
Appendix B

Phase I Final Report

1.0 Introduction

■ 1.1 Purpose of the Study

NCHRP Research Project 8-32(2), Multimodal Transportation – Development of a Performance-Based Planning Process, is intended to support a new era of transportation planning efforts at the federal, state, and regional levels. The impetus for these planning efforts is a series of factors that have not only increased awareness of a more broad range of goals and objectives for transportation, but have helped identify the diverse set of customers that the system must serve. These factors include:

- The ISTEA legislation with its emphasis on multimodal solutions and its long-range planning, financial planning, management system, and flexible funding provisions;
- Heightened concern about the most effective use of scarce resources in an era where traditional transportation funding sources are not generating sufficient revenue to meet perceived needs, yet the public continues to be in a “tax revolt” mood;
- Increased awareness and concern about the role of transportation in supporting economic competitiveness, as changes in the national and global economies place new demands on the transportation system, especially for freight and goods movement, and international trade agreements open new markets;
- Environmental laws and regulations and particularly the Clean Air Act and Energy Efficiency Act;
- Social and equity concerns reflected in legislation such as the Americans with Disabilities Act;
- Growth management, congestion management, and transportation/land use laws and regulations; and
- A variety of new technologies offering a wider range of transportation solutions including Intelligent Transportation Systems (ITS), alternative fuel vehicles, high-speed rail, etc.

This report documents the Phase 1 research which includes an inventory of the most recent research and applications in performance-based planning, development of a conceptual framework, and identification of methodological improvements to support application of performance measures to the planning process. A series of three regional “advisory group” meetings were conducted in Phase 1, and some of the more important findings from these meetings are incorporated into this report as well.

■ 1.2 The 8-32 Research Projects

NCHRP 8-32(2) is one of five projects which review emerging issues affecting planning and program decisions, assess current and new institutional and technical approaches, determine the steps required to address emerging issues, and develop a research action agenda. A 1993 workshop set a detailed research agenda, including five specific projects, of which 8-32(2) is one. The other four research projects in this series are:

- **8-32(1)** – Innovative Practices for Multimodal Transportation Planning for Freight and Passengers: The objective of this project is to identify examples of promising and innovating multimodal planning practices currently used for both freight and passenger transportation.
- **8-32(3)** – Integration of Land-Use Planning with Multimodal Transportation Planning: This project will provide planners and decision-makers with analytical tools that describe and measure the interrelationships between transportation facilities and services and land use on a regional and project-level basis.
- **8-32(4)** – Developing and Maintaining Partnerships for Multimodal Transportation Planning: This research will identify examples of successful partnerships in a variety of situations, and thereby develop strategies and tools for establishing such partnerships in freight and passenger transportation planning.
- **8-32(5)** – Multimodal Transportation Planning Data: The overall objective of this research is to develop guidelines on the availability and use of data to support statewide and metropolitan multimodal planning that meets ISTEA and subsequent regulations.

■ 1.3 The Work Program and Approach

The 8-32(2) Phase 1 work program follows closely the original research statement developed by NCHRP. That statement called for development of a framework and approach to transportation planning that integrates a broad set of objectives into a planning process focused on performance and outcome. The performance evaluation framework is to be applicable to a variety of surface transportation modes, to urban and rural settings, state and local contexts, freight and passenger movement.

The approach to this research statement incorporated five distinct tasks:

1. Assembly of a thorough inventory of the basic elements which comprise the performance-based process, including example goals, objectives, and performance measures, and the decision-making and planning approaches driven by the measures. Examples were drawn from the public and private sectors, from transportation and non-transportation fields. Sources included published plans, other research reports, interviews with practitioners, and focused case studies of current planning processes.

2. The case studies merit special mention, as they were an important source of information for this study. A broad range of transportation situations was included in the case studies, from statewide multimodal transportation planning efforts, to regional and facility-level implementation projects. We included multi-state undertakings as well as public-private partnerships and turnkey projects. Findings from these case studies are sprinkled throughout this Phase 1 report, and in some cases have been highlighted in text “boxes” within the report.
3. Development of a typology of goals and objectives, establishing relationships between the goals, objectives, and measurements of transportation system performance. The purpose of the typology in Phase 1 is to clarify how the selection of appropriate performance measures is a function of the particular goals and objectives, and further, how the data needs are in turn driven by the goals, objectives, and measures. The linkages between these elements of the process, and the feedback loops integrated into the process, are important defining features of a performance-based planning process.
4. Identification of analytical methods which could be necessary to operationalize a new generation of performance measures. These methods include data collection, storage, manipulation, and analysis procedures. A broad range of possible techniques, and potentially desirable methodological enhancements, are identified in order to accommodate a wide range of agency resources and needs.
5. Convening several advisory meetings to uncover examples of experience with performance-based planning techniques and to solicit feedback on the research to date. During 1995, three advisory meetings were conducted in Cincinnati, Portland (OR), and Atlanta. These meetings had a regional focus, involving participants from state DOTs, MPOs, transit authorities, and private owners/operators. The final advisory meeting was held in Washington DC, in April 1996, and include numerous participants from agencies and organizations with a national perspective, as well as additional local, regional and state agency participants.

Each of the first three tasks above culminated in a technical memorandum describing the research findings and conclusions. The three regional advisory meetings were documented in a separate memorandum. The findings of all five of these tasks have been integrated into this Phase 1 Final Report. The three technical memoranda, documentation of the 10 case studies, and a summary of the proceedings of the three regional advisory committee meetings were previously delivered to NCHRP and the Project Panel as an this Phase 1 Report when published in August 1996.

2.0 Experience to Date

This section provides a summary of the findings of our exploration into applications of performance-based planning methods within and outside of the field of transportation. The more complete documentation of this work will be found in Technical Memorandum No. 1, provided as an appendix to this report.

■ 2.1 Overview and Summary

The research documented in this section focuses on examples drawn from a wide range of sources. In keeping with the research statement for this project, there has been a special effort to investigate the use of performance measures in non-transportation fields and in non-governmental sectors to determine whether there are concepts or lessons which are of value in developing a framework for performance-based planning in the public transportation field.

This information comes from a review of recent studies from a variety of disciplines, as well as new interviews conducted by the research team. We have conducted a thorough review of public agency transportation planning efforts as documented in management system plans, regional transportation plans, and statewide plans. We have searched for examples of application of performance-based planning and management in the private sector freight transportation industry. Outside of the transportation arena, we have looked into private sector applications, such as the power generation industry and the services industry, as well as public sector applications including social services, education, and more.

Overall, this research has identified numerous worthwhile findings which offer guidance in the development and eventual implementation of a performance-based multimodal transportation planning methodology, as summarized in the following points:

- It is important to develop a methodological structure that can manage a potentially overwhelming number of alternative approaches and specific performance measures. To this end, it is useful to define broadly-acceptable categories and criteria to help select and organize performance measures in a way that improves their clarity and meaning. This structure and its various definitions and conventions then needs to be communicated to a broad audience to facilitate refinement and implementation of the concepts.
- A working definition of the terms that make up a performance-based planning framework is helpful, as evidenced by the wide variability found in recent applications. Suggesting common definitions of the terms “policies,” “goals,” “objectives,” “standards,” “strategies,” “recommendations,” etc., as simple as it sounds, will be very useful in developing broader understanding and application of the concepts. We provide suggested criteria for

defining goal and objective statements we believe will result in more “operational,” quantifiable statements.

- The concept of composite performance indexes which distill a variety of dimensions into a single measure is of interest to decision-makers, due to the potential complexity and volume of performance-related data. Experience gained in the regional advisory meetings, however, suggests that composite measures may mask important differences or nuances in the underlying data, and may be too coarse for evaluation of local and regional investment alternatives. Our proposed framework addresses this issue by accommodating both broad performance measures to guide long-range planning, and more specific evaluation criteria to be applied to more specific short-range planning tasks or implementation decisions.
- To date, the actual impact of performance measurement on the decision-making process has been somewhat limited. There are notable exceptions, but the evidence suggests that incremental application over time will be required to significantly alter the historical processes by which transportation investment decisions are made. As noted by participants at the Portland, Oregon regional advisory meeting, translation of the analytical process to policy formation and decision-making has been slow.

From the electric power generation industry come the concepts of *integrated resource planning (IRP)*, or *least cost planning (LCP)*, with potential application to transportation. These methods have taken a number of years to catch on in the utility industry, and it is likely that current efforts to apply IRP or LCP techniques to transportation will also require a significant amount of adaptation and time to infiltrate to any degree. Reasons for this include:

- Relative to the power generation industry, the greater degree of consumer choice in transportation leads to a significantly more complex mix of possible outputs, making it more difficult to actually measure productivity and to compare relative efficiency of competing alternatives. LCP techniques would require substantial enhancement to be transferable to the greatly varied world of transportation.
- As transportation planners, we have less complete knowledge about consumer response to both demand and capacity management strategies than do our counterparts in the utility industry. It is thus more difficult to isolate those measures which will best capture the effectiveness of alternative strategies, as well as more difficult to predict in advance the outcome of investment strategies which require long lead times.
- Relative to the utility industry, the public transportation sector has less information on total costs and benefits, and fewer and/or less sophisticated analytical tools. Ongoing efforts to identify the total costs and benefits of transportation, and to improve analytic capabilities to conduct the necessary evaluation of alternative strategies, will be of benefit in implementing performance-based methods in transportation.

A great deal of relevant information comes from the private service industries, where significant effort has been devoted to understanding the importance of the customer in defining and measuring performance:

- The relationship between customer satisfaction, productivity, and profitability is better appreciated in the service industry. Efficiency alone will not lead to sustained productivity or profitability; a high level of customer service and satisfaction is needed.
- Customer-oriented performance measures and standards are becoming the norm in service industries. This can be attributed in part to the increased competition for consumers' attention and business necessitated by the information technology boom. As customers have more immediate and complete access to knowledge about competitors' products and services, their perception of service and value will have an ever greater impact on choice among competing alternatives.
- Measurement of performance in the service sector bears certain similarities to that in the transportation sector. Important attributes of the products of the service industry include:
 - Services are often intangible, e.g., they are performances rather than products, for example maintaining ice-free pavement;
 - They are heterogeneous, that is, there is a wide range of variability in the acceptable standard of performance, making it difficult to compare across regions or customer bases;
 - They may be spontaneous in production and consumption, for example, a hair cut or a bus ride. This can actually be turned into a benefit, because it simplifies the collection of customer satisfaction data; and
 - They are generally more perishable than non-service outputs, in that once a service is provided, it has no "shelf life" and the customer has a short memory. The next bus trip must be just as good as the last to retain a positive customer perception.

These factors should be taken into consideration in determining *how* performance is measured in the transportation field, to the extent that a more service-oriented, customer-based approach is desirable.

Additional considerations gleaned from public sector, non-transportation fields include:

- Making goals *operational* versus *non-operational* is important in quantifying performance. A goal which can be unambiguously compared to an existing situation is operational. As an example, "reform criminals" is a non-operational goal; "double the rate of inmate participation in prison programs" is operational and can be *linked* to specific measures and effectively *tracked* with those measures.
- Measuring *outcome* rather than *output* is also a concept with value to transportation. While output is related to efficiency, outcome measures are a better indication of effectiveness. For example, "average length of hospital stay" is an output measure for the health care industry; "readmission rate" or "mortality" rate is a measure of outcome and effectiveness of the service. A transportation analogy might be "number of ice-related accidents" rather than "tons of salt applied." The former measures the outcome or impact of an effort or investment, the latter measures only the output of the crew.
- In comparative evaluation of organizations which compete for available funds, it is particularly important to isolate and account for external factors which impact outcome but not input. The same is true of transportation programs; the system of

performance measures needs to be concise enough to minimize the likelihood that external factors not picked up by the methodology are in fact responsible for the noted changes in performance measures.

These lessons are described in more detail in the following sections.

■ 2.2 Experiences in Transportation

The basis for any successful planning effort is a clear, concise, and achievable set of goals and objectives. This is neither new nor unique to performance-based planning. Unfortunately, the past practice has often been to de-emphasize or ignore broad-based goals and objectives shortly after plan development, as the focus progresses to evaluation and implementation of specific transportation projects. This is a relatively widespread short-coming of the current practice which performance-based planning can help address.

Certainly there has been a movement towards integration of performance criteria and project evaluation. ISTEA regulations have stipulated that there be consistency within all elements of the transportation plan, as well as between the plan and the projects which are eventually implemented. This explicit linkage has prompted most agencies to give more careful thought to the types of issues raised in the goals and objectives. There is now a greater tendency to integrate multimodal performance criteria in project evaluation to assess the achievement of the overall goals. However, our research and discussions with practitioners around the country strongly suggests that the linkages and feedback loops which are critical components of a successful performance-based process are not yet fully implemented in most cases.

2.2.1 Goals and Objectives

The composition of goals and objectives, as well as the terminology (“policies,” “goals,” “objectives,” “strategies,” “recommendations”) used to describe them vary widely in the transportation planning documents reviewed. Typically, however, the planning documents contain a series of very broad and general goals related to one or more policy areas, followed by a number of more specific goals or objectives. The following excerpts from recent statewide transportation plans illustrate this point:

- **“Manage, maintain, and expand system capacity**
 - Expand system capacity to relieve congestion and to facilitate interregional travel and commerce; and
 - Make cost-effective transportation investment decisions through the use of transportation management information systems.¹

¹ California Transportation Plan.

- **Goal #4: Transportation Safety and Convenience**

- Policy Statement B – Reduce injuries and property damage at Ohio’s rail-highway grade crossings; and
- Initiative: Upgrade Ohio’s 3,700 existing passively protected rail-highway grade crossings.”²

With reference to the previous comments about “operational” goals, one can see that some of these goals can be unambiguously evaluated and compared more readily than others. The following definitions are proposed to facilitate generation of operational goal and objective statements, and to promote understanding of the important nuances between performance-based planning and more traditional planning processes:

- **A goal is a general statement of a desired state or ideal function of a transportation system. For example,**
 - “Promote economic development.”³
 - “Protect the public’s investment in transportation.”⁴
- **An objective is a concrete step towards achieving a goal, stated in measurable terms, e.g.:**
 - “Reduce the number of commercial vehicles that exceed legal weight limits on the State Highway System.”⁵
 - “Reduce the number of at-grade railroad crossings.”⁶
- **Objectives may have specific performance standards which set out in clear, numerical terms a desired or required degree of achievement:**
 - “Provide transit service in all urban areas/corridors with more than xxx population.”
 - “Travel times in urban areas/corridors should not deteriorate below 1994 levels.”⁷

We found that relatively few of the planning documents we reviewed included specific, quantifiable performance *standards* which related to objectives. Thus, for example, there were many objectives found which called for “improving” or “reducing” a particular

² Ohio Statewide Transportation Plan, Access Ohio (October 1993).

³ Transportation Choices 2020; Part One, The Policy Framework (New Jersey DOT, December 1994).

⁴ 2020 Florida Transportation Plan.

⁵ Ibid.

⁶ Mississippi draft final Statewide Transportation Plan (November 1994).

⁷ Sample policy paper from the Texas Transportation Plan Issue Committee Notebook (Dye Management Group, 1994).

condition or occurrence, but it was less common to find *relative* numeric targets, e.g., “improve by 30 percent...” and even more unusual to see *absolute* targets such as, “reduce to XX the number of...”. The relative absence of such numeric performance standards may be due to agencies’ understandable reluctance to establish such a specific target without first gaining some experience with these new objectives and measures. While we have had Level of Service and other common measures around long enough to know what constitutes a “good” or “acceptable” standard of performance, this is less the case with many other quantitative measures such as delay, travel time, accessibility indices, etc. (See box below.)

Oregon Benchmarks as Performance Standards

The topic of performance standards was debated at length during the Portland, Oregon regional advisory meeting in November 1995. The Oregon Benchmarks define specific standards or thresholds of performance to be attained on a great variety of public policy matters, not confined to transportation. The Benchmarks affecting transportation include standards such as, ‘increase to 60 percent by the year 2010 the percentage of Oregonians who commute to and from work during peak hours by means other than a single occupant vehicle, or, increase to 88 percent the percentage of Oregonians who commute 30 minutes or less (one-way). Proponents of standards contend that a clearly-defined target, even if it proves to be unrealistic, is necessary to initiate meaningful action on the part of planners and decision-makers alike. Opponents counter that pursuit of standards tends to distort the planning process, diverting attention away from underlying objectives. Decisions become optimized to achieve certain targets, and “the solution becomes the goal.”

To avoid a situation in which the broader goals and objectives are lost in the pursuit of numerical targets, participants agreed that if standards are to be set, they should be flexible, rather than set in law, and should be incremental, so that periodic “successes” can be observed and revisions made to the process as necessary. A range of goals, rather than a single overriding goal, should be addressed by the standards, to reduce the likelihood of getting stuck on a single, possibly unattainable, goal.

Source: Regional Advisory Meeting, Portland, OR, November 1995

2.2.2 Issues that Drive Goals and Objectives

In preparing their transportation plans, state DOTs, MPOs, and other planning agencies address a wide range of issues. In identifying these issues, the agency defines, in effect, the role of their transportation system. For instance, by identifying “quality of life” as an issue for consideration in their Statewide Plan, the state of Missouri has established that the transportation system has a role in maintaining and enhancing quality of life, whether by easing congestion, providing disaster relief, or otherwise affecting the human environment. This notion of the *role* of the transportation system is continued in our later discussion of the performance-based planing framework, where we note the importance of defining goals and objectives that can be demonstrated to relate to the basic roles of the transportation system in society.

A recent survey of state transportation plans was performed in conjunction with the National Transportation System Framework/U.S. DOT Restructuring Process. This survey

included a review of 20 statewide intermodal transportation plans and management system work plans. This research was used to help identify the wide variety of issues addressed in these plans, and was supplemented by a review of management system work plans at the MPO level and of other county and local plans.

Table 2.1 presents 37 issues identified in the review of statewide planning efforts. The statewide plans were found to be the most comprehensive in terms of the breadth of goal and objective statements, as compared to the MPO, county, and local plans. Of the 20 states surveyed, as few as four and as many as 31 goal statements were identified in the plans. In some cases, however, a single goal statement has been defined so as to encompass a number of topics. For instance, one of Florida's goal statements encompasses mobility, environment, community values, and energy conservation.

The examples in Table 2.1 show that virtually all states surveyed addressed safety, economic development, the environment, system preservation, and intermodal efficiency. The influence of the ISTEA legislation is quite clear in this sample. On the other hand, relatively few states addressed issues such as improving the state DOT work force, rural development, and improved construction techniques. The sheer range of goals suggests that any framework for performance-based planning needs to be flexible rather than prescriptive in order to accommodate the different needs of different users.

2.2.3 Categories of Goals and Objectives

The breadth and depth of issues identified by transportation planning agencies produce challenges for decision-makers. Even if adequate information is provided for each issue identified, tradeoff decisions become increasingly complex as the volume of information multiplies. It is useful, therefore, to group the issues into broader categories, for which appropriate goal and objective statements can then be formulated. This will in turn keep manageable the number of performance measures adopted, and ensure that the measures and goals can be traced back to an identified issue raised during plan development.

The following nine categories of goals and objectives arise from the review, and are suggested for use in further development within the framework:

1. Economic Development;
2. Environment;
3. Safety;
4. Efficiency;
5. System Preservation;
6. Mobility;
7. Equity;
8. Stable Funding; and
9. Customer Service.

Table 2.1 Issues Cited in Statewide Transportation Plans

STATE	AL	CA	FL	ID	IL	IA	MD	MN	MS	MO	MT	NJ	OH	OR	SC	VT	WA	WV	WI
Economic Development	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cost Reduction	✓	✓				✓		✓		✓		✓	✓	✓			✓		✓
Environment	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓		✓
Safety	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	
Freight/Pax. Coordination	✓					✓	✓	✓	✓			✓	✓		✓		✓		✓
Mobility Disadvantaged	✓	✓	✓							✓	✓		✓	✓					
Intermodal Efficiency	✓	✓		✓	✓			✓	✓		✓	✓	✓	✓	✓		✓	✓	
Energy	✓	✓	✓	✓	✓	✓			✓			✓	✓	✓	✓		✓		
Public Involvement	✓	✓		✓		✓		✓		✓		✓	✓	✓	✓		✓		
Efficiency	✓	✓		✓		✓	✓	✓			✓	✓	✓	✓	✓	✓			✓
Rural Development	✓	✓									✓			✓					
System Presentation		✓	✓	✓	✓			✓	✓	✓	✓		✓	✓		✓	✓	✓	✓
Mobility		✓	✓		✓	✓	✓		✓	✓		✓	✓	✓					✓
Community Values		✓	✓		✓	✓		✓				✓		✓			✓		
Non-Highway Modes	✓	✓	✓	✓	✓		✓	✓			✓	✓		✓	✓			✓	✓
Congestion	✓	✓	✓	✓			✓			✓	✓	✓		✓			✓	✓	✓
New Technology		✓		✓	✓	✓		✓		✓	✓	✓		✓	✓				✓
Improve Planning Process		✓		✓	✓	✓				✓	✓	✓	✓	✓	✓				
Public/Private Partnerships	✓	✓		✓	✓	✓				✓	✓	✓	✓	✓	✓		✓		✓
Stable Funding		✓		✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓		
Multimodal Alternatives		✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓
Convenience						✓							✓				✓		
Accessibility		✓		✓		✓		✓		✓	✓	✓		✓		✓	✓		✓
Tourism, Recreation		✓				✓				✓	✓	✓		✓					
Quality of Life		✓					✓			✓		✓	✓	✓		✓			✓
Innovative Financing		✓					✓						✓	✓	✓				
US-Internat'l. Connections		✓	✓	✓				✓		✓	✓			✓		✓	✓		✓
Land Use & Transportation		✓	✓	✓		✓		✓		✓	✓	✓		✓	✓		✓		
Management Systems		✓							✓		✓								
Improve Const. Techniques											✓								
Crime/Security				✓						✓		✓		✓					
DOT Work Force																✓			
Pay Debt Service																		✓	
Improve Rail			✓			✓								✓				✓	
Improve Aviation			✓			✓								✓				✓	
Improve Air Quality		✓												✓	✓			✓	
New Construction									✓										

Source: State Transportation Plan Review, NTS Framework/USDOT Restructuring Process

Table 2.2 presents these categories of goals and objectives, and the more specific topical areas that are associated with each.

Several statewide plans recognized the need to improve customer service and develop a user-oriented transportation system. Consequently, customer service was added to the general categories for goals and objectives shown in Table 2.2. Iowa’s Transportation Plan, for example, is characterized as a report to Iowa’s “transportation customers.” In Missouri, “The Long-Range Transportation Plan will ensure that the Missouri Highway and Transportation Department proactively involves its customers from both the public and private sectors in the transportation decision-making process.”⁸

One of the most extensive uses of customer satisfaction measures to date has been undertaken by the Minnesota Department of Transportation (see box, below) where customer surveys will provide a significant portion of the data needed to generate performance measures. Another innovative customer service-oriented measure has been proposed for the Michigan CMS. The proposed measure is a log of consumer complaints classified by type and location to reflect the qualitative aspects of system performance. Also, in addition to standard performance measures, the Michigan CMS will allow the user to define custom performance measures through its ad hoc query capability and linkages to other management systems.

As shown in Table 2.2, all of the more specific topics can be related to one or more of these general categories. For example, congestion is relevant to both environmental quality and economic development. Also, concerns about stable funding sources for transportation appeared often enough to warrant its own general category, but the need for equity in the funding mechanism was also recognized by several goals. Thus, goals and objectives may overlap in several categories, suggesting that multiple performance measures might be used to track an issue (e.g., funding) from more than one view point, allowing decision-makers to “triangulate” on a best compromise solution where different users have different desired outcomes.

For example, the general goal of congestion reduction might result in one objective statement addressing economic development, such as “manage or reduce roadway congestion in the periods surrounding the peak hours” to maintain the economic viability of local and regional surface freight operations. A second objective statement addressing system efficiency might be “manage roadway congestion to a level consistent with efficient utilization of multimodal system capacity” which is aimed more directly at equilibrating congestion levels (and thus travel times or costs) among competing alternative modes. Each objective statement can be supported by performance measures which track different data, e.g., off-peak travel times on truck routes, versus differential travel times for defined trips in corridors with competing modes.

⁸ Missouri Long-Range Transportation Plan policy document.

Table 2.2 Issue Categories for Goals and Objectives

Economic Development <ul style="list-style-type: none">– New Technology– Congestion– Freight/Passenger Coordination– Rural Development– Tourism, Recreation– Quality of Life– International Connections– Improve Rail– Improve Aviation– New Construction	System Preservation <ul style="list-style-type: none">– Management Systems
Environment <ul style="list-style-type: none">– Congestion– Non-Highway Modes– Multimodal Alternatives– Land Use & Transportation– Improve Air Quality– Energy	Mobility <ul style="list-style-type: none">– Non-Highway Modes– Multimodal Alternatives– Convenience– Accessibility
Safety <ul style="list-style-type: none">– Crime/Security	Equity <ul style="list-style-type: none">– Community Values– Rural Development– Non-Highway Modes– Multimodal Alternatives– Improve Planning Process– Quality of Life– Land Use & Transportation– Public Involvement– Mobility Disadvantaged
Efficiency <ul style="list-style-type: none">– Cost Reduction– Congestion– Freight/Passenger Coordination– Non-Highway Modes– Multimodal Alternatives– Improve Planning Process– Intermodal Efficiency– Energy– Improve Construction Techniques– DOT Work Force	Stable Funding <ul style="list-style-type: none">– Public/Private Partnerships– Innovative Funding– Pay Debt Service
	Customer Service <ul style="list-style-type: none">– Customer Perceptions of Organization and System Performance

Focusing on the Customer – Mn/DOT’s “Family of Measures”

The Minnesota Department of Transportation (Mn/DOT) began its current Strategic Management Process in 1992 to involve citizens in clarifying transportation issues and needs. As a result of that process, Mn/DOT produced their *Family of Measures*, an organizational performance measurement framework, in 1995. This document presents the following vision for Mn/DOT: “to pioneer, from the *customer’s* (emphasis added) viewpoint, a seamless transportation system that offers more choice, flexibility, and ways of moving people and goods.”

The *Family of Measures* also presents some valuable core concepts of Mn/DOT’s performance measurement philosophy. One concept notes that “a well known principle of measurement states that what is measured gets most of the attention. The right measures, then, provide strong reinforcement of the key results that Mn/DOT wants to achieve.” A second provides some criteria for good performance measures. Mn/DOT asserts that the best measures are:

- Directed at what the customers think is most important;
- Aligned to support organizational priorities and strategies;
- Part of a family that is not too large or too small;
- Not always easy to implement, taking some work;
- Developed by the people closest to the work; and
- Providing frequent feedback to those doing the work leading to improvement.

With the *Family of Measures*, Mn/DOT has demonstrated an innovative, strategic approach to measure, track, and evaluate whether customer needs and public goals are being met with the most efficient use of resources. Customer satisfaction will be measured at least in part through market research surveys which will determine customer perceptions of system performance (e.g., condition, safety, commute time), public values and issues (e.g., satisfaction with air quality, promises kept on project completion), and organizational performance (e.g., employee satisfaction with diversity efforts, management perception of progress).

Source: Minnesota Department of Transportation, *Family of Measures*, February 1995.

2.2.4 Example Goal and Objective Statements by Category

Review of the many planning documents revealed almost as many styles in formulating goal and objective statements. One MPO’s “goal” may be another state’s “objective.” This can present a stumbling block for developing a performance-based planning process, since the process begins with goals and objectives, and includes multiple checks and feedback loops to monitor progress toward meeting those goals and objectives. To gauge the breadth of agency approaches and to seek to reconcile contrasting styles, we built on the definitions presented above. We inventoried examples of goal and objective statements currently used in practice, and present them in Table 2.3. In some instances, we moved a stated “goal” into the “objective” category, or vice versa, so that the statements are consistent with our proposed definitions. The examples help to further illustrate the incrementally more specific and quantifiable nature of objectives relative to goals.

Table 2.3 Example Goals and Objective Statements by Category

Category	Goal	Objective
ECONOMIC DEVELOPMENT	<ul style="list-style-type: none"> Address anticipated demand from increase in international trade. (Montana IMS) 	<ul style="list-style-type: none"> Improve access to passenger and freight facilities to serve international markets. (New Jersey’s “Transportation Choice 2020”)
ENVIRONMENT	<ul style="list-style-type: none"> Develop projects that are environmentally acceptable. (Alaska Intermodal Transportation Plan) 	<ul style="list-style-type: none"> Improve air quality in Texas through transportation measures. (Texas Transportation Plan)
SAFETY	<ul style="list-style-type: none"> Ensure high standards of safety in the transportation system. (Mississippi Statewide Transportation Plan) 	<ul style="list-style-type: none"> Reduce the rate of motor vehicle crashes, fatalities, and injuries, and bicycle and pedestrian fatalities and injuries on highways. (2020 Florida Transportation Plan)
EFFICIENCY	<ul style="list-style-type: none"> Develop strategies that improve the transfer of people and goods between modes, private facilities, and publicly owned systems by reducing delays and minimizing inconvenience, thus providing a more “seamless” transportation system. (Tucson, Arizona IMS) 	<ul style="list-style-type: none"> Utilize economies of scale by providing for joint use of ports by several tenants. (West Virginia Statewide Transportation Plan)
SYSTEM PRESERVATION	<ul style="list-style-type: none"> Preserve the highway infrastructure cost effectively to protect the public investment. (Washington Statewide Multimodal Transportation Plan) 	<ul style="list-style-type: none"> Improve construction techniques and materials to minimize construction delays and improve service life of transportation improvements. (“Access Ohio,” Ohio’s Statewide Plan)
MOBILITY	<ul style="list-style-type: none"> Work with the general public, public agencies, and private sector organizations to ensure basic mobility for all Michigan citizens by, at a minimum, providing safe, efficient, and economical access to employment, educational opportunities, and essential services. (Michigan Long Range Plan) 	<ul style="list-style-type: none"> Make public transportation travel time competitive with autos. (Oregon IMS)

Table 2.3 Example Goals and Objective Statements by Category (continued)

Category	Goal	Objective
EQUITY	<ul style="list-style-type: none"> Cooperate with Vermont residents, towns, regions, and other state agencies and interested parties in making transportation decisions that balance the needs of the human and natural environment. (Vermont Long Range Transportation Plan) 	<ul style="list-style-type: none"> Modify the Access Management Plan to provide more clear guidance and emphasize the sharing of responsibilities with local jurisdictions. (Montana Statewide Intermodal Transportation Plan)
STABLE FUNDING	<ul style="list-style-type: none"> Provide stable and flexible transportation funding. (California Transportation Plan) 	<ul style="list-style-type: none"> Seek to obtain more funding through non-traditional sources such as grants and foundations. (South Carolina Intermodal Transportation Plan)
CUSTOMER SERVICE	<ul style="list-style-type: none"> Optimize transportation investment by focusing on customer satisfaction. (Minnesota DOT “Family of Measures”) 	<ul style="list-style-type: none"> Maximize information on service availability and intermodal options (Metro, Oregon DOT, Port of Portland “Intermodal Management System Scope Development”)

2.2.5 Performance Measures

The way in which an agency decides to measure system or facility performance will have a profound impact on the types of projects which one implements in order to enhance performance. For example, one concern with the California Congestion Management Program (CMP)⁹ is its use of roadway level of service (LOS) as the only mandated measure of system performance; projects which enhance LOS would be given priority by virtue of this definition of system performance.

Many agencies are now striving to avoid California's problem by defining several measures, rather than trying to define system performance through one measure. The ISTEA management systems effort is partly responsible for a rapidly expanding awareness of the value of moving to more numerous and broad measures of system performance. For instance, as part of Ohio's Congestion Management System (CMS), performance measures will include, as a minimum, LOS, travel time, transit load factors, delay, person-hours of travel, and a congestion index. Other agencies are also following this example, but are following a tiered approach in which use of more "innovative" measures will be phased in as data collection programs are modified to better fit the needs.

Dimensions of Transportation Performance Measures

Performance measures may be characterized along a number of dimensions. These many dimensions make the exercise of performance-based planning a difficult one. Performance measures may be related to the broad policy topics described in the previous chapter. This dimension is the most direct link of performance measures back to policy goals and objectives. Performance measures may also be classified according to whether they are multimodal or mode-specific, by whether the measures are applicable to freight or passenger transportation, by the system level to which they apply (systemwide, corridor, or facility), by the planning jurisdiction to which they are most relevant, and by their perspective. The perspective of a performance measure may be that of the user or that of the agency or operator.

It is instructive, therefore, to consider these dimensions in developing, selecting, and implementing a set of performance measures in a planning process. Not only may it help reduce analytical effort by eliminating some irrelevant performance measures, but it will also ensure that adequate breadth is instilled in the planning process so that all relevant issues are addressed.

Based on the research, the following dimensions of performance measures were identified:

- **Sector** – freight, passenger;
- **Mode** – highway (auto, truck, transit), pipeline, rail, water, intermodal, bicycle, walk, other non-motorized modes (electronic "modes" were also proposed by some);

⁹ CMPs are prepared by local California governments acting at the county level through a "Congestion Management Agency." It is separate from the federal CMS process.

- **Perspective** – user versus supplier, condition versus performance;
- **Concern** – economic development, environment, safety, efficiency, system preservation, mobility, equity, stable funding;
- **Type of Application** – policy, regulatory, programmatic, implementation;
- **Spatial Concern** – metropolitan (urban versus suburban), rural, intercity/interurban, interstate, international;
- **Level of Responsibility** – federal, state, regional, local;
- **Use of Information** – management decision-making, diagnostic tool, tracking and monitoring, resource allocation, signaling systems between users and suppliers, information systems;
- **Timeframe** – present/short-term, future/long-term, point in time versus trend; and
- **Level of Refinement** – data item versus performance measure, primary versus secondary indicator, surrogate versus desired primary indicator, original versus pre-existing/secondary choice, primary versus composite measure.

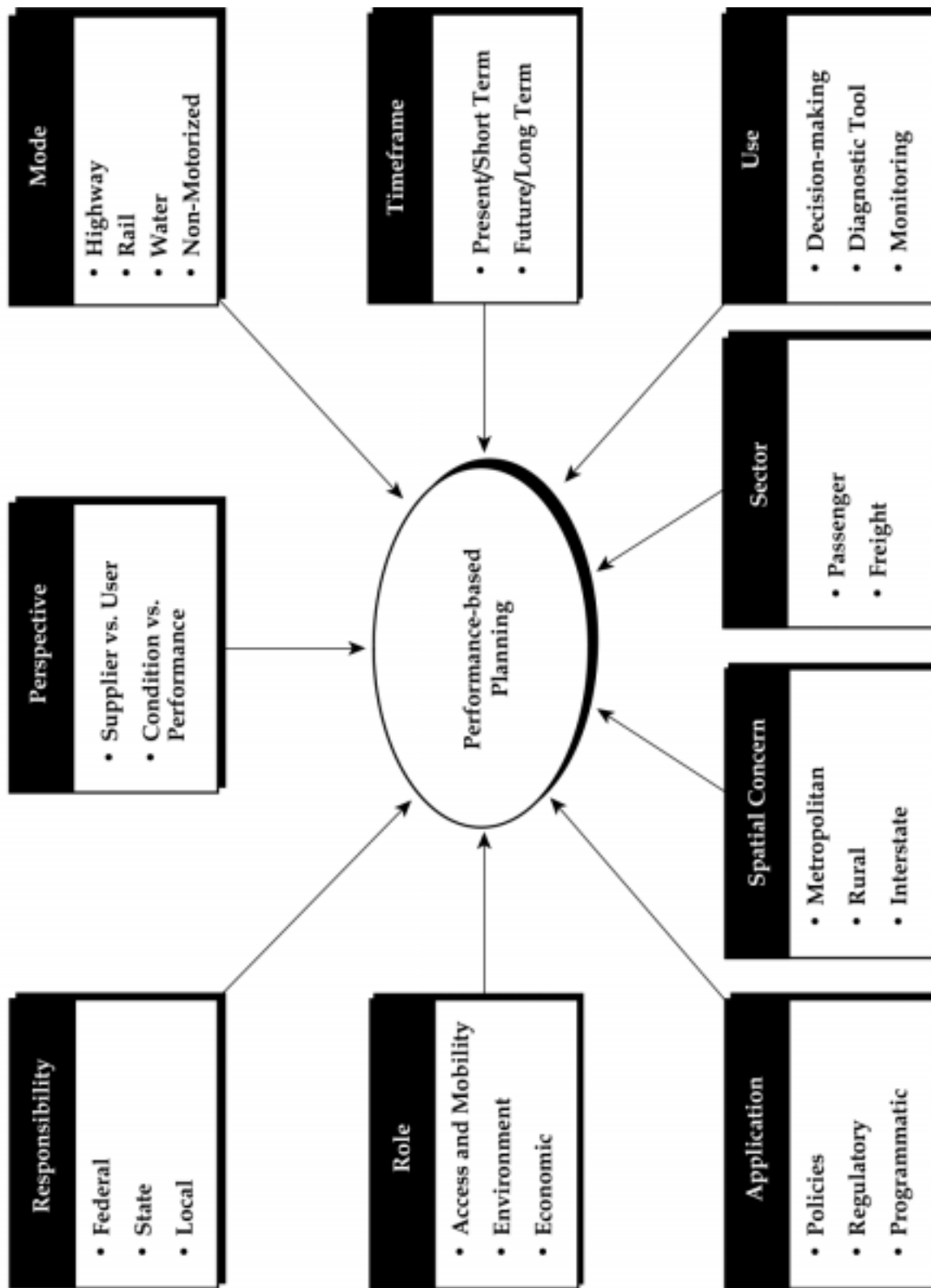
The categories in the dimensions listed above are not immutable. For example, the highway mode could be broken down even further into truck, bus, and auto. Most planning agencies categorize selected or proposed performance measures according to all or some of the dimensions listed above and shown in Figure 2.1. For example, the Michigan CMS workplan classifies proposed performance measures by system level (links versus systemwide trends), and by mode (highway, transit, person). The dimensions shown above are designed to encompass any number of classification systems.

Selection Criteria for Performance Measures

Several management system work plans and local and regional transportation plans laid out criteria for selecting performance measures as well as, or rather than, the measures themselves. These selection criteria are instructive as to agencies' concerns and the intended use of the performance measures. Agencies who used selection criteria usually were concerned with the actual "operationalizing" of the performance measures, and with the many different dimensions of performance measures listed in the previous section.

The following list presents common criteria for selection of performance measures and a discussion of each. It is adopted from a number of different sources, including Southern California Association of Governments' Regional Mobility Element, the Santa Clara County (CA) Subregional Deficiency Plan, and FHWA's *Analytical Procedures to Support a Congestion Management System*. Such a list can serve as a starting point to help planners select performance measures and balance the sometimes conflicting needs and limitations of decision-makers and analysts.

Figure 2.1 Dimensions of Performance Measurement



- **Measurability** – Is it possible to measure the performance measure with the tools and resources we have available? How much would it cost to adequately quantify this measure? What level of accuracy is needed for the measure to be useful? How reliable are the sources of data for this measure? Is needed data available?
- **Forecastability** – Can one realistically compare alternatives using this measure? Is it difficult to define this measure using existing forecasting tools?
- **Multimodality** – Does this measure encompass a number of different modes?
- **Clarity** – Is this measure understandable to policymakers? to transportation professionals? to the public?
- **Usefulness** – Is this measure useful? Is it a direct measure of congestion? Is it capable of diagnosing transportation deficiencies, i.e., a “triggering” device that will cause further study or action to occur?
- **Temporal Issues** – Is the measure comparable across time? That is, is it capable of expressing the magnitude, spatial, and temporal extent of congestion? Is it capable of discriminating between peak-period, off-peak, and daily congestion levels?
- **Geographic Scale** – Is the measure applicable to all areas of the state, region, local area? Can it discriminate between freeways and other surface facilities? Is it useful at a regional, subarea, or corridor level?
- **Multiple Indications of Goals** – How many of the project goals does the measure help to address? Is the measure relatable to thresholds that indicate how well the system is performing? Is it a measure of supply, demand, or both?
- **Control** – Is the characteristic capable of being controlled or corrected at the state and/or local government level?
- **Relevance** – Is the measure relevant to planning/budgeting processes? Does the reporting of these measures happen often enough to give decision-makers the information they need as often as they need it?
- **Ability to diagnose problems** – Is there a logical link between this measure and what actions/phenomena affect it? Is the measure too aggregated – to a level where a “black box” syndrome can occur?

Of course, selection criteria may vary from one agency to the next, depending upon need, resources, and capabilities. One common area of difference is in the degree to which agencies are willing or able to support new data collection procedures in order to implement new performance measures. We heard in the workshops and in our case studies that the cost and institutional obstacles to new data collection were an issue for many agencies, and a real “deal killer” for some. Therefore, some agencies will be most comfortable with measures that are readily quantifiable with existing data, and in most cases this will mean making do with a rather limited array of measures. Other agencies have already demonstrated a willingness to pursue useful measures of performance that required new data

collection efforts, or which will be supported by “surrogate” data until new data collections programs can be put in place. Each agency should learn to apply these selection criteria in a framework that suits their particular need and situation.¹⁰

Performance Measures by Category

Table 2.4 contains a list of performance measures associated with the categories listed previously. The list is not intended to be comprehensive; rather, it presents examples of how performance measures are used in practice. The list of measures was developed from a number of state and local planning documents. The research showed a great deal of overlap in the measures proposed by different agencies for different purposes. A measure taken from a CMS work plan, for example, might be found in numerous other sources, including other management systems.

Composite Performance Index

The concept of a composite “performance index” has been suggested as an efficient means to compare multimodal alternatives or to otherwise allow comparison across one or more of the “dimensions” described earlier. There are a few agencies that are actively pursuing variations of this concept. Among them, SCAG uses index values to assess mobility, the environment, finance, economic development, livable community, safety, and quality of service. Their mobility index, for instance, is a composite value of VMT, operating speeds, free flow speeds, average vehicle occupancy, and population.

This concept was the topic of discussion at a recent Management Systems Integration Committee meeting.¹¹ This meeting was attended by representatives from the states of Colorado, Florida, Missouri, Oregon, California, and Michigan, as well as FHWA. Representatives from the state of Colorado presented a suggested approach to a composite performance index that sought to reconcile the competing priorities of safety, infrastructure preservation, mobility, etc. After much discussion, the committee found that the Colorado approach is one possible method for integrating results of management systems in a manner that will support the planning and decision-making processes.

The group expressed concern, though, that composite performance indexes should not be used for project selection or prioritization. Management system professionals were encouraged to work to ensure that overall scores of performance are used only at the system level for funding allocation decisions and reports of overall system performance and status.

This concept is still under debate at a number of different levels. Although the composite concept may not evolve into practice, the debate process is positive. The attempt to address a wide variety of issues on a common scale is the first step toward developing a more effective way to evaluate and reconcile difficult tradeoff decisions. Decision-makers have indicated concern about their ability to grapple with multiple simultaneous measures.

¹⁰Pratt, R. and Lomax, T. *Performance Measures for Multimodal Transportation Systems*, presented at the 73rd Annual Meeting of the Transportation Research Board, Washington, DC, January 1994

¹¹FHWA, *Management Systems Integration Committee Meeting*, Denver, Colorado, January 1995.

Table 2.4. Examples of Performance Measures by Category

Category	Example Performance Measures
Economic Development	<ul style="list-style-type: none"> • Jobs supported • Economic costs of pollution, accidents, fatalities, lost time • Number of structures with clearance below 15 ft. 6 in.
Environment	<ul style="list-style-type: none"> • Change in tons of pollution generated • Change in tons of greenhouse gases generated • Number of transportation control measures accomplished versus planned
Safety	<ul style="list-style-type: none"> • Accidents/person-mile • Accidents at major intermodal crossings • Bicycle accidents per bicycle-mile of travel
Efficiency	<ul style="list-style-type: none"> • Work trips completed per vehicle hour of commute travel • Cost per revenue hour of transit vehicle • Vehicle-miles of travel/person-miles of travel (VMT/PMT)
System Preservation	<ul style="list-style-type: none"> • Percent of roadway/bridge system below standard condition • Percentage of budget allocated to system preservation activities
Mobility	<ul style="list-style-type: none"> • Mobility index (PMT/VMT times average speed or ton-mi/veh.-mi times average speed) • V/C ratio (or LOS) • Lost time due to congestion • Percent of population within “X” minutes of employment
Equity	<ul style="list-style-type: none"> • Percentage of investment in non-urban areas • Percentage allocation to various modes
Stable Funding	<ul style="list-style-type: none"> • Percentage of committed funds for plans • Tax and fee revenues and trends
Customer Service	<ul style="list-style-type: none"> • Customer perceptions of safety • Frequency of service • Response time to incidents

■ 2.3 Experience in Other Fields

We evaluated the application of performance-based planning concepts in other fields in an attempt to identify relevant, transferable lessons or methods. Several industries are of particular interest because of similarities with the breadth of issues and objectives that transportation system performance must address. These included the electric utility industry, the service industry, and several governmental agencies involved in delivery of services other than transportation

In the electric power generation and distribution field, performance has historically been oriented to minimizing rates within a set of service reliability criteria and subject to a reasonable rate of return. Cost control, efficient use of existing capacity, accommodation of co-generation (private competition), or environmental impacts were not significant factors until relatively recent times. The industry's response has been integrated resource planning, or least cost planning. Least cost planning, like most performance-based planning methods, has required new analytical tools, institutional structures, and data collection methods. Establishment of "energy collaboratives" has brought together utilities, regulators, private industry, and environmental and citizen interest groups into a joint decision-making framework, and the performance measures being considered have changed dramatically. The prospect of significant industry deregulation will reinforce this trend. An important lesson from the electric utility industry is to apply new planning methods incrementally, rather than attempt to impose a grand new scheme all at once, as considerable time and resources are required to effect the necessary change in institutional and organizational structures as well as analytical capabilities.

We also found relevant examples of performance measurement in the service industry, where customer service and customer satisfaction are a current focus of efforts to improve performance. Similar to transportation, the service industry must deal with many market segments and external factors. Virtually every service organization has been affected by recent economic trends, the quality movement, and recognition that rapid change in telecommunication and information systems technology is creating new opportunities as well as new risks for management. The implications of these factors for performance measurement are important to consider, even if, in many cases, the specific performance measures used by some industries are not directly applicable in a transportation context. For example, private sector practices highlight the importance of developing *customer-oriented* rather than *institutionally-oriented* measures of performance. The public transportation sector has begun to appreciate this distinction only in recent years, as already noted.

Other non-transportation public sector efforts in performance measurement were evaluated, including government programs at the federal, state, and local levels which have been the target of performance audits and evaluations. Pilot studies, such as those specified in the Federal Performance and Results Act, may be an appropriate method for implementing least cost or other performance-based methods in transportation. From the public sector, non-transportation fields come useful concepts such as operational versus non-operational agency goals, measuring efficiency (output) versus measuring effectiveness (outcome), use of performance measures for external evaluation versus internal decision-making, and recognition of the need to account for external factors when making comparative evaluations of programs.

2.3.1 The Electric Utility Industry

Electric power in the United States is provided by a mixture of public and private companies subject to a variety of governmental regulation. Regulatory bodies control the rates charged to customers and the return on investment earned by utilities. This situation has led to a somewhat different perspective on overall performance than that of a purely private industry. Since the rate of return is fixed, revenue requirements per kilowatt hour produced (i.e., the utility's cost of doing business) serve as the overall indicator of performance.

Revenue requirements per kilowatt hour are used, for example, by investors assessing the performance of utility companies or by utility companies themselves for assessing their bottom line.

Although revenue requirements reflect performance, the determination of costs that a utility company may pass on to its ratepayers is not entirely free of regulation (this insulates ratepayers from poor management decisions). In addition to other rules, utility companies must follow formal planning processes to determine the best combination of resources to meet the demand for power. Historically, utilities strove to select the lowest cost combination of supply resources (power generation plants, transmission lines, substations, and transformers) to meet the demand while maintaining reliable and safe service.

Industry Changes

While the basic planning process described above has not changed, a number of external factors impacting the industry have shifted its focus over the past decades. In an environment of ever-increasing demand, an expanding economy, and stable fuel costs in the 1960s, the planning focus was on providing reliable service while expanding capacity. In the 1970s, stabilizing or declining demand for power, high inflation and interest rates, fluctuating fuel prices, and a stagnant economy shifted the planning focus to finding the lowest cost combination of supply resources. With the 1980s and 1990s came an oversupply of capacity, environmental concerns, technology permitting efficient long-distance transmission of bulk power, selective deregulation, and increasing competition. In response to these factors, electric utility industry planning processes have evolved into the present-day integrated resource planning.

Integrated Resource Planning

Integrated resource planning may be defined as an iterative process to find the lowest total cost combination of both supply and demand management¹² resources that is consistent with maintaining service reliability and, increasingly, customer satisfaction. Regulatory agencies in many states now require utility companies to submit Integrated Resource Plans (IRPs) in support of their rate base cases. Thus, IRPs are a key element determining revenue requirements or overall performance.

Integrated resource planning typically includes four basic steps:

1. Identification of goals and key issues that the resource plan must address – Typical goals might relate to customer service, environmental protection, or return to company shareholders. Issues could include the disposition of an aging power plant or modification of demand-side-management (DSM) programs.

¹²Demand management resources include conservation programs, the promotion of energy efficient appliances to consumers, pricing mechanisms, and other Demand-Side-Management (DSM) programs.

2. Development of alternative load forecasts – Utilities use either an econometric approach or an end use approach to this task which also includes peak-period forecasting. The econometric approach relates the power consumption of an aggregate class of customers to economic variables. The end use approach relates power consumption of end users to their individual characteristics. Forecasts account for existing demand-side-management (DSM) programs.
3. Identification of need for additional resources – Utilities assess the costs and remaining lifetimes of existing supply and demand side resources to determine whether they are adequate to meet the projected demand. Supply resources such as power plants, electricity purchased from other organizations, and transmission and distribution (T&D) options are considered at the same time as DSM measures.
4. Assessment of broad array of alternatives – Utilities analyze different combinations of supply and demand resources in terms of their total cost and other stated criteria such as public acceptability, reliability, or socioeconomic impacts. Again, both supply and demand side options are considered at the same time. To minimize risk, uncertainty analysis is a key component of this step.

While specific practices and analytical methods vary widely from utility to utility, a guide sponsored by Oak Ridge National Laboratory outlined the characteristics of a good IRP. These include:

- Comprehensive and multiple load forecasts which treat peak loads and establish clear relationships with DSM programs;
- Thorough consideration of the full array of supply options including T&D options, purchased power, and renewable energy sources;
- Integration of demand and supply options;
- Thoughtful assessment of potential impact or implications of the inherent uncertainty of certain assumptions, projections, etc.;
- A full explanation of the preferred plan and its closest competitors;
- Use of appropriate time horizons (two to three years for actions plans, 10 to 20 years for planning, and 20 to 40 years to account for impacts);
- A short-term action plan that adequately documents a utility’s commitment to implement the long-term plan;
- Fairness (provision of information so that different interests can assess the plan from their own perspectives); and
- Clarity.

Not surprisingly, the practical application of integrated resource planning has presented considerable analytical challenges to the electric utility industry. Among the analytical

issues utilities must consider when preparing IRPs are the selection of appropriate time horizons, the explicit treatment of uncertainty, estimation of avoided energy and capacity costs, explicit consideration of reliability and reserve margins, quantifying environmental costs, and the analytical integration of supply and demand side resources. An ongoing body of research is addressing such issues over time and the IRP process will continue to evolve.

Application to Transportation Planning

There are many similarities between the electric utility industry and the transportation sector. Both industries have traditionally been capital-intensive and involved large public works projects. Both electric power and transportation services are provided by a mix of public and private entities. The private sector providers of both electric power and transportation services have been subject to increasing competition over the past two decades. Finally, the impact of both industries on the environment is a major concern.

Given the similarities between the two industries, the concept of integrated resource planning holds much promise for transportation planning applications. Indeed, there has been considerable recent interest in the concept which, when applied to transportation planning, is usually termed “least cost planning”¹³. Least cost planning principles would meet many of the requirements of ISTEA, including those for multimodal planning, public participation, and consideration of demand side strategies.

While current transportation planning practice incorporates some elements of least cost planning, the critical distinction is that least cost planning “develops a more complete set of demand and supply options, encompasses a wider set of objectives, and involves the participation of a broader range of parties.”¹⁴ As attractive as the theory of least cost planning seems for transportation planning, a number of practical and analytical difficulties remain to be worked out.

These difficulties stem in part from differences between the electric utility industry and the transportation field. The transportation field involves a greater level of consumer choice and produces a much more complex mix of outputs than the electric utility industry, thus complicating the application of least cost principles. For instance, there is no single, agreed-upon unit of production to represent the output of transportation systems. In energy planning, a megawatt saved is equivalent to a megawatt produced. In transportation, one of the more common “generic” output measurements is the passenger mile (or ton mile in the case of freight) but these units do not reflect accessibility, mobility, or qualitative considerations.

A study sponsored by the Washington State DOT outlines some of the practical barriers to implementing least cost planning principles to transportation. One major barrier listed

¹³The term “least cost planning” arose because the technique is intended to bring about the lowest total cost combination of supply and demand side components.

¹⁴Hanson, Mark, Stephen Kidwell, Dennis Ray, and Rodney Stevenson. “Electric Utility Least Cost Planning: Making It Work within a Multi-attribute Decision-Making Framework” *Journal of the American Planning Association* (57: 1), 34-42, Winter 1991.

was the lack of knowledge about consumer response to demand management strategies. The electric utility industry has much better information about consumer response to DSM simply because it has performed the necessary research (this barrier could be overcome in time). The study also cited a lack of analytical tools for analyzing comprehensive sets of alternatives, a lack of information on the total costs and benefits of travel, the political nature of transportation planning, and poor inter- and intra-agency coordination as barriers to least cost planning.

Apart from much academic attention, least cost planning principles have yet to be fully implemented by public transportation agencies. In the state of Washington, legislation passed in March 1994 requires regional transportation planning organizations (RTPOs) to use least cost planning methods in developing regional transportation plans. The legislation did not, however, offer any definition of least cost planning concepts or specific analytical methods. Development of guidelines and specific analytical procedures for the state is being overseen by the Puget Sound Regional Council (the MPO for the Seattle area). At present, there is not yet a body of practical implementation experience to draw upon. The Oregon Department of Transportation has also shown some interest in least cost planning, sponsoring a feasibility study on the subject. The feasibility study will be followed by a least cost planning case study to develop recommendations and implementation procedures.

Summary of Least Cost Planning Applications

Before applying least cost planning to transportation or even before developing analytical methods or models a number of changes must occur within the field. First, transportation planners and decision-makers must agree upon the definitions of least cost planning concepts. The means for costing various supply and demand options must then be agreed upon. Methods, procedures, and interagency coordination in the planning process would have to be improved. Finally, a set of performance measures to be used in comparing resource combinations must be agreed upon.

While the idea of least cost planning raises significant analytical challenges, it is both relevant and applicable to the transportation field as a conceptual framework. Perhaps the most significant lesson taken from the electric utility industry is that ideas like least cost planning should be implemented incrementally. Even after 10 years of development, least cost planning principles and practices are not fully standardized or agreed upon within the utility industry. With many people working on the same issues, however, the analytical problems will be solved over time. While the temptation is to implement least cost planning in one grand effort, an incremental approach will probably be more successful in translating least cost planning principles into practical performance-based planning methods.

As a final note, Least Cost Planning has its share of skeptics in the transportation planning arena. Integration of a sophisticated analytical process into the highly political transportation decision-making process may presume that we can rationalize the process to a higher degree than is realistic. One opinion states that we should incorporate these methods only as a guide in ranking projects or programs. We should first gain additional experience with these methods in cross-modal and interjurisdictional tradeoff applications, before attributing to them too much conflict-resolving power.

2.3.2 The Service Industry

Service industries are those included in Sections 6 through 9 of the Standard Industry Classification (SIC). They treat people or provide goods or facilities for them. The service sector is diverse, spanning industries such as tourism, financial services, health care, catering, and communications.

Service organizations have devoted increasing attention to concepts such as quality and customer service and the relationship between quality, customer satisfaction, productivity, and profitability are being explored. In this arena, “Good performance is defined as successfully achieving high resource utilization with a high level of customer service whilst meeting the cost and profit requirements of an organization. Thus, private companies are starting to recognize that productivity (i.e., efficiency) alone will not lead to profitability.”¹⁵

Some useful concepts may be drawn from recent literature on the subject. First, service quality may be measured internally, using a company’s internal monitoring systems or externally, using customer surveys and questionnaires. Service quality may be measured before, during, or after service delivery (for example, customers may be involved in specification of a product or service before it is delivered). Complaints are said to be a very poor measure of service quality since 65-90 percent of dissatisfied customers do not complain but merely do not patronize the business again, or do so less frequently.

One way service quality, productivity, and financial profitability may be linked together in service organizations is through establishing performance standards or targets. There are a number of types of performance standards including historical standards, internally-based standards (e.g., resources consumed to deliver a certain product), competitor-based standards, absolute standards, and best-in-field standards or benchmarks. Increasingly, however, organizations are moving towards customer-oriented standards. As an analogy, a highway department might move from measuring tons of salt spread on roads to measuring user safety by the number of accidents caused by ice.

Approach to Performance Measurement

Service sector managers approach performance measurement and control by focusing on four key characteristics of the industry that make the service sector distinct from a more tangible product-based industry (e.g., manufacturing). These qualities are:

- Intangibility,
- Heterogeneity,
- Simultaneity, and
- Perishability.

¹⁵Fitzgerald, Lin, Johnston, Robert, et al. *Performance Measurement in Service Business*, the Chartered Institute of Management Accountants, 1991.

First, most services are *intangible*. They may be performances rather than objects. Second, because service outputs are *heterogeneous*, the standard of performance may vary, especially where a high level of labor is involved. It is hard to ensure consistent quality from the same employee from day to day, and harder still to get comparability between employees – yet this will crucially affect what the customer receives.

Third, the production and consumption of many services are *simultaneous* in their production and consumption, for example, getting a haircut. Some elements of the service delivery process therefore cannot be counted, measured, inspected, tested, or verified in advance of sale for subsequent delivery to the customer. Fourth, services are perishable; that is, they can not be stored. *Perishability* thus removes the inventory buffer frequently used by manufacturing organizations to cope with fluctuations in demand. Therefore scheduling operations and controlling quality are key management problems in services, which are made more difficult by the presence of the customer in the service process. Although the simultaneity of production and consumption enables cross-selling and the collection of feedback from customers in real time, an unfavorable impression of the service process may erode a customer's satisfaction with the service product.

Taken together, these four characteristics pose a unique set of problems for service managers. They will also affect the process of performance measurement, not so much in terms of *what* is measured, but *how* it is measured.

Key Aspects of Service Performance

Evaluating and developing service operations involves the linking of three areas: quality, resource utilization (productivity), and cost and profit (financial performance). The challenge for service operations managers is not only to use their resources as efficiently as possible, even in times of budget constraints and downsizing, but to manage their resources to provide a high level of customer service. Of greatest interest to the transportation community are the quality and productivity aspects of service performance measurement. The following paragraphs summarize these aspects.

Service Quality Measurement

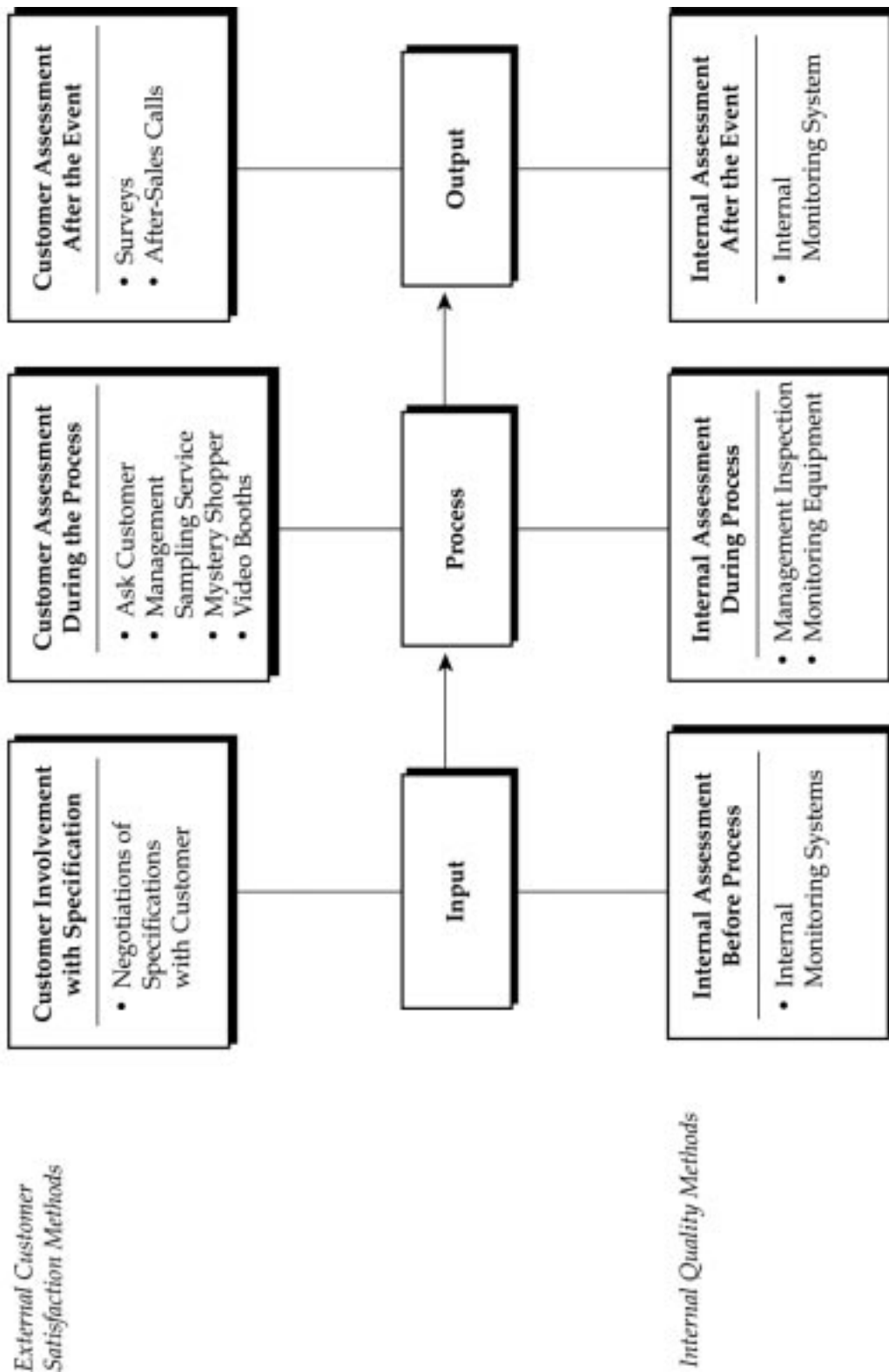
The measurement of service quality can be based on information collected from two different data sources. First, it can be measured *internally*, using the company's own internal control systems. Second, service quality can be measured *externally*, using customers' assessment of the level of service provided (through surveys and questionnaires, for example). Furthermore, service quality can be measured at the various stages in the service delivery process – at the input stage, during the process of service delivery, or after the service has been provided (i.e., the output stage). Service quality measurement methods at these various stages are shown in Figure 2.2.

Service Productivity Measurement

Resource utilization is often measured by service firms in terms of productivity, that is, a ratio of inputs to outputs:

- Productivity = Outputs/Inputs

Figure 2.2 Quality Measurement Methods in the Service Industry



Improving productivity can be achieved by reducing the level of inputs, increasing the level of outputs, or both. There are many different measures of output/input ratios which can be used in service organizations.

Service organizations struggle with a number of problems when they attempt to measure productivity. These problems are:

- Some service activities are not concerned with transforming inputs into outputs;
- Outputs may be difficult to quantify due to the intangible nature of the service;
- The number of services provided may be a poor indicator of the amount of service provided; and
- Cost tractability may be difficult.

The fact that it is difficult to measure productivity does not, however, make it any less important as a performance criterion. Service organizations may choose one or more input/output ratios as part of their range of business performance measures.

Choosing a Range of Performance Measures

In choosing a range of performance measures, service organizations are careful to balance the measures to ensure that all of the various dimensions of performance receive adequate representation in the evaluation process. For example, a decision to upgrade quality may have a short-term adverse affect on profitability because of the costs incurred, but it may lead to greater customer loyalty and a long-term gain in market share and profits. An analogy is found in highway construction and maintenance, where the best long-term use of short-term resources may be in the maintenance of an existing facility rather than the construction of a new facility. Maintenance of an existing roadway facility while it is still in fair to good operating condition is far more cost-effective than waiting until many layers of roadbed are damaged.

Since much of service is intangible, it is difficult to measure performance in some areas. “Hard” measures such as profitability tend to drive out “soft” measures like customer satisfaction, even though the intangible aspects of services may be important sources of competitive advantage. Monitoring the amount spent on these intangibles may be vital to competitive success, particularly as advanced technology gives consumers more immediate access to competitors’ services.

Service firms are beginning to expand their outlook beyond easily quantifiable aspects, such as cost and productivity, to other criteria which are important to competitive success. These aspects are synthesized into six generic performance dimensions:

1. Competitiveness;
2. Financial performance;
3. Quality;

4. Flexibility;
5. Resource utilization; and
6. Innovation.

Table 2.5 presents these six performance dimensions in terms of the key issues that each one addresses, and matches them to examples of performance measures that reflect each of the dimensions. A comparison of these dimensions to those commonly used by public-sector transportation agencies reveals some marked differences. For example, innovation, as a specific measure of performance, is often underemphasized or overlooked in public transportation planning. This is perhaps because innovation itself is not perceived to be a cause of improved quality.

Criteria for Selecting Key Service Performance Indicators

Service firm managers are learning that monitoring too many performance indicators can cause important information to be lost in a sea of data (see box, below.) The selection of a manageable set of key performance indicators therefore becomes important. The following criteria are commonly used to select a set of performance measures for service industries. They should:

- Be sensitive;
- Be important to customers;
- Cover the main strategic area of the business;
- Be significant for success/failure;
- Include quality, productivity, and finance measures;
- Be developed/selected by all levels of management; and
- Be limited to a manageable number of measures.

These criteria show the emphasis that service industries have on the customer. They also show that performance measurement process is an integrated part of the strategic planning process of the firm, as all levels of management are involved with their development, and they relate to the main strategic area of the business.

Indeed, part of the difficulty in identifying a finite set of performance measures for use in the public transportation sector is the overly-wide range of roles or “public goods” that we have come to expect from the transportation system. Our main strategic business area, i.e., movement of people and goods, must share the stage with other roles such as redressing economic inequities imposed by society, or providing for the economic health of a region. While many service businesses are able to externalize certain costs and impacts, the publicly-provided transportation system must increasingly account for and address such externalities, and even the undesirable side-effects of non-transportation activities. All of this complicates the process of selecting a manageable set of measures which address an acceptably-broad set of issues.

Table 2.5 Performance Measurement in Professional Services

Key Issues	Performance Dimension	Examples of Measures
<ul style="list-style-type: none"> • Ability to win new customers • Customer loyalty 	COMPETITIVENESS	<ul style="list-style-type: none"> • Percent (%) success in tendering • Percent (%) repeat business • Market share relative to key competitors
<ul style="list-style-type: none"> • Control of staff costs • Tracing of labor hours to individual jobs to aid pricing decisions 	FINANCIAL PERFORMANCE	<ul style="list-style-type: none"> • Staff costs • Debtor and creditor days • Value of work in progress • Profit per service
<ul style="list-style-type: none"> • Relationship building between customer and individual staff • Negotiation of project specification with customer • Measurement of customer satisfaction: use of Unstructured, informal methods 	QUALITY	<ul style="list-style-type: none"> • Investment in training: % non-chargeable: chargeable hours • Adherence to project specification and delivery promise • Customer satisfaction with various aspects of service
<ul style="list-style-type: none"> • Management of short-term volume, specification and delivery speed flexibility • Provision of flexibility through job scheduling, multi skilling, job rotation and staff discretion in dealing with customers 	FLEXIBILITY	<ul style="list-style-type: none"> • Percent (%) orders lost due to late delivery • Staff skill mix • Percent (%) hours bought in from other offices • Customer satisfaction with delivery speed
<ul style="list-style-type: none"> • Control of front office staff time 	RESOURCE UTILIZATION	<ul style="list-style-type: none"> • Ratio of hours chargeable to client and non-chargeable hours • Ratio of supervisors to staff
<ul style="list-style-type: none"> • Measurement of the success of the innovation process and the innovation itself 	INNOVATION	<ul style="list-style-type: none"> • Number of new services • New service introduction lead time • Percent (%) training spend invested in new services

Too Much Data, Too Little Information

One unintended side effect of the information technology revolution is that businesses are collecting reams of facts but deriving limited useful knowledge about their operations. In the opinion of logistics experts, businesses need to turn the focus to information, not data. The same is probably true for many planning agencies launching ISTEA-era Management Systems and data collection programs. In the words of Dale S. Rogers, director of the University of Nevada’s Center for Logistics Management, “Data is a raw stream of facts; information is what you have after you’ve had time to think about it for awhile. It’s like any raw material. It doesn’t have as much value as it does after it has gone through the manufacturing process.”

The advent of networked information systems has made it more difficult for many planners and operators to figure out what is relevant and what is not. In response, the trend in businesses who are aware of the problem is to provide people with the information they need, no more and no less. The difficulty is finding that balance between no more and no less. As in private business, public transportation planning agencies need to assess what they need to know to “do business” and then develop a supporting plan of information technology. In the world of performance-based planning, this means identifying the appropriate performance measures needed to answer the basic question of whether progress is being made towards important goals and objectives, and then defining specifically those data required to generate and track the measures.

Source: Adapted from A. Saccomano, in *Traffic World*, April 17, 1995.

Customer Orientation

As mentioned, customer orientation is a key aspect of the success of service organizations. Performance measures are used to address mismatches between the key gap in the service delivery process – what the organization measures and what its customers see as important. The performance measurement process, therefore, must start by defining precisely the bundle of services that the organization promises to provide. Then, the process must provide information to managers about how well that that bundle of services is being provided.

Measure What You Promise to Deliver

In *Moments of Truth*, Jan Carlzon of Federal Express writes, “We had caught ourselves in one of the most basic mistakes a service-oriented business can make: promising one thing and measuring another. In this case we were promising prompt and precise cargo delivery, yet we were measuring volume and whether the paperwork and packages got separated *en route*. In fact, a package could arrive four days later than promised without being recorded as delayed. Clearly we needed to start measuring our success in terms of our promises.”

Application to Transportation Planning

The key difference between performance measurement in service industries and performance measurement in transportation is that the current research on the service sector focuses on private industries, where the overriding motive is profit. In transportation

planning, on the other hand, the process is seldom guided by a profit motive alone, since most transportation planning activities are performed by the public sector. This difference aside, there are some key parallels between the service and transportation sectors, from which emerge some considerations for development of the framework:

- Performance measures must reflect the satisfaction of the transportation service user.
- Measuring performance before, during, and after the delivery of a transportation service can have profound effects on the organization’s ability to diagnose problems and develop solutions.
- An understanding of the relationship between internal performance measures (crew sizes, overtime hours worked, etc.) to external performance measures (vehicle hours of delay due to incidents, transit ridership, etc.) is another key to improving the outcome of a given level of effort.
- Given the significant involvement of people in the transportation service delivery process, performance measures must accommodate variations in individual skills, productivity, and quality.
- Since most transportation services are simultaneously produced and consumed, there are significant opportunities for collecting feedback from system users in real time.
- Although “soft” measures, such as customer perceptions of safety, are more difficult to measure than “hard” measures, such as number of highway accidents, transportation agencies should not neglect them.
- The performance measurement process should balance long- and short-term system needs, and should recognize the periodic need to exchange short-term results for long-term benefits.
- A package of performance measures should be sensitive to system improvements, be developed and selected by all levels of management, and be limited to as small a number of measures as will meet the demonstrated information needs of those involved.
- The performance measurement process must start by defining precisely the bundle of services that the organization promises to provide. In planning, this means defining carefully the goals and objectives in statements that can be operationalized. Then, the process must provide information to transportation decision-makers about how well that that bundle of services is being provided, by monitoring performance measures that are clearly linked to the service objectives.

2.3.3 Non-Transportation Public Agencies

A broad-based literature review produced some general points on performance measurement in the public sector that could be used to organize thinking on the topic for transportation. First, it is useful to recall that public agencies cannot measure their performance with the single indicator of profit. Because public agencies provide services

that for any number of reasons are not provided by the private market, performance must instead be measured against the goals and objectives of the agency or program in question. These may include goals that are equivalent to profit in the agency's "currency", but will rarely be as simple as maximizing net income.

Operational versus Non-Operational Goals

The first step in developing meaningful measurements of performance for public agencies is often to convert "non-operational" goals into "operational" goals. An operational goal is an imagined future state that can be unambiguously compared to the existing situation. A non-operational goal is a desired future state that cannot be compared unambiguously to the present state. To use an example from the criminal justice field, "reforming criminals" is a non-operational goal; "doubling the rate of inmate participation in prison programs" is an operational goal.

Efficiency versus Effectiveness

Once performance indicators have been developed, there is a distinction between *output* measures and *outcome* measures, which are analogous to the concepts of efficiency and effectiveness. Output measures reflect the quantity of resources used and the activities performed by an organization. Outcome measures, on the other hand, reflect the *success* of an agency or program *in meeting its stated goals and objectives*. For example, a law enforcement output measure might be numbers of arrests made or crimes investigated. Examples of outcome measures might include response time or citizen satisfaction. Table 2.6 lists examples of output and outcome measures gathered by a recent Congressional Budget Office study which help illustrate this concept.

Historically, public agencies have focused on measuring outputs rather than outcomes because of the difficulties associated with measuring outcomes. First, agencies and their constituents must define an agreed-upon set of goals and objectives, often a difficult task. Then, there is the problem of developing measures that meaningfully reflect outcomes. At this stage, agencies often resort to using output measures because they are concrete, easily quantified, and objective.

Once adequate performance outcome measures are developed, the question of causality remains. For example, a job training program might define as its performance outcome measure the number of participants who are employed six months after completing the program. Even if this statistic were accurately tracked, one could question whether the participants found jobs due to the training or simply because of an upturn in the economy. Isolation of external factors to the maximum extent feasible is desirable to ensure that outcome measures are reasonably precise indicators of changes in the measured activity.

Table 2.6 Examples of Output and Outcome Measures for Selected Programs

Output Measure	Outcome Measures
Elementary and Secondary Education	
Student-Days	Test Score Results
Student Graduated	Percentage of Graduates Employed
Dropout Rate	
Hospitals	
Patient-Days	Mortality Rates
Average Length of Stay	Patient Survey Results
Admissions	Readmission Rates
Public Transportation	
Vehicle Miles	Population Served (Percent)
Number of Passengers	Late Trips (Percent)
Police	
Hours of Patrol	Rates at Which Cases are Cleared
Crimes Investigated	Response Time
Number of Arrests	Citizen Satisfaction
Public Welfare Programs	
Number of Requests	Applications Processed in 45 Days
Amount of Assistance	Payment Error Rates
Road Maintenance	
Miles Resurfaced	Lane-Miles Improved (Percent)

External Evaluation versus Internal Decision-Making

Performance measurements are applied to at least two distinct types of applications. The first category involves evaluation of a program or agency by someone outside the organization. Such external evaluations are often peer comparisons that measure the efficiency of one agency or program to others of its kind. The second category involves the use of performance measures for decision-making within an agency or organization. Ranking capital investment alternatives, evaluating programs, and allocating a given level of resources within an agency are the types of internal decision-making that performance measures may assist.

Performance-based budgeting is a performance-based planning method that could be a subset of either of the categories described above. Where traditional public budgeting procedures have often allocated resources on the basis of the severity of the problems (e.g., when crime rates rise, prison budgets are increased), performance-based budgeting attempts to set budgets for programs and agencies based on desired program outcomes.

Several problems with the concept have been pointed out. Using performance-based budgeting to allocate resources among different types of programs requires an understanding of how to compare and tradeoff measures of their performance. Also, an underfunded program may perform poorly simply due to its underfunding while a successful program could see its resources cut or frozen.

2.3.4 Performance Measurement in the Federal Government

Recent surveys by the Congressional Budget Office and General Accounting Office have investigated the use of performance measures in federal agencies. In general, the study found that agencies have difficulty linking performance measures with their budget processes, that true measurement of outcomes was relatively rare, and that performance measurement systems function best where clear cause-and-effect relationships exist between the activities or outputs of an agency and the desired outcomes.

Since publication of the CBO and GAO studies, the Government Performance and Results Act of 1993 has given new impetus to performance measurement in federal agencies. The Act requires that heads of each federal agency submit a strategic plan to the Office of Management and Budget and the Congress by September 30, 1997. The strategic plans are to include:

- “A comprehensive mission statement” for the agency;
- “General goals and objectives, including outcome-related goals and objectives...”;
- “A description of how the goals and objectives are to be achieved, including a description of the...human, capital, information, and other resources” required;
- A description of how performance goals (required by another section of the law) relate to the goals and objectives;
- An identification of factors beyond the agency’s control which could affect its performance; and
- A description of the program evaluations used in establishing or revising general goals and objectives, and a schedule for future program evaluations.

By the fiscal year 1999, each agency will be required to submit an annual performance plan containing performance goals; an expression of the goals in an “objective, quantifiable, and measurable form”; a description of the resources required to achieve the performance goals; performance indicators to be used in measuring or assessing the relevant outputs, service levels, and outcomes of each program activity; a basis for comparing actual program results with the established goals; and the means for verifying measured performance values. The law does excuse agencies from expressing goals in “objective, quantifiable, and measurable form” if doing so is infeasible.

Beginning no later than March 31, 2000, each agency is required to submit an annual program performance report to the President and the Congress. These reports will use the methodology laid out in the strategic plans and performance plans to measure actual

performance against targeted performance for the previous three fiscal years (by 2002). If goals are not met, agencies must explain why, including explanations where goals turn out to be infeasible.

The Government Performance and Results Act also includes provisions that give greater accountability and flexibility to managers in meeting performance goals. Beginning in 1999, performance plans may include proposals to waive administrative procedural requirements and controls. Provisions of the Act may be altered depending on the results of a pilot studies on performance measurement, managerial accountability and flexibility, and performance budgeting to be carried out between fiscal years 1994 and 1998.

The provisions set out in the Act show that the federal government is using performance measures to inform rather than dictate the budget-making process. Performance-based planning methods are being implemented in a measured and flexible fashion and may be modified or done away with if the pilot studies do not produce good results. This approach is appropriate given the untested nature of the performance-based planning methods in most public agencies, and is advisable in implementation of performance-based planning in public transportation.

2.3.5 Performance Measurement in State and Local Governments

A series of recent Government Finance Officers Association (GFOA) research papers addresses the use of performance measurement by state and local governments in their budgeting processes. This section summarizes the findings of those reports.

Performance measures have been used in state and local government budgeting for some time. They make up a portion of the wide array of financial and non-financial data used to evaluate budget requests and monitor budget results. In some instances, they serve as the principle basis for resource allocation decisions.

A portion of the GFOA research effort examined the use of performance measures in operating budgets submitted by state and local governments to the GFOA's Distinguished Budget Presentation Awards Program. A smaller, more homogeneous sample of budgets was drawn from those documents for more extensive analysis.

Findings

Of the 554 budgets screened, 330 (60 percent) of the documents included performance measures. The more in-depth analysis of 43 city and county budgets produced the following findings:

- The use of performance measures in budgets can vary widely from jurisdiction to jurisdiction, from a low of 79 measures to a high of 4,326 measures. On average, budget documents contained 601 performance measures.
- The greatest portion of performance measures found in these budgets were output measures, which made up an average of 70 percent of the total number of measures.

- Generally, as the size of the jurisdiction increases, so does the number of indicators used in the budget. No correlation was found, however, between the use of specific indicator *types* and population size of the jurisdiction.
- The largest number of indicators, about 40 percent of the total, were associated with general government activities. The greater use of performance measures for these activities may be explained by the ready availability of indicators for administrative activities and the influence of chief executives and administrators over those activities.

Conclusions

Although it was not possible to generalize these findings to local governments as a whole because of the relatively small sample size, the following conclusions can be drawn about the use of performance measures in budgets from these and other research efforts.

- Only those performance measures that provide useful and practical information for key functions and activities should be included. Since the cost of data collection and reporting can be high, it may be impractical to provide performance data for every government activity.
- Performance measures should be linked to long-standing budget objectives. To measure program effectiveness and efficiency over time, decision-makers should be provided with performance data for budget objectives that are established for consecutive budget periods.
- Performance data should be disaggregated at the same level and covering the same fiscal years as is done for other budgetary information. As a result, performance data may be afforded the same consideration as other budget information when decision-makers weigh resource allocations.
- A mixture of output, outcome, efficiency, and other measures should be presented within the budget. Because a number of factors contribute to budget performance, a variety of information may help pinpoint the source(s) of program success or failure.
- Departments and agencies should play a key role in the development and selection of performance measures used in the budget. Managers should not be held accountable for program performance if they are not involved with setting and monitoring performance goals and objectives.

Out of necessity, budgetary decisions are based on factors in addition to program costs and performance. Accordingly, performance measurement should not be viewed as the only tool for resource allocation. If performance measurement is the key to allocation decisions, however, the budgetary process can help to reinforce the use of performance measurement in management and planning functions.

2.3.6 Other Experiences with Performance Measurement

Other areas with experience in the application of performance measurement with potential relevance to transportation planning include education and non-profit organizations.

Education

In an internal decision-making context, performance measurement and evaluation in education are focused on the individual student. Educators, teachers, and administrators rely heavily on the results of standardized and non-standardized achievement tests to evaluate whether an individual student is successfully learning. Average test scores also sometimes provide guidance in evaluating the performance of a particular program or curriculum. As in other fields, education professionals face challenges in developing meaningful performance measures. The debate over the need for, and content of, standardized measures in public education has been at times intense at the federal, state and local levels.

An important issue in measuring educational achievement is the need for standards. The well known system of assigning letter grades to students is an attempt to convey a broad array of quantitative (e.g., test scores) and qualitative (e.g., diligence, improvement, intelligence) characteristics. Yet because there is no standard meaning to these ratings, parents, universities, and potential employers often find letter grades inadequate or inaccurate. The National Council on Educational Standards and Testing has recognized this problem and called for a national voluntary system of standards representing what students should know and be able to do in order to earn certain grades.

In an external evaluation context, educational institutions are often ranked on the basis of standardized test scores or other quantifiable criteria. One example is the annual ranking of U.S. colleges and universities by *U.S. News and World Report* which relies on measures such as student selectivity, faculty resources, research activity, and reputation. In addition to a variety of quantifiable data such as number of faculty or research dollars, this report uses survey techniques to gather data on institutions' reputations.

Comparative Evaluation of Nonprofit Organizations

The comparative evaluation of social programs, health care facilities, and other non-profit organizations is an external evaluation application of performance measurement. Traditionally, such comparative evaluations were made by identifying appropriate performance measures and then listing the corresponding values for each organization in a matrix or other framework. Few attempts have been made to develop a single value or index that can be used to compare one organization to another. One major concern when performing comparative evaluations is accounting for external factors or exogenous variables that affect an organization's output but do not affect input variables.

In the last decade, a cost-effectiveness approach has often been used for comparative evaluation. One technique that is often applied is Data Envelopment Analysis (DEA), a linear programming technique developed in the management science field. DEA is used to measure the relative efficiency of nonprofit organizations. Since neither inputs nor outputs need be expressed in dollar terms, noncommensurate inputs and outputs may be accounted for in the analysis.

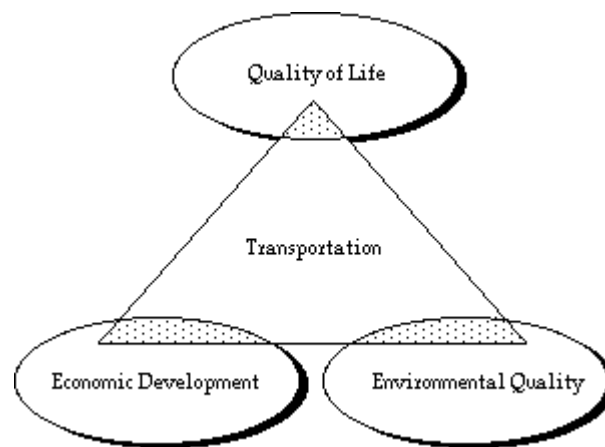
3.0 A Framework for Performance-Based Planning

■ 3.1 Overview

It is important to identify the relationship between goals and objectives and other key elements of the transportation planning process. A fundamental point of departure for performance-based planning is the definition of how transportation systems affect society. This perceived relationship between transportation systems and the functioning of an urban area, for example, becomes a critical foundation for measuring whether the transportation system is “performing” its intended ultimate functions.

Figure 3.1 depicts in much-simplified schematic form the relationship between transportation and three of the major roles often attributed to transportation systems. Transportation is one of the “empowering” factors that allows economic development, environmental quality, and quality of life to exist in an integrated way. Thus, for example, the mobility provided by transportation systems allows access to the employment, social, and other opportunities that provide the basic means of assuring an acceptable quality of life. This same mobility contributes to the overall economic development potential, or competitiveness, of the community. And finally, the provision of mobility is often accompanied by negative impacts to the natural environment, with a resulting impact on quality of life and perhaps economic development potential as well. Thus, the transportation system contributes in some way to each of these three fundamental roles, and also causes some interaction between the three roles.

Figure 3.1 Fundamental Roles of Transportation



The importance of the concept illustrated in Figure 3.1 is that if the underlying functional role of the transportation system is related to achieving some other greater purpose (e.g., economic development) then the related measures(s) of system performance should also reflect this broad purpose. The measures should not solely reflect the more specific transportation function (e.g., mobility) itself. Stated in the parlance of the public sector non-transportation fields we reviewed, the performance measures should reflect the *outcome* of transportation system investments on these fundamental roles, in addition to measuring the *output* of the system itself.

3.1.1 Relationship of Roles to Performance Measures

A second important concept embedded in Figure 3.1 is that performance measures should relate to that intersection of specific transportation functions and the more broad societal role. As has been heard so often in our research, it is important to measure *what we can influence* through investments in transportation. This is suggested by the shaded portions of Figure 3.1, and is best illustrated by example. Again using economic development as the example of a broad societal role for transportation, appropriate performance measures are those which describe the economy in ways that are clearly related to, and influenced by, the transportation system.

It follows that we must also measure that which we can reasonably attribute to some decision we have influenced through our methods. If the performance measures are drawn too broadly, we cannot say with any confidence that our chosen course of action is responsible for the change in the performance measure. For example, assume our broad goal is to enhance local economic activity and competitiveness through transportation investments. A more specific objective might then be to improve the access of employers to labor markets. Examples of poor measures include gross measures of productivity or employment in the local market, which are subject to influence by many external factors, some of them far more significant in their effect than transportation.

An example of a better performance measure would be the “number or percent of businesses with access to adequate labor supply within 30 minutes of the site.” Other formulations of this example measure include “number of employable residents within 30 minutes of major employment center” or similar. (Precise definition of “adequate” or “major” is best left to the individual application.) This measure has several important attributes:

- It measures changes in the accessibility of labor which can be attributed at least in part to transportation system investments;
- It is a measure of an element (access to labor) which has a clear linkage to the stated plan goals and objective; and
- It also has a clear linkage to one of the underlying roles of transportation, i.e., economic development.

Such a measure has other desirable attribute described elsewhere in the literature, e.g., it can be measured with observed or synthesized data, it can be made mode-neutral, etc. However, our primary concern here is the fact that it is well connected to the broad

strategic goals and roles of the transportation system. This clear linkage is missing in the majority of current implementations of transportation system performance measurement.

Once this relationship between transportation system performance and societal desires is accepted, the relationship between goals/objectives and the rest of the elements of performance-based planning falls more easily into place. This relationship relates to the appropriate performance measures for the stated goals and objectives, to data collection, and to analytical methods. Some further explanation and definition of the different elements is helpful.

3.1.2 Goals and Objectives

Most transportation planning efforts begin with a definition of goals and objectives, which are typically recorded in the official planning documents of the appropriate jurisdiction (e.g., Statewide Transportation Plan, Regional Transportation Plan, etc.) This rational perspective on planning assumes that investment in transportation systems is aimed at achieving some ultimate purpose. Goals and objectives relate to system performance in that they reflect different perceptions of what the transportation system should be achieving. These goals and objectives are often developed through extensive public outreach efforts and thus incorporate a broad community perspective of what elements of system performance are truly important. Understanding different goals and objectives is critical to identifying the different types of performance measures that might be incorporated into the planning process. And, as we described above, it is desirable to become more disciplined in our definition of goals and objectives in order to make them more operational and less ambiguous.

3.1.3 Performance Measures

One of the major changes to transportation planning that has resulted from ISTEA is the requirement for planners to identify and use performance measures in the transportation planning process. Beyond ISTEA, however, there is a growing demand among elected officials, other decision-makers, and planning professionals for greater accountability in the investment of public transportation funds. This sentiment is well documented in other governmental sectors as well as in private industry, and is related to a growing emphasis on the quality of service provided to the users or “customers” of the transportation system. Identification of more goal-specific performance measures is an important precept of greater accountability.

Thus, performance measures are critical elements of a performance-based planning process in that they determine what type of information is fed back into the investment and decision-making processes, and ultimately relate to how “successful” system performance is defined. On the analytical side, performance measures define the type of data that need to be collected to operationalize the performance measures, as well as the type of analytical tools that are necessary to translate data into information and thereby identify system deficiencies and opportunities.

3.1.4 Data

The performance measures selected as part of the planning process must be updated on a periodic basis, thus implying some amount of continuous or periodic data collection. The high cost of ongoing data collection programs is a common and significant concern of many DOTs and MPOs today. System operation-oriented performance measures may continue to rely to a great extent on data collection techniques that have been used for decades, such as traffic counts, travel time studies, travel delay studies, and classification counts.

Broader-defined performance measures are more likely to require spatially allocated socioeconomic information and other indicators of economic development or quality of life. Data on environmental impacts would be focused on the likely consequences of system operation on the natural or man-made environment. In some cases, the data could be surrogate measures (such as VMT) that act as indicators of impact. Intelligent Transportation Systems (ITS) technology is likely to play an important role in future data collection and manipulation strategies required to support a broader variety of performance measures.

3.1.5 Analytical Methods

The analytical methods required to operationalize each type of performance measure will clearly reflect the issues related to that measure and the type of data that are available for input. For example, system operation measures would be most affected by strategies aimed at improving the vehicle or person flow in key corridors. Thus, the analytical methods relevant to this type of strategy might include traffic flow simulation models, capacity and delay modeling packages, and network models. Measures that focus on the relationship between transportation system performance and other societal issues would require a broader range of analytical capability that relates concepts such as mobility and accessibility to specific outputs. Geographic information systems (GIS) could become an important foundation for such analysis in that the spatial allocation of the “benefits” and “costs” of transportation investment will most likely be an important element of system effectiveness. Performance measures relating to externalities would be best analyzed using existing impact models.

■ 3.2 Performance Measurement in the Planning Process

In one form or another, the elements above – goals and objectives, performance measures, data, and analytical methods – are all part of the existing planning process as it is carried out in most jurisdictions. Although the range of performance measures in use in most cases is quite narrow, they are nonetheless part of an existing process. What is new about the performance-based methodology is the *organization* of these elements, the *linkages* between elements in the process, and the presence of an ongoing monitoring process that provides *feedback* on the progress towards goals and objectives.

Figure 3.2 illustrates this point. Goals and objectives derived from the comprehensive planning process are related to the underlying roles of transportation. These goals should

in turn be reflected in appropriate performance measures. The measures then determine what data is required and what analytical methods are most appropriate. The data are supplied as input to the analytical methods, which enable the assessment of alternative strategies. The performance measures themselves may be useful in identifying alternative strategies for evaluation, by drawing attention to areas of unacceptable performance.

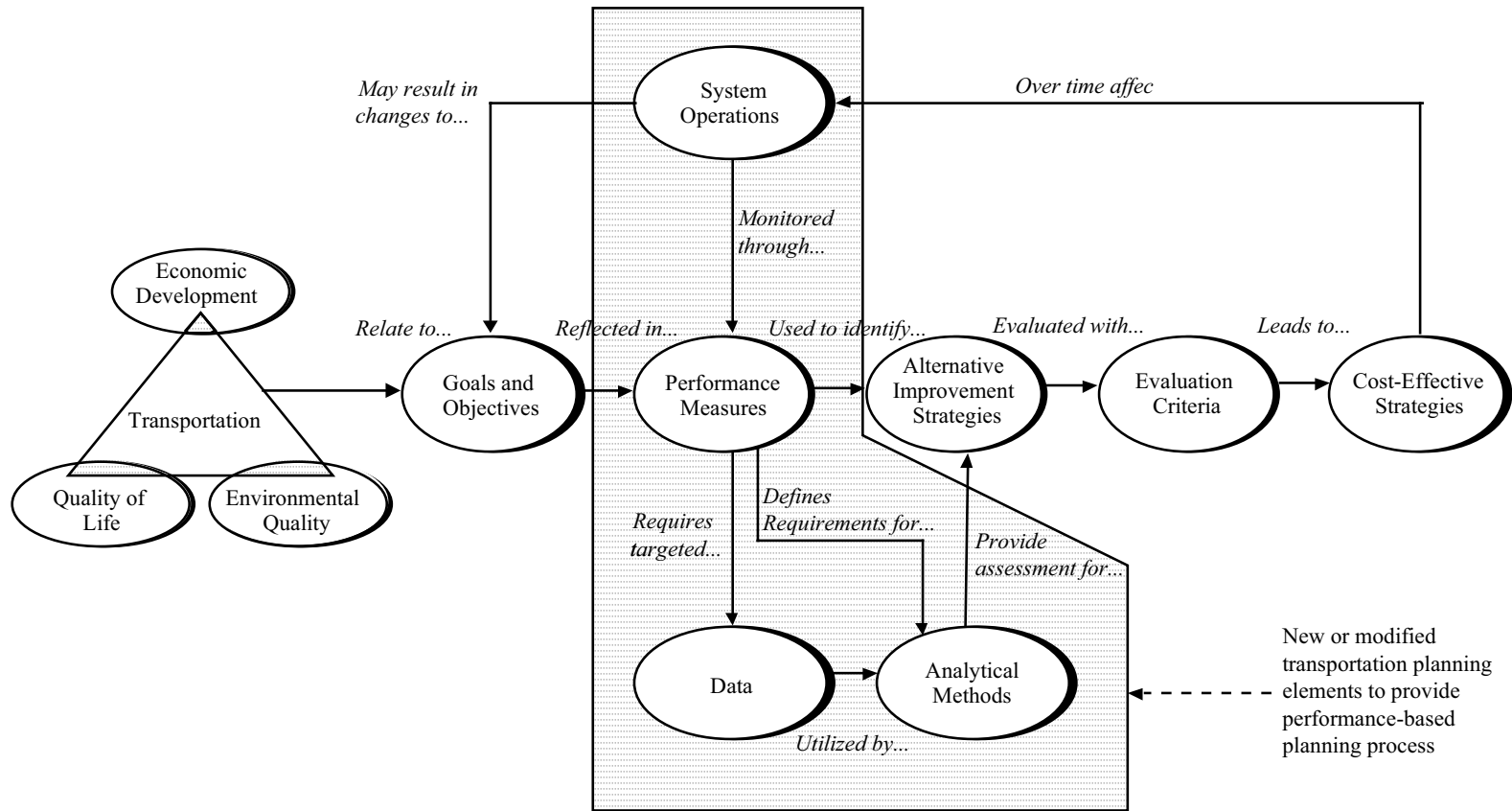
Continuing the description of Figure 3.2, alternative strategies may be assessed with evaluation criteria that are in fact distinct from the performance measures. This accommodates the fact that there can be many more consequences of actions than there are system performance measures. These evaluation criteria will likely cover a large variety of impacts of concern to local decision-makers. The evaluation criteria should, however, be closely related to the defined system performance measures. By so doing, there is a stronger connection between project-level evaluation/selection and system performance measurement. This is one of the defining characteristics of performance-based planning as refined in this study. These evaluation criteria may be more specific to the alternatives evaluated in a given cycle (e.g., may be mode-specific, or place greater emphasis on cost) to allow finer distinctions to be made between alternatives. They may be developed and organized into subsets for application to certain periodic procedures, such as capital budgeting, TIP development, etc.

Strategies which are cost-effective then emerge from the process, which over time will impact system operations. The system operations are monitored by the same performance measures which initially were used to identify and evaluate alternative strategies. This ongoing monitoring process will result in periodic adjustments to goals and objectives, and to the performance measures themselves. Most importantly, it will give a periodic assessment of progress towards longer-term goals and objectives, and towards attainment of the underlying roles of transportation, that is, economic development, quality of life, and environmental quality.

■ 3.3 A Typology of Goals and Objectives

Section 2.0, above, included examples of goals and objectives drawn from state and MPO transportation plans and management systems, as well as useful ideas and examples from other sectors and industries. This research project, however, is focusing on the evolutionary process of what the transportation planning process could look like, given greater attention and discipline towards establishing clear linkages and feedback loops between the elements. As mentioned earlier, a cornerstone of a performance-based planning process is the definition of what is meant by system performance. This quickly leads to the question of, what ultimately are we trying to accomplish with purposeful changes to the transportation system?

Figure 3.2 Elements of a Performance-Based Planning Process



It seems likely that the major transportation issues that will be faced by states and metropolitan areas will not change drastically over the next several years.¹ Thus, the goals and objectives that relate to such things as enhanced economic development opportunities, reduced congestion, etc. will continue to be found in most transportation plans. How we chose to define and monitor progress towards those goals, however, could change substantially. One fundamental shift suggested above is the from an “owner” perspective of system performance to a “user” perspective. A good illustration of this is found in the long-standing professional interest in finding ways to reduce congestion.

Identifying different approaches for measuring congestion has been an important topic in the transportation profession for many years. Most of the measures that were identified almost 40 years ago are still the major measures considered today. These measure the physical ability of the road system to handle vehicular demands, for example, the commonly used volume-to-capacity (v/c) ratio. However, congestion means different things to different groups. For the *operators or owners* of the road system, there are clear operations-based measures which relate performance to traffic volume and speed characteristics, as well as system-based measures which relate traffic levels (utilization) to system capacities. For operations reporting, the desired measures would rely on the traditional data collected in every metropolitan area, e.g., traffic counts, screenline counts, toll counts, boarding counts for transit, etc. For systems monitoring, the measures would need to identify both changes in breadth and depth of congestion, where breadth could be defined as the percent traffic affected, and depth could be the total time (duration) of delay.

For the *users* of the road system, there are different measures which reflect actual trip patterns and trip characteristics and allow comparison to desired trip characteristics. User-oriented monitoring and measurement would identify the differences between system measures and individual measures. For example, change in average travel times for specific origin-destination pairs, taken within a context of known average trip lengths and mode split data for a metropolitan area, permits assessment from the users point of view.

One of the reasons why there is possibly some discrepancy in the results of the congestion studies that have been conducted is precisely this difference between the target market characteristics of the individual trip (e.g., average trip time) versus that of the system/facility (e.g., average speed on a facility.)

In summary, the most commonly utilized performance measures in use today were derived from what, at first glance, appears to be diverse and unrelated groups. Managers have traditionally viewed performance in terms of cost-effectiveness and efficiency. Civil engineers have placed emphasis on levels of service, or facility-based performance monitoring. Systems engineers view queues and delay times as important measures of performance. Service providers have considered scheduling and routing issues as important determinants of transit system performance.

The performance measures which are derived from each school of thought carry with them owners’ value judgments as to what the user may perceive as “performance.” Fre-

¹One change which could take place over a fairly short time span with potentially dramatic impact on transportation is a rapid and large increase in petroleum prices.

quently, no direct and concise connection could be defined between the user and the elements being monitored with the performance measure. The monitored elements became a surrogate for the user, and have remained entrenched as current and accepted practice for the planning of transportation systems. The undesired result of this is the tendency to manage towards optimization of performance measures which are not necessarily good representations of performance from the users' perspective.

3.3.1 Components of the Typology

A significant shift is required in the utilization of performance measurement in the planning process. There is a need to more directly incorporate accurate measures of the users' perception of system performance. This will require greater inclusion of measures of system effectiveness, rather than system efficiency alone. As stated in the lexicon of the service industries, more emphasis is required on the outcome of our transportation planning processes and investments, as opposed to the output of those processes and investments.

While measures of output and efficiency have an important role in the overall delivery of transportation services, the tendency has been to default to these measures, and to assume that they reflect what the user wants out of the system. In fact, our research, and in particular our face-to-face discussions with practitioners, suggests that in most cases these measures have become surrogates for the customers' needs, and that all planning and programming activities tend to migrate towards optimization of the measures.

Although there are different ways of classifying goals and objectives for performance-based planning, a particularly useful approach for this project is shown in its most simple form in Table 3.1. The goals and objectives may be classified in three categories: **Efficiency, effectiveness, and externalities**, as follows:

Table 3.1 Example Typology of Goals and Objectives

Goals and Objectives	
Efficiency	Define movement itself; Focus is on system <i>output</i>
Effectiveness	Define purpose of movement; Focus is on <i>outcome</i> of actions
Externality	Define impact of system construction and operation; Focus is on <i>external</i> impact

- Goals and objectives which address **system efficiency** are about *movement itself*. The efficiency of the transportation system relates to those physical characteristics of system operation that correspond to vehicular or person flows. This is the traditional perspective of system performance and encompasses such topics as congestion relief, reduced costs of

travel, and improved travel times. There are also many **system efficiency** goals in use which require description of the output of transportation programs in measures such as the number of lane miles resurfaced, the number of revenue boardings, etc. These can be generally labeled efficiency or output goals and objectives.

- In contrast, transportation **system effectiveness** is best defined in relation to what transportation provides to a community, or what is the *purpose* of all the effort and investment. As stated in the service industries, effectiveness is about what one is trying to deliver, or what has been promised to the customer. Examples of such goals include statements such as, the transportation system should provide mobility for all citizens in the community, the transportation system should provide accessibility to economic activities, or transportation services should be provided and financed in an equitable way.
- **Externalities** associated with the transportation system relate to the environmental and societal impacts of system construction and operation. Examples of such externalities particularly germane to transportation include air quality, noise, dislocation of households and businesses, wetlands impacts, and water quality. There are also secondary or indirect impacts associated with the increased development that possibly occurs as a result of enhanced accessibility.

3.3.2 Desirable Attributes of Typology Elements

This classification of different goals and objectives is helpful to understanding the different types of performance measures that might be incorporated into the planning process. These three categories of goals and objectives may be usefully carried through the typology to include performance measures, data, and analytical methods. This helps to ensure that the choice of goals and objectives directly influences the type of performance measures and evaluation criteria selected, the type of data that need to be collected to operationalize these performance measures, the analytical methods that convert this data into information, and ultimately the types of consequences that result from the implementation of strategies and actions.

Table 3.2 illustrates the desirable characteristics of goals and objectives, performance measures, data, and analytical methods, in each of the three categories. For example, appropriate **efficiency** goals would define movement itself, and focus on system output. A corresponding performance measure, therefore, would demonstrate features such as system capacity and utilization. Data must be collected which reflects these system or facility attributes, and the chosen analytical methods must be capable of assessing condition with respect to capacity and utilization. (These are examples of a broad range of possible attributes.)

In the **effectiveness** row of Table 3.2, we see that different attributes should guide the identification and selection of goals, measures, data, and methods. To assess movement towards goals that speak to the *purpose* of actions, performance measures must demonstrate the outcome of actions in terms that system users themselves might adopt. This drives data needs as well, for it is then necessary to choose data that reflect the users' perception of outcome or service level, possibly at the trip level rather than the facility or

system level. This requires analytical methods capable of assessing conditions at the trip level, in user-familiar units or terms. Stated another way, the methods must focus on the “intersection” of the user and the system, rather than on the system itself.

Finally, attributes of elements in the **externality** row suggest goals that focus on external impacts; measures then must demonstrate the change in condition, or impact, resulting from action. In this category in particular, a variety of data are required, which are capable of describing environmental or societal resources, and/or which describe features such as public health, welfare, and economics. Analytical methods must now be capable of assessing the intersection of not only the system and the user, but also of the environment.

3.3.3 Examples of Appropriate Typology Elements

Having defined desirable attributes of each of the elements, it is possible to provide examples of goals and objectives, performance measures, data, and analytical methods for each case or category. These examples are not meant to be all-inclusive, but rather to demonstrate the range of possibilities within any given dimension of the typology.

Table 3.3 lists examples which further clarify the distinction between efficiency, effectiveness, and externality. These examples also help illustrate the important relationship across any horizontal row in the table, that is, how identification of goals and objectives should dictate the remaining elements, rather than the reverse. As noted by participants during the regional advisory meetings, it is important to not let the measures, and the availability of certain types of data, drive the process. Goals and objectives should not be skewed to fit the available measures.

Goals and Objectives

Goals and objectives relating to system or facility *efficiency* are most common in use. Typical examples include goals related to reduction of congestion, or provision of facilities and services at a reasonable (aggregate) cost. Congestion reduction objectives may be expressed in a variety of derivative ways, such as **average speed** or **travel time**. In contrast, the *effectiveness* of transportation investments is better tracked through goals and objectives which speak to mobility, accessibility, and reliability. For example, the effect of a system improvement might be to improve the users’ **access** to vital services or opportunities. Or, it may reduce the **per-shipment cost** (rather than the aggregate construction and operating cost) for shippers and carriers, or improve the **reliability** of those shipments. These are goals and objectives the user (whether commuter or commercial) can reconcile with their own particular calculus of trip-making decisions and values.

Goals related to *externalities* would include those dealing with air quality, open space or habitat preservation, or safety, to name a few. Another potentially broad goal would relate to **external costs** imposed upon society by transportation decisions. These type of goals bring together the system, the user (and non-user) and the natural environment, and reflect society’s desired interaction and tradeoffs between the three.

Table 3.2 Desirable Attributes of Typology Elements

	Goals and Objectives	Performance Measures	Data Collection and Monitoring	Analytical Methods
Efficiency	Define movement itself; Focus is on system output	Demonstrate system capacity and utilization	Reflect system or facility capacity and usage	Assess system and facility condition with respect to utilization and capacity
Effectiveness	Define purpose of movement; Focus is on outcome of actions	Demonstrate outcome in user-oriented measures	Reflect user impact, and perception, at the trip level	Assess intersection between system and user; assess condition from user point of view
Externality	Define impact of system construction and operation; Focus is on external impact	Demonstrate change in impact or condition resulting from actions	Reflect environmental or societal resources; public health, welfare and economics	Assess intersection of system, user, and environment; estimate contribution of transportation system to conditions

Table 3.3 Example Typology Elements

	Goals and Objectives	Performance Measures	Data Collection and Monitoring	Analytical Methods
Efficiency	<ul style="list-style-type: none"> • Congestion reduction • Travel time • Cost of providing service 	<ul style="list-style-type: none"> • v/c and related capacity measures • Speed and delay related measures 	<ul style="list-style-type: none"> • Vehicle counts • Travel time and speed • Construction/operating costs 	<ul style="list-style-type: none"> • HCM Methods • Simulation models • Demand models
Effectiveness	<ul style="list-style-type: none"> • Mobility • Accessibility • Trip (or shipment) cost and reliability 	<ul style="list-style-type: none"> • Percent population served by modes • Percent population within defined trip time • Cost per person or ton mile • Standard deviation of trip time 	<ul style="list-style-type: none"> • Spatially-linked demographic data • Trip origins and destinations • Cost of trip inputs • Knowledge of incident frequency 	<ul style="list-style-type: none"> • GIS-linked network models • Statistical sampling and analysis methods
Externality	<ul style="list-style-type: none"> • Air quality maintenance • Sensitive habitat preservation • Safety of travel 	<ul style="list-style-type: none"> • Vehicle emissions • Acres lost or preserved • System accidents or fatalities 	<ul style="list-style-type: none"> • VMT as surrogate • Project site impact • Accident severity 	<ul style="list-style-type: none"> • Emissions models linked to demand models • Risk analysis • Trend extrapolation

Performance Measures

Efficiency

Again, the traditional approach toward performance measures would focus on system *efficiency* and thus relate to such things as v/c, delay, level of service, and travel time. These measures tend to demonstrate utilization of the facility, or just the capacity of the system or one of its components. Indeed, a review of the performance measures selected by some of the MPOs which have already identified performance measures for their congestion management systems shows a continued emphasis on this type of measure. The regional meetings conducted for this research project revealed that despite the inclusion of more user-oriented goals and objectives in the current ISTEA-influenced statewide and regional plans and management systems, when it comes time to measure the benefit of a given action or strategy, most performance measures in use still focus on efficiency and output.

Effectiveness

A broader perspective on transportation system performance would suggest measures that relate to system effectiveness and externalities, in addition to efficiency. A key challenge is to measure system performance in ways that speak directly to the users' perception of effectiveness. Qualities such as mobility, reliability, and accessibility are frequently cited in planning goals, but less successfully carried forward into operational performance measures. These goals suggest performance measures such as the percent of population reasonably served by specified modes (one measure of mobility); the percent of population within a defined travel time of important opportunities such as employment or vital services (accessibility); or the standard deviation of travel time in an important corridor (reliability.) These example measures all can be operationalized in terms and units that the lay public or commercial transportation system user can understand and incorporate into their own decisions.

Often-cited reasons for the failure to faithfully translate goals and objectives include over-reliance on readily available data and analytical methods, limited resources to operationalize measures, and the inertial tendency for agencies to default to internal measures of service delivery (management performance) rather than external measures of system performance as perceived by the user.

Externalities

Performance measures associated with externalities would be related to the actual impacts of given actions or strategies. Because of the environmental analysis and reporting requirements that have long been in place, the measurement of environmental externalities is further along than that of effectiveness. Data sources and analytical methods have been evolved to a relatively high level. However, the actual measures chosen to describe external impacts could be improved to be more representative of the consumers' (users and non-users) own methods of valuing or assessing the situation. For example, rather than focusing only on emission measures, such as grams/mile or tons/day, conversion of these data to comparative estimates of, for example, number of annual violations of standards, might allow more direct linkage to planning goals and objectives. (The current requirement of the Clean Air Act for non-attainment areas to meet emission standards through reduction in vehicle miles traveled (VMT) is another system performance

measure that relates to this externalities category. However, VMT is a surrogate measure, and conveys little meaning to the typical user.)

Other measures, such as acres of habitat (or open space) lost or preserved through alternative actions, may have more direct meaning for the user, and are readily generated with current GIS technology.

Performance Measures for Non-Motorized Travel

The North Central Florida Regional Planning Council’s <i>Gainsville Mobility Plan</i> features performance measures for not only highways, but for pedestrians and bicycles as well. Pedestrian performance measures relate to sidewalk continuity, crossings and conflicts with vehicles, pedestrian amenities, maintenance of pedestrian facilities, vehicle LOS, and TDM/multimodal support. Bicycle performance measures relate to bicycle facilities provided conflicts with vehicles, speed differential, maintenance, vehicle LOS, and TDM/multimodal support. With these measures, agency staff are better able to assess the costs and benefits to non-motorized modes of travel relative to a variety of investment strategies.

Source: North Central Florida Regional Planning Council. *Gainsville Mobility Plan*; Draft, December 1994.

Data

The selection of performance measures which faithfully reflect the goals and objectives of a system plan will in turn dictate the type of data required to operationalize the measures. Contrary to frequently-observed current practice, the need for data should be determined by what kind of performance is being measured, and not the reverse. Traditionally, the availability of certain types of data has skewed if not outright dictated what kinds of measures would be used to evaluate progress towards goals. For example, the long tradition and relative ease of collecting traffic volume data and travel speed results in an abundance of measures derived from these data, all related to system or facility capacity and utilization, such as v/c , level of service, and cumulative delay.

Thus, efficiency-oriented performance measures rely on such data as traffic counts, travel time studies, travel delay studies, and classification counts. While these data are important to evaluation of system efficiency, they cannot support operationalization of measures which are more directly linked to effectiveness goals. Such data need to more accurately reflect the users’ own sensibilities and valuations of system performance, rather than that of operators. Research suggests, for example, that *reliability* of travel time, rather than overall duration of travel, is as or more valuable to users, particularly in public transit and the goods movement industry. Another example is the access provided by the system to different opportunities serving the users’ needs.

These measures require data that is not currently collected or estimated by most MPOs or states, such as travel-time deviations based on statistically-significant samples, or average travel time by all modes from typical origins to typical destinations. This latter example of accessibility would rely on spatially-allocated socioeconomic information and other indicators of economic development or quality of life. This is a type of data not historically collected or considered in any significant detail.

Externality data would focus on the impacts of system operation on society and the environment. Again, although there is considerable experience and history in the collection of environmental data, more work needs to be done to improve the degree to which the collected data reflect externality impacts in terms that are meaningful to the public and decision-makers, not just to trained specialists. The probable severity of a transportation-related accident, for example, might be more useful in a decision-making situation the accident rate or annual fatalities,

Analytical Methods

Analytical methods need to be selected to reflect the types of issues associated with each type of performance measure and the type of data available for input. Analytical methods relevant to system *efficiency* might include traffic flow simulation models, capacity and delay modeling packages, and network models. These are relatively common, and are in widespread use in most large metropolitan areas and at the state level.

Effectiveness measures would require a range of analytical capability that permits a wider examination of transportation impacts on society. Geographic information systems (GIS) would allow for the spatial allocation of the “benefits” and “costs” of transportation investments, as well as for readily measuring or projecting the accessibility between people and places, the amount of habitat impacted, etc. Appropriate sampling and analysis methods need to be used to develop better estimates of system reliability and cost of use.

Performance data relating to externalities may be analyzed using existing impact models. However, improvements in the linkage between transportation demand models and emissions models are desirable. There is also an emerging interest in risk analysis as a decision-making tool which fits well the emphasis on user perception and outcome that is fundamental to performance-based planning.

MIS Calls for Enhanced Analytical Tools

A midwestern MPO recently embarked on a Major Investment Study (MIS) of an environmentally and politically sensitive transportation corridor. The public involvement process is extensive, and numerous alternative alignments and modal options will be evaluated. Although several multimodal, system-level performance measures entered into the early project scoping stages, the available regional travel model outputs (link volumes) and derivative measures (volume/capacity ratios, speed and delay estimates) are to be the main source of data for analysis and comparative evaluation of the alternatives. The performance measures initially postulated by the agency cannot be estimated for future alternatives with the available analytical tools, and current data collection programs do not support computation of baseline measures. This example points up the need to evolve analytical methods to keep pace with the information demand created by more aggressive and inclusive public participation programs and other features of the ISTEA era, including performance-based planning.

4.0 Analytical Methods

■ 4.1 Overview

This section is a summarization of the Task 3 technical memorandum, and is focused on evaluation of analytical methods currently available to support performance-based planning, and identification of desirable methodological improvements which will support the development of a performance-based planning process. The information presented here is supplemented in considerably more detail in Appendix C, (under separate cover) which contains the full Task 3 technical memorandum.

We have frequently heard concerns expressed about the ability of public agencies and other transportation-related organizations to collect new types of transportation performance data. In many cases, budgetary constraints limit the amount of resources that can be devoted to the task, and even the ongoing, historic analytical processes are threatened. Agency staff are understandably skeptical about the likelihood of committing resources to new methods of data collection, manipulation, and analysis.

Concern is also expressed about the ability of current data collection and analysis methods to support development and evaluation of performance measures, or to facilitate the integration of these measures into the planning and decision-making processes. The experience to date with multimodal performance measures suggests that many agencies do not currently collect or generate the kinds of data, or possess the analytical tools, necessary to develop a set of robust performance measures, particularly those which address system effectiveness.

4.1.1 Desired Results

This research is intended to help initiate resolution of these concerns. By identifying the types of data that are most likely to support transportation performance measures, agencies may in time be able to incrementally redirect and re-focus their data collection and analysis efforts, without necessarily spending more resources on the product. By anticipating the long-term economies of more automated forms of data collection and analysis, agencies may be able to justify investments in higher-technology solutions that address several needs in addition to just data collection needs.

There are several desired outcomes of this step in the research process. One is to review the currently-practiced methods of data collection, manipulation, and analysis, and to identify the shortcomings of these methods as they relate to support of a performance-based planning process. A second desired outcome is to identify possible improvements to these practices which will provide a better link between the information collected and the analytical requirements of a performance-based process.

Finally, and perhaps most importantly at this stage, it is desirable to point the way for agencies to *incrementally* improve their analytical procedures so that new methods of data collection and analysis may be integrated with existing, more traditional methods. Although in the long run it is probable that analytical methods which are based upon new technology will supplant a significant portion of existing methods, most agencies will experience a protracted period during which the traditional and newer methods must coexist.

4.1.2 Findings

Technology will play an important role in bringing new data to the hands of transportation planners. Particularly in the areas of data collection and manipulation, the general movement towards automated and “intelligent” systems will provide greater access to electronic methods of data sampling and collection, storage, organization, and manipulation. Thus, even familiar types of data which are currently collected may be collected at lower cost, be of higher quality, and be manipulated to provide greater value, with the application of emerging intelligent transportation systems (ITS) technologies and procedures. These emerging systems have the potential to provide the information and communications foundation for a performance-based planning process.

For example, one of the typical shortcomings of a state DOT or MPO data collection effort is the sample size or frequency of sampling. There are certain desirable performance measures which rely upon development of statistically valid distributions, for example, the variance in travel time between defined points in a particular corridor. Current practice often limits the data to a single periodic (e.g., annual) observation, with little or no control over random or systematic fluctuations. Newer technologies will make it cost-effective to sample the same locations frequently, building up valid samples from which more dependable and useful summary statistics can readily be generated.

In the area of data analysis, computer software, rather than data collection hardware, will play an increasingly important role in evaluation of performance data. Many of the potential measures which might be developed to offer a more comprehensive picture of multimodal system performance require analytical capabilities that are not in widespread use today. Examples include demand forecasting models which are more sensitive to system operating conditions, travel costs, and other such variables; and accessibility or land use allocation models which will improve the spatial linkage between travel demand and socioeconomic or demographic data. Finally, methods for analyzing more qualitative “customer satisfaction” data might be made more accessible to transportation planners.

Three types of methods are reviewed in this section:

1. Data collection methods;
2. Methods for data storage, manipulation, and dissemination; and
3. Methods for data analysis and forecasting.

Each of these three sections presents a summary inventory of current methods, capabilities of the identified methods, evaluates the most promising new directions in performance-based planning methods, and identifies improvement actions required to enhance the methods.

A more comprehensive evaluation of the methods, in terms of their spatial focus, temporal focus, planning level of analysis, planning goals addressed, output information, current usage, accuracy, and relative cost range, may be found in Appendix C.

■ 4.2 Data Collection Methods

Our research of state DOTs and MPOs around the country confirmed the critical problem of data collection required to support many of the proposed multimodal performance measures. The resources available for data collection are limited, and the apparent lack of coordination between the existing data collection mandates creates inefficiencies that strain these resources as well as the patience of decision-makers and staff alike.

One of the key opportunities for improvements to data collection procedures lies in the spread of ITS technology to the nation's metropolitan regions, through the Early Deployment Programs as well as through other public and private initiatives. Information that is now gathered through laborious processes may be partially or fully automated through use of automatic detection and recording practices. Equally important, data which has historically been unavailable may soon be more readily assembled in areas where ITS strategies such as automated vehicle identification and advanced public transit systems are deployed.

4.2.1 Inventory of Methods

Current Methods

Current methods of data collection in widespread use which could support development of multimodal performance measures include:

- *Manual Traffic and Transit Surveillance* – On the highway side, this category includes traffic volume counts, spot speed observations, classification counts, aerial photography, videography, and license plate matching. For transit, this category includes boarding and alighting counts, peak load counts, and Section 15 reporting.
- *Manual Vehicle Surveillance* – This category includes floating car studies and the use of instrumented vehicles.
- *Manual Freight and Goods Movement Surveillance* – This category includes weight measurements, shipment records, average fuel consumption rate reports, travel logs, vehicle registration data and inspection records, Census of Transportation, Commodity Flow Survey, National Transportation Statistics Annual Report, Truck Inventory and Use Survey, and shipper logs.

- *User Surveys* – This category includes “home” travel surveys, roadside interviews and origin-destination surveys, onboard transit surveys, panel surveys, travel diaries, focus groups, and customer surveys.

Future Directions

The following data collection methods are emerging and will be increasingly available in the future:

- *Advanced Traffic Management Systems (ATMS)/Traffic Surveillance Technologies* – These ITS technologies collect information about the status of the traffic stream. Technologies in this category include loop detectors, infrared sensors, radar and microwave sensors, machine vision, aerial surveillance, closed circuit television, and acoustic, in-pavement magnetic and vehicle probes.
- *Advanced Traveler Information Systems (ATIS)/Vehicle Navigation and Surveillance Technologies* – These ITS technologies include vehicle navigation technologies, which determine the vehicle position in real time (GPS, LORAN, dead reckoning, localized beacons, map database matching and cellular triangulation); and vehicle surveillance technologies, which collect a variety of information about specified vehicles (weigh-in-motion devices, vehicle identification, vehicle classification, and vehicle location).
- *Payment Systems Technologies* – These ITS technologies not only allow electronic fund transfer between the traveler and the service provider, but also enable vehicle recognition. They include Automatic Vehicle Identification (AVI), smart cards, and electronic funds management systems.

4.2.2 Evaluation of Methods

Limitations of Existing Methods and Opportunities in Future Methods

Table 4.1 summarizes the limitations of existing methods in providing information relative to performance-based planning. It also presents a list of opportunities in new methods to enhance the performance-based planning process.

The most notable limitations of existing data collection methods include:

- Relatively high and labor-intensive operational costs;
- Inability to reflect dynamic fluctuations in traffic;
- Varying degrees of accuracy; and
- Limited incentives for data sharing between public and private interests.

Opportunities in the new methods described include:

- Ability to provide real-time data;
- Lower long-term operational costs (although capital costs are significant);

Table 4.1 Data Collection Methods – Limitations of Existing Methods/Opportunities in Future Methods

Current Procedures and Capabilities	Future Directions/Improvement Actions
<p>Manual Traffic and Transit Surveillance, and Manual Vehicle Surveillance</p> <ul style="list-style-type: none"> • Sporadic data collection practices • Data not reflecting dynamic fluctuations in traffic • Application with semi-accurate results • Limited temporal and spatial representation of traffic. 	<p>ITS/Advanced Traffic Management Systems (ATMS)/Traffic Surveillance Technologies</p> <ul style="list-style-type: none"> • Can provide an important source of real-time data • Can replace most manual traffic and vehicle surveillance functions • Individual sensors are primarily deployed through signalized traffic control, ramp metering, and detection programs • A few major urban areas have integrated their ATMS sensors into one traffic operations system where data is being processed in a central location and can be retrieved for planning purposes • Most metropolitan areas have deployed ATMS sensors in many subsystems which are not yet integrated into one system, or do not output MCEs that can be used in performance planning • Seventy U.S. metropolitan areas are currently in the process of planning and deploying integrated traffic management systems
<p>Manual Freight and Goods Movement Surveillance</p> <ul style="list-style-type: none"> • Complex data collection process involving sampling of truck performance and freight shipments • Limited cooperation by private sector; Information on the amount and location of truck trips is kept confidential for competitiveness 	<p>ITS/Advanced Traveler Information Systems (ATIS)/Vehicle Navigation and Surveillance Technologies</p> <ul style="list-style-type: none"> • Can replace most manual vehicle and freight surveillance functions, and some of the user survey functions • Can dramatically improve sample size and confidence on data • Would require private sector participation • ATIS technologies are in their early development stage in the U.S. • Privacy issue • Software needs to be developed for retrieving, checking and summarizing information from ATIS technologies • This information will need to be integrated with information from ATMS
<p>User Surveys</p> <ul style="list-style-type: none"> • Expensive development and application cost could be prohibitive 	<p>ITS/Payment Systems Technologies</p> <ul style="list-style-type: none"> • Using a combination of electronic readers and smart cards/tags this technology can replace most of the deterministic functions of user surveys (O-D patterns, route selection, travel time selection). Surveys are still needed to assess behavioral travel characteristics • Software needs to be developed for retrieving, checking and summarizing information from ATIS technologies • This information will need to be integrated with information from ATMS • Privacy issue

- Improved accuracy; and
- Improved incentives for public/private participation.

Dimensions of Data Collection Methods

Existing data collection methods produce order-of-magnitude to fairly-accurate results, while future data collection methods produce much more accurate information mainly because of the real-time dimension of ITS technologies, and because of the capability of accumulating more representative samples using ITS technologies. In terms of costs, existing data collection methods have lower development costs and higher application costs than future methods.

In terms of spatial focus, there are few differences between existing and future data collection methods. Certain data collection methods are appropriate for a single level of spatial analysis, while other methods might have multiple applications.

In terms of temporal focus, future data collection methods provide a much wider range of capabilities than existing methods: continuous second-by-second or minute-by-minute information is easily collected using ITS technologies in addition to hourly, daily, and average annual transportation performance information. This finer definition can provide valuable insight into the dynamic nature of traffic and transportation performance and form the basis for a more effective monitoring and management of transportation supply.

Dealing with the Cost of Data Collection

When ISTEA arrived on the scene, like many state and MPO planning agencies, the Colorado Department of Transportation (CDOT) expressed concern that the data required to drive performance measures to be used in their Congestion Management System (CMS) would prove overly costly. In order to simplify their efforts, their staff established three assumptions to help guide them through their performance measurement development process:

“Colorado will **not** expect system performance monitoring data to be at a level of detail sufficient to support the post-implementation evaluation of strategy effectiveness.

The system performance monitoring component of Colorado’s CMS will focus on collected data, not synthetic (modeled) data.

Colorado’s CMS will focus on traffic congestion issues... To the extent that the transportation planning process wants or needs to deal with “quality” issues, it will do so with modeled data as part of its process. That activity is **not** identified as a component of Colorado’s CMS.

With this approach, Colorado stressed an incremental, modular approach to collecting CMS data. They started slowly, building on the base of traffic data CDOT currently had on hand. While not addressing a full range of multimodal measures, CDOT was able to focus on issues that were of greatest interest to them.

Source: Rudy, Steven D. *Congestion Management System: The Early Years and the Colorado Experience*, Institute of Transportation Engineers 65th Annual Meeting, Compendium of Papers, 1995.

■ 4.3 Data Storage and Manipulation

The research, including the 10 case studies of transportation planning organizations and projects, has provided the research team with broad knowledge of current data storage, manipulation, and dissemination efforts underway at the federal, state, regional, and local levels. At the MPO level, for example, many regions are only now moving beyond the experimental phase with geographic information systems (GIS), or geographically-referenced databases. We found significant potential to tap into the organizational and analytical powers of these tools to better support data manipulation and dissemination.

Several emerging measures of effective performance are based upon spatial relationships between the traveling population and the transportation system. Measures such as the percent of population served by transit, or percent of population within a defined travel time of job centers (or other attractions) are important indicators of effectiveness. With the aid of geographically referenced transportation and land use data, these type of measures can be generated not only for observed conditions, but also be used to evaluate alternative future strategies.

As the benefits of improved data storage and manipulation and dissemination methods become more clear, some planning agencies are beginning to focus resources in this area. Michigan DOT, for instance, is making extensive efforts to redesign the “data model” used to support all its management systems. Integration of databases to allow access to many users, elimination of duplicative (and often conflicting) sources of similar data, a reduction in data processing and updating costs, and a careful review of the level, accuracy, and amount of data really necessary to support decision-making, are all objectives.

4.3.1 Inventory of Methods

Current Methods

Current data storage, manipulation, and dissemination methods include:

- *Highway Performance Monitoring System (HPMS) and Highway Economic Requirements System (HERS)* – These methods are statewide and urban area databases of a stratified sample of roadways. They are used to summarize highway conditions; select a set of needed improvements to highways based on minimum tolerable conditions specified by the program user (HPMS) or economic criteria based on benefit-cost analysis (HERS); and estimate the costs and consequences of these improvements.
- *Computerized Databases* – These databases could include information relative to highway, transit, freight, or other transportation system information. They are developed by federal, state, and local agencies for the purpose of planning, budgeting, monitoring, and evaluating the transportation system.
- *Geographic Information Systems (GIS) and Computerized Mapping* – These methods are used to store, organize, display, and analyze geographically-referenced transportation-related data.

Future Directions

The following data storage and manipulation methods are emerging and will be increasingly available in the future:

Advanced Traveler Information Systems (ATIS)/Communications Technologies – ITS communications technologies transmit and receive information from mobile and stationary sources (highway advisory radio, FM subcarrier, spread spectrum, microwave, infrared, commercial broadcasts, infrared or microwave beacons, cellular phones, two-way radio, and two-way satellites).

Interagency Coordination Technologies – These ITS technologies connect traveler-related facilities to other agencies such as police, emergency service providers, weather forecasters and observers, traffic management centers (TMS), transit operators, etc.

Database Processing Technologies – These ITS technologies manipulate, configure, or format transportation-related data for sharing among various platforms. General purpose database software is currently being adapted to transportation needs such as data fusion, maps, and travel services.

Work Scheduling, Reporting, and Inspection Technologies – With these technologies, can combine the data collection and data storage processes into one. These technologies include palm-sized and notebook computers, hand-held portable data entry terminals, bar-code scanners, electronic clipboards, and voice recognition systems.

4.3.2 Evaluation of Methods

Limitations of Existing Methods and Opportunities in Future Methods

Table 4.2 summarizes the limitations of existing data storage and manipulation methods relative to the needs of performance-based planning. It also presents a list of opportunities present in new methods to enhance the process.

At this time, there is significant interest around the country in the development and enhancement of existing technologies and methods for data storage, manipulation, and dissemination. GIS and computerized mapping is where much of the attention is now focused. Although the development and implementation of GIS may tax scarce agency resources, there are notable benefits to these systems, including:

- Potential for integration of micro- and macro-scale analytical techniques;
- Ability to provide geographically-referenced indicators (“number of employees within 10 miles of downtown”); and
- Improved graphical representation of transportation-related information.

Table 4.2 Data Storage, Manipulation, and Dissemination Methods – Limitations of Existing Methods/Opportunities in Future Methods

Current Procedures and Capabilities	Future Directions/Improvement Actions
<p>Computerized Databases (including Highway, Transit, and Freight Databases)</p> <ul style="list-style-type: none"> • Database management systems are often incompatible with one another, impeding the efficient and timely exchange of information 	<ul style="list-style-type: none"> • Coordinated and integrated approach to database system development and use will make better use of shared information and will help coordinate decisions • Emerging technologies can enable improved data acquisition (using ITS) and locational-based processing, retrieval, and display of information (using GIS) in support of database systems • Innovative attributes of ITS databases include real-time data processing, data fusion, and expert systems that perform initial screenings of traffic control actions • Development and maintenance of ITS databases can be partly funded by the private sector that could sell real-time traffic information, or business directories/"yellow pages" of service information • Only a few major metropolitan areas in the U.S. have developed embryonic traveler information databases • Federal and state agencies are currently facilitating the development/coordination of travel databases
<p>GIS and Computerized Mapping</p> <ul style="list-style-type: none"> • GIS provides for the integration of micro- and macro-scale analytical techniques • GIS allows for the visualization of changes over time • Development and implementation of GIS may be complex, time-consuming and costly for those agencies who do not already use it • The FHWA is currently conducting the "Geographic Information System-Transportation ISTE, Management Systems Server Net Prototype Pooled Fund Study" to address the management and monitoring systems as well as the statewide and metropolitan transportation planning requirements of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). 	<ul style="list-style-type: none"> • As ITS evolve, there is an increasing integration with GIS to develop and operate geographic user interfaces at Traffic Management Centers for traffic surveillance, and for use in Advance Traveler Information Systems, In-Vehicle Information Systems, and Route Guidance <p>Technologies for work scheduling, reporting and inspection</p> <ul style="list-style-type: none"> • This equipment can be used in conjunction with a distance measuring instrument or a GIS receiver in order to attach location tags to data collected in the field • These technologies can significantly reduce laborious and time-consuming field data collection • These technologies can also provide quick access to the transportation system database

**Table 4.2 Data Storage, Manipulation, and Dissemination Methods –
Limitations of Existing Methods/Opportunities in Future Methods (continued)**

Current Procedures and Capabilities	Future Directions/Improvement Actions
<p>ITS/Advanced Traveler Information Systems (ATIS)/Communications Technologies</p> <ul style="list-style-type: none"> • ITS communications technologies facilitate the dissemination of information on real-time traffic performance, and real-time traffic control measures • There is little compatibility in ITS communications technologies currently used in the U.S. Communications Standards are currently being developed by the federal government • These technologies are in their early deployment stage in the U.S. 	
<p>ITS/Inter-Agency Coordination Technologies</p> <ul style="list-style-type: none"> • Interagency coordination is an increasingly important function for monitoring, planning budgeting, evaluating, and implementing real-time traffic control actions • Federal and state agencies are currently working towards catalyzing public/private and interagency institutional relationships • Regional interagency coordination is currently starting at major urban areas around operating traffic management centers 	

Additional benefits lie in future methods, including:

- More efficient links to data collection process, thereby reducing labor costs in data input;
- Greater incentives for private sector involvement (with ITS technologies), which will enhance the content and availability of stored data; and
- Potential for improved data sharing among transportation and non-transportation agencies.

Dimensions of Data Storage Methods

The planning horizons for existing methods for data storage, manipulation, and dissemination focus on medium- and long-term planning primarily because of the level of effort involved in developing and maintaining a database. Future automated databases, however, are more likely to be integral parts of short-term transportation control strategies that can also be used in medium- and long-term planning.

Further, the goal of improved customer service will be better served using future methods for data storage, manipulation, and dissemination because ITS technologies provide better tractability and accountability related to the individual customer/traveler. For example, customized real-time real-location traffic information can be provided to a truck that is equipped with a GPS transponder and a communications system; only general traffic information is currently disseminated using the traditional highway advisory radio technology.

Widely used existing methods for data storage, manipulation, and dissemination include traditional databases, HPMS, and HERS, while the use of GIS is growing. The use of future methods is limited primarily because ITS deployment is currently preoccupied with deployment of hardware rather than developing software or value-added services.

Existing data storage, manipulation, and dissemination methods produce order-of-magnitude to fairly-accurate results, while future methods produce much more accurate information mainly because of the real-time dimension of ITS technologies, and because of the capability of accumulating more robust and representative samples using ITS technologies. In terms of costs, future methods have similar development costs and lower application costs than existing methods. However, prerequisites to ITS methods for data storage, manipulation, and dissemination include deployment of traffic monitoring hardware and integration of roadside hardware with data storage and dissemination systems.

Future data storage, manipulation, and dissemination methods have the potential to be more comprehensive than existing methods in terms of spatial focus. In terms of temporal focus, future methods provide a much wider range of capabilities than existing methods: continuous second-by-second or minute-by-minute information will be stored, manipulated and disseminated using ITS technologies in addition to hourly, daily, and average annual transportation performance information. Thus, the dynamic nature of traffic and transportation performance will be taken into account in the fine-tuning of transportation supply which in turn will be able to address both recurrent and incident-related congestion.

Urban Goods Movement and the ‘Dependable LOS’

A case study conducted for the San Francisco Bay Area Metropolitan Transportation Commission (MTC) points out the importance of dependability of the transportation system to trucking operations which are vital to the economic health of the region. The productivity of companies such as United Parcel Service and Consolidated Freightways hinges on the ability to avoid peak congestion, with most local distribution activities taking before or after the peak commute periods. Thus, the predictability of freeways and arterials during the midday and the “shoulders” of the peak period is critical to these companies. System reliability is deemed to be more important than top operating speed to the efficiency of goods movement within the urban area.

Conventional utilization and efficiency measures are inadequate to identify the contribution of a reliable system to the economic well-being of the region. The concept of a “Dependable Level of Service” on principal truck routes has been proposed to fill this gap. Such a measure will require real-time traffic surveillance to monitor and manage traffic flows, as well as the analytic capability to develop valid statistical measures from the data. In the MTC region, Caltrans’ Traffic Operating System (TOS) will eventually provide this capability on freeways. However, because the dependability of conditions on select arterials can be as important for efficient goods movement as on adjacent freeways, it will be desirable to extend this kind of monitoring to the arterial streets as well. Such a system could be used to enhance the reliability of arterial transit bus service as well.

The MTC study concludes that monitoring and managing the off-peak dependability of the system is critical to efficient goods movement. The various ITS strategies evaluated in this NCHRP report are well suited to the particular analytical requirements of this type of performance measurement.

Source: David W. Jones, Intermodal Performance Measures for the Bay Area Transportation System, Draft Report, December 1994.

■ 4.4 Data Analysis and Forecasting Methods

Much of the value in improved data collection, manipulation and evaluation methods lies in the resulting improvement in descriptive analysis. Certainly, using performance measures to report on the current condition of the transportation system is a valuable improvement to the planning process. However, it will always be desirable to generate better estimates of *future* activity and performance, in order to support decisions related to significant investment strategies, regulatory policies, etc.

The research highlighted the limited ability of many traditional forecasting methods to generate the kind of data needed to support more robust, multimodal performance measures. The over-reliance on facility utilization measures such as volume to capacity (V/C) ratio and transit patronage has led to a generation of forecasting tools which are unable to produce reliable indicators of broad, multimodal system performance, and which do not adequately support tradeoff decisions between alternative modal strategies.

The research also pointed to the potential benefits of linking demand forecasting methods to both the databases and to exogenous models used for various purposes. There are opportunities to take greater advantage of the various components by linking them more directly. For example, a GIS database can be a very powerful tool for organizing and presenting the results of multiple alternative analyses. This same method in turn provides better data for improved forecasts in subsequent iterations. Finally, more direct and uniform linkage to exogenous analytical tools, such as emissions inventories, will improve the ability to generate measures of environmental performance.

4.4.1 Inventory Of Methods

Current Methods

Current data analysis and forecasting methods include:

- *Sketch Planning Techniques* – These techniques include sketch planning demand models, systematic analysis and transfer of empirical data, quick-response travel estimation techniques, level of service (LOS), V/C ratio, and vehicle volume and speed estimation procedures.
- *Macroscopic Simulation Models* – These traffic models are based on deterministic relationships developed through research on highway capacity and traffic flow. The simulation for a macroscopic model takes place on a highway section-by-section basis rather than on an individual vehicle basis. Typical software packages include TRANSYT-7F, CORFLO, and FREQ.
- *Microscopic Simulation Models* – These traffic models simulate the movement of individual vehicles, based on theories of car-following and lane-changing. Typically, the model simulates a statistical distribution of vehicles that enter the transportation network and then tracks them through the network on a second-by-second basis. Typical software packages include NETSIM, FRESIM, and INTEGRATION.
- *Land Use Allocation Models* – These models reflect the effects of the transportation system (i.e., effects on accessibility, economic development potential, etc.) on the type spatial distribution of future development.
- *Travel Demand Models* – Traditional travel demand models follow a four-step process, including trip generation, trip distribution, mode choice, trip assignment, and activity-based models. A number of software packages can be used to implement this process, including TRANPLAN, MinUTP, and EMME/2.
- *Freight and Goods Movement Models* – These methods include trend analysis, freight network models, and freight transportation demand models. Trend analysis uses historical growth rates for certain key markets, and projects these growth rates into the future, modified by correction factors reflecting competitive conditions, macroeconomic environments, and projections of technological efficiency improvements. Freight network models can handle a large number of freight modes, network links, and nodes, and can contain explicit mode choice algorithms based on minimization of cost and time by mode and route. Freight transportation demand models are similar to network models, although they differ in that demand models explicitly estimate behavioral relationships such as mode and route choice.

- *Impact Models* – These models are used to estimate emissions, fuel consumption, and safety impacts of transportation improvements. Typical software packages include MOBILE and EMFAC.

Future Directions

The following data analysis and forecasting methods are emerging and will be increasingly available in the future:

- *Traffic Prediction Models* – These ITS technologies can be used to predict future traffic characteristics based on real-time information. Algorithms under development include real-time traffic prediction and traffic assignment.
- *Traffic Control Models* – These ITS-related models relate to the real-time control of traffic. Algorithms under development include optimal control and incident detection, and the mutual effects of these processes on one another.
- *Routing Models* – These ITS-related models relate to the routing of vehicles, including the generating of step-by-step driving instructions to a specified destination. Algorithms under development include the scheduling of drivers, vehicles, and cargo; route selection; commercial vehicle scheduling; and route guidance.

4.4.2 Evaluation of Methods

Limitations of Existing Methods and Opportunities in Future Methods

Table 4.3 summarizes the limitations of existing forecasting methods in providing information relative to performance-based planning. It also presents a list of opportunities in new methods to enhance the performance-based planning process.

At this time, there are notable gaps between the abilities of existing tools. Sketch planning techniques only produce order-of-magnitude results, which lose utility as the planning process moves beyond its initial stages. Simulation models are successful in estimating operational changes in traffic flow such as delay, speed, and queuing, but do not consider the trip generation, trip distribution, mode choice, and route choice in system evaluation. Conversely, traditional four-step travel demand models are generally unable to incorporate the effect operational changes into their estimates of generation, distribution, mode choice, and route choice.

Future methods will seek to not only bridge these gaps, but to improve the depth and breadth of forecasts of transportation system performance. Improvements include:

- Incorporation of trip generation, trip distribution, and mode choice in simulation models;
- Enhancements/modifications to traditional four-step process, including peak spreading, dynamic assignment, representation of traveler information, trip chaining, sensitivity to emissions and fuel consumption procedures, and non-motorized travel; and

Table 4.3 Data Analysis and Forecasting Methods – Limitations of Existing Methods/Opportunities in Future Methods

Current Procedures and Capabilities	Future Directions/Improvement Actions
<p>Sketch Planning Analysis Techniques</p> <ul style="list-style-type: none"> • Sketch planning techniques produce only order-of-magnitude results with limited accuracy • These techniques can play a valuable screening role during the early phases of the analysis 	<ul style="list-style-type: none"> • Enhancements include post or parallel processors such as time-of-day models, parking choice models, etc.
<p>Macroscopic and Microscopic Simulation Models</p> <ul style="list-style-type: none"> • Traffic simulation models are successful in accurately estimating changes in traffic operational characteristics such as delay, speed, and queuing • Traffic simulation models do not consider trip generation, trip distribution, mode choice, and major route choice in their evaluation of changes in transportation systems 	<ul style="list-style-type: none"> • Incorporate trip generation/trip distribution/mode choice in the simulation process • Enhancement towards real-time information and modeling of vehicle routings and how drivers react to changing conditions • Explicitly differentiate and represent informed (real-time information) and uninformed (historical information only) drivers.
<p>Regional Travel Demand Models</p> <ul style="list-style-type: none"> • Evaluating changes in transportation systems and operations requires specific analytical capabilities, such as the consideration of trip generation, trip distribution, mode choice, major route choice, and the representation of traffic flow in a network presently found only in the structure of a travel demand model • Travel demand models have only limited capability to accurately estimate changes in traffic operational characteristics such as delay, speed, and queuing 	<ul style="list-style-type: none"> • Integration of GIS capabilities allows calculation of “accessibility” measures which are sensitive to land use policy or actions • Improved forecasting of speed, delay and queuing • Peak spreading • Dynamic assignment • Representation of traveler information • Enhanced sensitivity of emissions and fuel consumption procedures • Modeling trip chaining behavior • Mode choice modeling improvements • Modeling non-motorized travel • Linked regional/simulation models <ul style="list-style-type: none"> - Full integration of travel demand models and simulation models into a single software - Prediction of travelers’ response to information - Also see desired capabilities and improvement actions in travel demand models and simulation models

Table 4.3 Data Analysis and Forecasting Methods – Limitations of Existing Methods/Opportunities in Future Methods (continued)

Current Procedures and Capabilities	Future Directions/Improvement Actions
<p>Land Use Allocation Models</p> <ul style="list-style-type: none"> • It is very costly to develop and calibrate a land-use allocation model 	<ul style="list-style-type: none"> • Linkage to the travel demand modeling process will lower the development cost
<p>Freight and Goods Movement Models</p> <ul style="list-style-type: none"> • A “Quick Response” Freight Manual is currently under development by the FHWA 	<ul style="list-style-type: none"> • Many of the factors influencing freight demand cannot be fully quantified. Incorporation of the effect of these factors into freight forecasts requires judgment.
<p>Impact Models</p> <ul style="list-style-type: none"> • The most significant weakness of current emissions and fuel consumption models is that they do not take into account differences in vehicle operating mode (acceleration, deceleration, cruising, idle) 	<ul style="list-style-type: none"> • Develop emission models and emission rates sensitive to vehicle operating mode (ongoing) • Develop accident prediction models sensitive to levels of congestion and to the presence of another accident
	<p>ITS/Traffic Prediction Models</p>
	<ul style="list-style-type: none"> • These models will provide the backbone for real-time traffic information • These models require development of behavioral traffic prediction algorithms that estimate drivers’ reaction to changing traffic conditions • These models require development of corrective feedback mechanisms to perform frequent reality checks. • Incorporation of mode choice and trip generation in ITS traffic prediction models.
	<p>ITS/Traffic Control Models</p>
	<ul style="list-style-type: none"> • Inputs/ outputs of these models can be very useful in performance-based planning. • Algorithms will need to be developed to aggregate model inputs/ outputs so that they become useful in the planning process
	<p>ITS/ Routing Models</p>
	<ul style="list-style-type: none"> • Routing models will need to be linked with Traffic Prediction models and Traffic Control models

- Use of real-time modeling of vehicle routings to more accurately predict future travel characteristics.

Dimensions of Data Analysis Methods

Historically, transportation analysis and forecasting tools were developed to model performance in distinct transportation subnetworks (freeways, arterials, corridors, etc.) and in distinct transportation subsystems (highway, transit, freight). Typically, these transportation subnetworks and subsystems have distinct operational characteristics that were reflected in the development of analytical and forecasting tools. This is one reason for the limited applicability of analytical and forecasting tools across transportation modes.

The planning horizons for existing methods for data analysis and forecasting range from short- to medium- to long-term. ITS data analysis and forecasting tools, however, focus on short-term planning horizons since they are integral parts of short-term transportation control strategies. Historical information on system performance however, can be used in medium- and long-term planning.

The goal of improved customer service will be better served using ITS methods for data analysis and forecasting because some ITS short-term forecasting tools focus on the individual customer/traveler. For example, ITS routing models will provide step-by-step driving instructions to a traveler-specified destination. Similarly, in the area of freight transportation these models will assist in the scheduling of drivers, vehicles, and cargo taking into account real-time traffic conditions.

Widely used existing methods for data analysis and forecasting include sketch planning analysis techniques, regional travel demand models, and impact models; there is a growing use of simulation models, while there is limited use of land use models, and freight and goods movement models. The use of “future” ITS methods is limited primarily because ITS deployment is currently preoccupied with deployment of hardware rather than developing software or value-added services.

Existing data analysis and forecasting methods produce order-of-magnitude to fairly-accurate results, while future methods produce much more accurate information mainly because of the real-time dimension of ITS technologies, and because of the capability of accumulating more robust and more representative samples using ITS technologies. In terms of costs, future analysis and forecasting methods have similar development costs and application costs to existing methods. However, prerequisites to ITS methods for data analysis and forecasting include the deployment of traffic monitoring hardware, the integration of roadside hardware with data storage and dissemination systems, and the development of ITS databases.

A review of existing data analysis and forecasting methods shows that certain methods are appropriate for a single level of spatial and/or temporal analysis, while other methods might have multiple applications. Future data analysis and forecasting methods focus on real-time or near-real-time performance to produce optimal traffic control and to provide customer-specific routing information.