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Foreword

The first part of this Record contains papers presented at a mid-year meeting of the Committee on Transportation Data and Information Systems, held in Washington, D.C., October 24–25, 1989. Francis B. Francois states that there is a need to find more effective ways to collect and analyze the data and information necessary as we move into the 21st century; but he cautions that there is a need to avoid information gridlock, as we are deluged with data and high speed computers capable of whirling out more information than the professional can digest and use. Francois further discusses the information and data gaps in working on the AASHTO Transportation 2020 effort. Three transportation challenges of the 1990s, according to Francois, include, in the area of highway safety, particularly, accident data which will support highway project decision making in a more meaningful way; in the area of congestion, currently there is no consistent, effective way to measure congestion; and in planning, it is imperative to collect and analyze data that will support mobility planning, as opposed to only planning for individual needs.

Alan Pisarski discusses appropriate institutional forms that a comprehensive transportation information program might take. He delineates the purpose and scope of such a discussion, surveys some of the institutional forms and types now operating in this sphere, and examines the functions that our institutions must perform in order to be effective.

Edward Weiner discusses the basic data that are needed in national planning activities; technological improvements that might assist in the data inventory area; needs and requirements of local data surveys; and data gaps and accessibility. The author concludes with a specific proposal to improve future data.

David R. McElhaney discusses the three basic data series in the Office of Highway Information Management, FHWA. They include the Highway Performance Monitoring System, the Highway Users and Finance Data, and Nationwide Personal Transportation Study (NPTS). The author also discusses the Bureau of the Census Truck Inventory and Use Survey (TIVS) and the Nationwide Truck Activity and Commodity Survey.

Samuel L. Zimmerman discusses four major types of data needed for strategic planning. They include factors that influence transit demand, the system extent, system operations and related costs, and system condition. The Section 15 data set and its effectiveness in providing national analysis of transit productivity and efficiency is reviewed. The author also identifies transit rehabilitation and replacement and transit safety and security as increasingly important issues for the coming decade.

Charles L. Purvis reviews a survey of large metropolitan organizations to ascertain past, current, and future data collection plans with respect to household travel surveys and related auxiliary surveys. Thirty-eight metropolitan areas responded including the 20 largest metropolitan areas in the United States.

The workshop reports from this meeting are given, as follows: urban report by Alan Pisarski, statewide report by Michael Meyer, and national data by Gary Maring.

Howard J. Simkowitz discusses research underway on integrating Geographic Information System (GIS) technology and transportation models. The author examines the data requirements of various transportation models, demands on the structure of GIS data bases, the interface of the model with GIS, and the content and structure of the transportation data base.

The other papers contained in this Record focus on statewide traffic data standards (Albright; Albright and Wilkinson), design of statewide traffic monitoring system (Taqui), factors affecting the adoption of information systems in state DOTs (Lane and Hartgen), and improved methods for collection travel time information (Rickman et al.).

Transportation Data–Getting More, but Avoiding Information Gridlock

FRANCIS B. FRANCOIS

Short Circuit was the name of a recent motion picture featuring a robot who, through an accident, became "humanized." The robot had the unique skill of being able to quickly skim books and other materials, and store all the contents in its memory. One of the film's appealing comic features was the robot's habit of frequently saying "more input" after devouring a shelf of books, as he sought to enlarge his information bank about everything.

The motion picture was a hit in modern America because the robot helped us find humor in today's computerized, complex world. The phrase "more input," and its predecessor, "more data," have become standbys of modern decision making, in both government and the private sector. We are told that our era can be called the beginning of the "Information Age." Writing in the current issue of *Omni* magazine, futurists Marvin Cetron and Owen Davies tell us that: "About half of all service workers (43 percent of the labor force by 2000) will be involved in collecting, analyzing, synthesizing, structuring, storing, or retrieving information as a basis of knowledge." (*1*)

Looking toward the year 2000 in their *Omni* article, the two futurists also predict a number of trends that will continue to complicate our transportation system, including:

- More development in the suburbs, and increased urbanization of the suburbs with more "downtowns," office parks, shopping centers, and entertainment districts,
- Creation of "penturbia," as population expands beyond the suburbs into outlying towns and urban areas, and
- Increased job mobility, meaning more changes in home-to-work trip routes.

The transportation profession is one that relies heavily on data and information processing, ranging from the conceptual planning of transportation projects, through their program planning and project development, financing, and on through construction, operations, and maintenance. But in the words of that great entertainer Al Jolson, "Folks, you ain't seen nothing yet."

Complicated as is today's transportation world, tomorrow's will be far more complicated. This will be true for many reasons, including the increasing globalization of America's economy and life-style, changing demographics, and a society that will require even greater mobility. The movement needs of goods and commodities will change, and our transportation systems must be able to respond. Transportation professionals from all modes and disciplines will be seeking "more input."

American Association of State Highway and Transportation Officials, 444 North Capital Street N.W. #225, Washington, D.C. 20001.

Two great challenges await us in the area of transportation data and information systems as we approach the 21st century. The first is to find more effective ways to collect and analyze needed data and information. The second challenge will be to avoid information gridlock, as we are deluged with data and increasingly high-speed computers capable of whirling out more information than transportation professionals can digest and use.

This TRB Conference is concerned with both of these challenges and comes at an important time when we are engaged in a once-in-a-generation examination of America's transportation requirements. The conference precedes the 1990 Federal Census, when we hope to acquire a collection of new data that will help us keep this nation mobile over the coming decade. And it comes at a time when many transportation professionals in FHWA, other agencies of U.S. DOT, and AASHTO are completing reports that have presented many of the problems with current data-gathering and analysis systems.

It is not my role here to prescribe what should be done to improve our transportation data-gathering and information-handling, for the eminent participants in this conference are far more capable of doing this than I am. But I would like to suggest some areas where attention is needed, and briefly describe some activities that AASHTO has been involved with.

In January 1987, AASHTO launched "Transportation 2020," led by the Task Force on a Consensus Transportation Program. The initial goal within AASHTO was to seek a new consensus on the future direction of the nation's highway and public transportation systems, a goal that was later expanded within AASHTO to include all five transportation modes and transportation research. AASHTO's objective was to produce state transportation officials' recommendations for the future direction of the five transportation modes transportation research, and national transportation policies. This work has been essentially completed and the state recommendations have been provided to the U.S. DOT as it works to develop federal recommendations for national transportation policies.

In the course of AASHTO's work, professionals worked closely with FHWA, UMTA and other federal agencies. Using the state-supplied data contained in the FHWA's Highway Performance Monitoring System (HPMS), the Task Force tried to draw from it useful information for developing policy recommendations. The following observations stem from that experience:

1. The HPMS information proved to be the best highway data available to AASHTO, and enabled the task force to

make many projections that the transportation professionals in the states believe are sufficiently sound for deciding upon overall national highway policies. But at the same time, the data was insufficient in several areas:

—Although good data on the condition of the Interstate highway system is available from the HPMS, the data is weaker for primary and secondary highways, and of limited use for local systems, partly because of progressively weaker statistical sampling and data reporting difficulties.

—Because the HPMS is based on statistical sampling of existing highways and roads, and designed to consider improvements to those facilities, by definition it does not deal effectively with new roads on new alignments. To gather limited data on the need for new facilities that are not taken into account by the HPMS, AASHTO had to poll the states.

2. Data on America's transit systems is incomplete and subject to different interpretations. AASHTO and the American Public Transit Association proceeded to make an independent analysis using its own sources of information and data from the UMTA and could not fully agree on the results.

3. Information on the aviation mode was reasonably complete for AASHTO's purposes, except with respect to airport access.

4. With respect to airport access and other intermodal access questions, AASHTO found no reliable data and had to develop its own.

Based on the experience with existing data, several clear weaknesses are evident in the highway area. Some of these come about because of progressively weaker sampling as one moves down through the functional classifications of highways from the Interstate system. In fairness, it must be noted that many states and their local governments dislike data collection and reporting, and have objected to increased sampling on the lesser systems. In any case, clearly, good, reliable data on local roads is not gathered regularly. Data on the lower level state systems is not as solid as it should be for effective planning.

Certainly every participant in this conference can cite his or her concerns about today's transportation data, so I do not want to take further time here to review AASHTO's experiences over the past 3 years. Suffice it to say that AASHTO's work would have been much easier with better data, and better analyses techniques for the data that was available.

Looking ahead, there is reason to hope for better information with regard to our highway system. In particular, the pavement management system now being placed in operation by the states will provide much better information, as will the coming bridge management systems. During Tom Larson's term as FWHA Administrator, a concerted effort will be made to modernize and improve the HPMS. One goal of this conference should be to develop recommendations on how best to do this.

Based on AASHTO's experience, it is also hoped that during this conference data needs in all transportation modes, and intermodal data needs, will also be considered. AASHTO is becoming more involved in intermodal issues, because it is believed that many of tomorrow's transportation issues will be intermodal. To make good intermodal decisions, it is imperative to have adequate data and effective ways to analyze it for public policy purposes and to assist private sector decision making.

Three transportation issues of the 1990s in particular will provide a data challenge—where it is imperative to generate more meaningful data and learn how to use it.

The first challenge is in the area of highway safety, particularly for sound accident data which will support highway project decision making in a more meaningful way than is currently possible. I recognize the difficulty of law enforcement officials in gathering on-site accident data, and the problems faced by engineers in analyzing collected accident data seeking cause-effect relationships. This is a difficult area, but doing a better job with the data may help further reduce the highway death rate, something that is important as VMT at least doubles over the next decades.

The second challenge is with respect to the congestion problem. Polls sponsored by AASHTO, the media, and politicians all point to congestion as one of the top transportation issues faced by America, and how to relieve it or live with it is the subject of thousands of conversations every day. And yet, currently there is no consistent, effective way to measure congestion and analyze why it is occurring and what might be done about it. At least for city-suburban areas with a population of 1 million or greater, it is important to have more solid, consistent data and learn how to effectively analyze it.

The third challenge is related to the second: how to collect and analyze data that will support mobility planning, as opposed to only planning for individual modes. Looking at the problems of maintaining mobility for both people and goods in the nation's congested metropolitan areas, it is increasingly recognized that mobility planning and programming may be the best way to develop solutions. But currently tools are not available to do this on a consistent, effective basis. An effective congestion-monitoring system is basic for analyzing mobility needs and developing meaningful metroplitan mobility plans.

It is clear that transportation in America needs "more input." I believe that with the help of those gathered here we will get it. We must be certain that the transportation data we gather is meaningful, to both public and private sector transportation agencies, at all levels. I would hope that tomorrow's transportation data base will be effective not just at the national level, but at the state and local levels, too, and for metropolitan regions. And I also hope that as new data systems are established, we will recognize the problem of possible transportation information gridlock.

Every decision maker knows there is such a thing as "too much data," or as it was put in one political campaign in the Washington area a few years ago, "paralysis by analysis." Curiosity should not carry us away in the search for new data mines to open. The data sought should be useful and meaningful, not simply "interesting."

The possibility of information gridlock grows as our computer-based society progresses, and is a concern to the member departments of AASHTO. Increasingly decision makers recognize the need for a systematic approach to data management, one that will bring together from all relative sources the vital information required to manage a state transportation agency. In October 1989, AASHTO approved an overall guide for states to follow in establishing executive information management systems. More work will be done in this area.

One of the next projects is to develop a glossary of terms agreed to by all states, with the goal of establishing data banks in all states that are both compatible and comparable. This would make possible state-to-state comparisons that often cannot now be made, because of the "apples and oranges" problems that too often exist.

As you work at this conference, please consider how data can be both managed and coordinated through compatible federal, state and local systems, so that further Balkanization of our data files can be avoided.

REFERENCE

1. M. Cetron and O. Davies. Future Trends. *Omni*, Vol. 12, Oct. 1989.

Information for Transportation Decision Making: Institutional Challenges

ALAN E. PISARSKI

Helping to initiate a discussion of the appropriate institutional forms that a comprehensive transportation information program might take is the goal of this paper. The purpose and scope of such a discussion are delineated; some of the institutional forms and types now operating in this sphere are surveyed; and the functions that institutions must perform in order to be effective are examined. In the first part of this paper, the aim is to establish an overview of the scope and character of national transportation data development. In the second part, the major transportation data-collecting institutions, federal, state, local, and private are examined, with particular emphasis on those federal entities within the U.S. DOT. In the third part, the institutional functions to be performed in the development of a National Transportation Statistical System are reviewed. These include: assembling data needs; program design; funding; program coordination; and product delivery. Preliminary observations are presented in a brief concluding section, not to draw definitive final conclusions and make recommendations, but rather to help guide further discussion. Fundamentally, these observations examine the argument that the present national transportation data program needs new institutions and institutional arrangements to give structure to the scope and scale of its activities.

OVERVIEW OF A COMPREHENSIVE TRANSPORTATION DATA PROGRAM

Purpose

This paper is part of an overall effort to assess the capabilities and needs of a transportation information program to support better transportation decision making in general and the U.S. DOT's policy planning requirements in particular. The study finds its immediate cause in the Secretary's Strategic Policy Study that early rediscovered the serious lack of effective information to support the policy planning effort. Although it was not possible to develop the needed information in time to meet the needs of the Secretary's initiative, it was decided to begin the process of forming an effective transportation information program to better inform future applications. This is appropriate to the conception of the policy planning effort as a continuing activity. Perhaps more significantly, the programs and policies proposed as part of the new policy are in many respects very "data-intensive" compared with past policies. Emphases in the policy on strategic assessment and system monitoring, policy evaluation, and so forth will demand more of the national transportation data system than it is presently capable of delivering.

6501 Waterway Drive, Falls Church, Va. 22044.

Institutional Framework for an Information Program

The component elements of a comprehensive transportation information program are varied and complex. They include the technical skills required to design, assemble, and produce information; the software and hardware and other logistical capabilities to collate, store, and manipulate data; and the financial resources to support ongoing activities.

But this description neglects the more intangible elements that often are the main ingredients of success of a large scale program of public activity. These intangible elements include the public and institutional support that ratifies a public program and substitutes for the market success that justifies a private endeavor; and the public and private institutions that design, manage, ratify, and sustain the program over time. These institutional elements and their role in the success of transportation information programs are the focus of this paper.

The elements for a viable transportation information program are the following:

- Technical skills must be assembled and organized,
- Effective program designs must be created or adopted,
- Financial and other resources must be acquired, and
- Public support must be developed and sustained.

All of these elements must be assembled, focused, and managed if a program is to be launched successfully and then able to sustain itself over time. The history of transportation information programs has been that they have been initiated, usually with some success, in response to an ad hoc need, but have been unable to sustain themselves over the years. Technical skills have not been lacking. Program designs have been generally responsive. Resources and support have been weak but usually adequate. However, the lack of an institutional framework to give permanence to the ad hoc efforts has fundamentally precluded the prospect for long-term effectiveness.

An effective transportation information program must be primarily focused on the development of continuing data series-monitoring trends in supply, demand, and system performance rather than in squandering resources in ad hoc projects and responses to perennial "fire drills." Continuing programs require the application of common definitions and procedures employed uniformly over time. Although it could be argued that it is possible to accomplish this definitional permanence with different organizational entities coming and going, the most likely opportunity for success will be produced by an institution with permanence that can operate and sustain a continuing process over time, particularly one with a resource base that does not fluctuate erratically.

Scope of Data Coverage

It is appropriate to be more specific about the nature and scope of the data activities to be included in this assessment. First, it should be clearly recognized that no definitive delineation of the data set that is the object of such an undertaking exists. This is not to criticize the current effort, but rather to establish that a long-term need for such delineation has existed since the inception of national programs of transportation information development. The only serious effort at explicit delineation of a scope for a national program is "The Red Book" produced at Congressional request by the Office of the Secretary, U.S. DOT in 1969. Although never receiving formal support from U.S. DOT or Congress, this document has served as the informal boundary of the appropriate scope of a national transportation information program for 20 years (*1*).

The general focus of the kinds of data programs of interest are those engaged in meeting policy and planning data requirements. This, of course, can be interpreted broadly to include almost every activity of the department, other public agencies, and the entire transportation industry. In this case, it is more narrowly defined to include the data that permits broad assessment of the present and prospective supply, demand, and performance characteristics of the transportation system. The Canadian program in transport statistics refers to this data set as statistics "in support of policy, legislative, planning, regulatory, forecasting and monitoring functions" (*2*). A key concept in defining the scope of this data set is that its focus is most often on the relationship of transportation to broader economic and social factors in the nation.

More generic criteria to help establish the scope of the data of interest are that it includes "general purpose" statistical data on transportation—for example, information applicable to more than one program and more than one application; it typically focuses on the development of recurring data series that provide time series trend information as opposed to one time ad hoc issue coverage. In this sense, it includes data about

- Facility inventory, condition, and performance,
- Equipment inventory, condition and use,
- Carrier performance and condition,
- Passenger and freight flows,
- Demographics and general economic activity,
- Safety and security, and
- Finance and program administration.

It is perhaps useful to define certain data and related activities out of the scope of interest of this assessment. Out of scope areas include engineering data on structures, facilities, and vehicles; administrative data on departmental, state, local, and private firm operating accounts and personnel matters generally characterized by the label of Management Information Systems; and regulatory data that support day-to-day departmental, state, and local regulatory functions such as licensing and inspections. There certainly are occasions when these sources are valuable for meeting the information needs of the policy planning process, but fundamentally they represent secondary applications of these activities.

The defining concept regarding the data set that is the goal of these efforts concerns whether the data are (a) those necessary for the U.S. DOT to meet its internal needs and support its mandated programs, or (b) are the data needs to be extended to meet the needs of the U.S. DOT and those other agencies linked to the U.S. DOT programmatically such as states and localities, or (c) further extended to meet general policy needs regarding all of the transport industry, and (d) yet further extended to meet industry needs for data for marketing and competitive analysis. How the U.S. DOT and the Congress construe the requirement will be crucial for program development.

GENERIC INSTITUTIONAL TYPES

The array of institutions and institutional arrangements associated with transportation information is formidable. It is appropriate for the purposes of this assessment to review those institutions and arrangements, not with the intent to perform an exhaustive inventory of every entity in the transportation data field, but rather to identify the generic institutional types that are involved. Thus a typology of institutions, functions, and activities is intended rather than a comprehensive listing.

Federal Institutions

Fundamentally the federal system for producing all statistics, not just transportation statistics, is a decentralized system. Many agencies may engage in the production, use, and dissemination of statistics. There have been numerous discussions from time to time about the merits of shifting to a more centralized system, notably by Duncan and Clemence (*3*). In other countries, such operations may be more centralized with a single ministry or statistical office managing the nation's statistical efforts. In that ministry, typically a transportation division serves as the recognized center of national transportation statistics. Staffing would consist of people knowledgeable in all areas of transportation. Most, if not all, appropriations for statistical activities would go to that division, which would be in charge of delineating the national transportation information program. The Canadian approach is somewhat of a hybrid between a centralized system and the far more decentralized United States approach. The Transport Division of Statistics Canada is the source of most of the significant Canadian national statistical measures in transport. However, although 60 percent of its funding is directly appropriated, the remainder is "cost shared" with funding received from other federal agencies and provincial governments. A memorandum of understanding between agencies structures these arrangements.

In the United States, the central reality regarding the production and dissemination of national transportation statistics is that it is a multi-purpose system with multiple masters. Generally, the national system contains at least three elements: a system of national accounts (SNA); a regulatory system(s); and, for lack of a better word, a transport system. This is paralleled in other countries as well. A description of these elements follows.

System of National Accounts

This, fundamentally, amounts to the accounting "book" of the nation—the accounting of goods and services produced and received, the gross national product system, and the foreign trade statistics. The indexes of prices and the statistics of employment can also be considered part of this system for functional purposes. In the United States, as in other countries, these statistics are the most rigorously defined and formal, and usually have the longest continuous history. In the United States, these systems are planned and managed by the Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS). Data collection is predominantly conducted by the Bureau of the Census from major funding provided by the user agencies. In support of these programs, "nation defining" statistical systems, such as The Standard Industrial Classification and The Classifications of Occupations and Industries, are developed.

Regulatory System

The existence of a "Regulatory System" in the United States can be questioned given the recent deregulation at the federal level. (The Canadian program defines its system in two parts (a) an SNA, and (b) Regulatory and Transport system. With deregulation, the United States system may soon be best described in the same way.) In an historical context, the statistical systems of the Interstate Commerce Commission (ICC) and The Civil Aeronautics Board (CAB) were a central, critical element of the nation's statistical knowledge about air, rail, bus, pipeline, and trucking modes. Although these systems are basically gone, the current national system is largely a residue of this regulatory past. Significant user groups grew up around these systems with both regulatory and nonregulatory applications. The CAB system, absent some of the more arcane statistical elements of regulation, has been carried over into the U.S. DOT's aviation statistical program. The ICC's program has diminished significantly in scope and coverage. Other activities of government such as Foreign Trade and Customs reporting, and Income Tax data sources can be construed as part of the regulatory system. In Europe, this system has been the centerpiece of the transportation statistical system. Particularly the customs system permitted the extensive organization of freight and passenger flow data. The decline of regulation as part of the Europe 1992 program will challenge the systems of many nations. The regulatory statistical system also can include the data gathered by the FMC, FAA, FRA, and NHTSA as part of their regulatory roles.

Transport System

The "Transport System" can be briefly, and inadequately, defined as the data developed by the U.S. DOT and other transportation-related agencies, such as the Corps of Engineers and the Department of Agriculture, to meet their policy, economic analysis, planning, and monitoring needs. The referenced regulatory elements of U.S. DOT agencies can also be included here.

The hallmark of this system is that the U.S. DOT is a late arrival on the statistical scene. Therefore, it has sought to meet its statistical needs by adopting and adapting the statistical products of the other systems. The U.S. DOT's history extends about 25 years, whereas the SNA and Regulatory Systems had almost a century of background. This has proven detrimental in the following ways: (a) the concepts and modes of expression of the SNA, although entirely appropriate to it, are often imperfect or even misleading for transport purposes; (b) the regulatory system was characterized by explicitly, and sometimes arbitrarily, defined reporting criteria that constrained possible analyses; (c) the depth and power of coverage in the regulatory system has been a function of the degree of government regulatory involvement which can differ sharply from other policy needs; and (d) changes in the systems, often made without consultation with U.S. DOT or other transport data users, most particularly the demise of regulatory reporting in the 1980s, left nonregulatory users without information support. (This was particularly important because alternative duplicating data collection activities were precluded by law.)

One of the predominant institutions in the federal transport statistics picture has been the Office of Statistical Policy at the Office of Management and Budget (OMB). This organization, using various names, and functioning from various locations in government over the years, reviews applications by agencies for statistical undertakings based on statistical and political grounds and concerns for public reporting burdens. Because of a lack of staffing and appropriate expertise, it has never been able to fully develop its program coordination functions. At one time, OMB sponsored an interagency transportation statistics coordinating group, but it was suspended apparently because of a lack of available staff support. A recent Bureau of the Census group that coordinates services-oriented statistics has partially filled that role.

State and Local Institutions

Although individual states and local governments will undertake active statistical programs to meet their own needs, the national statistical system contains few data series produced by states designed to be comprehensive national data sets. To be sure, there are many state-generated data sets of value when summed nationally, particularly in the highway area such as highway traffic, spending, and fuel consumption reporting.

For the most part, state and local efforts consist of reporting programs mandated by U.S. DOT agencies as part of funding requirements. The Highway Performance Monitoring System (HPMS) of the FHWA is perhaps the best example of such a program. This program, along with additional summary reports, comprise an effective summary tool of the status and condition of the federal-aid highway system. It is to be noted that the process of reporting is required by Congress on a biennial basis. Similar reporting activities exist in UMTA's programs for program assistance recipients, generally transit properties. The FAA has similar reporting requirements for aviation properties. None of these activities truly represent joint undertakings of state or local agencies with federal authorities. Also to be noted is that these systems are victims of their original genesis in program reporting. Thus the HPMS does not represent nonfederal aid local roads, and UMTA reporting does not provide data on private transit facilities.

Increasingly these agencies or their public interest group representatives such as AASHTO, NGA, NARC, and NACO are recognizing the importance of improved data for their organizational policy and planning functions and those of their members, and have moved to respond to these needs. They represent a powerful, potential force for effective data program development. One particularly significant activity may represent a model for future actions. In 1980, U.S. DOT, with the Bureau of Census, developed a package of special, uniformly defined transport-oriented tabulations of the decennial census. More than 160 metropolitan areas and states purchased this jointly defined tabular package with federal assistance. This approach saved time and money, and increased uniformity. For 1990, the approach is being expanded to include all states and metropolitan areas under the U.S. DOT program eligible assistance. There are other examples of joint state undertakings to produce national data sets. Most recently, this has been stimulated by the 2020 process. Of particular note is a soon-to-be released report by an AASHTO Committee of the data difficulties observed in the 2020 process.

Intra-U.S. DOT Institutions

It is almost impossible to characterize the diverse number of organizations within the U.S. DOT engaged in data development activities. The one clear indication to be obtained from a review of the U.S. DOT organizational structure regarding information programs is the lack of a central statistical organization. A number of organizations in the Office of the Secretary play parts of a central statistical role. The Office of Information Resource Management, under the Administrative Secretariat, performs the OMB statistical policy liaison and data collection review functions and other oversight functions in its Information Requirements Division. The Transportation Systems Center, no longer in the Office of the Secretary, contains the Center for Transportation Information within its Office of Information Resources, which performs departmentwide statistical reporting functions. Elements of the Policy Secretariat perform statistical overview functions as well.

In the administrations, offices involved with producing statistics are widely distributed and given names that may or may not signal their data-related functions. There is no simple way to identify the key statistical office in any administration, or to determine any functional equivalence between offices of the different administrations. No administration has a central statistical coordination office or function, other than for paperwork management. Fortunately, informal coordination and exchange of experience occurs between professionals in the various programs, but it is not supported by any formal structure. The following listing seeks to identify those offices in the U.S. DOT with significant information functions as here defined:

- Office of the Secretary
  - Office of Economics
  - Office of International Aviation
  - Office of Aviation Analysis
  - Office of Information Resource Management
  - Office of Intergovernmental and Consumer Affairs
- Coast Guard
  - Office of Law Enforcement and Defense Operations
  - Office of Navigation Safety and Waterway Services
  - Office of Command Control and Communications
- Federal Aviation Administration
  - Office of Management Systems
  - Office of Aviation Policy and Plans
  - Office of Planning and Programming
  - Office of Air Traffic Eval. and Analysis
  - Office of Aviation Safety Analysis
- Federal Highway Administration
  - Office of Policy Development
  - Office of Information Management
  - Office of Planning
  - Office of Motor Carrier Information Management and Analysis
- Federal Rail Administration
  - Office of Policy
  - Office of Freight Services
  - Office of Passenger Services
- National Highway Traffic Safety Administration
  - National Center for Statistics and Analysis
  - Office of Market Incentives
  - Office of Alcohol and State Programs
  - Office of Defects Investigation
- Urban Mass Transportation Administration
  - Office of Capital and Formula Assistance
  - Office of Planning
  - Office of Mobility Enhancement
- Maritime Administration
  - Office of Information Resource Management
  - Office of Trade Analysis and Insurance
  - Office of Policy and Plans
- Research and Special Programs Administration
  - Office of Aviation Information Management
  - Office of Research and Technology
  - Office of Program Management and Information
  - Office of Emergency Transportation
  - Office of Pipeline Safety
  - Office of Hazardous Materials Transportation
  - Office of Information Resources (TSC)

Private Institutions

The increased involvement in data development programs of some private sector organizations has been one of the bright spots in transportation data systems since deregulation. The process of establishing more active programs has been highly variable from organization to organization and it is unclear what stimuli have been at work to create effective programs in some cases but not others.

Some of the more active programs have been initiated at the Association of American Railroads (AAR) and the American Trucking Associations. These programs certainly reflect the greater needs for data among their constituents stemming from the market-driven effects of deregulation on competition within and between these industries. On the other hand, organizations such as the American Bus Association and Air Transport Association have seen real declines in their data-oriented activities. Importantly, one of the casualties of deregulation was the Transportation Association of America (TAA), which focused heavily on regulatory issues. Its information programs and perspective on the industry were important elements in the transport data picture.

The residual effects of regulation and deregulation are still with us. Many private sector firms still have fears about government reporting based on years of unpleasant experience with the ICC or other regulatory organizations. They resist individually or through their associations any attempts at expanded industry reporting, often even resisting reporting that would be held confidentially within the industry. At the same time, deregulation has made the marketplace more data-intensive, engendering strong interest in marketing data to serve the industry, but not in reporting about the industry itself. One of the major changes generated by deregulation was the increasing importance of segments of the transportation industry that had been minor players before, and for which data reporting was minimal, notably package express carriers, freight forwarders, brokers, private carriers, and short line railroads.

In some cases, new institutional approaches have evolved. In the public sector, the Bureau of the Census has moved to fill important data gaps about transportation industries previously covered by regulatory reporting. The confidentiality rules of the bureau appear to help calm fears about individual reporting of some deregulated firms.

In the private sector, the AAR has developed a contractual relationship with the FRA and the ICC to manage and assist in developing data concerning its industry. This has proven to be an effective new data development instrument.

Another innovation has evolved from the program that produced Transportation Facts and Trends, a national summary of transportation activity in the TAA. When that association declined with deregulation, the document was continued privately by former TAA staff on an interim basis with the new name "Transportation in America." It has now been adopted and given new status and support by a private foundation, The Eno Foundation for Transportation, Inc.

The role of private firms in data development pertinent to transportation has been limited for the most part to niche filling. In the passenger sphere, most data are developed by organizations oriented to the intercity travel and tourism industry focusing on magazine advertising marketing. Primary data of value are produced by these organizations, most notably the U.S. Travel Data Center. Worth noting is that the most extensive surveying of intercity travel in the United States performed since the demise of the National Travel Survey in 1977 was conducted by the Canadian government to assist its tourism planning. In the freight data sphere, a mixture of economic consulting firms and ad hoc data development firms have sought to meet industry needs as a result of increased demand and reduced supply for data resulting from deregulation. The recent TRB-Transportation Research Forum on freight data needs documented those limited developments. The most important government-private vendor relationships to be recognized is that transportation data vendors are primarily value-added operators manipulating, modifying, and supplementing public data sources. They enhance, but do not replace, public sources.

Two developments may affect private sector data development capabilities. One is the growing interest in Geographic Information Systems (GIS) stemming from new developments in computer processing and geographic base files. This may stimulate greater interest in the data sets appropriate to GIS systems. A related technological development is the growing use of computers for electronic data interchange (EDI) in managing freight shipments. This could expand opportunities for private and public data development but with very complex institutional ramifications. The means will soon exist for an industry to assemble its automated working files, purge them of individual identifications, and produce nationally useful vehicle, commodity, or passenger flow statistics on a current and continuing basis.

INSTITUTIONAL FUNCTIONS OF A TRANSPORTATION PROGRAM

A distinct set of functions is associated with the effective development and operation of a comprehensive information program which generates special institutional requirements. The following discussion treats these institutional requirements.

Assembling Data Needs

The assessment and determination of information needs is a critical professional function of an effective program. The needs assessment function has many facets.

Center of Comments

The community of transportation data users lacks a mechanism through which it can express its information needs. Users from all sectors, federal, state, and local agencies, private establishments, and private and public operators, have disparate information needs and no useful institutional entity to which to they can express their requirements and see those requirements collated with others into a comprehensive statement. In some instances, private operators may be able to take action to collect the information themselves. But when such action is beyond the capability of an individual actor or even an entire industry, or is more appropriately a public program, the private sector has no public source to which to express its needs. As an example of an approach to this problem, Canada established a Federal-Provincial Committee on Transportation Statistics in 1976 to provide a forum to discuss transport statistics issues.

One aspect of this function is linked to the ability to locate needed information. Often organizations will assume that data must exist somewhere to meet their needs, but that they have just failed to locate it. They may waste valuable resources in a fruitless search for nonexistent data.

Certain distinctions about the character and scope of this function differentiate it from other functions. First, the value of the function is in acting as a collector and collator of information requirements. This is distinct from the function of the action agency that might actually collect data to respond to deficiencies. Second, it is also distinct from the function of a data repository that may serve users as the prime source of information about information. These functions may all be well served by combining them in a single institution, but they need to be recognized as discrete functions.

Needs Identification

Aside from the value of an "assembly point" for expressions of public and private information needs, there is a further needs-related function. This is an analytical function that includes evaluation of existing available sources and identification of key gaps and deficiencies. Although the first function may be seen as one to be performed by a secretariat-type institution, this function must be the province of transportation analysts and statistical professionals. This function may also serve to discover opportunities in the statistical system for beneficial changes as well as identifying deficiencies.

Not the least of the professional functions involved is the construction of appropriate typological nomenclature for describing information and information requirements. Many elements of the transportation industry suffer from the lack of commonly accepted detailed definitions of terminology. Transportation is a complex, fascinating mix of engineering, economics, sociology, and other disciplines. This expands the range and scope of data requirements and adds to the semantic and definitional problems involved. The recent publication of an urban public transportation glossary by the Committee on Public Transportation Planning and Development of the TRB is one example of the kind of work that is needed.

Secondarily, an institutional entity engaged in assembling and organizing information needs may become "a locus of concern" for better transportation information.

Comprehensive Program Design

An important function allied to the identification of needs and gaps is the program design function. Fundamentally, this function involves both analysis and synthesis—analysis of future data demands based on long term policy trends and synthesis of existing needs and resources into a comprehensive needs statement as input to design.

Comprehensive program design is perhaps the most challenging professional task in an information program. It must be a prospective activity, taking into account future transportation trends and the likely directions for policy and analytical focus.

A current case serves well as an example. Departmental interest and support for intercity passenger travel surveys declined in the 1970s. The demise of the Census Bureau's National Travel Survey after 1977 was permitted without concern for a substitute. The element of the 1983 Nationwide Personal Travel Study (NPTS) focusing on long distance travel was limited in scope and depth. Even the presence of this minimal element in the 1990 NPTS has been threatened by funding troubles. At the same time, the national policy trend is toward extensive consideration of intercity travel congestion problems and ways to serve it by traditional means or by consideration of prospective opportunities for private or public high speed rail operations and new air technologies. Very soon, it will become clear that the kinds of data needed for the sophisticated analyses required are lacking. The development of intercity passenger data surveys will require a number of years to create, thus delaying the analytical and decision process. This demonstrates the clear need for the development of a design function which can anticipate future data requirements and link disparate needs in an overall comprehensive program.

Funding

Lack of adequate funding and erratic variations in funding availability have damaged the effectiveness of some transportation data programs important for policy decision making. A critical function for any data program will be the assessment of resource needs and the building of a funding mechanism to sustain the program on a continuing basis. As noted elsewhere, interest in data programs suffers peaks and valleys. The weakness of past programs has been the inability to establish stable funding mechanisms during periods of peak interest to sustain project efforts during periods of declining concern. This has resulted in a cyclical funding process peaking when data subjects are in vogue, as during the energy crisis of the 1970s, and then trying to reconstruct viable programs again after periods of disinterest.

A number of funding mechanisms have been employed at various times to sustain programs or individual projects. All of them can be considered as options for future funding. The institutional variations involved in these funding alternatives are important to consider.

Centralized Funding

The most evident funding approach for public national data programs is Congressional appropriations. There has never been a centralized DOT line item for data. From time to time, individual programs have become line items, especially in the modal administrations rather than on a departmentwide basis. Other agencies concerned with transportation data, either as using agencies or collectors, such as the ICC, the Corps of Engineers, the Bureau of the Census, and so forth have rarely given transportation data the status of a budget line item on a sustained basis. This is important beyond the funding effects it implies, because it contributes to the lack of Congressional focus on the subject.

A number of variant forms of centralized funding are worth noting. These include U.S. DOT budgeting of data programs through specific data-related line items; U.S. DOT funding of data programs as part of program funding generally when data are highly related to and justified by a specific program; and funding from within the budget of a data collection agency as part of its overall program. Each of these approaches has been used from time to time in the evolution of developing a national transportation program. A central issue in such a decentralized approach is the question of whether an agreed-to program—for example, a national travel survey—should be funded at the U.S. DOT and contracted to the Bureau of the Census, or funded directly at the Bureau by the Congress. There are pros and cons associated with each approach not the least of which is deciding on the path most likely to produce the needed funding. (The Canadian system formalizes this process with a Memorandum of Understanding between the Ministry of Transport, The National Transportation Agency, and Statistics Canada in which the functional and funding obligations of each agency are spelled out. "A Base Program," funded within Statistics Canada, is acknowledged and "A Cost Recovery Program," funded by the other agencies, is identified.)

Consortium Funding

One of the effects of a lack of centralized funding or the lack of a single large scale program funding source has been the tendency to develop consortia of interest around individual projects or programs to provide needed funding. In this approach, a "lead agency," usually self-defined, determines a need and establishes a project to respond. It seeks agencies with similar needs and interests that will contribute to financially support the effort. This approach has all the positive and negative aspects inherent in joint activity. It can be negatively characterized as "pass the hat financing," in which programs engage in a scavenger hunt for would-be supporters with money, while time and money are wasted in endless meetings and coordination. On the positive side, it represents something of a system of "checks and balances" in which appropriately related interests must be sought and properly represented to gain needed funding. Many of the U.S. DOT's major data programs have been funded in this way. Of particular importance as a case in point is the 1990 NPTS.

Pooled Funding

Pooled funding may be considered as a special case of consortium funding. It is akin to subscription funding often used in the private sector. In this approach, an idea for a project is advanced by "sponsors" who permit prospective users to "buy in" for a fee. These users are not sponsors and have no management responsibilities. This is most notably used in data collection programs developed jointly between the federal government and state and local governments. In 1980, this method was used by local government agencies (MPOs) working with states to purchase special tabulations of U.S. DOT-developed transportation-related decennial census data. A variant form will be used to develop the 1990 decennial package of census reports.

Cost Recovery Funding

In federal statistical programs, the question of cost recovery has been a major issue. In efforts to reduce costs, programs have been required to try to recover components of their costs from users. Problems of pricing policy then become significant. There are problems of seeking to recover the full costs of collection or only of processing, printing, and dissemination—akin to issues of average versus marginal cost pricing. There are problems of time value of data—for example, pricing early reporting higher than second or third hand distribution. The fact that government does not copyright its statistical products makes extensive recovery of costs highly unlikely. These issues are a product of the differing goals of private and public data collection programs. Private programs developed for profit rarely care about the broad use of their data except in a marketing sense; in fact, they have a strong interest in curtailing uncompensated use, whereas public programs collect data they deem to be in the public interest and almost always have an interest in the broadest public use of their data. Charging fees for the data can conflict with this goal.

There are few examples of user fees paying a major share of data collection and processing costs in the transportation sphere. A significant exception was the approach to handling data requests in the program of aviation statistics of the former Civil Aeronautics Board. It contracted out its statistical reporting process to firms that would provide data processing services to requestors for a fee. The approach was apparently successful in the highly data-oriented aviation industry.

Private Funding

The private sector has been active in recent years in developing transportation statistics in certain sectors. Much of this has been as a result of losses in public data reporting and the increased demand for information among carriers resulting from deregulation. These private programs have enjoyed varying degrees of qualitative and financial success.

An important dichotomy needs to be made in private data collection between the limited number of primary source data collection efforts and the more typical value-added private efforts that market enhanced versions of publicly produced primary sources. In the latter case, in which the firms depend heavily on the public system for their sources, little is contributed to actual funding of data collection. In fact, the effects may even be deleterious as users become remote from the information sources. Where private industry is the primary source of data collection, a key question is whether public agencies, federal or other, are the major source of the revenue supporting the private venture. This is true in many cases. As a result, the public funding question remains a problem, whether to do a project or buy it from a vendor. Some cases do exist of private funding support of public data collection efforts usually on a partial basis but these efforts are quite rare.

Program Coordination and Monitoring

The funding process often serves as a monitoring and coordination system for information programs in that program sponsors, often working in a consortium, will meet regularly and receive reports on program status as part of their fiscal management responsibilities. But program coordination and program monitoring needs go well beyond this indirect tool. Literally dozens of federal agencies have the responsibility and means to collect data of transportation interest. For instance, the Department of Agriculture tracks arrivals and departures of farm product shipments at major freight terminals; the Customs and Passport agencies obtain information pertinent to international travel monitoring, and so forth. No mechanisms currently exist to assure coordination of decisions about data collection efforts between interested agencies.

One of the key events in the history of federal transport statistics was the dramatic changes in federal reporting as a result of deregulation of air, rail, truck, and bus travel. In many instances, significant data requirements were met by the regulatory reporting in these modal sectors outside the needs of the regulatory agencies themselves. Large public and private user constituencies grew up depending on these sources, particularly because the general purpose statistical agencies, such as the Bureau of the Census, were precluded from duplicating regulatory efforts. The agencies took different perspectives regarding meeting the needs of outside users when regulatory reporting requirements declined. The CAB recognized an obligation to be responsive to outside users: The ICC did not. Varying degrees of coordination resulted in varying degrees of availability of data.

No formal or serious informal mechanisms exist in transport data collection to make user and producer agencies, whether public or private, aware of changes in reporting systems, publications of data, and so forth unless covered by federal register reporting requirements.

Delivery Systems

A key part of the functions of a comprehensive transportation information program is maintaining and improving the relationship between the producer and user of statistics. Any institution engaged in this function must recognize user needs and organize the institutional framework to be responsive. Among the key elements in the interface are the need for timeliness and for the appropriate design and availability of products.

One of the major weaknesses of publicly provided transportation data programs is the lack of timely reporting. This is often a product of inadequate resources—first in that data are collected infrequently; second, when collected take too long to process and prepare for release. This latter problem may result from problems of staff resources, financial capability, or lack of priority given to these needs.

Part of the concern regarding responsiveness to users is in the process of developing user products. Some data programs exist only for the purpose of meeting the internal needs of an agency. Even here, the ability to rapidly prepare requested tabulations in a cost-effective manner is important. But in the majority of cases, data programs, especially those producing general purpose statistics, must function as a wholesaler and retailer. Client needs in terms of data content, quality, timing, and costs must be considered.

The question of user costs for work products generates a number of policy issues. In some cases, a program with limited resources can do damage to itself in providing products at below cost or no cost to users, reducing funds available for other applications. In some programs, even where user products are properly priced, the program agency may not be permitted to receive funds. Consequently, responsive user products that "sell" well may be a net drain on resources. A further public policy question arises over pricing policies that may retard the distribution of important survey results obtained at substantial public expense. An argument can be made that such cost recovery approaches are not cost-effective. If substantial public funds were warranted to obtain information, a very small incremental increase in public costs would typically be warranted to assure broadest dissemination of the results.

All of these questions are part of the topic of building strong support for data programs among prospective constituents. No public transportation information program in the United States has ever actively engaged in identifying and building rapport with prospective constituents.

Interrelated with this question of user support are the mechanisms by which data programs are justified. Fundamentally, these mechanisms reduce to being a function of the persuasiveness of the program officials involved. There are no objective tests of need for data, no measures of data adequacy in a program, and no cost-effectiveness tests that prove the value of additional information. Data program officials can assemble lists of users who requested certain information. They can appeal to the reason and objectivity of public officials and legislators, or use the arguments of professional judgment. Development of better means of assessing and proving data needs are required. This is particularly true given the dramatic costs that can be involved in large scale data programs.

CONCLUDING OBSERVATIONS

Helping to initiate a discussion of the appropriate institutional forms that a comprehensive transportation information program might take was the goal of this paper. It has delineated the purpose and scope of such a discussion; surveyed some of the institutional forms and types now operating in this sphere; and examined the functions that institutions must perform in order to be effective.

Observations at this stage are necessarily preliminary, but perhaps can help guide further discussion:

1. The present national transportation data program does need new institutions and institutional arrangements to give structure to the scope and scale of its activities.

2. It is too easy to suggest that a centralized institutional arrangement is needed for a transportation information program to succeed. This is usually the reflex response to statistical program problems in transportation. It may turn out that centralization is desirable, at least for certain functions, but much more discussion and analysis are required before arriving at such a conclusion. The transport sector is so multifaceted and diverse that a distributed system of statistical development reflecting that diversity may be more appropriate with some centralized coordinating elements. Minimally, discussion should focus on what program elements are appropriate to and benefited by centralization.

3. A National Transportation Statistical System (NTSS) needs to be explicitly defined. A context-setting document that explicitly includes and excludes the scope of data and data programs of interest is needed.

4. The forms and content of possible memoranda of understanding between producer and user agencies following the Canadian model should be explored.

5. Mechanisms for providing opportunities for input and assembly of expressions of data needs are required. Institutional mechanisms to accomplish this must be explored.

6. Separate Intra-U.S. DOT and interagency institutions are needed to coordinate data programs and plans.

7. An assessment of alternative institutional mechanisms to produce and manage data that are employed in other sectors of the economy and in transportation statistical systems abroad would be very valuable.

8. Private-public mechanisms for data development need to be assessed. The ability of the private sector to produce data and the ability of the public sector to purchase it needs to be better defined.

9. The opportunities for new forms of data development based on emerging technologies need to be seriously evaluated. The institutional structures necessary for their implementation are key to their prospective utility. Public actions needed to facilitate these institutional arrangements should be identified.

10. The Congress must be engaged in this discussion. Congressional requests for information in the past, particularly for recurring reporting such as HPMS, have led to the initiation of most of the effective programs that do exist. On the other hand, congressional disinterest in transportation data needs, as manifested in its response to the "red book" 20 years ago, instilled a similar disinterest within DOT that caused most of the national transportation data program weaknesses until now.

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Transportation Data Used Currently for National Planning Activities

Edward Weiner

The informed development and implementation of transportation policies is a continuous process that needs to be supported by an array of data, collected not only about the transportation system, but also about the traveler and goods moved by the system.

INFORMATION NEEDS

National policy studies range from quick responses to official requests regarding a particular issue, to multiyear comprehensive assessments of the entire transportation system and its consequences. The major studies initiated every 5 to 8 years to satisfy the changing perspective on the "transportation problem" are the focus of this paper.

Major data collection efforts are rarely initiated because of the needs of a specific policy study. When they are, they are very expensive. The critical issues identified in a policy study are varied, making it difficult to anticipate the specific questions of officials who request these national policy studies. Time, expense, and Office of Management and Budget (OMB) review requirements preclude data collection on a national scale during a 6 month or 1 year study effort.

Benchmark surveys such as the Decennial Census, the Commodity Transportation Survey, the Nationwide Personal Travel Survey (NPTS), and the Census Bureau Census of Transportation take several years to design, put in the field, process, and publish.

National transportation studies must therefore be limited to the data available at the time of the study. Unfortunately, each study seems to raise questions that cannot be answered by available data. Like generals who are always preparing to fight the last war, data collection efforts are often designed around yesterday's hot issues. As Edgar Horwood's *third law of data states*, "The data you have for the present crisis was collected to relate to the previous one."

POLICY NEEDS

It is important to remember that policy makers are generally problem oriented. They need to respond to issues of the day such as the oil shortages, budget constraints, transportation disasters, public outcries, and so forth.

Policy makers therefore need information which is

- Problem specific,

U.S. DOT, Office of The Secretary of Transportation, 400 7th Street S.W., Room 10305, Washington, D.C. 20590.

- Timely,
- Easily understandable, and
- Cost efficient.

These constraints are often difficult for analysts who prefer to carry out complete, theoretically sound analyses before rendering a judgment or making a recommendation. Moreover, it remains the task of the analyst to design analytical studies, including data requirements which meet these constraints, and at the same time gain a better understanding of the issues and identifying the options for policy makers.

Consequently, data requirements and survey designs accommodate immediate needs of the policy makers and the longer term needs of the analysts, as well as the costs and respondent burden of collecting information. Generally, no one survey or survey type can fill all the needs for transportation data. A mix of data sources is necessary to address the variety of issues and need for information. This mix requires an integrated, comprehensive, and continuing data collection programs to provide a base for trend analysis.

BENCHMARK SURVEYS

It is also important to keep in mind the need for and value of time-series data. New surveys rarely can provide us now with a trend of the past. Data collected 5 or 10 years ago is usually lost forever. In addition, when a study is cancelled or postponed now, then that data point is lost forever.

The basic data needed in national transportation planning activities are

- The number, characteristics, and location of the population,
- The travel generated by each sector of the population,
- The movement of goods within the United States and in foreign trade,
- The inventory, condition, and performance of the transportation infrastructure,
- The inventory and use of the equipment used in transportation,
- The characteristics and economics of shippers and transportation carriers,
- Safety and security information, and
- Finance and program administration.

These types of data have been around for years, but often at the wrong level of geography, for the wrong type of characteristics, or in a form that cannot be matched with other data. Often lacking are the common denominators necessary to perform the required analysis.

TECHNOLOGICAL IMPROVEMENTS

Technological forces at work now might generate the data when it is needed. These include the development of automated vehicle monitoring and identification systems, geographic information systems including the TIGER system, computer-aided survey methodology, and the use of microcomputers for data management and analysis, satellite-based communication and remote sensing, and electronic interchange of shipping documents.

Although technological forces provide opportunities, institutional forces often work against the planning community. Examples include budgetary and staffing problems for data collection organizations, the loss of data collection programs because of deregulation, paperwork reduction requirements, and efforts to privatize or defederalize data collection programs.

LOCAL DATA SURVEYS

To cope with these trends, proposals have surfaced over the last few years to encourage local and state planning agencies to collect data that can be used at the national level. As an illustration, urbanized areas have conducted extensive origin-destination personal travel surveys over the years. According to Charles Purvis, 13 major travel surveys have been conducted in the large metro areas in the last 10 years. Spanning the "Census Season" from 1989 to 1992, at least 16 metro areas are planning to conduct household travel surveys. This compares with 7 areas that conducted surveys from 1979 to 1982. These large metropolitan areas comprise almost half the population of the United States.

One would expect that these data would be useful for the national studies. However, metropolitan areas do survey work for their own use. They use their own definitions, categories, geography, and factoring procedures. Their mode and trip purpose categories are not standardized, and the linked-multimodal trips are summarized differently. These surveys are expensive and generally funded by federal-aid planning funds, yet they are rarely generalizable for national purposes.

NATIONWIDE PERSONAL TRANSPORTATION SURVEY

The only meaningful, all-purpose, all-mode, all-trip-length national travel survey is the NPTS which has been collected in 1969, 1977, and 1983. As a consequence of budget constraints, the 1983 survey consisted of only 8,000 households nationwide compared with 18,000 households in 1977. In the 1990 NPTS, there is expected to be 20,000 samples taken nationwide plus another 20,000 samples taken in major metropolitan areas as enhancements to the standard sample for individual areas which choose to fund the supplemental samples. This expansion in sample size was accomplished by using telephone interviews instead of home interviews. The trade-off, however, is a much-reduced content of the survey.

DECENNIAL CENSUS

From a national perspective, it is well to point out that less than 1 percent of all the trips collected in the NPTS are 100 miles or longer, but they account for 20 percent of the personal vehicle travel miles.

Another excellent source has been the decennial census, in which journey-to-work travel is recorded for 16 percent of the households in the United States. Census has obtained worker travel characteristics ever since the 1960 decennial census. These data are excellent for national studies because of their nationwide uniformity, and for local studies because of their large sample size and geographic detail. The data are also comparable between censuses.

Information on the travel habits of the population, and the location and the characteristics of the population, as estimated annually by the Bureau of the Census, are two powerful data elements for policy analysis for national planning activities.

DATA GAPS

"Data gaps" is an issue that needs to be divided into two distinct categories. The first is the commercial transportation providers, such as the airlines, railroads, and the trucking companies; and the second is government-provided transportation facilities and services, such as highways, mass transit, and airports.

There is a substantial data gap in the commercial area because of corporate privacy, trade secrets, and deregulation. On the government side, the data gap stems from state and local reluctance to provide data that are viewed as important only to the federal government.

DATA ACCESSIBILITY

On both public and private sides, there are also "knowledge gaps." Data were or are now generally available in some form. However, it is too old, too difficult to access, and no longer provided in appropriate forms. Data are often available on absolute media using ancient formats. Data are often coded according to geographic areas that are not compatible to the area needs of the particular study underway. Also, only 10 percent of data has been made available on paper. The other 90 percent remains unsummarized, and not printed, generally making it unavailable.

Some of these problems will be mitigated by microcomputer-based data management software, and by the increasingly usable technology of geographical information systems.

In particular, the Census Bureau TIGER file, which consists of all 3.8 million miles of roads in the United States, could be the basis for a universal geographic information system which can tie together all the disparate data sets on highway and transit transportation in one place.

RECOMMENDATIONS

Some specific proposals could improve the quality of future data. In order to ensure that accurate transportation data is available to policy makers at federal, state and local levels, efforts should be undertaken to foster more efficient methods of data acquisition and dissemination. These efforts should encompass improved methods of data assembly, including the use of advanced statistical or simulation techniques for estimating missing but pertinent information items. Once collected, these data must be made readily available in a form that is easily accessible to interested groups and analysts.

Improvements should be made in the following areas:

1. Improved accessibility of information sources to more potential users through microcomputer-based media and enhanced communications technology;
2. Improved usefulness of future data to be more directly usable by giving data users a say in the design of data collection programs;
3. Continued adaptation of electronic technology in collecting transportation data;
4. Improved data collection efficiency through the use of statistical samples and electronically-based, unobtrusive monitoring systems;
5. Improved quality and accuracy of data currently collected, particularly through computerized data edit procedures that will result in fewer errors in the data set;
6. Improved coordination of transportation data programs with the activities of the Bureau of the Census to strengthen the value of each data source to each other, and to allow more detailed analysis of issues related to national economic and demographic patterns;
7. Expanded usefulness of the NPTS by development of easy-to-use procedures for accessing the data and providing for correlation of various data sets;
8. Development of a formal process of technology exchange and training of transportation personnel in the field;
9. Development of common data reporting schemes that will enhance both data interchange and encourage development of common analysis procedures; and
10. Increased level of resources devoted to data collection, particularly to basic time series data.

Current National Highway Data Requirements

David R. McElhaney

The Committee on Transportation Data and Information Systems deserves congratulations for sponsoring this conference. The committee has existed, under different names, for the past 25 years and has made numerous major contributions toward promoting the collection of meaningful transportation data for the nation. It has been an effective vehicle for disseminating information on available data. It has also been effective in helping to steer the efforts of data collectors, such as the FHWA's Office of Highway Information Management and numerous Bureau of the Census efforts. How fitting it is that as the nation contemplates the direction of our transportation policy, plans, and programs for the next several decades, this conference is being conducted to reanalyze our transportation data needs.

I was asked to talk about current data systems for highways, which I shall do, but I would also like to take this opportunity to offer some personal opinions on future data needs. Maybe some of these thoughts will be useful this afternoon at one of your concurrent workshops on the development of recommendations for future data improvements and information system needs.

The current FHWA data system for highway information is almost totally dependent upon the states. Those working in the FHWA evaluate, summarize, and interpret the data submitted, and maintain the information for national and state analyses. The staff also develops trend indicators and perform some of the national analyses. This cooperative federal-state arrangement was started in 1936 and has worked well over years. The data that the U.S. DOT and the FHWA need at a national scale are mostly derivative of the data that the states need to support their highway program. As the nation's socioeconomic characteristics and transportation demands have changed, so have our data needs. Through meetings such as this, data items and categories were modified and updated in a collaborative process.

The primary driving force behind this cooperative data program was to provide a wide range of information to serve a variety of transportation planning activities. Reasonable estimates for planning purposes were generally adequate to provide a basis for projections of future patterns.

However, a distinct change began evolving in recent years. This change was the use of some of the state-supplied data for the apportionment of federal-aid highway funds. The states and the FHWA took on new roles for which neither had much experience. Previously (and still for some programs), apportionment data was somewhat noncontroversial when the Census Bureau gave FHWA population figures every 10 years, and the Post Office Department provided the Postal Road mileage. With that system, the recipients of funds had no input into data that was used in the apportionment calculations. Life was much simpler when the FWHA did not find itself in a "watchdog" position. The change to the use of data supplied by the states has slowly begun to significantly influence the cooperative process. A higher degree of accuracy is now needed for some data series to ensure that federal-aid funds are distributed to the states in a fair and equitable manner. This, as one would expect, has generated comprehensive dialogue between the state supplying the data and the FHWA, which must use the data in apportioning federal-aid funds. It has also resulted in a significant increase of FHWA's oversight of state-related data collection activities and the procedures in use by the states to derive certain data items. Because of the monetary implications, we have also seen, and will continue to see, a higher degree of program oversight by organizations such as the General Accounting Office.

Federal Highway Administration, U.S. Department of Transportation, 400 7th St. S.W., HHP-40, Washington, D.C. 20418.

PRIMARY DATA SERIES

The Office of Highway Information Management maintains three basic data series:

1. The Highway Performance Monitoring System and related data series consist of information about the highway system, its use, extent, condition, operations, and resulting performance.
2. The Highway Users and Finance data provide information regarding the users and economics of the system: tax structure, road users costs, and costs to build, maintain, and operate the system.
3. The Nationwide Personal Transportation Study (NPTS) provides data on the personal travel habits of the population, which is collected as part of the decennial census.

In addition to these activities, a fourth area will also be discussed here, the Bureau of the Census Truck Inventory and Use Survey (TIUS) and the follow-on Nationwide Truck Activity and Commodity Survey being sponsored by FHWA.

Also, there are a number of other important national data programs with which FHWA closely coordinates. The National Bridge Inventory concentrates on the type and condition of the bridges in the United States. Similarly, the Fatal Accident Reporting System (FARS) is maintained by the National Highway Traffic Safety Administration (NHTSA). Others are the Office of Motor Carriers' SAFETYNET truck accident reporting system and the FHWA Fiscal Management Information System. There are many others. Because of time limitations, only the systems mentioned earlier will be discussed here.

Highway Performance Monitoring System (HPMS)

The Highway Performance Monitoring System, or HPMS was established by FHWA in 1978 in response to a series of earlier one-time special national studies requested by Congress. The system, established as an ongoing and continually updated statistical data base, has many uses. One primary use is to provide basic information for the Biennial Reports to Congress titled *The Status of the Nation's Highways and Bridges*. Another use is a source for our annual mileage and travel tables for the publication, *Highway Statistics*. Prior to the HPMS, each congressionally-mandated study required the collection of massive amounts of data for one point in time. It was difficult to develop any trend data from these studies because definitions, categories, standards, and geographical detail were different in each of the studies. Routine statistical reports were out of date and lacked correlation among the many data items. After much frustration, it was generally agreed that a continuous, comprehensive, and comparable data system was necessary.

The HPMS provides basic information on all roadway mileage in the nation, such as extent, functional classification, jurisdictional responsibility, and the like. Detailed information concerning the extent, performance, operating characteristics, usage, pavement type, composition, condition, and so forth, is obtained for a sample of about 102,000 arterial and collector roadway sections. Additional information is reported by the states in the form of areawide summary data, which includes fatal and injury accident data. HPMS data is reported by all states and is stratified into three sub-state components (rural, small urban, and urbanized). Six functional systems within each sub-state component are sampled separately. The HPMS provides consistent, accurate information for national and state purposes. It can and has been supplemented for sub-state areas in a number of states.

In addition to information on the physical highway system, the states also collect truck weight, vehicle classification, and traffic count data. Each month, the states provide information on traffic volumes by hour of the day, day of the week, and month of the year from some 3,500 permanent traffic counters throughout the United States. Annually, the states provide information on the vehicle classes using the nation's highways as well as the weight of the trucks.

Highway User and Finance System

Some of the characteristics of our Highway User and Finance System, or the data reported under the *Guide for Reporting Highway Statistics* merit attention. Comprehensive data on the economics of the highway system, tax structure, revenues, and expenditures by highway system that have been reported by the states are published in the annual *Highway Statistics*. Highway finance data encompass complete, comprehensive information on receipts and disbursements for highways by all units of government. This makes 43 years of data and provides a continuing baseline of information for state and national policy deliberations.

Other data in the Highway User component of this series include motor fuel, vehicle registrations, and licensed drivers. Motor fuel data, reported monthly, are used for many purposes, including estimates of Federal Highway Trust Fund receipts attributable to each state. Thus, this data series serves as the basis for calculating the state 85 percent minimum allocation of funds. Therefore, motor fuel data are used indirectly in apportioning these funds. Motor fuel data have also been proposed by some as a candidate factor for apportioning funds in the new post-Interstate programs in the upcoming highway reauthorization bill.

Personal Travel Surveys

Another subject worth discussing is the travel data collected directly from highway users at the household level. There are two basic sources of such information. One is from the decennial Census, which includes a 16 percent sample of work trip characteristics. Others at this conference have focused on this important cooperative undertaking so the topic does not need elaboration here. The other is from the Nationwide Personal Transportation Study (NPTS), which has been conducted on a 5- to 7-year basis since 1969.

The NPTS is a nationwide inventory of households to determine the residents' travel characteristics on a typical day. The travel characteristics collected include all person-trips for all lengths by all modes. The sample, distributed over each day of the week for a full 12-month period, also contains an inventory of the motor vehicles available to the households and their use in the previous year. Various other socioeconomic and demographic data related to the travel characteristics in subsequent analyses are also obtained. The NPTS is a cooperative survey sponsored by four agencies of the U.S. Department of Transportation (OST, UMTA, NHTSA, and FHWA). FHWA has the technical and administrative lead for the survey, as well as for the coordination of the analyses and publication of results. The NPTS is the only nationwide continuing, comprehensive survey of personal travel, and is used by researchers, policy development staff of various organizations, national associations, other federal agencies, state, and local governments, students, and private sector organizations concerned with the relationship of travel to demographics. It is an excellent source of current personal travel characteristics and, because of its relative consistency and similarity from survey to survey, it is a valuable tool for assessing trends in these travel characteristics over time.

It is hoped that the next survey will commence in February 1990, with data collection from 18,000 households spread over 12 months. All household members, ages 14 and older, will be personally interviewed, with proxy interviews for household members 5 to 13 years old.

Previous surveys in 1969, 1977, and 1983 were conducted by personal interviews by the Bureau of the Census. Two significant changes were introduced for the 1990 survey. It will be conducted by a private contractor, Research Triangle Institute of North Carolina, using a computer-assisted telephone interview technique otherwise known as CATI. Observations by my staff of the pretest activity conducted this past summer, as well as the review of preliminary pretest results, are encouraging and reinforce the position that CATI is an effective data-collection technique.

In addition to the 18,000-household national sample, arrangements have been made whereby interested Metropolitan Planning Organizations (MPOs) can contract directly with RTI to enhance the sample for their respective areas. Enhanced samples would be available to the MPOs in addition to their portion of the sample included in the national survey and would provide valuable travel data and related characteristics at a reasonable cost. Many MPOs have expressed an interest in doing this.

The OMB clearance request for data collection is currently being finalized within the department. Inasmuch as the Office of Management and Budget (OMB) cleared the pretest earlier this summer, we are optimistic. The schedule for the NPTS is for data collection from February 1990 to January 1991; receipt of dataset from RTI in the spring of 1991; release of public-use tape in the summer of 1991; and report of survey results in late 1991.

Truck Surveys

Although the Census and NPTS focus heavily on personal transportation, two other important studies focus heavily on freight movement on our highways. The quinquennial Truck Inventory and Use Survey (TIUS), conducted by the U.S. Bureau of the Census, provides data on the physical and operational characteristics of the nation's truck fleet. The data are developed for a sample of private and commercial trucks drawn from vehicle registration files for the 50 states and the District of Columbia. Data related to truck activity for calendar year 1987 was collected in 1988. Processing the data has been underway during 1989. Survey results are expected to be available at the end of this year.

The TIUS is the most important single Census survey for truck policy analysis. Among the data items collected are average weight, maximum gross weight, annual miles of travel, miles per gallon, products carried, and areas of operation for different truck configurations operated by a variety of motor carriers.

The Nationwide Truck Activity and Commodity Survey (NTACS) is financed primarily by FHWA and conducted, under contract, by the Bureau of the Census as a follow-on to the TIUS. The NTACS measures detailed trip characteristics and other information for trucks on randomly sampled days. The sample includes all trucks which were reported as carrying commodities over long distances in the 1987 TIUS, approximately half the trucks which were reported as carrying commodities locally in the 1987 TIUS, and a small portion of the remaining 1987 TIUS respondents. The NTACS questionnaires are being distributed for sample days throughout a year, recently starting in fall of 1989.

The NTACS provides the only effective, empirical link between data on truck characteristics, travel patterns, commodity flows, and highway condition. The NTACS is also the only source of data on commodity flows by truck and on the interactions between trucking and other economic activity. These data are essential for long-range forecasts of highway use, for analyses of the economic performance of the trucking industry, and for analyses of impacts of trucking and highways on other sectors of the economy.

The combined TIUS and NTACS cover all forms of trucking (except that done by government trucks), and offer unprecedented detail on vehicle, shipment, and economic characteristics. Results of this study are anticipated by the end of calendar year 1990.

ANTICIPATED CHANGES

A number of improvements should be incorporated into the highway statistical system.

HPMS

Several major changes have been made to the HPMS over the past 5 years, the most significant change being in the area of pavement data. Recent changes were made to enrich our knowledge of pavements by collecting standardized calibrated roughness data (the International Roughness Index which is reported in inches per mile) so that pavement roughness can be compared among states. This valuable information will be available next year. Similarly, FHWA and the states have made significant efforts to improve the quality of the traffic data. More work remains in this area, however.

Additional changes will be needed in HPMS in the next 5 years for at least three reasons. First, the 1990 decennial Census will significantly change the urban boundaries. Second, it appears that the highway reauthorization legislation will offer new challenges in system designation. The proposed System of National Significance (SONS) has been mentioned by other speakers, and the selection of that system must be reflected in the HPMS. Third, it is important to be sure that HPMS is fully sensitive to current and emerging issues. In this vein, some fine-tuning may be necessary to adequately reflect urban and suburban congestion issues. Next might be the geographical identification of the location of the sampled roadway segments. Maybe the TIGER system can help here. The traffic data must continue to improve as it becomes more extensively used for apportionment. Truck data must also continue to improve. As for new data items, there will not be many, or perhaps any, but that does not mean that there will not be any improvement or changes to the system.

Highway User and Finance

Changes in highway finance data series are likely to focus on improving the completeness and accuracy of information on local government capital outlay by functional system. Some states have not developed the capacity to report this information on a continuing basis although the data series was established 10 years ago. Improvements are needed to better serve the needs of the transportation community.

Motor fuel reporting is well established and considered complete and fairly reliable. However, there are some problems in achieving complete, accurate reporting by the states for interstate motorcarrier fuel use and gasohol sales. Continuing cooperation of the states is needed to strengthen the reporting in these areas. The data will, likewise, become even stronger as state and federal initiatives to eliminate tax evasion and fuel diversion are implemented.

Another data item that needs strengthening is on heavy truck registrations, which is very incomplete. It is necessary to fill in the holes on this one now that trucking has become so important in moving freight.

OTHER GENERAL CHANGES

We hope to see some standardization of data categories and definitions. We must also enhance data transfer and accessibility by use of microcomputers. Also, we will see a more statistical approach in which one data collection cell will be part of a larger universe of some data item; the data collected can do double duty. This is the approach advocated in the FHWA *Traffic Monitoring Guide*. In addition, data must be more quickly transferred from the observation point to electronic media. An illustration of this is the Computer-Assisted Telephone Survey being used for the new NPTS. It is essentially a "paperless" survey in which edits and rationality checks are done on-line as the data are being collected. With paperless surveys, summaries can be made hourly, daily, monthly, or in whatever time frame the customer wants. Similar initiatives to assemble selected traffic data at a central location will also, no doubt, evolve.

In addition, data must be more easily and readily available to all who need it in a timely manner. To that end, efforts are underway to bring on-line an extensive historical data base that will be accessible to everyone through the use of modems and microcomputers. Queries will allow analysts to cross-correlate finance, travel, and system usage in ways only limited by their imagination. If there is enough interest in this historical data base, it may be expanded and a CD-ROM data file issued.

Data collection, of course, is not the objective of these efforts. Rather, the goal is to obtain the right information in order to be responsive to current and emerging issues. In order to be responsive, it is important to carefully consider actions that make the right data become the right information. Two good illustrations are the recent Urban Land Institute booklet on *Myths and Facts about Transportation and Growth*, (*1*) and Alan Pisarski's *Commuting in America* published by the Eno Foundation (*2*).

Over the next few years, we will need to confront the problem of replacing the experience of the people involved with the data collection activities in the states as they reach retirement age. Of course, there will be new personnel filling the jobs, but the experience gained by 30 or more years of data collection and analysis activities cannot be easily replaced. Correct data are mandatory in our business, and an experienced person can quickly spot inaccurate data. This experience is hard to replace. We must take the necessary steps to ensure that our expertise is maintained.

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National Transportation Data Needs for the 1990s: Transit Strategic Planning

SAMUEL ZIMMERMAN

The data needs associated with national transit strategic planning for the 1990s are outlined in this paper. The major new issues that transit strategic planning in the 1990s will likely deal with are addressed. Based on an examination of these issues and available data resources, the need for additional ongoing data-collection efforts in support of national (and local) strategic decision making are noted.

The creation of the Interstate Highway Program in 1956 set the tone for all federal grant-in-aid to transportation programs that followed. Construction of the Interstate system is supported by user fees placed in a trust fund. It is administered by an arm of the federal government, but actual planning and construction is carried out by the states using a common set of standards that they developed, both in cooperation with other states and in cooperation with the federal government. Finally, reflecting the national interest in defense, interstate commerce, and travel, the clear majority (90 percent) of the cost of the Interstate system is paid by federal taxes.

For such arrangements to work, whether they are for construction of a highway system, the implementation of new public transportation services and facilities, or a new airport and airway system, a variety of data must be available to support federal strategic decision making—that is, decisions on the nature and magnitude of federal transportation programs. This information, consistent with the nature of strategic planning, must focus on those factors related to the need for the basic "product" that the federal government provides, financial assistance.

For public transportation, four major types of data are needed for federal strategic planning. The first consists of the factors that influence transit demand, the second describes system extent, the third, describes system operations and related costs, and the fourth, describes system condition, in no particular order. A number of data resources are useful for identifying changes in the factors influencing the demand for public transportation. One is obviously the decennial Census and others include national surveys such as the Nationwide Personal Transportation Survey (NPTS).

Most of the second and third types of information, describing the extent of the nation's transit systems, their operations, and costs, have come from the data collected under the rubric of "Section 15," a part of the federal transit law requiring the collection of a uniform data set as a prerequisite for receiving federal assistance.

The Section 15 data set includes, for each transit operator in the country, data describing the size and composition of the vehicle fleet, extent of fixed-guideway facilities, levels of service provided, accidents and fatalities, operating and maintenance costs, ridership and revenue, subsidies, and employment. All can be stratified and summarized a number of different ways—for example, by operator size and mode.

The Section 15 data set has been used successfully the past 9 years for national analyses of transit productivity, efficiency, and effectiveness. Many of these studies were used in preparation of the biannual reports to the Congress on the *Current Performance and Condition of Public Mass Transportation Systems* required by Section 308 of the Urban Mass Transportation Act (UMT Act).

To assess whether or not Section 15 will be adequate for the national transit strategic planning of the 1990s, one needs to know what new issues are likely to emerge during the period that the planning will cover.

The recent series of outreach meetings held around the nation in support of the preparation of a National Transportation Policy (NTP) suggested, among other things, that the emphasis in federal surface transportation investment should shift from new construction to the restoration and upgrading of the existing transportation system. It also identified the need for a stronger federal role in promoting transportation safety. Because these are relatively new federal policy emphasis areas for transit, the discussion below will focus exclusively on their data needs from the perspective of national strategic planning.

REHABILITATION AND REPLACEMENT

In the wake of the great wave of public takeovers of private transit operators in the late 1960s and early 1970s, a large number of new maintenance and operating facilities were constructed for all modes. In the mid- to late-1970s and on into the 1980s, a large number of new rail systems began operation. Beginning with the first gasoline crisis in 1973 and accelerating after the second in 1979, transit fleets were expanded. Much if not most of this new construction and expansion was supported with federal funds.

Applying any set of rules or standards on facility updating and equipment and vehicle replacement to the transit systems, whose history is briefly noted above, suggests that the decade of the 1990s will mark the beginning of a significant period of transit rehabilitation and replacement. The precise implications for federal transportation programs are somewhat unclear.

Rail transit modernization requirements were examined as part of the congressionally directed Rail Modernization Study completed in 1987. However, the basic thrust of that study

Office of Planning, Urban Mass Transportation Administration, U.S. Department of Transportation, UGM-70, 400 7th Street S.W., Washington, D.C. 20590.

was to determine the cost of bringing the nation's then-existing rail transit systems, most of which had originally been built decades earlier with nonfederal funds, to modern standards.

The early 1980s time frame of that study meant that no attention was paid to the rail systems which had been constructed more recently largely with federal funds. Also, the study was a single-time effort, meaning that the condition data collected for the newer, expanding systems that were open at the time (e.g., Washington and Atlanta), is becoming rapidly dated. Finally, no comparable evaluation of fixed facilities for other modes (e.g., bus operating and maintenance bases, malls, fringe parking, ferry terminals, etc.) was done.

Assessing the magnitude of future rehabilitation and replacement activities for all modes and how they will be distributed in time and by geography requires a significant amount of system condition data. Unfortunately, these data are not now routinely collected at the national level, and sorry to say, much of it may not be available even locally.

As an example of this situation, in 1986 the Federal City Council (FCC), a group of key business and professional community leaders in Washington, D.C., completed a study of transit finance in the Washington region. The purpose of that strategic planning effort, undertaken in cooperation with local officials and the Urban Mass Transportation Administration (UMTA), was to make estimates of all outyear costs associated with public transportation in the Washington area. The idea was that once this estimate was in hand, local officials could then assess the ability of existing revenue sources to handle forecasted costs, and begin the process of developing new ones if needed.

Perhaps the most significant work done as part of that study was to inventory all the region's transit facilities and equipment in enough detail to estimate rehabilitation and replacement costs over time. This involved the classification of all capital resources into about 50 categories, estimating their number by date of acquisition or beginning of service, estimating the dates for either major rehabilitation or replacement, and the respective unit costs. Although the Washington area already had a transit capital plant worth more than $4.5 billion and an approximately $500 million annual operating and maintenance budget in 1986, the FCC study marked the first time that such an inventory had been attempted.

The study found that by the end of the century, annual rehabilitation and replacement requirements would go up by more than 400 percent in real dollars to a point ($160 million in 1986 dollars) where they would be equivalent to about 35 percent of the total 1986 annual local transit operating and maintenance cost. Subsequent to the FCC study, the Washington Metropolitan Area Transit Authority (WMATA) has undertaken a much more detailed one of its own, and moved to establish a sinking fund to pay for the outyear replacement and rehabilitation costs the study will identify.

Similar studies have recently been completed in Chicago, Philadelphia, and Baltimore; New York had done one earlier. Only Baltimore did the type of detailed inventory accomplished as part of the FCC study, although an engineering assessment of the condition of the Chicago Transit Authority heavy rail system is now underway. Unfortunately, there was not a consistent format for the data generated by these studies, nor were consistent assumptions and methods used to produce it.

Clearly, if the type of disinvestment in the nation's urban transit systems that occurred prior to 1970 is to be avoided in the future, local financial planning for new transit capital investments and for subsequent operations must reflect these costs as early as possible. Federal government strategic planning data needs are different than those for local financial planning, but it still must have better information on system condition than is presently available through Section 15.

A national transit system condition data set, comparable to that used by the Highway Performance Monitoring System (HPMS), would describe the number, size, and condition of fixed transit facilities, as well as all vehicles and significant ancillary equipment. Acquisition and operation initiation dates would be collected along with the expected dates for major overhauls and replacement based on consistently applied standards. Estimates of the costs associated with rehabilitation and replacement might also be included.

Care would have to be exercised to ensure that the data collected was not more detailed than necessary to support national-scale planning and policy analysis. This could be assured by using a sampling procedure similar in concept to that utilized by HPMS, collecting the data on a periodic basis but not every year. The triennial reviews required by Section 9 of the UMT Act might provide a good opportunity to keep such a national system condition data base current.

SAFETY AND SECURITY

In terms of the safety information needed for national strategic planning, although accident and fatality data is being collected under the auspices of Section 15, there is little national information available on accident causes and incidents of crime, particularly as related to substance abuse. In addition, there is no consistency between the data collected for Section 15 and that available from other federal accident and safety reporting systems (e.g., the National Highway Traffic Safety Administration's Fatal Accident Reporting System, "FARS," and National Accident Sampling System, "NASS").

Without a more comprehensive set of data on accidents and their causes, and crime against transit passengers, personnel, and property, it is difficult to properly identify important safety and security problems, formulate potential responses at federal and other levels, and evaluate them. The first attempt at improving this situation will be a redesign of the safety-related data being collected for Section 15 purposes. A semiannual drug program reporting system is also being established under UMTA's new drug rule.

SUMMARY AND CONCLUSIONS

The discussion identified transit rehabilitation and replacement and transit safety and security as increasingly important issues for the coming decade. It attempted to show the linkage between these issues and the information needed to support decision making on actions to address them at the federal level.

Unfortunately, local and state governments, the source of most national strategic planning data, are only now starting to assess transit system rehabilitation and replacement costs, although their estimation should have been part of the financial planning which preceded implementation. It almost seems that the assumption in the 1960s, 1970s, and 1980s, when many of the new systems were being implemented and others expanded, was that the same financing arrangements which were in place for their implementation would be in place for their inevitable overhauling. However, if we have learned anything from the recently completed hearings around the nation in support of a new National Transportation Policy, it is that the financial arrangements that have served us so well in the past may have to be "renegotiated" in the future.

One reason for this change is that the focus of past federal transportation programs, to assist in implementing new services and facilities, will be shifting to the rehabilitation and replacement of existing resources. Because the proper balance between building new and maintaining old is rightfully a local decision, increased flexibility in the federal delivery system will be in order. Good information on rehabilitation and replacement requirements will, therefore, be as important in the future as information on the factors influencing the need for new facilities and services was in the past.

At the same time, there is a growing recognition of the need for improved safety and security reporting systems, in part related to the nation's broader drug problem. Better data is needed to document trends in transit safety and security in order to correlate system and other parameters to the frequency and severity of incidents. With this data in hand, corrective actions can be formulated and analyzed.

In the case of both rehabilitation and replacement and safety and security, it is the task of local, state, and federal planning processes to produce needed data if good decisions are to be made by any level of government.

The opinions expressed above are those of the author and do not necessarily represent those of the Urban Mass Transportation Administration.

Survey of Travel Surveys II

CHARLES L. PURVIS

A survey of large metropolitan planning organizations was conducted to ascertain past, current, and future data collection plans with respect to household travel surveys and related, auxiliary surveys. Thirty-eight metropolitan areas responded to this survey of travel surveys, including the largest 20 metropolitan areas in the United States. Responses to the survey can be grouped into five general patterns: (a) regions conducting household surveys on a 10-year census cycle; (b) regions conducting household surveys on a 10-year off-census cycle; (c) regions on a 15-plus-year cycle; (d) regions conducting surveys on a tracking and continual cycle; and (e) regions not conducting household travel surveys. The survey provides a springboard to establish a network of metropolitan transportation planners involved in household travel survey analysis. Cooperation between regional agencies will foster greater awareness of the necessary tools and procedures to weight and expand survey results, develop and apply trip-linking procedures, and integrate survey results into updated, reestimated travel demand models.

This survey of metropolitan area data collection plans was intended to develop a dialogue between regional agency staffs planning and conducting household travel surveys from 1989 to 1992. This dialogue may then evolve into an informal network of regional transportation planners and engineers involved in transportation data collection, analysis, and travel demand forecasting. The methods and procedures—the insights and experiences—can perhaps be transferred to other regions, as well.

This "survey of travel surveys" was originally conducted as a mail-out, mail-back survey during March and April 1989. Telephone follow-up for late responses was necessary. The survey instrument (Figure 1) included questions on past travel surveys conducted from 1978 to 1988 and planned travel surveys for 1989 to 1992. Respondents volunteered answers on household travel surveys, truck and goods movement surveys, external cordon surveys, and on-board transit user surveys. Questions were asked about sample size, survey costs, and projected budgets. Surveys were sent to the 37 largest metropolitan areas in the United States with more than 1 million population (Table 1). The "Survey of Travel Survey II" resurveyed the largest metropolitan areas about changes in data collection plans and surveyed all 80 metropolitan areas with greater than 430,000 population.

SURVEY RESULTS

Thirty-eight metropolitan areas responded to this survey of travel surveys, including the largest 20 metropolitan areas in the United States. Only eight of the 43 smaller metropolitan areas (430,000 to 1,000,000 population) responded to this survey.

Responses can be grouped into five general patterns:

1. Regions conducting household surveys on a 10-year census cycle,
2. Regions conducting household surveys on a 10-year off-census cycle,
3. Regions conducting household surveys on a 15-plus-year cycle,
4. Regions conducting household surveys on a tracking and continual cycle, and
5. Regions not conducting household surveys.

The first group is composed of 8 regions which conducted their last household survey between 1978 and 1982 and are planning to conduct a new household travel survey between 1989 and 1992, coincident with the 1990 Census. The regions include: Chicago (last survey in 1979), the San Francisco Bay Area (1981), Detroit (1980), Cleveland (1978), Atlanta (1980), Pittsburgh (1978 to 1980), and Minneapolis-St. Paul (1982). Milwaukee conducted a small-scale travel survey in 1984 and 1985 and is planning a household survey in 1991 and 1992. These eight represent the 10-year census cycle survey group

The 10-year off-census cycle group is composed of 6 regions that conducted major household travel surveys from 1985 to 1988 and are not planning household travel surveys for 1989 to 1992. They include (with their last household travel survey in parentheses) Philadelphia (1986 and 1988), Washington, D.C. (1987 to 88), Baltimore (1988), San Diego (1986), Phoenix (1986 and 1988), and Denver (1985).

The third group includes regions where household travel surveys are conducted infrequently—every 14 to 26 years. The ten regions included here in this group are: New York (1963 to 1964), Los Angeles (1976), Boston (1963), St. Louis (1965 to 1966), Buffalo (1973), and Albuquerque (1962). Also included in this group are Kansas City, Missouri; San Antonio, Texas; Columbus, Ohio; and Tucson, Arizona.

A new pattern of household travel survey data collection is emerging in which travel data is collected on an ongoing or "tracking" basis. These regions are either planning or conducting longitudinal surveys or "panel surveys" (same group of respondents). The four regions in this group include Dallas-Fort Worth (1984), Houston (1984), Seattle (1987 to 1988), and Portland (1985 and 1988). All plan to conduct travel surveys between 1989 and 1992. The Bay Area also has plans to conduct a panel survey to complement a standard one-day trip diary travel survey.

The last and fifth group of regions includes those not using the household travel survey as a tool in travel demand model development or for their regional transportation data base. Miami (population 2.64 million) and Norfolk (1.16 million)

Metropolitan Transportation Commission, 101 Eighth Street, Oakland, Calif. 94607.

A. Have you completed a Household Travel Survey over the past ten years (1978-1988) ?

☐ Yes ☐ No. If Yes, then:

1. What type of Travel Survey(s) did you do?____________________
2. When was the survey data collected?____________________
3. What was the sample size?____________________
4. How much did this Survey Cost?____________________
5. What other information on your Survey would you care to discuss?____________________

B Do you plan to conduct a Household Travel Survey over the next few years (1989-1992), specifically to coincide with the 1990 Census?

☐ Yes ☐ No. If Yes, then:

1. What type of Travel Survey(s) will you do?____________________
2. When will you collect the survey data?____________________
3. What is your projected sample size?____________________
4. How much will you budget for your Survey ?____________________
5. What other information on your proposed Survey would you care to discuss?____________________

C. Survey Respondent / Staff Contact(s) / Agency:____________________

____________________ Phone Number:____________________

FIGURE 1 Survey of travel surveys.

typify this group. Also included in this group are Providence, Rhode Island; Hartford, Connecticut; Louisville, Kentucky; Toledo, Ohio; Harrisburg, Pennsylvania; Springfield, Massachusetts; New Haven, Connecticut; and Wichita, Kansas. It is expected that the smaller the region, the less likely that the regional transportation planning agency will be planning or conducting household travel surveys. Typically, state departments of transportation would be responsible for collecting this type of regional transportation data for smaller regions.

At least 22 metropolitan areas are planning to conduct household travel surveys from 1989 to 1992. This compares with 7 regions conducting similar surveys during the 1980 census period (1978 to 1982). Most of the regions contemplating surveys for 1990 are developing sample designs and budgeting proposals this past spring and summer (1989).

A list of regional agency contacts is shown in Table 2. Phone numbers and agency affiliations are included. Detailed survey results are described later.

Long-term follow-up is needed to provide the transportation practitioner with the necessary tools and procedures to weight and expand the survey results; develop and apply trip-linking procedures; and integrate survey results into updated, reestimated travel demand models. The regions may develop this program as a "network" or "user support group"; or role(s) can be defined for the federal government of other organizations (TRB, NARC, etc.) to provide this support. The intent is for regional planning staffs to learn from the insights and experiences of colleagues undertaking similar tasks and challenges.

New York (New York Metropolitan Transportation Council–NYMTC)

1978–1988 Household Travel Surveys

No household travel surveys were conducted from 1978 to 1988.

1990 Household Travel Survey

NYMTC has entered into a contract with RTI to purchase between 800 and 1,000 additional samples of the National Personal Transportation Survey (NPTS). The Metropolitan

TABLE 1 METROPOLITAN AREAS RANKED BY 1988 POPULATION (440,000+POPULATION)

	Region	Agency	Staff Contact(s)	Telephone
1	New York	NYMTC	Lawrence Hammel	(212) 938-3341
2	Los Angeles	SCAG	Hong Kim	(213) 385-1000
3	Chicago	CATS	Ed Christopher	(312) 793-3467
4	San Francisco Bay	MTC	Chuck Purvis; Patrick Hackett	(415) 464-7731
5	Philadelphia	DVRPC	Thabet Zakaria	(215) 592-1800
6	Detroit	SEMCOG	Robert Newhouser	(313) 961-4266
7	Boston	CTPS	Ian Harrington; Ken Miller	(617) 973-7080
8	Dallas/Ft.Worth	NCTCOG	Gordon Shunk; Michael Morris	(817) 640-3300
9	Washington, D.C.	MetroWashCOG	George Wickstrom	(202) 223-6800
10	Houston	HGAC	Alan Clark	(713) 627-3200
11	Miami	MetroDade	Jose-Luis Mesa	(305) 375-4507
12	Cleveland	NOACA	Joe Cole	(216) 241-2414
13	Atlanta	ARC	Patti Schropp	(404) 656-7737
14	St. Louis	E-W GCC	Martin Altman; Al Boudreau	(314) 421-4220
15	Seattle	PSCOG	Elaine Murakami; Bob Sicko; Tim Watterson	(206) 464-5355
16	Minneapolis/St.Paul	Metro Council	Stephen Alderson	(612) 291-6337
17	San Diego	SANDAG	Lois Fonseca	(619) 236-5354
18	Baltimore	BRCOG	Gene Bandy	(301) 554-5628
19	Pittsburgh	SPRPC	Wade Fox; Chuck DiPietro; Ted Treadway	(412) 391-5593
20	Phoenix	MAGTPO	Mark Schlappi	(602) 255-7867
22	Denver	DRCOG	George Scheuernstahl; Chuck Green	(303) 455-1000
24	Kansas City	MARC	Fred Schwartz	(816) 474-4240
25	Milwaukee	SEWRPC	Ken Yunker	(414) 547-6721
26	Portland	METRO	Keith Lawton	(503) 221-1646
28	Norfolk	SVPDC	John Crosby; Dwight Farmer	(804) 420-8300
29	Columbus	MORPC	Robert Lawler	(614) 228-2663
30	San Antonio	BC-COG	David F. Pearson	(512) 227-8651
33	Buffalo	NFTC	Tim Trabold	(716) 856-2026
34	Providence	RI-Dept Admin	D. M. Tonnessen	(401) 277-2656
36	Hartford	CRCOG	Tom Maziarz	(203) 522-2217
42	Louisville	KIPDA	Norman Nezelkewicz	(502) 589-4406
59	Tucson	ADOT-PAGTPD	T.R. Buick	(602) 628-5314
63	Toledo	TMACOG	William Knight	(419) 241-9155
66	Harrisburg	T-C RPC	Dave Royer	(717) 234-2639
69	New Haven	SCRCOG	Herbert Burstein	(203) 234-7555
70	Springfield	PVPC	James P. Cope	(413) 781-6045
75	Albuquerque	MRGCOG	John Hoffmeister	(505) 247-1750
77	Wichita	W-SC MAPD	David Peterson	(316) 268-4457

TABLE 2 METROPOLITAN AREA TRAVEL SURVEYS—CONTACT LIST

Rank	Metropolitan Area	1980 Population	1980 Rank	1986 Population	1988 Population	% Change 1980-88
1	New York	17,539,532	1	17,967,800	18,120,200	3.3%
2	Los Angeles	11,497,549	2	13,074,800	13,769,700	19.8%
3	Chicago	7,937,307	3	8,116,100	8,180,900	3.1%
4	San Francisco-Oakland	5,367,900	5	5,877,800	6,041,800	12.6%
5	Philadelphia	5,680,509	4	5,832,600	5,963,300	5.0%
6	Detroit	4,752,764	6	4,600,700	4,620,200	-2.8%
7	Boston	3,971,792	7	4,055,700	4,109,900	3.5%
8	Dallas-Fort Worth	2,930,568	10	3,655,300	3,766,100	28.5%
9	Washington, DC	3,250,921	8	3,563,000	3,734,200	14.9%
10	Houston	3,099,942	9	3,634,300	3,641,500	17.5%
11	Miami	2,643,766	12	2,912,000	3,000,500	13.5%
12	Cleveland	2,834,062	11	2,765,600	2,769,000	-2.3%
13	Atlanta	2,138,143	16	2,560,500	2,736,600	28.0%
14	St Louis	2,376,971	14	2,438,000	2,466,700	3.8%
15	Seattle	2,093,285	18	2,284,500	2,420,800	15.6%
16	Minneapolis-St Paul	2,137,133	17	2,295,200	2,387,500	11.7%
17	San Diego	1,861,846	19	2,201,300	2,370,400	27.3%
18	Baltimore	2,199,497	15	2,280,000	2,342,500	6.5%
19	Pittsburgh	2,423,311	13	2,316,100	2,284,100	-5.7%
20	Phoenix	1,509,227	24	1,900,200	2,029,500	34.5%
21	Tampa-St Petersburg	1,613,600	22	1,914,300	1,995,100	23.6%

TABLE 2 *(continued on next page)*

TABLE 2 (*continued*)

Rank	Metropolitan Area	1980 Population	1980 Rank	1986 Population	1988 Population	% Change 1980-88
22	Denver	1,618,461	21	1,847,400	1,858,000	14.8%
23	Cincinnati	1,660,258	20	1,690,100	1,728,500	4.1%
24	Kansas City	1,433,464	25	1,517,800	1,575,400	9.9%
25	Milwaukee	1,570,152	23	1,552,000	1,571,700	0.1%
26	Portland	1,297,977	26	1,364,100	1,414,200	9.0%
27	Sacramento	1,099,814	32	1,291,400	1,385,200	25.9%
28	Norfolk	1,160,311	31	1,309,500	1,380,200	19.0%
29	Columbus	1,243,827	28	1,299,400	1,344,300	8.1%
30	San Antonio	1,072,125	34	1,276,400	1,323,200	23.4%
31	New Orleans	1,256,668	27	1,334,400	1,306,900	4.0%
32	Indianapolis	1,166,575	30	1,212,600	1,236,600	6.0%
33	Buffalo	1,242,826	29	1,181,600	1,175,600	-5.4%
34	Providence	1,083,139	33	1,108,500	1,125,400	3.9%
35	Charlotte	971,447	36	1,065,400	1,112,000	14.5%
36	Hartford	1,013,508	35	1,043,500	1,067,600	5.3%
37	Salt Lake City	910,222	41	1,041,400	1,065,000	17.0%
38	Rochester, NY	971,230	37	980,300	980,100	0.9%
39	Memphis, TN	913,472	40	959,500	979,300	7.2%
40	Nashville, TN	850,505	45	930,700	971,800	14.3%
41	Orlando, FLA	699,906	51	898,400	971,200	38.8%
42	Louisville, KY-IN	956,436	38	962,800	967,000	1.1%
43	Oklahoma City, OK	860,969	43	982,900	963,800	11.9%
44	Dayton, OH	942,083	39	933,500	948,000	0.6%
45	Greensboro, NC	851,444	44	899,500	924,700	8.6%
46	Birmingham, AL	883,993	42	911,000	923,400	4.5%
47	Jacksonville, FLA	722,252	50	852,700	898,100	24.3%
48	Albany, NY	835,880	46	843,600	850,800	1.8%
49	Richmond, VA	761,311	48	810,200	844,300	10.9%
50	Honolulu, HA	762,565	47	816,700	838,500	10.0%
51	West Palm Beach, FL	576,754	58	755,600	818,500	41.9%
52	Austin, TX	536,693	63	726,400	748,500	39.5%
53	Scranton, PA	728,796	49	725,900	736,600	1.1%
54	Tulsa, OK	657,173	52	733,500	727,600	10.7%
55	Raleigh-Durham, NC	560,775	61	650,600	683,500	21.9%
56	Allentown, PA-NJ	635,481	54	656,800	677,100	6.5%
57	Grand Rapids, MI	601,680	56	648,800	665,200	10.6%
58	Syracuse, NY	642,971	53	649,300	650,300	1.1%
59	Tucson, AZ	531,443	64	602,400	636,000	19.7%
60	Las Vegas, NEV	463,087	72	569,500	631,300	36.3%
61	Omaha, NE	585,122	57	614,300	621,600	6.2%
62	Greenville, SC	570,211	59	606,400	621,400	9.0%
63	Toledo, OH	616,864	55	611,200	616,500	-0.1%
64	Fresno, CA	514,621	67	587,600	614,800	19.5%
65	Knoxville, TN	565,970	60	591,100	599,600	5.9%
66	Harrisburg, PA	556,242	62	577,300	591,100	6.3%
67	El Paso, TX	479,899	70	561,500	585,900	22.1%
68	Baton Rouge, LA	494,151	69	545,700	536,500	8.6%
69	New Haven, CONN	500,462	68	512,300	523,700	4.6%
70	Springfield, MA	515,259	66	517,800	522,500	1.4%
71	Bakersfield, CA	403,089	84	494,200	520,000	29.0%
72	Little Rock, ARK	474,464	71	505,600	513,100	8.1%
73	Charleston, SC	430,346	77	485,700	510,800	18.7%
74	Youngstown, OH	531,350	65	510,000	501,700	-5.6%
75	Albuquerque, NM	420,262	80	474,400	493,100	17.3%
76	Mobile, AL	443,536	74	470,000	485,600	9.5%
77	Wichita, KS	442,401	75	470,000	483,100	9.2%
78	Columbia, SC	409,955	82	444,700	456,500	11.4%
79	Stockton, CA	347,342	94	432,700	455,700	31.2%
80	Johnson City, TN-VA	433,638	76	443,400	442,300	2.0%

Transportation Authority (MTA) conducted a telephone home interview survey of more than 20,500 households during April and May 1989—a Total Travel Survey (TTS). The TTS obtained the total diary for one adult member (aged 16 or older) in each household. Preliminary findings on the TTS are beginning to be received. In addition, the MTA will conduct a fall 1989 intercept survey of riders on its subways in New York City (including the heavy rail operation on Staten Island) and the Long Island Rail Road. Surveys of riders on the Metro-North Commuter Railroad were done recently and do not require updating. The total cost for all current survey work is $3 million. Origin-destination surveys of passenger cars and commercial vehicles were just completed for vehicles entering and leaving part of the Manhattan CBD as part of a highway corridor study. NYMTC coordinates an annual Hub-Bound Travel Survey which is a count of all persons and vehicles entering and leaving the Manhattan CBD.

Los Angeles (Southern California Association of Governments–SCAG)

1976 Household Travel Survey

A telephone survey sampled 6,947 households out of 4.028 million regional housholds (0.17 percent). Used in a travel demand model update, the survey was conducted as part of the California Statewide Travel Survey (1976 to 1980) in which 18,300 household samples were collected statewide.

1990 Household Travel Survey

A sample design was completed under contract to UC Irvine—Institute for Transportation Studies (ITS). Budget and sample size are to be determined, and a truck survey for development of truck models is being considered.

Chicago (Chicago Area Transportation Study–CATS)

1979 Household Travel Survey

Home interviews were conducted in 1979 and 1980, 300 household samples regionwide.

1988–1992 Household Travel Surveys

A five-year program is using self-administered mail-back surveys and 1 to 2 percent of all households are being surveyed.

Officials budgeted $500,000 for the project. The method, adapted from work done in Ithaca and Albany, New York, has been tested with positive results. Chicago CBD used it in November 1988; McHenry County in the spring of 1989; Lake and Will Counties in the fall of 1989; DuPage County in the spring of 1990; and Cook County in the fall of 1990 (tentative). The mail-out, mail-back method captured the expected 20 percent or 400 travel surveys (Chicago CBD). Overall, 1 out of every 15.5 households was surveyed with the total data base representing 1 out of every 76.7 households, or 1.3 percent (2,000 questionnaires mailed in a population of 31,000 households).

San Francisco Bay Area (Metropolitan Transportation Commission–MTC)

1981 Household Travel Survey

A telephone survey with mail-out trip diary cards was conducted in the spring of 1981, including 7,091 total households and 6,209 households for weekday travel. Officials budgeted $365,000 for survey consulting. The survey was used in estimating full set of auto ownership, trip generation, trip distribution, and mode choice models. Several major reports focused on trip-linking, sample weighting, and trip characteristics. Comparisons were made between 1965 and 1980 trip rates.

1990 Household Travel Survey

A telephone survey similar to the 1981 survey was conducted. In the spring of 1990, a household panel survey of 1,500 households will complement the main sample. The panel survey (at $210,000) will include a multi-day trip diary component. The main survey will include one-day trip diaries for about 9,900 household samples (at $700,000). BART is adding on $100,000 to the MTC surveys for a "BART User and Non-User Panel Survey." Truck and external cordon surveys are postponed indefinitely. Officials have budgeted about $500,000 for transit operator on-board and marketing surveys, and about $75,000 for HOV-lane users survey (fall 1989). A sample design working paper for the 1990 household survey is complete. The RFP for the two MTC surveys and the BART Panel Survey ($1.01 million) will be released mid-November 1989. A Survey Advisory Panel of University of California, Berkeley, University of California, Davis and Stanford academicians has met periodically.

Philadelphia (Delaware Valley Regional Planning Commission–DVRPC)

1986 and 1988 Household Travel Surveys

Done in the fall of 1986 and fall of 1988, the survey looked at 2,500 sample households. The $260,000 survey was conducted by a consultant. Design, analysis, and application were completed by DVRPC staff.

1989–1992 Household Travel Surveys

No household travel surveys are planned from 1989 to 1992. External cordon surveys are planned for this period.

Detroit (Southeast Michigan Council of Governments–SEMCOG)

1980 Household Travel Survey

This trip diary and home interview survey sampled 2,500 households. The survey generated socioeconomic characteristics of households and total trip-making (mode, origin and destination) during the survey week. Samples were selected in clusters.

The 1990 Household Travel Survey

SEMCOG will coordinate and participate in NPTS add-on effort. The sample size and budget are to be determined. The goal is to collect updated trip length, mode split, and trip-generation parameters for updating travel models. The year 1980 was an anomalous one and many of those survey results had questionable validity.

Boston (Central Transportation Planning Staff–CTPS)

Household Travel Surveys

No household travel surveys were conducted from 1978 to 1988. The last home interview survey in the Boston region was conducted in 1963.

1990 Household Travel Survey

CTPS plans this survey for the spring of 1990 as part of the Route 128 Circumferential Highway Data Collection Project. The sample size is estimated at 0.25 percent of 1.2 million regional households, or 3,000 sample households (at a cost of $100 per household). The survey will be used to update work and nonwork trip models. The City of Boston has done and will continue to do cordon surveys for Boston proper.

Dallas-Fort Worth (North Central Texas Council of Governments–NCTCOG)

Home Interview Survey

This Home Interview Survey sample of 2,500 households in the spring of 1984. Officials budgeted about $540,000 for home interview and work place surveys combined ($320,000 for consultant). Simultaneous work place and on-board transit surveys were also conducted.

1989–1992 Household Travel Surveys

For 1989 to 1992, NCTCOG will have a "continuing telephone home interview survey." This program will begin in late 1989. About $50,000 annually will be budgeted for the telephone survey. Also, major emphasis will be placed on special generator surveys; activity centers survey (attraction rates); external cordon surveys; and a CBD cordon survey.

Washington, D.C. (Metropolitan Washington Council of Governments–MetroWashCOG)

1987–1988 Household Travel Survey

Mail-out trip diaries were used and 7,000 households were sampled at a cost of $50 per household. Data was compared with the 1985 Annual Housing Survey (AHS) (very close match). Also, WMATA conducted an on-board survey in 1985. Employment surveys are conducted every 5 years.

1989–1992 Household Travel Surveys

The 1990 Survey efforts will focus on external cordon surveys; truck surveys; interstate travel; and employment surveys. Approximately $200,000 per year is spent on data collection, although it is desired to spend $400,000 annually. WMATA is planning to conduct an on-board survey in 1990.

Houston-Galveston (Houston-Galveston Area Council–HGAC)

1984 Household Travel Survey

Using the mail-out, mail-back approach, the survey was conducted in October 1984. Less than 1 percent of Houston households were sampled: 1,500 households at a cost of $400,000 for use in the travel model update. Also, transit operator conducted a major on-board survey in 1985. Houston Metro conducted an on-board transit survey in 1988.

1990 Household Travel Survey

This survey was budgeted at $75,000 for 1,000 households. Also, proposed are a CBD cordon, external cordon surveys, and extensive 24-hour traffic counts (budgeted at about $90,000). H–GAC may participate in the National Personal Transportation Survey (NPTS) add-on program *if* a local funding source is found.

Miami (Metro Dade–MPO)

Household Travel Surveys

No household travel surveys were conducted from 1978 to 1988. On-board transit surveys, license plate surveys, and roadside interview surveys were conducted.

1989–1992 Household Travel Surveys

No household surveys are planned from 1989 to 1992.

Cleveland (Northeast Ohio Area Coordinating Agency)

1978 Household Travel Survey

Home interviews (not telephone) were made with 1,100 sample households. Used in mode-choice model updates, the survey was intended as a transit-rich supplement to the 1963 home interview survey (1963 surveyed 1 in 3 households). Also, transit trip tables were developed from an all-routes, on-board survey conducted by GCRTA in 1976 and 1986 (20 percent return rate; $60,000 to $70,000). The 1970 and 1980 journey-to-work packages were used extensively in work trip model application (would desire an Ohio statewide package in 1990).

1989–1992 Household Travel Survey

Data will be collected in three phases: Phase I—fiscal year 1989 to 1990—at $30,000 for a needs assessment and questionnaire development. Phase II—fiscal year 1990 to 1991—to test sample survey, computer coding, and so forth at $60,000. Phase III—fiscal year 1991 to 1992—to conduct full sample (at least 2,000 sample households are desired). Phase III has not yet been budgeted. The survey will probably be conducted in 1992. Also, a 3-year work program for urban goods movement (UGM) may include a truck survey component. The last comprehensive truck-taxi and external cordon surveys were done in 1963.

Atlanta (Atlanta Regional Commission–ARC)

1980 Household Travel Survey

Home interviews with completion of travel logs were done with 4,900 household samples at a cost of about $100,000. The data collected were: person travel by mode and purpose, availability of alternative modes, and choices being made; and an origin-destination subsample.

1990 Household Travel Survey

ARC plans to issue an RFP and let a contract this year to determine survey needs for 1990.

St. Louis (East-West Gateway Coordinating Council)

Household Travel Surveys

No household travel surveys were conducted from 1978 to 1988. The last home interview survey conducted in the St. Louis region was in 1965 and 1966.

1990 Household Travel Survey

The council is currently undertaking an in-house review of data needs with respect to 1990 data collection efforts. Activities are being coordinated with Missouri and Illinois State Departments of Transportation.

Seattle (Puget Sound Council of Governments–PSCOG)

1985–1988 Household Travel Surveys

The sample included 4,831 households at $97,500 contract costs plus $172,000 other costs. The surveys were Kitsap County, spring 1985 (783 households, $74,500 total costs); Seattle, November 1986 (768 households, $23,000 cost to PSCOG); Eastside King County, May 1987 (800 households, $40,000 cost to PSCOG); Pierce County, September 1987 (800 households, $45,000); Snohomish County and Shoreline, September 1987 (880 households, $45,000); and South King County, Spring 1988 (800 households, $42,000 cost to PSCOG). Other contract costs were paid by Metro Transit for the Seattle and King County Surveys. (Previous household travel surveys were conducted in 1961 and 1977.)

1989 Panel Survey

The Puget Sound Transportation Panel surveys will begin in the Fall of 1989. The panel is composed of 1,600 households in the four-county central Puget Sound region (King, Kitsap, Pierce, and Snohomish counties). The panel shall include 1,000 single-occupant vehicle households; 425 transit-user households; and 200 carpool-user households. A two-day trip diary will be collected from all sample households for all household members age 15 or older with $180,000 budgeted for the fall of 1989 and fall of 1990.

Minneapolis-St. Paul (Metropolitan Council)

1982 Household Travel Survey

Telephone survey with mail-out trip diary cards was done with 2,460 households with $70,000 budgeted for a survey consultant. Data were collected from September 1982 and February 1983.

1990 Household Travel Survey

Telephone surveys of 1 to 3 percent (9,000 to 27,000) of the region's households were conducted. The 9,000 household survey is estimated to cost $485,000; 18,000 sample survey estimated at $935,000; and 27,000 household sample estimated at $1,365,000. Also, employment survey, commercial vehicle and truck survey, external O-D roadside interviews, and special generator surveys will be done. Total data collection costs (excluding UTPP purchase and Model Development Costs) range from $910,000 to $2,025,000. $270,000 for transit operator's on-board survey is also budgeted.

San Diego (San Diego Association of Governments–SANDAG)

1986 Household Travel Survey

A home and roadside survey was done in the summer of 1986 of 2,754 households and 2,395 vehicle drivers for an external cordon and roadside interview survey. The total cost was $150,000.

1989–1992 Household Travel Survey

No household surveys are planned from 1989 to 1992. SANDAG will probably do a survey in 1995.

Baltimore (Baltimore Regional Council of Governments–BRCOG)

1988 Household Travel Survey

A telephone survey was done in the spring of 1988 of 2,000 households, 300 in each county plus 200 at a cost of $20,000. Work trip and socioeconomic information only was collected. Also, roadside postcard surveys were done in 1985 (I–95 and US–40 at toll booths) and November 1988 (general O-D). Also, an MTA transit on-board O-D survey was conducted in November 1984 for bus and rail passengers.

1989–1992 Household Travel Survey

No household surveys are planned from 1989 to 1992. A postcard origin-destination survey for Carroll County was conducted recently.

Pittsburgh (Southwestern Pennsylvania Regional Planning Commission–SPRPC)

1978, 1979, and 1980 Household Travel Surveys

The 1978 survey used a full sample; and 1979 and 1980, half sample each year, with 1,400 sample households. The cost was $90,000 over three years for data collection and analysis. The survey was designed and conducted by SPRPC staff. A home interview survey is to measure household trip rates, trip lengths, auto availability, and auto occupancy.

1990 Household Travel Survey

The proposed survey is to be conducted by telephone and mail-back rather than by home visit. Stratified sampling is aimed at 450 sample regional households. RFP to hire survey consultant was released October 1989 with $75,000 budgeted for 450 sample households ($15,000 consultant; $60,000 in-house). Trip diaries are to be collected for all household members age five or older.

Phoenix (Maricopa Association of Governments–MAG)

1981, 1988, and 1989 Household Travel Survey

From October 1988 to February 1989, 3,000 household were sampled at a cost of $170,000. Mail-out trip diaries were done with telephone interviews. Trip diaries were completed for household members age five or older. Extensive methodology and results report is undergoing current review.

1989–1992 Household Travel Survey

No household surveys are planned from 1989 to 1992.

Denver (Denver Regional Council of Governments–DRCOG)

1985 Household Travel Survey

Interviews were done with 1,600–plus households at a cost of $60,000. The survey was used for home-based work, home-based nonwork, nonhome-based, and internal-external model updates.

1989–1992 Household Travel Survey

No household surveys are planned from 1989 to 1992.

Kansas City (Mid-America Regional Council–MARC)

Household Surveys

No household surveys were conducted from 1978 to 1988. The 1990 and 1991 Travel Survey used the postcard mail-out and mail-back method. Budget and sample size are undetermined.

Milwaukee (Southeastern Wisconsin Regional Planning Commission–SWRPC)

1984–85 small-scale Household Travel Survey

The survey focused on 2,000 households (0.3 percent sampling rate). Also, external cordon survey (70 percent sample); truck survey (10 percent sample); and transit survey (3 percent sample). The total cost was $400,000. The small-scale survey did *not* permit survey accuracy checking and adjustment, trip distribution and attraction model updating, analysis of regional- and community-level trip generators, analysis of sub-region to sub-region travel patterns, and analysis of selected sub-regional and socioeconomic group travel patterns.

1991 or 1992 Household Travel Survey

If special state funding is provided the following will be carried out: a large-scale household survey (15,000 samples, 2.5 percent); an external cordon survey (70 percent); a truck survey (10 percent); and transit survey (15 percent). Approximate cost is $1.5 million. The large-scale survey will be coordinated with the 1990 Census and will address limitations of small-scale survey. Large-scale surveys similar to those proposed for 1991 and 1992 were conducted in 1963 and 1972. Desire is to conduct updated surveys, as in 1991 and 1992, every 10 years in conjunction with the U.S. Census. Special funding is necessary to conduct surveys. Proposed funding is small—$1.5 million once every 10 years—compared to annual highway construction and transit capital and operations funding of more than $300 million in southeastern Wisconsin.

Portland (Metropolitan Service District–METRO)

1985 and 1988 Household Travel Surveys

Telephone surveys were made in 1985 and May 1988: 1985, 5,000 households, $100,000, and 1988, 2,000 households (transit weighted), $40,000. Contractors underestimated costs both times and quality may have suffered. A 1988 survey included the East Corridor only to evaluate Light Rail behavior impact.

1990 Household Travel Survey

The April to May 1990 survey will not produce trip information, only demographic and location of workplace information. This is to start a "tracking" or updating system for socio-economic data. The purpose is to establish a Census benchmark. Also, an external cordon survey is being conducted between January and May 1989.

Norfolk (Southeastern Virginia Planning District Commission–SVPDC)

Household Travel Surveys

No household surveys were conducted from 1978 to 1988.

1989–1992 Household Travel Surveys

No household surveys are planned from 1989 to 1992. The Virginia Department of Transportation (VDOT) is evaluating alternative, cheaper techniques.

Columbus (Mid-Ohio Regional Planning Commission–MORPC)

1988 Travel Survey

This postcard survey, 3,000 samples, costs $7,000. This was a home-based trip generation survey that yielded information about number of persons, workers, and geographic location.

1989 Travel Survey

This was a phone survey of work trips for ridesharing analyses. The survey is to be conducted November 1989 for $15,000 with a sample size of 400. The survey will collect information on mode of travel, household demographics, time of travel, frequency of travel, and attitudes towards non-drive alone modes.

San Antonio (Bexar County Metropolitan Planning Organization)

Household Travel Surveys

No household surveys were conducted from 1978 to 1988.

1990 Household Travel Survey

This survey included a home travel survey, workplace travel survey, and external travel survey. Data collection is planned for January through May 1990. Budget and sample size are undetermined at this time. Requests for proposals have just been sent out. The transit system also plans an on-board origin-destination survey in 1990.

Buffalo (Niagara Frontier Transportation Committee–NFTC)

Household Travel Surveys

No household surveys were conducted from 1978 to 1988. The last household survey was conducted by the New York State DOT in 1973.

1990–1991 Household Travel Survey

Plans for household travel, cordon line, goods movement, and on-board transit surveys are included in this program. Projected sample size and budget is undetermined at this time. Preparations in the form of draft study designs are now being developed to identify sample sizes and the associated financial resources.

Providence (Rhode Island Department of Administration)

1978–1988 Household Travel Surveys

No household surveys were conducted from 1978 to 1988.

1989–1992 Household Travel Surveys

No household surveys are planned from 1989 to 1992.

Hartford, Connecticut (Capitol Region Council of Governments–CRCOG)

1978–1988 Household Travel Surveys

No household surveys were conducted from 1978 to 1988.

1989–1992 Household Travel Surveys

No household surveys are planned from 1989 to 1992.

Louisville (Kentuckiana Regional Planning and Development Agency–KIPDA)

1978–1988 Household Travel Surveys

No household surveys were conducted from 1978 to 1988.

1989–1992 Household Travel Surveys

No household surveys are planned from 1989 to 1992.

Tucson (Arizona DOT–Pima Association of Governments–ADOT–PAGTPD)

1978–1988 Household Travel Surveys

No household surveys were conducted from 1978 to 1988.

1989 Household Travel Survey

The survey will be conducted in the fall of 1989. The survey will collect travel logs of 1,000 sample households. The budget is $176,000.

Toledo (Toledo Metropolitan Area Council of Governments–TMACOG)

1978–1988 Household Travel Surveys

No household surveys were conducted from 1978 to 1988.

1989–1992 Household Travel Surveys

No household surveys are planned from 1989 to 1992. In fiscal years 1989, 1990, and 1991. TMACOG will be collecting other information and data on 1990 base year. Included are aerial photos, traffic counts, cordonline counts, transit ridership survey, and employment information.

Harrisburg (Tri-County Regional Planning Commission)

1978–1988 Household Travel Surveys

No household surveys were conducted for 1978–1988.

1989–1992 Household Travel Surveys

No household surveys are planned from 1989 to 1992.

Springfield, Massachusetts (Pioneer Valley Planning Commission)

1978–1988 Household Travel Surveys

No household surveys were conducted from 1978 to 1988.

1989–1992 Household Travel Surveys

No household surveys are planned from 1989 to 1992.

New Haven (South Central Regional Council of Governments)

1978–1988 Household Travel Surveys

No household surveys were conducted from 1978 to 1988.

1989–1992 Household Travel Surveys

No household surveys are planned from 1989 to 1992.

Urban Workshop Report

ALAN E. PISARSKI

The Urban Workshop began with an assessment of current trends and issues in the Urban Planning process and their relationship to data requirements.

STRATEGIC PLANNING AND POLICY ISSUES

First, it was concluded that the pendulum is swinging back toward longer range thinking, not instead of—but in addition to—the recent short-range focus of planning. The future emphasis will be on both factors rather than on one or the other. Highway operations planning is an example of the short-term focus, and land use planning is an example of the focus on the longer term. Second, the scale of activities is again balanced between broad regional efforts and highly localized trouble-shooting activities. All of these trends will place extensive information burdens on the planning process.

Dramatic changes in the demographic, economic, and spatial character of metropolitan centers have challenged local planning capabilities. The lack of adequate financial resources and supporting programs to produce adequate data has retarded the effectiveness of metropolitan planning.

The prime issue is highway congestion, in both urban and suburban areas. Parts of the congestion concern include the relating of existing facilities and services to the new circumferential patterns of contemporary commuting. Although most critical in high growth areas, all parts of the nation are experiencing congestion effects. The adequacy of current planning tools and data to forecast and assess prospective demand, and evaluate alternative responses is in serious question.

Beyond congestion issues are those that relate to obtaining greater capacity and efficiency in the use of existing facilities including operational and management improvements for highways and transit. The ability to evaluate the effectiveness and consequences of various supply and demand "management" schemes is a critical need for the current planning process. The growing needs to serve non-work related travel and congestion emphasizes the need for comprehensive planning rather than simply commuter-related planning.

6501 Waterway Drive, Falls Church, Va. 22044.

A final set of issues relates to the linkage of transportation to overall land use concerns, access to low-cost housing, and the problems of dealing with rapid growth.

CONCLUSIONS AND RECOMMENDATIONS

1. The mandated requirement for a continuing process of monitoring and reporting transportation trends in urban areas that was rescinded in 1983 needs to be reconsidered. The value of such a process is agreed to by all, but it is not clear that federal mandates must be the answer.
2. The program to produce the special journey to work package (the CTPP), an agreement between the states and the Bureau of the Census, is the single highest priority for meeting urban data requirements and should be fully supported by local governments, Metropolitan Planning Organizations (MPOs), states, and federal agencies.
3. UMTA and FHWA should undertake programs to encourage and support collateral data collection activities in the 1990s that would complement the decennial census data collection effort. These collateral activities include surveying non-work trips, consideration of urban freight data needs, and external travel, particularly in small metropolitan areas.
4. Consideration should be given to a continuing performance measurement process for metropolitan areas. The data set developed in a study of performance measurement needs in 1976 should form the basis for such a reevaluation. An NCHRP synthesis of effective practice in this area is warranted.
5. A national congestion-monitoring data set providing public information on traffic trends in major cities was identified as a needed and useful undertaking to inform national policy and support comparative analyses in individual metropolitan areas.
6. A condition and performance monitoring capability for transit, akin to the HPMS is needed, particularly to gain knowledge of capital reconstruction needs for fixed transit facilities. A parallel highway program related to UMTA Section 15 reporting was noted as desirable.

Statewide Workshop Report

MICHAEL D. MEYER

The Statewide Workshop identified planning and policy issues and noted gaps in the available data. On the basis of these issues, conclusions and recommendations were drawn.

STRATEGIC PLANNING AND POLICY ISSUES

These issues are

- Facility maintenance, rehabilitation, condition, and performance;
- Intermodalism;
- Safety;
- Congestion;
- Mobility Planning—need for a good definition;
- Payoffs of investment in terms of equity, economic development, and environmental impacts;
- Non-federal aid system;
- Trucking and commercial travel;
- Non-capital strategies;
- Corridor preservation;
- Road pricing; and
- Fund apportionment.

GAPS IN THE DATA

Gaps in the data are

- Trucking;
- New roads on new alignments;
- Transit data;
- Access to intermodal facilities such as airports, ports, and so forth;
- Performance measures;
- Before and after data to measure results of improvements;
- Non-work, non-home based work trips;
- Cost and benefit information;
- Traveler attitudes; and
- Usefulness of Geographic Information System (GIS) systems.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations merit attention:

Georgia Institute of Technology, Department of Civil Engineering, Room 326, Atlanta, Ga. 30332.

1. Greater coordination between data bases that state DOTs deal with such as pavement management systems, HPMS, and so forth. FHWA should take the lead in fostering coordination and implementation of standards in terminology.
2. GIS should foster the above coordination. Steps need to be taken to disseminate information on availability and uses of GIS with emphasis on keeping it simple to promote quicker implementation.
3. Further research and implementation of results of collection of data on trucks such as automated vehicle detection and crescent study procedures is needed.
4. Data are needed for evaluating intermodal concepts such as substitution of high speed rail for air in trips of less than 400 miles, better access between highways and ports, and cost allocation between modes.
5. User benefits are important evaluative measures. What do they mean to other parts of society and the economy such as economic development and the environment?
6. An authoritative review should be made of the relationship between transportation investment and economic development, productivity, and competitiveness along with a determination of the data required.
7. Performance and LOS data is required. HPMS should be modified if possible, to include such a measure.
8. There is sufficient data in rural and non-urban areas of the states. Complete data bases across each state to allow consistency in planning between urban and rural areas are needed.
9. A strategy should be established for collecting condition data on state transit facilities.
10. At least 2 percent of all federal transportation aid to metropolitan areas and states go to transportation planning and research with data collection, data management, and analysis a major part of a transportation research and planning effort.
11. With relation to aviation data, there needs to be a consistency in data and analysis to relate national airspace planning to physical plans for airports.
12. Better information is needed about such topics as fuel consumption and evasion of taxes, because this important information is used to allocate funds.
13. The 1990 Census should be used to check forecasts to see how the models might be improved.
14. To avoid information gridlock, a review should be made of management strategies for data collection. The TRB Committee on Data and Information Systems should do a prototype study of what a good data management system should be.

Recommendations for National Data

GARY MARING

The workshop considered five markets as follows: urban and suburban, rural, intercity passenger, intercity freight, and international. The strategic policy issues, data gaps, and conclusions and recommendations have been organized with respect to these markets.

STRATEGIC PLANNING AND POLICY ISSUES

The following issues deserve consideration:

- Urban-suburban
  - —Congestion
  - —System management
  - —Infrastructure rehabilitation and expansion
  - —Land use and transportation integration
  - —Funding flexibility
- Rural
  - —Infrastructure preservation
  - —Local rural road needs
  - —Rail branch line abandonment
  - —Rural mobility problems
- Intercity passenger
  - —Airport and airway congestion
  - —Major highway corridor congestion
  - —New intercity air and rail technology
  - —Funding flexibility
- Intercity freight
  - —Truck size and weight
  - —User fee equity
  - —Economic deregulation
  - —Tax and registration uniformity
  - —Safety and HazMat
- International
  - —Competitiveness
  - —Port connections
  - —Container standards and weights

GAPS IN DATA

The gaps in data are

- Urban and suburban
  - —consistency in urban boundary definition
  - —Measurement of congestion
  - —Geographic specificity
- Rural
  - —Rural public transportation
  - —Local road needs
- Intercity passenger
  - —Lack of National Travel Survey for long trips
- Intercity freight
  - —Commodity transportation survey
  - —Intermodal movements
  - —Air cargo
- International:
  - —Domestic leg of foreign commerce

CONCLUSIONS AND RECOMMENDATIONS

The workshop produced the following conclusions and recommendations:

Urban

1. Encourage urban boundary consistency for metropolitan areas between data bases. FHWA uses a federal aid boundary definition which may differ from those used by urban area studies. The urban boundary should be larger than that captured in HPMS. The boundaries should be extended to include areas of growth (20-year forecasts).
2. Uniform measures of congestion should be developed. One recommendation would be lane miles at some level of service (e.g., D). Data items should be included in HPMS, if not now included, to calculate congestion.
3. HPMS should include some coding to allow identification of sub-area geography such as the suburbs. This would allow identifying area types with problems such as the current interest in suburban congestion.
4. Develop means within HPMS for measuring trip length to aid in activities such as functional classification and determining systems of national significance. Measures of more than volume are required. Some measure like trip length is probably necessary.
5. The Section 15 data base should be expanded to obtain condition data on fixed plant.

Rural

1. An aggregate measure of local road needs, which is not captured in HPMS is needed. This reporting should be by some method other than segment sampling.
2. On the rail side, for short-line railroads, some measure of the abandonment impact on local roads and the agricultural economy is required. Financial and flow data would be desirable.

Federal Highway Administration, U.S. Department of Transportation, 400 7th St. S.W., HPP-10, Washington, D.C. 20590.

Intercity Passenger

1. There is a lack of data on longer trips. The National Travel Survey formerly captured long trips on all modes. This is especially important when considering new technology and proposals for activities such as substitution of high-speed rail for intermediate length trips (100 to 400 miles), tilt engine vertical take-off aircraft, and so forth. There is a need to collect information on longer trips in all modes.

2. There is a need for information on intercity buses and rural bus service including financial and flow data.

Intercity Freight

1. There is a lack of commodity O-D data. The last commodity transportation survey was done in 1977. Since then, much has happened relative to deregulation and changes in sizes and weights, and no one has a picture of the impact of these changes. Better data across modes is required.

2. There is a need for better truck safety data by truck configuration, and a way to relate accident data to exposure data.

International

Obtain better data and analysis on international flows. Data is collected, but not well reported and compiled. For example, a means is needed to measure the impact of containers on the road systems.

Other

1. Relative to all modes and markets, GIS provides the mechanism to coordinate data bases on a common basis, especially as related to networks and flows.

2. There should be a re-evaluation of partnerships in data collection at three levels.

—Between federal agencies—Agriculture, DOT, Energy, Census, and so forth;

—Between federal, state, and local; and

—Government—Private relative to deregulation, privatization, and so on.

Highway Performance Monitoring System: Kentucky's Approach

MOHAMMED TAQUI

The Kentucky Transportation Cabinet (KYTC) participated with great interest in implementing the FHWA's Highway Performance Monitoring System (HPMS) from its inception in 1978. One of FWHA's basic objectives was to gather the most up-to-date necessary information for the biennial report to Congress concerning condition, performance, and needs of the nation's highway system and to justify continued or increased highway funding. This effort by the FHWA was similar to some of the work the KYTC had been performing for legislative requests and for funding justification to the state's General Assembly. The HPMS concept of determining performance in relation to available or anticipated funds with statistical reliability and the overall needs convinced KYTC top level management about its effectiveness and usefulness to the department. Therefore, they provided necessary support to implement and expand this program to include other systems (state primary and federal-aid). Continuing spot-checks, refinements, and other enhancements of critical data items in sample sections by Kentucky officials have provided the desired quality capable of providing management with a remarkably consistent, flexible tool for developing and analyzing alternate programs, different scenarios, and so forth.

HPMS was reviewed in depth by the U.S. General Accounting Office (GAO) at congressional request to determine its usefulness and overall data quality. Kentucky was one of 6 states visited by GAO to evaluate HPMS. After detailed examination and consultation with staff, GAO concluded that the HPMS program and its analytical package was a reasonable tool for analyzing capital investment need estimates, because the models used key engineering elements based on nationally accepted standards. The data collection and quality control procedures were adequate to ensure needed precision levels.

At the statewide level, HPMS takes into account 2,681 samples comprising 3,675 miles of the total state-maintained system (27,289 miles), about a 13.5 percent sample. This sample has been statistically designed and kept up-to-date for analysis and data reporting requirements. Samples were selected separately from individual major urbanized areas for analysis. Kentucky has 100 percent of Interstate system on the HPMS file because of its importance in I-4R apportionment and the periodic need to perform project level analysis. Expected precision levels vary from 90-5 to 80-10. The Traffic Monitoring Guide (TMG) recommendations and SHRP's sites have been integrated with the overall HPMS program for ease in data collection activities and to avoid duplication of efforts.

Commonwealth of Kentucky, Transportation Department, Frankfort, Ky. 40622.

ANALYTICAL PACKAGE AND ITS APPLICATION

The HPMS Analytical Package has been designed to respond to questions concerning the determination of investment levels necessary to accomplish alternate objectives. With increasing construction and maintenance costs, and fluctuating revenues from fuel usage, prudent investment of available resources is essential. HPMS is capable of providing information not only on the funding required for ultimate system performance, but also on the effect on future systems performance resulting from insufficient funding. The package also makes it possible to analyze alternative funding levels, minimum acceptable conditions, design standards, and future travel with resulting performance measures.

The analytical package consists of a series of computer models which use HPMS data as primary input. The package consists of (a) needs analysis, (b) investment analysis, (c) impact analysis, (d) deferred cost analysis, and (e) multiple deficiency and composite analysis. The most important feature is the needs analysis model.

Needs Analysis

This model simulates the improvements required to keep the operating conditions of a highway system from falling below prescribed (user flexible) minimum acceptable conditions (MAC) during any preassigned analysis period. Needs are directly related to the MAC. Analysis and use have indicated that lane width, pavement condition, alignment adequacy, and volume-to-service flow ratio are very sensitive parameters that significantly affect needs. The other items that affect needs are travel demand and widening feasibility that is coded on each record. These are not models parameters, but their impact is significant. In order for needs to be reasonable and convincing, the user must make some assumptions concerning the MAC. After considerable analysis, KYTC decided to use the following assumptions with regard to the MAC:

1. No minor widening is performed (i.e., adding 1-ft or 2-ft width per lane to the roadway of an existing facility). In other words, the prevailing lane width of 8 to 10 ft on rural low-volume collectors is considered tolerable with some reduction in service level and safety aspects.
2. The existing curvature and gradient characteristics on the collector system cause some restrictions in the speed limit because of the design speed of curves. Hence, reduction in speed on low volume collectors is tolerable. Actually, it is unsafe on some collectors to travel at the prevailing speed limit.

3. The threshold value of PSI by system for resurfacing is very subjective and depends upon economic considerations and available funding.

In essence, the rationale was that the systems will still have some problems, but none that are currently considered serious enough to justify capital improvements. MAC have been established by a combination of engineering judgment, budgetary demands, and the best acceptable situation for the traveling public. The MAC established for Kentucky adequately safeguard public safety and minimizes long-term capital and improvement costs by making cost effective and timely capital improvements needed over the year of analysis.

Needs are analyzed in four possible scenarios:

- Full needs,
- Constrained full needs,
- Maintaining overall system condition "status quo," and
- Maintain system performance.

Full needs does not mean system perfection. It implies that no roadway section would exhibit physical and operational characteristics that fall below the MAC standards used to identify deficiencies. Because the MAC are significantly below full design standards for new roads, there will be some deficiencies (problems) that are not considered serious enough to require any capital improvement.

Constraint full needs list only those capacity-related improvements that can reasonably be expected to be accomplished particularly in congested urbanized areas where right-of-way is very critical. Operating characteristics are going to decline under the scenario in urbanized areas because of the lack of right-of-way for major widening. The required highway capacity resulting from traffic demand cannot be met because of prohibitive costs.

The third scenario is to maintain the status quo. This option represents the investment required to maintain an overall composite rating. The weakness of this method is that the overall composite index overshadows significant changes in the other components. In other words, on higher functional systems, pavement conditions tend to improve, and performance declines slightly, but the composite index remains essentially the same.

Maintain system performance scenario represents the cost of preventing further service deterioration. It does not exhibit any improvement in the average service level. This strategy shows the cost and investment required to keep the functional system performance the same as it was designed to do or at the same level as now. It permits continuation of overall quality of highway condition, service and safety, and accessibility. It also permits necessary capacity improvements to ensure retention of current service.

Present System Characteristics

As of December 31, 1988, the public road mileage in Kentucky totaled 69,848 miles. It carried 31.5 billion vehicle miles of travel (VMT). This represents about 8,294 VMT per person. Almost 11.2 percent (3.5 billion) was accounted for by trucks. About 90 percent (62,250 miles) of the total mileage is in rural areas with an annual VMT of 18.5 billion. The 10 percent (7,598 miles) of the total mileage is in urban areas with an annual VMT of 13 billion. The VMT split between rural and urban is 59 to 41 percent, respectively. About 27,289 miles of the total road system is maintained by the state and accounts for 27 billion or 86 percent of the total VMT. Approximately 13,820 miles are on the federal-aid system with an annual VMT of 26 billion which is 83 percent of total VMT.

The total statewide capital expenditures by the federal-aid system from 1980 to 1988 have obligations that vary from a minimum of $321 million in 1980 to a maximum of $662 million in 1987. Similarly, the capital expenditures vary from a minimum of $332 million in 1982 to a maximum of $524 in 1988. (See Table 1 and Figure 1.)

The statewide total expenditures by major categories are presented in Figure 2 and Table 2. The expenditures vary from $740 million to $1.04 billion.

Overall federal-aid system performance on a scale of 0 to 100 was about 74 in 1988. It varied substantially by system (Interstate, 66; rural roads, 88; and urban roads, 68). The system condition over the past 7 years has been maintained by an average annual capital overlay expenditure of $427 million that includes about $70 million on non-federal-aid system maintained by the state. There is slight increase in operating speed and decrease in vehicle operating cost on

TABLE 1 CAPITAL EXPENDITURES ON THE FEDERAL AID SYSTEM (IN $MILLIONS)

	1980	1981	1982	1983	1984	1985	1986	1987	1988
INTERSTATE	117	81	73	90	148	124	123	90	100
PRIMARY	252	151	96	122	144	144	196	213	196
URBAN	47	29	34	48	31	20	28	42	56
SECONDARY	49	66	66	45	54	37	54	69	78
NON-FEDERAL	41	35	63	57	39	53	65	88	94
TOTAL	506	362	332	362	416	378	466	502	524

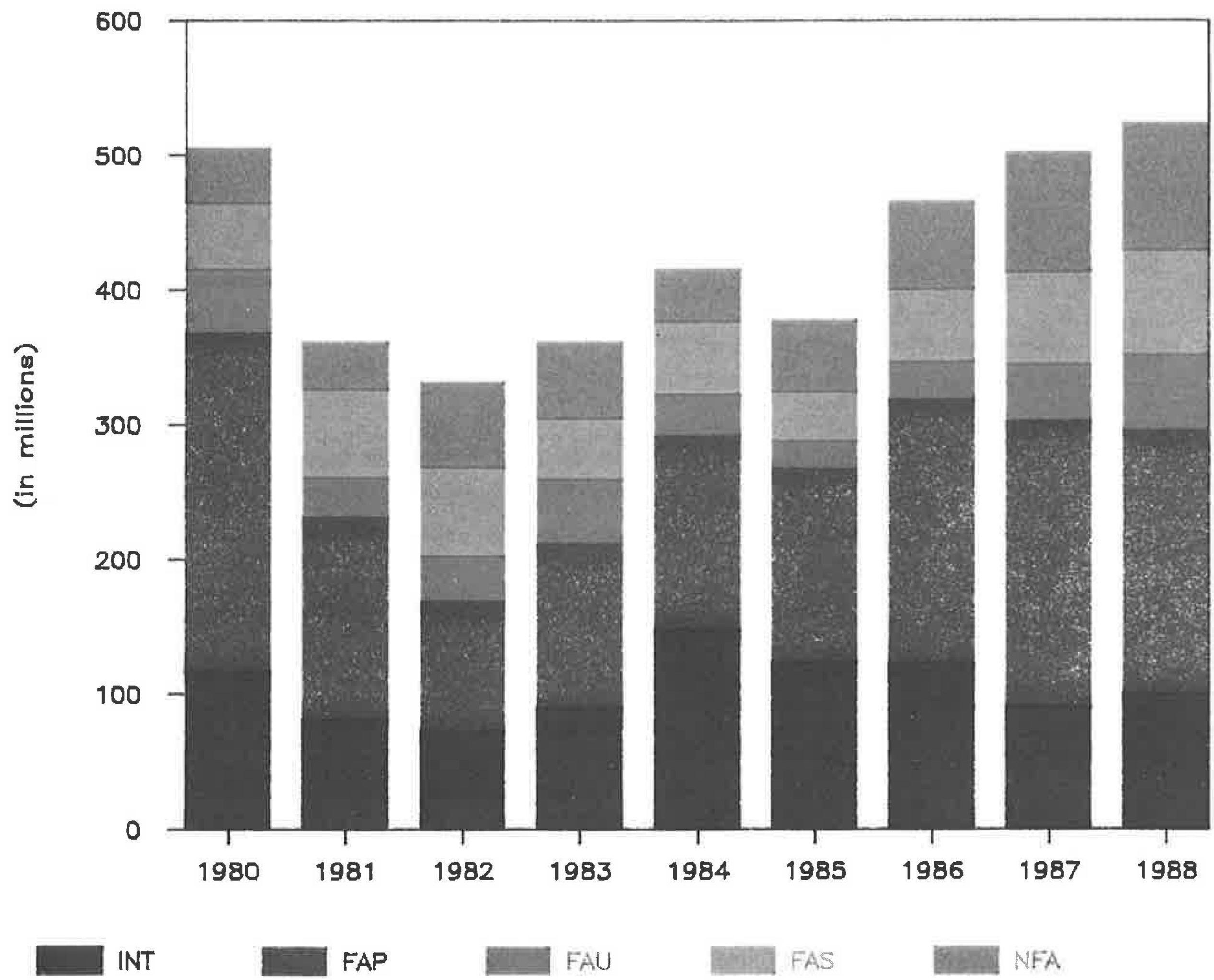

FIGURE 1 Expenditures on the Federal Aid System.

TABLE 2 STATEWIDE TOTAL EXPENDITURES (IN $THOUSANDS)

ITEMS	1980	1981	1982	1983	1984	1985	1986	1987	1988
1. CAPITAL OUTLAYS:									
a. State Maintained System	496,350	373,890	334,022	369,629	412,618	367,583	485,648	483,103	520,710
b. Local Road System	36,432	14,126	15,227	19,393	22,657	30,517	41,626	62,517	48,108
2. MAINTENANCE:									
a. State Maintained System	120,434	119,848	122,001	121,152	121,274	126,137	136,541	138,861	141,993
b. Local Road System	8,522	1	29	120	196	323	774	278	274
3. ADMINISTRATION:									
a. State Maintained System	37,318	35,168	33,198	37,891	40,672	51,481	47,288	59,062	33,831
b. Local Road System	2,320	989	1,068	1,366	1,600	2,159	2,966	4,396	3,387
4. DEBT SERVICES:									
a. General Obligation Bonds	18,067	18,064	18,099	18,093	18,060	18,056	18,052	18,064	18,071
b. Toll Roads Lease Rentals	54,826	47,702	58,989	55,167	54,693	40,593	43,787	33,426	31,813
c. Resource Recovery Rentals	35,114	42,105	54,658	46,301	46,219	70,857	20,093	42,503	23,913
d. Economic Development Rentals	--	--	--	--	19,363	35,751	35,710	35,600	13,804
5. REVENUE SHARING GRANTS:									
a. Cities	4,509	13,568	13,433	13,688	13,213	13,089	16,378	24,005	26,317
b. Counties	28,417	31,861	32,133	31,341	36,313	31,403	49,333	57,076	67,308
c. Rural Secondary	37,416	36,872	59,264	46,143	36,579	48,169	46,567	67,575	59,627
6. MASS TRANSPORTATION:	2,331	3,708	4,228	3,084	2,022	4,103	2,805	1,787	828
7. LAW ENFORCEMENT:	3,364	2,301	4,381	4,851	6,302	5,344	7,702	7,880	9,096
TOTAL	885,420	740,203	750,730	768,219	831,781	845,565	955,270	1,036,133	999,080

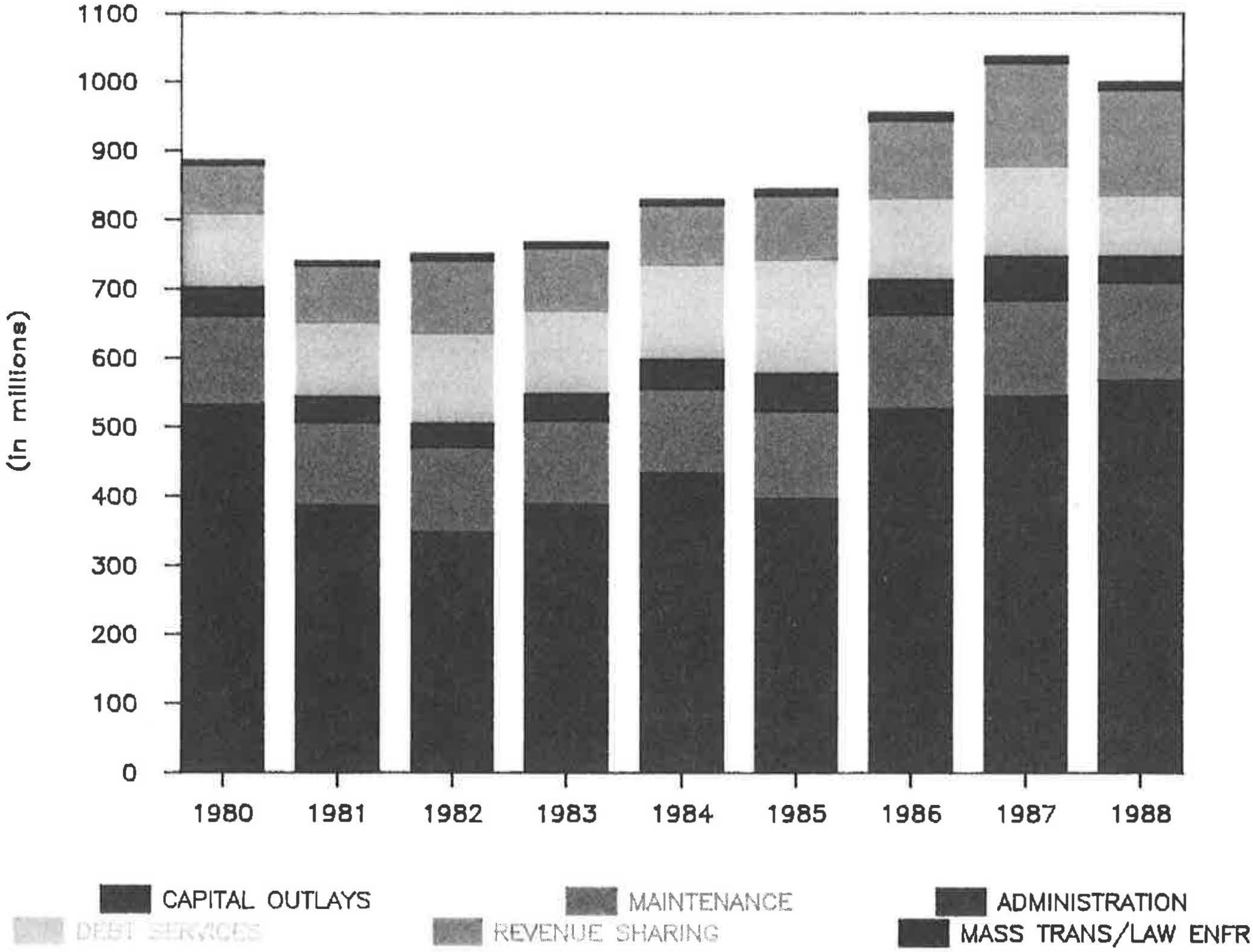

FIGURE 2 Statewide total expenditures.

rural and urban roads. But on the Interstate system, there is some reduction in operating speed and increase in operating cost. This illustrates that past expenditures on the Interstate system were insufficient to accommodate increased travel demand.

NEEDS

Full Constrained Needs

The needs analysis shows that the funds required for the cabinet to accomplish full constrained needs for the next 22 years is \$11.1 billion or an average of \$504.5 million per year.

Assuming anticipated federal-aid with state match of \$178.2 million per year and the continued availability of state funds from the 210 account of about \$100 million per year, an additional \$226.3 million per year is required to correct the deficiencies.

Maintain Current Highway System Integrity (status quo)

Under this scheme, it would cost \$9.2 billion for 22 years or an average of \$419 million per year to maintain the overall highway system condition.

Maintain Current System Performance

Under this scenario, an investment of \$10.4 billion for 22 years or an average of \$471 million per year is required to maintain current system performance.

Expected Federal Funds–System Performance

Expected federal funds with appropriate state match by category is used to determine system performance during the 22-year analysis period. The resulting system performance under this scenario is shown in Table 3 and Figure 3. It is clear from

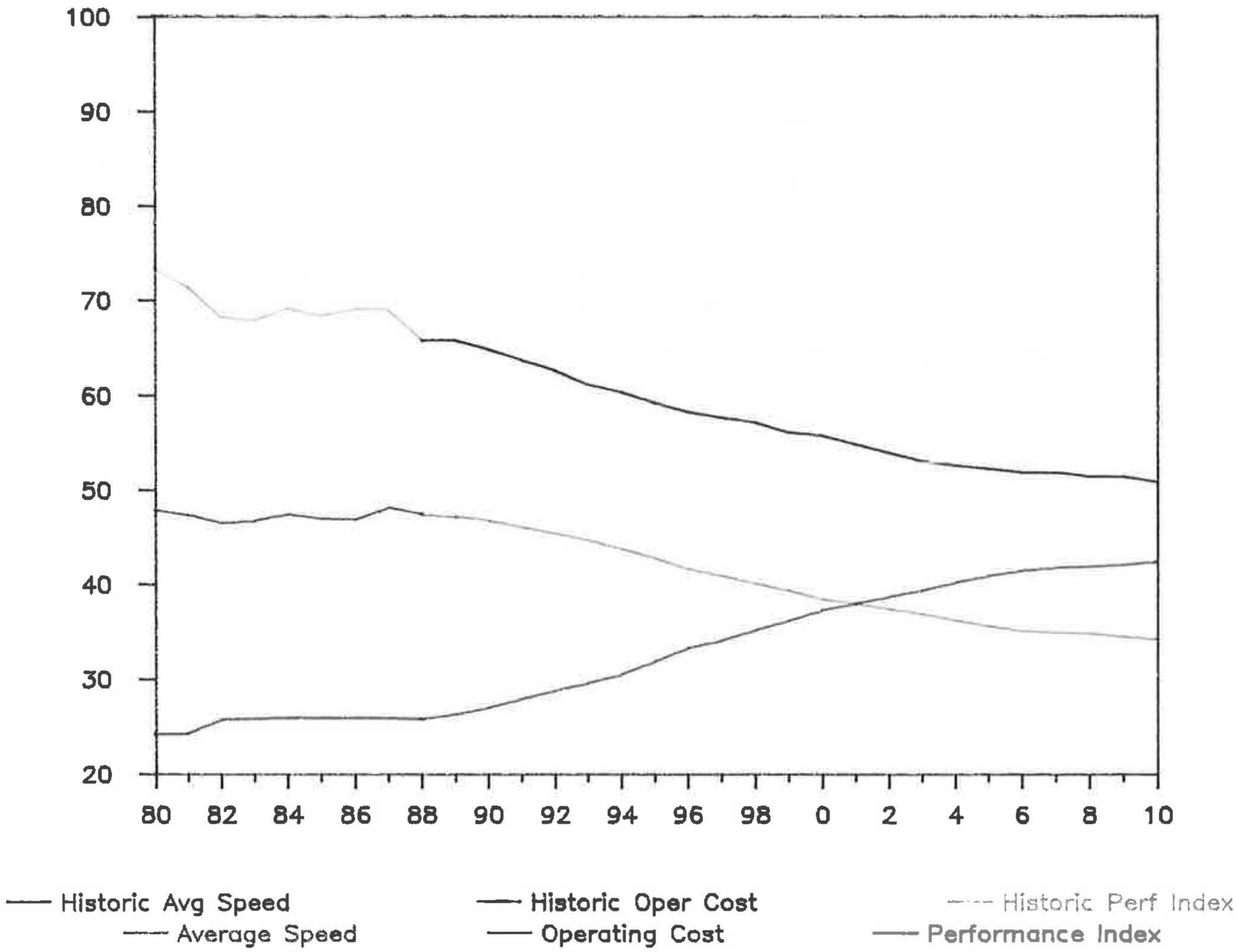

FIGURE 3 Performance measures for expected funds on Interstates.

TABLE 3 EXPECTED FUNDING

YEAR	INTERSTATE AVERAGE SPEED		INTERSTATE OPERATING COST		INTERSTATE PERFORMANCE INDEX	
80	48.0		24.2		73.5	
81	47.4		24.3		71.5	
82	46.5		25.8		68.3	
83	46.8		25.9		67.9	
84	47.5		26.0		69.3	
85	47.0		26.0		68.4	
86	46.9		26.0		69.2	
87	48.2		25.9		69.2	
88	47.5	47.5	25.8	25.8	65.9	65.9
89		47.2		26.4		65.9
90		46.8		27.1		64.9
91		46.1		28.0		63.8
92		45.4		28.9		62.7
93		44.7		29.7		61.2
94		43.8		30.6		60.4
95		42.8		32.0		59.3
96		41.7		33.4		58.3
97		40.9		34.2		57.7
98		40.1		35.3		57.2
99		39.4		36.3		56.1
0		38.4		37.4		55.8
1		38.0		38.1		54.9
2		37.4		38.8		54.0
3		36.9		39.5		53.1
4		36.2		40.3		52.6
5		35.6		41.0		52.3
6		35.1		41.6		51.9
7		34.9		41.9		51.9
8		34.8		42.0		51.5
9		34.5		42.2		51.5
10		34.2		42.6		50.9

Figure 3 that the performance index declines significantly affecting overall quality of mobility in terms of decreased operating speed and increased vehicle operating cost and congestion in urban areas.

Other Uses

- Interstate needs (short- and long-range);
- Truck miles of travel by system to estimate the expected revenue before passage of the "weight-distance tax";
- As justification to the Transportation Subcommittee about the validity of truck VMT;
- Provision of VMT, percent trucks, vehicle occupancy, operating speed, cost and pollutants to the MPOs, Cabinet for Natural Resources and Environmental Protection, State Police, and so forth; and
- Optimization of available financial resources in order to yield maximum attainable system performances.

These are just a few of the many uses being made of the HPMS program in Kentucky. New uses are continually being found as various problems and issues (particularly funding shortfalls) face the highway program.

Integrating Geographic Information System Technology and Transportation Models

HOWARD J. SIMKOWITZ

The potential of geographic information system (GIS) technology in transportation has been recognized for some time. However, only recently has GIS technology been adapted to meet the requirements of transportation systems. The results presented are based on research being conducted by the Caliper Corporation on integrating GIS technology and transportation models. First, the data requirements of various transportation models are explored. The data requirements include sequential text files for both inputs and outputs, tables containing vectors and matrices, and connected networks of nodes and links with their associated attributes. The data requirements, in turn, make a variety of demands on the structure of the GIS data bases and the way the model interfaces with the GIS. Next, the content and structure of a transportation organization's data bases are discussed and compared with the requirements imposed by the various model types. The traditional GIS formulation is specified, and its limitations for transportation analysis discussed. The concept of a transportation GIS is developed. Research has shown that rather than a mere addition of features to the existing GIS formulation, a transportation GIS requires a hybrid architecture that incorporates important transportation data structures and specialized procedural input, processing, and output modules. This new formulation makes it possible to optimize both the GIS functionality (e.g., thematic mapping, complex spatial manipulations, and rapid spatial and key field queries) as well as the transportation and operations research modeling needs (e.g., integration with compact, highly efficient connected networks and tables containing vectors and two-dimensional matrices to produce and analyze chains, tours, and other model outputs). The introduction of these transportation objects facilitates nearly all transportation applications of GIS and greatly increases ease of use by transportation professionals. The use of modern software concepts for the user interface makes GIS more accessible to nonprogrammers and persons not trained in GIS, and an extensible architecture increases the potential scope and integration of transportation applications. Of critical importance is the introduction of numerous transportation application modules. Other research results being reported include dynamic segmentation of linear feature data bases and the ability to handle extremely large networks and data bases on microcomputers. Operational experience with Caliper Corporation's GIS for transportation, TransCAD, is reviewed. The breadth of applications is startling and illustrates the power of a generic transportation GIS used as a platform for all types of transportation analysis. Experience indicates that important productivity gains for transportation organizations and professionals will result from the adoption of a transportation GIS.

A geographic information system (GIS) is a computerized data base management system for the capture, storage, retrieval, analysis, and display of spatial (i.e., locationally defined) data.

Caliper Corporation, 4819 Cumberland Avenue, Chevy Chase, Md. 20815.

The advent of inexpensive, easily accessible GIS technology has placed the entire transportation analysis and modeling process in a new and exciting light. Whereas in the past, transportation data were displayed and analyzed in a tabular format or, at best, by using greatly simplified straight line network abstractions, today it is possible to integrate transportation data bases and models into a GIS system. A transportation GIS requires important extensions of the traditional GIS formulation that was developed for environmental research.

The results presented in this paper are based on research being conducted by the Caliper Corporation on expanding the definition of a GIS to contain necessary transportation extensions. These extensions not only result in a flexible representation of reality but also provide spatial analytical tools that enable the analyst to ask fundamentally new questions about diverse data sets that have important bearing on the solutions to transportation problems. These extensions facilitate the integration of GIS technology and transportation models. Caliper's research has resulted in the development of a transportation GIS, TransCAD. All reported concepts and results have been incorporated into the TransCAD software.

CLASSIFICATION OF TRANSPORTATION MODELS

There are a number of ways of classifying transportation models. For the purpose of this paper, classification will focus on the required data formats for inputs and outputs. Some models require as inputs and outputs one or more attributes from a selected set of records in a GIS data base. Models in this category include the following: accident analysis in which each record is a point on the roadway and the attributes describe the accident's setting and participants; pavement management in which each record is a road segment, the input attributes describe distress, vehicle volumes, and road type, and the output attributes define a condition ranking or a strategy of treatment; and a trip-generation model in which each record is a traffic analysis zone, the input attributes describe the propensity for trip making, and the output attributes describe the estimated trip productions and attractions.

Spatial distribution models require the ability to manipulate vectors and matrices of data. The gravity model, used to estimate trip distribution between a set of origins and destinations, requires vectors containing trip productions and attractions at each traffic analysis zone and matrices that contain the minimum cost of traveling between zones as inputs to the model. The model outputs a new matrix of estimated trips between all traffic analysis zone pairs.

The transportation and operations research literature is filled with models that require a connected network formulation to solve the algorithms. These include shortest-path routines (useful for truck permitting, hazardous materials routing, and detouring), traffic assignment models, routing and scheduling models (for creating optimal vehicle tours), maximum flow network models, location and allocation models, and network-based signal timing models. Inputs to these models require a selected set of nodes and links with a subset of attributes to be used to determine the generalized cost of traversing each node and link. Outputs include attributes on nodes (e.g., intersection counts and turning movements) and links (e.g., flows, paths, and tours). Network problems can take an unacceptably long time to solve or be limited to small, unrepresentative abstractions if an efficient network formulation is not used.

Although it is possible to fit a generic model into one of these groups, in reality this distinction can become a bit fuzzy, particularly as a modeling system grows in complexity. For example, while a pavement management system requires information about all road segments and their spatial relationship to each other, it is only of secondary concern how one might traverse the roads to get from Point A to Point B. But what if the traffic engineer determines that a detour around the construction site is required? Determining the path of the detour requires a network formulation.

It is obvious that these various model types make different demands on a GIS data base structural design. The traditional GIS formulation is poorly equipped to deal with these demands.

TRANSPORTATION AGENCY DATA BASES

Transportation agencies collect and maintain large amounts of data. If a generalization can be made, it is that these data bases are large, unwieldy, unrelated to each other, and poorly integrated. A data base may contain hundreds of thousands of records, each with hundreds of fields. For example, a typical state accident reporting form contains more than 100 data items describing the vehicles and individuals involved as well as the accident setting. A sign inventory might include information on sign and pole type, date installed, and current condition.

A road segment data base for pavement management might contain entries detailing the original roadway composition plus all repair and reconstruction activities, 10 or more deficiency ratings, and the annual traffic counts. A roadway inventory, possibly maintained by a different office, could include more detailed traffic counts, lane information, and surface type. The segment endpoints might not be the same as those used for pavement management.

The planning staff may have built data bases for predicting traffic generation and origin-destination flows using socioeconomic data anchored to census blocks, tracts, traffic analysis zones, or economic regions. The data bases might include the multitude of data summarized with each decennial census supplemented by agency surveys. The regional planning network is typically an abstraction of the actual highway and transit network. Thus its segmentation is different from both the pavement management and roadway inventory data bases.

It is not unusual for one agency to use a variety of segmenting schemes and referencing systems (e.g., milepoint, reference post, state plane coordinates, longitude and latitude, and Cartesian coordinates), greatly complicating the task of spatially relating data.

USING GIS TO INTEGRATE DATA WITHIN AND ACROSS AGENCIES

A GIS typically can deal with three types of data bases: points, lines, and polygons. The simplest of these is a point data base that might be used for accidents and signs. When dealing with a large area, a point data base might also be used to represent collapsed polygons (e.g., using the city centroid as the spatial reference in a point data base of cities). A segment data base, used for roads, transit routes, and the like, contains segments, nodes at the ends of each segment, and intermediate shape points that give each segment a realistic profile. Shape points are stored differently from nodes. They have coordinates but no attribute data and, therefore, take up little space in the data base. A polygon data base is used for boundary data such as traffic analysis zones, engineering districts, and state outlines.

GIS can relate previously unrelatable transportation data bases into a comprehensive information management system. This can be accomplished in two ways. When an existing data base is converted to a GIS format, a common locational reference (usually longitude and latitude) is added to each record. Thus, a correspondence between longitude and latitude and state plane coordinates, milepoint, street names, and any other geocoding system is determined by the GIS's data base builder. Procedures have been developed that, in most cases, will automatically compute these transformations during the data base building process.

An alternative would be to calculate the common reference each time a data item was used. One such method is termed dynamic segmentation. Changes in attribute data that have been geocoded by milepoint are used to determine a temporary segment partitioning "on the fly." The idea is that the base network is segmented only when one of the attributes being analyzed changes. If not implemented carefully, such a real-time partitioning could greatly impair the efficiency of the GIS software. Procedures have been developed that extract data from route-milepoint files and create true GIS data bases with the minimum necessary segmentation.

DATA VISUALIZATION, SPATIAL ANALYSIS, AND QUERIES

At its most basic level, a GIS makes it possible to visualize data quickly in many ways. It is possible to zoom in and out on a map display and show the objects in the data bases color-coded by grouping or highlighted by selection. Accident sites on a highway—near intersections, along curves, clustered near schools—can be color-coded by severity. Traffic analysis zones can be color-coded by trip production, income level, trip attraction, or some other parameter of interest. Traffic volumes can be displayed as single bandwidths and traffic assignments as dual bandwidths. Intermediate shape points (coordinate points that give curvature to road segments) make it possible to display routes according to their actual trajectory and not as straight lines connecting the nodes.

A GIS also makes it possible to ask intelligent questions about how the data are spatially related. How many accidents occurred within 2 mi of a university? How many construction dollars are scheduled for each state engineering district? Which signs are within the boundaries of a construction project? How many people live in a 0.5-mi buffer around a proposed hazardous materials truck route? Which transit routes come closest to the largest number of transit dependents? Which are the deficient bridges within a particular congressional district?

A well-designed GIS should store data in a way that allows quick answers to these types of spatial queries. A unique spatial indexing scheme has been developed to do this. The indexing scheme works in world coordinates (longitude and latitude) and is not dependent on dividing the cartographic data base into small mapsheets stored as physically separate files as is done in traditional environmentally oriented GIS programs.

In addition to rapid spatial querying, a GIS requires rapid attribute querying as well. Which road segments are Interstate 95? Which accidents involved a fatality? Which census tracts have a majority of low-income residents? Which road segments are in the worst condition, in descending order of needed repair?

Spatial and key field queries can be combined in interesting and informative ways. Which fatal accidents occurred within 2 mi of a university? Which road segment contains 505 Main Street (and pinpoint the address location on the map)? Which traffic analysis zones within 1 mi of the central business district have a high concentration of housing?

Not only can a GIS integrate various types of data, it can also integrate data collected at various degrees of resolution. Building lots digitized with great precision can be displayed along with census tracts that were digitized at 1 : 100,000 scale. If there are obvious discrepancies between lot boundaries and census tract boundaries (which follow street centerlines), on-screen editing can be used to correct them.

TRANSPORTATION MODEL DATA REQUIREMENTS

Any particular transportation model requires only a small subset of the agency's data. However, these data may come from diverse data sets. They can, for the first time, be easily related using a GIS. For example, a road reconstruction project could benefit greatly from a thorough understanding of accident experience, vehicle volumes, and turning movements. The best route for a truck carrying hazardous materials depends not just on road classifications, lane widths, and bridge and tunnel restrictions, but also on the number of people living and working near the proposed route. It also should account for hospital and school locations and accident histories by time of day.

From the above discussion, it is clear that transportation models require a variety of data constructs. Depending on these constructs, different demands are made on the GIS. The simplest request by a model is for the GIS to create a sequential file in the format required for input to the model. Complexities of varying degrees arise when trying to get the outputs of the model back into the GIS so that they can be analyzed spatially, working with vectors and matrices that are not part of the traditional GIS formulation, and working efficiently with large, realistic networks.

Network models make important demands on how the data are structured for optimal problem solution. Although a network model might require only a few fields of data as input, the GIS segment data base over which the model is to be solved may have to be recast into a connected link-node formatted network. At each node, the model must have sufficient information to determine quickly which links lead to adjoining nodes.

Because of the enormous amounts of data being processed, GIS operations are of necessity disk-based. That is, the data are read from the disk as needed. By contrast, transportation network models are usually solved by first reading the entire network and the relevant attributes such as length, travel time, and capacity, into random access memory (RAM). Because it is not feasible to read an entire GIS data base into RAM, this is a further argument for a compact network structure different from the one optimized for GIS functionality. A forward star formulation permits adjacent nodes to be quickly identified by the network algorithms. Only the fields required for modeling need to be stored in memory. Shape points, which are important for calculating segment length and for accurately displaying results, are also not needed when solving a network model and need not be brought into memory.

A process that integrates and optimizes the GIS functionality and the modeling functionality has been developed. The GIS data bases can be of enormous size, each with 16 million records of up to 1,000 fields. The network segments are selected by using the GIS querying tools previously described. The network builder turns the GIS segment data base into a compact connected network that contains only the fields required by the model.

As was seen earlier, in addition to point, segment, and polygon data, some transportation models require data in table format. Vectors are used to store trip productions and attractions, supply and demand, and the like. Two-dimensional matrices are used to store minimum travel times, origin-destination flows, and other centroid-to-centroid data. A full set of table manipulation functions has been developed, including those that provide a direct link between tables and the GIS data bases.

The tables are also available for spatial analysis. For example, a distribution table of origin-destination flows between centroids can be represented on the map display as straight line bands whose widths are proportional to the flow.

Research has resulted in the introduction of additional transportation objects to exploit fully the network model formulations in the GIS framework. Results from the models are stored as paths or tours connecting nodes. These transportation objects are new entities, not commonly found in a GIS. They are available for display, manipulation, and analysis using the GIS tools. Thus, optimal routes follow their cartographic paths by making use of the shape points stored with each segment. The flows that result from an assignment model are displayed as dual bandwidths on the map display.

Even tabular data can be displayed on the map as proportional bandwidths connecting centroids.

A macro language has been created for extracting the information required by transportation models from the GIS data bases and for putting model solutions back into the GIS. The macro language permits the implementation of generic models over which the user exerts considerable control. For example, when solving a shortest-path, traveling-salesman, or assignment model, the user is able to select the variables to be included in the generalized cost function as well as their weights.

GIS AS AN INTEGRATOR OF MODELS

Just as a GIS can integrate formerly diverse data bases, a well-designed GIS can serve as a platform for integrating formerly unrelated models. Because the data bases are accessible through the GIS, if the outputs from one model running on the GIS platform can be inserted into one or more of the GIS data bases, these newly created data can serve as inputs to a different model running on the same platform. In turn, outputs from this second model can be used as inputs to a third model or as improved inputs to the first model.

An example can be found in the pavement management process. The traditional pavement management formulation does not require a connected network for its solution. Deficiencies, road type, and the amount of traffic serve as inputs to the pavement management process. Outputs may be a priority ranking of segments, a list of recommended treatments, and, ultimately, the establishment of projects. At this point, a GIS serving as a platform for analysis can extend the pavement management process. Different projects can be scheduled to have minimum impact on traffic flow over the entire network by testing their impacts, singly and in combination, through network assignment models. For a particular project, segments having the highest volume/capacity ratios can be identified as good candidates for signed detours. A shortest-path model can be used to route traffic around these hot spots.

Combining a traffic assignment model and an intersection optimization model illustrates how models can be linked to improve input data assumptions. Initial phasings and turning movement penalties are assumed for the assignment model. The turning movements output by the assignment model serve as inputs to a signal-timing model which then outputs new phasing along with new turn penalties. The updated turn penalties can then be fed into the traffic assignment model, resulting in changes in the predicted assignments. This iterative process could be continued until a satisfactory convergence is reached.

MODELING ENVIRONMENT

Research results indicate that a differentiation between the GIS functionality and the modeling environment is essential for optimal performance. A macro language has been developed that tightly integrates the GIS and the modeling aspects. Each transportation model is a separate executable computer program. An associated command file containing the macros is used to provide communication between the model and the GIS platform. This structure makes it possible for users to add models of all types to the GIS platform. Because the models are stand-alone computer programs, they can be written in any programming language and can use the full memory of the machine. In fact, a DOS Extender compiler has been used so that models running on 386-based PCs can manipulate RAM-based networks containing hundreds of thousands of links and nodes.

TransCAD contains a large number of models that take advantage of this structure. These models include shortest-path procedures, traffic assignment models, routing and scheduling, general network solvers, and allocation models. In addition, many other models have been interfaced with the software. These include pavement management, accident diagramming, highway capacity, and signal timing. A number of researchers are currently interfacing their models with TransCAD. The structure is being continually expanded to include additional transportation objects as required by the new models.

CONCLUSIONS

The traditional GIS formulation's strengths are in mapping display and polygon processing, but a transportation GIS requires new data structures, data objects, interfaces, and procedures to fulfill its potential. Table and network-based models, in particular, place significant demands on the GIS architecture. Research into data base design, transportation objects, and user interface has resulted in the development of TransCAD, a GIS that is fundamentally different from the traditional environmentally oriented GIS. TransCAD is a transportation GIS that provides all the tools that the transportation analyst needs, and at the same time supports complex transportation and operations research models and algorithms in a comprehensive and cohesive structure.

Revision of Statewide Traffic Data Standards Indicated During Implementation of a Traffic Monitoring System

DAVID PRESTON ALBRIGHT

The New Mexico State Highway and Transportation Department developed the first statewide traffic monitoring standards. The standards went into effect October 1, 1988. To implement the standards, a mainframe computer-based traffic monitoring system was designed to receive, summarize, and report traffic data. The system became operational on June 1, 1989. During the development of the traffic monitoring system, modifications of the state traffic data standards were indicated. Modifications were for standards related to data collection, summarization, and analysis. Existing standards require refinement, and new standards must be written to address changing traffic monitoring technology and report requirements. Research activities will also further refine the data standards. Research issues identified during implementation of the traffic monitoring system may result in standards modification. A primary research issue raised was the impact of data summarization on summary statistic accuracy and precision. To address this issue, an alternative to data summarization by roadway functional classification was conceptualized and is currently being investigated. The revisions indicated to the traffic data standards demonstrate the importance of annual standards review. In the future, traffic monitoring issues may be more appropriately addressed because of the existence and continuing refinement of traffic monitoring standards.

The New Mexico State Highway and Transportation Department, in cooperation with the FHWA, developed statewide traffic monitoring standards. Adherence to the traffic data standards is required for governmental agencies and private consulting engineering firms. The standards are mandatory on all state roads and on all roads for which state or federal moneys are proposed to be used.

The process of drafting the standards began with a consultation of New Mexico traffic monitoring technicians in March 1988 (*1*). Draft standards were presented for federal and state review. Eighty-nine traffic monitoring standards were signed by the Secretary of the Highway and Transportation Department and became effective October 1, 1989 (*2*). From this date, equivalent traffic data were collected in New Mexico.

A system to accept, evaluate, and report the data was needed next. This system would be developed to electronically receive all traffic data collected in the state. All data collected would need to be tested for compliance with state standards. After testing, the system would be required to store compliant data in a primary data file for planning and engineering use, and to store noncompliant data in a research file for further analysis. Such a system would also be needed to produce daily, monthly, quarterly, and annual traffic reports.

To meet these needs, a traffic monitoring system was designed by the department and developed by a private consultant on the department's VAX Model 8550 mainframe computer. The traffic monitoring system was installed for daily operation on June 1, 1989.

One of the traffic monitoring standards requires an annual review and, if required, revision to the standards. During the development of the traffic monitoring system, limitations in the initial state standards were identified. In some instances, midyear waivers from the standards were provided before the annual review of standards.

The principal modifications to the traffic monitoring standards, which were indicated in the first year of statewide, standardized traffic data collection, are identified in this paper. Modifications indicated to the initial standards are organized into three groups: data collection, data summarization, and data analysis. Within each of these groups, modifications are organized on the basis of current standards revision, new standards which should be developed, and recommended traffic monitoring research that may impact future traffic data standards.

DATA COLLECTION STANDARDS

The New Mexico standards identified the procedure, equipment requirements, and period for collecting traffic data. During implementation of the traffic monitoring system, modifications were identified for standards revision and development of new standards, related to the data collection period. Data collection research issues were recommended related to standards designed to ensure base data integrity.

Revision of Current Data Collection Standards

One characteristic of equivalent data is the uniform period of data collection. There are required periods for permanent and portable traffic recording device data acceptance. Portable traffic recording device activities are termed coverage or short-term counts, and include vehicle volume, classification, and weight data collection.

New Mexico State Highway and Transportation Department, P.O. Box 1149, Sante Fe, N. Mex. 87504-1149.

One of the state standards specifies that a minimum of 48 consecutive hours of data will be reported for each coverage count site. The count period was derived from the improvement in the mean traffic statistic when based on a 48-hr count as compared with a 24-hr count. This improvement was identified in the *Traffic Monitoring Guide* published by FHWA in 1985 (*3*).

The standards are designed to enable consistent computation of traffic summary statistics from permanent and portable traffic monitoring devices. The primary summary statistics computed are annual average daily traffic (AADT), estimating traffic during a 7-day week; annual average weekday traffic (AAWDT), estimating traffic during the typical work week; and annual average weekend traffic (AAWET), estimating typical traffic on the weekend. Because of variability between the first four weekdays and Friday, the standards stipulated that coverage counts would be taken for 48 consecutive hours from Monday through Thursday.

This standard resulted in each traffic recording device being used at one site each week. The devices were set early Monday morning and recorded traffic data for 48 consecutive hours. Unfortunately, not enough week day hours remained to move the devices to another site and record a second 48-hr period. The efficient use of equipment and personnel suggested that the standard be modified.

Hourly automatic traffic recorder (ATR) data were reviewed, and the variability of Friday traffic was typically found beginning Friday afternoon. Friday morning traffic was similar to traffic recorded in the preceding 3 days. On this basis, an immediate waiver from state standards was granted in coverage count activities. The waiver specified that the 48 consecutive hours will be in either the AAWDT (00:00 Monday to 13:00 Friday) window or the AAWET (13:00 Friday to 24:00 Sunday) window. The existing standard was modified during system implementation in response to concern for efficient field data collection and on the basis of a review of existing traffic data.

A second revision of data collection standards was initiated by field equipment limitations. One of the principles of the state standards and the traffic monitoring system is "nesting." There is vertical nesting of counts as recommended in the *Traffic Monitoring Guide*. Vertical nesting of counts includes, for example, vehicle weight data being disaggregated and accessible for vehicle volume and classification data uses.

In addition to vertical nesting, the state standards also provide horizontal nesting, which is the disaggregation of summary statistics to base traffic data, and access to the data among organizations. The traffic count activities of other governmental units and the private sector in New Mexico are identical, and data are summarized identically, so the data base and summary statistics are equivalent and may be compared directly.

The state standards included vehicle speed compliance monitoring in the vertical nesting. Although the federal speed compliance activities are for one direction and for 24 hr, one standard required that compliance monitoring will be based on 48-hr intervals in both directions. This would nest volume data, and perhaps classification depending on the device used, with the speed data.

The traffic monitoring devices available to department field crews on October 1, 1989, could not accurately record the nested speed data. The alternatives were to collect data without volume and classification vertical nesting or to collect no speed data. A waiver during the first year of standard data was provided. The waiver permits 24-hr speed monitoring in one direction. The traffic monitoring system software was modified to accept and report these data. The volumes cannot be used for other applications because they do not have a standard short-term coverage count period. This standard modification is an interim procedure. As equipment is upgraded, speed data collection activity will return to the principle of vertical nesting.

This modification of the state standards exemplifies the method used by the department to implement the traffic monitoring standards. Implementation included responsiveness to data collection activities and physical equipment limitations. The process of setting standards also defined the justification for upgrading traffic monitoring devices and established the data collection specification for new equipment acquisition.

New Data Collection Standards

When the state standards were signed into effect, all automated vehicle classification monitoring conducted in New Mexico used portable equipment. The standards reflected this in requiring that vehicle classification counts be taken over 48-hr. The period would ensure vertical nesting of the data.

During implementation of the traffic monitoring system, the state traffic activities were extended to include permanent vehicle classification devices at nine sites. The sites are the traffic monitoring locations for the 12 New Mexico Strategic Highway Research Program (SHRP) sample road segments. The permanent devices, automatic vehicle classifications (AVCs), will be operational in 1990. The existing standard should be rewritten so the period only defines short-term classification counts. New standards must be prepared.

New standards will be needed to define base data and summary statistics for the AVCs. Although this discussion could be included under data summarization standards, it is developed at this point because the new standards will be generated from new data collection activities.

Classification summary statistics from AVCs will be defined parallel to traffic volume summary statistics provided from ATRs. Data will be summarized for each day, typical days of the week will be summarized by month, and monthly typical days of the week will be summarized for the annual traffic statistics. For a given site, there will be typical daily vehicle classification based on a 7-day week, the work week, and the weekend.

Unlike volume information, there will not be automatic computation of mean vehicle classification statistics by functional classification of roadway. The coefficient of variation (CV) of the vehicle classifications for each functional classification of roadway will be reviewed. The review will discern if some or all road classifications are appropriate for grouping vehicle classification data. If some grouping of data is indicated, monthly classification ratios (MCRs) could be calculated and used in a manner similar to monthly traffic ratios for adjusting coverage count activities.

Prior to installing the number of counters that would be required to establish an MCR, a benefit-cost analysis will be conducted. The analysis would have to be positive before new standards are written to permit MCR adjustment of coverage count classification data to annual summary classification statistics.

The same demand for new standards caused by AVC installation was also created by changes in truck weight monitoring. When the standards were written, only portable weigh-in-motion (WIM) devices were proposed for New Mexico truck weight monitoring and inclusion in the traffic monitoring system. During implementation, it became evident that the traffic monitoring system should be written to accept data from permanent weighing stations. New truck weighing devices that would present a different magnitude of data than the portable WIM devices were planned for installation.

The data collection devices to be installed in New Mexico, for which new data standards must be written, are permanent Automatic Vehicle Weighing (AVW) stations. The two types of devices that will be installed and operational by 1990 to 1991 are roadway and bridge WIM systems.

The traffic monitoring system could be modified to receive permanent WIM data. However, the system cannot be revised to test and summarize these data until standards are written to define appropriate site daily, weekly, monthly, and annual data summarization from permanent devices. The new AVW standards will be drafted parallel to the volume and vehicle classification summary statistics. The monthly weight ratios (MWRs) will initially be standardized as unique, significant only at the site at which they are collected, until data can be reviewed to determine if weight data can be grouped among sites.

The development of standard traffic data, and standard implementation through the traffic monitoring system, creates the opportunity to closely compare equivalent data. New standards are required to conduct counts using improved technologies. Standardized data and new types of data lead to traffic monitoring research.

Research Issues for Data Collection Standards

Whereas new standards are needed to summarize data from new traffic monitoring devices, further examination of MCRs and MWRs exemplifies a data summarization research activity. In the area of traffic data collection, there are two additional examples of needed traffic monitoring system research. These research activities will require further development of the traffic monitoring system software and may result in revision of the data standards. The data collection research activities relate to base data integrity.

A key principle on which the state standards and the traffic monitoring system were built is data integrity. The standards specify that during traffic monitoring, missing or inaccurate data may not be completed, filled in, or replaced for any type of traffic count, at any location, under any circumstance. This relates to "truth in data": traffic data users must have confidence that a 48-hr count is an actual 48-hr count, without use of imputation techniques or professional judgment with unknown and inestimable bias.

The data integrity standards were required to correct then-current traffic data practices. However, a valid, related research activity is needed to examine alternative imputation techniques, given varying missing data points, to determine the error. It must be noted that this activity is only valid if the data used to test imputation approaches are equivalent data. The traffic monitoring system data base of standardized data will need to have been in operation for at least 1 year before this research activity can proceed. With an adequate data base, alternative imputation techniques in varying data cases, by data type, can take place.

If this research activity determines that under specific circumstances specific imputation techniques can be applied, the standards may be revised accordingly. The principle of traffic monitoring data integrity is important and retained in this procedure. There will be no data manipulation until the statistical impact of that manipulation has been demonstrated. Even in this instance, should an imputation technique be appropriate within well-defined boundaries, the traffic monitoring system will retain the base data prior to imputation to continue to monitor the activity. Imputation techniques are essentially hypotheses. The distinction between actually counted base data and hypotheses for imputing missing points will be preserved. This will permit alternative hypotheses to be posed in the future, and the impact may be assessed on the associated summary statistics.

A second research activity related to base data integrity was discovered during implementation of the traffic monitoring system. The development of and testing for compliance with state standards achieved horizontally nested current data collection. It also achieved uniform computation and application of annual growth factors (AGFs) for road segments not counted in the current year. The AGFs are based on the mean growth rate for the same functionally classified roads, provided there is a minimum of five ATR sites that have standard data to aggregate for this purpose.

Until the traffic monitoring system was interfaced with the department's Consolidated Highway Database (CHDB) historical traffic data, it was not fully appreciated that most road segments in New Mexico will not be counted in the first years of traffic monitoring system operation. The data collected beginning October 1, 1989, will be equivalent, and the factors from these data will be equivalent, but the majority of traffic volumes in the state data base are the result of inconsistent data collection and data estimation.

A research proposal was developed to examine methods of testing for historical traffic data obsolescence. Through the department's CHDB, all historical traffic data are readily identifiable by unique road segment. When a coverage count is taken and adjusted for seasonality and axle correction, it is entered through the traffic monitoring system into the CHDB for general user computer access. A research activity is needed to test the date and quantity of other, noncounted, contiguous road segments. Because the CHDB has all road characteristics, intersecting roads and associated volumes will also necessarily be examined.

Alternative procedures will be developed to replace the uncounted, historically factored data when defined as obsolete. The potential replacement data would be based on the contiguous road segment count data. Traffic counts on segments with obsolete data will then be taken to determine if the data obsolescence procedure produced results consistent with count-based summary statistics.

This proposed research activity is scheduled to begin in July 1990 and be completed by July 1991. Recommended standards modification, if the research project is successful, would be presented during annual standards review in September 1991. If successfully developed and approved by the department and FHWA, a data obsolescence procedure would be in place by October 1, 1992.

DATA SUMMARIZATION STANDARDS

Data summarization is the procedure used to aggregate collected traffic data. The aggregation takes the form of attempting to represent the central tendency of the data in mean statistics (primarily for volume, classification, and weight), and median statistics (primarily for speed). Summary statistics also include the growth, axle, and seasonal adjustment factors noted during the description of changes in data collection standards. The way in which data are summarized fundamentally affects the adequacy of the resulting traffic statistics. During implementation of the traffic monitoring system, revision of current standards and research issues were identified.

Revision of Current Data Summarization Standards

The state traffic monitoring standards establish a series of definitions for ATR data summary statistics. AADT is defined as the mean of monthly average daily traffic (MADTs/12). Similarly, AAWDT is the mean of monthly average weekday traffic (MAWDTs/12), and AAWET is the mean of monthly average weekend traffic (MAWETs/12).

Additional related summary statistic definitions include the following:

- MADT is the mean of monthly average days of the week (MADWs/7).
- MADW is the sum of all daily volumes of each day, Sunday through Saturday, in a month divided by the number of occurrences of standard accepted data for that day in the month. This will produce an average for each day of the week for that month.
- MAWDT is the mean of MADWs for Monday through Thursday in a given month.
- MAWET is the mean of MADWs for Friday through Sunday in a given month.

Alternative summary statistic computation procedures are available for standard testing. One approach, which is not appropriate for research activity because it requires unlimited missing data estimation, is to define AADT as the sum of all daily traffic in a year divided by 365.

The standards also define the minimum number of days with standard data for use of a permanent counter in computing mean adjustment factors by functional classification of roadway. "Included" ATRs are those within a functional classification, for a given count year, for which MTRs may be calculated. "Excluded" ATRs are those within a functional classification, for a given count year, for which MTRs may not be calculated. This is typically based on an inadequate sample of days of the week. The related standard specifies that for any ATR monthly traffic summary, if there are not 2 days with standard traffic data, for each day of the week, MTRs will not be calculated.

The standard was written incorrectly. The intention was to exclude data from ATRs with too few standard data in computing the mean MTR by functional classification used in adjusting coverage counts. However, there is still a need to calculate the MTR at the site and to be used appropriately. The traffic monitoring system was functionally developed to compute MTR for site-specific purposes for included and excluded ATRs. The standards required revision to distinguish between the minimum data for computing summary statistics at a specific site and the minimum data for including the summary statistics for functional classification adjustment factors.

A related data summarization error in the initial state standards concerns excluded ATR data. For excluded ATRs, the standards required annual average summary statistics at that site to be based on the same functional classification coverage count mean statistics. The coverage count functional classification growth rate was to be used to adjust the excluded ATR's previous year annual summary statistics to the current year.

An excluded ATR meant only that the summary data should not be included in functional classification mean adjustment factors. It did not mean that there were no valid data at the site. Moreover, if a growth rate must be applied, a more standard consistent source would be from other ATRs on the same functional classification. The standard must be revised to use site-specific data. The distinction needed in revising the standard summarization is between site-specific data use and use in mean adjustment factors by functional classification.

Data Summarization Standards Research

Data summarization is the dominant subject of traffic monitoring research identified during implementation of the traffic monitoring system. Examples of needed summarization research have been indicated above. Research concerning the number of ATR sites required for mean adjustment factor calculation, minimum standard data days for included ATR sites, and an alternative to functional classification summarization are identified in this section.

The state standards required the installation of a minimum of eight ATRs for each functional classification of roadway. The standards permit grouping of the formal classification scheme to reduce the number of classifications by variability of data. Grouping of classifications is determined by cluster analysis. The standards further note that for application of the mean traffic volume summary statistics by functional classification, there must be a minimum of five ATRs for each functional classification or group of functional classifications.

The department has conducted cluster analysis of permanent counter data. It was found that the monthly data summaries could be grouped by four rural functional classes (Interstate, Principal Arterial, Minor Arterial and Major Collector, and Minor Collector and Local Road) and four urban functional classes (Interstate, Principal Arterial, Minor Arterial, and Collectors and Local Roads) (*4*).

The installation of a minimum of eight devices by functional classification group is based on estimated equipment malfunction so that there will be a minimum of five included ATR sites. However, in the absence of equipment-maintenance monitoring, and because of completion practices for missing data, there is no way to correlate missing data by station with standard data requirements. One research need is to examine the research file data, collected but not standard compliant, by counter device. This will require modification of traffic monitoring system reports to conduct the equipment maintenance research, and may in turn result in modification of the standards. It will also be important to include in this equipment research activity newly installed AVC and AVW devices.

Under the state standards, functional classification monthly traffic summary data must be based on a representative sample of the days within the month, which will include a minimum of two days for each day of the week. This initial threshold for standard data days came from the experience of the traffic data professionals participating in the standards consultation. Other alternatives exist for defining included and excluded permanent device data. One alternative is the requirement of 14 consecutive days in a month, as stated in Appendix K of the *Highway Performance Monitoring System* (HPMS) manual (*5*). One of the data summarization research issues that will be investigated is the evaluation of alternative requirements, including the requirements under the present standards and HPMS.

In each of the data summarization research issues considered, roadway functional classification of data has been assumed. One of the primary research and development issues raised during development of the traffic monitoring system was an alternative data summarization method to this procedure.

The standards require that annual and monthly adjustment factors be based on the mean statistics from ATRs on the same roadway functional classification. Regional traffic variation will be analyzed across time, but now there will be no regional adjustment within a functional classification. The standards assume the validity of functional classification of data and use of monthly traffic adjustment factors as representative of seasonal variation.

The summarization of traffic data by functional classification of roads constrains traffic data. The way in which traffic data are summarized constrains data in four ways. The base data are grouped by hour. The hourly data are grouped by weekday and by the three summary statistics related to weekday hours. The weekday traffic summaries are grouped by month. The monthly traffic data are grouped by functional classification of roadways.

When a traffic planner or engineer applies the resulting summary statistics, the statistics have been affected, to some extent, by the process. The structure of this method of summarizing base data may be termed "functional classification summarized base data." The concern for this method is related to summary data accuracy and precision.

Traffic summary statistics must be adequate to their use. Adequacy depends on the accuracy and precision of the summary statistics. In previous New Mexico practice, this was not a concern only because no attempt was made to estimate or calculate confidence level and interval of summary statistics. Under the state standards, summary statistics must be accompanied with a statement of accuracy and precision.

Because of the importance of summary statistic accuracy and precision in many applications (from pavement design to traffic flow simulation), any error in variability caused by the summarization method would be an appropriate subject for research. The issue that arose during traffic monitoring system implementation is whether additional variability is introduced when constraining data by constructs as provided in functional classification summarized base data. The hypothesis formed was that functional class definition constrains summarization of monthly data, monthly definition of days constrains daily or weekly summarization of data, and uniform definition of the three key summary statistics into days of the week constrains summarization of hourly or 15-min base collected data.

The basis for the hypothesis is that data do not necessarily conform to these constraints, and inasmuch as they do not conform to these constraints, variability of the data is improperly modified. For example, traffic volume on a given road segment may be grouped in time intervals between 16:45 and 19:15 hours, or very commonly between 13:15 and 16:00. This would not be true for all segments, which makes the point that the data should determine the groups of data for analysis.

Taking this principle further, what defines "typical workday" travel may vary from roadway to roadway. What defines the representation of work and weekend days may be defined by the traffic on the roadway.

Under the current functional classification summarization method, monthly traffic summaries provide identical constraint on the data. In rural areas, the seasonal shift in traffic may relate more directly to crop periods than calendar months. In urban areas, the seasonal holiday or major event traffic may result in the mean statistic not representing the central tendency of the traffic for the month in which the events occur. Just as the traffic flows define the period of grouping the traffic, and the representation of work and weekend days, so the seasonal summarization of data may be based on the observed variance of the data rather than on the calendar seasons.

Finally, functional classification of roads is only an approximate representation of appropriately grouped roadways. Because a road segment is functionally classified in a group of other roadways does not mean that the actual traffic seasons are identical. The mean traffic summaries for roads in the same functional classification may not represent the character of the traffic.

The alternative is to define the operational classification of roads on the basis of the seasonal traffic variation. In "operational classification," the principle is that the data should define the categories, rather than the categories define the traffic data summaries.

Proposed for traffic monitoring system research and development is the use of both data summarization methods. The development of operational classification traffic summary statistics will allow comparison of functional classification summary statistics for the same roadways. Monthly traffic summary statistics may be compared with seasonal summaries. The functional classification monthly traffic ratio and adjustment factor may be compared with the operational classification seasonal traffic ratio and adjustment factor for the same road segment. By comparing the ratios and factors on roads with known data, the ability of either adjustment to estimate reality can be observed. Similarly, weekday traffic summary statistics may be compared with variable day, and hourly with time increment traffic summary statistics. This will indicate whether there is a benefit from the revised summarization of traffic data.

Preliminary investigation of the impact of the proposed summarization procedure has been conducted. One of the first activities in assessing the potential of operational classification was based on prestandard, 1988 ATR daily traffic summary statistics. The daily volumes in August, September, and October were reviewed at seven ATR sites. The findings raised additional questions. Why did the September average daily traffic approximate unity with the annual average daily traffic, as typical nationally? The question became more interesting when the daily traffic summary for the September holiday was virtually identical with the September average daily traffic volume. This raised the contraintuitive result that the typical daily volume at the ATR sites was represented by a specific holiday at that site.

The problem with the initial data review could be partially attributed to previous data completion practices and to the examination of daily traffic summaries. The analysis proceeded to the review of hourly traffic volumes, principally peak hour volumes significant in, among other applications, pavement design and traffic simulation.

Traffic volume during 1988 from two permanent counters, rural and urban, were analyzed. Three hourly volumes (based around the peak hour) for Wednesdays throughout the 1-year period were reviewed. The monthly coefficients of variation were reduced through grouping of weeks based on data variability rather than month.

Two examples using November 1988 data illustrate the results of this initial experiment. At the rural Interstate counter location, the 95 percent confidence interval for the Wednesday 16:00 to 17:00 hourly volume mean was ± 33.4 percent. This interval improved to ± 7.8 percent when the data were grouped by season. The Wednesday peak hour statistic for the urban arterial counter location, with a 95 percent confidence interval of ± 15 percent, was reduced to ± 2 percent when the data were grouped by season.

The preliminary improvement of the seasonal peak hour data summary statistics through operational seasonal data partitioning suggests that more accurate and precise summary statistics may be calculated with alternative summarization methods. The improvement may enable further development of traffic data uses, such as comprehensive transportation modeling, previously restricted by traffic data limitations (*6*).

The operational summarization procedure is experimental. It is intended as a research activity that would occur within the traffic monitoring system at the same time the functional classification summarization and reporting procedures are conducted. Additionally, it is not proposed that the current functional classification reporting be replaced. For historical purposes, this procedure should be supported.

Traffic monitoring system software development for further experimentation with operational classification summarization has begun and is scheduled for completion by September 1990. Same standard-compliant data will be summarized using both functional and operational classification methods, and the impact analyzed for common traffic adjustment factors based on mean summary statistics.

DATA ANALYSIS STANDARDS

The state traffic monitoring standards address some data analysis practice. Truth in labeling, as described above, provides information the traffic professional needs to analyze both base and summarized data. The standards also address data analysis in requiring that all traffic data be transmitted with confidence level and interval. During traffic monitoring system implementation, a need was discovered to revise the current standards and create standards.

Revision of Data Analysis Standards

The state standards stipulate that all published or transmitted summary statistics must include a confidence level and interval and indicate one of the three standard units of volume measurement. The intention of the standards was that not only system-level, but also site-specific accuracy and precision should be identified and communicated as an integral part of any data analysis.

There was inadequate data from which to conclude specific or characteristic confidence in the traffic summary statistics. During implementation of the traffic monitoring system, other research was examined for default values. Proposed default values for characteristic confidence in the data, by data type and collection method, made assumptions which could not be confirmed by the New Mexico data base (*7*). The decision was made to defer the calculation or estimation of confidence level and interval until the traffic monitoring system data base had developed and data analysis could appropriately proceed. The implementation of confidence level and interval information was rescheduled to begin in July 1990.

A similar revision to the initial standards related to the desired accuracy and precision of the traffic data. Not only at a system level, but also at a site level, the standards defined a desired summary statistic confidence level of 95 percent and a mean variability interval of ± 10 percent. The standard did not take into account the inherent variability of traffic at some sites for some summary statistics. More appropriately, the standard should be revised to state the actual objective of the traffic monitoring program: to conduct the count activities in such a way as to reflect and document the central tendency and variability of the traffic.

New Data Analysis Standard

A new data analysis standard was indicated during implementation of the traffic monitoring system. It is related to accuracy and precision issues for vehicle classification and weight data.

As noted above, the state standards require the publication of confidence level and interval with traffic summary statistics. Not addressed in the present standards is the indication of data variability in summary vehicle classification and weight statistics. On what would the variability of the data be based? Would there be a separate indication of variability by vehicle classification, and one for the resulting axle correction factor? Would there be an indication of variability by truck weight interval, and one for the resulting pavement loading characteristics? New standards will need to be written to address these issues. Now the direction of the state standards is to comprehensive summary statistic accuracy and precision calculation or estimation. The feasibility of this direction will be assessed as the data base becomes more extensive through AVC and AVW data.

SUMMARY

A traffic monitoring system was required to implement the New Mexico traffic monitoring standards. During implementation, modifications to the state standards were identified. After the first year of statewide standardized data activity, the interpretation of some standards has changed and the requirement for additional standards has been recognized.

Consistent in the process is the central importance of standardized traffic data collection, summarization, and analysis. The specific changes indicated in this paper were not anticipated when the standards were adopted. However, that changes would be required was anticipated and structured into the data standards as a review process. The experience of implementing standards in New Mexico emphasizes the importance of making annual review a primary characteristic of standardized traffic data.

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Design, Development, and Implementation of a Statewide Traffic Monitoring System

DAVID PRESTON ALBRIGHT AND JOSEPH E. WILKINSON

Statewide traffic monitoring standards were established October 1988, by the New Mexico State Highway and Transportation Department. The quantity of data to be tested for compliance with the standards required the design, development, and implementation of a computer-based data analysis system. The Traffic Monitoring System (TMS) is the mainframe software package developed to implement the data standards. The system was designed in the Statistical Analysis System (SAS) and installed June 1, 1989. The conceptual design of TMS and the SAS components are transferrable to other environments. The TMS is designed to process traffic volume, classification, speed, and weight data. There are four basic components of the system. A "User Interface and Automatic Initiation" component reports system condition and controls automatic data processing and report generation. The second component, "State Standards Edit Programs," validates raw traffic field data. The third component of the system is "Traffic Data Files." Standard traffic data are placed in the primary data files, and data not in compliance with the standards are stored in separate research files. The fourth component, "Report Generation Programs," produces required traffic monitoring reports. The TMS provides an efficient implementation of statewide traffic monitoring standards. The system preserves the integrity of the base data while meeting current reporting requirements. The TMS offers an opportunity for analytically addressing current and future traffic monitoring issues.

In 1986 the New Mexico State Highway and Transportation Department began a process of evaluating and upgrading traffic data applications. After review of initial efforts in 1987, it was demonstrated that a comprehensive study of traffic data collection, summarization, and analysis was needed. This study was undertaken by the department, in cooperation with the FHWA, and was completed in May 1988. The study identified the importance of equivalent traffic data for current planning and engineering data uses (*1*).

The importance of ensuring equivalent traffic data by defining and enforcing traffic data standards was the primary finding of the study. Study results, combined with FHWA's *Traffic Monitoring Guide*, led to development of the New Mexico State Traffic Monitoring Standards (*2*). The State Standards became effective on October 1, 1988, and are required on all New Mexico roads for which state or federal funds are used, or proposed to be used (*3*).

The 89 traffic monitoring standards address traffic volume, speed, classification, and weight data. The standards apply to data collected by the state, Metropolitan Planning Organizations (MPOs), county and city governmental agencies, and private consulting engineering firms. The quantity of data to be tested for compliance with the standards required the design, development, and implementation of a computer-based data analysis system.

D. P. Albright, New Mexico State Highway and Transportation Department, P.O. Box 1149, 1120 Cerillos Road, Sante Fe, N. Mex. 87504. J. E. Wilkinson, Chaparral Systems Corp., Devargas Center, Sante Fe, N. Mex. 87501-1498.

The Traffic Monitoring System (TMS) is the mainframe software package designed by the Highway and Transportation Department to implement state traffic data standards. The TMS was developed by Chaparral Systems Corporation and was installed on June 1, 1989.

TMS was programmed in Statistical Analysis System (SAS), a software system for data analysis. SAS provides the capability for supplementing basic reporting functions with statistical studies of any level of complexity. SAS also provides the considerable flexibility necessitated by changes in technology and reporting requirements.

The system is designed to run as an application under the Digital Equipment Corporation (DEC) All-In-One package. Consequently, the user interface is specific to the DEC VMS operating system. However, the conceptual design of the system and the SAS components are transferrable to other environments.

The design of TMS addresses traffic monitoring activities from data collection to report generation. TMS processes digital traffic volume, classification, speed, and weight data, and also checks for compliance with state standards. TMS associates the traffic data collected with cumulative milepoint of unique road segments as defined in the department's Consolidated Highway Data Base (CHDB). TMS summarizes the data in a form that is appropriate for both reporting and research applications. TMS directly generates summary traffic statistics on daily, monthly, quarterly, and annual reports. TMS was designed so that each of these features are in an easy-to-use framework that require minimal operator training and intervention.

Implementation of the TMS design is identified in this paper. This implementation is described by reviewing the primary data principles on which the system was built; the basic components of the TMS; system operation; reports generated; and continuing system development.

PRIMARY TMS DATA PRINCIPLES

The Traffic Monitoring System was built on three primary data principles. They are security and truth-in-data, assuring data retention through system integrity, and automating the traffic data process as fully as possible.

Security and truth-in-data are important principles on which TMS was developed. Security ensures that the data are not modified, and that when data are summarized, the base data can be retrieved. Truth-in-data ensures that data users have identified what the data are, and how the data have been summarized.

An important driving force behind development of the TMS was the concept of data integrity. Consequently, both the raw data files and the SAS data files are read-only files. This avoids many problems associated with various users applying different estimation procedures for missing data. The TMS reports are also read-only documents which cannot be modified in the All-In-One DEC application. Additionally, sites with statistics based on actual observations are distinguished from sites where statistics have been estimated according to functional classification. Furthermore, the data must be protected through software system integrity. This was referred to as making the data and the system "bullet-proof." TMS incorporates numerous system integrity features in addition to data integrity. The TMS is designed to recover itself automatically, or with minimal intervention, in the case of catastrophic system failure. The system restart capability allows cumulative files and programs to be reset so they can be restarted to receive and store data, without generating duplicate data.

The third data principle of TMS is that the volume of data requires that most of the TMS work be done automatically. Each morning, a TMS job automatically gathers all of the traffic counts collected the previous 24 hours. These include Automatic Traffic Recorder (ATR), Automatic Vehicle Classification (AVC), and Automatic Vehicle Weighing (AVW) counts, and counts taken from portable devices. Portable traffic monitoring activities include coverage and special counts, speed counts, turning movement counts, and portable weigh-in-motion (WIM) counts.

These data are then automatically processed. This processing includes conversion to a standard format when necessary, editing for compliance with state standards, and summarization into the daily TMS cumulative files. After this processing has been completed, an electronic mail message is automatically sent to the primary TMS operator. This message is a single statement describing the results of the daily run. The operator can then get more detailed status information using the TMS menus. This information includes a detailed edit log which describes the status of each count or ATR file processed.

At the beginning of each month, a monthly processing job is automatically submitted, but in a "hold" status. This allows the primary system operator to release the job for processing when all data for the preceding month have been captured. The monthly run consists of edits for state standards, summarization into monthly TMS files, and monthly reports. The monthly reports are official TMS reports, which means that they are given "read-only" protection. A reader can not modify the contents of these files, which are available to anyone with All-In-One access.

The annual run summarizes the monthly data into annual TMS files, and generates the annual official reports. Additionally, TMS updates the department's CHDB traffic statistics, making them generally available. The annual reports are also official reports that are given "read-only" protection.

BASIC TMS COMPONENTS

The first component of the TMS is the User Interface and Automatic Initiation. This component controls the TMS. It initiates automatic operations and provides communications between the user and the computer software. It controls the automatic data processing and report generation procedures. Through the interface, the user also receives messages concerning system status. These include lists of data files received from the field, input data rejected and stored in a separate logical Research File as a result of noncompliance with state standards, and reports generated.

The second component of the TMS is the State Standards Edit Programs. New Mexico Traffic Monitoring Standards functionally require two separate SAS edit programs. The first looks at the raw traffic data from the field on a daily basis. Edit checks are applied to the data, site-by-site, to ensure that valid, consistent data are being received and that the devices in the field are functioning properly. The second program takes the daily data and computes monthly summary traffic statistics, which must also adhere to state standards. Both edits can be performed automatically, on a daily and monthly basis, and the results are communicated to the user through the User Interface.

In addition to the editing programs, the State Standards Edit Programs contain several other data manipulation programs. These carry out data reformatting, data identification, and file manipulation operations.

The third Traffic Monitoring System Component is Traffic Data Files. The traffic data are placed in one of more than a dozen SAS data files, depending on type (such as volume, classification, speed, and weight). Data elements within these files were chosen because of monthly or annual reporting requirements, or with the expectation that the elements would be significant in future research. All the raw input data are archived as well, recognizing that reporting or research requirements might change with time.

Report Generation Programs is the fourth component of the TMS. A set of monthly and annual standard reports were identified by the state as being necessary for either external or internal reporting requirements. Each report is generated by a SAS program, using the SAS data files as input. Reports may be produced either automatically at predetermined times, or manually through the User Interface. The user can view the report documents prior to be printed.

A new report can be added by creating a new SAS program and adding it into the User Interface. This is accomplished through the Technical Administration menus. Both the SAS primary and research traffic data files, and the raw input data, are available for research applications.

TMS OPERATION

Users interact with TMS through a menu-driven interface. The three sets of menus correspond to the three organizational roles required for TMS: user management, technical management, and system operations.

The User Management menus allow TMS responsibilities to be assigned to specific individuals. This function controls the routing of status messages to specific TMS personnel. User Management menus also contain the menus available to System Operations.

Technical Management menus provide the capability of configuring the TMS. Primarily, this involves the addition of reports and the control of numerous system parameters.

The System Operations menus and displays are illustrated in Figure 1.

The System Operator has four menu options. "Status monitoring" allows one to view the system log to determine the outcome of the automatic runs. "Reports" allows the generation of personal reports and the viewing and printing of both official and personal reports. It also has report indexing features. "Data files" allows the viewing or printing of raw data files, annotation of raw data files, and processing of coverage or other short-term count files. "Job control" provides the capability of releasing jobs in "hold" status.

The Status Monitoring display occurs when the STS option is selected from the Main Menu. (See Figure 2.) Each numbered line in the body of the display represents one of the components of the automatic processing runs. The overall outcome of each component is given in this display.

If the operator wants more information about the component, the item can be selected and a more detailed report (if available) will be presented. If the operator requires historical information, a specific component and a range of dates can be selected, and the system will display only that component for the dates requested.

The "Reports" selections shown in Figure 3 allow the generation of personal reports and the viewing, printing, and indexing of official reports. To generate a personal report, the information becomes a word processing document that can be printed, viewed, or edited from the word processing menu.

Official reports are viewed or printed through this menu. Each report has associated print options attached that cause it to be properly printed. For example, some of the reports are printed in landscape mode, if that is their proper orientation. These print options are controlled through the Technical Management menus.

The Index option allows the user to select a subset of the numerous reports for more convenient manipulation. This allows easy selection of the reports thus indexed for viewing or printing. (See Figure 4.)

This menu allows raw data files to be annotated, printed, or read. Annotation allows comments about a specific data file to be stored for future reference. For example, a count that is excessively high might have occurred on the day of a special event. This could be noted for future reference with this facility.

The files are printed or read in their source format. This allows easy determination of any technical problems resulting in improper file formats.

If coverage and special count or turning movement files are selected, the option is provided to process the files. If this option is selected, any coverage or special counts that have been uploaded since the last automatic run (or last exercise of this option) will be processed and the results made available through the "Reports" menu.

The job control menu allows the operator to release any jobs that have been submitted in hold status. The operator in this way controls when monthly and annual runs actually occur. (See Figure 5.)

If there are data whose collection has been delayed by technical problems, the operator can wait until the job has been released.

TMS REPORTS

The following reports are generated by the TMS. Most are designed to run automatically on either a monthly or annual basis. However, the user may run a report at any time through the User Interface, by specifying the desired time interval and site. Note that some reports use historical data, not just information from the current year.

1. Annual vehicle miles traveled (AVMT) by
   - Administrative classification,
   - Functional classification,
   - Vehicle and administrative classifications,
   - Vehicle and functional classifications in percent, by vehicle and functional classifications, and
   - Vehicle classification, by year.
2. Daily average vehicle miles traveled (DVMT) by
   - County and administrative classification,
   - County and functional classification,
   - District and administrative classification,
   - District and functional classification, and
   - Month with monthly variation.

```
------------------------------------------------------------
Operator Name     Primary System Operator    Mon 19-Jun-1989

                  Traffic Monitoring System

         STS  Status monitoring

         RPT  Reports

         DAT  Data files

         JOB  Job control


         Enter selection and press RETURN
------------------------------------------------------------
```

FIGURE 1 Main TMS menu.

```
----------------------------------------------------------------
                  TMS System Log Inquiry
----------------------------------------------------------------
Event/Report             Date     Status  Text
1  DAILY EDITS SUMMARY   89-06-19 Info    Daily ATR data edits
2  DAILY TC-II CONVERT   89-06-19 Info    Daily TC-II data
3  DAILY TC-II COLLECT   89-06-19 Success TC-II consolidation
4  DAILY TC-III COLLECT  89-06-19 Success TC-III consolidation
5  DAILY CSC COLLECT     89-06-19 Info    No CSC data
6  DAILY TURN COLLECT    89-06-19 Info    No turn-mvmnt data
7  DAILY MPO COLLECT     89-06-19 Info    No MPO data
8  DAILY MESSAGE CHECK   89-06-19 Success Message status check
9  DAILY CHDB EXTRACT    89-06-19 Success Task Daily CHDB
10 DAILY EDITS SUMMARY   89-06-19 Info    Daily ATR data edits
----------------------------------------------------------------
Event/Report:
Start Date:                           End Date:
Press RETURN to continue, or line number you want to select,
or EXIT SCREEN:
----------------------------------------------------------------
```

FIGURE 2 **Status monitoring (STS) display.**

```
----------------------------------------------------------------
Operator Name    Primary System Operator    Mon 19-Jun-1989
                        TMS Reports
   SEL  Select    Folder:  AVMT
                  Abbrev:  AVMT BY V F CLASS
                  Title:  Annual Vehicle Miles Traveled by VT
                  Created:  1989-05-03
         G    Generate (personal report)
         R    Read     (official report)
         P    Print    (official report)
         I    Index    (official reports)
         Enter selection and press RETURN
----------------------------------------------------------------
```

FIGURE 3 **Reports (RPT) menu.**

```
------------------------------------------------------------
Operator Name   Primary System Operator      Mon 19-Jun-1989
                   TMS Data File Functions
          SEL  Select Counter Type:  TC-II RAW DATA
                     Location Code:  B74
                         File Name:  B74-1989-06-18-03-28.DAT
          A    Annotate
          P    Print
          R    Read
     Enter selection and press RETURN
------------------------------------------------------------
```

FIGURE 4 Data files (DAT) menu.

```
------------------------------------------------------------
Operator Name    Primary System Operator      Mon 19-Jun-1989
                       TMS Job Control
          SEL  Select                Job:
                                     Entry:
                                     Status:
          RJ   Release (start) current job
          C    Check job status
          Enter selection and press RETURN
------------------------------------------------------------
```

FIGURE 5 Job control (JOB) menu.

3. Annual Summary Statistics at ATR Sites by Year with Annual Variation
4. Annual Average Daily Traffic (AADT) by Vehicle Classification
5. Monthly Summary Statistics at ATR Sites by
   - Functional classification,
   - Administrative classification,
   - Day of week, and
   - Year with annual variation.
6. Hourly summary statistics at ATR sites by direction.
7. Traffic ratios and factors.
8. Current and three-year average monthly traffic ratio (MTR) by functional classification.
9. Current and three-year average annual average growth factors (AGFs) by functional classification.
10. Other ratios and factors—
    - Truck weight,
    - Equivalent single axle loading (ESAL) analysis, and
    - Equivalent single axle loading (ESAL) by functional classification.
11. Other Reports
    - Speed summary report,
    - Turning movement report,
    - Random samples for coverage counts,
    - District traffic maps, and
    - Municipal traffic flow maps.

The TMS provides direct generation of traffic reports, yet preserves data integrity and truth-in-data. The flexibility of the system described earlier identifies reports that can be modified and added as reporting requirements change.

Continuing Development of TMS

During the implementation and acceptance testing of the Traffic Monitoring System, additional system development was indicated. The areas of development in the coming year include volume and capacity analysis, conduct and enhancement of research activities, and interface between TMS and other information system tools.

One of the important areas of TMS continuing development is capacity analysis. In the coming year, existing road segment and intersection capacity analysis software will be integrated with TMS and CHDB. The integration will include retrieval of TMS and CHDB data elements required to compute maximum service flow, volume and capacity and level of service. The data will be transmitted to the capacity analysis software and the capacity characteristics will be calculated. The resulting statistics will be loaded to the CHDB.

Development of TMS will include enhanced facilities for traffic monitoring research and development. In the coming year, TMS will provide alternative methods of traffic data summarization, while continuing to support the data summarization procedures as specified in the state standards.

Other system research refinements concern file identification and report printing. There is a need within TMS to develop a research data file location system which would include adding fields to report edit logs and development of a system for locating data files by content for research purposes. This enhancement of TMS would permit cut-and-paste to select types of data, facilitate nonprogrammer creation of a SAS file or files, and provide a menu of SAS routines to answer research data inquiries. There is a related need to develop an ad hoc report generator which would produce reports using the same cut-and-paste interface in the research data file location system. This additional system development would allow the results of traffic research inquiries to be quickly printed. These two research refinements are planned for TMS development in 1990.

TMS will be integrated with other data information systems. By 1991 TMS is planned to be integrated with the department's Geographic Information System, Global Positioning System, and statewide simulation model based on EMME2 and TMODEL2 operating in the VAX environment. These efforts will serve to further refine the location of traffic data, and to make the data more readily available for a variety of data uses.

SUMMARY

The TMS has provided an effective means of implementing the State Traffic Monitoring Standards. The resulting data base is appropriate for efficient, accurate information for current traffic data uses. System flexibility and facility for statistical analysis of the data are provided through development in SAS.

The TMS is also appropriate for examining traffic monitoring research issues, such as alternative data summarization methods. In the future, the system will be refined for research reporting, and integrated with other traffic software packages and information systems.

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Factors Affecting Adoption of Information Systems in State Departments of Transportation

JEFFREY S. LANE AND DAVID T. HARTGEN

A recent survey of state departments of transportation purchasing practices for major management information systems is discussed in this paper. The study is based on responses from 26 states to a questionnaire covering four large information systems. State DOTs spent an average of $13.2 million on four systems (Computer Aided Drafting and Design (CADD), Geographic Information Systems (GIS), Roadway Data, and Capital Project Management); another $5.75 million is currently planned for spending in the next three years. Although total costs per access point range from $7,400 for Capital Project Management to $113,000 for CADD, they are expected to fall by 50 percent. System diffusion has been slow for some systems—more than 40 years—and fairly rapid for others—18 to 22 years—for CADD and GIS. The projected dates for complete system diffusion is similarly wide-ranging: 1995 for GIS, but 2005 for Roadway Data and 2010 for Capital Project Management systems. These differences result primarily from the large gap between leading and lagging states. Leading states, such as Texas, Pennsylvania, Wisconsin, and Washington, are installing information systems an average of 13 years ahead of lagging states. The gap between states is primarily because of the leading states' larger relative investment in hardware and software, and greater relative number of skilled computer personnel per employee. Several suggestions are made on how lagging states can catch up, including investing in computer infrastructure, setting clear priorities, networking with other states, and supporting professional organizations' efforts to modernize systems.

The 1970s and 1980s have witnessed a revolution in information processing technologies. Within the span of just a few years, the unit cost of information systems [cost per millions of instructions per second (MIPs)] have fallen dramatically. The last ten years have seen many advances, particularly in the availability of microcomputers, larger and faster mainframes, increasing functionality, relational data bases, graphical and fourth generation computer languages, geographical information systems, communications networks for local and wide areas, the advent of minicomputers and distributed processing, and the beginnings of data, voice, and image integration. The effect of this evolution is to decentralize computing power, and along with it responsibility and authority, while increasing analytical capability data access. Experts believe that these trends will continue: by the turn of the century, the average office worker's computing power is likely to be orders of magnitude larger than that possessed by entire companies in the 1960s, at a fraction of the cost.

Department of Geography and Earth Sciences, University of North Carolina at Charlotte, Charlotte, N.C. 28223.

State highway departments have participated in these trends. But limited budgets, lengthy recapitalization processes, periodic management changes, staff and skill shortages, small research and development budgets, and heavy prior investments in information processing technology have meant that these organizations often find it difficult to modernize quickly. Internal pressures for modernization, increasing knowledge of agency personnel, and fiscal opportunities have encouraged change.

Since 1970, the diffusion of computerized information systems in the field of transportation has been steady. But progress has been more rapid in some states than in others. Understanding the reasons behind these differences suggests that three items be examined: (a) "carriers"—those factors which encourage adoption of innovation, (b) "barriers"—those factors which impede adoption of innovation, and (c) "leaders"—the innovators in the field and the characteristics they possess which put them on the leading edge of innovation (*1*, *2*). This paper intends to provide some understanding of the diffusion of computerized transportation information systems in state-level DOTs, the processes of diffusion, and the traits that innovators in the transportation field possess. In this way, the diffusion process can be accelerated by providing information about pitfalls and suggesting positive ideas.

In recent years, many states and local governments have begun the process of developing integrated management information system (MIS) capabilities. In the transportation sector, efforts began in the late 1960s and focused primarily on highway locations for accident data reporting and public assistance (*3*). Storage and retrieval systems for highway data were well established by the mid-1970s (*4*), with two agencies (Texas and Illinois) planning the development of distributed systems using minicomputers, and 20 states using or developing integrated data base systems. This 1978 National Cooperative Highway Research Program (NCHRP) study recommended that "Maximum use should be made of user-controlled, interactive systems with on-line terminals which allow data input at the source, reduce errors, have information available when needed, and allow all data to be available to all users." A 1986 workshop on file linkages, sponsored by FHWA (*5*), found that all 10 participating states were developing integrated information systems, often driven by the need for better accident data. The workshop concluded that "file linkage" (integration), as a management tool, had far more comprehensive potential and that highway safety was a principal [driving factor], but that discussion could not be confined to safety only. A recent review of integrated information systems (*6*) found efforts to develop integrated information systems underway in Pennsylvania, Wisconsin, Idaho, Washington, Maine, Utah, Michigan, Kansas, Colorado, New York, and Kentucky, to name a few. Although each state adopted different approaches and focuses, all states were extensively involved in strategic planning for the end result: integrated information on a modern MIS. NCHRP recently advertised for new systems development in GIS and executive MISs.

ADOPTION PROCESS

Diffusion is the process by which a product, idea, or service moves through a potential market. The sequence of diffusion for many innovations begins slowly, then builds speed, but later slows and eventually ceases. This produces a normal bell-shaped curve (percent of adoptions versus time) showing which adoptions were first (leaders) and which were last (laggards) (*2*). If the number of adopters is cumulated, an S-shaped curve results. Figures 1a and b show typical curves.

Basic Elements of Diffusion Process

Rogers (*2*) and other diffusion researchers identify several basic elements of the diffusion process that are useful.

1. Carriers—factors which assist or encourage adoption to take place. Among the most commonly observed factors are
   - Money
   - Management directives
   - Service or product failures
   - Presence of champions
   - Actions of competitors
   - New market creation
   - New management approaches
   - Staff ideas
   - Literature searches
   - External assistance
   - New technology
   - Legal orders (laws, ordinances, etc.)

2. Barriers—Factors which slow or stop the process of innovation
   - Lack of communication
   - Turf battles
   - Lack of fiscal reserves
   - Outdated technology
   - Ignorance of one's field

3. Leaders—innovators in an area are called leaders, while those who tend to lag behind are called laggards. The differences between leaders and laggards has been related to
   - Education or experience
   - Professional expertise
   - Awareness of technology
   - Negotiating or managing skills
   - Views about innovation

The adoption process can also be thought of as a technology lifecycle (Figure 1). In this model, the adopter moves through stages of adoption, honeymoon, increasing dissatisfaction, review of alternatives, decision to adopt, and subsequent adoption of a new or revised product. Adopter satisfaction with the product is likely to peak just after the decision to adopt—before actual adoption or the honeymoon phase lets the adopter see the flaws—and lowest just before the review of alternatives. Figure 1 shows these stages.

Variables Affecting Diffusion Process

The literature concerning innovation and diffusion suggests many different variables which may affect a particular adoption process. Six categories of variables have been identified which might affect the adoption of computerized information systems in state DOTs.

1. *System characteristics (functionality)*—the functionality of a particular system is a measure of how that system serves the user's needs. Systems with a low measure of functionality are likely targets for replacement or updating.
2. *Agency characteristics*—the size (*7*) and spending capital (*8*) of an agency have been proposed as having positive effects on the rate of diffusion. The presence of internal mechanisms of change, such as development groups in the agency, has been used in the study of diffusion in retail operations (*9*).
3. *Management characteristics*—conference attendance (*10*, *11*) and knowledge of current literature in one's field of work (*10*) have been cited as characteristics of innovators. The length of time at a position within the same agency also has been proposed as having an effect on innovativeness.
4. *Geography*—the degree of interaction with nearby universities and communication with other groups similar to the one being examined (*10*, *12*) have been used as explanatory variables in several studies, including cultural diffusion.
5. *Vendor characteristics*—supplier aggressiveness may also play a part in the decision on when a system is chosen (*10*). Support, product price, and other similar features will often influence adoption.
6. *Governmental factors*—the introduction of a government mandate or the availability of government funding might prompt the adoption of a system that otherwise would be deemed too costly to produce.

The information in Table 1 suggests how these factors might be expected to affect innovation.

METHODOLOGY

For this research, state-level DOTs were questioned regarding different types of information systems. It was not possible to review all such systems, therefore four systems were chosen to represent a range of diffusion levels, function, and other concerns. These four systems are as follows:

1. CADD (Computer Aided Drafting and Design),
2. GIS (Geographic Information Systems),
3. Roadway Data Inventory Systems, and
4. Capital Project Management Systems.

These four systems were chosen because each system was thought to be at a different stage of development, thus providing an opportunity to study information systems at various stages of diffusion. The survey instrument was designed to gather information in several areas that literature in the fields of both diffusion and transportation research has identified as being important to the adoption of innovation. A mail-out questionnaire was sent to each DOT, with one questionnaire going to each state. The questionnaire was broken into five two-page parts, one part for each of the four systems and a background sheet to be answered by the head of the computer division. A copy of the survey instrument (for the CADD system) is provided (Figure 2). A total of 26 states answered all or part of the questionnaire, which included a series of follow-up telephone calls. Table 2 summarizes the survey's findings, and Table 3 shows data on the responses. Figures 3–6 show the pattern of responding states; data was most complete for the CADD and background information sections of the survey.

The methods used in the study are simple statistics, mapping, and logistic curve analysis. Simple statistics, such as means comparison, are easy to create and can be converted into charts or diagrams that can be used to visually emphasize characteristics of an individual system or a group of systems. Mapping the spatial characteristics of a diffusion process has been used extensively in diffusion research (*1*, *13*). Logistic curve analysis is also a popular tool among many diffusion researchers (*12*, *14*, *15*).

Logistic curves, or S-shaped curves, are used to determine the level that an innovation has reached within its potential marketplace. The highest level that a particular innovation

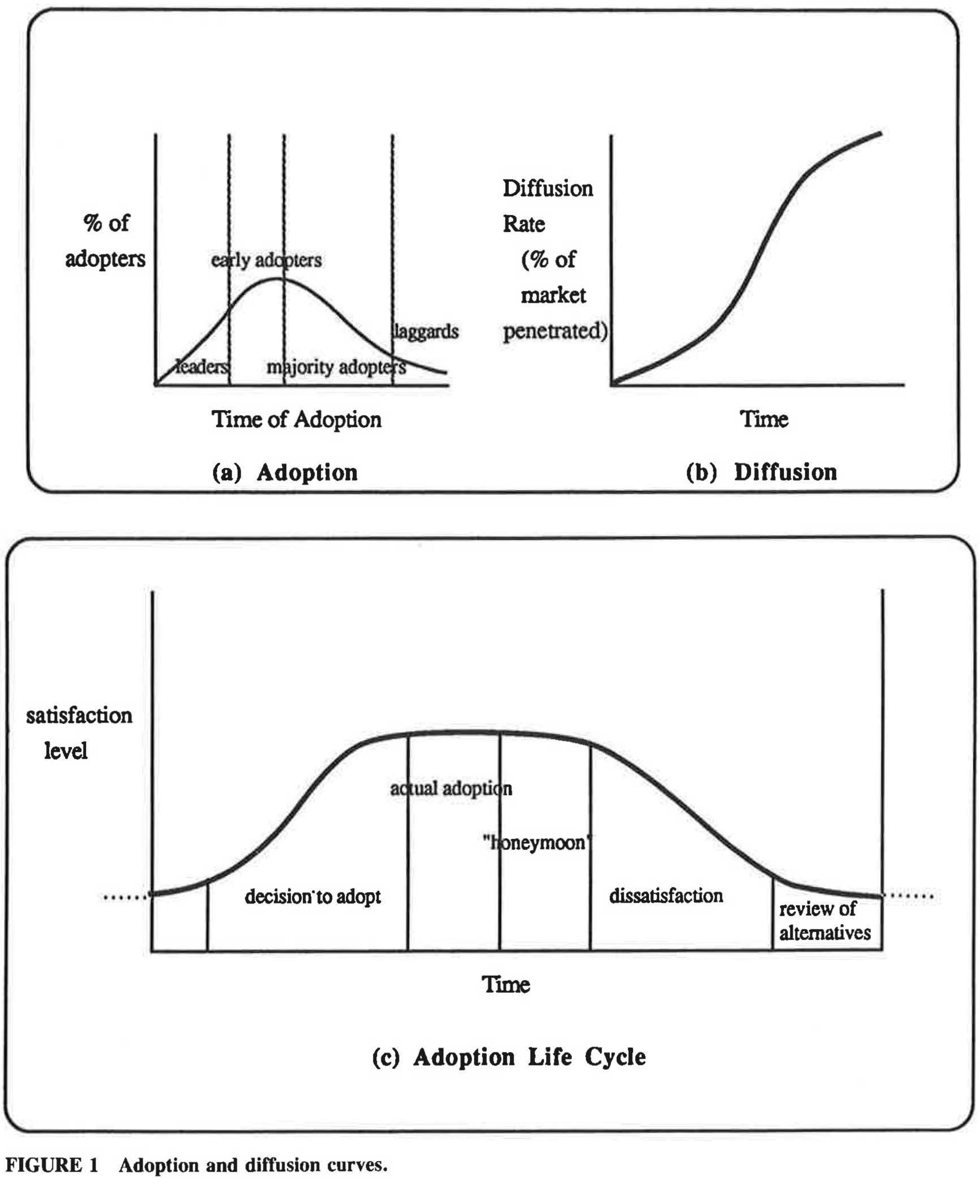

FIGURE 1 Adoption and diffusion curves.

TABLE 1 VARIABLE CATEGORIES AND DEFINITIONS

Category	Definitions: Conceptual	Definitions: Operational	Purpose/Level of Measurement
A. System Itself			
1.	Functionality	Desired Characteristics of a System	It is proposed that the degree of functionality is positively related to the speed of diffusion.
B. Agency Characteristics			
1.	Size	Employment	It is proposed that the size of an agency may be correlated to its willingness to adopt innovation.
2.	Wealth/Capital	Operating Budget	It is proposed that the amount of available capital in an agency is positively related to the willingness to adopt innovation.
3.	Internal Mechanisms for Change	Presence of Development Groups/Facilities	It is proposed that the presence of development groups which may adapt or modify systems will positively influence adoption.
C. People/Management			
1.	Awareness of progress in the field	Conference Attendance & Literature Read	It is proposed that an awareness of the transporttion field is positively related to the acceptance of innovation.
2.	Familiarity with position in agency	Length of Time at Current Position in Agency	It is proposed that the length of time a manager spends at the same position will be related to the willingness to adopt innovation.
D. Geography/Organization Interaction			
1.	Size of Community	Population of City/SMSA	It is proposed that the size of the metropolitan area around an agency has a positive effect upon the speed of diffusion.
2.	Distance/Interaction with Related Organizations	Presence/Interaction with a University	It is proposed that interaction with a university will aid the diffusion process.
		Interaction with the Same or Similar Agencies	It is proposed that the degree of interaction with similar agencies will increase the speed of diffusion.
E. Supplier Factors			
1.	Sales Aggressiveness	Number of Contacts with a Supplier/Distributor Prior to Adoption of System	It is proposed that the number of contacts with a a supplier or distributor of a system will increase the speed of adoption.
F. Governmental Factors			
1.	Government Impetus for Innovation	Government Mandate Calling for the Acquisition of a Computer System or Funding	It is proposed that the presence of government mandates or government funding will have a positive effect on the speed of diffusion.

Please Return To: David T. Hartgen
Department of Geography and Earth Sciences
University of North Carolina at Charlotte
Charlotte, N.C. 28223

Questionnaire number ______
State ____________________

Please answer, as accurately as possible, the questions below concerning characteristics of your DOT.

1) How many people were employed in your entire DOT in the previous fiscal year (1988)? ______________

2) How many operators, programmers, technicians, and supervisory personnel were employed in the CADD, GIS, roadway data inventory, and capital projects management system areas in your agency in the previous fiscal year (1988)?

____

3) What was your agency's operating budget for the CADD, GIS, roadway data inventory, and capital projects management systems in the previous fiscal year (1988)? __________

4) Please place a check mark (√) beside the functions this DOT normally performs:

design computer systems _____
build computer systems _____
modify computer systems _____

5) How many individual computerized workstations (terminals) does your DOT currently have? __________

6) Do you currently have a formal or structured planning process which allows you to assess computing needs in your DOT?

circle one: YES NO

TO THE PERSON WHO COMPLETES THIS FORM:

7) On the average, how many professional conferences do you attend a year? ________/year

8) On the average, how many technical periodicals (magazines, newsletters) do you see a month? _______/month

9) How long have you been employed in this agency? (years/months) _____/_____

10) How long have you been employed in your current position? (years/months) _____/_____

Please indicate with a check mark (√) if you would like a copy of our results: _____

Thank you for your cooperation.

FIGURE 2 Survey instrument.

FIGURE 2 *(continued)*

Please Return To: David T. Hartgen
Department of Geography and Earth Sciences
University of North Carolina at Charlotte
Charlotte, N.C. 28223

CADD
State ________________
Questionnaire No. _____

CADD system manager:

Please answer the following questions concerning the CADD system your agency currently has. The answers will be used in a nationwide study to determine how state transportation agencies make choices about the acquisition of computer equipment.

==

1) Please place a check mark (√) indicating the importance of the following reasons why your agency decided to focus on the area of computer-aided design.

	unimportant	somewhat important	very important	don't know/ not applicable
Federal regulation or requirement	_____	_____	_____	_____
High agency priority	_____	_____	_____	_____
Increase staff productivity	_____	_____	_____	_____
Easy to integrate with existing equipment	_____	_____	_____	_____
Availabilty of federal grant	_____	_____	_____	_____
Dissatisfied with previous system perfomance	_____	_____	_____	_____
Previous system was outdated	_____	_____	_____	_____
Other ____________________ *(please explain)*	_____	_____	_____	_____

2) Please name the CADD system and version you have:

system name ____________________

system version ____________________

3) Please place a check mark (√) indicating the importance of each factor below in the decision-making process of which particular CADD system version you chose.

	unimportant	somewhat important	very important	don't know/ not applicable
Review of professional literature	_____	_____	_____	_____
Communication with a college	_____	_____	_____	_____
Several agency persons "pushing" the system	_____	_____	_____	_____
Discussions with other state DOT's	_____	_____	_____	_____
Compatability with existing equipment	_____	_____	_____	_____
Result of a formal evaluation	_____	_____	_____	_____
Supplier or vendor salesmanship	_____	_____	_____	_____
Other ____________________ *(please explain)*	_____	_____	_____	_____

4) If you believe that another state DOT was important in the decision-making process, then please list in order of importance up to three state DOT's that most influenced the decision of which system you chose.

state DOT #1 ____________________

state DOT #2 ____________________

state DOT #3 ____________________

5) How long did this decision-making process (pre-installation) take? (years/months) _____/_____

6) When was your CADD system first installed? (month/year) _____/_____

7) How many people are presently able to use your CADD system simultaneously?

(how many access points)? __________

FIGURE 2 (*continued*)

8) Was the acquisition of any new hardware or software required to operate your CADD system?

circle one: YES NO

9) What is the cost of each of the following elements of your CADD system to date (including capital, personnel, contracts, operation)?

Planning	$________
Equipment	$________
Consulting	$________
Training	$________
Development	$________
Operation (after installation)	$________
Other	$________
Total system cost	$________

10) Please indicate the percentage of funding the following source(s) used to develop (prior to operation) your CADD system:

	% of funding
Federal funds	____
State funds	____
User fees	____
Private sector financing	____
Other ____________ (*please explain*)	____

11) How well does your CADD system fit your present needs?

(*circle one*)

very poorly	poorly	adequately	well	very well
1	2	3	4	5

12) How many more access points to your CADD system are planned for in the future? __________

13) By what date are these access points planned to be entered into your CADD system? (month/year) ____/____

14) How much more money is currently planned for your CADD system? $________

15) In the forseeable future, is your DOT planning to keep a CADD system? *circle one*: YES NO

TO THE PERSON WHO COMPLETES THIS FORM:

16) On the average, how many professional conferences do you attend a year? ______/year

17) On the average, how many technical periodicals (magazines, newsletters) do you see a month? ______/month

18) How long have you been employed in this agency? (years/months) ____/____

19) How long have you been employed in your current position? (years/months) ____/____

Please return this questionnaire to the Computer Systems Director. Thank you for your cooperation.

TABLE 2 PAST AND FUTURE PLANNED STATE DOT INVESTMENTS IN FOUR INFORMATION SYSTEMS

	CADD	GIS	Roadway Data Inventory	Capital Project Management
Planning Process Length (yrs)	1.52	2.2	3.43	2.64
Installed (years ago)	4.43	3.43	13.53	8.19
Access Points	90.45	40.27	113.87	54.46
Total Costs	$10,282,614	$1,215,471	$1,395,888	$405,921
Federal Share of Funding	.05%	48.8	40.24	25.2
Satisfaction Level (1-5)	3.91	3.86	3.68	3.38
Future Access Points	41.20	190.8	197.33	52.80
Years to Installation of Planned Access Points	1.74	2.97	2.20	2.50
Planned Future Expenditures	$2,191,222	$2,360,000	$207,272	$992,250
Past Cost/Access Point	$113,682	$30,183	$12,258	$7,442
Future Cost/Access Point	$53,185	$12,368	$1,050	$18,797

can achieve is called its "ceiling." Typically, a logistic curve graph has time or some function of time represented on the x-axis and the accumulated percentage of adopters on the y-axis. (Refer to Figure 1.) The logistic curve's slope is usually gradual at first, followed by a sharper incline as the innovation "catches on" among potential adopters. The final phase ends with a leveling off as the market becomes saturated.

FINDINGS

In the analysis that follows, it is important to realize that diffusion rates are measured by the number of respondents reporting (26 states). If nonresponding states were considered, then the adoption rates would probably be lower.

Present Level of Diffusion

The results of the study reveal several interesting features of the innovation process in DOTs. The graph in Figure 7 shows the current level of diffusion for each of the information systems being studied. Perhaps not surprisingly, GISs are the least diffused information system among state DOTs at the present time, with 57 percent of respondents now in possession of a geographic information system. CADD systems are completely (100 percent) diffused among state DOTs with every respondent having such a system in place. Roadway Data Inventory systems and Capital Project Management systems fall in between these two extremes, being 87 and 61 percent diffused, respectively.

The average number of years since an information system was installed is shown in Figure 8. GISs are the most recent systems to be added, installed on an average of less than 2.7 years ago. Roadway Data Inventory systems are the oldest, having been installed, on average, more than 11.5 years ago. The need to handle the large amount of roadway data that is necessary for a state-level DOT to function effectively made such a system appear to be an invaluable asset. At the time Roadway Data Inventory systems were first being installed in DOTs, the remaining three systems were either not technologically feasible or were considered a less vital addition to the agencies. Another interesting feature of this graph is that although CADD systems came on-line an average of only 4.24 years ago, they are the only systems surveyed that were completely diffused throughout the DOTs that responded. This indicates the very high priority that DOTs attached to these systems.

Rates of diffusion can also be seen in the logistics curves shown in Figure 9. The first states having Roadway Data systems were installed in 1965, adoption climbed steadily to the early 1980s, then leveled off. Capital Project Management systems followed a similar course. CADD systems began in the early 1970s, but then "took off" in the early 1980s, reaching their ceiling at the present time. GIS systems appear to be following a similar track to CADD. At its present rate of diffusion, GISs could be totally diffused in just a few years (estimated at 1995). However, at present rates of diffusion, Capital Project Management systems and Roadway Data

TABLE 3 STATES RESPONDING TO SURVEY OF INFORMATION SYSTEMS

	STATE	BACKGROUND	CADD	GIS	ROADWAY DATA	CAPITAL PROJECT
1	Alaska			✓	✓	
2	Arkansas	✓	✓	✓	✓	
3	California	✓	✓	✓	✓	✓
4	Colorado	✓	✓	✓	✓	✓
5	Georgia	✓	✓	✓	✓	
6	Idaho	✓	✓		✓	✓
7	Indiana	✓	✓	✓	✓	
8	Iowa	✓	✓	✓	✓	
9	Maine	✓	✓	✓	✓	✓
10	Maryland	✓	✓	✓	✓	✓
11	Mississippi	✓	✓		✓	✓
12	Montana	✓	✓			
13	Nebraska	✓	✓	✓	✓	
14	Nevada	✓	✓	✓	✓	✓
15	New York	✓	✓	✓	✓	✓
16	N. Carolina	✓	✓	✓	✓	✓
17	N. Dakota	✓	✓			
18	Oklahoma	✓	✓		✓	✓
19	Rhode Isl.	✓	✓	✓	✓	✓
20	S. Carolina		✓			
21	Tennessee	✓	✓		✓	✓
22	Texas	✓	✓	✓	✓	✓
23	Utah	✓	✓		✓	✓
24	Vermont	✓	✓		✓	
25	W. Virginia	✓	✓		✓	✓
26	Wyoming	✓	✓		✓	

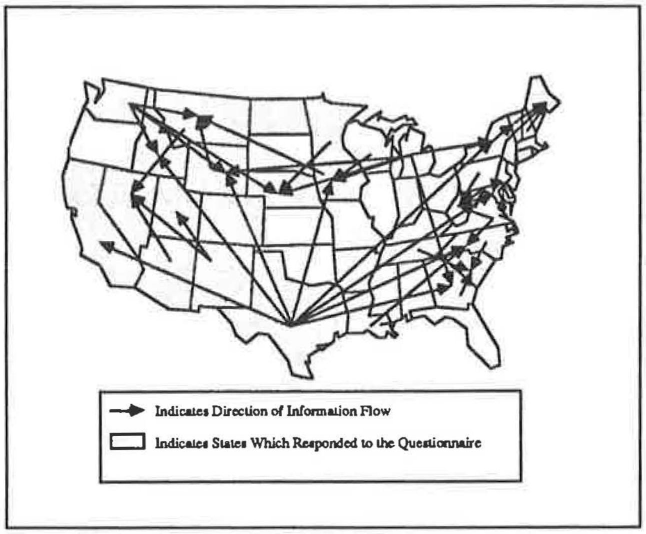

FIGURE 3 **CADD communication between state DOTs.**

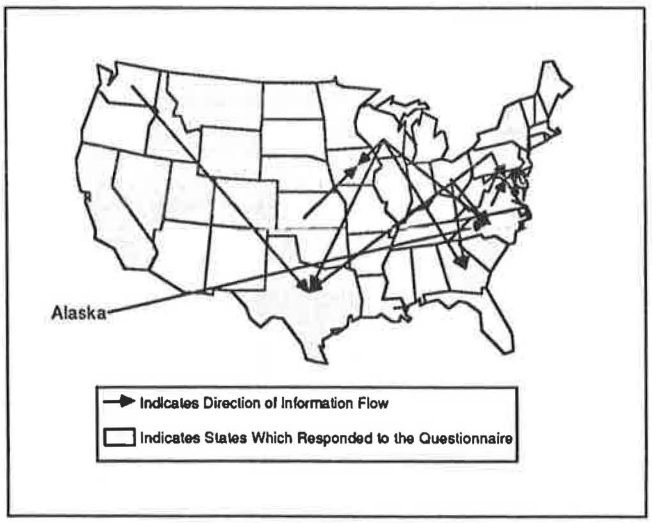

FIGURE 4 **GIS communication between state DOTs.**

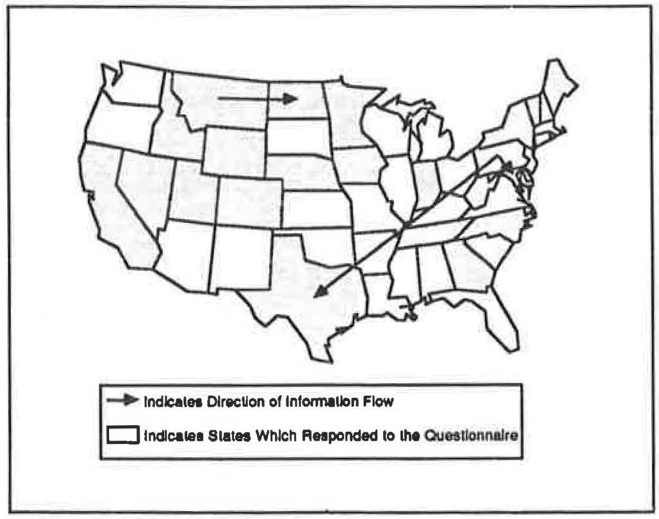

FIGURE 5 **Roadway data inventory system communication flow between state DOTs.**

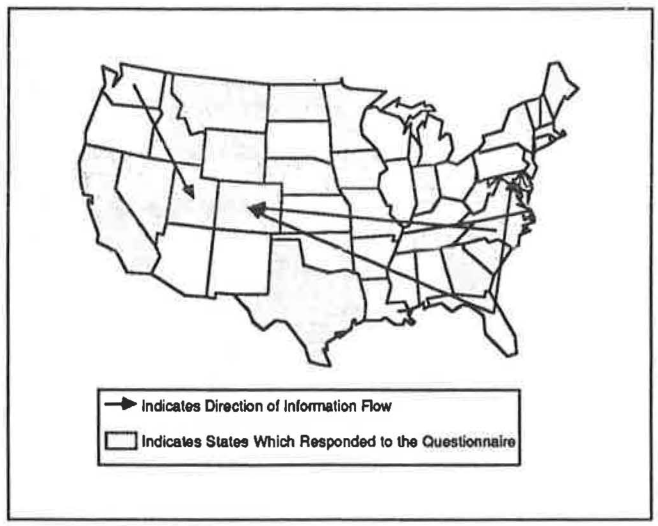

FIGURE 6 **Capital project management system communication flow between state DOTs.**

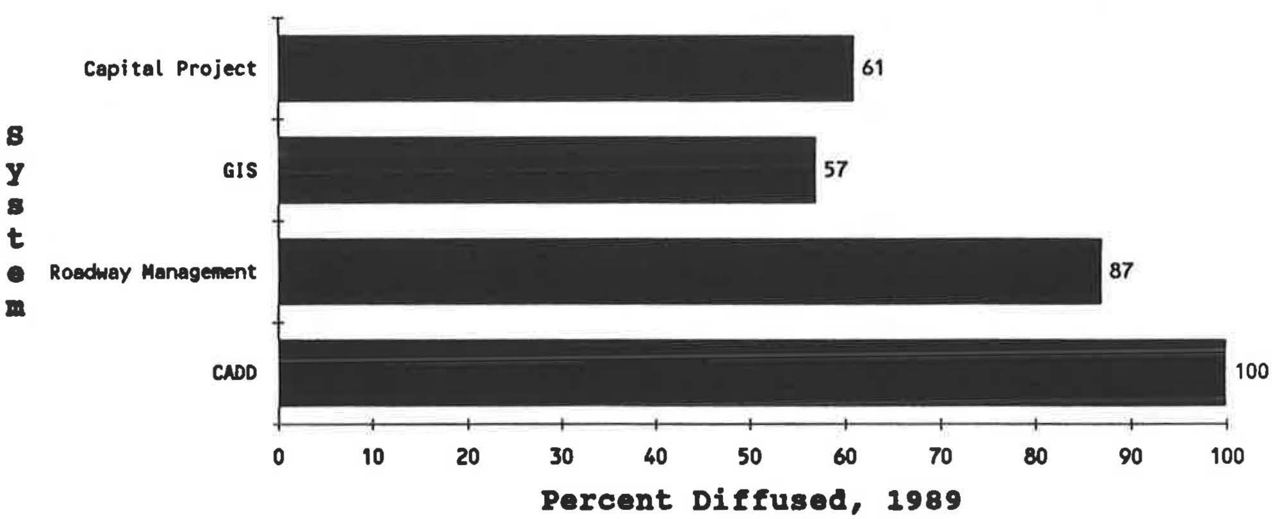

FIGURE 7 **Information system diffusion among state DOTs.**

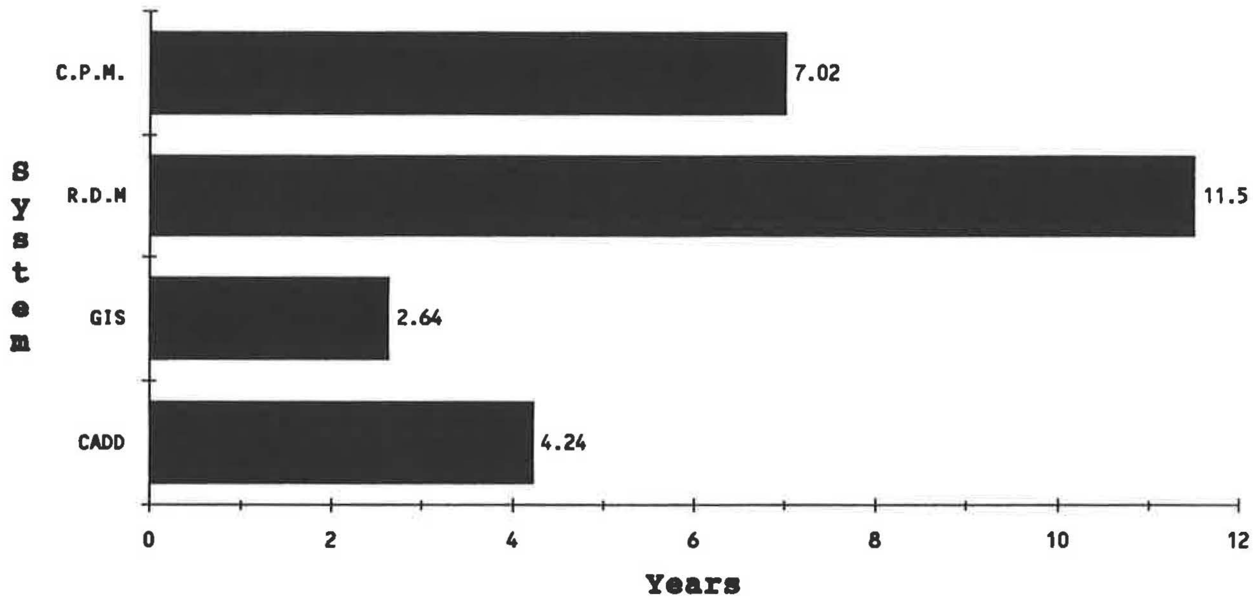

FIGURE 8 Average number of years since system installation occurred.

Inventory systems are unlikely to reach total diffusion before 2010 or 2005, respectively. This would imply diffusion times for these four systems as follows:

System	*Diffusion Time*
CADD	18 years (1971 to 1989)
GIS	22 years (1973 to 1995)
Roadway Data Inventory	40 years (1965 to 2005)
Capital Project Management	42 years (1968 to 2010)

The states have invested heavily in these systems. On average, DOTs have spent $10.2 million on CADD, $1.4 million on Roadway Data Inventory systems, $1.2 million on GIS, and $405,000 on Capital Project Management systems (Table 2). The total installation cost per access point (workstation or terminal) was highest for CADD ($113,682) and lowest for Capital Project Management ($7,442). State DOTs also plan future expenses for each system: GIS and Capital Projects future dollars are projected at twice present expenses. However, the projected cost per new access point will be lower, except for Capital Project Management systems, where a second round of basic development efforts is still taking place.

Factors Influencing Adoption of MIS Products

This discussion suggests that certain factors have propelled the diffusion process of CADD and GIS beyond those of Roadway Data and Capital Project Management systems. What are these factors?

To investigate these issues, Figure 10 shows responses to perceived importance of six variables in selecting a system to focus on. Clearly, the most critical variables are (a) perceived gains in productivity and performance, (b) perceived high agency priority, and (c) a presently outdated system. In other words, a squeaking wheel, with a need to fix it, gets the attention. In the present case, the "need" is the pressure to reduce operating costs by improving agency productivity. It is not enough for an outdated computer system to have problems; the system must serve a high priority function, and the agency must perceive that improvements in the old system will yield productivity gains.

Data in Figure 10 also suggest that several factors are less critical in focusing an agency's attention on certain systems. Grant money alone does not increase attention, nor will federal mandates (alone). Surprisingly, even the long-term goal of data system integration is not as critical. The message of these charts is clear: do not wave financial carrots or regulatory sticks. Instead show how improvements will accomplish high priority objectives, save money, and improve system performance.

Does it follow from Figure 10 that CADD and GIS systems are perceived as more critical than Roadway Data or Capital Project Management systems? Figure 11 shows a comparison of views on each system. Surprisingly, all systems rated high on "agency priority." Data in Figure 11 suggest that at the time they were implemented, all systems were a high priority; after implementation, priority naturally shifted to other systems. The image produced is one of a careful agency, selecting its targets sequentially, and implementing them in sequence. If adoption of Roadway Data and Capital Project Management systems has slowed—and apparently it has—then it would seem to be that these systems are not making the case that they are necessary, productivity will be gained, and that they are presently outdated.

A key element arising from our explanation is the idea of an agency's power structure—that is, which agency division holds the greatest sway. It is our experience that in the majority of state DOTs, it is the design and engineering division. One might view Figure 9 as an indicator of the shift in power over the past 15 years away from planning and financial functions, and toward engineering and design functions. Remembering that these agencies were originally engineering oriented in the 1950s, Figure 9 suggests a resurgence of traditional functions after an interim period of relatively greater attention to planning and fiscal matters. Further investigation of this

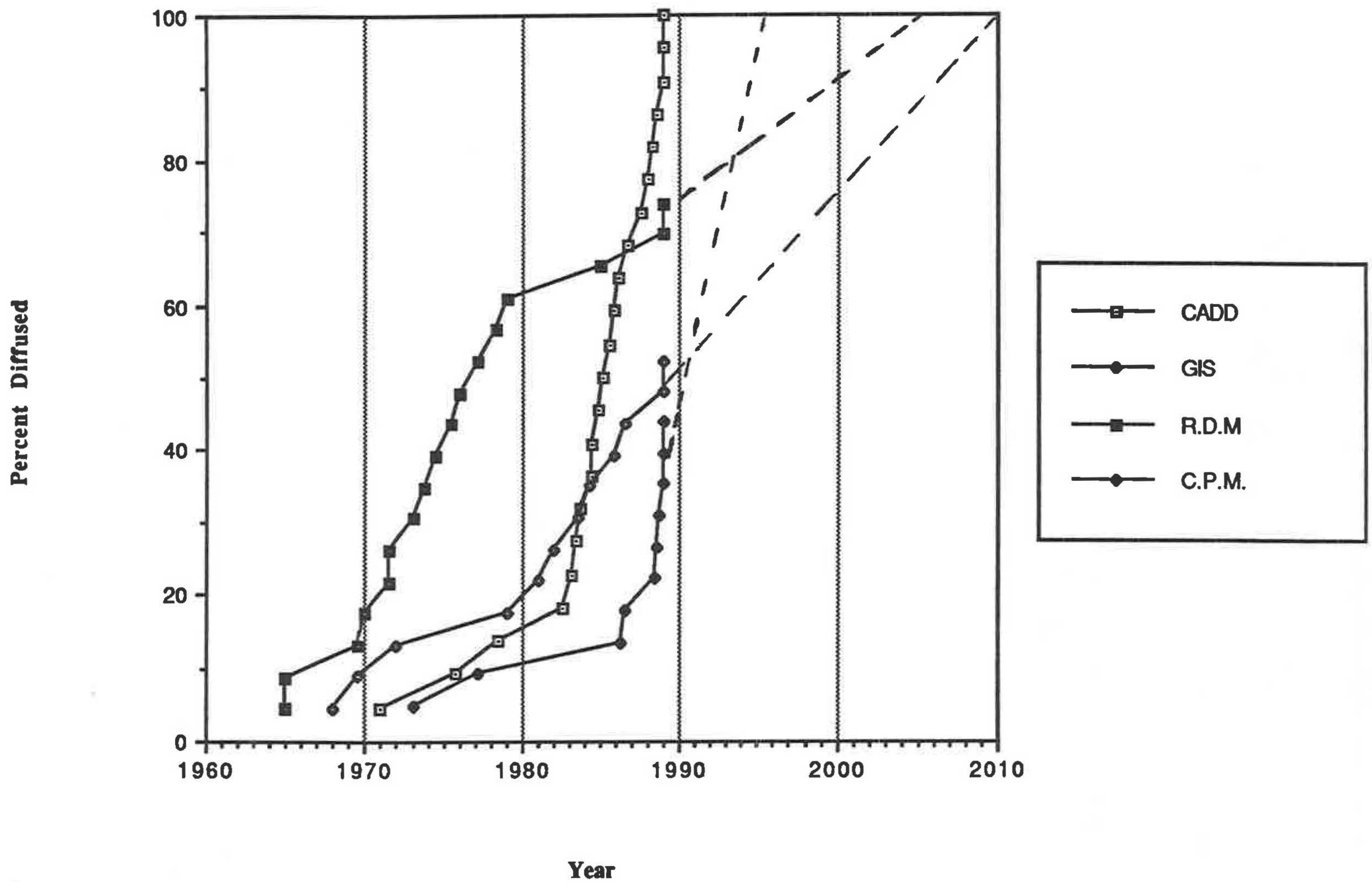

FIGURE 9 Diffusion of information systems in state DOTs.

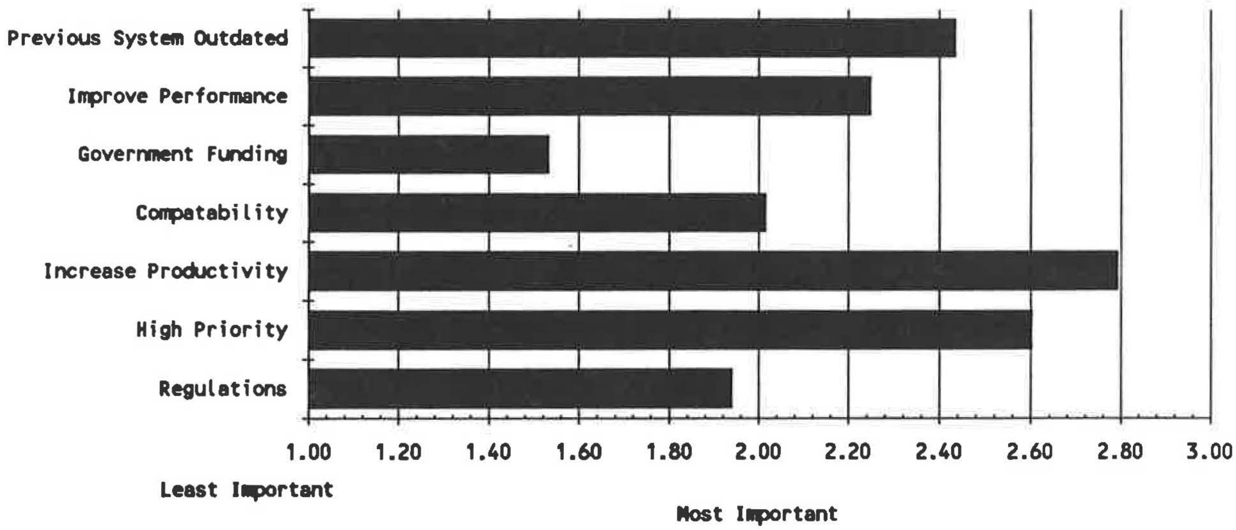

FIGURE 10 Importance of six variables to the selection of an information system.

would require a broad study of the evolution of power bases inside these organizations.

How Do Agencies Select MIS Products?

The process of product selection appears to be a deliberate one, based largely on comparisons. As Figure 12 shows, the state DOTs appear to be careful consumers of information systems, relying mostly on comparative evaluation of alternative systems and on the experiences of other state DOTs. System compatibility (with existing systems) and the presence of product "champions" inside the agency also seem to be important. Of much less importance were literature reviews, salespersons' pitches, and university expertise. The high showing of champions (within an agency) is disturbing because it is not clear why such persons deserve such influence or whether they may have conflicts of interest in making recommendations. The image suggested here is of a conservative yet vulnerable agency, asking advice of peers, doing its own evaluation, and resisting the input of others, yet relying heavily on inside champions' views.

Do these images vary for different systems? No. Figure 13 shows the same pattern of reliance for each of the four systems studied.

Who Are the Leaders?

Two approaches to this question are possible. First, one can simply list the adopters by date. This approach shows which respondents reported early development times. Because a complete survey is not available, however, this list would likely be inaccurate.

To enhance the first approach, another method would be to identify which states were contacted, as each developed its system, and trace these contact networks to their sources. Our survey yielded only sketchy information on these networks, but enough was found to describe.

Our most complete description was for CADD (Figure 3). Here respondents mentioned most frequently direct contacts with Texas (8), Washington (4), and New York and New Mexico, (2 each). Against this national picture, there are several regional distinctions: in the Southeast, Georgia, South Carolina, North Carolina, and Virginia all helped each other; in the Northeast, Maine obtained information from New Hampshire, Vermont, and New York; and in the West, Nevada, Idaho, Montana, Arizona, and New Mexico all interacted. Texas is of particular interest. It influenced eight states directly and four indirectly (South Carolina, through Georgia; Maine through New York; West Virginia through Maryland; and Montana through Iowa).

For GIS (Figure 4), the leaders appear to be Wisconsin (4 contacts) and Pennsylvania (2). No clear leader emerged, but Wisconsin seemed to be held in the highest regard. Regional clustering of information flows has not yet evolved.

The data was very sparse for both Roadway Data and Capital Project Management systems. It may be that because these systems were installed quite some time ago and were largely developed in-house, the amount of communication has not been recorded or was lower at the outset.

Leaders versus Laggards

To sharpen understanding of the adoption process, the characteristics of leaders (the first 25 percent of adopters) and laggards (the last 25 percent of adopters) were reviewed. Because the sample is incomplete and diffusion is ongoing, some laggards may be early adopters. If this is the case, the differences between these groups are likely to be smaller than if a complete sample was available.

Figure 14 compares the characteristics of information system managers of leading and lagging systems. The figure suggests leaders are more experienced, but they do not have as much exposure to professional input. In all cases, the differences are not large.

However, leading and lagging states do differ on other traits. System innovation is, on the average, *13 years ahead* in the

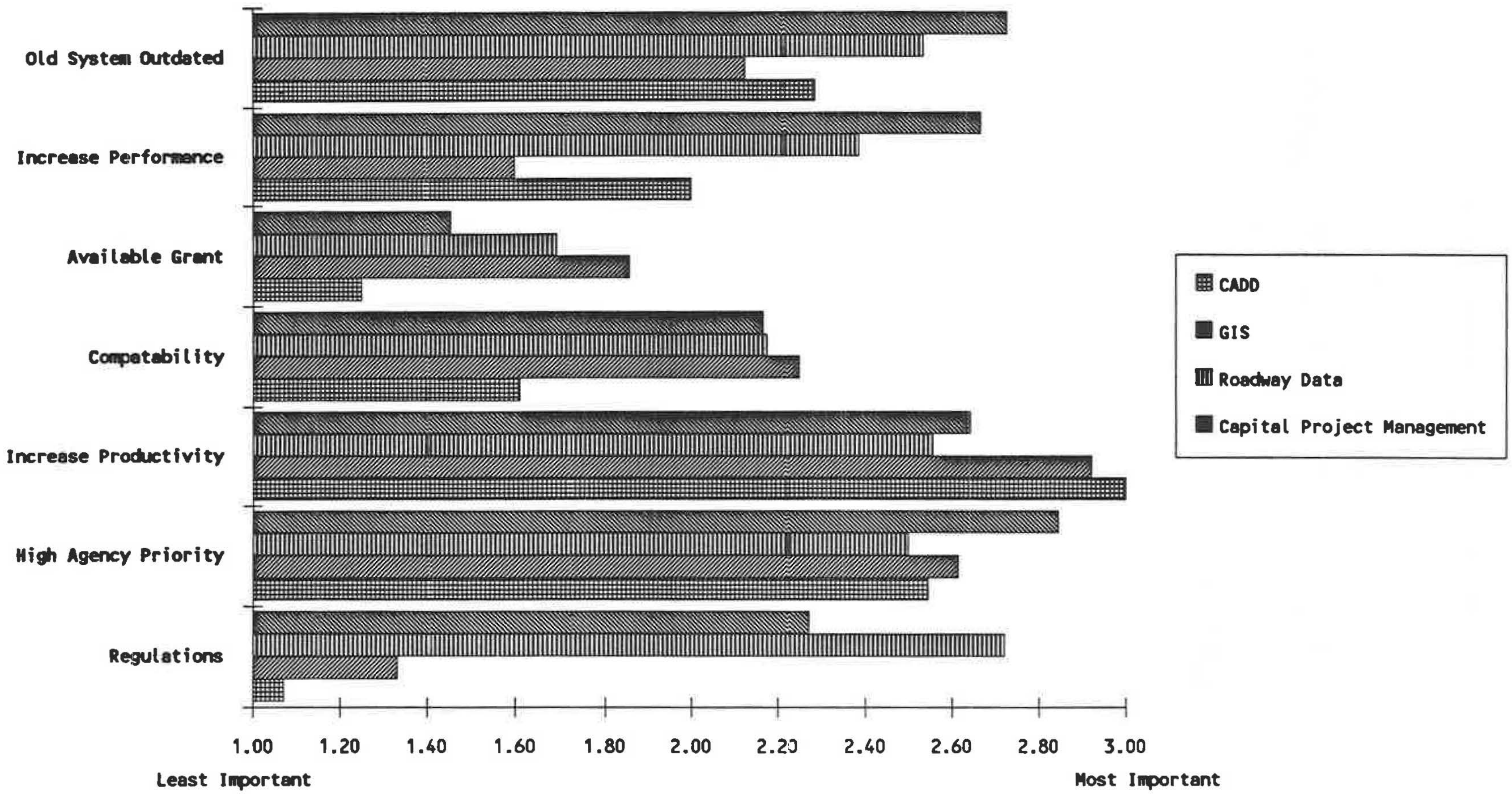

FIGURE 11 Importance of six factors to the development of an information system, by system.

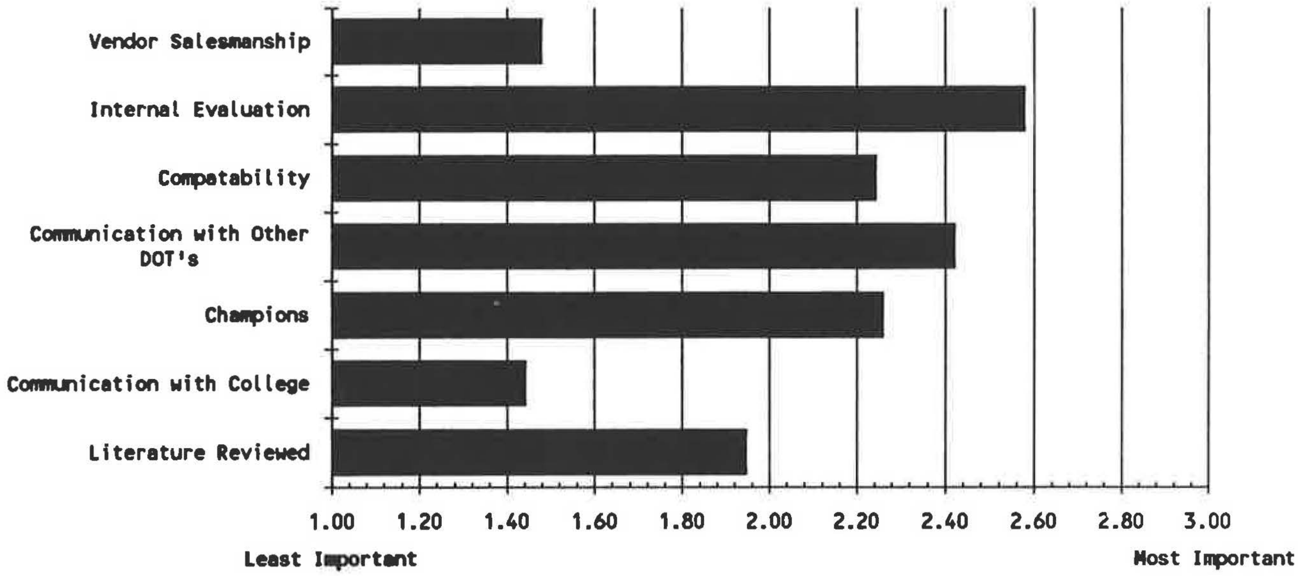

FIGURE 12 Importance of six variables to the selection of system version.

leading states. Table 4 suggests that leader agencies are bigger, more computer literate, and better staffed with computer expertise. On average, leaders have 46 percent more workstations per employee, spend 71 percent more money per employee on systems, and have 257 percent more computer experts per employee.

Ironically, laggards rated the factors cited as being most critical to system adoption consistently higher than did leaders. The pressures are greater on the smaller agency, but the tools are not present to do the job. The image is that of a tired horse being exhorted by his master to catch up, but not being given the sustenance to do so.

POLICY IMPLICATIONS AND CONCLUSIONS

Large differences exist in the status of state DOT information systems. Some systems are completely diffused, others are diffusing very rapidly, and still others are not diffusing at all. CADD and GISs are moving very rapidly, but Roadway Data and Capital Project Management systems are moving very slowly. Future plans for these systems are likewise skewed. State DOTs plan to more than double investment in both GIS and Capital Project Management systems, but will increase funding for Roadway Data and CADD by only 20 percent.

System priority depends on (a) perceived gains in productivity, (b) how outdated the current system is, and (c) the priority an agency places on a system's functions.

The amount of time it takes to reach a system's ceiling is quite long, even for the most rapidly diffusing systems. CADD diffusion took 18 years. Capital Project Management systems are estimated to take 42 years to achieve complete adoption (in the year 2010).

The perceived leaders in CADD are Texas and Washington. For GIS Wisconsin and Pennsylvania are the perceived leaders. For other systems, no clear picture emerges. Texas has influenced more than 50 percent of the state DOT's CADD systems through direct or indirect contact. With the exception of a few national leaders, most states tend to network with neighboring states, with regional networks apparent in the Southeast, Northeast, West, and central United States.

The speed of adoption appears to be a function of organization size, computer investment, and priority. Large states that have invested in computer infrastructure are leading in innovation, with adoption times averaging 13 years ahead of lagging states. System managers in both leading and lagging states are similar in the amount of experience they have. Lagging states are in high-pressure situations: management expects improvements in productivity and performance, but funds and manpower are inadequate to meet these demands.

Agency's system selection processes are generally conservative and methodical, relying primarily on internal evaluations and advice from other DOTs. However, states appear to be vulnerable to the views of agency champions (people who push a particular system for whatever reason) in their selection processes.

How can the pace of adoption for information systems be accelerated? The results of this survey indicate a number of approaches:

1. *Provide the money*. Lagging states are unlikely to catch up to the leaders unless they are able to invest in the computer infrastructure needed to permit adoption. Larger budgets for basic computer access (terminals, skilled people, mainframe computing power, and up-to-date software) must be made available.

2. *Set clear priorities*. In lagging states especially, everything seems to have a high priority! Most managers know that kind of pace can not be sustained. Agencies need to sort out, decide on, then move forward with systems that are key to their operations.

3. *Network with other DOTs*. It was surprising to find the lack of communication among states and the degree of isolation in many systems. On a handful of states are perceived as leaders. The others need to get out and interact with their peers. Leading states could set up "buddy systems" to help nearby lagging states. Additionally, communication with nearby universities was rated the lowest of all factors on which system

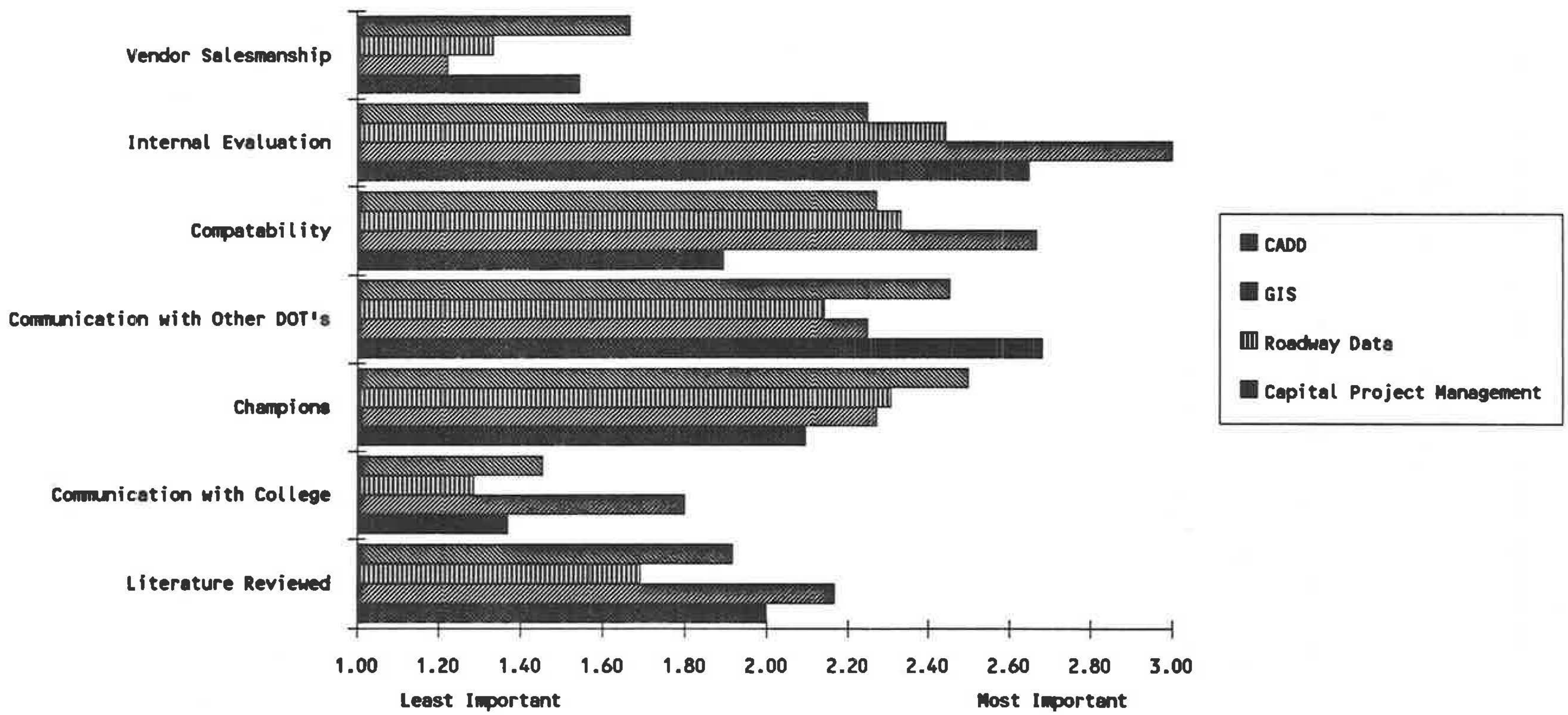

FIGURE 13 Importance of six variables to the selection of four system's version.

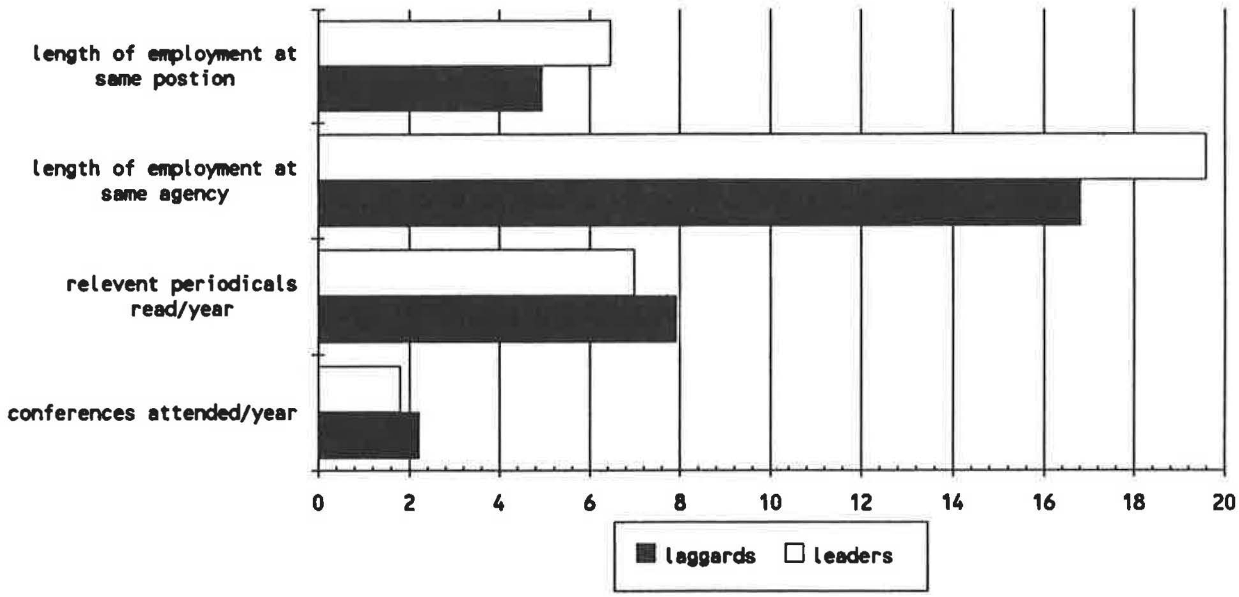

FIGURE 14 **Selected characteristics of information system managers.**

TABLE 4 CHARACTERISTICS OF LEADING AND LAGGING AGENCIES

	Leading	Lagging	Difference
Years since installation	14.79	1.73	13.06 yrs
Agency Size (Employees)	5,812	3,299	76%
Number of I.S. Employees	147	23	539%
Number of I.S. Employees/ Number of all Employees	.0253	.007	257%
Number of Workstations	1,086	444	144%
Workstations per Employee	.19	.13	46%
Budget for CADD, GIS, Roadway Data, and Capital Project Management	$2,341,667	775,000	202%
Computer Budget per Employee	$403	$235	71%
Perceived Importance to System Priority (scale of 1 to 3)			
productivity	2.69	2.88	-.21
agency priority	2.50	2.65	-.15
integration with other systems	2.20	1.87	+.37
performance	2.10	2.36	-.26
federal regulation	2.07	1.79	+.28
grant funds available	1.50	1.33	+.17
outdated systems	2.36	2.60	-.24

was chosen. Increasing interaction with these institutions could create a valuable source of information.

4. *Management responsibility*. Ultimately, managers decide on the pace of change. In lagging states, managers need to shoulder their responsibilities and increase the pace.

5. *Federal role*. The federal government's role in system innovation is multifaceted. Its most important role is to encourage and support modernization. It can also offer assistance by facilitating networking through conferences, publications, and workshops.

6. *AASHTO, TRB, and PTN Role*. Associations such as TRB and AASHTO can be very important to technology diffusion. The PTN (Public Transportation Network) was specifically designed to assist in the diffusion of technological innovation in DOTs. Since its establishment in February 1983, PTN has provided technical assistance to DOTs, conducted workshops, and encouraged networking (*16*). CADD diffusion has been supported by AASHTO Committee works and software development. Although GISs are diffusing rapidly without a considerable external support effort, AASHTO and TRB have recently instituted research for GIS design. Although the impacts of these organizations are not specifically addressed in this paper, continued involvement in these systems through committees and research activities and expanded involvement in other systems is appropriate.

This paper ends on a high note: the state of diffusion is advanced in the systems reviewed and progress is rapid. Although gaps between leading and lagging states are large, they can be reduced by positive, coordinated efforts. it is hoped that deficiencies in state-level DOT technical development have been identified in this paper, and some contribution made toward eliminating those deficiencies.

ACKNOWLEDGMENT

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Improved Method for Collecting Travel Time Information

Toby D. Rickman, Mark E. Hallenbeck, and Margaret Schroeder

A primary difficulty in evaluating most new traffic control and traffic operations systems that are developed, tested, and installed is to determine the impacts those systems have on traffic behavior. To collect the data necessary to evaluate the systems, researchers have traditionally used floating car surveys and other data collection techniques. However, it is costly to perform the number of floating car surveys required to accurately measure the reasonably small changes in travel times that individual vehicles accrue as a result of traffic control system improvements. A more cost-effective and potentially more accurate alternative to the floating car survey for collecting that travel time information is described. Observers with lap-top computers collect license plate information. A series of simple computer programs performs the required license plate matching and produces summaries describing the travel characteristics of the traffic stream. This method of data collection costs less than floating car surveys, provides a larger number of travel time runs for a given level of personnel involvement within a given period, and can provide additional information on the traffic stream being monitored—for example, origin-destination information—at no additional cost.

A primary difficulty in evaluating the impacts of many of the new traffic control and traffic operations systems that are developed, tested, and installed is to determine the impacts those systems have on traffic performance. Although simulations created with NETSIM, FRESIM, or some other model can play an important part in developing the system's control algorithms and operating parameters, simulation programs are necessarily limited to using "static" input data that have been previously collected. These data are usually adequate for system development, but they rarely include the variability found in real-world traffic operations.

Thus, system improvements must be evaluated under real traffic conditions. This evaluation requires the collection of travel time information for vehicles passing through the study area. Before-and-after travel time studies measure the vehicle performance within the study area, and statistical techniques then determine the impacts of the new control system.

The collection and evaluation of traffic performance data pose two major limitations on these important evaluations:

- Traffic performance is extremely variable, and
- Collection of traffic performance data is costly.

These two factors hamper engineers in collecting a sufficient amount of traffic performance data to measure the reasonably small gains in individual vehicle performance that result from most new systems.

For example, a 2-mi section of arterial may contain four or more traffic signals. Depending on how well the signals are timed, the road's level of congestion, and when in the cycle a vehicle enters the network, a vehicle may encounter between zero and four red lights while traversing the network. The delay the vehicle experiences directly relates to the number of red lights it meets, and these delays create a wide variation in travel times along the road section. As a result of this high level of variation, a large number of travel times is necessary to adequately determine the mean travel time of vehicles passing through the system. Only with a valid measure of the mean travel time and the distribution of the travel time can statements about improvements to service be made with confidence.

Depending on the number of stop lights and the level of congestion, one team of two persons in a vehicle can usually make about three peak-period, peak-direction travel time runs on a 3-mi stretch of arterial during one peak hour. If sample sizes larger than three are needed (and with large coefficients of variation, any level of acceptable statistical precision requires more than three runs), additional days of data collection are required, or additional vehicles and data collection teams must be used. Even when multiple days of data collection are performed to examine variation over time, with the small number of data points collected using the floating car method, it is difficult to know whether measured differences are caused by different conditions on subsequent days or by the inherent variation in travel times on that road.

Both additional days of data collection and additional crews collecting information substantially increase the cost of data collection. If congestion on the subject arterial varies throughout the peak hour (which is often common), the three runs collected by a single crew may have very different travel times, and many days of data collection may be necessary to collect enough data to adequately describe changes in the road's travel times during the peak.

The relatively high cost of collecting travel time information means that most new signal systems (and many other traffic operations systems) are not adequately evaluated when they are installed and tested in the field. However, because the authors needed large amounts of travel time information to evaluate a number of ongoing projects, they developed a variation on the traditional license plate matching survey to provide better travel time information at a lower cost than floating car surveys could provide. That method is described and compared with other available methods.

T. D. Rickman, Washington State Department of Transportation, Bellevue, Wash. M. E. Hallenbeck, Washington State Transportation Center, University of Washington, Seattle, Wash. M. Schroeder, Department of Civil Engineering, University of Washington, Seattle, Wash.

THE NEW DATA COLLECTION SYSTEM

Engineers have used license plate matching for many years to collect traffic data. Traditionally, observers wrote down license plates on paper and then keypunched them into a computer, or spoke them into a tape recorder and then transcribed them onto punch cards. Both systems had limitations. Not only was staff time required to collect data, but also a considerable amount of office time was required to transcribe the data into a computer-usable format.

The advent of inexpensive lap-top computers allows license plate information to be collected more cost-effectively and efficiently. At least two observers are equipped with inexpensive ($400 per computer, although more expensive and capable lap-tops can also be used) lap-tops that run a simple BASIC program. (Additional observers with computers proportionately improve the collected data.) The observers type the first four digits of the licenses of vehicles that pass their location and then press the computer's RETURN key. The BASIC program accepts the input, reads the computer's system clock, and adds the newest entry and the time of that vehicle's passing to a file of four-digit license plates. This process continues until the data collection activity has finished.

Upon completion of the data collection effort, the files from all the lap-top computers are transfered to a microcomputer in the central office. A simple FORTRAN program is then run, which

- Matches license plate numbers from the various lap-top files,
- Compares the times of the two matched observations of each license plate,
- Computes the travel time between each set of observation points for each license plate, and
- Creates a file containing all of the matches and travel times.

Minitab (or any one of a number of computer programs) is then used to read and summarize the output file. (The output files can be read by almost any standard microcomputer statistics, analysis, or graphics package, including Minitab, SPSS PC, SAS, or Lotus 1-2-3.) Output from Minitab includes the mean, median, standard deviation, and a simple scattergram of the travel times between the two study locations. This information is used to examine the data for spurious matches, which are then removed from the data set with a simple text editor. Minitab is then run again to produce the final travel time statistics for the study area.

The entire computerized analysis process can take from 20 min to a few hours to complete, depending on the style of lap-top computer (whether it is MS-DOS compatible and uses standard disk drives, or whether it requires a modem or hardwire data transfer to move data to the central computer) and the number of additional graphing and statistical tests to be performed.

For simple freeway or arterial travel time studies, a two-person crew can collect the data. A good typist (roughly 60 wpm) can enter as many as 900 four-character license plates in 1 hr, provided volumes are heavy (about 1,500 vehicles per hour) and the observers have good visibility. For a freeway section with only one or two exits, two such output files usually result in more than 100 matched license plates, providing an accurate picture of travel times during the given period. When computerized license plate matching is compared with the three or four travel time runs possible with a two-person floating car survey, the advantages of the former method become apparent.

On arterials or freeway sections with many entry and exit points observers, and on complex traffic signal networks, the number of matches between any two observation points may be significantly lower than that achieved on shorter freeway sections and simple arterials. The decrease occurs because many vehicles observed at one end of a complex network stop in or depart the network and do not reach later observation locations. Nevertheless, even within complex networks, the study teams may obtain between 11 and 40 valid travel times per hour, considerably more than would be possible with the same personnel and the floating car methodology. With the computerized methods, the number of matches is simply a function of the percentage of license plates recorded at each location and the traffic volume flowing between the two study points.

MULTIPLE DATA COLLECTION POINTS

The license plate survey can also provide some additional information that is not readily collected with the floating cars. This information is related to origin-destination (O/D) data, which have traditionally been collected with the license plate matching technique. With multiple observers (more than two), the relative volume of vehicles traveling from one location to another can be measured. This measurement has been an important and traditional part of freeway license plate studies—for example, studies of which off-ramps people who enter at a particular ramp use). However, this type of information can be just as important in arterial networks.

On arterials, a variety of paths through the network can be measured simultaneously if observers with lap-tops are placed throughout the network (see Figure 1). Not only do matches indicate which paths vehicles are taking through the network and how well the path selected for the floating car survey is flowing, but also they indicate how well the network as a whole is functioning under the selected operating plan. This is particularly important for grid networks in which vehicles may follow many paths between their entry points and final destinations.

One advantage of the license plate survey is that it collects data from the real traffic stream, whereas the floating car survey measures travel time along an arbitrarily selected path at what the driver estimates to be the average speed. For simple arterials, this path is easily selected. For complex grids, neither the paths that motorists use nor the proportion of vehicles making specific sets of turning movements may be so readily identifiable.

Programs such as TRANSYT-7F attempt to optimize vehicular movement for an entire network. They try to balance the movements and delay experienced by all vehicles on all links in the network, not just movements and delays for vehicles on selected parts of the network. Therefore, to accurately measure the impacts of a TRANSYT-7F signal plan, a researcher should measure traffic performance throughout the

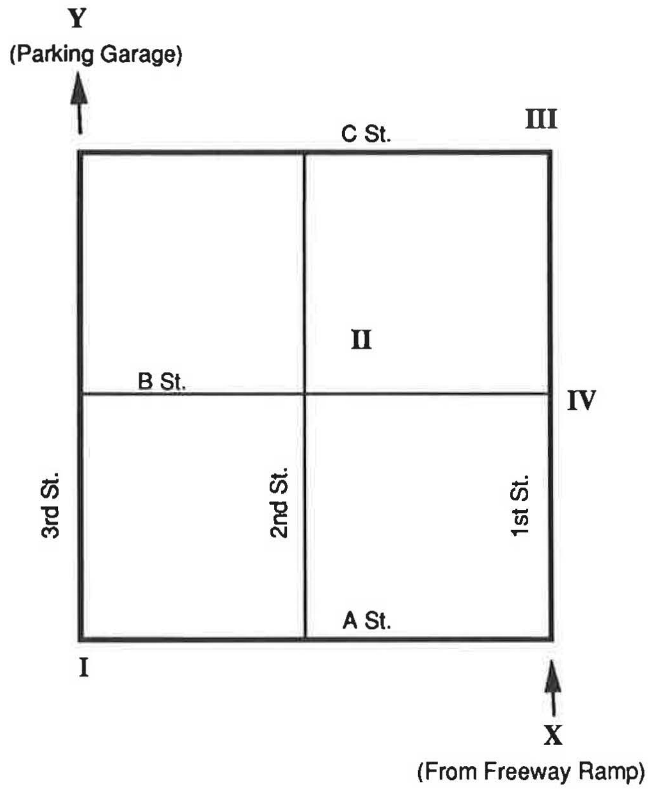

FIGURE 1 Arterial data collection.

network, not just on a few selected links or arterials. As a practical matter, this is impossible for even moderately complex networks because of the number of vehicle paths that must be measured and the distribution of travel and stop times associated with each path.

The collection of license plate data at multiple intersections makes this type of measurement possible. By expanding the number of observers and lap-tops used, data may be collected at many points within a study area. Matching license plate files from any combination of these locations can then provide travel time information for a number of routes, regardless of the specific path those vehicles took.

For example, in Figure 1, a motorist traveling from the freeway ramp at Point X to the parking garage at Point Y could follow several paths. Among the more obvious are the following:

- 1st Street to C Street, turn left, and then turn right on 3rd Street;
- Left on A Street, then turn right on 3rd Street; and
- 1st Street to B Street, turn left, and then turn right on 3rd street.

Observers at both Points X and Y would provide travel time information between these two points regardless of the paths selected. Given that signal timing plan changes often result in travel path changes, before-and-after data at these two points would better measure total system time between these two points than a floating car run along one specific path.

The addition of observer locations at Points I, II, and III would enhance the data collection effort even more at the low marginal cost of three temporary data collection persons. With license plate information at these points, the engineer could also determine travel times between X and I, I and Y, and all of the other combinations of points. In addition, statistics suggest that the number of matches observed between these points would be directly proportionate to the number of vehicles taking that travel path (provided there were no biases in the ability of observers recording the license plates—for example, poor visibility at one location). That is, the number of matches would indicate the importance of each path between X and Y. Such data are not possible with a floating car survey, and although they could be collected by other means, they are a "free" side benefit of the license plate method.

Placing additional observers at intermediate points of a network also increases the number of matches that will be made along a route because fewer vehicles leave the network between observers. Further, it provides travel time information at intermediate points in the network, and these intermediate travel times provide an additional check on the total travel time through the network. In Figure 1, for example, many people may travel from Point X to Point IV, and many others may travel from Point IV to Point III, but few may travel from Point X to Point III. By placing an observer at Point IV as well as at Points X and III, not only can the matches between Points X and III be used to compute travel time, but the sum of travel times between X and IV, and IV and III can also be used in case few matches are made between X and III.

ADVANTAGES AND DISADVANTAGES OF LICENSE PLATE MATCHING

Until now only the good points of the computerized license plate matching technique have been examined. However, all methods have advantages and disadvantages. Three principle methods for collecting travel time and vehicle performance information are briefly compared in this section. The three methodologies compared are

- Floating car survey,
- License plate matching with a voice recorder, and
- License plate matching with lap-top computers.

Floating Car Surveys

The advantages of the floating car survey are that

- The driver can positively identify the travel time measured,
- Collectors can easily record the travel time to the intermediate points on the roadway, and
- The recorder can note the cause of any delay the vehicle experiences during the travel time run.

The disadvantages of a floating car survey are that

- Extensive staffing is required to drive the vehicles and record the data if a large number of travel times are desired;

- Either extensive staff time is needed to transcribe the data from the recording sheets into a computer usable format, or the data must be collected initially on a portable computer;
- Because of staffing requirements, this method is costly for the amount of data gathered;
- Because the funds are usually not available, an insufficient amount of data is commonly recorded to adequately describe the travel time as a distribution of times with a mean, median, and standard deviation; and
- Behavior of the vehicle's driver can influence the travel times collected.

Despite its drawbacks, this method is the most widely used for travel time studies because of the perceived reliability of the data, the ease with which a small number of data points can be compiled, and the simultaneous collection of both travel time data and a limited amount of delay information.

Tape Recorded License Plate Surveys

The advantages of using voice recorders for performing license plate matching are that the voice recorders are inexpensive and this method provides a cost-effective way to collect large amounts of data. Another advantage of a voice recorder is that the observers can record license plates without taking their eyes off the traffic stream.

The disadvantages of voice recorders are as follows:

- Recording problems: Background noise can hamper the data compilation process. Voice quality in general can be a major problem when voice recorders are used.
- Cost: Although the cost of the recording devices is small, the conversion of the data from the recordings into machine readable formats can be costly. The recorders must be played with a time counter while the license plate information is transcribed into a computer-readable form. Estimates of the time required to complete this process range from 3 to 7 hr per hour of data recorded (*1*).
- Synchronization: Coordinating the time stamp with the voice recorders can be a problem.
- Tape accuracy: The accuracy of the tape machine requires periodic time marks on the tape during the data collection.
- Spurious matches: Incorrect license plate matches can occur if only a portion of the license plate is recorded, which is common.

Computerized License Plate Surveys

The advantages of using lap-top computers in travel time studies are as follows:

- Data recording: Observers can easily record the data by entering the license plate on a computer keyboard. The computer accurately records the entered plate number along with the accurate time.
- Synchronization: The computers are easily synchronized in the office and do not rely on the use of different watches.
- Data formating: The data transfer easily from the lap-top computer to a disk file on a desktop computer. More advanced computers record the data directly on a usable computer disk file. The computer can be programmed to record the data in a form the matching program can read. This process eliminates keypunching errors that can occur when license plates have to be transcribed onto a computer file for matching.
- Cost: As with the voice recorder method, the use of computers is a cost-effective way to collect a large amount of data with only a minimum number of people. Because the data do not need to be transcribed or recoded, the use of computers reduces the cost of personnel required both in the office and in the field.

The cost comparison of the different methods in Figure 2 indicates that computers have a tremendous advantage over a floating car survey and save 40 percent compared with the use of voice recorders (*2*).

The disadvantages of lap-top computers are that the machines are still relatively expensive ($200 to $400 for an inexpensive model without a disk drive and $700 to $1,200 for an MS-DOS-compatible, dual-disk-drive model); the license plate matching method does not obtain any delay information at specific locations along a route; and unless the entire license plate is recorded, spurious matches can occur. The problem of spurious matches is described below.

Spurious Matches

Data collectors often enter only a portion of the license plate in a license plate matching survey (*3*). Partial entry eases the data collector's task by reducing the number of digits to identify and type. After attempting various numbers of digits, it was found that the collection of up to four digits was possible with lap-tops when the data collectors were not accomplished typists. Because more than one plate can have the same first

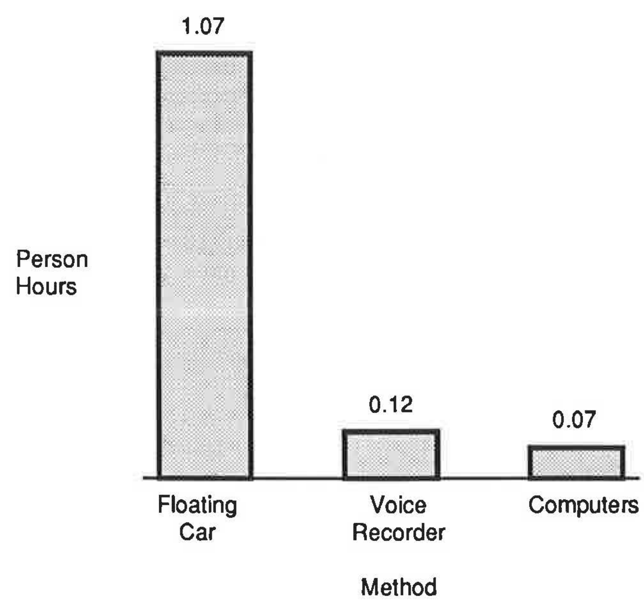

FIGURE 2 Cost comparison of data collection methods. Costs include staff time to travel to study site, collect the data, and reformat the data into a computer-usable format and are based on experience during the I-405 CORFLO study for FHWA.

four digits, different vehicles can be incorrectly matched at the end and beginning of the roadway section. (For example, license plates ABC 123 and ABC 199 would be incorrectly matched because only the first four digits of the plates, "ABC 1," would have been recorded.)

Several methods can be used to deal with the influence of spurious matches on the results of the data collection. These responses include

- Eliminating duplicate matches,
- Establishing a minimum and a maximum travel time expected during the study (*4*) and eliminating matches outside of this boundary,
- Using graphs to recognize unrealistic outliers,
- Comparing smaller time intervals so that the chance of spurious matches is reduced, and
- Recording more digits of the license plates.

Duplicates should not be eliminated until other data integrity checks have been performed. This is a simple step that a computer can easily do. It eliminates data that are strongly suspect (with at least a 50 percent possibility of being incorrect).

The process of establishing a minimum and a maximum travel time expected during the study (*4*) and eliminating matches outside this boundary is somewhat arbitrary and can influence the validity of the data. However, it can be a necessary process when large study times and large numbers of license plates are involved. It is also necessary for long arterial sections in which some vehicles may enter the network, stop at a store within the network, and then exit the network during the study period.

Minimums and maximums can be set by either some form of calculation (speeds should not exceed 100 mph or be below 2 mph) or can be the mean travel time plus some multiple of the standard deviation of the measured travel time.

A study of methods for dealing with spurious matches suggested the use of the median rather than the mean travel time to represent average traffic conditions (*4*). Use of the median value allows spurious matches to be ignored. This method does yield a value for the travel time that reasonably represents the expected value, as can be seen in Figure 3.

However, the problem with using only the median value without eliminating the spurious matches is that the standard deviation of the data cannot be determined. It is important to have an expected value and a measure of the standard error to be able to describe the data as a distribution of travel times.

Graphical methods can also help in recognizing spurious matches. The same data shown in Figure 3 are displayed in Figure 4 in a different format. The data shown in these figures were collected on a freeway section during 1 hr of license plate data collection. The majority of the data points are at 500 sec, which indicates a speed of 18 mph. The data points in the range of 2,000 sec represent vehicles that would have been traveling at 5 mph at the same time and in the same traffic stream as the other vehicles traveling at almost 20 mph. Obviously, these few data points represent spurious matches and can be eliminated from the data.

Another method for reducing the number of spurious matches compares smaller time intervals, which reduces the chance of spurious matches. Figure 5 shows 1 hr of data. The travel time is hard to distinguish because of the large number of spurious matches and the variation of traffic speeds over that fairly long time period. A 15-min segment during this same hour produced the data shown in Figure 6, in which the travel time is distinguishable at 320 sec. The three outliers in this 15-min segment are easily recognized and eliminated. This method is actually quite similar to placing constraints on the minimum and maximum travel times, but it allows those constraints to vary over time, just as traffic conditions may vary over time with congestion.

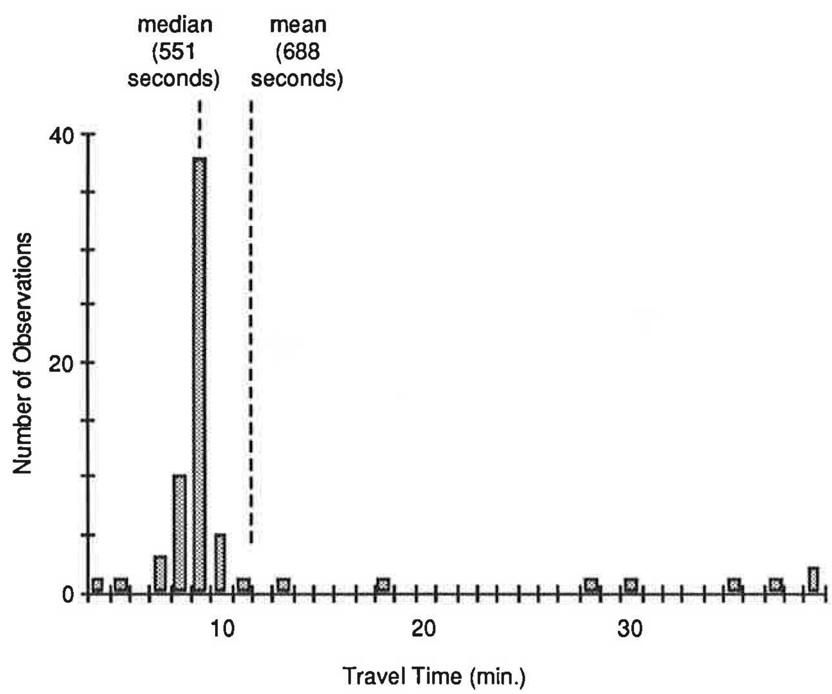

FIGURE 3 Median versus mean for travel time data (1 hr, 3 digits).

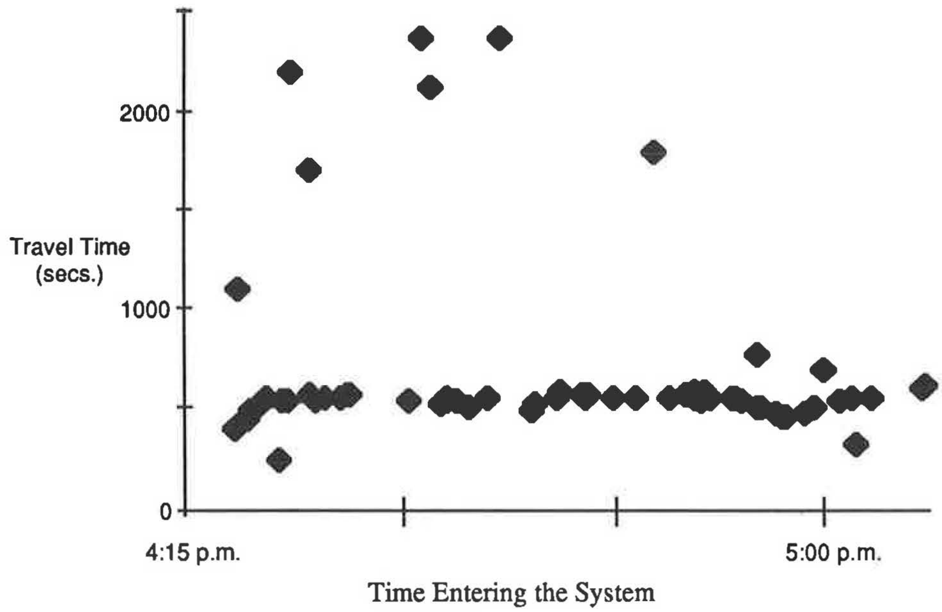

FIGURE 4 Travel time data (1 hr, 4 digits).

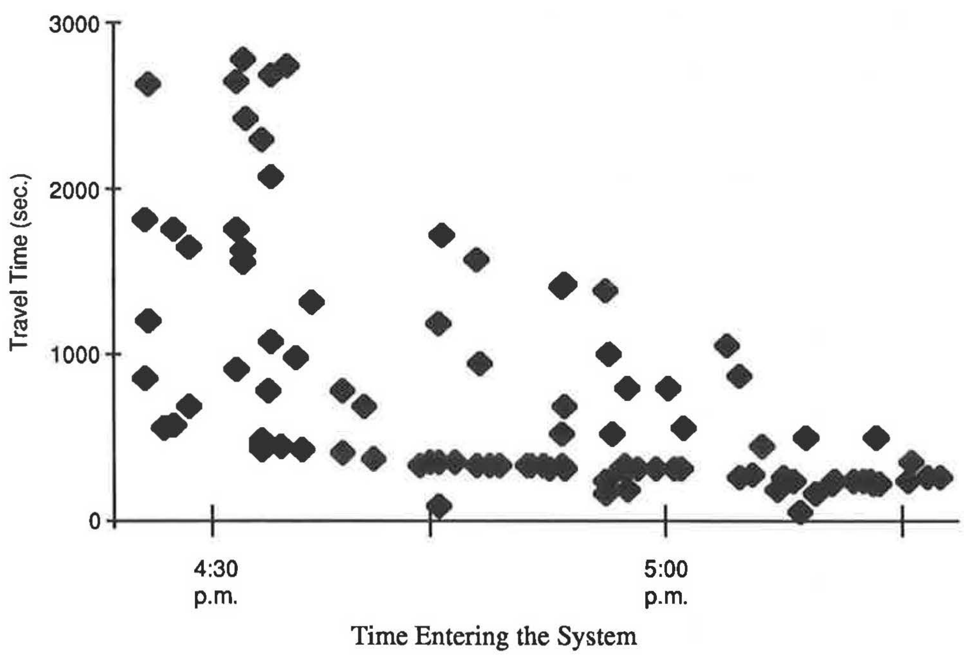

FIGURE 5 Travel time data (1 hr, 3 digits).

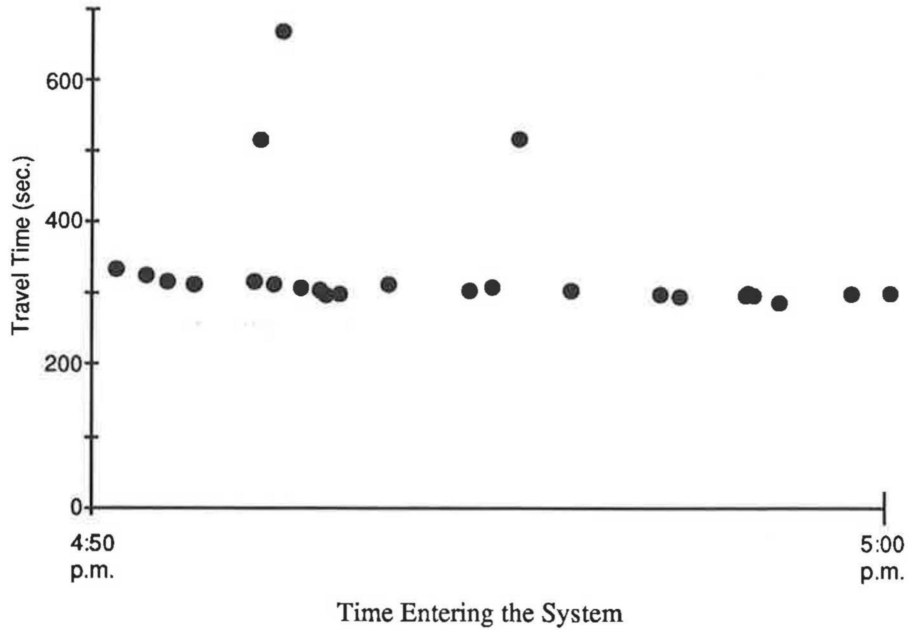

FIGURE 6 Travel time data (15 min, 3 digits).

Recording more digits of the license plates is also a way to eliminate spurious matches. The number of spurious matches is statistically related to the uniqueness of the number recorded and thus the number of digits. In the case of license plates, if the whole license plate is recorded, spurious matches occur only because of errors in data entry. However, observers have difficulty recording the whole license plate, and so the question becomes, how many digits are needed? The data shown in Figure 4 are 1 hr of matches from the freeway section described earlier. Four digits of license plates were recorded. These data contrast with the data in Figure 5, also collected for 1 hr on the same section of highway, but with only three recorded digits. With three entered digits, spurious matches become difficult to distinguish from the real matches, but with four digits, the erroneous matches are easy to determine. This examination was repeated several times with different data sets. Through statistical analysis it was determined that four-digit entries provide the best combination of ease of data entry and a low level of spurious matching.

LICENSE PLATE AND FLOATING CAR SURVEY COMPARISON

As part of the development of the computerized license plate matching system, the floating car and license plate matching methodologies were compared. Parallel data sets were collected using both the computerized license plate method and floating car surveys. Four tests were conducted on three arterials in Bellevue, Washington, a suburb of Seattle. Streets involved in the comparison were NE Eighth Street, Bel-Red Road, and 148th Avenue.

Highlights of the resulting comparisons are shown in Table 1. In all cases, the number of staff needed for the license plate travel time study was equal to or less than the staff required for the floating car methodology.

As Table 1 shows, the license plate methodology collected more travel times than the floating car methodology in all cases (ranging from 1.83 to 15 times the floating car data collection). In the case of NE Eighth, the majority of vehicles entering the study area turned off the study arterial to access parking within the study area, rather than reaching the far end of the study area where the second observer was located. An observer located in the middle of the study area obtained a substantially greater number of matches than shown in this table, both from the entry point to the middle of the arterial and from the middle of the arterial to the exit point. These travel times confirmed the original NE Eighth estimate.

As expected because of the fairly high variation in travel times associated with arterial travel time runs, the travel times for the license plate survey usually differed slightly from the floating car survey (see Figure 7). This difference was not statistically significant in any of the test cases. One interesting finding of the comparison was that the standard deviation of the license plate travel times was higher than the standard deviation of the floating car runs.

This difference, it is believed, was caused by a number of factors, including the following:

- The same drivers made all of the floating car runs, and their driving habits may have caused the runs to be very similar.
- The floating car drivers were told to "drive the average speed." Therefore they tended to drive consistently from trip to trip and passed about as many cars as passed them. Thus no extreme travel times were likely to be included in the floating car runs.
- The travel time runs were made in a loop pattern. This means that the drivers entering onto the study arterial had to turn from a side street to enter traffic. Their entrance required a break in the oncoming traffic. As a result, the floating cars tended to enter the study area at the same part of the signal

TABLE 1 COMPARISON OF FLOATING CAR AND COMPUTERIZED LICENSE PLATE TRAVEL TIME METHODS

	Mean Travel Times		Number of Travel Time Runs		t - statistic*
	Floating Car	License Plate	Floating Car	License Plate	
Bel-Red Road Eastbound PM	590	590	5	27	0
148th Avenue Southbound PM	453	487	3	45	-0.44
NE Eighth Eastbound PM	242	264	6	11	-0.40
148th Avenue Southbound AM	247	257	5	38	-0.27

* The Student's T statistic is used here to compare the mean travel times of the two travel time distributions. All t values are within the critical T value at the level of alpha = 0.005, and the associated degrees of freedom for each test. This indicates that there is no statistical difference between the two travel time methodologies.

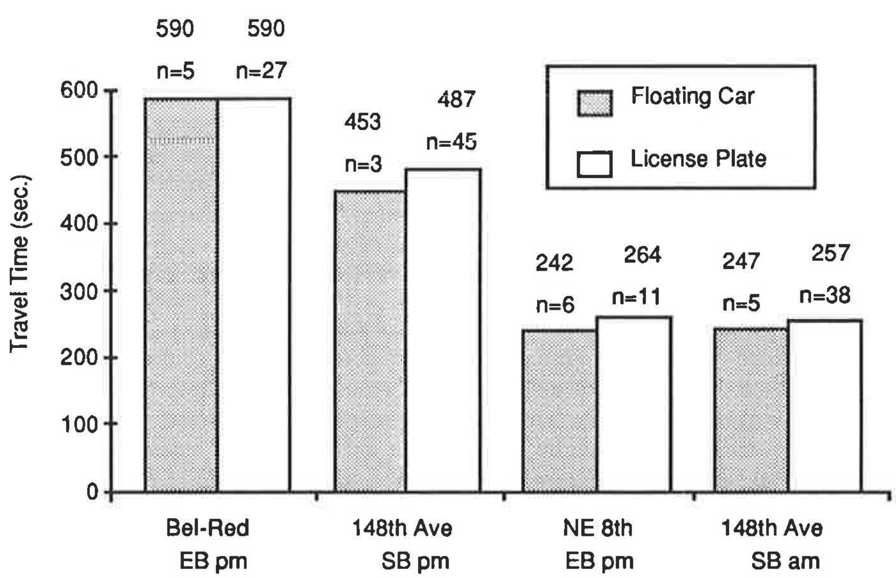

FIGURE 7 March floating car versus license plate travel times.

cycle each trip. This situation probably resulted in more consistent trip times than if the floating car had reached the beginning of the study area at random times in the signal phasing.

T-tests were used to statistically compare the travel times collected with the two methods. In addition to the full arterial travel times, these tests were also applied to the travel times collected for partial trips through the arterial. Table 1 shows that there were no statistically significant differences between the floating car and license plate methods when the entire arterial was examined. In only 1 out of 11 cases were the travel times measured over the partial arterials statistically different, and this instance occurred most likely as a result of the floating car runs making or missing a single traffic light more often than the vehicles measured with the license plate method.

As a result of the above comparisons, it was concluded that the license plate survey methodology produces results that are statistically the same as the floating car results. However, the larger number of observations in the license plate survey data set means that the results produce a higher level of statistical confidence in the estimates of mean vehicular travel time than the results of the traditional floating car method.

DATA COLLECTION CONSIDERATIONS

Basic Considerations For Performing License Plate Studies

The data collection teams that used the lap-top computers for the license plate studies noted several considerations that would improve the ease and reliability of computerized license plate surveys:

- Read the license plate as the vehicle approaches. This is especially important at higher speeds on freeways.
- Use observation points above the traffic stream when possible. Often the angle of the approaching vehicles makes the license plate difficult to read if the person is not above the traffic while recording the data.
- Concentrate on one lane of traffic. If a person is not used to recording plates for each lane of traffic, then one lane should be selected to increase the probability of matches. This process does raise a question about the travel time in different lanes. Two studies conducted by the authors indicated that travel times can differ statistically from lane to lane.
- Read as many plates as possible. Some plates are dirty, mangled, or missing on the front bumper, but the point of the study is to match as many plates as possible, so the data collectors should try to record all they can.
- Errors can occur if the plate is read or entered incorrectly or the number is transposed. The data should be checked for errors if possible. For example, if one computer is recording capital letters and the other is not, then matches will not result unless the matching program can account for this.

Extra Considerations For Arterial Data Collection

Arterials pose a special problem for license plate matching data collection. The largest drawback of the license plate matching scheme is that data are not collected along the length of the arterial but are only collected where observers are stationed. In addition, the data collected are only cumulative data (reflecting the time needed to reach a specific point); the collected information does not reveal the number, location, or extent of specific delays that vehicles encounter as they travel between two points.

The loss of specific delay information makes placement of observers especially important. Observers must stand where the most useful data will be obtained. In addition to the basic criteria for placing observers, described above, another important consideration for arterials is whether the data should be collected before or immediately after an intersection. Data collected immediately after an intersection (Observer X in Figure 8) include the delay time at that intersection. Data collected before an intersection (observer Y in Figure 8) do not include delay time at that intersection.

The difference between these two data collection points may or may not be important, depending on the objective of the data collection effort. If the intent is simply to compare before and after conditions, the only consideration is to ensure that the before and after studies collect data at the same point. Other than that, the inclusion of the delay at any particular intersection is important only if the delay at that intersection is important to the study. For example, if the signal is the last signal in a coordinated group of signals and the study is trying to measure the time required to pass through the coordinated lights, the delay time at the final intersection should be included in the travel time estimate.

Collecting data after vehicles cross the stop line (from Position X) is the generally accepted location. The difficulty with collecting from this location is that observers often have trouble reading the license plates of vehicles in the second and later rows of a platoon that starts from a green light at that intersection. The tightness of a platoon starting up from a

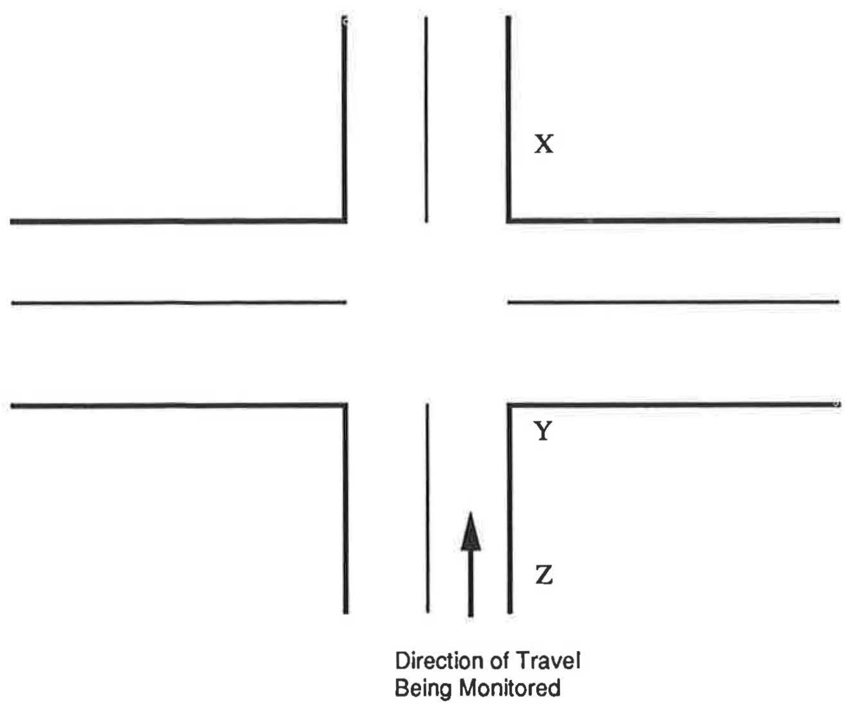

FIGURE 8 Options for arterial observer locations.

green light also causes a large number of vehicles to pass the observer in a very short time. In many cases, the combination of these two factors significantly reduces the percentage of vehicles passing a point that are entered into the license plate matching files.

To increase the number of license plates entered into the file, licenses can be entered when the approaching vehicles reach the back of the queue at the intersection (or the stop line when there is no queue). This procedure allows data on the delay imposed by that signal to be lost, but it usually increases the number of vehicles entered into the matching file. This increase occurs because the vehicles reaching the back of the queue at an intersection tend to be more dispersed and slow as they approach. Both these factors improve the observer's ability to read and enter license plates. Choosing Position Y over Position X also allows the observer to walk in the direction of travel (from Point Y towards Point Z in Figure 6) as vehicles queue. This movement further improves the observer's view and increases the accuracy of the license plate data entry.

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