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ALTERNATIVE PERFORMANCE MEASURES FOR TRANSPORTATION PLANNING: EVOLUTION TOWARD MULTIMODAL PLANNING

Dr. Michael D. Meyer, P.E.

Georgia Institute of Technology
Atlanta, Georgia 30332

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16. Abstract

This report presents the results of a research project which examined the incorporation of mobility and accessibility concerns into transportation planning. The questions addressed include: how is system performance defined, and who defines it?; what is the difference between an "output" and an "outcome"?; what are the most appropriate performance measures and how should they be used?; what are the implications of performance based planning on data collection and on the types of analysis tools that are available to transportation planners?; and how do performance measures relate to goals, objectives, and measures of effectiveness? This research was based on extensive case studies of State transportation agency, metropolitan planning organization (MPO), and transit agency planning efforts that were characteristic of the performance-based planning process suggested by ISTEA. In particular, potential MPO case studies were identified through a telephone survey of the largest 50 MPO's in the country. In addition, on-going research and planning efforts at the State and national levels were monitored for application in this research. The key findings which include: mobility and accessibility should be important measures of system performance; travel time and modal availability should be the foundation for mobility measures; accessibility measures should be incorporated into project, plan, and system evaluation approaches; and market segmentation and distributional affects of mobility and accessibility changes should be part of measuring system performance.

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Alternative Performance Measures for Transportation Planning: Evolution Toward Multimodal Planning

1.0 INTRODUCTION

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 established an important foundation for multimodal planning in the United States. Not only did ISTEA provide flexibility in the use of federal funds for investments in the transportation system, but it also outlined a vision of, and a planning process for, a transportation system that calls for system integration and coordination with other societal concerns. Historically, ISTEA will most likely be viewed as one of the first federal transportation initiatives to formally require States and metropolitan areas to incorporate some sense of system performance into the planning and decision making processes. This was done most visibly through the required use of management systems (this requirement later changed to optional use), although there were many other elements of the planning process that were related to improved understanding of how well the transportation system was performing.

In a broader context, this focus on transportation system performance reflected a general policy and corporate trend of better measuring the results of government and business action. In education, health, and public safety, in particular, a great deal of public and professional attention had been given over the previous five years to the results of often large expenditures. This national trend in performance measurement and accountability which was first seen in transportation in a significant way with the use of FTA's Section 15 monitoring reports was extended in concept to the entire transportation system by ISTEA.

The ISTEA focus on system performance has created a substantial professional interest in the substance and approach of a new planning concept called "performance-based planning". Most of the past research on measuring system performance and almost all of the current practice in transportation planning has focussed on more traditional measures that relate the performance of a transportation facility to the theoretical capacity of that facility to handle estimated demands. The best example of such a measure is the relationship of estimated vehicular demand to theoretical road capacity, or as is known in the profession, "volume to capacity" (v/c). In transit, an analogous measure is "load factor" which is the relationship between riders on the vehicle compared to theoretical space available to handle a capacity load. However, this perspective on facility performance is primarily one taken by the operators or owners of the facility. State departments of transportation, transit operators, port authorities, and other "owners" of transportation facilities have measures which illustrate how efficient a particular facility or service is operating. ISTEA provided a different perspective for transportation planning, one that is more concerned with the users or stakeholders of the transportation system. This perspective suggests that the operation of a transportation facility is indeed important; however, this facility or service is just one element of a user's trip. A users' perspective on transportation system performance leads to a definition of system performance that is more concerned with the ultimate purpose of transportation systems--***user mobility and accessibility.***

Researchers and practitioners alike have become acutely aware of the need for a different approach toward measuring system performance and monitoring goal achievement. Many agencies are currently developing performance measures and indices which will provide needed information for informed decision-making in the current multimodal environment. This report presents the results of a research project which examined the evolving understanding and use of multimodal performance measures within the transportation planning profession. In particular, the focus of the research was on the incorporation of mobility and accessibility concepts into performance-based planning.

During this research, several key questions continually surfaced from transportation officials who were interviewed as part of the project. These questions are listed in this introductory section so they can provide an indication of the key issues that must be addressed by those interested in developing a performance-based planning process. In addition, they provide a general guide to the type of information provided in this report. These questions are:

- How is system performance defined, and who defines it?
- What is the difference between an "output" and an "outcome"?
- What are the most appropriate performance measures and how should they be used?
- What are the implications of performance based planning on data collection and on the types of analysis tools that are available to transportation planners?
- How do performance measures relate to goals, objectives, and measures of effectiveness?

The answers to these questions are critical to the development of a performance-based planning process that is meaningful to State and local transportation officials.

This research was based on extensive case studies of State transportation agency, metropolitan planning organization (MPO), and transit agency planning efforts that were characteristic of the performance-based planning process suggested by ISTEA. In particular, potential MPO case studies were identified through a telephone survey of the largest 50 MPO's in the country. In addition, on-going research and planning efforts at the State and national levels were monitored for application in this research. For example, the U.S. Department of Transportation sponsored a National Conference on National Transportation System Performance on November 1-2, 1995 which provided a unique overview of performance-based planning at the national level. Several on-going National Cooperative Highway Research Program (NCHRP) and Transit Cooperative Research Program (TCRP) projects also provided important background information. In particular, TCRP project H-2 "Measuring and Valuing Transit Benefits and Disbenefits" and

NCHRP Project 8-32(2) "Multimodal Transportation: Development of a Performance-Based Planning Process" identified some important elements of performance-based planning, especially in relation to transit investments, that helped guide this research project.

Section 2 of this report discusses the historical evolution of the use of performance measures in transportation planning. Section 3 presents a typology for the way performance measures, both "traditional" and "state-of-the-art", can be incorporated into transportation planning. Section 4 presents the case studies of performance-based planning examples that served as the foundation of the recommendations and conclusions which are found in Section 5. This Section provides specific recommendations on how the transportation planning profession should incorporate a broader definition of system performance into the planning process. A extensive bibliography and reference list of illustrative literature for this topic is provided in the Appendix.

2.0 EVOLUTION OF PERFORMANCE MEASURES IN TRANSPORTATION PLANNING

Transportation decision making has historically been influenced by modally-based funding categories. Accordingly, such decision making became oriented toward determining the most cost efficient expansion of modally-defined infrastructure. And the planning that preceded this decision making, not surprisingly, dealt with specific modal concerns. However, the environment for transportation planning changed with the passage of ISTEA in 1991 and the Clean Air Act Amendments (CAAA) in 1990. These benchmark pieces of legislation have arguably provided State and local jurisdictions with more flexibility in determining transportation priorities. In the case of the CAAA, the priorities of such investment are oriented toward system improvements that improve air quality. This flexibility, and an increasing trend toward viewing transportation as a means of accomplishing some end, has led to a great deal of interest in broadening the view of what "successful" transportation system performance means. To understand the current challenge to the transportation profession regarding a more flexible perspective on system performance, it is first useful to review the evolution of the use of performance measures in transportation planning.

2.1 A FOCUS ON THE PERFORMANCE OF THE ROAD SYSTEM

The primary developmental period for the systematic approach toward transportation planning that characterizes current practice occurred in the 1960's and 1970's. Transportation planning during this period was concerned with many issues, but primarily the focus was on system expansion to meet the growing demands for automobile travel and the corresponding characteristics of high speed and safe use of the road system. Average vehicular speed, estimated usage of the system or network links (such as volume to capacity), accidents, and costs became the most used criteria for evaluating alternative transportation system plans. The 1962 transportation plan for the Chicago region, for example, used five evaluation criteria in the determination of a recommended plan--miles of proposed routes, average weekday vehicle miles, daily vehicle equivalent hours of travel, daily and annual traffic fatalities, and overall costs to complete the proposed system as well as cost per vehicle mile [Chicago Area Transportation Study, 1962].

As the nation's urban road system expanded, congestion on this system and the concomitant effects on the environment became an important issue to system users, decision makers, and analysts. Congestion, the effects of congestion, and measuring congestion levels were thus some of the important system performance issues that drew the interest of transportation professionals in the 1980's and 1990's (see [Meyer, 1994] for an overview). However, much of this professional interest focussed on measures that had been developed in the mid-1950's by engineers and planners who were interested in the impacts of congestion on vehicle flow. Suggested measures of congestion during this period focussed on three major factors:

> <u>Operational characteristics</u> of traffic flow which includes speeds, delays, and overall travel times,
>
> <u>Volume to capacity</u> characteristics which requires comparison of actual volumes to road capacity, and
>
> <u>Freedom of movement</u> characteristics which would require a determination of the percentage of vehicles restricted from free movement and the durations of such restrictions.

As noted by Pignataro, several types of congestion indices surfaced from this early work [Pignataro, 1983].

1. The ratio of the actual travel time a vehicle occupies a section of roadway to the optimum travel time

2. Simple travel time to traverse a specified section of roadway

3. Reduction in speed which occurs at high volumes without corresponding changes in volumes

4. Relationship of average overall speed to speed changes and frequency of speed changes per mile

5. Relationship of time loss to driver inconvenience and discomfort

Much of this earlier work resulted in the method of highway capacity analysis and level of service determination that is common to transportation engineering today (although the recent version of the Highway Capacity Manual has moved away from the volume to capacity measure to one focussed on vehicular delay, thus trying to incorporate a travel time element into facility performance). In addition, this earlier work focussed exclusively on specific facility characteristics, with little attempt to develop a regional or subregional measure of congestion. This pioneering work, however, did not go unnoticed as alternative measures of congestion were developed for the 1990's.

More recently, the transportation profession has begun to examine once again how congestion should be measured. Kraus, Mohring, and Pinfold [1976] estimated a model of the welfare cost of congestion concluding that congestion cost the U.S. approximately 10 percent of the gross national product at the time the article was written. Lindley published a more practical approach to measuring congestion [Lindley, 1987]. This approach addressed congestion on urban freeways only, and used as the primary source of data the 1984 Highway Performance Monitoring System (HPMS) survey of approximately 50% of the freeway sections in the U.S. in urban areas over 50,000 population. Congestion was defined as occurring whenever the volume to capacity ratios for the HPMS section rose above 0.77, the breakpoint between levels of service C and D. The cost of congestion was estimated as a function of vehicle miles traveled under congested conditions including some measure of delay costs for recurring congestion. Cost of non-recurring congestion was estimated in similar fashion, based on flow rates past incidents of various types and their probable frequencies.

In 1989, the General Accounting Office (GAO) published a report on traffic congestion which surveyed efforts in the U.S. to measure congestion [GAO, 1989]. None of the measures cited by the GAO were as useful as the Lindley approach although a number are likely to be necessary input data in any effort to estimate the prevalence and costs of congestion. These included: traffic density, average travel speed, maximum service flow rate, volume-to-capacity ratios, average daily traffic volume and daily vehicle miles traveled.

Schrank, Turner, and Lomax [1993] of the Texas Transportation Institute (TTI) undertook one of the more systematic approaches to measuring congestion in U.S. cities. Similar to Lindley's approach, these researchers assumed "congested" facilities were those which experienced performance above some threshold value. The value selected was 13,000 daily vehicle miles of travel per lane-mile on freeways and 5,000 daily vehicle miles of travel per lane-mile on principal arterials. Much of the data for this assessment came from the national HPMS database.

Another effort using the HPMS database was focused on a much broader examination of comparative performance measures of state DOT transportation programs [Hartgen and Krauss, 1992]. This study examined 14 data items associated with each of the 50 state transportation agency program characteristics and resulting performance data. The performance data from the HPMS sections of most interest to this review was the change over time in the percentage of urban Interstate and other freeways that were congested. From 1984 to 1989, the percentage of urban freeways experiencing congestion increased significantly. For example, the percent of the urban Interstate HPMS sections considered congested went from 36.8% in 1984 to 52.6% in 1989. However, in 1990, the percent congested increased only slightly to 52.8%. The authors concluded, "in summary, the 1990 statistics show continued improvement, but with a leveling off of congestion increases."

Other efforts to assess changing congestion levels have relied on national data that come primarily from the U.S. Census journey-to-work data. Perhaps the most interesting use of this data was made by Gordon, Richardson, and Jun [1991] in which 1980 journey-to-work data was compared to the results of the 1985 American Housing Survey for the top 20 metropolitan areas in the country. The authors found that the work trip travel times fell or remained almost constant over this time period. Commuting times tended to be shorter in cities experiencing rapid growth. Based on this analysis, the authors suggest that the phenomenon reflected in the data is one whereby individuals and firms adjust rationally to adverse changes in physical and economic conditions such as high travel times so as to keep commuting times within tolerable limits. This adjustment process is primarily oriented to the spatial relocation of activities and residential locations to maintain this trip time tolerance. Congestion mitigation is thus nothing more than the process of allowing rational (economic) location decisions to occur, and of not placing restrictions on the way this land use pattern occurs.

This preliminary discussion of congestion measures provides two important points of departure for the discussion that follows. First, identifying different approaches toward 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, although as was mentioned earlier, with little application at the metropolitan level. Second, the discussion of congestion measures must necessarily begin with the identification of the target market. 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 to system capacities. For the users of the road system, there are different measures which reflect actual trip patterns and trip characteristics. For operations reporting, desired measures would rely on the traditional counts taken 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 would be the total time (in minutes or hours) of delay. User-based monitoring would identify the differences between system measures and individual measures, such as changes 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. One of the reasons why there is possibly some discrepancy in the results of congestion studies is precisely the difference in 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 segment).

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 extremely important determinants of performance.

The performance measures which are derived from each "school of thought" carry with them value judgments as to what the user may perceive as performance [Meyer and Mazur, 1995]. Frequently, no direct and concise connection can 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. In fact, many of these performance measures were originally used as design standards for transportation systems. In this original use, these measures were normative; that is, they described how much a project *ought* to cost, how infrastructure *ought* to perform, how and when service *ought* to be provided, and how the distributions of demand and supply *ought* to be handled. Each group of performance measures carried with them distinct assumptions about the nature of the system, and expected or projected trends in the future.

As transportation planning evolved, performance measures were later utilized to monitor, retrospectively, the performance of the design against observed conditions in terms of capacity, cost, etc. In this role, performance measures were empirical. In essence, the designed system (what *ought* to be) was compared with reality (what is). This distinction is important to note because of the limitations that were placed on the use of these performance measures, and the subsequent ability (or inability) to develop more robust and useful performance measures. Historically, the normative role defined the development of empirical studies which followed.

In the transition from the normative to the empirical role, early performance measures could remain focussed and useful for the purpose at hand. For example, level of service for highways could be used to both design and monitor highway capacity. However, the time has passed for such mode-specific views of transportation to serve as the basis of broad-based planning. With the continuing need to make difficult choices between competing alternatives, there is a need to reverse the order of the empirical and normative roles. More and more, there is a desire to use empirical standards to now define the development of normative standards. Using the previous highway example, many agencies now find themselves trying to use highway level of service to define all types of transportation performance. In many cases, the focused empirical performance measures do not adequately explain the complex value judgments underlying the original normative measures.

The evolution of performance measures from their early use as design tools continues today. While many agencies find the traditional measures convenient, especially since it took so long to make decision-makers "comfortable" with their meaning, other agencies are now finding it necessary to rethink transportation planning from a much broader perspective of what role transportation service really provides to a state or metropolitan area. The remaining part of this

Section provides an overview of the types of performance measures currently in use by transportation planners and the characteristics of the non-traditional performance measures being contemplated by several metropolitan areas.

2.2 TYPICAL SYSTEM PERFORMANCE MEASURES IN USE TODAY

As the fourth year of planning and funding under ISTEA continues, most agencies still approach transportation planning activities with a traditional toolbox of performance measures. These traditional measures can be identified by their unimodal focus and non-user perspective of performance. The most common measures include capacity, safety, and highway congestion; and efficiency and "cost-effectiveness" for transit. Road-oriented measures are usually defined by methods in the Highway Capacity Manual (HCM), although as noted earlier, the newest version of the HCM uses average vehicular delay as a major performance measure even though many of the applications found by this research project still relied on volume-to-capacity measures. The HCM specifies modally segregated service level measures. Modules for each mode compute stand-alone measures intended for independent design and monitoring of each element of the mode. Techniques are not specified for defining a systemwide (or even a mode-wide) performance level.

This lack of a system perspective within capacity measures has sparked limited use of congestion indices to measure roadway performance over a wide area. Congestion indices borrow a great deal from the HCM, and incorporate some measure of delay or travel (e.g. VMT or volume) aggregated over a corridor or region A corridor aggregation would allow for an "apple to apple" comparison of roadway segments throughout a region. The systems level perspective has found increasing use lately with the increased interest on the air quality impacts of transportation. Several examples of roadway-based performance measures are listed in Table 2-1. This list comes from a review of practice for the Federal Highway Administration of what analytical capability was necessary to support effective congestion management system planning [Cambridge Systematics, 1994]. Note in this list the different scales of application that these measures could be used at, and the degree to which the performance measure could be "forecasted" with current modeling approaches. This latter characteristic provides a critical ability of looking at system performance levels with or without changes in the network in a planning context.

The list in Table 2-1 represents a much greater number of performance measures than one would find in use in any particular State or metropolitan area. Each has important data collection requirements associated with it, and thus some level of costs. This means that is unlikely that more than three or four of these measures would be used in any one jurisdiction for monitoring purposes. However, these performance measures can also be used as criteria in the evaluation of transportation projects and plans. Therefore, this list can serve many purposes for the

Table 2-1 Performance Measures for the Road System

SYSTEM/PERFORMANCE

	Corridor	Area-wide/ Subarea	Forecastable
<u>Time-Related Measures</u>			
Average Travel Speed	●		
Average Travel Time	●		●
Average Travel Rate	●	●	●
Travel Time Contours		●	●
Origin-Destination Travel Time	●	●	
Percent Travel Time Under Delay Conditions	●	●	
Percent of Time Average Speed Below	●		
<u>Volume Measures</u>			
VMT/Lane Mile	●	●	
Traffic Volume	●	●	●
<u>Congestion Indices</u>			
Congestion Index	●	●**	
Roadway Congestion Index	●	●	●
TTI's Suggested Congestion Index	●	●	●
Excess Delay	●	●**	
<u>Delay Measures</u>			
Delay/Trip	●		
Delay/VMT	●		
Minute-miles of delay	●		
Delay due to construction/incidents	●		
<u>Level-of-Service Measures</u>			
Lane-miles at/of LOS "X"	●	●	
VHT/VMT at/of LOS "X"	●	●	
Predominant Intersection LOS	●		
Number of Congested Intersections	●		
<u>Vehicle Occupancy/Ridership Measures</u>			
Average Vehicle Ridership	●	●	
Persons/Vehicle	●	●	

**Weighted average

Source: Cambridge Systematics

transportation planning process of today.

Transit agencies have, by necessity, developed a slightly more robust set of performance measures to both meet the Section 15 reporting requirements and to "justify" the expenditure of tax dollars on publicly financed services. Transit performance measures, such as those listed in Table 2-2, have traditionally been categorized as efficiency or effectiveness measures. Efficiency measures relate service inputs to outputs, and usually include performance criteria such as costs, productivity, utilization, etc. Effectiveness measures, on the other hand, relate service provision to service need, and usually include criteria such as utilization, access, convenience, etc. [Washington and Stokes, 1988] In most cases, however, these performance measures are used for monitoring the performance of the transit program and the degree to which this performance is measuring up to financial expectations. These measures are often not used as part of the transportation planning process (although they are now more likely to be used in the context of major investment studies).

In summary, the focus on system performance over the past several years has been defined in many areas as a measurement of the performance of the road system. This focus is certainly an important one given the critical role the highway network plays in most metropolitan transportation systems. However, ISTEA provides a much broader perspective on transportation system performance. Defining this additional perspective necessarily requires one to look beyond road performance and ultimately relate the fundamental role of transportation systems to expectations of system performance.

2.3 MOBILITY/ACCESSIBILITY-ORIENTED PERFORMANCE MEASURES: TOWARD A BROADER PERSPECTIVE

Several States and metropolitan areas, typically in response to legislation, have begun to experiment with a cadre of "new" performance measures which facilitate a multimodal, systems view of transportation. To date there has been little attention given to multimodal performance measures. In fact, much of the innovative work in multimodal performance measures over the past few decades has been initiated by planners interested in comparing transportation alternatives from a multimodal perspective. A recent national review of multimodal evaluation in passenger transportation, for example, identified a limited set of projects that used multimodal evaluation criteria [Rutherford, 1994]. The different types of criteria used in these studies are shown in Table 2-3. The conclusions of this review are quite revealing in terms of the current state-of-practice of multimodal evaluation. As noted in the report:

Table 2-2 Common Transit Performance Measures

MEASURE	INDICATOR	TYPE
Labor Productivity	Revenue vehicle miles per employee	Efficiency
	Revenue vehicle hours per employee	Efficiency
	Operating expense per employee	Efficiency
Vehicle Utilization	Revenue vehicle miles per vehicle	Efficiency
	Revenue hours per vehicle	Efficiency
Cost per Produced Unit Output	Operating expense per vehicle mile	Efficiency
	Operating expense per seat mile	Efficiency
	Operating expense per vehicle hour	Efficiency
Accessibility	Percent population served Employees within 30/45/60 minutes Mode Share Transit travel time ÷ highway travel time	Effectiveness
Service Utilization	Total passengers per vehicle	Effectiveness
	Passengers per service area population	Effectiveness
	Passengers per revenue vehicle mile	Effectiveness
	Passengers per revenue vehicle hour	Effectiveness
Subsidy	Subsidy per passenger trip	Efficiency
	Operating ratio	Efficiency
	Subsidy per vehicle mile	Efficiency

Source: Mercier and Stoner, p. 227, as modified

Table 2-3 Classification of Criteria Source: [Rutherford, 1995]

General Category	Typical Criteria
1. Transportation System Performance	Number of trips by mode Vehicle miles traveled Congestion Peak hour congestion Transit boardings Highway level of service
2. Mobility	Mobility options Improved movement of people
3. Accessibility	% within 30 minutes, etc. Transit and highway speeds
4. System Development, Coordination and Integration	Terminal transitions Transportation system development Regional importance Projects in existing plans
5. Land Use	Compatibility with land use plans Growth inducement
6. Freight	Reduced goods movement costs
7. Socioeconomic	Homes or businesses displaced Maximize economic benefit Historic impacts Construction employment
8. Environmental	Air Quality Sensitive areas Natural environment
9. Energy	Energy consumption
10. Safety	Annual accidents by mode Safety ratings
11. Equity	Equity of benefit and burden
12. Costs	Capital costs Operating costs
13. Cost Effectiveness	Annualized costs per trip or mile FTA (UMTA) index
14. Financial Arrangements	Funds required Funding feasibility - Build/operate Public/private sources
15. Institutional Factors	Ease of staging and expansion Nonimplementing agency support
16. Other	Fatal flaw Right of way opportunities Enforcement Recreation

- Few of the studies used a wide range of evaluation criteria

- Mobility, system coordination and integration, land use, freight, energy, safety, cost-effectiveness, equity, financial arrangements, and institutional factors were left out of most studies

- Few mobility measures were used

- Many of the measures used to assess performance and cost may be redundant

At the transit project decision level, the most important influence on broadening the evaluation perspective comes from ISTEA's changing the relevant provisions of the Federal Transit Act. The major changes are found in 49 USC 5309 (formerly Section 3), which now reads as follows:

5309(e)(2)

A grant or loan for construction of a new fixed guideway system or extension of any fixed guideway system may not be made under this section unless the Secretary determines that the proposed project is:

* based on the results of an alternatives analysis and preliminary engineering;

* justified based on a comprehensive review of its mobility improvements, environmental benefits, cost-effectiveness, and operating efficiencies; and

* supported by an acceptable degree of local financial commitment, including evidence of stable and dependable funding sources to construct, maintain, and operate the system or extension.

5309(e)(3)

In making determinations under this subsection, the Secretary shall:

* consider the direct and indirect costs of relevant alternatives;

* account for costs related to such factors as congestion relief, improved mobility, air pollution, noise pollution, congestion, energy consumption, and all associated ancillary and mitigation costs necessary to implement each alternative analyzed; and

* shall identify and consider transit supportive existing land use policies and future patterns, and consider other factors including the degree to which the project increases the mobility of the transit dependent population or promotes economic development, and other factors that the Secretary deems appropriate to carry out the purposes of this Act.

5309(4)
The Secretary shall issue guidelines that set forth the means by which the Secretary shall evaluate results of alternatives analysis, project justification, and the degree of local financial commitment.

Project justification criteria shall be adjusted to reflect differences in local land costs, construction costs, and operating costs.

5309(6)
A new fixed guideway system or extension shall not be subject to the requirements of this subsection and the simultaneous evaluation of such projects in more than one corridor in a metropolitan area shall not be limited if:

* the project is located within an extreme or severe nonattainment area and is a transportation control measure, as defined by the Clean Air Act, that is required to carry out an approved State Implementation Plan; or

* assistance provided under this section accounts for less than $25 million, or less than one third of the total costs of the project or an appropriate program of projects as determined by the Secretary.

In addition to these legislative requirements, the Federal Transit Administration (FTA) began considering new guidance on the substance and process of transit project planning. For example, the following criteria were discussed in an FTA white paper in 1992 that was examining the different evaluation considerations that should be incorporated into major investment studies.

* **For "cost-effectiveness"**

  - the *total incremental costs per incremental transit passenger-trip* or possibly, per passenger-mile in certain cases), where the projected streams of capital costs, operating costs, and passenger-trips have been (in the case of the costs) expressed in constant dollar terms, and (in all cases) the ridership and costs have been discounted at the social discount rate. The figures would also be "levelized" so as to produce a statistic that characterizes the average year while avoiding the problems inherent in examining the situation for certain "design years" only.

* **For "mobility improvements"**

  - the projected aggregate monetary *value of travel time savings* per year anticipated from the new investment, compared with the TSM alternative. This aggregate includes the travel time impacts on people using competitive modes, along with those on the trips made by transit (both new and existing transit riders). It is a *net* figure in that travel time increases should be explicitly considered and used to offset the time savings of those people who experience savings. Each year's projected time savings would be discounted and levelized in a manner identical to that used for the *incremental cost per passenger-trip* measure. FTA plans to work towards improved forecasting methods that will allow induced trips to be appraised also. The value would be expressed in absolute terms, as well as in percentage change terms for the region. The value of the time savings will be calculated using a value of time based a standardized percentage of the local average wage rate.

- the number of *zero-car households* (or alternatively, the people resident in those households) located within ½ mile of boarding points for the proposed system increment.

* **For "operating efficiencies"**

- the forecast *change in operating cost per vehicle service-hour* (or service-mile), for that part of the system that will be directly affected by the proposed new investment compared to the TSM alternative. If in the rare event it can be credibly argued that there are significant economies of scale or of scope, the full system could be considered. The value would be expressed in absolute and percentage change terms, for the region.

- the forecast *change in passengers per vehicle service-hour* (or service-mile), calculated on the same basis, again in absolute and regional percentage change terms, compared to the TSM alternative.

- the forecast *change in passenger miles per vehicle service-hour* (or service-mile), calculated on the same basis, again in absolute and regional percentage change terms, compared to the TSM alternative.

* **For "environmental benefits"**

- the monetary *value of the forecast change in criteria pollutant emissions and in greenhouse gas emissions*, ascribable to the proposed new investment, compared to the TSM alternative. The measure should be expressed in tons per year (or per day), and calculated in present value terms by discounting and levelizing in a manner identical to that used for the cost-effectiveness measure. The value would be expressed in absolute and percentage change terms. The monetary value will be calculated using standardized unit values for emission reductions, based on EPA-based analyses of the costs of alternative means of achieving emission reductions.

- the forecast *change in the consumption of fuels of different types*, ascribable to the proposed new investment, again discounted and possibly levelized. Again, the value would be expressed in absolute and percentage change terms, compared to the TSM alternative.

* **For "transit supportive existing land use policies and future patterns"**

  - the degree to which local land use policies and the development market are likely to foster transit supportive land use, measured in terms of the degree to which local land use policies are supportive of the proposed transit investment, and commitment to these policies.

Mobility: As seen above, the amended Federal Transit Act explicitly asks for consideration of "mobility improvements" in project decisions. Although mobility can be defined in many ways, the working definition in this research is as follows:

Mobility = The ability and knowledge to travel from one location to another.

Ability means that there is at least one option available to make a trip and that this option is affordable, safe and reliable. Knowledge means that the potential users of the transportation system are aware of their options and of the characteristics associated with each. Mobility can thus be enhanced by increasing the number of options available to system users, or by making the characteristics of these options more appealing to the users. Likewise, mobility could be enhanced by providing improved information (e.g., through traveler information systems) on travel options to potential system users.

How to measure "mobility" is a challenge. Similar in nature to a congestion index, a mobility index would provide a means for assessing the ability of people or goods to move in a corridor or area in a quick, safe, efficient and reliable manner. The emphasis of a mobility index would be on the user, unlike traditional measures (or even the multimodal evaluations discussed above) which utilize a provider or system perspective on performance. A mobility index could be a unified measure for travel within a corridor across all modes.

Some areas have experimented with a mobility index of one form or another. Some examples of "mobility indices" which have recently been proposed include areawide level-of-service, a congestion severity index (CSI), a roadway congestion index (RCI), a transportation adequacy measure, and a personal mobility index [Ewing, 1992]. Other research in the area has resulted in the development of a countywide mobility index for assessing the economic development impacts of transportation [Eck, 1978]. Additionally, Lomax has suggested use of a "speed of person-volume" and a "person-movement index"; these indices essentially evaluate the person-throughput in a corridor [Lomax, 1990].

Accessibility: As with mobility, the concept of accessibility stems from the derived nature of travel. Accessibility in this context is defined as follows:

Accessibility = ***The means by which an individual can accomplish some economic or social activity.***

Note that this fairly general definition of accessibility provides for accessibility without the actual movement of people and goods. For example, the use of telecommunications provides access to a wide variety of business, shopping, and personal activities without the user ever having to travel. Thus, mobility generally implies having accessibility (assuming the mode of travel has physical access to the desired destination), but accessibility does not necessarily mean having mobility. While mobility indices are designed to address the quality and reliability issues, accessibility indices seek to tie transportation planning activities more closely with other urban planning activities by assessing the quality of land use interaction provided by the transportation system. These indices are sensitive to the socioeconomic attributes and travel needs of subareas, and allow land use decisions to have a part in the overall transportation strategy. Accessibility indicates the transport linkage between zones of a region, and measures the locational advantages of each zone for various land uses based on the interaction potential [Zakaria, 1974; Wickstrom, 1971].

Accessibility is the cornerstone of the four-step transportation planning process. The gravity and intervening opportunity models for trip distribution, the logit model formulation of mode choice, and the shortest path algorithm for trip assignment all rely upon a macro-level assessment of the quality of linkages between zones [Meyer, 1984]. In spite of this fundamental need for consideration of accessibility, there has been very little work to incorporate accessibility into performance monitoring. A few accessibility-type indices have been proposed. In one method, a regional accessibility index would be calculated for each subarea in a region based on the proportion of regional opportunities (e.g. employment) reachable on each mode in a given travel time, factored by the percentage of subarea population using each mode; these subarea accessibility indices can be aggregated as desired for the region [Wickstrom, 1971]. In another method, the number of land use activities reachable within a specific travel impedance from a zone would be assessed; the sum of the number of opportunities reached from each zone is a measure of accessibility for that particular alternative [Zakaria, 1974].

One of the more recent studies of accessibility was conducted by Susan Handy [1994]. Handy had an extensive discussion on the distinction between local and regional accessibility; it primarily revolved around location of the activity (near or far), size and form of activity concentration, and the type of products sold (convenience or comparison). This distinction was necessary to test if people would accept some form of accessibility tradeoff.

Handy suggests that both quantitative and qualitative measures are needed to fully grasp the level of accessibility afforded an area. Quantitative measures could include items such as travel time or size of destination; some consideration should be given to non-home-based measures since shopping trips are frequently part of a larger trip chain. Qualitative accessibility measures could be grouped into areas of overall urban structure (community links and grain, street layout, etc.), housing design (orientation, complexity), street design (amenities, scale and activity) and commercial design (configuration, concentration). Handy states that although the trend has been to develop more mathematically complex measurement systems, a more simple quantitative measure combined with qualitative measures may provide a better grasp of accessibility characteristics for a community.

Perhaps the best summary of the value of accessibility as a criterion for evaluation is found in an early report from the FHWA entitled, "Accessibility--Its Use As An Evaluation Criterion in Testing and Evaluating Alternative Transportation Systems."[Cohen and Basner, 1972]. In defining the use of accessibility in transportation planning, the authors summarize the major benefits in its use as follows:

* Many planning studies have used accessibility explicitly in its analytical techniques and thus it can be operationalized very easily with existing models

* It can reflect a wide variety of goals related to land use, system performance, and social concerns

* When based on travel time, accessibility can be used to evaluate plans consisting of one mode or plans having many modal alternatives

* It can be used not only to measure aggregate or regional effects, but also disaggregate and distributional effects within metropolitan areas and by socio economic groupings

* The concept is easily obtained and the results are understandable to policy makers and interested citizens

Given an increasing focus on multimodal planning and the implementation of performance-based planning, there is a clear need to better understand how a much wider definition of system performance can be achieved, and more importantly how such definitions can be used in the planning and analysis process. Preliminary examination of this issue will be found in the next section.

3.0 CONCEPTUAL FRAMEWORK FOR PERFORMANCE-BASED PLANNING

Performance-based planning is defined in this research as the planning for system and facility improvements that lead to enhanced performance of the transportation system where desired system performance is explicitly stated at the outset and monitored over time. In this context, performance is defined through an open process by users and stakeholders of that system, and is periodically monitored to assess progress toward achieving acceptable performance levels. This definition raises important questions about who should define acceptable performance levels, what measures of performance should be used, and how should the concept of system performance be integrated into the different new elements of transportation planning.

Past research on system performance and almost all of the current practice in transportation planning has focussed on more traditional measures that relate the performance of a transportation facility to the theoretical capacity of that facility to handle estimated demands. As noted in the previous Section, many agencies are currently developing performance measures and indices to provide needed information for decision-making in the current multimodal transportation policy environment. However, the point of departure for much of this effort is a performance-oriented "retrofit" of the traditional planning process. A true performance-based planning process must be thought through very carefully, focussing not only on the types of measures that will be used to monitor system performance, but also on how planning goals and evaluation criteria relate to system performance (and vice versa), and on what analysis tools are required to integrate planning into a systems performance perspective.

An alternative approach for framing the transportation planning process in terms of systems performance is needed, and is proposed in the following paragraphs. This approach is based on guiding principles outlined in Meyer and Miller [1984] and Meyer [1980]. Most importantly, this approach assumes that a primary function of transportation planning is to produce information for decision makers on not only alternative transportation investments, but also on those areas of systems performance which are deficient and where opportunities for improvement exist. Desirable system performance is thus related to decision maker goals and visions of what constitutes the ultimate purposes of transportation investment.

The evolution toward performance assessment within transportation planning began with the relatively recent requirements to prepare impact studies and environmental analyses for individual site developments. While some people may point to the metropolitan planning process and Interstate highway planning as an earlier example of performance assessment and the use of performance measures, these examples actually relied on evaluation criteria. This points to a distinction which needs to be made between evaluation criteria, which stem from a system perspective, and performance measures, which stem from a user perspective.

Evaluation criteria, as utilized in the traditional metropolitan planning process, have focussed on the relative efficiency of alternative options. With an efficiency focus, a certain level of transportation investment becomes a given, and attention shifts to allocating resources to achieve the largest benefit in terms of regional congestion relief or other signs of system improvement. An analysis based on evaluation criteria tends to focus on narrow transportation issues, and in doing so ignores any potential for enhancing system performance through non-transportation means such as land use (and vice-versa).

Performance measures, as illustrated within site impact studies, relate the effectiveness of site development proposals to transportation performance and other societal goals. These measures allow an assessment of performance through modification of both on-site and off-site design characteristics, as well as an assessment of the project's merit in its own right through consideration of the no-build alternative). In essence, site impact studies are the first true example of jointly assessing transportation and the other factors which affect system performance, as well as relating transportation performance to other community goals.

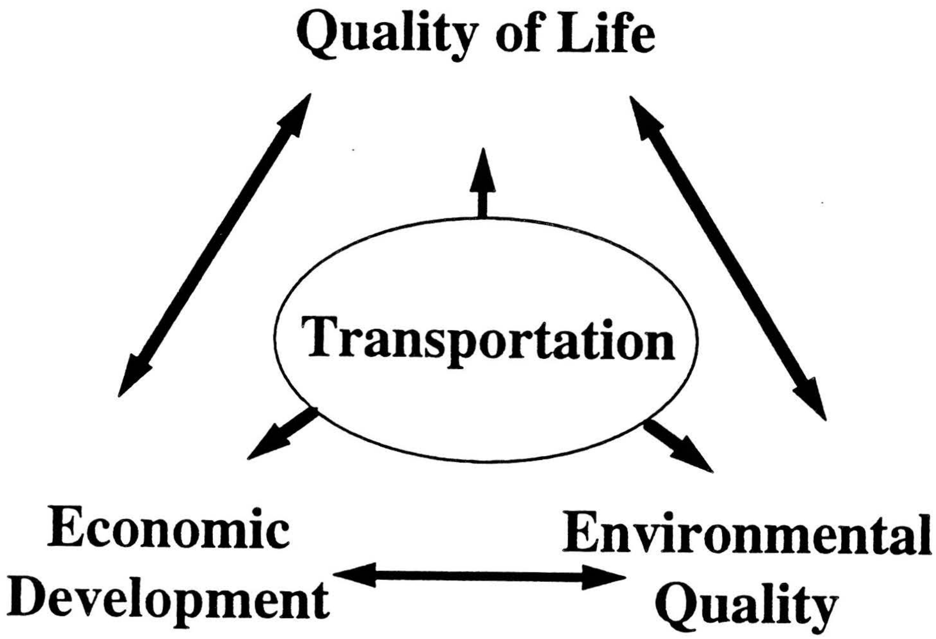
The current framework for planning is based on an historical path that originates in a tradition of facility expansion. In this tradition, the concept of performance is defined as being primarily oriented toward measures that justify the need for increased system capacity. As noted earlier, transportation planning as defined by ISTEA should be much broader than this, examining how system performance can be incorporated into all aspects and stages of the process.

3.1 CONCEPTUAL TYPOLOGY FOR PERFORMANCE-BASED PLANNING

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 function. Figure 3-1 shows a very simple 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 function in an integrated way. Thus, for example, the mobility provided by transportation systems allows access to the economic opportunities that provide the basic means of assuring an acceptable quality of life. Likewise, the provision of this mobility is often done with technology that negatively impacts the natural environment, and thus affects quality of life. The importance of the concept illustrated in Figure 3-1 is that *if the underlying functional role of transportation is related to achieving some other purpose, the measure of system performance should also relate to this purpose.* This leads to the next levels of the typology for performance-based planning shown in Figure 3-2. These levels relate to the definition of goals and objectives, performance measures, data collection, and analytical methods.

Goals and Objectives: Most transportation planning efforts begin with a definition of goals and objectives. This rational perspective on planning assumes that investment in transportation systems is aimed at achieving some ultimate purpose. Goals and objectives again relate to system

Figure 3-1 Ultimate Role of Transportation



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.

As seen in Figure 3-2, the goals and objectives are classified in three categories: efficiency, effectiveness, and externalities. In this context, ***efficiency*** of the transportation system relates to the physical characteristics of system operation that corresponds to vehicular or person flows. This is the traditional perspective of system performance and includes such topics as congestion relief, reduced costs of travel, and improved travel times. The ***effectiveness*** of the transportation system is defined more often in relation to what transportation provides to a community. Examples of such relationships include, 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. The ***externalities*** associated with the transportation system relate to the environmental and societal impacts of system construction and operation such as air quality, noise, dislocation of households and businesses, wetlands impacts, water quality, and secondary/tertiary impacts associated with the increased development that possibly occurs with enhanced accessibility.

These categories of goals and objectives are carried through the different planning elements of the typology shown in Figure 3-2 because they affect the type of performance measures

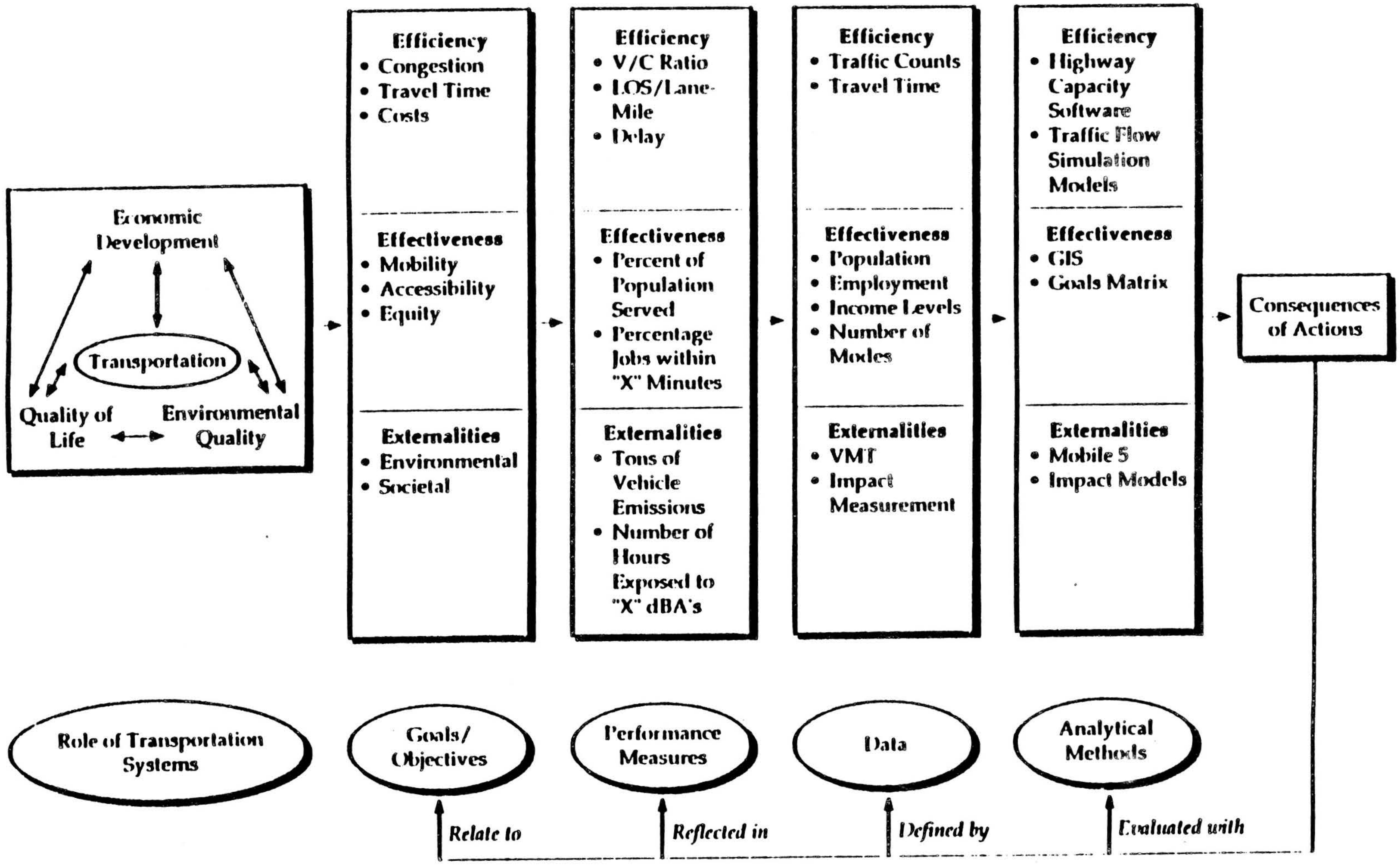


Figure 3-2 Conceptual Framework for the Elements of Performance-based Planning

selected, the type of data that need to be collected to operationalize these performance measures, the type of analytical methods that use this data, and ultimately the types of consequences that result from the implementation of strategies and actions. This classification of goals and objectives is critical to understanding the different types of performance measures that might be incorporated into the planning process.

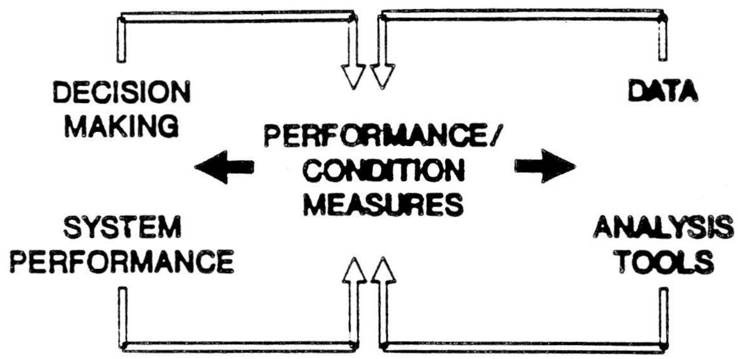
Performance Measures: One of the major changes to transportation planning that has come out of ISTEA is the requirement for planners to identify and use performance measures in the transportation planning process. These measures are critical elements of a performance-based planning process in that they determine what type of information is fed back into the investment decision-making process and ultimately, of course, 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 identify system deficiencies and opportunities. Figure 3-3 illustrates the relationship between performance measures and these four factors. The arrows showing the reverse relationships indicate that the current status of data, analytical capability, types of decisions, and perceived important functions of transportation will clearly have important influences on the types of performance measures selected.

As noted in Figure 3-2, performance measures can be classified according to the categories of goals and objectives discussed earlier. The traditional approach toward performance measures would focus on system efficiency and thus relate to such things as volume/capacity, delay, level of service, and travel time. Indeed, an overview of the performance measures selected by some of the metropolitan planning organizations (MPOs) which have already identified a preliminary set of performance measures for their congestion management systems show a heavy emphasis on this type of measure. However, a much broader perspective on system performance suggests performance measures should relate to system effectiveness and perhaps to externalities. The key challenge in this broader perspective is to measure such things as mobility and accessibility. The performance measures associated with externalities would be related to the actual impacts; the current requirement of the Clean Air Act for nonattainment areas to meet emission standards through reduction in vehicle miles traveled (VMT) is a system performance measure that relates to this externality category.

Data: The performance measures selected as part of the planning process must be updated on a periodic basis, thus implying some form of data collection. The efficiency-oriented measures would rely on data collection techniques that have been used for decades, such as traffic counts, travel time studies, travel delay studies, and classification counts. Data for effectiveness measures would be much more related to spatially allocated socio-economic information and other indicators of economic development or quality of life. Externality data would be focussed 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.

Analytical Methods: The analytical methods for each type of performance measure category would clearly reflect the types of issues that would be addressed in that category and the

Figure 3-3 Performance Measures and Their Relationship to Decisions and the Technical Process



type of data that are available for input. For example, efficiency 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. Effectiveness measures 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 and emerging impact models.

Consequences of Actions: The product of the planning process is information that leads to the implementation of cost effective projects. Once these projects are implemented, their impact on system performance should be felt (subject to the scale effects associated with the scale of implementation). The consequences of these actions can be evaluated with the analytical methods described earlier; they can be defined by the data collected as part of system monitoring; they are reflected in the measures identified earlier as being critical to system performance; and they ultimately relate to the goals and objectives established at the outset of the process.

It is important to note that there can be many more consequences of actions than there are system performance measures. The process of evaluating individual projects in the context of the goals and objectives established at the outset should be based on evaluation criteria or measures of effectiveness. These criteria will likely cover a large variety of impacts of concern to local decision-makers. However, some of these evaluation criteria should be related to the defined system performance measures. By so doing, there is a strong linkage between project evaluation and system performance measurement. This is one of the defining characteristics of performance-based planning.

4.0 CASE STUDIES OF PERFORMANCE-BASED PLANNING

States and MPOs have been responding to the ISTEA planning requirements in many different ways. Some have adopted the multimodal planning philosophy as the basis of their planning process and are attempting to provide a true transportation perspective on investment in the system. Others are implementing management systems that provide an ability to target key areas of performance deficiency for improvement. Although in their infancy, these approaches have many of the characteristics described in the previous section as being critical for performance-based planning.

The following case studies should be considered as illustrations of the early steps being taken in the U.S. to develop a performance-based planning process. In many ways, ISTEA has begun the evolution toward such planning, although the exact nature and scope of the planning framework often varies from one location to another. These case studies illustrate quite well the different approaches being taken, in some cases, even before ISTEA became law.

4.1 Metropolitan Transportation Commission--Bay Area

Perhaps the best example of multimodal evaluation was found at the Metropolitan Transportation Commission in the Bay area. The Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area experimented with a multimodal performance assessment for project selection as part of the Regional Transportation Plan (RTP). MTC dramatically modified its project selection and programming procedures in 1992 to take advantage of the funding flexibility in ISTEA. The new procedures rely more upon multimodal performance measures for many criteria, including mobility. The process is intended to select projects with a portion of the total regional surface transportation program (STP) and congestion mitigation and air quality (CMAQ) funds.

A project is required to get passing marks in all five criteria in an initial project screening. (The five criteria are consistency, financial, project specific, air quality, and ADA requirements). Passing projects are then competitively ranked based on performance measures in four categories. The performance measures were structured so that all modes would compete on an equal footing. The four categories, along with the multimodal performance considerations in each category, are as follows:

1) **Maintain/sustain the Metropolitan Transportation System (worth 30% of total score)**

   Will rely primarily upon results of ISTEA management systems, and the performance measures to be adopted for these systems.

2) **Improve efficiency and effectiveness of the metropolitan transportation system (MTS) (worth 30% of total score)**

Safety and Security - All projects assessed based on mode specific criteria.
Congestion relief - Assessment of ability of project to enhance service to all components of the MTS.
Cost effectiveness - A cross mode assessment of cost-benefit.
Freight Movement - Assessment of importance of project for truck traffic.
Intermodal Facilities - Assessment of project's ability to enhance freight movement through all components of the MTS.

3) **System Expansion (worth 15% of total score)**

Emphasis placed on need to accommodate current demand
Demand can be demonstrated by LOS data, volumes, load factors, empirical observation, or other data developed as part of a special study.

4) **External Impacts (worth 25% of total score)**

Emphasis on improvement in air quality, implementation of most effective TCMs and ability to create a modal shift.

One potential shortcoming of the methodology is that limited consideration is given to the multimodal nature of a passenger project in and of itself. Each category allows points to be assigned to a project based on its features as either a road, transit, or bicycle/pedestrian project; however, the points are not cumulative above a set maximum. For example, a road widening project which also incorporates bicycle lanes into the design would be given scores on both features; if, however, it received the maximum number of points for the capacity enhancing features of the project, it could not receive any additional points for the bicycle enhancing features. This type of structure may have the unintended effect of discouraging "luxury" features of a project which do not add appreciably to the overall score (especially since the-cost-effectiveness component of the score may suffer).

MTC has begun to address this issue by directly considering a new generation of performance measures. David Jones, in work for MTC, has suggested that user, provider, and environmental factors be incorporated into the performance measures. One potential way to do this and provide a multimodal measure is by using person-trips and shipments as the primary units of analysis rather than modally biased measures such as vehicle-trips or vehicle-miles. Jones' suggestion to MTC was to use the following performance measures:

Safety:	Accidents/fatalities per 1,000,000 trips
Reliability:	% of on-time guaranteed overnight deliveries/transit runs.

Cost:	Average out-of-pocket cost per trip.
Travel Time:	Average travel time per commute trip.
Air Pollution:	Aggregate emissions and emissions per trip.
Energy Efficiency:	Aggregate fuel consumption and consumption per trip.
Resource efficiency/ Asset Utilization	Trips completed per vehicle hour of passenger travel.

Most of these measures could be directly estimated using the MTC travel demand model. [Jones, 1993]. MTC is currently reviewing this work, and may incorporate some of its contents within the MTS Management Plan which is under development. This MTS Management Plan is aimed at developing a new monitoring strategy for direct use in the regional transportation planning process. The plan is being approached as a separate system for peak and off-peak operations with person flow emphasized during the peak and traffic flow (including goods movement) emphasized in the off-peak (MTC called this the "core" of their new plan).

MTC is in the process of testing various performance measures on corridors throughout the Bay Area to determine limitations with the performance measures and the overall management plan framework. Some of the measures being tested include travel time, delay time, transit accessibility, and the measures suggested by Jones.

4.2 Cobb County(GA) Transit Strategic Plan

A good example of how both mobility and accessibility measures can be used in a transit planning exercise is found in a recent study in Cobb County, Georgia. Cobb County Transit (CCT) commissioned a study to examine future directions of transit investment in the County. Entitled, "Multimodal Strategic Plan for Public Transportation in Cobb County" [Cobb County Transit, 1994], this study was based on an extensive statement of goals and objectives which were developed as part of a public outreach effort. Many of the specific objectives identified by local officials related to making proposed transit services relevant to the local economy and to the communities in the County. The proposed goals, objectives and measures of effectiveness are shown in Table 4-1. As seen in this table, some measures such as "number of employment concentrations of 7,500 or more employees served by the transit alternative" fit the accessibility category. Measures such as "percent of trips destined to Cobb in a transit service area that can be served by the transit alternative" fit the mobility category.

The important lesson from the Cobb County strategic planning example is that the desired performance of the transit system was defined by the stakeholders and transit agency customers. Local officials and the business community were very supportive of the transit system and proposed expansion in services as long as it served the economic needs of the county. This was defined differently be various groups; the business community primarily viewed this as meaning providing access to jobs, while local officials defined this as being access between and among major activity centers in the county. However, the general reasons for the level of support for the

Table 4-1: Cobb County Transit Goals and Objectives for Strategic Transit Planning

Goal 1: *Transit service in Cobb County should be supportive of, and be fully integrated with, the economic growth of the County.*

Objective 1.1: Provide major employment centers with transit services that reflect the local and regional demand patterns for each center.

MOE 1.1.1: Number of employment concentrations of 7,500 employees or more served by the transit alternative
MOE 1.1.2: Number of individual employment sites of 3,000 employees or more served by the transit alternative
MOE 1.1.3: Number of employment linked by transit service to other Cobb activity centers

Objective 1.2: Provide transit service to special activity centers, other than major employment centers, which support the County's economy (e.g., major retail areas and the convention center).

MOE 1.2.1: Number of special activity centers served by the transit service
MOE 1.2.2: Number of major transit markets connected by the transit alternative with special activity centers.

Objective 1.3: Provide good connections to the regional transportation network that strengthen the County's position as a regional center of economic activity.

MOE 1.3.1: Percent of trips in a transit service market area destined to outside Cobb that can be served by the transit alternative.
MOE 1.3.2: Percent of trips destined to Cobb in a transit service area that can be served by the transit alternative.

Objective 1.4: Relate transit service improvements to desired land use patterns and characteristics

MOE 1.4.1: Degree to which transit service improvements reinforce adopted County land use plan.
MOE 1.4.2: Percent higher density County population found within transit service area.
MOE 1.4.3: Percent higher density County employment found within transit service area.

Goal 2: *Transit service in Cobb County should provide mobility options for major transit markets in the County.*

Objective 2.1: Provide transit services that promote efficient trip-making within the County and that interconnect with the regional transportation system.

Table 4-1, cont'd

MOE 2.1.1: Degree to which transit service serves major origin-destination patterns
MOE 2.1.2: Person-miles traveled on transit service
MOE 2.1.3: Person-miles per revenue vehicle miles for transit service

Objective 2.2: Provide transit services that are accessible to those with limited including satisfying the minimum requirements of the Americans Disabilities Act.

MOE 2.2.1: Degree to which disabled population live within transit service area.
MOE 2.2.2: Degree to which limited mobility population live within transit service area.
MOE 2.2.3: Degree to which disabled have access to service.

Objective 2.3: Provide transit service to special activity centers, other than major employment or retail centers (e.g., educational institutions).

MOE 2.3.1: Number of special activity centers served by the transit service
MOE 2.3.2: Number of major transit markets connected by the transit alternative with special activity centers.

Objective 2.4: Integrate transit services with other aspects of the transportation system, especially those that provide good access to transit services (e.g., sidewalks).

MOE 2.4.1: Degree to which transit service is integrated into total transportation system with associated transit-friendly infrastructure.

Goal 3: *Transit service in Cobb County should improve the quality of the environment for all County citizens, and contribute to solving regional environmental problems.*

Objective 3.1: Target transit service investments in areas that will reduce roadway congestion and vehicle emissions.

MOE 3.1.1: Reduction of vehicle miles traveled due to service
MOE 3.1.2: Reduction in vehicle emissions
MOE 3.1.3: Reduction in congestion levels at key locations in service area

Objective 3.2: Provide transit services that are safe, convenient and affordable in order to attract automobile users.

MOE 3.2.1: Percent population served in market area
MOE 3.2.2: Ratio of transit travel time to auto travel time for representative trip

Objective 3.3: Provide good connections to the regional transit network to make long distance transit travel attractive for these types of trips.

MOE 3.3.1: Percent of trips in a transit service market area destined to outside Cobb that can be served by transit service.
MOE 3.3.2: Percent of trips destined to Cobb in a transit service area that can be served by transit service.

Objective 3.4: Encourage policies in the public and private sectors that will discourage the use of the single occupant vehicle.

MOE 3.4.1: Degree to which success of alternative depends on proactive stance on single occupant vehicle use reduction.

Goal 4: *Transit service in Cobb County should be appropriate and cost effective for the markets to be served.*

Objective 4.1: Provide transit services that meet Goals 1, 2, and 3 in the most cost effective manner possible.

MOE 4.1.1: Dollars spent per rider, initial capital and operating
MOE 4.1.2: Dollars spent per emission ton reduced

Objective 4.2: Provide transit services that provide the greatest benefit to the citizens of the County.

MOE 4.2.1: Degree to which transit service serves major origin-destination patterns in the County.
MOE 4.2.2: Number of employment concentrations of 7,500 employees or more served by the transit service
MOE 4.2.3: Number of individual employment sites of 3,000 employees or more served by the transit service
MOE 4.2.4: Number of employment concentrations connected to other Cobb activity centers
MOE 4.2.5: Percent population served in market area

Objective 4.3: Design transit services that meet the specific needs of different markets in the County.

MOE 4.3.1: Degree to which transit service serves major origin-destination patterns in the County.
MOE 4.3.2: Degree to which transit service characteristics relate to perceived willingness of potential customers to use service.

system were fairly consistent among the different groups--providing access to important sites in the county.

4.3 Capital District Transportation Committee [Albany, NY]

The Capital District Transportation Committee (CDTC) is the metropolitan planning organization for the Albany, New York region. The CDTC has been one of the nation's leaders in incorporating performance measures into transportation planning, in particular in three areas--project evaluation, policy evaluation, and on-going system monitoring. The basic approach to the use of performance measures is based on the following set of assumptions: [Poorman and Posca, 1994; and reported in Poorman, 1995]]

"1. It is legitimate to present some impacts in monetary terms

2. It is more appropriate to present other impact quantitatively, but not in monetary terms

3. Other impacts do not lend themselves to quantitative measurement and are more appropriately discussed in narrative fashion"

The CDTC project evaluation process has evolved over the past 20 years from a one primarily focussed on benefit/cost ratios to one now considering a much broader set of issues (the latter developed in direct response to ISTEA). As shown in Figure 4-1, the project evaluation form includes a wide variety of issues of concern to local officials. John Poorman, the CDTC planning staff director, reported several characteristics of this process that are critical to understand the implications of performance-based planning: [Poorman, 1995]

1. The process successfully combines technical and policy issues in a non-deterministic manner (i.e, there is no single project score).

2. Implementation of this approach requires capable staff and adequate tools. As note by Poorman, over 200 computer simulations were required to identify the values associated with the evaluation measures for 100 projects.

3. Even though the process is designed specifically to avoid the "single index" or "bottom line" approach, local officials felt more comfortable with some quantifiable measure that allows easy comparison of one project to another.

4. It was very difficult providing a single evaluation process that considered all types of projects (e.g., comparing enhancement projects with repair and maintenance with capacity/mobility projects),

Figure 4-1 Project Evaluation Form Used in Albany, New York

PROJECT TITLE ____________________
LOCATION ____________________
DESCRIPTION ____________________
PURPOSE ____________________

1993-98 PROJECT COST (Federal Share) ($M) ____
POST 1997-98 COST ____
ANNUALIZED COST ($1000/yr) ____

TRANSPORTATION SYSTEM AND USER SAVINGS
Total System and User Savings ($1000/yr) ____
- Safety Benefits ($1000/yr) ____
- Travel Time Savings ($1000/yr) ____
- Energy and User Cost Savings ($1000/yr) ____
- Life Cycle Cost Savings ($1000/yr) ____

Benefit/Cost Ratio ____

CONGESTION RELIEF
Daily Excess Vehicle Hours of Delay Saved ____
Daily Excess Vehicle Hours Saved / $ M annual (/ $M initial) ____( )

AIR QUALITY
Hydrocarbon Emission Reductions ____
Hydrocarbon Emission Reductions / $ M annual (/ $M initial) ____( )

NOISE REDUCTION:

RESIDENTIAL TRAFFIC:

COMMUNITY AND ECOLOGICAL DISRUPTION:

ACCESS TO THE PUBLIC TRANSPORTATION SYSTEM:

MODAL INTEGRATION:

PROVISION OF ALTERNATIVE MODES:

SYSTEM LINKAGE:

ECONOMIC DEVELOPMENT:

OTHER:

The second performance-based planning process adopted by CDTC was used in the update of the region's transportation plan. The process of updating the transportation plan was viewed as a once-in-a-decade opportunity to establish a vision for the region and for articulating the role that transportation should play in achieving this vision. Basic to this approach was the effort to develop what CDTC officials called "core performance measures". These core measures are shown in Figure 4-2. As noted by CDTC officials, many of these measures were based on previous work undertaken by the MPO. However, the public process of defining these measures produced some that had never been used before in the transportation planning process (such as access measurement).

Table 4-2 shows how these measures were to be operationalized in terms of measurement. Direct and indirect impacts are represented as are those that can be measured in monetary terms and those that are best represented in the abstract. Of some interest in Figure 4-2 and Table 4-2 is the wide range of impacts that are of interest to the CDTC region. In addition, some unique aspects of this approach include converting only commercial travel time into dollar equivalents, by focussing on incremental costs and impacts, and by limiting monetary calculations to only those impacts which involve direct or indirect monetary expense that is not primarily distributional in nature (for more detailed discussion, see [Poorman, 1995]). The CDTC experience with performance measures in transportation plan update resulted in the following observations:

1. It is possible to define a broad set of plan performance measures that are both meaningful to the technical process and to policy makers

2. Non-traditional measures (such as those relating to land use and access) can be integrated successfully into an evaluation process with more traditional measures

3. A "full-cost" approach to the impacts of transportation plans can be a useful approach for transportation planning and decision-making

4. As before, the process requires a capable staff and good technical tools

The third area of performance measure use by the CDTC was in the development of the region's congestion management system (CMS). The CDTC officials consciously wanted to link the core performance measures with those performance measures developed for the CMS. In this way, the CMS would be an implementing mechanism for the transportation plan. Local officials developed two goals that were to direct the development of the CMS.

Support growth in economic activity and maintain quality of life in the region by limiting the amount of excess delay

Avoid and mitigate congestion on all modes by implementing demand management programs before expanding capacity

Figure 4-2 Core Performance Measures For Transportation Planning in Albany, New York

CORE SYSTEM PERFORMANCE MEASURES

Transportation Service

Access: What travel alternatives exist? *(Measure: Pct. of person trips within a defined non-auto (walk, bike, transit) to auto difference[1]; pct. of person trips with a travel time advantage for non-drive-alone modes (including carpools); number or percentage of major freight movements with modal alternatives[2])*

Accessibility: How much time does travel take? *(Measures: travel time between representative locations, including major intermodal facilities; peak vs. non-peak, by quickest mode)*

Congestion: What is the level of exposure to traffic congestion? *(Measures: hours of excess delay: recurring, non-recurring by mode [auto, transit, freight, bike, pedestrian] per unit of travel [3])*

Flexibility: Can the system respond to unexpected conditions? *(Measures: reserve capacity on system[4]; pct. of person trips that could be accommodated by modes other than auto in an emergency[5]; number of corridors with reasonable alternatives during closure or disruption[6]; amount of risk associated with fixed capacity investment[7])*

Resource Requirements

Safety: What are the safety costs associated with transportation? *(Measure: estimated societal cost of transport. accidents)*

Energy: How much energy is consumed in providing, maintaining and using the transportation system? *(Measure: equivalent BTUs/day for transp. capital, maintenance, operation and use)*

Economic Cost: How much does the transportation system and its use cost, in addition to safety and energy costs? *(Measures: annualized capital, maintenance, operating and [monetary] user costs for transp. system; value of commercial time in travel)*

External Effects

Air Quality: What is the effect of the transportation system on air quality? *(Measures: daily emission levels (HC and NOx); air quality attainment status)*

Land Use: How does the transportation system affect land use? *(Measures: amount of open space; dislocation of existing residences and businesses; land use - transportation compatibility index[8]; community character[9])*

Environmental: How does the transportation system affect key environmental features? *(Measures: impacts on sensitive areas [wetlands, parklands, historic areas, archaeological sites, etc.); noise exposure [10]])*

Economic: How does the transportation system support the economic health of the region? *(Measures: narrative discussion of economic-activity supporting or constraining features of transportation system)*

Table 4-2 Transportation Impact Typology

FACTOR		IMPACT TYPE: Monetary Expense	IMPACT TYPE: Abstract Value	IMPACT TYPE: Distributional Effect	PRIMARY IMPACT ON: Direct User	PRIMARY IMPACT ON: Direct Gov't	PRIMARY IMPACT ON: Indirect Social
Private Vehicle Ownership	?	X			X		
Private Vehicle Operation	?	X			X		
Transit Fares	?	X			X		
Parking - cost of provision and use		X			X		
Accidents - full cost	?	X			X		
Time Spent in Travel - commercial		X			X		
Congestion - commercial		X			X		
All infrastructure - maintain/replace	?	X				X	
New Infrastructure - capital	?	X				X	
Operating expense - transit	?	X				X	
Transp-Related Police/Justice/Fire	?	X				X	
Regional Air Pollution		X					X
Global Air Pollution		X					X
Vibration Damage		X					X
Water Quality Damage		X					X
Waste Disposal		X					X
Energy - security and trade effects		X					X
Time Spent in Travel - personal			X		X		
Congestion - personal			X		X		
Access (travel opportunity)			X		X		
Accessibility (time proximity)			X		X		
Flexibility and Risk			X		X		
Noise exposure			X				X
Aesthetics			X				X
Equity Impacts				X			X
Property Value Impacts (incl. noise)				X			X
Land Use Effects				X			X
Economic Development				X			X

Notes

A "?" in the second column indicates that care must be taken so that costs are not double-counted elsewhere within other cost categories.
Impacts above the double line can be considered monetary costs of the transportation system.
Impacts below the double line can be considered significant, non-monetary impacts of the transportation system.

CDTC's approach to quantifying the monetary impacts of the transportation system and it use is documented in "Estimated Marginal Monetary Costs of Transportation in the Capital District", April 1995.

Table 4-3 shows the performance measures that were defined for the CMS and the values for baseline and future conditions of the transportation network. Importantly, the CDTC has developed a schedule of data collection that must be followed to operationalize the CMS. For example, traffic volumes at key locations will be undertaken continuously whereas at other network locations counts will be taken every three years. Land use changes as evidenced through building permit activity will occur monthly and carpool information will be collected every two months.

Overall, CDTC's experience with system performance measurement is probably the most extensive of any metropolitan area in the U.S. As noted by Poorman, "the CDTC's progression from an enhanced TIP evaluation process to a thorough articulation of core performance measures, estimation of monetary costs of transportation impacts and incorporation of all these factors in its CMS monitoring process has demonstrated the value of serious measurement of transportation system performance. The planning and programming decisions made through the CDTC process are rooted in objective evaluation of system performance and the incremental effects of alternative actions." [Poorman, 1995]

4.4 Metropolitan Transportation Planning in Oregon

Oregon was one of the first states in the U.S. to adopt statewide goals relating to land use and development patterns. The Land Conservation and Development Act, passed in 1974, established state-wide goals and required cities and counties to adopt enforceable comprehensive plans which comply with the state goals. It was in fact due to this legislation that the Portland metropolitan area adopted the Urban Growth Boundary which indicated where public services would be provided to support urban growth. Outside this Boundary, urban development is strictly restricted. Within the boundary, land use designations, high capacity transportation investment, water, sewer, and other infrastructure plans have been prepared to support urban development.

In April, 1991, the Oregon Land Conservation and Development Commission adopted rules on how to implement the goals of the state legislation in the transportation area. By this past May, cities and counties were to have amended their subdivision and code regulations, and by May, 1996 to amend their comprehensive plans to comply with the new requirements.

The transportation and land use measures include the following:

--consider changes in land use density that will be conducive to transportation services

--consider establishing maximum parking limits for commercial development

Table 4-3 Congestion Management System Performance Measures for Albany, NY

Performance Measures of Congestion			1990	1995	2000 No Build	2000 TIP	2015 No Build	2015 Committed
Congestion	Recurring Excess Person Hours of Delay	Peak Hour	1,988	5,008	7,672	4,808	16,172	10,769
		Daily	6,546	17,426	27,119	14,623	57,758	34,298
	Recurring and Non-recurring Excess Person Hours of Delay	Average Daily						
		Annual						
	Excess Person Hours of Peak Hour Delay Per PMT		1.1	2.4	3.4	2.1	6.0	4.0
	Excess Vehicle Hours of Delay By Truck	Peak Hour	39	104	155	107	340	240
		Daily	125	347	529	311	1,171	732
	Number of Corridors with Critical Congestion Levels		14	24	29	19	33	24
Congestion Related Performance Measures								
Access	Percent of PM Peak Hour Trips Transit Accessible		18.60%					15.20%
	Percent of PM Peak Hour Trips With Transit Advantage		0.40%					0.33%
	Percent of PM Peak Hour Trips Accessible by Bicycle			28.9%				26.4%
	Safe Pedestrian Access: Number of Traffic Signals With Pedestrian Protected Phases							
Accessibility	Travel Time between Representative Locations; see Table 5 Selkirk Yards to Saratoga Springs shown here (minutes, PM Pk)		58.8	63.9	68.5	68.2	82.3	78.4
	Percent of PM Pk Hr Trips With More Than 5 Minutes Delay		2.7%	10.1%	13.8%	7.6%	27.6%	19.2%
Flexibility	Reserve Capacity on the Urban Expressway and Arterial System (PM Peak Hour Vehicle Miles of Capacity)		554,900	476,146	416,518	469,957	321,106	371,191
Safety	Estimated Annual Societal Cost of Transportation Accidents, Millions of Dollars ($M)		$510.0 M	$689.7 M	813.4 M	$763.2 M	$1,108.4 M	$1,053.3 M
Air Quality	Daily Hydrocarbon (HC) Emissions (kg)		47,632	34,837	22,428	21,788	18,601	18,002
	Daily Nitrogen Oxide (NOx) Emissions (kg)		53,661	48,903	36,460	36,333	31,033	30,846
Land Use	Residential Use Traffic Conflict: Miles at LOC "E" or "F"		82.4					126.0
	Arterial Land Access Conflict: Miles at LOC "E" or "F"		29.9					49.5
	Miles of Arterials with Service Roads, Driveway Consolidation and Corridor Management Actions							
	Percentage of New Development Built with Pedestrian and Transit-Oriented Design							
Demand Management	Park-and-Ride Spaces Available							
	Millions of Daily Vehicle Miles Travelled (VMT)		17.7	20.5	22.5	22.3	26.5	26.3
	Daily VMT per Capita		22.8	25.7	27.6	27.4	31.2	30.9
	Daily Transit Ridership		55,000	47,600				46,000
	Peak Hour Vehicle Occupancy							
	Journey to Work SOV Mode Share		76.4%					

--adopt changes to subdivision and development ordinances to encourage more transit, pedestrian and bicycle friendly development, such as a 10% reduction in the number of parking spaces per capita, encouraging development near transit stops, and providing convenient pedestrian access.

The only system performance-type measure that is required of Portland Metro, the MPO for the Portland area, is to plan for a reduction in vehicle miles traveled per capita, with targets to increase over 10 years, a 10% reduction over 20 years, and a 20% reduction over 30 years.

In perhaps the most comprehensive approach to developing accessibility performance measures, Eugene, Oregon has been examining different ways of measuring the accessibility performance of the transportation system. As a point of departure, the MPO planners have borrowed a definition of "accessibility" from a recent modeling practice manual published by the National Association of Regional Councils (NARC). This definition is as follows:

> *"Accessibility is an indication of the ease of reaching desired locations. Conceptually, accessibility is a function of some generalized price, which depends on standard measures of separation (time, cost), on modal characteristics which influence perception (such as comfort, speed, directness, consistency, degree of physical effort, and extent of waiting), on personal characteristics which influence perception (such as income, age, family status, and physical condition), and on the quality of the desired activity at the destination location (e.g., the quantity and mix of retail stores, in the case of a shopping trip). Accessibility between two locations is sometimes measured as location-to-location time by a specific mode (usually highway), but also can be measured as cost or as a composite of time, cost, and other modal, personal, and locational attributes."*

Based on this definition of accessibility, the MPO planners have proposed a variety of measures that can be used to assess accessibility at different scales of analysis. Table 3-3 shows how different measures can be used in such an evaluation scheme. The definition of a composite accessibility measure as used in several geographic applications deserves further development.

The composite accessibility measure is based on a logit model logsum method which represents an expected maximum utility of travel to or from given activities by all available modes. The derivation of this approach follows.

The logit model is based on the following equation which estimates the probability that an individual *j* will choose mode *m* given the *n* number of modes available to make the trip.

$$Pm\backslash j = \frac{e^{V_m}}{\sum_{m=1-n} e^{V_m}}$$

Each mode of transportation that is available between each origin zone I and each destination zone J has set of attributes associated with it. For example, an auto trip between this origin-destination pair would take an estimated time to travel and cost a certain amount. Likewise, a transit trip between the same two zones would have a travel time and a fare associated with it. The set of attributes for a particular mode that is available for a specific trip is said to be the associated utility of that mode. This utility for a mode is denoted in the above equation as V_{mode}. The above equation would thus look like the following if one wanted to estimate the probability of an individual choosing to take a car for a trip:

$$P_{car} = \frac{e^{V(car)}}{e^{V(bus)} + e^{V(bike)} + e^{V(car)} + e^{V(walk)}}$$

The estimation of the utility equations (the V's) for the modes available for a trip would look something like the following:

$$V_{car} = A_{car} + \beta_1(ivtt_{car}) + \beta_2\ (\text{Parking cost}_j) + ...$$

$$V_{bus} = A_{bus} + \beta_1(ivtt_{bus}) + \beta_4(\text{Fare}) + \beta_5(ovtt) + ...$$

$$V_{walk} = A_{walk} + \beta_6(ovtt_{walk}) + \beta_6(\text{distance } i\text{-}j) + \beta_7(\text{autos}) + ...$$

$$V_{bike} = \Phi + \beta_8(ovtt_{bike}) + \beta_9(\text{distance } i\text{-}j) + \beta_{10}(\text{autos}) + ...$$

In this case, there are four possible modes available to make a trip between zones I and J--car, bus, walk, and bike. The denominator of the above equation, that is, the sum of the individual utilities associated with all of the modes available for a trip, represents in some sense a level of transportation accessibility provided by the transportation system to the zones I and J. Oregon planners take the logsum of this value and divide it be the coefficient in the utility equations for the value of travel time which results in accessibility being expressed in terms of "equivalent minutes of in-vehicle travel time", expressed mathematically as:

$$\text{Equivalent Minutes} = \frac{-\ln \sum_{m=1-n} e^{V_m}}{\beta_1}.$$

The importance of this approach for estimating transportation accessibilty is that it allows for parking cost, operating cost, in-vehicle and out-of-vehicle time to be expressed as equivalent minutes. Thus, given characteristics of each J (attraction zone) - retail, service, manufacturing employment, etc.; accessibility of each home zone (I) can be expressed (through use of a corresponding origin destination matrix) in terms of the number of attractions within "x" minutes.

As noted in a preliminary report on this approach, there are several advantages and disadvantages to this approach. [Reiff, 1993]

Advantages

- Every traffic analysis zone has an accessibility indicator that can be compared to other zones. A major system improvement or an increase in congestion will change the accessibility of virtually every zone. One can quickly tell who benefits or loses, and to what degree.

- By combining the influences of land use and transportation system changes in a single indicator, the relative importance of each will be more apparent.

- The accessibility indicator can be mapped using geographic information systems. Relative accessibility across the region can be discerned at a glance.

Disadvantages

- Requires estimation of a logit model. Data might not be available to calibrate such a model.

- May be difficult to implement. Destination choice model must be re-run for every scenario.

4.5 Washington, D.C. Metropolitan Area

The MPO for the Washington, DC region, the National Capital Regional Transportation Planning Board (NCRTPB) has expended considerable resources on the development and refinement of their Congestion Management System (CMS). Within this process they have worked carefully to define how the CMS will supplement and enhance the current transportation planning process, as well as how the process itself could be restructured to capture the opportunities provided by all of the management systems.

The CMS Work Plan developed for Washington, DC exhibits some of the characteristics of the conceptual planning framework proposed earlier. For instance, the NCRTPB has structured its CMS system in terms of travel corridors, activity centers, and intermodal facilities. One of the reasons this structure was chosen was that it allows tailoring of the goals, performance measures, data collection and analytical tools to the unique aspects of each element. The elements are connected and interdependent, but they are oriented at vastly different user-groups.

While the CMS is not as broadly structured as the proposed framework (for example, effectiveness issues are not explicitly incorporated), it reflects a logical interconnection between the goals, performance measures, data and tools for each element. The goals are viewed in terms of four categories: travel time, capacity and usage, efficiency, and externalities/other. Twenty-five performance measures were defined for these four goals. Capabilities either exist or are being developed for data collection and evaluation techniques at various scales of analysis (site-specific, sub-area, corridor, or region-wide) which will directly relate back to the four goals.

While this initial work plan for the CMS exhibits some characteristics of the "traditional" system view of transportation, the intent is to expand the scope of the goals and performance measures as data collection and analytical capabilities and resources are enhanced. To facilitate these capabilities, Washington has begun development of a Regional Data Clearinghouse to provide a common data source for regional planning needs, to facilitate a multiyear plan for integrated data collection, and to focus resource expenditures where data are lacking. The Regional Data Clearinghouse will be one element Geographic Information System for Transportation (GIS-T) which will speed data extraction and analysis, expedite comparison of performance and investment strategies for different system elements in the same geographic area, and allow sharing of data between various stages of the overall planning process in the region.

Investment strategies identified in the CMS process will become one piece of information considered by decision-makers within the overall transportation planning process. For the-time-being, only the four goal categories of travel time, capacity and usage, efficiency, and externalities will be considered by the CMS. Some of the individual jurisdictions in the Washington region have a process in place to directly and consistently address the relationship between transportation and broader societal goals in a manner similar to that proposed in the conceptual framework.

Perhaps the most comprehensive, performance-based planning process in the metropolitan area occurs in Montgomery County, Maryland, a suburb of Washington, DC. The County Council adopted the Adequate Public Facilities Ordinance in 1973 in order to promote orderly growth by providing the necessary public facilities (transportation, schools, water/sewer, and public safety) before development could occur. Development plan applications must pass two different transportation tests before they can be approved by the Planning Board--a subregional, Policy Area, review that relates the impact of predicted traffic volumes to a level of service for the entire Policy Area (of which the county is divided into 22); and a local area transportation review which assesses proposed volume impacts on local intersections. Interestingly, the level of service standards are selected for these areas in such a way that greater traffic congestion (i.e., a lower level of service") is allowed in areas where greater transit availability provides an alternative mode of travel. Where transit access is lower, a higher level of service is adopted. In this way, Montgomery County officials hope to provide for a relatively consistent level of service throughout the county.

The 22 policy areas are designated as having one of six level of service groupings (Group I--lowest transit availability to Group VI--subway and expanded bus service). Absolute ceilings of development units are set for those policy areas where the amount of existing and approved development exceeds the level of development set by the County Council (based on the public infrastructure to support this level). The underlying measures of transit availability and use include categories relating to coverage, frequency of service, accessibility, and use. The corresponding values are as follows:

Coverage	1. % households within 1/4 mile of bus stops 2. % households within ½ mile of rail stations 3. % jobs within 1/4 mile of bus stop 4. % jobs within ½ mile of rail station
Frequency	1. Average bus frequency 2. Average train frequency
Accessibility	1. Ratio of sidewalk miles to street miles 2. Ratio of bikeway miles to street miles 3. Number of secure bicycle parking spaces 4. Number of park-and-ride spaces
Use	1. % non-auto driver work origins 2. % non-auto driver work destinations 3. % walk/bike to Metro stations

Basic to this approach is the ability to estimate the areawide level of service or congestion levels for the policy areas. In order to do this, the County Planning Board uses an index entitled the Average Congestion Index which is the average volume to capacity ratio on all road segments in the policy area weighted by the vehicle miles traveled associated with each segment. In mathematical terms, this Index becomes:

$$ACI = \frac{\text{Sum } [(\text{volume/capacity})_I \times \text{VMT}_I]}{\text{Sum VMT}}$$

In the latest update of the Annual Growth Policy, the Planning Board considered several modifications to this index, in particular with regard to the inclusion of freeway volumes in the calculation which because of the high VMT tended to weight the policy area level of service to that experienced by the area's freeway links. Of this date, no decision has been made in modifying the ACI, although interestingly one proposed modification was to replace the level of service measure for the system with a user-oriented areawide delay index which evaluates the delay to users on the links in the policy area.

In Silver Spring, the County has established staged ceilings for development because of development levels exceeding the levels appropriate for the provision of adequate facilities. In this case, additional measures are used to assure consistency in transportation and development impact. These include:

- maximum of 17,500 public and private long-term parking spaces
- employers with more than 25 employees must attain 25% mass transit use and auto occupancy rates of 1.3 persons per vehicle during the peak periods, or attain some combination of employee mode choice that results in at least 46% non-drivers during the peak periods
- new, non-residential development must attain 30% mass transit use and auto occupancy rates of 1.3 persons per vehicle during peak periods, or attain some combination of employee mode choice that results in at least 50% non-drivers during the peak periods
- the Silver Spring Transportation Management District must annually submit a report, which among other things, reports on the status of pre-defined critical signalized intersections

Clearly, the Montgomery County example provides the most comprehensive illustration of applying system performance measures to decisions relating to land use and provision of infrastructure. Perhaps most interestingly, one of the modifications that is now being considered in the County is to apply a user-based performance measure which better reflects the performance of the system experienced by the user of the system.

4.5 California's Congestion Management Program

The statewide Congestion Management Program (CMP), which has been in effect since 1990, is aimed at developing multimodal transportation recommendations that are eligible for funding consideration in the statewide transportation improvement program (STIP) process, and the coordination of transportation, land use, and air quality decisions. The CMP requirements have been implemented, in one form or another, through county-level Congestion Management Agencies (CMAs) in 32 urban counties.

The CMP statute currently stipulates the use of highway level-of-service (LOS) standards as the performance measure for quantifying congestion and triggering preparation of "deficiency plans" if traffic congestion worsens below county-adopted performance standards. Transit standards relating to routing, frequency and coordination are also identified in statute, but their use and application are not legislatively defined. Each jurisdiction must comply with all steps of the CMP process, including preparation of a deficiency plan, in order to compete for a pool of flexible state funds made available through Proposition 111.

In 1992, a bill was passed in the California Assembly which made some minor modifications to the CMP program, and resulted in formation of a study team to investigate more sweeping changes in the program, including use of other performance measures to maximize modal flexibility in programming decisions and improve mobility at the corridor or regional scale. These changes were targeted at some of the criticisms of the then current performance measures mandated by the CMP. These criticisms included:

- Emphasis on mitigating LOS at individual locations, combined with a pot of money for CMP performance, perpetuates the tendency to add capacity rather than optimize operations.

- Many people are concerned that reliance on LOS versus a multimodal/regional analysis discourages infill development and pushes development further out into the urban fringe.

- Most agencies agree that LOS is not an effective indicator of multimodal mobility; further, the transit standards are considered too general to be either measured or enforced, and are not functionally linked to the rest of the transportation system.

- The uncertainty involved with travel demand modeling for individual links and intersections is greater than the sensitivity in shifting from on LOS to another.

- LOS is not a good performance measure for congestion reduction or air quality improvement since it is too location-specific to help determine cumulative impacts within an air basin.

- Current methods for performance measurement tend to address specific weak spots in the system without regard to policies that define overall development objectives.

- Cities may opt out of the CMP process because savings from high compliance and monitoring costs coupled with potential revenue from new development could outweigh their relatively modest gas tax revenue.

The study team developed a short list of twelve candidate performance measures which were evaluated against fourteen criteria to assess the utility of each measure in meeting key aspects of congestion management and air quality plan performance (see Table 4-4). The California study

Table 4-4 Candidate CMP Performance Measures for California

MEASURE	CONCERNS ADDRESSED					ACCEPTANCE			EFFORT	TRIGGER	ACCOUNTABILITY	
	Congestion	Air Quality	Mobility	Multi-Modality	Regional Goal Consistency	User-Oriented	Understandable	Objectivity	Level of Difficulty	Value	Land Use	Traffic
Level of Service	Good	Fair-Poor	Fair-Poor	Fair-Poor	Fair-Poor	Fair	Good	Good	Easy	Fair	Fair	Fair
Hours of Delay	Good	Fair	Fair	Fair	Fair	Good	Good	Good	Fairly Easy	Fair	Fair	Fair
Travel Time, Vehicle Only	Good	Poor	Good	Poor	Fair	Good	Good	Good	Fairly Easy	Fair	Fair	Fair
Travel Time, All Modes	Good	Fair-Poor	Good	Good	Fair-Good	Very Good	Good	Good	Mod. Difficult	Fair-Good	Fair-Good	Fair
Modal Split	Poor	Good	Fair	Good	Good	Fair-Poor	Good	Good	Fairly Difficult	Fair	Fair	Fair
Average Vehicle Occupancy	Poor	Good	Poor	Fair-Good	Fair-Good	Poor	Good	Good	Fairly Easy	Fair	Fair	Fair
APO/AVR/Veh. Trip per 100	Poor	Good	Poor	Good	Good	Poor	Fair-Good	Good	Mod. Difficult	Good	Fair-Good	Good
VMT	Poor	Good	Poor	Poor	Good	Poor	Good	Good	Fairly Easy	Fair	Fair	Fair
VMT/Person Trip	Poor	Good	Fair-Good	Good	Good	Fair-Poor	Fair-Good	Good	Mod. Difficult	Good	Good	Good
Person Throughput	Good	Fair-Good	Good	Good	Good	Fair	Fair-Poor	Good	Fairly Difficult	Fair	Poor	Fair-Good
Accessibility: % employees within X min.	Fair-Poor	Poor	Very Good	Good	Good	Good	Fair-Good	Good	Mod. Difficult	Good	Very Good	Good
Accessibility: % employees within X miles	Poor	Good	Good	Poor	Good	Good	Fair-Good	Good	Fairly Easy	Fair-Good	Very Good	Fair-Poor

Source: Comsis Corporation, et al, 1993

initially considered use of both LOS and a multimodal mobility measure as triggering mechanisms in the CMP process. However, it now appears that the CMAs will keep LOS as a triggering mechanism for monitoring and deficiency plan purposes, while allowing adoption and supplementary use of mobility measures by individual counties. This result may stem from an inability to find one performance measure which meets the following compliance tests:

- compatibility with the goals of the regional transportation plan;
- usability for all aspects of the CMP process (planning/programming, deficiency indications, and monitoring mitigation);
- objectivity and basis on empirical evidence;
- local accountability for land use decisions and enforceability (in other words, consistent with LOS in terms of monitoring and mitigation);
- incorporation of transit standards and performance, and;
- political and legal acceptability to CMA decision-making bodies.

The California Department of Transportation (Caltrans) also took an aggressive approach in developing an initial set of performance measures for its Intermodal Management System (IMS). Building upon some of the experiences gained from the CMP, draft performance indicators were developed for both passenger and freight services in the areas of mobility, financial, environmental, economic, safety, quality of life and intermodal transfer facilities. The basic service units utilized for monitoring system performance were person-miles per capita for personal travel and ton-miles for goods movement.

Specific mobility-type measures under consideration for performance monitoring included:

- A mobility index which would reflect the number of person-miles delivered for every hour a vehicle is on the system;
- Time lost due to congestion per person-mile, and;
- Capacity utilization (v/c ratios or LOS).

The initial set of performance measures was reduced, however, when it became apparent to state officials that operationalizing these measures required a large data set which did not exist.

4.6 Minnesota DOT's Family of Performance Measures

As part of its strategic management process initiated in 1992, the Minnesota Department of Transportation (MnDOT) established a set of performance measures that would allow MnDOT officials to measure the level to which the organization was providing quality products and services. These performance measures are to be used throughout the Department at all levels of management structure, i.e., headquarters, division, office and work group, to guide resource allocation. This set of performance measures, referred to as a "family of measures", is shown in Figure 4-3. Several observations of this set of performance measures merit attention.

The overall goal of "optimizing the transportation investment" was divided into three weighted sets of related performance categories--system performance, public values/issues, and organizational performance/values. In other words, achieving the overall goal of optimal transportation investment requires successful performance in the actual operation of the transportation system, the overall impact on society and perceptions thereof, and the efficiency with which the DOT can provide this investment. Importantly, a guiding principle for this management approach was to satisfy the DOT's customers. Customer satisfaction, which was to be measured through market research surveys, related to the customer perceptions of the condition and performance of the transportation system, the perceptions of how the transportation system is serving its ultimate roles of serving society in an environmentally sensitive way, and employee satisfaction with DOT progress.

Of interest to this research, many of the performance measures are fairly unusual in a sense of traditional transportation planning. Note that such measures as "cost per mile of passenger service" and "pavement quality index" are typical system owner measures. However, the MnDOT set of measures also included such things as: mile of detour travel, economic indicators for people and goods movement, percent of goods and people moved with option of more than one mode choice, miles of travel eliminated by telecommuting, savings to the public from partnerships, and average metro area commute time. Most of these measures are more oriented to the user and the perceptions of the customer than they are measures of organizational output of the DOT.

4.7 Washington State

The Washington State legislature passed in 1990 a Growth Management Act that was intended to provide a guide to development and land use in the state. The Act requires that urban counties and those counties experiencing substantial growth adopt a comprehensive plan by July 1, 1994. Similar to the Portland example, each comprehensive plan must designate an urban growth area along with the corresponding land use, housing, utilities, and transportation investments. Importantly, the transportation element of the adopted plan must include locally-defined level of service standards for roads and transit which will be used to monitor deteriorating performance of the transportation system.

Figure 4-3 Minnesota DOT's Family of Performance Measures

To measure, track and evaluate whether customer needs and public goals are being met throughout the state with the most efficient use of resources.

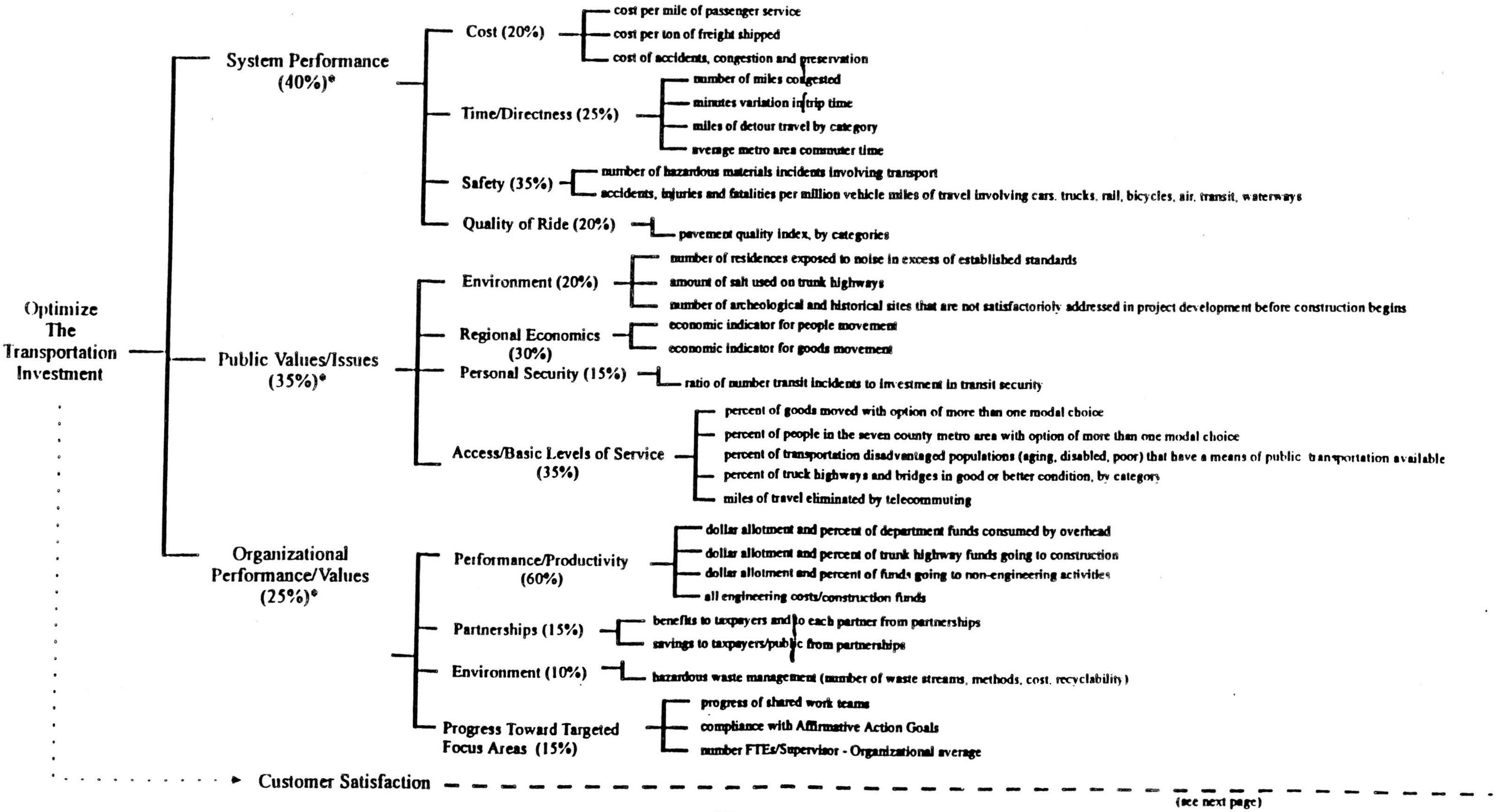


Figure 4-3, cont'd

Mn/DOT - Family of Measures To Optimize The Transportation Investment:

→ **Customer Satisfaction (to be measured via market research surveys)**

- System Performance
  Customer Perceptions of:
  - condition of the system
  - amount of work being done to improve the system
  - time it takes to travel to places people/goods need to go
  - time it takes to drive through highway construction areas
  - ease of travel through construction work zones
  - satisfaction with commuter time
  - safety while in travel status
- Public Values/Issues
  Customer Perceptions of:
  - satisfaction with air quality
  - amount of salt used on trunk highways
  - satisfaction with transportation decisions which impact the environment
  - satisfaction with involvement in pre-project planning (informed consent)
  - satisfaction with completed projects
  - promises kept on project completion
- Organizational Performance/Values
  Management/Employee Satisfaction:
  - management perception of progress toward targeted focus areas
  - employee satisfaction with diversity efforts
  - employee satisfaction with communication of agency goals

Cities and counties must adopt ordinances which prohibit the approval of proposed developments which cause levels of service to fall below the adopted standards unless transportation improvements are made concurrent with the development. The road level of service standards are the typical LOS A to F assessment found in traffic engineering handbooks. Transit level of service standards have yet to be determined, and apparently are the subject of considerable discussion among transit planners.

Another state legislative initiative is the Commute Trip Reduction Act with was passed in 1991 and incorporated into Washington's Clean Air Act. The purpose of this law is to encourage the use of alternatives to single occupant vehicles for commute trips by requiring specific trip reduction targets for major employers. Major employers are defined as those employers having more than 100 full-time, weekday employees at a work site who begin work between 6:00 and 9:00 a.m. and who are located in counties over 150,000 population. The law states that major employers must show a reduction in vehicle miles traveled per commute trip by employee of 15 percent by 1995, 25 percent by 1997 and 35 percent by 1999 with the base comparison being the 1992 average VMT per commute trip for the area in which the employer is located.

In addition, each county and city that has a major employer located in it must adopt a commute trip reduction plan and ordinance that includes, 1) goals for trip reductions of single occupant vehicle commute trips and vehicle miles traveled per employee for commute trips, requirements for major public and private employers to implement commute trip reduction programs, and a review of local parking policies to determine consistency with commute trip reduction goals.

4.8 Florida

Florida adopted a Growth Management Law in 1985 that required the state to develop a state comprehensive plan and each local government to adopt a comprehensive planning process that was consistent with the state plan. Each local plan was required to have elements relating to capital improvements, future land use, traffic circulation, water systems, conservation, housing, recreation and intergovernmental coordination. Of perhaps greatest importance, Section 3177 of this statute stated that "it is the intent of the Legislature that public facilities and services needed to support development shall be available concurrent with the impacts of such development...." This is known nationally as the "concurrency" requirement. In order to determine what was needed to support development, the law required the local comprehensive plans to assess the current performance of the possibly affected systems and to develop level of service standards that could be used as a target performance measure to assess impact. The affected systems included sanitary sewer, drainage, potable water, solid wasted, parks and recreation, roads, and public transit (if it existed in the community). Interestingly, the Florida statute also requires local governments to "discourage" the proliferation of urban sprawl. The Florida Department of Community Affairs which has oversight responsibility for the implementation of the local comprehensive planning requirement has interpreted this requirement to mean that land use projections and provision of infrastructure that is not conducive to denser urban areas is not consistent with state law. For example, the DCA has provided the following "indicators" of acceptable transportation consistency (note that many of the indicators are land use elements):

--adequate planning for mixed use development

--reducing strip development land use patterns

--direct development to projected transit corridors

--commit to providing a level of service in these corridors that allows residents to rely on transit

--coordinate zoning, parking, and other land development regulation to ensure densities

--minimal allowance of median or curb cuts

The level of service standards for roads are based primarily on the adopted A to F measures found in traditional traffic engineering. For example, Figure 4-4 shows the level of service standards adopted by the Florida Department of Transportation for all state highways.

Recently, the Florida Legislature has revised the Growth Management Laws to allow cities and counties some flexibility. Cities and counties may now designate Transportation Concurrency Management Areas (TCMAs) as part of their comprehensive plan. Within the TCMAs, cities and counties may adopt their own LOS standards for most roadways, regardless of Florida DOT standards. Localities must also adopt policies to guarantee adequate "levels of mobility" within the TCMAs. Measurement of "levels of mobility" was not specified, except to say that localities shall establish "numerical indicators against which the achievement of the mobility goals of the community can be judged, such as modal split, annual transit trips per capita, auto occupancy rates...."

Also, the City of Miami is now analyzing "corridor LOS" related to person-throughput. Basically, a volume-to-capacity type ratio would be determined which includes person-trips on highway and transit, as well as the practical capacity of roads and transit systems.

4.9 Summary

This Section has presented an overview of performance-based transportation planning as it is beginning to evolve in the U.S. Such planning is an important step in providing this-market-orientation described above. The concept of system performance, and importantly what constitutes acceptable performance, should be found throughout the planning process, from the

Figure 4-4 Florida DOT LOS Standards for Concurrency Determinations

	Freeways	Principal Arterials	Minor Arterials
Existing Urbanized Areas	D	D	E
Other Existing Cities	C	C	D
Transitioning Areas	C	C	D
Rural Areas	C	C	D
Special Trans. Areas	D	E	E
Parallel to Exclus. Transit Facility	D	E	E
Constrained or Backlogged	Maintain	Maintain	Maintain

initial states of how transportation is viewed as a factor in achieving a variety of goals to the characteristics of the analysis tools that provide input into decision-making.

Performance-based planning is not just performance measures. As more groups become involved in transportation planning, we are likely to see a wide variety of interests and concepts of system performance incorporated into the planning process. In many ways, this was the promise of ISTEA. The challenge to the transportation profession is to incorporate these concepts and interests into the planning process so that the eventual investments in the transportation system relate to the concerns of most interest to society. Some guidelines for doing this are presented in the next Section.

5.0 *Performance-based Transportation Planning: Observations and Conclusions*

This research project has examined key characteristics of performance-based transportation planning. Several illustrations of such planning as it is evolving today were presented in the previous Section. Based on these case studies and on the review of the literature undertaken throughout this project the following observations can be made.

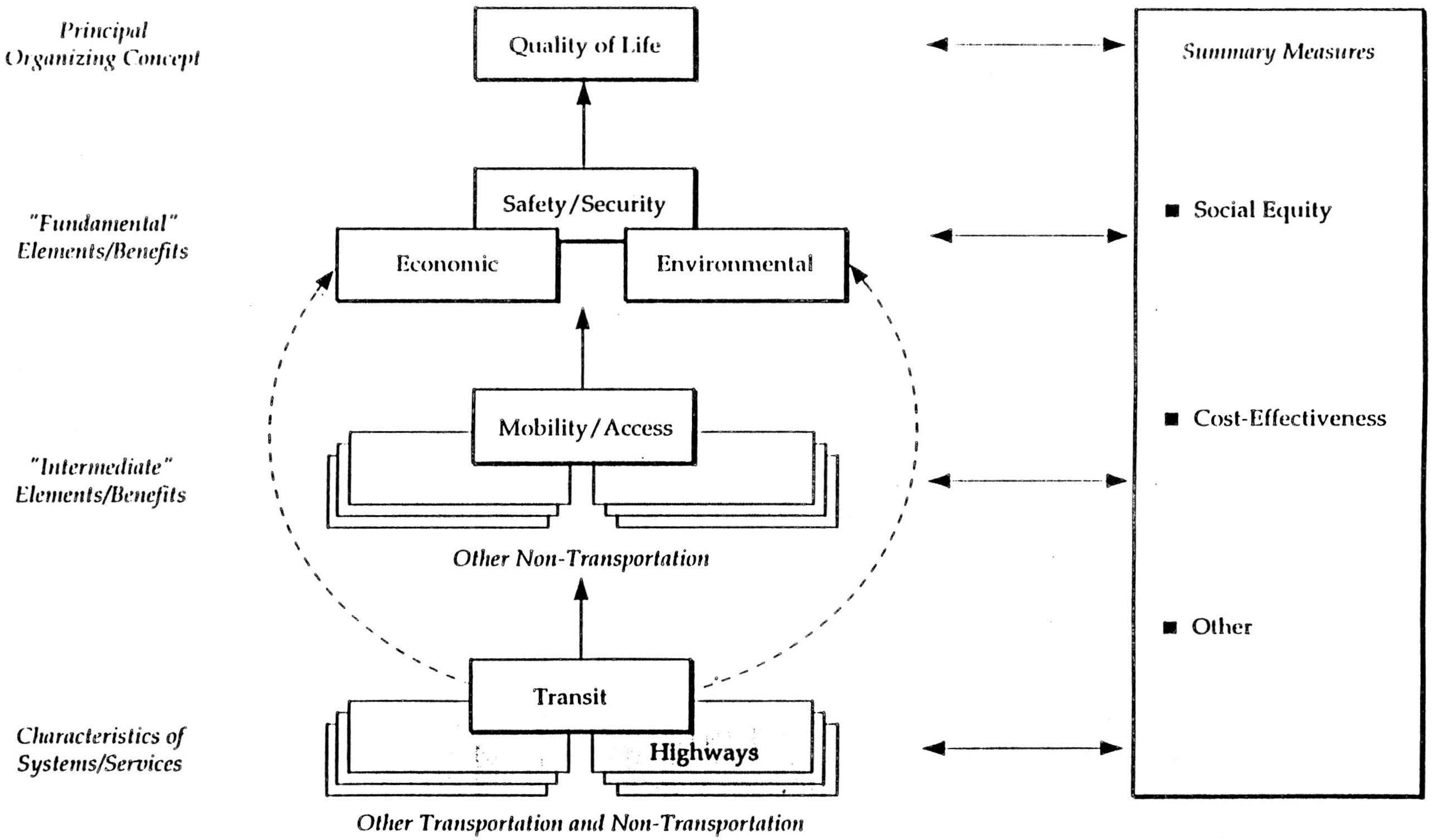
5.1 *Important Observations*

System Performance As A Concern: ISTEA provided a broader perspective on what role transportation plays in a metropolitan area. In addition, in an era of increased accountability, knowing what is happening on the transportation system and what impact investment is having in the region becomes an important consideration in the public debate that surrounds such investment. Monitoring system performance thus becomes a critical element of successful transportation planning. As was shown in the case studies, such performance can be defined in many different ways with a major distinction being made between measures that are most relevant to the owners of the transportation system, and those of most concern to the users of the system. Both measures have an important role to play in a metropolitan transportation planning process.

Measurement of System Performance Must Be Closely Linked To Fundamental Roles of Transportation: As was shown in Figure 3-2, the initial step in conceptualizing performance-based planning was articulating what roles transportation is to serve in a metropolitan area. The measures of whether the system is performing as expected should thus be related to these fundamental roles for the transportation system. Congestion on individual links in the network does not say much about system performance as it relates to quality of life, economic development or environmental quality. Volume-to-capacity ratios can be symptomatic of the performance of some links in the network as it relates to these fundamental roles, but by themselves they do not say much regarding the ultimate linkage to the purpose of transportation.

In transit planning, this linkage is best described in recent work for the Transit Cooperative Research Program on the benefits of transit investment. Figure 5-1 illustrates the concept of a hierarchy of benefits ("roles") for transit investment. At the bottom of this hierarchy is the basic characteristics of the transportation system itself, such as lane-miles, ridership, volume to capacity measures, costs, vehicle occupancy, etc. In many areas, these characteristics become the "performance measures" for the system. However, in reality, there are more important benefits of the transportation system that are measurable. In Figure 5-1, the next level of benefits, denoted as "intermediate" benefits, relate to what the transportation system provides, that is, mobility and access. The next level, or "fundamental" benefits, link transportation investment to the different roles such investment can play. In this example, these roles lead to improved safety/security, enhanced economic opportunity, and excellent environmental quality. The final level is the principal organizing concept which is defined by all of the elements and benefits lower on the hierarchy and directly dependent upon them as well.

Figure 5-1: Framework for Transit Impact Measurement and Valuation



Source: [Cambridge Systematics, 1995b]

Figure 5-1 is analogous to Figure 3-2 in that higher levels of system benefits (and thus linkage to system performance) are suggested as being critical for measuring the effectiveness of the transportation system. This fits in nicely with the case studies presented earlier which focussed on "core values and goals" and a "family of measures." The key points are that system performance needs to be viewed above the level of simply defining the characteristics of the system and that linking performance measurement to the fundamental roles, goals, or benefits of the transportation system becomes a critical first step in establishing a performance-based planning process.

Outputs vs Outcomes: Another way of discussing the previous observation is by identifying the difference between output and outcome measures. Many transportation agencies are quite familiar with output measures. These measures are indicators of the direct production of an organization such as revenue bus hours or miles and lane-miles. Outcome measures relate to the ultimate effect these outputs have on the region. Referencing Figure 5-1, outcome measures would relate to quality of life at the most basic level, and safety/security, environmental quality, and economic opportunity at the next level. A key challenge in performance-based planning is to define system performance from an outcome perspective.

Mobility and Accessibility: ISTEA clearly defined "improved mobility" as an important goals of transportation planning. As was shown in several of the case studies, mobility was being incorporated into performance measurement and project/plan evaluation. Still others were experimenting with measures of accessibility and how such measures could be used to assess system performance. As transportation planning evolves over the next several years, mobility and accessibility measures are likely to plan an increasingly important role in the planning process.

In both cases, measures of mobility and accessibility beg the question of mobility and accessibility for whom? The distributional effects of transportation investment on different socio-economic groups and different geographic areas of a metropolitan region strongly suggest that performance-based planning should be based on a market-segmentation approach which clearly identifies existing and future travel markets and who will benefit and who will pay for changes to mobility and accessibility. This approach also suggests careful identification of the mobility/accessibility benefits for those currently using the system, as well as for those induced to making trips because of enhanced system performance.

Travel Time Is A Key Performance Indicator: Many of the performance measures related to mobility use or have at their foundation some estimate of travel time. At the conceptual level, one could argue that improved mobility is best defined as the reduction in generalized costs of travel associated with changes to the transportation system. Generalized costs in this context include out-of-pocket expense and changes in characteristics of the trip that can be assigned a monetary value (such as travel time). Note that in this case the net change in generalized cost would most likely occur to existing users of that portion of the transportation system (transit and auto users) targeted for investment, as well as new users that now take advantage of the transportation opportunity available to them. This distinction between existing and induced trips places greater emphasis on the importance of market segmentation as a technical approach to analysis in that the amount of new trips taken will be directly related to the socio-economic and trip making characteristics of different market groups.

For project evaluation then, travel time savings becomes a key evaluation criterion. At the network or corridor level, system performance can also be linked closely to total travel time for trips taken on the system. The critical perspective in the use of travel time at this level is that performance is linked to the total trip, (from origin to destination), not just to the experience found on individual segments of the trip. This "total trip" perspective is very much attuned to the user orientation of performance measurement discussed in Section 1. Adopting a total trip perspective recognizes the fact that trip making in a metropolitan transportation system very seldom occurs on a network under the control of one jurisdiction (this does not consider through trips which tend to use the higher level road system). Bottlenecks in the system, and thus delay to the user, can often occur at access, egress, or transfer points which most likely will not be under the control of the agency responsible for the line haul portion of the trip. Travel time from specific origins and destinations thus becomes an important indicator of the performance of the transportation system from the perspective of the user. Note that this could be further refined to include relative travel time ratios for a trip of one mode compared to another. Thus, one measure of mobility in a corridor might be total travel time for an origin and destination by auto, and the ratio of travel time by transit compared to the auto trip time. The change in these measures over time provides a surrogate value of the change in mobility in this corridor.

Performance Measures Should Be Closely Tied To Project Evaluation Criteria: Just as performance measures need to be linked closely with the fundamental roles of transportation and the subsequent goals, these measures should also be closely related to project evaluation criteria. This relationship becomes an important system performance tie to the stated purpose of transportation investment. If investment is occurring because of its expected impact on job creation, then clearly a measure of system performance should be the increase in jobs that can be attributed to this investment. An important consideration in this linkage, however, is that many major investment studies have numerous evaluation criteria that are used during the assessment process. It would be very difficult to adopt all of these criteria for performance measures and implement a systematic and comprehensive data collection program that would monitor these measures over time. Such data collection requirements would be prohibitive to most transportation planning agencies in the U.S. Therefore, the identification of performance measures should be targeted to those concerns (e.g., mobility and accessibility) that are considered fundamental to the success of the transportation system for which new data might have to be collected, and on those characteristics of system performance for which data is already collected and which provide meaningful assessments of the performance of the transportation system.

A Strategic Data Collection and Management Plan Is Essential: The success of performance measurement is directly tied to the availability of data. For example, an important criterion adopted by the participants in the California CMP study for recommending performance measures was the desire to rely on existing data. This was especially important for smaller MPO's which did not have the resources to adopt a new and expensive data collection effort.

A critical element to performance-based planning is the development of a strategic data collection program. The term "strategic" is used to describe such an effort in that the program should encompass the entire spectrum of data that needs to be collected, which agencies will be the source of such data, and the frequency of data collection.

An example of such a program as it relates to performance measurement is shown in Figure 5-2. This data collection program is being adopted by the MPO in Albany, NY to support its performance-based planning process. The program includes the data collection activities of other agencies as well as the desired frequency of collection. Such a concept is critical to support the use of performance measures in the planning process.

New Data Management and Analysis Techniques Provide Strong Support For Performance Measurement: Data availability was noted in the previous observation as being critical in the definition of performance measures. However, the technology of data collection is evolving, with techniques being used today that were unavailable several years ago. The traditional methods of on-road traffic counts, speed measurements and ridership counts will continue for many years to be the mainstay of data collection activities. However, new techniques such as video and machine vision recognition of vehicular movement, aerial photography, automatic vehicle identification, instrumented vehicles, and advanced passenger information systems could provide important new sources of data that would be useful in system performance monitoring.

In addition to these new data collection techniques, analysis tools such as geographic information systems (GIS) provide critically important analytical capability for organizing spatially defined data. For example, an accessibility performance measure which relates to the number of major employment sites within a certain travel time could be easily determined through the use of a GIS-based transportation model. The evolution in analysis tools is allowing transportation planners to become more sophisticated in their analysis efforts. This sophistication can relate to performance measurement as well.

5.2 Guidelines For Selecting Performance Measures

This research project has examined several efforts to implement a performance-based planning process. Based on this research, it seems likely that, in most cases, those metropolitan areas that use performance measures will identify a select few that represent the most important concerns to the citizens and officials of the region. Given the large number of candidate measures available, it is useful to have some guidance on the selection of these measures. The guidelines shown in Figure 5-3 provide a checklist that can be used to assess the usefulness of potential performance measures. Some of these guidelines are straight-forward, and others require some thought. For example, being measurable is an important prerequisite for a performance measure (although surrogate measures could be used in direct substitution of the desired outcome measure).

Figure 5-2: A Data Collection Program In Support of Performance-based Planning

Source: [Poorman, 1995]

DATA ITEM	CURRENT COLLECTION FREQUENCY	DESIRED COLLECTION FREQUENCY
Traffic Volumes and Classification		
Freeway Segments	3 years (some continuous)	continuous
Cordon and Screen lines	3 years	3 years
Other Arterials	3 years	3 years
Other Collectors	as needed	3 years
Local Roads	as needed	as needed
Major Signalized Intersections	as needed	3 to 4 years
Other Intersections	as needed	as needed
Roadway Characteristics		
Number of lanes, width	no schedule	when changes occur
Traffic control	with intersection counts	with intersection counts
Changes in bicycle and pedestrian accommodation	not collected	when changes occur
Pedestrian Counts	with intersection counts	with intersection counts
Travel Speed		
Speed and delay: major arterials	as needed	as needed plus every 5 years to calibrate models
Frequency and extent of incident delays	not collected	daily
Vehicle Occupancy		
Cordon and Screen lines	no schedule	2 years
With DMV accident data	1991-1993 available	annually
Transit Ridership		
CDTA by route, bus trip	daily	daily, summarize annually
CDTA by demographic group	no schedule	3 years
Upstate transit by route, trip	daily	daily, summarize annually
Other transit by route	unknown	daily, summarize annually
Park-and-Ride Lot Usage		
Vehicles at designated lots	not collected	annual field survey
Persons per arriving vehicle	not collected	annual field survey

Table 5-2: continued

DATA ITEM	CURRENT COLLECTION FREQUENCY	DESIRED COLLECTION FREQUENCY
Commuter Register Usage		
New Commuter Register entries	monthly	monthly
Carpools formed	2 months	2 months
Average carpool trip length	2 months	2 months
Carpool longevity	2 months	2 months
Arterial Management		
Traffic signal spacing: major arterials	partial inventory, being updated	when changes occur
Driveway spacing (frequency):major arterials	1994-95 inventory	when changes occur
Land Use Changes		
Building permit activity	monthly	monthly
New development	not collected	annually
New development built with Pedestrian and Transit Oriented Design	not collected	annually
New development with Service Roads, Driveway Consolidation and Corridor Management Actions	not collected	annually
Closing or elimination of activity	not collected	annually
Goods Movement		
Truck volumes as a percent of travel	with intersection counts	with intersection counts
Journey-to-Work Information		
Mode of trip	10 years (Census)	5 years
Time of day of trip	10 years (Census)	5 years
Origin-Destination information	10 years (Census)	5 years
Demographics of commuter	10 years (Census)	5 years
Travel Behavior, All Purposes		
Mode of trip	20+ years	10-15 years
Trip purpose	20+ years	10-15 years
Time of day	20+ years	10-15 years
Occupancy	20+ years	10-15 years
Trip chaining	20+ years	10-15 years
Demographics of traveler	20+ years	10-15 years

Source: [Poorman, 1995]

Figure 5-3 Criteria for Selecting Measures

- Be measurable
- Have a clear and intuitive meaning, so that it is understandable to those who will use it and to non-transportation professionals
- Be acceptable and useful to transportation professionals
- Be comparable across time and between geographical areas (facilities, corridors, subareas, and metropolitan regions)
- Have a strong functional relationship to actual system operations, so that, once changes occur in system operations, changes to the system can readily be determined from it
- Be consistent with measures identified for other systems
- Provide for the most cost-effective means of data collection
- Be theoretically and functionally related to other predictable measures (e.g. road performance characteristics) suggesting that it too might be forecasted with some success
- Where appropriate, provide for multiple indications of achievement of goals, e.g., reducing congestion and improving air quality
- Where appropriate, be based on statistically sound measurement techniques

Most transportation planning staff will have a good sense of the difficulties associated with data collection, so the discussion on measurability should not be complicated. However, measures that have a clear and intuitive meaning to non-transportation professional, for example, might require a significant outreach effort. Congestion or mobility indices might have some meaning to technical staff, but hold very little "real world" meaning to local officials.

The guidelines shown in Figure 5-3 are not offered as an all-inclusive list of every consideration that should be given to performance measures. Each metropolitan area would likely have its own requirements and desired characteristics of performance measures. Appendix A, which presents the results of the evaluation process for the California CMP study, is an example of the types of concerns that could be incorporated into a jurisdiction-specific effort. However, there is an important need for the performance measures to satisfy one critical requirement -- they must be relevant to the types of decisions that will be made to improve the performance of the transportation system. This means that decision makers and system users should have an important role to play in defining the appropriate measures.

5.3 Conclusions

This research has provided an initial examination of the current status and likely evolution of performance-based transportation planning. The impetus for such planning comes from the ISTEA legislation, however, it seems likely that the current trends in society toward improved accountability and enhanced utilization of scarce resources would have led transportation planning in this direction in any case. Several important conclusions result from this research.

Mobility and Accessibility Should Be Important Measures of System Performance-- As noted in earlier sections, the identification of performance measures should be tied to the desires and requirements of local decision makers. In addition, these measures of system performance should also be linked to the ultimate roles that the transportation system plays in a metropolitan area. Although the identification of these measures should be primarily left to the local level, every effort should be made to encourage the adoption of mobility and accessibility measures. These two types of measures provide the closest linkage to the ultimate purpose of the transportation system, and go beyond simple measurement of the characteristics of system performance.

Travel Time (and Related Measures) And Availability of Alternative Modes Should Be The Foundation For Mobility Measures-- Mobility was defined in this report as the ability and knowledge to travel from one location to another. Most measures of this ability include some estimate of travel time (or delay or speed). Travel time thus becomes a critical element in the assessment of system performance. Few metropolitan areas conduct travel time surveys, instead relying on survey results or estimates that come from model runs. It seems likely that that the user perspective on system performance will require more attention given to actual travel times for specified trips. In addition, the definition of mobility suggests that ability to travel means having travel options. This can be interpreted as meaning having numerous modal options available for a trip (such as is the case in the Oregon composite index approach), and also characterizing the respective trips by the relative travel time of the modes available. Some caution needs to be exercised in defining mobility in the context of the number of travel options available to an individual. Taking this definition to an extreme would suggest that adding modal options even in the absence of expected ridership and taking into account the associated costs of providing such service would have a beneficial impact on mobility. This is certainly not a likely scenario in practice and thus results in a suggested approach of weighting mode availability by usage.

Accessibility Measures Should Be An Integral Part of Project, Plan, and System Evaluation-- Accessibility measures are extremely useful indicators of transportation system and service effectiveness. As shown in the Cobb County Transit case study, local officials and business leaders were unanimous in linking transit service to the provision of access to employers and major activity centers. Within a project planning effort, such measures could be defined simply as the level to which major sites are served by transportation within a certain threshold time. At the regional level, this measure could be aggregated to measure the percent employment opportunities that are within a certain travel time, or even linked to specific types of activity centers (e.g., percent population accessible to recreation areas or medical facilities or the central business district or a suburban retail center by travel time). At a more aggregate level, the travel time element can be eliminated from the definition of the measure so that the function that the accessibility will serve can be achieved even without taking a trip. For example, telecommunications could provide access to work or shopping opportunities without ever making a trip. Accessibility for the user is enhanced, but travel does not occur. In addition, this broader definition of accessibility allows one to look at non-transportation solutions to problems such as urban design and land use patterns.

Performance Measures Should Reflect The Desires of the Transportation System User-- This report has described the difference between an "owner" perspective on system performance and a user orientation. For many years, the key indicators of system performance were related primarily to providing input into decisions relating to individual elements of the transportation system under the jurisdictional control of one agency. The users of the system, however, do not distinguish elements of the transportation system by who has control over their provision and operation. A users perspective on system performance therefore necessarily requires an extensive outreach effort to identify what characteristics of system performance are most important. Clearly, traditional measures such as volume-to-capacity and ridership will continue to provide important input into organizational decisions. However, a much broader definition of system performance as seen from the eyes of the customer or user would be an important addition to the perception of successful transportation system performance.

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Market Segmentation and Distributional Effects of Mobility and Accessibility Changes Should Be Part of Measuring System Performance-- The importance of mobility and accessibility as measures of system performance needs to be balanced with an understanding of the relative impacts on society of such changes in the transportation system. This means that market segmentation approaches for analysis and evaluation are critical to identify distributional impacts. As noted earlier, this also means distinguishing the impacts between existing users of the transportation system and services and those new users to the system that are taking advantage of the new travel opportunity presented by enhancements to system performance. Current analysis processes are able to adopt such a market segmentation approach, however, such an approach has significant implications for data collection, technical tools, and evaluation methodologies. For example, assessing changes in mobility might require a determination of changes in consumer surplus of those affected by the change. This in turn requires a fairly sophisticated demand model and associated demand functions that can be used to estimate this change in consumer surplus.

In summary, transportation planning is a dynamic process, responding to and reflecting the trends of society. In an era of increased public accountability and responsiveness, the transportation sector has been increasingly under pressure to justify its expenditures. From the planning perspective, this means that the planning process should be designed to provide feedback linkages between what is actually happening on the system to the identification of strategies for enhancing system performance. In this report, the type of transportation planning process that can respond to these needs is called a performance-based planning process. Such planning is an important evolutionary step in a planning process that has been evolving over the past 50 years, and provides an important link between investment decisions and system response. Such an approach is critical for the future of transportation in an era of scarce resources.

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Appendix A

Performance Evaluation For The California Congestion Management Program Study

Source: Comsis, Inc., "Statewide Congestion Management Air Quality Coordination Study," Los Angeles County Metropolitan Transportation Authority, January, 1994.

MEASURE: Level of Service

DEFINITION AND MEASUREMENT:	Measures relationship between volume and capacity on designated facilities. Recommend in definition: ● Use all facilities above specified functional class, no exceptions: use links, not intersections. ● Measure peak conditions, not daily. ● Look at weighted system LOS as well as individual links.
CONCERNS ADDRESSES:	
● Congestion	Reasonable method of gauging roadway congestion.
● Air Quality	Inconsistent measure re. A/Q: Better LOS means better speed means lower emissions; however, if better LOS achieved through additional capacity, then VMT increases and A/Q may suffer.
● Mobility	Better LOS means higher speeds, but accessibility and travel time may not be improving because of land use dispersion.
● Multiple (non-SOV) Modes	Only reflects highway vehicular travel; greater use of higher occupancy modes could produce a better LOS, but effect is hard to discern.
● Consistency with Regional Goals	If regional goal is to limit growth in vehicle travel, may be in conflict.
ACCEPTANCE:	
● User Oriented	Addresses vehicle movement, not people. Does reflect driving conditions encountered.
● Understandable	LOS not inherently obvious, but broad use has resulted in reasonable level of public understanding.
● Objectivity	Objective, as long as consistently defined and applied.
COST/OPERATIONAL DIFFICULTY:	Easy because necessary analysis procedures and data sources well-established. Need volume information (from counts or forecasts) and respective capacities. Can get complex if intersection level of detail is included.
KEY POLICY QUESTIONS:	
● Value as "Triggering Mechanism"	Is an informative measure, but alone doesn't present total picture. If used as a "monitoring" measure only, may signal problem when too late to repair. This concern can be removed through model forecasting of LOS. The threshold that is established is important.
● Local Accountability for Land Use	In near term. LOS can be aided through dispersed land use; may result in long term problems re. congestion solutions.
● Local Responsibility for Traffic	High as regards local problems, low as regards systemic problems.

MEASURE: Delay

DEFINITION AND MEASUREMENT:	Measured in minutes or hours of delay experienced by system users. For network of LOS facilities, compare travel time during congested period (peak) with uncongested (off-peak). Weight delay on each segment by volumes. This can be estimated through counts combined with travel time measurements, or models.
CONCERNS ADDRESSED:	
• Congestion	Good measure of congestion intensity on link or system, although doesn't give much insight as to cause.
• Air Quality	Tells about restricted flow and sub-optimal speeds, but doesn't address VMT reduction.
• Mobility	Good measure of ease/difficulty of personal (or goods) movement, but does not directly address accessibility.
• Multiple (non-SOV) Modes	As defined, only measures highway/vehicle travel. Could be expanded to include delay on transit also.
• Consistency with Regional Goals	Dispersed land use policies or capacity expansions could result in near-term delay reductions, but not be consistent with regional efficiency/air quality needs.
ACCEPTANCE:	
• User Oriented	Reflects time losses/savings to people, but is still oriented to vehicle users; could be measured for other modes.
• Understandable	Fairly obvious meaning.
• Objectivity	As long as measurement rules are firm, OK.
COST/OPERATIONAL DIFFICULTY:	Can measure from manually-obtained data - don't require a model, though can be a source. Can use floating car runs or license matching to determine travel times on designated facilities, peak vs. off-peak.
KEY POLICY QUESTIONS:	
• Value as "Triggering Mechanism"	Not as diagnostic or scalable as LOS. Gives no insight to underlying land use and behavioral trends.
• Local Accountability for Land Use	As with LOS, delay can be aided by new capacity or dispersed land use.
• Local Responsibility for Traffic	Can't separate local contribution from external contributions.

MEASURE: Travel Time (Vehicle Only)

DEFINITION AND MEASUREMENT:	Measures travel time for traveler to move from one location to another. In this case, assumes measurement of time to travel from point to point in the designated network of facilities from which LOS is calculated. Must be evaluated relative to some datum or standard.
CONCERNS ADDRESSED:	
• Congestion	Lower travel time means less congestion, but must be related to distance context.
• Air Quality	Not a direct measure of pollution-causing congestion, or use of efficient modes.
• Mobility	Good measure of ease of movement for highway users; problem is that more capacity/dispersed land use can improve travel time in near term, but result in longer trip lengths and more travel time in the longer term.
• Multiple (non-SOV) Modes	This measure (vehicles only) focuses only on private vehicles.
• Consistency with Regional Goals	If regional goal is to limit growth in vehicle travel or manage land use, travel time improvements may be in conflict. It matters what modes are being used.
ACCEPTANCE:	
• User Oriented	Clearly reflects situation improvements to the traveler.
• Understandable	Fairly easy to understand, as long as basis well defined.
• Objectivity	As long as measurement rules are firm, OK.
COST/OPERATIONAL DIFFICULTY:	Can measure manually or with models. Manually, use floating car runs over specified facilities, or other techniques. With models, pick travel times off of data base for specified origin-destination pairs. Modest effort, but start up cost involved.
KEY POLICY QUESTIONS:	
• Value as "Triggering Mechanism"	Has excellent potential but is not in popular use. Also, may show initial positive trends under capacity increase/land use dispersal programs which may lead to longer term degradation.
• Local Accountability for Land Us	Land use dispersal can lead to short term improvements in travel time.
• Local Responsibility for Traffic	Good measure of performance, but better at broadscale than highly localized scale. Can't control contributions from other jurisdictions.

MEASURE: Travel Time (All Motorized Modes)

DEFINITION AND MEASUREMENT:	Measures travel time not only for private vehicles, but also for transit and carpools. This becomes more complex because it is really more important to measure the reference trips from door to door, rather than just along a facility segment. Requires more complex measurements, and/or use of models. Must be evaluated relative to some datum or standard.
CONCERNS ADDRESSED:	
• Congestion	Lower travel time means less congestion/better service, but must be related to distance context.
• Air Quality	Not a direct measure of pollution-causing congestion, or use of efficient modes.
• Mobility	Good measure of ease of movement for travelers by all modes; capacity/dispersed land use conundrum encountered with vehicle travel time measure still applies for the most part.
• Multiple (non-SOV) Modes	Because this measure also includes transit and carpools, comparing their times gives insight into modal opportunities and investments.
• Consistency with Regional Goals	Travel time improvements - even if multimodally measured - may still mask near term slippage in management goals, though seeing relative improvements in alternative mode times would be a plus.
ACCEPTANCE:	
• User Oriented	Better than vehicle-only travel time, because reflects improvements in opportunities across modes.
• Understandable	Fairly easy to understand, as long as basis well defined.
• Objectivity	As long as measurement rules are firm, OK.
COST/OPERATIONAL DIFFICULTY:	This may be more costly and complex than vehicle-only travel time. Would need to do comparative door-to-door measurements and distinguish among modes. For this would either have to use models, or invest in somewhat more intensive field data collection.
KEY POLICY QUESTIONS:	
• Value as "Triggering Mechanism"	Has good characteristics, particularly as a multi-modal measure, but better at broad scale than highly localized scale.
• Local Accountability for Land Use	Again, land use dispersal can lead to short term improvements in travel time: however, having multiple modes measured gives insights as to whether modal treatments are in right direction.
• Local Responsibility for Traffic	As above.

MEASURE: Modal Split

DEFINITION AND MEASUREMENT:	Measures percent of people traveling by mode.
CONCERNS ADDRESSED:	
• Congestion	Not a measure of congestion.
• Air Quality	Good for air quality; measures percentage of people using alternative modes.
• Mobility	Limited value. May tell about traveler options, but doesn't tell about the quality of that service.
• Multiple (non-SOV) Modes	Directly indicates use of alternative modes. Quality of the experience of those modes is not known.
• Consistency with Regional Goals	Should not run counter to regional goals.
ACCEPTANCE:	
• User Oriented	Tells about travel beyond terms of the private vehicle, but does not reflect the quality of service or activity options.
• Understandable	Percentage of persons by mode is fairly easy to understand.
• Objectivity	Hard to distort measure, but depends on definition of what population is being measured.
COST/OPERATIONAL DIFFICULTY:	Not easy. Would have to perform surveys or use modeled estimates.
KEY POLICY QUESTIONS:	
• Value as "Triggering Mechanism"	Good supporting trigger mechanism. Tells if shift in LOS is due to efficiency (greater use of higher-occupancy modes) or simply pushing the growth away. Not good as solo trigger measure.
• Local Accountability for Land Use	Useful but not free-standing measure to indicate whether land use patterns are integrated and being matched with travel alternatives.
• Local Responsibility for Traffic	Good barometer for traffic composition toward or away from more efficient modes: not as focused or all-encompassing as AVR or VMT per person trip.

Measure: Average Vehicle Occupancy

DEFINITION AND MEASUREMENT:	Measured as average number of occupants per private vehicle.
CONCERNS ADDRESSED:	
• Congestion	Poor measure of congestion, per se.
• Air Quality	Useful measure for air quality, since begins to demonstrate efficiency. Unfortunately, does not encompass transit and non-motorized modes.
• Mobility	Not a good measure of mobility.
• Multiple (non-SOV) Modes	Fair to good measure of use of other modes; limited in that does not incorporate transit or non-motorized.
• Consistency with Regional Goals	Generally would be consistent with regional efficiency and air quality goals; again, may be deficient in not including transit or non-motorized.
ACCEPTANCE:	
• User Oriented	Goes beyond pure vehicle performance, but doesn't reflect quality of conditions to the user.
• Understandable	Easy to understand, except may be confusing in that transit use rates don't affect one way or the other.
• Objectivity	As long as measurement rules are firm, OK.
COST/OPERATIONAL DIFFICULTY:	Can measure from manually-obtained data, using roadside observations.
KEY POLICY QUESTIONS:	
• Value as "Triggering Mechanism"	Useful supporting measure to LOS, because it helps to diagnose the nature of underlying problems, though there are more focused measures.
• Local Accountability for Land Use	Helps in land use accountability, because managed land use and higher occupancy levels should go hand in hand.
• Local Responsibility for Traffic	Helps in traffic accountability; lower occupancies generally equate to greater traffic.

MEASURE: All Travel Modes

DEFINITION AND MEASUREMENT:	Is similar to Average Vehicle Occupancy, but is more complete in that it encompasses all modes of travel. It measures total person trip movements relative to the number of vehicle trip movements to make those trips. Because it involves all travel and not just private vehicles, this measure cannot be made simply through roadside observations, but rather through work-end surveys or total travel system surveys. Work-end surveys (employee travel surveys) if incorporated as part of a TRO or ETRP requirement, could be an accurate and cost effective way to get this information. Systemwide surveys would be expensive, but models could be used.
CONCERNS ADDRESSED:	
• Congestion	Poor measure of congestion, per se.
• Air Quality	Good measure for air quality, since it demonstrates rates of use of higher occupancy and non-motorized modes.
• Mobility	Not a good measure of mobility because travel quality is not expressed.
• Multiple (non-SOV) Modes	Very good measure of use of alternatives modes.
• Consistency with Regional Goals	Generally should be consistent with regional efficiency and air quality goals.
ACCEPTANCE:	
• User Oriented	Goes beyond pure vehicle performance, but doesn't reflect quality of conditions to the user.
• Understandable	Relatively easy to understand with proper explanation.
• Objectivity	As long as measurement rules are firm, OK.
COST/OPERATIONAL DIFFICULTY:	Would be more data/cost intensive than vehicle occupancy. Best approach is to do work-end survey.
KEY POLICY QUESTIONS:	
• Value as "Triggering Mechanism"	A good supporting measure to LOS, because it helps to diagnose the nature of underlying conditions. Better than AVO because it encompasses all modes.
• Local Accountability for Land Use	Helps in land use accountability, because managed land use and higher transit utilization and occupancy levels should go hand in hand.
• Local Responsibility for Traffic	Useful in traffic accountability: lower occupancies and transit use generally equate to greater traffic.

MEASURE: Total Vehicle Travel

DEFINITION AND MEASUREMENT:	Measures total vehicle travel on the highway system. Obtained by correlating vehicle counts on the designated LOS system of highways and multiplying by segment length.
CONCERNS ADDRESSED:	
• Congestion	Poor measure of congestion.
• Air Quality	Good measure for air quality, since VMT is direct component for emissions (also need vehicle trips and speeds).
• Mobility	Poor measure for mobility.
• Multiple (non-SOV) Modes	Poor measure for multi-modal use; describes only vehicle movements.
• Consistency with Regional Goals	Ties in well with regional measures of effectiveness.
ACCEPTANCE:	
• User Oriented	Means little to users.
• Understandable	Fairly easy to understand, as long as basis well defined.
• Objectivity	As long as measurement rules are firm, OK.
COST/OPERATIONAL DIFFICULTY:	Can measure manually or with models. Manually, correlate vehicle counts on LOS facilities with segment length. With models, can do more completely for system as a whole, and see distribution by functional class. Would not be substantially more difficult to calculate than LOS (use same basic information).
KEY POLICY QUESTIONS:	
• Value as "Triggering Mechanism"	Is a key component measure for air quality and system performance, but not particularly meaningful as a trigger mechanism.
• Local Accountability for Land Use	Land use dispersal can lead to increases in VMT, so it helps as a tracking measure. But there are better measures.
• Local Responsibility for Traffic	Fair measure of performance, good tracking measure: question meaning if cannot separate local from external traffic.

MEASURE: Person Throughput (P.T./Hr./Mile of Facility)

DEFINITION AND MEASUREMENT:	Measures efficiency of travel by showing how effectively an average mile of transportation facility capacity is in moving people. If the facility is either well-managed (TSM-type capacity enhancements) or carries a high percentage of transit/multi-occupant vehicle users, then throughput will be high. Throughput can be measured for just vehicles on a highway, or also for transit lines, or combinations.
CONCERNS ADDRESSED:	
• Congestion	Good measure of congestion. Reflects how many people the system is moving per unit of time, so higher values represent less congestion. Can overlook spot sources of congestion unless done on a link basis also.
• Air Quality	Fair to good measure for air quality; more throughput should mean higher speeds and greater use of efficient modes; but could also show positive under conditions of capacity expansions or land use shifts.
• Mobility	Fair measure for mobility; begins to reflect speed of travel to user.
• Multiple (non-SOV) Modes	Good measure for multimodal purposes; on densely used facilities, higher values indicate greater use of higher occupancy modes.
• Consistency with Regional Goals	Generally should be consistent with regional efficiency goals, may be in conflict with air quality goals under conditions of capacity expansion or land use dispersion.
ACCEPTANCE:	
• User Oriented	Has some value to users: while generally a system measure, higher values generally mean better transportation service.
• Understandable	Understanding is not intuitive.
• Objectivity	As long as measurement rules are firm, OK.
COST/OPERATIONAL DIFFICULTY:	Must measure with models, cannot do easily with manual methods and field data.
KEY POLICY QUESTIONS:	
• Value as "Triggering Mechanism"	Fair as a triggering mechanism; is a very effective efficiency measure.
• Local Accountability for Land Use	Can be an inconsistent measure on land use.
• Local Responsibility for Traffic	Fair to good measure on traffic; again, may conceal sub-optimal land use or highway capacity decisions.

MEASURE: Accessibility - % Employees with X Minutes

DEFINITION AND MEASUREMENT:	Measures accessibility of each employment area/activity center by measuring the % or number of employees (or population) within a specified travel time. Can be reversed to measure $ of jobs within x minutes of each residential area, or modified to address non-employment travel objectives.
CONCERNS ADDRESSED:	
• Congestion	Not a direct measure of congestion, but does reflect congestion to the extent that congestion reduces accessibility.
• Air Quality	Not a measure of air quality.
• Mobility	Measures not just the ease of travel, but also - and more important - the ease of achieving travel objectives.
• Multiple (non-SOV) Modes	Can be measured for each travel mode, so long as the requisite calculations are carried out.
• Consistency with Regional Goals	Should not run counter to regional goals.
ACCEPTANCE:	
• User Oriented	Clearly reflects situation improvements to the trip maker.
• Understandable	Relatively easy to understand, with proper explanation.
• Objectivity	As long as measurement rules are firm, OK.
COST/OPERATIONAL DIFFICULTY:	Requires network analysis programs and techniques to develop efficiently, but travel demand models are not needed. Manual computation is possible but inefficient.
KEY POLICY QUESTIONS:	
• Value as "Triggering Mechanism"	Useful in that it provides a direct measure of balanced land use benefits along with reflecting congestion impacts, both measurable at the local area. Must be evaluated relative to some standard.
• Local Accountability for Land Use	Directly measures the benefit of balanced land use at both the local and regional levels.
• Local Responsibility for Traffic	Indirectly reflects the impacts of congestion on local areas, but can't separate local contribution from external contributions.

MEASURE: Accessibility - % Employees with X Minutes

DEFINITION AND MEASUREMENT:	Measures accessibility of each employment area/activity center by measuring the % or number of employees (or population) within a specified travel time. Can be reversed to measure $ of jobs within x minutes of each residential area, or modified to address non-employment travel objectives.
CONCERNS ADDRESSED:	
• Congestion	Not a direct measure of congestion, but does reflect congestion to the extent that congestion reduces accessibility.
• Air Quality	Not a measure of air quality.
• Mobility	Measures not just the ease of travel, but also - and more important - the ease of achieving travel objectives.
• Multiple (non-SOV) Modes	Can be measured for each travel mode, so long as the requisite calculations are carried out.
• Consistency with Regional Goals	Should not run counter to regional goals.
ACCEPTANCE:	
• User Oriented	Clearly reflects situation improvements to the trip maker.
• Understandable	Relatively easy to understand, with proper explanation.
• Objectivity	As long as measurement rules are firm, OK.
COST/OPERATIONAL DIFFICULTY:	Requires network analysis programs and techniques to develop efficiently, but travel demand models are not needed. Manual computation is possible but inefficient.
KEY POLICY QUESTIONS:	
• Value as "Triggering Mechanism"	Useful in that it provides a direct measure of balanced land use benefits along with reflecting congestion impacts, both measurable at the local area. Must be evaluated relative to some standard.
• Local Accountability for Land Use	Directly measures the benefit of balanced land use at both the local and regional levels.
• Local Responsibility for Traffic	Indirectly reflects the impacts of congestion on local areas, but can't separate local contribution from external contributions.

MEASURE: Accessibility - % Employees with X Miles

DEFINITION AND MEASUREMENT:	Measures accessibility of each employment area/activity center by measuring the % or number of employees (or population) within a specified distance. Can be reversed/modified as described for the minutes-based accessibility measure.
CONCERNS ADDRESSED:	
• Congestion	Not a measure of congestion.
• Air Quality	Measures the potential for VMT savings afforded by reducing travel distances and vice-versa.
• Mobility	Measures the ease of achieving travel objectives, but only to the extent that speeds are uniform.
• Multiple (non-SOV) Modes	Measure is not mode-specific.
• Consistency with Regional Goals	Should not run counter to regional goals.
ACCEPTANCE:	
• User Oriented	Reflects benefit of having travel objectives close at hand.
• Understandable	Relatively easy to understand.
• Objectivity	As long as measurement rules are firm, OK.
COST/OPERATIONAL DIFFICULTY:	Can be measured manually, with GIS, or with a highway network analysis program used in combination with population and employment data.
KEY POLICY QUESTIONS:	
• Value as "Triggering Mechanism"	Useful as a relatively easy local area measure of balanced land use benefits, but does not address congestion.
• Local Accountability for Land Use	Measures the potential for VMT reduction as a benefit of balanced land use.
• Local Responsibility for Traffic	Not a measure of congestion.