-generation and distribution procedures. Conventional traffic-assignment techniques were used to determine the link volumes.

b. Rapid City, South Dakota: To identify future highway needs, the quick-response procedures (i.e., trip generation, distribution, and assignment) were applied manually. Some problems resulted from the all-or-nothing traffic-assignment analysis, and adjustment factors were calculated to smooth out the traffic volume.

c. Hot Springs, Arkansas: To evaluate the system effects of a major highway improvement, it was necessary to synthesize the changes in travel patterns caused by the improvement. The manual trip-generation and distribution procedures from NCHRP Report 187 were used to develop the trip patterns; these results were assigned to the highway network by using a computerized traffic-assignment procedure.

d. Santa Barbara County, California: To analyze the impacts of forecast growth on the transportation system, identify problems and needs, and make recommendations for improvements, traffic forecasts were developed for the area. The quick-response procedures for trip generation, distribution, and assignment were employed. A computerized version of the trip-distribution procedure was used to reduce the time required for computations.

2. Corridor or subarea analysis

a. Brockton, Massachusetts: Previous analysis of the existing traffic conditions indicated that the traffic flow along the east-west corridor appeared to be severely impeded at several locations. A further study was desired to determine the future traffic impacts at these sites and to evaluate the possibility of roadway improvements to improve the east-west traffic flow. To further study the problems at one of the critical locations along the corridor, the quick-response procedures were applied in combination with available computer traffic-assignment programs. The approach involved the sequential application of the conventional transportation planning steps of trip generation, trip distribution, modal split, and traffic assignment. This method produced traffic-volume estimates for a 1975 base year and 1985 and 1995 forecast years.

b. Manchester, New Hampshire: In order to evaluate the traffic impacts of the rapid growth of a subarea in Manchester, an analysis of the existing transportation plan was required to determine whether the plan provided adequate improvements to accommodate the new growth. This analysis was accomplished by applying the trip-generation procedures from NCHRP Report 187 for the traffic zones in the subarea. Computerized UTPS procedures were used for the quick-response distribution analysis.

c. Salt Lake City and Ogden, Utah: Several rapidly growing cities in a suburban area near Salt Lake City and Ogden (population ranged from 10 000 to 50 000) were developing master plans and needed information on future street and highway needs. To determine these needs, the roadway spacing technique described in NCHRP Report 187 was applied. Some adjustments were necessary to reflect the terrain in the areas.

d. Northern Charles County, Maryland: A proposed bypass was evaluated to determine whether the improvement would solve a traffic problem at the intersection of two major state routes. The quick-response trip generation, distribution, assignment, and intersection capacity analysis techniques were applied; adjustments were required to account for the highway system configuration in the corridor.

e. Washington, D.C., to Annapolis, Maryland: To evaluate changes in the Route 50 corridor work travel given alternative configurations of the facility as well as alternative high-occupancy-vehicle (HOV) treatments, the pivot-point analysis technique was applied. By using district-level trip tables supplied by the regional planning agency, the pivot-point technique estimated changes in the forecast choices of mode and route in the corridor.

3. Site-impact analysis

a. Phoenix, Arizona: A regional shopping center and associated commercial/residential development was proposed, and an analysis of the traffic impact in the vicinity of this development was requested.

b. Sioux Falls, South Dakota: Two large residential developments were proposed in an undeveloped area adjacent to the city, and the traffic impact of these developments on the surrounding streets was desired.

c. Hartford, Connecticut: A shopping mall was proposed, and the impact of the mall on regional trip patterns and on traffic congestion in the vicinity of the mall was desired.

d. Springfield, Illinois: A residential and commercial development was proposed on a 600-acre site and the traffic impact of the development was requested.

The general approach for conducting the above analyses was similar. That is, the trips generated by the proposed developments were estimated by using trip-generation rates, and these trips were distributed and assigned to the highway network serving the developments. This assigned traffic was then added to the ambient traffic to provide an estimate of the traffic after the development had opened. Various modifications were made to this general approach to reflect data availability and unique conditions within the vicinity of the developments.

The applications listed above obviously addressed a wide range of urban transportation problems. These illustrations, however, are not meant to represent an exhaustive listing of the quick-response applications but rather some examples of the types of problems being evaluated with these techniques.

From reviewing the responses to the first survey, some general observations on the quick-response techniques may be gleaned. These are listed as follows:

1. The predominant use of the quick-response procedure was in evaluating the traffic impact of proposed land use changes. This is probably due to the frequency of this problem type in urban areas as

well as the suitability of quick-response techniques for evaluating localized traffic impacts.

2. The manual application of quick-response techniques is extremely cumbersome and time-consuming (particularly trip distribution and trip assignment). This problem surfaces primarily when quick-response techniques are used for long-range system analysis.

3. Modifications to the procedures are necessary in order to reflect unique local conditions. Data availability also requires some changes to be made in the use of the procedures. If available, local data and travel-demand relationships should be used in lieu of the transferable parameters from NCHRP Report 187.

The second survey of quick-response users was conducted in November 1981 and produced results similar to those uncovered in the first survey. Again, the applications were summarized into three general categories. These were

1. Corridor or subarea analysis,
2. Site-impact analysis, and
3. Intersection capacity analysis.

These categories correspond roughly to the following levels of planning identified in the draft conference material: project planning, urban-microscale planning, and systems operations.

The categories were modified from those used in evaluating the results of the first survey. A long-range systems analysis category was not included because only one of the respondents had used the techniques for this purpose. A category on intersection capacity was added due to the large number of applications in this area. As was the case with the earlier survey, the predominant use of the techniques was for site-impact analysis (40 percent). About 34 percent of the respondents used the techniques for corridor or subarea analysis; the remaining 26 percent of the respondents used the procedures for intersection capacity analysis.

Some examples of the types of applications noted in the responses to the second survey are listed below:

1. Corridor or subarea analysis

a. Kansas City, Missouri-Kansas: The mode-choice technique for corridor-level review of needs for major transit improvements was used; however, the forms in DOT's sketch-planning manual (2) were used and a program was written for a programmable calculator. The trip-smoothing procedure from NCHRP Report 187 was used extensively in converting raw computer traffic assignments to smoothed volumes. A basic program was written for a microcomputer to perform the smoothing of the volumes.

b. Portland, Oregon: Quick-response techniques were used in the preparation of a transportation corridor refinement study to the areawide transportation master plan. The refinement study investigated several alternative routes and their impact on adjacent land development. The study also looked at the ability of several routes to serve projected land developments (e.g., regional shopping centers, multifamily housing, and eight industrial sites).

c. Jefferson County, Colorado: The quick-response procedures were used to conduct a small-area transportation study for a 9-mile^2 portion of Jefferson County. The regional travel demand models were used to estimate traffic for the rest of the urban area.

d. Brevard County, Florida: The quick-response techniques were used to evaluate zoning regulations for a subarea of Brevard County. This was undertaken to determine the transportation impact that would occur if the land was developed fully as provided for in the current zoning.

e. Jacksonville, Florida: The quick-response techniques were used in a subarea study to determine (a) 1990 highway and mass transit needs in light of projected population and employment, (b) highway facilities deemed deficient, either now or in 1990, and (c) improvements that would alleviate deficiencies and improve traffic operations.

f. Seattle, Washington: The automobile traffic impacts resulting from converting a major CBD arterial to a bus-only facility were estimated. This was accomplished by carving out the CBD from the regional network and capturing the regional trips entering or passing through the CBD. Detailed traffic assignments were then performed to the resultant subarea.

2. Site-impact analysis

a. Des Moines, Iowa: The number of trips that would be generated by the construction of a new office building was estimated. This information was needed for a City Council meeting during which the addition of a traffic signal near the proposed building was to be discussed.

b. Albany, Georgia: The need for additional transportation service to accommodate a major redevelopment in the Albany CBD was analyzed. This redevelopment proposal included a new civic center complex with an arts center, library, hotels, and shops. These impact evaluations were developed by using the conventional travel-estimation models and the trip-generation information from NCHRP Report 187.

c. Huntsville, Alabama: The traffic impact of a regional shopping center (1 000 000 gross ft^2 of floor area) was evaluated. In the evaluation, the trip estimates and travel-time factors were taken from the on-going planning process. The traffic-assignment procedure described in NCHRP Report 187 was used. This evaluation was conducted as part of an overall review of a rezoning proposal.

d. Columbia, South Carolina: The traffic impact of a proposed shopping center on a nearby intersection was determined. Also, the trip-generation tables and the percent of traffic by time-of-day tables were used to estimate the traffic that would result from new subdivisions.

e. Brevard County, Florida: The impact of a 1 200 000-ft^2 shopping center was evaluated. The analysis included systems effects (volume/capacity), intersection traffic operations, air-quality and noise analysis, and social neighborhood effects. The quick-response techniques were also used to evaluate rezonings of large tracts of land for industry use and for large residential developments.

f. Shreveport, Louisiana: The transportation impacts in the vicinity of an industrial park resulting from the addition of several developments within the industrial park were assessed. The quick-response techniques--trip generation, distribution, assignment, and capacity analysis--were used to perform the analysis.

3. Intersection capacity analysis

a. Omaha, Nebraska: The critical-movement-summation technique was used to determine the level of service for several intersections within a major travel corridor.

b. Tacoma, Washington: The critical-movement-summation technique was used to evaluate the capacity of an intersection influenced by a major new development.

c. Eugene, Oregon: Two intersection-widening proposals identified in the transportation plan were analyzed from a level-of-service perspective.

Again, this second survey indicates a wide use of the quick-response techniques for evaluating various transportation problems. A rather interesting finding from the survey was the lack of quick-response applications for long-range systems analysis. It may be that applications were made for this purpose but were not documented or the limitation of the procedures for performing long-range systems analysis may be discouraging applications. Some of these limitations are presented in the following section.

LIMITATIONS OF THE QUICK-RESPONSE PROCEDURES

The quick-response procedures currently available for use by urban transportation planning analysts are being applied to address a variety of problems; however, these applications have served to identify certain limitations. These are listed below:

1. For the purpose of long-range systems planning, the quick-response procedures do not provide timely results or, in some cases, results at the desired level of detail. For example, sketch-planning procedures such as the Community Aggregate Planning Model (CAPM) and roadway spacing are very efficient yet do not yield traffic volumes on a facility basis. The quick-response procedures described in NCHRP Report 187 do result in traffic estimates on facilities but a significant amount of effort is required to obtain the estimates. This high level of effort is primarily due to the time-consuming process of computing the trip-generation, distribution, and assignment results. Some of this computation time is being reduced with the computerization (main-frame, microcomputer, and programmable calculator) of certain quick-response procedures. Many analysts, however, are continuing to apply the conventional, network-based procedures (e.g., UTPS) to perform long-range system planning.
2. Although the quick-response techniques were designed to operate with a limited amount of data input, in many cases these limited data are not available. The availability of the 1980 census urban transportation-related data may serve to mitigate this limitation.
3. The use of transferable parameters is viewed as an extremely desirable aspect of the quick-response procedures; however, certain of these relationships were developed from some rather dated information. This raises some credibility problems when it is attempted to use this information in an evaluation of alternative plans or projects. This problem is of particular concern when the residential trip-generation relationships described in NCHRP Report 187 are used, since these relationships were developed primarily from survey information collected in the 1960s.
4. In many urban areas, a major issue involves the analysis of external traffic. The quick-response procedures focus almost exclusively on internal traffic considerations; therefore, the analyst must rely on conventional approaches (e.g, roadside O-D surveys) to analyze the external traffic.
5. The manual, all-or-nothing traffic-assignment approach causes problems where there are several alternative routes to access proposed developments. In these situations, the subjective determination of routes is difficult to defend.
6. To streamline the application of the quick-response procedures, certain assumptions had to be made. In some cases, these assumptions inherent in the quick-response procedures were not fully understood. As a result, certain applications were performed that produced unrealistic estimates.

SUMMARY AND RECOMMENDATIONS

Despite the above limitations, many successful applications have been made of the quick-response procedures. These applications were made with a full understanding of the limitations of the procedures, and the results were viewed in the proper context. Although some accuracy may have been sacrificed, there is a general consensus that the quick-response techniques do provide reasonable results in a realistic time frame and are useful for evaluating a wide range of transportation problems. These applications cover several levels of planning, including long-range systems planning, project planning, urban-microscale planning, and systems operations. Clearly, certain enhancements and further developments are necessary to address some of the deficiencies noted in the applications. The following recommendations are offered:

1. A simplified method for defining networks for use in a computerized traffic assignment should be developed. The manual assignment techniques are useful for a many-to-one traffic assignment but become unmanageable for many-to-many traffic assignments (e.g., assignment of a regional trip table). The conventional network development and coding procedures are very time consuming.
2. Easy-to-use software for microcomputer applications of the quick-response techniques should be made available. Many users of the manual procedures become discouraged with the time-consuming calculations that are required for large-scale problem solving. In these instances, the aura of quick response is readily lost.
3. The use of transferable parameters is a highly desirable feature of quick-response applications, particularly from the time- and cost-saving perspectives. In order to facilitate the use of transferable parameters, the trip-generation relationships for specific land use categories and detailed residential analysis should be updated. More recent information would improve not only the accuracy of the results but also the credibility of those results in the minds of many state and local officials.
4. Given the common problem of evaluating the traffic impact of major new developments (e.g., shopping centers, industrial parks), more complete information is needed on the trip-making characteristics of such developments. Although the Institute of Transportation Engineers maintains a very comprehensive listing of trip rates for various developments, more detailed information is needed on the trip purpose, primary versus linked trips, and diverted versus undiverted linked trips. In any traffic impact analysis, the critical number, and the number subjected to the closest scrutiny, is the trips generated by the development. To ensure technically valid and justifiable analyses, a thorough understanding of the generated trips is required.
5. To overcome the lack of information available on external traffic analysis, data from external surveys should be reviewed to determine whether transferable relationships can be established.
6. Case studies should be developed that illustrate the applications of quick-response procedures. These examples would serve as a guide for future applications in addition to enhancing the credibility of the procedures.

REFERENCES

1. A.B. Sosslau, A.B. Hassam, M.M. Carter, and G.V. Wickstrom. Quick-Response Urban Travel Estimation Techniques and Transferable Parameters: User's Guide. NCHRP, Rept. 187, 1978.
2. Transit Corridor Analysis--A Manual Sketch Planning Technique. U.S. Department of Transportation, Sept. 1976.

Research Needs

1. Impacts of transportation system changes on average trip lengths

a. To identify short-range relationships, use before-and-after surveys of travel behavior in response to major transportation system changes, such as new rail transit systems or extensions and new urban freeways
b. Determine the impacts of changes on both work and nonwork travel
c. To identify long-range relationships, use longitudinal data, taking care to account for lifecycle, income level, and other changes
d. Test results against city-to-city variations

2. Improved data-collection methodologies

a. Review current data-collection methods
b. Review quick-response data needs and survey-based needs
c. Develop approaches to data collection that take advantage of new technologies, data uses, etc.
d. Test methods
e. Develop manuals, case studies, and training

3. Streamlining of network-based analytical approaches, including simplification of modeling procedures

a. Identify weakness in current techniques vis-à-vis possibilities with new microcomputer and other computer technology
b. Specify new concepts
c. Develop and test new concepts
d. Prepare case studies and training materials

4. Adaptation of readily available microcomputer general software and technology in data collection and modeling

a. Review and evaluate projecting software and technology
b. Refine planning-context scenarios
c. Specify case studies
d. Prepare case studies based on existing software capabilities
e. Develop new software
f. Prepare any additional training approaches

5. Quick-response methods missing from current techniques for considering external travel

a. Develop framework for quick-response approach
b. Evaluate current external survey data
c. Develop quick-response method tables, nomographs, etc.
d. Prepare manual on case study and training

6. Manuals of reference data

a. Critique existing references such as Characteristics of Urban Transportation Systems (CUTS), Characteristics of Urban Travel Demand (CUTD), and Traveler Response to Transportation System Changes and define missing or outdated information
b. Specify rule-of-thumb techniques
c. Develop and test new techniques; collect data and update manuals
d. Prepare case studies and appropriate training materials

7. Transportation pricing on interactions between land use and transportation systems

a. Specify hypothesis about interactions
b. Define decision scenarios that can benefit from better understanding
c. Prepare research statement
d. Conduct research, including measurement of data collection
e. Develop plan to operationalize the research into transferable planning techniques

8. New methods for costing, pricing, and evaluation, including design standards

a. Establish specific requirements following survey of existing techniques
b. Develop new manual on computerized techniques
c. Prepare case studies by using new techniques
d. Prepare any additional training approaches

9. Traffic engineering and transit operations management tools

a. Survey what is available as detailed analytical tools
b. Develop typical application scenarios
c. Specify techniques
d. Develop and package tools, including necessary training
e. Develop research statements to fill the gaps

10. Existing techniques for identification and solution of prototypical problems and issues of today

a. Define planning-context scenarios and identify typical user groups
b. Survey and evaluate existing methods (manual and computerized)
c. Synthesize new approaches by applying available methods
d. Specify case studies
e. Generalize existing methods as case studies
f. Identify gaps in techniques requiring further R&D

11. Educational needs

a. Accelerate local acceptance of better techniques
b. Determine alternatives
c. Redirect formal academic training

Workshop on Transit and Highway Operations and Management Techniques

Workshop Summary

EDWARD WEINER, U.S. Department of Transportation

This workshop focused on methods to estimate near-term demand changes due to typical automobile, transit, and paratransit projects. Participants reviewed a number of operations and management techniques to determine whether travel-analysis methods are available and used in planning. Options included those dealing with TSM options, freeways, reserved lanes, priority parking, transit fare and service changes, express bus operation, and demand-responsive services. Methods of travel demand include traditional models, newer disaggregate methods, and pivot-point and other hybrid procedures.

The workshop addressed five questions with regard to transit and highway operations and management techniques:

1. Are these techniques applicable in each of the five planning contexts, i.e., strategic, long-range, project, microscale, and operations?
2. Do travel analysis methods exist for each of these techniques and are they adequate?
3. Are these travel analysis techniques used in practice?
4. What is the cause of the gap between the state of the art and the state of the practice, where it exists?
5. What is needed to improve the quality of travel analysis for each technique, and what further research is needed, if any?

With regard to the first question, it was concluded that these transit and highway operations and management techniques are generally used in the shorter-term planning contexts at the subregional level. Their primary application is in project planning, microscale planning, and operations planning. There are, however, some specific applications in strategic planning (such as assessing alternative transit fare and service policies and the effects of regulatory reform) and in long-range planning [such as the evaluation of high-occupancy-vehicle (HOV) operations plans for new freeways and systemwide analyses of transit networks].

The remaining four questions were addressed for each highway and transit operations and management technique. A number of issues and conclusions recurred in the course of discussions. These are summarized below.

STATE OF THE ART

The paper by Miller and Kirby provided the background for this discussion.

There is a wide range of travel analysis methods available for analyzing transit and highway operations and management techniques. No one method is applicable to all techniques. There is little information on the quality and cost of these methods. They have not been subjected to a uniform set of tests to permit distinguishing among them in terms of their relevance, accuracy, and economy of use. No documentation exists on the failure of these methods to aid others in their use.

Research is needed in a number of application areas to improve travel analysis methods, such as transit-route planning, urban truck travel, some demand-responsive and specialized transit services, and planning for infrastructure rehabilitation.

STATE OF THE PRACTICE

The paper by Ryan summarized the state of the practice for this discussion.

Operational planners are not making widespread use of new travel analysis methods. Rather, they are using results adapted from other areas. A great deal of professional judgment is being used instead of detailed analysis. There appears to be little concern for accuracy. Where the implementation of a transit or highway operations or management technique does not achieve the desired results, adjustments are made in the implementation. In some situations, the implementation cannot be changed and the area must accept the outcomes or terminate the application, if possible.

CAUSE OF THE GAP BETWEEN ART AND PRACTICE

The gap between the state of the art and the state of the practice in travel analysis methods is primarily institutional in nature. Most of the applications of transit and highway operations and management techniques are small; the impacts of these projects are also small. There is a lack of awareness of analysis methods and applications, an inadequate supply of trained practitioners, lack of access to computing facilities, and insufficient data to utilize sophisticated travel analysis methods.

Many of these operations and management projects, such as ridesharing, are implemented by private companies or nontransportation agencies, such as transit services for the elderly and handicapped, and larger issues of social benefit are not of interest. Often these services are implemented because of legal requirements, such as service for the elderly and handicapped, or to solve a specific problem, such as ridesharing to reduce parking requirements at a work location. In such situations, there is little interest in the evaluation of alternatives.

In addition, many of the organizations implementing these projects do not have personnel familiar with travel analysis methods, nor do they have adequate data to perform the analysis. Often the projects are too small to permit expenditures for an adequate travel analysis.

In public agencies where there is concern for the impacts, benefits, and costs of alternative techniques, there is a lack of information on the quality, cost, and applicability of new travel analysis methods. Traffic engineering departments and public transit agencies often use simple methods or rules of thumb tempered by professional judgment. Even where techniques exist for a particular application, they are often not packaged for easy use.

CLOSING THE GAP BETWEEN ART AND PRACTICE

There are many opportunities for closing the gap between the state of the art and the state of the practice. There are three categories of actions that can be taken:

1. Make new travel analysis methods more usable,
2. Increase the capability of operational planners, and
3. Improve communication between those with knowledge and those who need it.

In the first category, there is a need to synthesize information on new travel analysis methods. Practitioners need to know the array of methods that exists, range of applicability, cost and time requirements, data needs, accuracy of results, and where to obtain them. The methods must be packaged in a user-friendly environment and be easily accessible. Technical assistance must be available to help in their use. It will be necessary to provide the level and intensity of technical assistance that was typical in the 1960s when conventional travel analysis methods were disseminated.

As part of this effort to diffuse new travel analysis methods, there is a need to demonstrate the utility of travel analysis in supporting decision-making and minimizing risk. It must be clear that the cost of good travel analyses will be more than paid for by avoiding poorer choices of projects to implement.

The application of travel analysis methods to these small-scale applications looks well suited to the use of microcomputers. With the cost of microcomputers dropping, their acquisition is within the budgets of many organizations that previously did not have access to computing facilities. Use of these computers would make the cost of applying travel analysis methods low enough to permit their use for smaller projects.

Case studies were favored as a means to demonstrate the usability and usefulness of travel analysis methods. Practitioners can see how these methods were actually applied, the type of results achieved, and their use in the overall planning and decisionmaking process.

With regard to some applications of travel analysis methods, there appear to be mismatches between the level of sophistication and the analytical requirements of the application. Travel analysis methods for ridesharing, rural service, and high-density circulator systems were identified as areas where this seems to occur.

With regard to the second category, practicing planners will require training in order to use the new generation of travel analysis methods no matter how user friendly they are made. As with any professional field where new ideas and techniques are being developed, the professionals must acquire this new knowledge to be continuously useful. Opportunities must be found to retrain the cadre of practicing planners over a wide spectrum of need. Some planners who are familiar with the theory of these new techniques may require only short courses to catch up on the most recent methods. Others may require longer-term training to learn the new concepts and applications. Still others may need sabbaticals to permit a major retraining experience.

It is understandable that little of this retraining has occurred in urban transportation planning. Operating agencies find it difficult to budget the funds and spare the staff time for such retraining. There has not been a clear understanding of the importance of retraining especially in a field that seemed so new only a few years ago. But an increasing number of public and private organizations are coming to recognize the necessity of continuous training of their personnel to avoid functional obsolescence.

There are opportunities for additional training courses and materials over the entire spectrum of need. The greatest need is in the area of applications. Existing courses given by FHWA and UMTA were considered to be excellent. More of this type are needed. Courses and seminars in which applications are exchanged are particularly helpful. Where possible, the courses and seminars should be given at several locations around the country to minimize the time and cost of attending them.

In the third category of actions, communication needs to be facilitated between those having knowledge of the applications of new travel analysis methods and those needing it. This problem is particularly acute in the area of highway and transit operations and management techniques where the universe of possible users is so large and where many organizations are not connected to communications networks that provide such information. It is clear that many potential users of travel analysis methods do not know when to do a travel analysis nor the methods available. And, even worse, they do not know where to obtain help. Many are reluctant to ask for assistance and expose their ignorance.

There is a clear challenge to develop new approaches to providing technical assistance to the large number of potential users of travel analysis methods with their widely varying capabilities and analysis needs. Information brokers that can identify users and establish communications networks would substantially facilitate the diffusion of new travel analysis methods.

Two approaches currently being used are meeting with considerable success. The SMD Briefs, which are one-page summaries on the progress of various service and methods demonstrations, were considered informative and succinct. The announcement cards from the Technology Sharing Program reach a large audience with brief descriptions of newly available reports.

Distributions of reports, however, have their limitations. Most practitioners do not have immediate use for the material in these reports. They are filed and must be recalled when needed. Also, once the initial distribution of the report is made, it is difficult to obtain copies. Further, potential users of this information need assistance in applying it to their circumstances. In their paper, Miller and Kirby discuss the currently available summaries on the state of the art. It is clear that considerable work will be required to bridge the communications gulf.

RECOMMENDATIONS ON RESEARCH AND PRACTICE

In the realm of transit and highway operations and management techniques, where the bulk of projects is small, there is still a need for simple, accurate, and easily usable travel analysis methods. It appears that the use of the microcomputer in the application of these techniques would increase their accessibility while keeping the cost of their use low.

Several specific subjects requiring research and methodological development were identified. However, for many of these techniques, actual travel impact information is very limited. This is hampering theoretical and methodological developments. More empirical data are required on before-and-after conditions in order to produce forecasting methods. Wherever possible, data should be collected on these types of techniques. As these data become available, syntheses of experience should be produced and disseminated, and research should be undertaken to understand the impact process and to develop additional travel analysis methods.

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

GERALD MILLER and RONALD KIRBY, The Urban Institute

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 sociodemographic 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 that would occur in response to alternative fare and service changes.

Project Planning

Several types of project-planning activities involve systems-management and operations issues. One obvious context is the development of TSM projects themselves. Actions found within this category range from traffic signal coordination to park-and-ride lots and congestion-bypass lanes for buses and other high-occupancy-vehicle (HOV) traffic. Similarly, supporting analyses of travel impacts range from traffic engineering of individual intersections to elaborate and expensive model projections of transit patronage and traffic volumes. Since the smaller-scale projects also fall within the microscale and operations context, they will be treated in that discussion. The larger-scale projects--busways and other HOV priority facilities--are included here as project-planning issues.

Management and operations issues are important in the project-planning context from two perspectives. First, the operating plan for a new facility may significantly affect its merits as a wise investment of capital funds. The operating plan for Interstate 66 within the Washington, D.C., beltway is an excellent example. The cost-effectiveness and environmental impacts of the four-lane facility reserved in the peak hours for buses and other HOV traffic are substantially different from those of an alternative design that might have included six to eight lanes open to general traffic. Similarly large differences in project merit can be found for major transit facilities in variations of feeder bus and park-and-ride strategies, fare policies, and busway operating plans. Second, a comprehensive application of TSM actions serves as the basis for evaluation of project merit. It is assumed that a project is justified when, compared with a no-build situation, the project produces benefits that more than offset its costs; the analysis of an optimized no-build alternative is of equal importance to the assessment of the options to build. The comprehensive TSM alternative required by UMTA in analyses of major transit alternatives is an example of this role for system operations planning.

Microscale and Operations Planning

Planning for transportation facilities and services in small subareas or for specific transit routes is clearly the setting in which most operations and management issues arise. Planning tasks in this category include the assessment of traffic engineering actions and transit route characteristics to improve access to (and minimize impacts of major new developments, reduction and elimination of unproductive transit routes and route segments, provision of services to special user groups, and such relatively new strategies as parking management and automobile restrictions. Analytical support of these planning activities varies markedly in the degree to which it involves travel demand consideration.

PLANNING METHODS

Since the planning contexts identified above represent ongoing planning activities at the local and state levels, analyses are being done--at least in a general sense--to support the decisions being made. In some cases, the analytical support is an elaborate and extensive effort using complex modeling techniques and computer software. In other situations, the analytical work consists of professional judgment based loosely on rules of thumb and/or past experience. This section attempts to summarize the analytical work typically associated with management and operations planning in each of the context areas.

Strategic/Long-Range Planning

Several transit agencies (1-3) are currently assessing alternative service plans for implementation over a 5-10-year period. The intent of the studies is to develop alternative sets of transit service standards that represent a range of (bus) service levels. To provide upper management officials and board members with enough data to choose among the options, the studies are developing a range of cost and impact data, operating costs, patronage, farebox revenues, geographic coverage, and service characteristics (average headways, fares, route spacing, etc.) for a number of local jurisdictions and subareas. Since the decision at hand is the selection of general service standards to serve as policy guidance for service and fare changes, the detail in which the final results are presented is quite aggregate. More detailed analysis and data, if needed, would be developed in later operations planning and implementation efforts.

The travel forecasts needed in these efforts are determined by several considerations. In addition to systemwide transit ridership projections, patronage estimates are needed in sufficient detail to (a) identify riders in different fare zones so that alternative fare policies can be represented and accurate fare revenue calculations can be done, (b) permit the analyst to equilibrate transit supply and demand, and (c) summarize ridership impacts by jurisdiction or subarea for evaluation purposes.

These planning efforts have varied significantly in their analytical support. At one extreme, a number of transit agencies have used the traditional modeling approach, coding a full transit network and employing the network-analysis, mode-choice estimation, and transit-assignment phases of the model set for each of the service options. This method has enabled the analysts to equilibrate service and ridership within their specified minimum and maximum loading standards, provided access to a wealth of evaluation data at a fine geographic level, made available a variety of mechanisms to represent fare policies, and involved a significant level of effort in time and money.

This detail was achieved only with a significant investment of time, staff, and computer costs, however. Further, the fare policies explored were quite limited in their variety and complexity, and the results presented to local decisionmakers were (and should have been) significantly more aggregated than those produced in the analysis. Consequently, some doubt exists that the level of detail and effort in which the analysis was performed was appropriate for the nature of the decision at hand.

At the other extreme, one transit agency has estimated impacts on patronage and revenues on the basis of past experience with service and fare changes. The analysis has consisted of adjustments to existing transit volumes obtained from passenger counts and an on-board survey. The adjustments have been made at the district level, and with fewer than 20 districts in the region, are quite aggregate. Each fare and service policy combination is translated into changes from existing conditions and is used with an elasticity derived from before-and-after counts taken around past fare and service changes to derive patronage and revenue impacts. Application of these elasticities has been done with some reference, largely judgmental, to the comparative levels of service, accessibility to transit, and socioeconomic conditions that prevail in the before-and-after data and in each district.

Again, some doubt exists as to the appropriateness of this approach for strategic service planning. The heavy reliance on the good judgment of the analyst together with the very general nature of the results leave many prospective users with reservations as to its accuracy.

Between these two extremes are several cases in which transit operators have derived (or intend to derive) simplified patronage models from their conventional model sets. The simplifications mainly involve concentration on one behavioral change (mode choice alone, foregoing route-choice analyses) and conversion to an incremental structure that examines changes in service characteristics rather than their absolute values.

Project Planning

The development of an operating plan for new transportation facilities is a key, although often overlooked, part of planning for new highway and transit facilities. Although operations and management of the transit system is an obvious concept, operations and management of highway facilities is a relatively new idea--and in many cases a missed opportunity. Ramp metering, contraflow operations, reversible lanes, and time-of-day restrictions offer a range of options for true management of highway facilities that are at least as important in their planning and development as alignment, numbers of lanes, and interchange locations.

Recent planning efforts for new highway facilities have shown a rapid evolution in their sophistication. Several have examined HOV-lane alternatives during highway location studies and have documented these options in an environmental impact statement (EIS) (4-6). The analyses have relied on sketch methods, primarily the incremental logit (pivot-point) approach to estimating changes in transit and carpool or vanpool volumes. The sketch analysis might be considered inappropriate for the level of detail with which other aspects of the alternatives were analyzed and for support of the detailed environmental work (noise, air quality, etc.) presented in the EIS. However, the approach was effectively determined by the general lack of resources--time, appropriate staff, and data--available at the relatively late stage of the project development process. The conventional focus on structural, drainage, and geometric design issues somewhat minimized the opportunity for a more involved analysis of travel demand issues.

Similar problems can be identified in planning studies for major new transit facilities. Although UMTA's procedures have for some time provided for a specific, detailed analysis of alternatives, the rigor with which operations and management issues are treated has varied significantly. Again, many of these difficulties are most easily seen in the development of operating plans for busways and HOV lanes. A busway with stations and access ramps presents a virtually limitless number of potential operating strategies. At one extreme, all collector and line-haul services can be integrated, and each bus will provide a one-seat ride from residential areas to the downtown and make few, if any, station stops along the way. At the other extreme, the collection and distribution functions can be fully separated, and trunk-line buses will operate only on the guideway, making frequent station stops to allow transfers to and from a supporting network of feeder buses. Combinations of these two types of service can be used to match transit service to the specific travel patterns in a corridor.

Because the operating plan contributes heavily to the costs and effectiveness of the facility, the process used to identify the most effective operating scheme is critical. In some cases, however, minimal resources have been reserved for refinement of the operating plan originally assumed for the project and little scrutiny has been given to the operating assumptions when initial transit patronage estimates become available (7,8). The addition of carpools and vanpools to the facility further complicates the operating plan development by introducing such issues as minimum occupancy requirements and potential capacity problems.

Later project development efforts have devoted more consideration to operations analyses in project planning, however. The recent analysis of the extension of the HOV lanes on Shirley Highway in Washington's Virginia suburbs included a significant effort to project changes in mode and route choices (9). Full applications of mode-choice and traffic-assignment models for each design alternative (facility length and interchange locations) were used to develop detailed estimates of traffic volumes, transit patronage, and user costs. Careful attention was given to the representation of highway congestion on both the general traffic lanes and connecting arterials. Diversions of HOV traffic from the Shirley Highway HOV lane to the I-66 reserved lanes were explicitly addressed in the route-choice analysis. Efforts are currently under way to refine this process in preparation for analyses of other potential HOV facilities in the region (10).

Recent transit guideway planning has also included significantly greater effort for the development of operating plans. One study (11) structured a three-stage process for plan development that proceeded from a conceptual definition through an initial detailed specification to a final plan that was revised and refined to match the patronage levels and travel patterns in the corridor. The final operating plan for the busway included a mix of express services focused on the center city and local busway services stopping at busway stations served by feeder buses. The process significantly increased the reliability of the service, patronage, and cost estimates in that it ensured that these estimates reflect an appropriate, efficient operating scheme for the facility.

Microscale and Operations Planning

The final context area includes most activities associated with operations and management analyses. Nearly all TSM actions fall in this area, as does the day-to-day management of transit systems. To structure the discussion, it is useful to identify three major groups of activities in this context area:

1. Transit operations,
2. Traffic engineering, and
3. Ridesharing and paratransit.

Transit operations planning might be further categorized into route-level planning and farebox revenue forecasting. Summaries of current practice in both of these areas have recently been prepared through surveys of selected transit agencies (12,13). Route-level demand forecasting is done largely through very simple methods: professional judgment, comparisons with similar routes, rules of thumb, and applications of elasticities. Most of these applications are associated with system expansion (new routes or significant extensions) or major route changes (splitting or combining routes). System contractions (elimination of routes, reduced hours of service) are nearly always assessed with data on existing ridership rather than with a forecast of patronage changes. Minor system changes (headway adjustments) are typically undertaken in response to perceived loading problems (too many or too few riders) and are also based on existing ridership rather than on projections.

A common observation among the transit agencies was that they need only a general indication of the ridership potential of system expansion proposals. Consequently, they find most useful techniques for estimating transit demand to be those that require the least time and cost to apply and still provide reasonable results. In many cases, the agencies seek to increase the reliability of the analysis by employing several of the simple methods to get a range of projections and use judgment to reach some conclusion on the most likely outcome. Reliability in general does not appear to be a chief concern, however. The most striking indication of this lack of emphasis is that follow-up data are almost never used to verify the accuracy of the projections. This suggests that the agencies view route-level planning as an ongoing effort in which any inaccuracies introduced now can be corrected in the near future at little (or at least acceptable) cost to the agency. The costs of being wrong in the forecasts are not sufficient to warrant more sophisticated analysis, even assuming that added sophistication produces greater reliability.

Fare analyses are usually done at the system, rather than route, level. Again, simple approaches dominate and the Simpson-Curtin shrinkage ratio (10 percent fare increase leads to a 3 percent patronage loss) continues as an (unofficial) industry standard. Adjustments to the ratio based on local experience are the most common refinement in the process. Again, the use of a seemingly crude method (crude in the sense that it is extremely aggregate and assumes widespread transferability) can be explained by the context in which it has been applied. Most fare changes have been increments within the existing fare structure rather than major revisions of the structure. Further, until recently the relative costs of transit and automobile travel have not fluctuated significantly in real terms; both are lagging behind general inflation. Consequently, a simple rule of thumb based on similar past fare increases has been an adequate guide for most fare changes.

As financial planning assumes greater importance, however, it is fairly clear that some changes will be needed in fare analyses. To the extent that significant changes in fare structures are contemplated, more sophistication will be needed in identifying individual transit markets, representing alternative fare structures and levels, and assessing the ridership and revenue impacts within each market. Some movement can therefore be expected away from simple aggregate methods to the more detailed and involved methods that have traditionally been used in longer-range regionwide planning efforts.

Traffic engineering activities encompass a wide variety of specific actions; they range from analyses of individual intersections to studies of traffic flow on freeway or arterial facilities and evaluation of circulation patterns in a subarea (14,15). At the intersection level, standard manually applied techniques are routine. Large-scale analyses of arterial segments and subareas are also often done on an individual intersection basis. Some risk is apparent in this approach when used for large-scale facilities in that significant changes in levels of service on a facility can cause broad changes in travel patterns and traffic impacts. For example, alleviation of significant queuing problems along one segment of an arterial can introduce similar problems at downstream locations where they did not previously exist. Similarly, significant travel-time improvements can cause changes in route choices that could lead to a significant diversion of traffic from other highway segments to the improved facility.

Techniques are available to examine these issues and they are used fairly regularly for large-scale applications, e.g., major CBD circulation analyses or studies of important, heavily congested facilities (15). These applications are typically done by consultants and represent a setting that is quite different from the more routine issues addressed by a typical traffic engineer in a local jurisdiction. Limitations on the ability of the engineer to use the more sophisticated techniques when appropriate appear to include poor access to facilities with which to apply computer software and limited availability of data on travel patterns beyond traffic counts on street segments. Some movement toward improved integration of planning and traffic engineering methods can be seen in the various manual procedures packaged as the quick-response methods (16). A number of these methods provide low-cost, quick-turnaround ways of estimating travel patterns and examining the impacts of traffic flow improvements and new developments.

A variety of approaches have been identified for the assessment of various ridesharing and paratransit programs. Potential demand for paratransit service has been analyzed through noncommittal surveys in which respondents identify their likely frequency of use and the analyst adjusts the results to correct for the upward bias inherent in the noncommittal responses (17). In distinct contrast, other methods have been proposed for use of traditional modeling techniques and software to estimate paratransit patronage (18).

By far the most common approach, however, is reference to published summaries of past implementation experience tempered with professional judgment (14). Reliance on this approach is largely explained by the comparatively recent emergence of ridesharing and paratransit programs. With relatively few programs in operation, the information available on successes, failures, and their causes is somewhat limited. Development of in-depth understanding and analytical models of the programs' impacts is consequently also limited.

The nature of ridesharing and paratransit programs suggests that the standard approach to their analysis may not be significantly less rigorous than is appropriate, however. The programs are typically implemented with specific objectives, are targeted toward specific travel markets, and begin as modest, low-cost operations. These conditions suggest that general ideas on the likely impacts and cost of such programs are sufficient to proceed with relatively low-risk implementation. Thus, collection of data on implemented programs and the setting in which they are introduced may continue to be the most common and appropriate approach to the analysis of these programs. Several compilations of this nature are available and are finding widespread application (19).

GAPS: STATE OF THE ART VERSUS STATE OF THE PRACTICE

Awareness

In many instances, the most significant discrepancies between available methods and current practice can be attributed to a lack of awareness of the need and/or opportunity to do a particular analysis. For example, transit agencies often find their planning staffs focusing on short-range route-level problems while broader questions on longer-term service policies and financial health often remain unanswered. Similarly, the need for a true operating plan for highway facilities is somewhat unrecognized. The de facto operating plans that result may well lead to a very inefficient use of scarce transportation resources.

Analytical Skills

The shift in emphasis from long-range large-scale issues toward short-term management and operations has been accompanied by some shift in the location of supporting analyses. Staffs of transit operators, city planning and public works departments, and city and county traffic engineers are responsible for these emerging activities, whereas regional planning staffs often remain somewhat removed. One result is that analytical skills maintained by the regional planning staffs are not well focused on management and operations issues faced by staff at the local agencies. Since many of these issues involve travel demand considerations, an opportunity is missed to use skills available locally in increasingly important analyses.

Computing Facilities

A parallel situation often exists with regard to the computing facilities available to local staffs. Although the need for analyses has decentralized, local agency staffs often have poor access to the centralized computing capabilities typically maintained at the central planning agency. The remoteness and usually lengthy turnaround time associated with the central facility are particularly unsuited for many management and operations analyses. The numerous small-scale issues and variety of alternative solutions found in many short-term contexts require inexpensive, quick-turn-around processing of a large number of analyses. To the extent that this access is not available and that central staffs cannot accomplish these localized analyses for the various agencies in their regions, a significant limitation may exist on the ability of local agencies to expand their analytical capabilities.

Data

Similar observations can be made on the data maintained by regional planning agencies and its potential usefulness to local staffs. Growth projections, land use and demographic data, and travel forecasts available at the central agency can be quite valuable to planners in local jurisdictions. Provisions for ready access to this information are important if it is to be used in a timely fashion.

Analytical Methods

Finally, in a number of contexts, the available techniques appear insufficient for the analyses required. In some cases, this problem reflects the relative newness of the situation. Experience with employer-based ridesharing programs is still very limited and consequently data, understanding, and analytical methods for this strategy remain equally limited. In other cases, the problem appears to be more one of failure to adapt existing techniques to new situations: The use of detailed coded networks to analyze strategic transit service options reflects the lack of an alternative approach more than it indicates the suitability of the network-based analysis.

A number of examples of the need to improve specific analytical capabilities are as follows:

1. Sketch-planning techniques for strategic financial and service planning for transit agencies;
2. Representation of level-of-service improvements caused by HOV facilities, their effect on route and mode choices, and the equilibration of supply and demand impacts;
3. More informed applications of simplified methods for route-level demand forecasting that specifically recognize the existence of various travel markets and the differences in their travel behavior; and
4. Analytical summaries of experience with TSM actions that attempt to draw conclusions on potential impacts and appropriate applications in addition to the more common case-study presentations.

PRIORITIES

These discrepancies between the state of the art and current practice suggest a number of priorities for the transportation planning community in general and travel demand specialists in particular.

First, it is imperative that closer association be established with transportation professionals (traffic engineers, city planners, transit operations staff), whose responsibilities increasingly involve travel demand issues. Planners and planning agencies must reassess their roles and their skills to identify specific contributions they can make to management and operations analyses. The benefits in terms of the usefulness of these activities to the relevance and vitality of the planning agencies are obvious.

Second, more attention must be given to upgrading the capabilities of transportation professionals at local jurisdictions and transit agencies. Better access to central planning staffs, data bases, and computing capabilities would in many contexts be a significant improvement. The continued development of case studies documenting successful applications of various analytical techniques to real-world management problems is also an important focus in this regard. The use of microcomputer technology to enhance local capabilities may also be appropriate.

Finally, it is important to continue the collection, synthesis, and distribution of information on various management and operations strategies as they are implemented. This documentation can play a key role in enhancing the awareness of the opportunities provided by various strategies, in improving our understanding of their impacts and appropriate uses, and, where appropriate, in developing new planning tools to support their analysis.

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Research Needs

1. Traffic engineering

   a. Retrain traffic engineers: use of travel-analysis methods and coordination with planners
   b. Apply microcomputer technology
   c. Provide technical assistance in learning to apply new methods

2. Parking management

   a. Perform before-and-after studies
   b. Validate methods
   c. Incorporate parking supply into network model

3. Transit route and service planning

   a. Provide technical assistance
   b. Train personnel in planning methods
   c. Develop better packaging of techniques
   d. Validate sketch-planning methods
   e. Develop analysis methods for service substitute planning

4. Fare policy

   a. Investigate fare-collection techniques
   b. Study market segments and long-term versus short-term effects

5. Ridesharing

   a. Collect better before-and-after data
   b. Study ridesharing process
   c. Develop methods to analyze impacts of ridesharing alternatives

6. HOV priorities

   a. Investigate techniques and validation
   b. Improve dissemination (information broker)

7. Before-and-after data on automobile restraints

8. Specialized transit services

   a. Collect better before-and-after data
   b. Develop better understanding of process
   c. Develop methods to analyze impacts

9. Empirical research on demand management

10. Dissemination of experience with high-density area circulator systems

11. Local rural service

   a. Estimate impacts of rural service alternatives
   b. Determine effects of deregulation
   c. Study benefits and costs

12. Demand-responsive service

   a. Study check-point service
   b. Provide technical assistance
   c. Make before-and-after studies

13. Before-and-after data on reconstruction diversion

14. Improved coordination between planners and maintenance personnel in facility rehabilitation

15. Goods-movement data

Workshop on Investment and Financial Analysis Techniques

Workshop Summary: Investment and Financial Analysis in Transportation in the 1980s

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The workshop participants addressed the investment and financial issues in transportation in the 1980s. These included the perceived major issues for both highway and transit. Specifically, these issues were addressed in the light of current travel analysis methods to provide acceptable evaluations. For each issue a subjective determination was made as to the state of the art, the state of the practice, implementation barriers, and research needed for existing models available in the transportation field. The state of the art was defined as whether adequate models existed for use in the analysis of any given issue. A subjective determination rated the state of the art as good, fair, weak, or nonexistent. The state of the practice dealt with whether models that were available were in regular use in analyzing the issues. The state of the practice was subjectively rated to be widely used, limited, or not used. The state of the practice could be limited because of the need for large-scale computers, intensive training on the part of individuals using the models, or, perhaps, inadequate resources on the part of certain planning agencies for making models available to planners.

Implementation barriers limit the state of the practice and can be the result of a wide variety of reasons. Limited resources--money, personnel, or other things--could have an impact on implementation. In addition, a lack of information sharing at all levels of planning agencies could result in reduced implementation. The workshop participants also made a subjective evaluation as to whether additional research was needed to develop models for addressing the issues identified. As a part of its activities, the workshop prepared nine specific research statements, which were considered to be of a high priority in improving travel analysis methods for the issues listed.

The participants discussed the differences in analysis capabilities that existed between various levels of planning agencies. In general, the higher the level of planning agency (i.e., from local to federal government), the more resources are available for the use of improved analytical tools. Thus, the lower levels of planning agencies may not have access to or utilize specific models for analyzing issues, not because the models are not in existence, but because the resources of the lower-level planning agencies are limited. In addition, the lower-level planning agencies often have planners who have general expertise, whereas a higher-level planning agency may have specialists in specific areas. Many of the models available for the analysis of specific issues require a certain level of expertise often found only in specialists.

It was in the context of the above considerations that participants of the workshop outlined the major issues in investment and financial areas for the 1980s and reviewed the analytical tools currently available. Table 1 provides a summary of the major investment and financial issues in the 1980s considered by the workshop participants. In addition, Table 1 provides a subjective measure of the state of the art, the state of the practice, implementation barriers, and research needed for the analytical tools currently available to address these issues. Also, one can see from Table 1 that certain issues apply only to highways or transit, whereas others apply to both modes of transportation. The following discussion elaborates on the major issues listed in Table 1.

MAJOR ISSUES

Capital Investment Versus Long-Term Maintenance and Operations

In both the highway and the transit fields, it is necessary to analyze from an investment and financial aspect whether it is more appropriate to provide funds for capital investments or to use available resources for long-term maintenance and operations.

A planner should be able to differentiate between a return on investment that might be made in capital outlays and an investment in maintenance and operations. Although it is readily admitted that many planning agencies do not provide as much analysis as is really needed in this area, it was felt that the analytical tools in existence were good and that little or no research was needed to improve on these analytical tools. However, it was felt that the state of the practice was very limited in the use of available models. The workshop participants felt that neither local planning agencies nor even planning agencies at the state level provided analysis in this area on a routine basis. Thus, the state of the practice appears to be limited.

There are implementation barriers to the use of models in this particular area. A certain amount of data is needed in terms of maintenance and operations costs; these data are not always readily available at the state and local levels. The cost of collecting data can be quite extensive, and some of the data have never been collected, particularly in the maintenance area. In addition, the expertise that would be needed for a comprehensive analysis in this area may not be so readily available in local planning agencies as it might be in higher-level planning agencies with more resources.

Reduction in Standards

Reduction in standards primarily applies to the highway field and relates to the use of resources to construct new facilities or to maintain existing facilities at lower standards than current design standards. Because of the limited resources available for construction of new highway facilities as well as for the maintenance of existing facilities, there have been arguments that the geometric and safety standards of highways should be reduced in order to have more miles of facilities constructed or maintained.

The workshop participants felt that the models available to provide in-depth analysis in this area are generally adequate and available; that is, the state of the art is good. In addition, the participants felt that no major research is needed in this area. However, the workshop participants felt that

Table 1. Investment and financial issues in the 1980s.

Issue	State of the Art	State of the Practice	Barriers to Implementation	Research Needed
Capital investment versus long-term maintenance and operations (H, T)	Good	Limited	Yes	Minor to none
Reduction in standards (H)	Good	Limited	Yes	Minor to none
Revenue forecasting				
User fees (H, T)	Good	Wide	No	Minor to none
Related fees (H, T)	Good	Limited	Yes	Minor to none
Nonrelated fees (H, T)	Weak	None	Yes	Yes
Disinvestment (H, T)	Good	Limited	Yes	Minor to none
Interaction among demand, financing, and land use	Good	Limited	Yes	Minor to none
Maintenance investment impacts and sequencing (H, T)	Good	Limited	Yes	Minor to none
Life-cycle costing (H, T)	Good	Limited	Yes	Minor to none
Marginal reconstruction programs (H, T)	Good	Limited	Yes	Minor to none
Resource allocation to local areas (H, T)	Good	Limited	Yes	Minor to none
Cost reallocation (H)	Fair	Limited	Yes	Yes
Traffic operations improvements (H)	Weak	Limited	Yes	Yes
Highway system management (H)	Weak	Limited	Yes	Yes
Parking management (H, T)	Weak	Limited	Yes	Yes
Marketing (T)	Good	Limited to none	Yes	Minor to none
Deregulation (T)	Weak	None	Yes	Yes
Demand response to service changes (T)	Good	Limited	Yes	Minor to none
Equity (T)	Good	Limited	Yes	Minor to none
User-side subsidy (T)	Weak	Limited	Yes	Yes
Fragmentation of services (T)	Weak	Limited	Yes	Yes
Allocation of subsidy to state and local levels (T)	Good	Limited	Yes	Minor to none
Impact of alternative service options (T)	Weak	Limited	Yes	Yes

Note: H = highway, T = transit.

the state of the practice was limited because of the resources and expertise needed for in-depth analysis in this area. There are implementation barriers to the use of models in this area, primarily due to computer capabilities, data availability, and expertise required in lower-level planning agencies.

Revenue Forecasting

User Fees

Revenue forecasting applies to both highway and transit modes of transportation. Revenue forecasting from user fees would be related to fees collected from gasoline taxes and automobile registration and to other fees charged for activities related to the transportation field. The workshop participants felt that the analytical capabilities in this area are good and have been for many years. Very little research is needed to improve on revenue forecasting from user fees. The state of the practice in the use of these models is widespread, and there appear to be no major implementation barriers to the use of the analytical methods. Most federal, state, city, and county planning agencies or revenue departments annually forecast revenue that will be received from user fees. Normally, the forecasts are reasonably accurate and have provided adequate information in the past.

Related Fees

Related fees would be those fees that could be derived from other than direct user charges. These may be an assessment of taxes on increased value of land or other property adjacent to a subway station, an interchange, or other transportation improvement. The analytical tools available for forecasting fees that could be derived from related activities are good, but the state of the practice is very limited. The participants felt that additional research is not needed in this area, since there has been a substantial amount of work in developing models to forecast the impact of transportation improvements on various activities. There are barriers to implementation, and again they are related to the resources available for a particular planning agency.

Nonrelated Fees

The nonrelated fees apply to both highway and transit modes of transportation. These fees might be derived from additional taxes placed on business activities that may have an increase in revenue due to the construction of a specific transportation facility or the improvement of an existing transportation facility. These business activities could be a wide variety of business concerns such as restaurants, shopping centers, movie theaters, or other revenue-producing business enterprises. The workshop participants felt that the existing tools available for analyzing the impact in the area of nonrelated fees are very weak. Although some minor work has been done in this area, it is not to the extent that would make the state of the art adequate to provide an in-depth analysis on the major issues. The state of the practice is in essence nonexistent, and a substantial amount of research is needed to develop better forecasting tools. In addition, there are many implementation barriers, which include not only the lack of resources but also the lack of adequate methodologies for analysis.

Disinvestment

Disinvestment would apply to both highway and transit modes of transportation. It is related to the discontinuance of a facility or an operation. An investment and financial analysis should include the alternative of abandoning a highway or transit facility or operation. The continuance of a transportation facility or operation may not always be in the best economic interests of the public. The workshop participants felt that the analytical tools were good at the current time, although the state of the practice was limited. There is not necessarily a need for research on developing models for analysis in this area. There are barriers to implementation that are related to resources as well as expertise available to utilize the existing analytical tools.

Interaction Among Demand, Financing, and Land Use

The interaction among demand for travel, land use, and the financing of the facilities applies to both highway and transit operations. The current ability to analyze these interactions is quite good. Although the state of the practice is limited, work done on these interrelationships has provided the analytical tools needed. There are barriers to implementation and, again, these barriers are related to resources and expertise required for utilization of existing models. Often, lower levels of planning agencies do not have the resources needed to provide for the analysis in this area.

Maintenance Investment Impacts and Sequencing

The allocation of resources to maintenance and the scheduling of maintenance projects are very important economic considerations in both the highway and the transit fields. The amount of maintenance performed and the intervals at which the maintenance is scheduled have a direct bearing on the total amount of resources that will be required for a given facility. The analytical tools are in existence and the state of the art is good for providing investment and financial analysis in this area. However, the state of the practice is very limited, even though very little research appears to be needed in this particular area. There are barriers to implementation, which, as in many of the other categories, are due to a limited amount of resources available at various levels of planning agencies.

Life-Cycle Costing

The rate of return on an investment is greatly influenced by the life-cycle costing of the item under consideration. Life-cycle costing applies to both highway and transit modes of transportation. Although there appears to be a limited amount of work done at this level in many planning agencies, the state of the art appears to be good for determining life-cycle costing. The workshop participants felt that no major additional research is needed; however, again there are barriers to implementation. It appears that adequate analysis in life-cycle costing is not readily conducted by all planning agencies.

Marginal Reconstruction Programs

The concept of evaluating reconstruction programs on a marginal basis applies to both highway and transit modes of transportation. This concept would also include combining improvements, which would tend to increase the rate of return on the investment of public monies. Often it is more economically advantageous to conduct reconstruction programs on a marginal basis by adding the more significant programs on a specific scheduling basis than to provide for an entire reconstruction project at one time. The analytical tools for conducting analysis in this area are considered to be good, although the state of the practice is limited. The workshop participants felt that little or no research is needed to improve analysis in this area. There are barriers to implementation, which again are related to resources and expertise available at various levels of planning.

Resource Allocation to Local Areas

One of the financial problems in both the highway and transit fields has been the acquisition of resources at different levels of government. Generally, the higher level of government can collect resources (i.e., taxes) with more ease. Local communities often have difficulty in developing a financial base other than from property taxes. Thus, the allocation of resources to local communities from higher levels of government is important in the transportation field. In addition, the return on the investment of public monies can be greatly altered depending on the allocation of resources in a state or region.

The analytical tools for conducting analysis in this area are quite good, although the state of the practice has been limited. Much of the allocation of funds in the state is done on a political basis rather than on an economic basis; thus, there are barriers to implementation, not only from limited resources but from a political point as well. The workshop participants did not feel that substantial additional research was needed in this particular area.

Cost Reallocation

Cost reallocation is applicable primarily to highways; it addresses the issue of who pays for highways. This is to say what share of highway costs should be borne by such groups as the trucking industry, automobile drivers, and the many other groups that in some way use our nation's highways. This area is very important in the investment and financial analysis of highways and has a direct impact on the funds available for both construction and maintenance of highway facilities. The analytical tools available for analyzing investment and financial considerations in this area are considered to be only fair. There has been much work in this area in years past, but many of the studies have contradicted each other. The state of the practice is limited; some states do more than others in cost reallocation. There continue to be barriers to implementation, some of which are due to insufficient technical knowledge. Some are also due to a lack of data in this area. Additional research is needed to develop better procedures for cost reallocation as it applies to the highway field.

Traffic Operations Improvements

Traffic operations improvements apply primarily to the highway field, although there could be secondary impacts in the transit area. Investment of public monies in improving traffic operations can lead to a good return on investment; however, the workshop participants considered that the state of the art for conducting an economic analysis in this area is weak and that the state of the practice has been limited. Although one can generally quantify the benefits to motorists for a specific traffic operation improvement, it is difficult at this time to ascertain the total economic benefit to the community when the improvement is compared with other types of projects for investment. There have been barriers to implementation, as indicated above, due to resource limitations as well as to the expertise that might be available at different levels of planning. Additional research is needed to improve the techniques that could be used for analysis in traffic operations improvements.

Highway System Management

Management of the highway system applies to the highway field, although again there could be indirect benefits in the transit area. There has not been major attention given in the United States to the efficient management of the highway system. Generally, the highway system has been viewed as a facility without a need for overall system management. The way in which the highway system is utilized and allocated for use by various groups will have an impact on the economic conditions of a state or the country. However, little work has been done in analysis in this area in the past, and the analytical tools are considered to be weak. Additional research is needed to improve the analysis capabilities in this area. The state of the practice has been limited or nonexistent, and there are, of course, barriers to implementation. Part of the reason for the barriers is the different political jurisdictions that have control over the highway system as well as the lack of expertise to analyze the investment and financial considerations in this area.

Parking Management

The management of parking, whether in a CBD or in other urban areas, is important to both highways and transit. The availability of parking and the way in which it is allocated and managed have a very definite impact on the demand for modes of travel as well as on private businesses. Little work has been done except for some analyses of parking-management strategies as they would affect the investment of public funds. The analytical tools in this area are considered to be weak, and the state of the practice has been very limited. Additional research is needed to improve the analytical capabilities in this area. There are barriers to implementation, some of which are related to resources and expertise that are required. Other barriers are related to the fact that many of the parking issues are decided in the political arena rather than on an investment and financial basis.

Marketing

Marketing applies primarily to transit and includes many activities other than advertising. The workshop participants felt that in the transit field, there has been a severe lack of planning, research, product development, product testing, pricing, and advertising, which would tend to improve the return on investment in the transit field. Admittedly, there are many transit agencies that have had promotional or advertising programs; however, without the planning, research, product development, product testing, and pricing, the advertising is of little benefit. The state of the art in the marketing field is good and has been well established for many years. It is readily accepted and used in most businesses in the private sector; but marketing has been almost nonexistent in the transit field. The participants felt that no additional research was needed in this area, since the marketing field is well established. There have been barriers to implementation. Many of the barriers deal with a lack of resources as well as the expertise in local transit operations to develop comprehensive marketing programs for their operations.

Deregulation

Deregulation includes a variety of activities such as the provision of alternative services, differential fare structures, revenue, pricing, and many other activities that apply primarily to the transit field. The emphasis on deregulation has increased substantially in the past few years in the airlines industry as well as in railroads and trucking. However, deregulation has not been considered to any great extent in the urban transit area, and very little work has been done. Therefore, the workshop participants felt that the state of the art for analysis in this area is weak and that the state of the practice does not exist. Much research is needed to be able to know the impacts that various areas of deregulation would have in the urban transit field. There are barriers to implementation, some of which are directly related to the infrastructure of the transit field. An attitudinal change must occur in the transit field in order for more work to be done in deregulation. However, the potential for improvements in the investment of public monies through deregulation analysis and implementation could prove to be substantial.

Demand Response to Service Changes

Demand response to service changes applies primarily to the transit field. The workshop participants felt that the state of the art of the analytical tools in this area is good, particularly for those areas in which service changes have been made. There has been a reasonable amount of work done in this area, although the state of the practice is considered to be limited. At the local levels there has not been a reasonable amount of analysis regarding demand response to service changes. There are barriers to implementation, and some of these are due to the infrastructure in the transit field. Even though there could be an improvement in the investment of public monies through various service changes, the ability to make changes is often determined on a political basis rather than on an economic one. The participants felt that no additional research was needed to improve the analytical tools in this area.

Equity

Equity applies primarily to transit operations. The issue is concerned with the equity in which funds are utilized for the total population. Often the benefits of transit are not equitably distributed throughout the urban area. The state of the art of the analytical tools in this area is quite good, although the state of the practice has been limited. It does not appear that a substantial amount of research is needed to improve the analysis capabilities in this area. There are barriers to implementation, some of which are imposed by regulations placed on operators of transit properties. In addition, political considerations are often prominent in the allocation of transit resources.

User-Side Subsidy

The user-side subsidy issue applies to the transit field. Some work has been conducted in analyzing the impacts on investment with user-side subsidies; however, the state of the art in analytical tools is considered to be weak. In addition, the state of the practice has been very limited, and research is needed in this area. There could be great potential for improving the investment in the transit area through user-side subsidies, but without the capabilities of good financial analysis, it is difficult to indicate to decisionmakers the potential impacts of this type of subsidy.

Fragmentation of Services

Fragmentation applies to the transit field and is concerned with the impact of providing a wide range of services that are not necessarily under a central management scheme. This issue is related, to a certain extent, to the deregulation issue. Some would argue that if deregulation occurs, there would be such a fragmentation of services that the consumer would then be at a disadvantage in securing transit services. However, there has been little evidence that this indeed might occur. Unfortunately, the state of the art in analytical tools is considered to be weak for analyzing the impacts on the community that would occur should a collective group of services be available but not be a part of any coalition or central management. The state of the practice in this area has been very limited, and additional research is needed to improve the analytical capabilities. There are barriers to implementation due to a lack of data, analytical tools, and expertise. In addition, the infrastructure for transit is not conducive to promoting comprehensive analysis in this area.

Allocation of Subsidy to State and Local Levels

The manner in which subsidies are allocated to state and local levels of government applies to the transit field. The return on the investment of public funds could be greatly increased, depending on the method of allocation. Often allocations are made on a political basis rather than on economic investment considerations. The state of the art in analytical tools is considered to be good for conducting analyses in this area, although the state of the practice is considered to be limited. The workshop participants did not feel that additional research is really needed. There are barriers to implementation. Some of the barriers are, of course, related to available resources and expertise, but many of them are related to the political concerns for allocating subsidies to any level of government.

Impact of Alternative Service Options

This issue applies primarily to the transit field and is concerned with the impact of alternative services such as vanpools, carpools, express bus services, and subscription services that could be made available in the public transportation field. The state of the art in analytical tools in this area is considered to be weak, and the state of the practice has been very limited. Additional research is needed in improving the methodologies for analysis. There have been barriers to implementation, which are partly due to resources and expertise available at different levels of planning. The potential for improving the investment of public funds in public transportation appears to be good through the provision of alternative service options. However, without adequate capabilities for analysis of the impact of alternative service options, it is difficult to provide the level of information needed for decisionmaking.

RESEARCH NEEDS

The workshop participants developed nine statements of research needs that should lead to the improvement in analysis in the investment and financial areas. These are summarized below:

1. Deregulation of urban public transportation services,
2. Evaluation of investment in traffic operational improvements,
3. Alternative services--introduction of new service,
4. Estimation of highway goods-movement demand,
5. User-side subsidies to increase revenues and service diversity,
6. Impact of ridesharing on transit revenues,
7. Financial impacts of highway management,
8. Estimation of land value changes as the result of transport investment by using demand-analysis principles and tools, and
9. Analysis of the financial impacts of parking-management strategies.

As can be seen above, the research needs statements tend to support those areas in Table 1 that indicated the need for additional research. Statements were prepared that addressed issues in deregulation, alternative services, goods movement, parking, and highway system management, as well as others.

SUMMARY

From the foregoing discussion it is seen that relative to the issues of investment and financial analysis in the highway and transit field, the analytical tools are generally good, although there are weak areas. In addition, the majority of areas do not need substantial additional research. Two of the more critical assessments in reviewing these issues are the conclusions that the state of the practice is limited in almost every area and that there are barriers to implementation in all areas except one. This indicates that, even though there has been a reasonably good level of development of analytical tools in addressing critical issues, the technology transfer has been so poorly conducted that the analytical tools are almost never utilized, particularly at the local level. In addition to the lack of technology transfer, the analytical tools that have been developed often require such enormous computer and resource capabilities that local planning agencies simply are unable to use them. In addition, the models have not routinely been made readily available through time sharing or other means of gaining access to the analytical tools.

It would appear from the discussion of these issues that more emphasis in the 1980s should be placed on technology sharing than, perhaps, on the development of new models or analytical tools, although there are some needs in this area. It would therefore seem appropriate that a major emphasis be directed in the 1980s to increasing the state of the practice of the various analytical tools in the transportation planning area to enable adequate analysis in the investment and financial areas of highway and transit modes of transportation.

State of the Practice: Investment and Financial Analysis

GARY E. MARING, Federal Highway Administration

Financing of transportation improvements emerged as a significant issue in the latter part of the 1970s and is rapidly becoming the key issue of the 1980s. Pat Choate has eloquently described in America in Ruins (1) the state of our public infrastructure. What transportation lobbyists have warned about for years is finally happening: U.S. highways and transit facilities are wearing out and at the same time the money to renew them is being reduced. Transportation needs are staggering. The latest cost estimate for completion of the Interstate system is $38.9 billion; Interstate 4R needs are about $47 billion. Estimated capital requirements for the primary, secondary, and urban systems in the 1980s amount to more than $100 billion just to maintain current conditions. Transit capital needs are estimated at more than $40 billion dollars.

At the same time, we face a national debate on the intergovernmental and private-sector responsibilities for addressing the problem. New Federalism proposes turning back federal highway and transit programs to the states while state and local governments are scrambling to prevent collapse of their infrastructure. Federal revenue enhancement is discussed but very much uncertain. Major new authorization bills for highway and transit must await answers to the revenue question. Major debate is heating up on the relative cost-allocation responsibilities for highway improvements. The federal government is proposing to withdraw from transit operating support.

I must admit great difficulty in focusing on analytical methods for the 1980s when the policy issues and program directions are so unsettled. But on the other hand, we know that there is a massive problem to be addressed and we must begin to rationally develop programs and financing mechanisms if we are to turn around the trend of deterioration in our transportation systems that we have witnessed during the last decade.

Some of the major issues in my mind as I begin this paper are as follows:

1. How can we overcome public resistance to financing mechanisms to meet our capital investment and maintenance needs?
2. To what extent can tools and techniques of the analyst and researcher help solve our financing problems? What tools do we need to respond to the maintenance focus of future programs?
3. Whose responsibility is it to do urban transportation financial planning and forecasting?
4. Shall we emphasize near-term operational agency accounting and budgeting processes (e.g., 2 years), short-range financial planning and programming (say, 3-5 years), mediumto longer-range financial planning (5-15 years), or all of these?

My contribution is to address the state of the practice. I have to make some assumptions in order to narrow the range of uncertainty in this topic and put some bounds on the problem. Therefore, I will focus the state of the practice in the following ways:

1. I will address financing mechanisms primarily at the local level. This is principally to focus the discussion on what I believe is the critical level for this workshop.
2. I will focus on mediumand longer-range financial planning (5-15 years) and not on near-term accounting and budgeting tools; it is not that the latter is not important but only that this makes the topic manageable and deals with what I believe is the principal focus of the workshop.
3. I will deal only briefly with related investment analysis and priority programming tools.

LOCAL FINANCING MECHANISMS

Some may question why this section is included in the paper dealing with methods. I believe that our analytical techniques must be capable of addressing the merits of specific revenue proposals and calculating the financial, travel, and equity impacts of each measure. There must be a sound basis for moving forward to elected officials with specific programs and revenue proposals. The primary local financing mechanisms for highway and transit are listed below (2):

1. Local highway-financing techniques

   a. User pay mechanisms
      (1) Motor fuel tax
      (2) Motor vehicle fees and taxes
      (3) Parking tax
      (4) tolls
   b. Nonuser mechanisms
      (1) Property tax
      (2) Sales tax
      (3) Local payroll or income tax
      (4) Bond financing
      (5) Private financing

2. Local transit-financing techniques

   a. Broad-based taxes and revenue sources
      (1) Retail sales tax
      (2) Property tax
      (3) Payroll tax
      (4) Income tax
      (5) Occupancy and other taxes
      (6) Lottery
   b. Charges on motor vehicle users
      (1) Motor fuel tax
      (2) Motor vehicle tax
      (3) Bridge and tunnel tolls
      (4) Commercial parking tax
   c. Charges on property benefitting from transit
      (1) Service charges
      (2) Special-benefit assessment
      (3) Tax increments dedicated to transit
   d. Borrowing strategies
      (1) Conventional bonds
      (2) Equipment trust certificates
      (3) Tax-exempt industrial bonds
      (4) Grant anticipation notes
   e. Joint ventures with private sector
      (1) Leasing air rights
      (2) Leasing property adjacent to transit facilities
      (3) Participation in land development

In contrast to the states, which primarily rely on user fees, local municipalities collect most of their local highway revenue (69 percent in 1979) from general-fund appropriations and property taxes. Table 1 shows the existing distribution of municipal highway revenue sources. A recent American Public Transit Association (APTA) survey (3) indicates that sales taxes and property taxes are the predominant sources of local transit financing.

Table 1. Local sources of municipal highway revenue.

Source	Amount ($000 000 000s) 1970	1979	Percentage of Local Revenue Sources 1970	1979
General fund	0.9	3.1	38	53
Property tax	0.6	0.9	25	16
Highway-user revenue	0.2	0.5	8	9
Miscellaneous receipts	0.3	0.6	12	10
Bond proceeds	0.4	0.7	17	12
Total	2.4	5.8		

States and localities are obviously faced with many problems and inadequacies in existing revenue sources. Some of these problems include

1. A revenue base that is not sensitive to inflation,
2. Fluctuating construction costs,
3. Fluctuating fuel consumption,
4. Sensitivity to social and political pressures (e.g., Proposition 13), and
5. Increasing demands for transportation facilities, services, and maintenance.

The specific solution to highway and transit financing is unique to each local area. However, it is clear that additional revenue is needed in most areas. User-oriented mechanisms have been generally found to be more acceptable to the public and more equitable. However, they have suffered from the inability to keep pace with inflation. In contrast, nonuser mechanisms generally have the reverse characteristics. The magnitude of financial needs in most areas will likely require a package of mechanisms, user and nonuser.

Creative financing is the name of the game in real estate and should become the game plan for transportation in the 1980s.

Private-sector financing is put forth as one of the solutions. Toll financing is being considered. Metropolitan area sales and gas taxes (added on to those of the state) are being more widely explored. Employer taxes are being explored for transit financing. Special-assessment districts have been used successfully and may have wider application.

I will not begin to offer the pros and cons of the various mechanisms but, suffice to say, we must explore all of these and more. There are many legal and institutional issues associated with several of these. Also, there is little information available on what, if any, analytical techniques have been applied to determine impacts and equity among specific revenue mechanisms.

FINANCIAL PLANNING AND FORECASTING

A survey of FHWA field offices to collect recent examples of urban transportation financial planning studies confirmed my expectations that comprehensive urban transportation financial planning is not occurring to any significant extent. Following is a brief overall summary of studies submitted.

Eighteen reports were received based on our request for examples of financial planning contained in urban transportation planning reports. These reports addressed in varying degrees the anticipated revenues to meet projected capital improvement costs. They were prepared by 4 states, 1 city, 1 chamber of commerce, and 12 MPOs.

Twelve of the reports were long-range urban transportation studies to the year 2000. Six were in the short to medium (5- to 10-year) range. Six dealt with highways, four solely with transit, and eight with both modes. Most reports were for intermediate and large metropolitan areas. Five, however, were for smaller urbanized areas.

Generally, all reports expressed the need for financial planning, largely because of the uncertainty of federal funding, inadequacy of revenues, inflation and rapidly rising capital, and operational and maintenance costs. Most reflected the need for increased revenues to meet the shortfall between projected costs and revenues from existing sources.

The most recent studies decried the uncertainty of future federal funding, particularly since federal funding provided the bulk of available revenues. Most difficult to predict was the federal funding for Interstate substitution, the Federal Aid Urban System (FAUS), revenue sharing, and transit capital grants and operating subsidies. Most reports projected future federal funding on the basis of past funding, but few placed real confidence in these estimates. Several stated that stable funding could only come from increased federal motor fuel taxes.

Some of the reports recommended a more equitable disbursement of federal and state funds by the states and requested elimination of other agency revenues from state fuel taxes. Several reports stressed the need for greater state fuel taxes and other taxing mechanisms to improve state highway revenues.

Inflation causes considerable difficulty to fiscal forecasting. Most of the reports used constant dollars in estimating future costs. Some used different inflation rates (high or low) to give a range of future costs. Almost all of the long-range studies reported that inflation greatly exaggerated the differential between fixed revenues and spiraling costs.

Most of the earlier studies offered little or no solution to the sizeable shortfalls between revenues and costs other than increasing revenues from federal sources. The more recent studies, however, recommended that increased revenues be found from local sources.

The following were recommended as potential local revenue sources for highways and transit:

1. Local-option fuel tax,
2. Local sales tax,
3. Local income tax,
4. Commuter tax,
5. Employer/employee tax,
6. Household tax,
7. Payroll tax,
8. Municipal bonds,
9. Special-assessment districts,
10. General fund,
11. Transit impaction fees,
12. Increased fares,
13. Parking fees and licenses,
14. Tolls,
15. Merchant subsidies,
16. Equipment trust certificates (transit),
17. New buy/lease arrangements (transit),
18. Real estate value increment, and
19. Private financing.

Private financing for highway capital improvements was discussed in several reports. Land developers routinely fund the development of local streets and all or portions of arterials that abut on or provide access to the development. Also, adjacent property owners are frequently assessed for street improvements. In some cases, special-assessment districts are formed to fund road and street improvements that would benefit the district. The Baltimore Regional Planning Commission reports that nearly 10 percent of Baltimore County's highway capital program is paid by developers and petitioners and is not considered as income to the general fund. Benefit assessments, merchant subsidies, and value capture are other techniques for raising private funds.

A literature review for a recently initiated FHWA contract on the use of private funds for highway improvements has revealed some additional examples of private-sector involvement in highway funding.

In Broward County, Florida, a computerized model has been prepared to assess charges to developers for necessary roadway and intersection improvements within a 4- to 6-mile radius of the development. A trip-generation and assignment procedure is used to determine the impact on roadways and intersections. The developer is assessed when there is a projected impact on the level of service, and the funds are accumulated in a trust fund until the improvements have been made.

In Denver, Colorado, quasi-public special-improvement districts are funding and constructing infrastructure improvements. Under enabling state law the districts have authority to tax property within the district. With taxing authority, the district is able to use general obligation bonds to finance its capital improvements. Three contiguous districts in southeast Denver have formed the Southeast Public Improvement Authority. The plan for the joint authority has 42 road improvements with an estimated cost of $18 million. This includes an interchange on I-25. Although the district is quasi-public and must obtain reviews and approvals from local agencies, it is essentially a creation of private property owners.

A brief description of the individual financial studies follows.

<u>Urban Area Transportation Study, Winston-Salem, North Carolina</u>

In a joint state department of transportation and MPO study, three different scenarios were employed as a means of forecasting future funding availability to implement the transportation plan. They are

1. Funding continuing at current trends,
2. Funding continuing at historic trends, and
3. Funding below current trends.

In each scenario, a low and a high forecast are given in terms of lane miles that can be constructed. This is obtained by combining lane miles funded federally or by the state and lane miles funded by private developers. On this basis a detailed listing of projects by lane mile is given for each scenario. The report uses lane miles for selection and comparison; the conclusion is that it is not possible to estimate future costs at this time.

<u>Regional Transportation Plan, Portland, Oregon</u>

A comprehensive plan for the development of transportation facilities to serve the expected needs to the year 2000 was presented. It documents the substantial public financial commitment required for both highways and transit and the necessity for the development of new sources of revenue.

The report discusses federal, state, and local funding sources and compares revenues to costs. The total cost of capital highway improvements, operation, maintenance, and rehabilitation is estimated at $2.3 billion (1981 dollars). Normal revenues are expected to leave a shortfall of $1.25 billion, which must be borne by increasing non-highway-related local revenue sources. Additional sources of revenue are not detailed other than to provide several general financing options that are available to the region.

The financial analyses for the recommended light rail transit system show that it will cost approximately $2.5 billion to build and operate. Even with an assumed federal operating subsidy, there will be an annual operating shortfall of approximately $226.8 million. Local sources for meeting the shortfall were not identified.

<u>Future of Transit Operating Finance, Southern California</u>

The future impacts of California's Proposition A, the phase-out of federal subsidies as they affect the transit operation in Southern California, are discussed. Over the past 15 years transit in the Southern California Association of Governments (SCAG) region has gone from a self-supporting system to a much larger operation that now requires $300 million per year in subsidies. These subsidies are not attributable to the growth of the system but rather to a steady decrease in real fare rates and somewhat less to the real increases in operating cost per patron.

There are 38 transit operators in the area; the Orange County Transit District is the largest. The operators in Los Angeles and Orange Counties are in the most trouble with the pending loss of operating subsidies.

Some recommendations are made to return to zone fares and to reduce and eliminate some discount fares. The possibilities of raising revenues by the establishment of benefit-assessment districts is discussed. Benefit assessment is based on existing space for operations rather than for capital improvements. Value-capture mechanisms are suggested for new development.

A paper on the value-capture tactic is included with the report and an assessment is shown for a hypothetical Mid-Wilshire site. These mechanisms are to be more fully reported in an upcoming transit capital study.

<u>Financing Transportation Improvements, Rapid City, South Dakota</u>

The report's objectives were to determine the area's future transportation needs to the year 2000 and to assess the area's ability financially to meet these needs. As noted, it makes little sense to propose transportation improvement programs beyond the area's ability and desire to implement them.

The report addresses the following financial concerns:

1. Financial resources currently available,
2. Year 2000 financial resources, and
3. Adequacy of projected financial resources to meet transportation needs.

A number of recommendations for increasing revenues are made, e.g., special assessments, equitable distribution of funds, systematic monitoring of revenues and expenditures, bonding for capital improvements, increased utilization of tax levies, and special innovative taxes such as a city gas tax and an incremental tax.

<u>Street and Road Maintenance Needs, San Francisco Bay Area</u>

This study outlines the needs of the Bay Area's cities and counties for increased revenues by local gas tax to offset spiraling maintenance costs and reduced revenues. There are 17 000 miles of county roads and city streets in the Bay Area. Yearly maintenance needs amount to $268 million. Local jurisdictions have budgeted only $167 million for maintenance yearly, which is $101 million short of the required amount.

In the study it is estimated that a 1-cent local gas tax would raise $26 million a year, which necessitates a regional gas tax of 5 cents to meet the maintenance shortfall for the next several years. Recent state legislation allows counties to piggyback on the state gasoline tax.

Chamber of Commerce Regional Mobility Plan, Houston, Texas

A unique plan was that prepared by the Houston Chamber of Commerce in cooperation with state and local agencies. Such an undertaking indicates the concern of the private sector in advocating transportation needs to facilitate economic development.

The Chamber's multimodal regional mobility plan includes (a) more than 170 miles of added capacity on existing freeways, (b) almost 300 miles of new freeways, (c) more than 30 miles of high-capacity transit ways, (d) about 1400 miles of new arterial streets and roads, (e) new grade separations at roads and railroads, (f) several thousand new buses, (g) maintenance and park-and-ride facilities, and (h) rehabilitation of old freeway surfaces.

The estimated cost of the plan is a staggering $16 billion (1981 dollars) over the next 15 years. Existing sources will yield an estimated $6.9 billion over this same period, leaving a shortfall of $9.3 billion.

The report summarizes the options available to close the gap. New funding sources include

1. An increase in the area's share of state funds to 30 percent,
2. The implementation of a 50 percent fare-box increase,
3. The conversion of the motor fuel tax to a percentage and a significant increase,
4. The application of state and local sales tax to motor fuels,
5. An increase is motor vehicle registration fees,
6. The dedication of motor vehicle sales tax revenues,
7. The use of toll facilities wherever feasible,
8. An increase in city and county capital expenditures for bridges and roads,
9. The reestablishment of the state public transportation fund, and
10. The issue of revenue bonds for selected MTA capital improvements.

The feasibility of private-sector participation is also discussed.

The analytic base for most of these studies must be described as relatively primitive. Trend-line analysis is generally the most sophisticated forecasting technique used. Little or no impact assessment is conducted. The operator-specific studies tend to be more quantitive and analytic. Only one study dealt extensively with maintenance needs.

The state of the practice reflects financial planning as often a last step in the planning process and too often an afterthought. The long-range transportation plan is adopted, and then questions begin to surface regarding the financial feasibility. Existing revenue sources are examined and projected through a trend-line procedure. A shortfall is quickly identified and suggestions for additional revenue are mentioned generally without thorough analysis or recommendations for implementation of specific mechanisms. Only in relatively few cases are there systematic efforts to fiscally constrain the transportation plan through an iterative process. Life-cycle costing is not yet a reality in most plans and analyses. Some higher-growth areas are beginning to develop ultimate land use and transportation plans, to cost them out, and then gradually to pare the plans and program based on likely revenues.

The desirable components of a financial or fiscal planning study would seem to include doing the following:

1. Review and analyze existing revenue sources;
2. Forecast revenue based on existing revenue sources;
3. Cost out transportation plans and/or long-range program;
4. Compare proposed plan and/or long-range program costs with projected revenues;
5. Consider changes in plan or program emphasis (e.g., TSM);
6. Constrain plan or program and/or develop new or expanded revenue mechanisms;
7. If plan or program is to be significantly constrained, cycle back through travel and land use forecasts;
8. If new or expanded revenue sources are to be developed, analyze revenue potential, pros and cons, impacts, etc., and provide concrete recommendations for state and local officials;
9. Cycle back through process as necessary.

These steps are shown conceptually in Figure 1.

HIGHWAY FINANCIAL FORECASTING METHODS

A brief review of state transportation revenue-forecasting methods may provide some insight for improved urban financial planning methods. The Oregon Department of Transportation surveyed the other states in October 1981 regarding their revenue-forecasting procedures. Thirty-two states reported on such procedures.

The different forecasting techniques or types of models were classified as follows:

1. Historical trend analysis (including simple linear regression analysis with time as the independent variable) coupled with an assessment of conditions expected over the forecast period;
2. Single-equation multiple-regression model;
3. Multiple-equation econometric model; and
4. Other.

The results are summarized in Table 2.

Several conclusions emerge from this limited (and admittedly unscientific) survey of the fuel tax revenue-forecasting procedures used by other states. Perhaps the most obvious is that the various states use a wide variety of different forecasting methods. In terms of the complexity of the procedure, these range from what one state characterized as a simple educated-guess approach to relatively complex multiple-equation econometric models.

The largest number of states continue to rely primarily on a relatively nonformalized judgment approach to forecasting their fuel tax revenues. Typically this involves an analysis of historical and current trends and a judgmental assessment of how these trends may be modified by national and local conditions expected over the forecast period.

The second largest number of states use a single-

Figure 1. Financial forecasting and the transportation planning process.

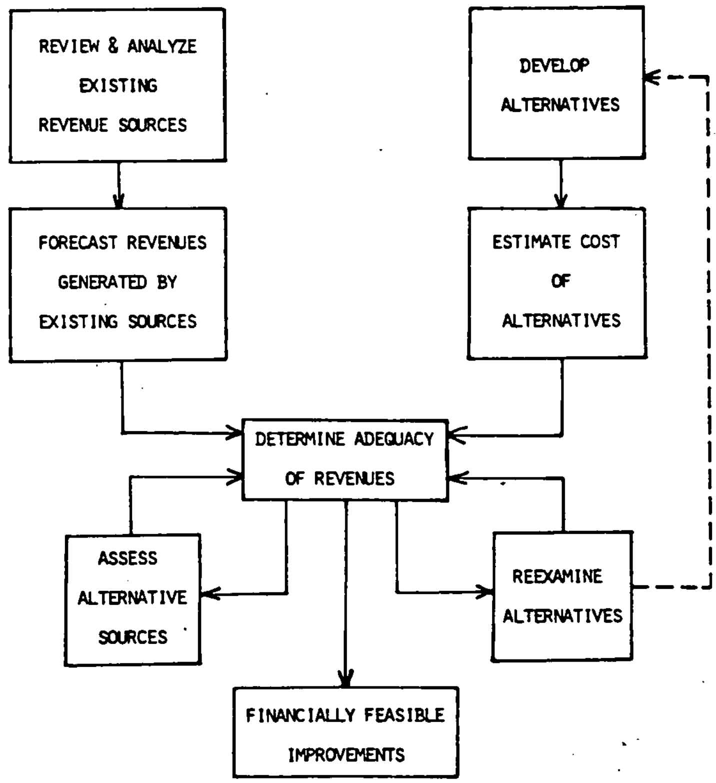


Table 2. Classification of fuel tax revenue-forecasting methods used by states.

State	Forecasting Method Used: Historical Trend Analysis	Single-Equation Multiple-Regression Model	Multiple-Equation Econometric Model	Other
Alabama	X		-[a]	-[a]
Arkansas	X			
California		X		
Connecticut		X		
Delaware	X			
Florida	X			
Hawaii				X
Idaho		X		
Illinois	X			
Indiana	X			
Iowa	X			-[b]
Kansas	X			
Kentucky			-[a]	X
Mississippi		X		
Missouri	X			
Montana	X			
Nebraska	X			
Nevada	X			
New Mexico				X
New York	X			
North Carolina		X		
Ohio	X			
Pennsylvania	X			
Rhode Island			X	
South Dakota	X		-[a]	
Texas			X	
Utah		X		
Virginia			X	
Washington		X		
West Virginia	X			
Wisconsin			X	-[b]
Wyoming	X			

Note: Data are from the Oregon Department of Transportation.
[a]Has used this method in the recent past but is not currently using it.
[b]Is experimenting with but does not yet actually use this technique as primary forecasting method.

equation multiple-regression model as their primary forecasting method. Although the precise form of these equations varies from state to state, fuel consumption (or fuel tax revenue) is typically modeled as a function of a limited number of independent variables such as real income per capita, number of registered vehicles per capita, and the real price of gasoline. The forecast values of the independent variables are usually obtained from a national econometric service such as Data Resources Inc. or from an econometric model of the overall state economy.

It appears that relatively few states use a more complex multiple-equation econometric model approach as their primary fuel tax revenue-forecasting procedure. A few states have used this type of approach in the past but have found that a simpler approach tends to forecast just as well and has the added advantage of being easier to explain and use. At any rate, the more complex multiple-equation models that are used by some states tend to be fairly specific to these states and thus are often not easily adaptable for use by other states.

NCHRP (Project 8-22) sponsored the formulation of a forecasting method to project state transportation revenues that takes into consideration current and anticipated changes in economic and energy conditions and policies. The procedure emphasizes forecasts of the principal determinations of highway revenue: motor fuel consumption, motor vehicle registration, and licensed drivers. This model is in the process of being tested in several states.

The model, as with most other state revenue-forecasting models, would have application to urban transportation only to the extent that gas tax and motor vehicle revenues are to be analyzed. As mentioned earlier, these user mechanisms are a relatively small part of local financing sources.

Financial management and forecasting at the county and municipal levels is principally focused on budgeting and accounting and the function is generally housed in the budget office. Forecasts generally have a one- to two-year horizon. Local governments are showing considerable interest in multiyear forecasting, i.e., projecting revenues and expenditures for three to five years. The perceived advantages are to be able to take steps earlier to ensure that revenue and expenditure gaps will not occur and that the jurisdiction need not resort to last-minute measures to avoid fiscal difficulties. Transportation expenditures and revenues are of course part of the overall local financial-forecasting process, although transportation expenditures generally account for less than 10 percent of local budgets.

TRANSIT FINANCIAL-FORECASTING METHODS

A recent UMTA publication (4) describes transit state of the practice in financial forecasting. Discussions were held with 26 operators throughout the United States. Discussions with the operators attempted to examine both the annual budgeting process and the longer-range forecasting procedures, e.g., five years. However, only in rare instances has a great deal of effort been devoted to planning beyond the one-year horizon. Most operators cited too many unknowns and external factors as the reasons for not being able to perform credible longer-range financial planning. Discussion focused on four areas: fare revenues, labor costs, maintenance costs, and nonfederal subsidies.

The discussion revealed that methods, data processing, and data-collection procedures were designed for operating departments and accounting functions, not for financial forecasting. Two observations were made: (a) financial planners and operating staff must work together, and (b) much of the data needed by both groups should come from the same source. Transit financial forecasting is described as a process of integrating information internal to a transit agency together with external information for the purpose of determining what resources will be required for a given level of service or alternatively what level of service can be provided with a given level of resources. Financial forecasting picks up where the accounting and budget function leaves off and is a forward-looking emphasis on the economic consequences of alternative assumptions.

At the Airlie House conference in 1981, a paper by Jones and Wentworth for the financing workshop described the development of their new modular financial-forecasting system at Tri-Met in Portland, Oregon. Figure 2 shows a schematic financial-forecasting system. The system would include a number of techniques or models, each forecasting a distinct segment of costs or revenues, which are applied together to predict future cash flows for the agency. Having examined this structure in the light of the state of the art, Jones and Wentworth went on to suggest research needs in five areas: standardization of financial-planning package(s) for transit agencies, development of applications portfolio of revenue-forecasting models, development of applications portfolio of operations cost-forecasting models, development of applications portfolio of capital programming and construction models, and provision of training and support.

The proposed financial-forecasting system does not explicitly link to the travel demand forecasting process. Ideally, transit pricing and operating strategies would feed not only into the cost models but also into the travel demand modeling process.

INVESTMENT ANALYSIS AND PRIORITY PROGRAMMING TOOLS

Although there has been significant progress at the statewide level in the use of needs assessment, in-

Figure 2. Transit financial-forecasting system.

REVENUE MODELS		COST MODELS	
INPUT	Revenue Line Items	Cost Line Items	INPUT
NON-CAPITAL REVENUES	Fare Revenues Tax Base Revenues Federal Operating Assistance (Section 5) Federal Technical/Demonstration Grants Miscellaneous (Interest on investments, etc.) State Operating Assistance Other	Bus Operator Costs Other Transportation and Operations Costs Fuel Maintenance General and Administrative including pension cost	OPERATING COSTS
CAPITAL REVENUES	Federal Capital State Capital Local Capital Other Local Assistance	Capital Costs: Vehicles, facilities and equipment Vehicle replacement Debt Service Project Scheduling Life-cycle Costing	CAPITAL COSTS
OUTPUT	SUMMARY FINANCIAL FORECAST		OUTPUT

vestment analysis, and priority programming tools, little application has been made to the urban transportation planning process. At the statewide level the highway needs and investment analysis process typically deals with capital, operational, and maintenance options as simply conceptualized in the matrix shown below, which portrays trade-offs between and within the capital, operational, and maintenance categories of investment (5):

	Total Funding Level		
Needs	$X	$Y	$Z
Capital			
Option 1	X^1	Y^1	Z^1
Option 2	X^2	Y^2	Z^2
Option 3	X^3	Y^3	Z^3
Maintenance			
Option 1	X^4	Y^4	Z^4
Option 2	X^5	Y^5	Z^5
Option 3	X^6	Y^6	Z^6
Operating			
Option 1	X^7	Y^7	Z^7
Option 2	X^8	Y^8	Z^8
Option 3	X^9	Y^9	Z^9

The urban planning process and travel demand forecasting have principally focused on alternative capital plans and programs. We need to reorient our focus and the tools with which to analyze alternative investments. It appears that new tools linking highway maintenance and rehabilitation with operations and major construction investments and then with urban travel demand forecasting procedures would be a necessary input to investment analysis and priority programming. Outputs of the travel demand forecasting process such as volumes, speeds, and truck movements provide useful input to determining maintenance, operational, and capital needs and assessing cost-effectiveness of such investments, but there must also be a link back to travel demand as investment levels change.

Some existing statewide highway investment tools that may have some application to urban investment analysis include the Highway Performance Monitoring System (HPMS) models, HWY NEEDS model, HIAP model (6), and pavement management tools developed by FHWA and others. HWY NEEDS is primarily used to analyze highway capacity and geometric deficiencies section by section. HIAP is a priority programming tool (taking input from HWY NEEDS or other similar models) and is based on maximizing user benefit. HPMS models that will soon be made available to the states will provide the capability to do more complex investment analyses by calculating performance measures for each investment level.

Pavement management is of great interest now, both to FHWA and the states. A number of pavement management information systems have been developed. The systems generally rank pavement sections based on factors such as deflection, roughness, and cracking. Composite indices of performance are generally calculated.

Remaining structural life is estimated based on AASHTO relationships from the road tests. At least one MPO, Metropolitan Transportation Commission (MTC), in Berkeley, California, has done a pavement management inventory and analysis. MTC provided staff support to the counties and cities in the region to develop their backlog costs (deferred maintenance) and ongoing maintenance costs. Backlog costs for the area were estimated to be $300-500 million. Annual ongoing maintenance costs are estimated at $268 million. Local jurisdictions only budgeted $167 million in the last year. Figure 3 (7) shows how deterioration accelerates as roads get older. If maintenance is not done, pavement condition worsens and the street segment slides down the curve into the next maintenance category and repair costs accelerate.

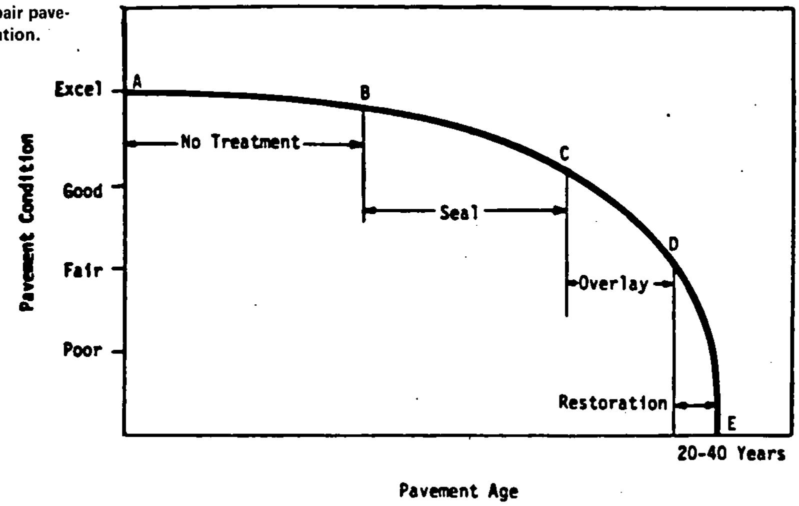
INTERGOVERNMENTAL RESPONSIBILITIES

Many actors come into the process when we move from travel forecasting into financing and implementation issues. The role of the MPO in all of this is less than clear. Budgeting and short-range financial planning are traditionally operational agency responsibilities and should probably remain that way. Improvements are needed in those areas, as described in the section on transit financial forecasting. There does seem to be a void in medium-range to longer-term urban financial planning (5-15 years), which from our informal survey is beginning to be filled by MPOs and in a few cases states, cities, operators, or even the private sector. As with other areas of transport planning and project development, the specific state and local transit or highway responsibilities for financial planning and investment analysis are difficult to generalize. MPOs have traditionally focused on long-range capital transportation planning with little attention to financial forecasting, alternative levels of investment, and maintenance needs. Transit operators and municipalities with local transit and street functions are typically involved with the budgeting process and very short-range financial forecasting. The state DOTs have made the most progress in medium- to longer-range financial planning, investment analysis, and programming. These analyses generally cover both rural and urban sections of the state highway system. State revenue mechanisms are developed principally to fund the state system; there is some passthrough to help fund county and municipal systems.

What then are the roles of the MPOs and local operational agencies? Transit agencies are attempting to move beyond their one-year budgeting focus to a three- to five-year short-range financial planning horizon. Municipalities and counties are struggling to do the same with their street and road responsibilities. To the farthest extent possible, they are searching for other revenue mechanisms. The MPO then may have a longer-range role in the 5- to 15-year horizon to assess capital and maintenance needs, alternative investment levels, and revenue mechanisms for the transit and highway system in the region. But what functional or administrative systems should be included? State responsibility and input on the higher-level systems are obvious. To the extent that local transit agencies and highway agencies assess needs on their systems, these can be input to a regional financial and investment analysis.

Assuming that this can be accomplished technically, what then is the MPO role in analyzing revenue mechanisms? The various roads and streets in a metropolitan area are the financial responsibility of the state, counties, and cities, each with their separate revenue mechanisms. On the transit side, revenue generation is often the responsibility of a regional transit authority. The MPO as a forum of local elected officials will certainly have a policy role in debating new or expanded revenue mechanisms in the area, particularly where areawide revenue schemes are being debated. The state policy role is also important in determining highway and transit revenue mechanisms, improvement programs, and state aid to localities for highways and transit. Again, it is very difficult to generalize such responsibilities.

Figure 3. Treatments needed to repair pavement at different stages of deterioration.



JURISDICTION	TREATMENT NEEDED (% of Area) (Approx. Position on curve) NT (A-B)	S (B-C)	OL (C-D)	R (D-E)	BACKLOG COST (millions of $)	CYCLICAL NEEDS (millions of $)	CYCLICAL EXPENDITURES (millions of $)
Alameda Co.	40	38	14	7	23.3	3.6	0.6
Napa County	72	22	6	0	1.8	1.5	1.6
Alameda	76	16	7	1	1.0	0.7	0
Albany	60	19	19	2	0.8	0.1	0.2
Berkeley	38	17	19	27	19.6	1.3	0
Daly City	63	17	16	4	3.9	0.8	0.3
Fremont	68	11	18	3	11.7	2.2	0.5
Oakland	31	20	44	5	37.9	3.2	0.3
San Francisco	60	28	9	2	12.5	7.9	3.5
San Leandro	69	23	6	2	1.9	1.0	0.5
San Mateo	59	37	4	0	2.2	1.1	0.2
TOTALS (for sample)	56	24	15	5	116.5	23.7	7.7

WHERE DO WE GO FROM HERE?

Some obvious conclusions emerge from this discussion:

1. We do have a financial crisis in meeting urban transportation needs. Federal policy directions have increased uncertainties in local financing.
2. Expanded and new state and local revenue sources must be found to finance urban transportation needs.
3. Medium-range to longer-term urban transportation financial planning must be instituted to lend realism to plans and programs. Some interaction will be necessary among transportation plans, financial plans, and land use plans.
4. Intergovernmental responsibilities for budgeting, short-range fiscal analyses, and medium-range to long-term financial planning must be clarified.
5. Responsive analytic techniques are needed to analyze and forecast revenue mechanisms and associated impacts.
6. Improved transit operator cost and revenue models are needed. These models should also link with the travel demand forecasting process.
7. We need new or revised urban highway investment analysis tools that can analyze maintenance, reconstruction, and TSM and major construction alternatives and interact with the urban travel demand forecasting process.

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Research Needs

1. Impact of deregulation on urban public transportation services

a. Assess the magnitude of new service options to be introduced in a deregulated environment
b. Assess the probable impact of new service options on demand for each service and shift from other services
c. Assess the potential change in revenue from the introduction of new service options
d. Assess the potential change in fare structure and the resulting impact on demand for the services
e. Assess the probable pricing policies that may result from the introduction of competing services of different quality
f. Assess the impact on each market segment of each of the above steps

2. Evaluation of investment in traffic operational improvements

a. Develop better estimate of user benefits, fuel consumption, and air-quality impacts of traffic operational system efficiency improvements
b. Gather data for
(1) Various vehicles in the fleet
(2) Stop and speed-change cycles and respective fuel consumption data under different system configurations and levels of service

3. Alternative services--introduction of new service

a. Determine shifts in demand as a result of introduction of new services
b. Determine financial success or viability of a new service and impact on existing service
c. Develop better understanding of factors that would influence ridership choice and the extent to which they would influence it (factors other than service variables such as fare, time, frequency)

4. Estimation of highway goods-movement demand

a. Use prior research to document our current understanding of highway goods-movement demand--its characteristics and sensitivity to cost allocation and regulation issues
b. Collect information and data as necessary to address gaps in our current understanding of highway goods-movement demand
c. Develop relationships between demand characteristics and economic and institutional factors affecting emand characteristics at two levels--system and facility specific
d. Develop guidelines on application of these relationships for revenue and demand estimation in systems and project-planning contexts
e. Disseminate study results

5. User-side subsidies to increase revenues and service diversity

a. Develop analysis to explore types, costs, and benefits of user-side subsidy programs for transit systems of different sizes and complexities as well as demand and added net revenues from increased fare levels for the general riding public
b. Look at cost impacts of different selected eligibility-group definitions
c. Analyze conditions (e.g., regulatory, financial) needed for private-sector investment to provide new services that are eligible for receipt of user-side subsidies
d. Set up demonstration projects to generate missing analysis data (e.g., large city public transit user-side subsidies) and refine analysis methods

6. Impact of ridesharing on transit revenues

a. Assess feasibility of initiating a ridesharing-vanpooling program in area in coordination with transit service
b. Determine ridership for ridesharing
c. Estimate effect on transit ridership
d. Estimate effect on transit service level and possibility of reduced fixed-route cost
e. Determine effect on traffic volumes
f. Estimate resulting transit deficit structure

7. Financial impacts of highway management

a. Assess the cost and travel behavior impacts of such strategies as automobile-restricted zones, congestion pricing, alternative toll policies, etc.
b. Improve current demand models to specify these strategies and to obtain empirical results on which to calibrate travel behavior

8. Estimation of land value changes as result of transport investment by using demand-analysis principles and tools

a. Look at both cross-sectional and most important longitudinal response to actual investments
b. Correlate measured change in land value with both accessibility and facility demand by recognizing exogenous factors (e.g., availability of vacant/developable parcels, zoning)
c. Model developer's potential response to alternative value-capture mechanisms

9. Analysis of financial impacts of parking-management strategies

a. Analyze response to longitudinal changes in parking-fee levels and structure
b. Differentiate fringe from independent parking facilities

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