CHAPTER 2—OBJECTIVES FOR MEASURING MOBILITY

Chapter Summary

The needs and audiences for mobility information are more varied and complicated in an era of flexible funding decisions and diverse transportation improvement programs. Many communities are linking transportation and land use decisions together in ways that change the techniques that are useful for measuring performance.

Implementation decisions and performance measures should be based on an assessment of these community goals. Communicating these ideas requires concepts and definitions that the public and technical experts understand. Toward this end, a definition of mobility is proposed that mirrors the public's perception and is consistent with the targets for most transportation improvement programs.

Mobility is the ability to reach a destination in a time and cost that are satisfactory.

An analysis of transportation system performance measurement needs conducted in the National Cooperative Highway Research Program (NCHRP) project *Quantifying Congestion* (*1*) recommended that travel time-based measures be used to estimate and present mobility and congestion information. The needs identified by a discussion of the uses and the audiences for congestion can best be satisfied by measures such as travel time, travel speed, travel rate, and travel delay. In most situations, the use and presentation of mobility information should also be in travel time-related quantities. This chapter begins from this point and re-examines some of the conclusions and definitions developed in *Quantifying Congestion* (*1*) in relation to the needs of the *Urban Mobility Report*.

2.1 Needs for Mobility Measures

While the needs for mobility information are clearly best satisfied by travel time measures, there is always the question of "where is the data?" *Quantifying Congestion* (*1*) separated the issue of which measures should be used from the data concerns. Travel time measures do not preclude the use of other data, procedures, surrogates, or models when appropriate. The key point was that the set of mobility measures that are used should satisfy the needs for the information and the presentation of that information to the range of audiences.

The decision process used by travelers to select trip modes and routes, and by the transportation or land use professional analyzing alternatives, is influenced by travel time, convenience, user cost, dependability, and access to alternative travel choices. Travel time is also used to justify capital and operating improvements.

A system of performance measurement techniques that use travel time-based measures to estimate the effect of improvements on person travel and freight movement offers a better chance of satisfying the full range of potential needs than conventional level-of-service (LOS)

measures (*2*). Technical procedures and data used to create the LOS measures can be adapted to produce time-based measures. The procedures were developed in a time when construction was typically the selected option, and operational improvements were done on a small scale and cost level. The more complicated situation that transportation professionals face in the 21st century means that new techniques and data are available, but the analysis needs are also broader and often cross traditional modal and funding category boundaries.

Exhibit 2-1 lists seven situations identified in *Quantifying Congestion* (*1*) that significantly influence the needs for mobility measurement: scope, location, mode, roadway type, time, planning context, and level of detail.

Exhibit 2-1. Variation in Mobility Measurement Needs.

GEOGRAPHIC SCOPE	Intersection/Interchange Facility Segment Route/Corridor Sector/Subregion Region State/Nation	LOCATION	CBD Core CBD Fringe Central City Suburbs Suburban Fringe Seasonal/Resort Stadium, Arena or Sports Complex
TRANSPORTATION MODE	Roadways HOV or Bus-Only Lanes HOT Lanes Managed Lanes Car Pools Buses Rail in Roadway or Median Exclusive Guideway Transit	ROADWAY TYPE	Freeways and Toll Roads Expressways and Super Arterials Principal Arterials Minor Arterials Collectors Local Streets
TIME OF DAY / DAY OF WEEK	Morning Peak Afternoon Peak Noon Peak Midday Evening Daily Average Weekday Average Special Events Holiday or Weekend	PLANNING CONTEXT	Existing Conditions Existing Demand/Modified Supply Future Demand/Existing Supply Future Year Conditions
		LEVEL OF DETAIL	Policy Planning Design Operations (Also see Uses, Users and Audiences)

HOV = High-occupancy Vehicle
HOT = High-occupancy Toll Lane
Source: Reference (*1*)

2.2 Uses and Audiences

The range of uses and potential audiences for mobility information is significant for their broad nature and their expansion in the last decade. The specifications of any particular application are dictated by the analytical needs and the presentation of information to the audiences.

The expansion of decision alternatives and public involvement in those decisions that has occurred over the last decade has placed greater and more complicated demands on mobility measurement. The conflict between more detailed analyses and ways to present information to non-technical audiences is one example of these demands. The expansion of computing power has made alternative analysis and future scenarios easier to test, but the direct travel time and speed information that should be the focus of informing the public is not always available.

Travel time and speed estimating procedures that produce information for technical uses and non-technical audiences are needed for situations like this, and are an important part of the mobility measurement process. The procedures include relatively simple calculations that use easily obtained data, procedures that can be used by agencies responsible for system operations, techniques that can use operations data to improve a wide range of other transportation analyses, and methods that work well with travel demand models.

Exhibit 2-2 shows how the three basic categories of analysis relate to the four most common types of analysis. It serves as a general guide for practitioners generating mobility information and for identifying the appropriate data collection and analysis strategies.

Exhibit 2-2. Applications of Mobility Analysis Methods.

Analysis Category	Type of Analysis Method			
	Point-Based Travel Time Analysis	**Direct Travel Time Measurement**	**Sampling Travel Time on Segments**	**Empirical Travel Time Estimation**
Function				
Policy Analysis				☆
Project Prioritization	T			☆
Planning or Alternative Analysis	T	T	☆	☆
Design	☆	☆	☆	
Operation		☆		
Analysis Period				
Existing Conditions	☆	☆	☆	T[1]
Future Conditions				
Short Range	☆	☆	☆	T[1]
Long Range	T			☆
Analysis Scope and Scale				
Intersections	☆	T		
Single Roadway	T	☆	T	
Corridor		☆	☆	T
Sub-area			☆	☆
Areawide			☆	☆

☆ Application in most analyses.
T Limited application.
[1] Particularly when needed as base condition for analysis of future conditions.
Source: NCHRP (*1*)

As a specific example, Exhibit 2-3 presents an overview of potential uses of performance measures. As shown, a variety of transportation applications can make use of performance measures, and significant overlap exists in the requirements of each application.

Exhibit 2-3. Potential Uses of Congestion Performance Measures.

Potential Uses of Performance Measures	Specific Applications	Requirements of Performance Measures
Roadway Operations—Real-time Applications	Incident Management	Current and expected traffic states due to traffic flow breakdowns (travel time based); throughput; diversion volumes
	Traveler Information/Diversion	
	Coordinated Freeway-Arterial Control	
	Weather Management	
	Special Event Management	
Roadway Operations—Operational Planning	Incident Management	Detail on detection, verification, on-scene, and response times
	Traveler Information/Diversion	Trip- and corridor-based performance Effects of information content and timeliness
	Coordinated Freeway-Arterial Control	Effects of improved ramp and signal timing plans
	Evaluations of Operational Improvements	Consistent before/after measurements (travel time performance)
	Safety Countermeasures	Consistent before/after measurements (crash histories and profiles)
Transportation Planning	Travel Demand Forecasting	Ability to identify and rank deficiencies; inputs to assignment process; volumes and speeds for calibration
	Demand Management	Trip- and corridor-based performance
	Air Quality Analysis	Inputs to emission models
	National Performance	Corridor-based and areawide performance
	Congestion Management	Trip- and corridor-based performance
	Truck Travel Estimation; Parking Utilization and Facility Planning; High-occupancy Vehicles, Paratransit, and Multimodal Demand Estimation; Congestion Pricing Policy	Trip- and corridor-based and areawide performance
	Freight and Intermodal Planning	Trip- and corridor-based performance
Transportation Programming	Investment Analysis; Programmatic Funding Levels	Corridor-based and areawide performance
Homeland Security	Evacuation Planning	Trip- and corridor-based performance
Transportation Research	Traffic Flow Model Development	Highly detailed (time/space) performance measures
Emergency Response	Route Planning	Trip- and corridor-based performance
Freight Carriers	Resource requirements	

Source: NCHRP (*3*)

The analysis categories in Exhibit 2-2 are described as:

- **Function**—For most types of general policy, programming, or planning purposes, estimating procedures provide useful results with a minimum of data collection. More specific design and operation concerns require more precision, and direct measures of travel time or travel speed are usually very desirable.

- **Analysis period**—Most techniques can produce useful information for existing conditions, but future conditions require some travel speed estimating procedures (e.g., empirical models or *Highway Capacity Manual* (*HCM*). Estimating procedures are also required for existing conditions where future scenarios will be analyzed. This approach provides uniformity of results, avoiding inconsistencies caused by different data collection/estimation procedures.

- **Analysis scope and scale**—*HCM* analysis procedures may continue to be used for most intersection analyses and possibly for short roadway segments. Direct travel time measures are more useful for analysis areas greater than short roadway segments. Some sampling process is useful to limit data collection requirements for large corridors, sub-areas, and regional analyses.

The broader range of uses and audiences for mobility information identified here does not mean every analytical procedure is worthless. Those procedures can be adapted to quantify the mobility of people and goods by incorporating vehicle occupancies, freight movement, and other factors. While there may be a wider range of improvement alternatives, the analyses are consistent with the goals of a transportation system—to get people and goods safely, quickly, and reliably to their destination.

Mobility can be estimated by analyses and measurement of speed and travel rates. Within this context, various transportation groups should re-examine current practices of developing mobility information and analyzing potential improvement projects or programs. The broader perspective suggests that traditional roadway operating analysis procedures be complemented by direct travel time measurements and assessments, especially in the future.

These needs indicate an evolutionary approach is required (*1*). Limited travel time studies in severely congested locations or corridors with significant multimodal characteristics may improve mobility estimates initially. With more extensive use of direct measurement to follow as funds are available, advanced technology systems are installed or mobility levels fall toward unacceptable levels. It is important to retain some historical database whenever possible to allow trend analyses to be developed. The limited initial travel time studies may provide the very useful function of calibrating national procedures with local travel time and speed information.

Direct collection of travel time and speed data is encouraged whenever possible to provide information for local studies, to provide a basis for trend monitoring, and to calibrate national averages to local freeway and street operation. Travel time and speed estimation

techniques may, however, be necessary where resource constraints exist or where future conditions are analyzed.

Exhibit 2-4 presents several principles that would help guide the development of mobility monitoring programs. The principles are applicable to both passenger and freight mobility monitoring. By applying the appropriate cost factors for passenger and freight travel, mobility impacts can be monetized.

Exhibit 2-4. Basic Principles for Roadway Mobility Monitoring.

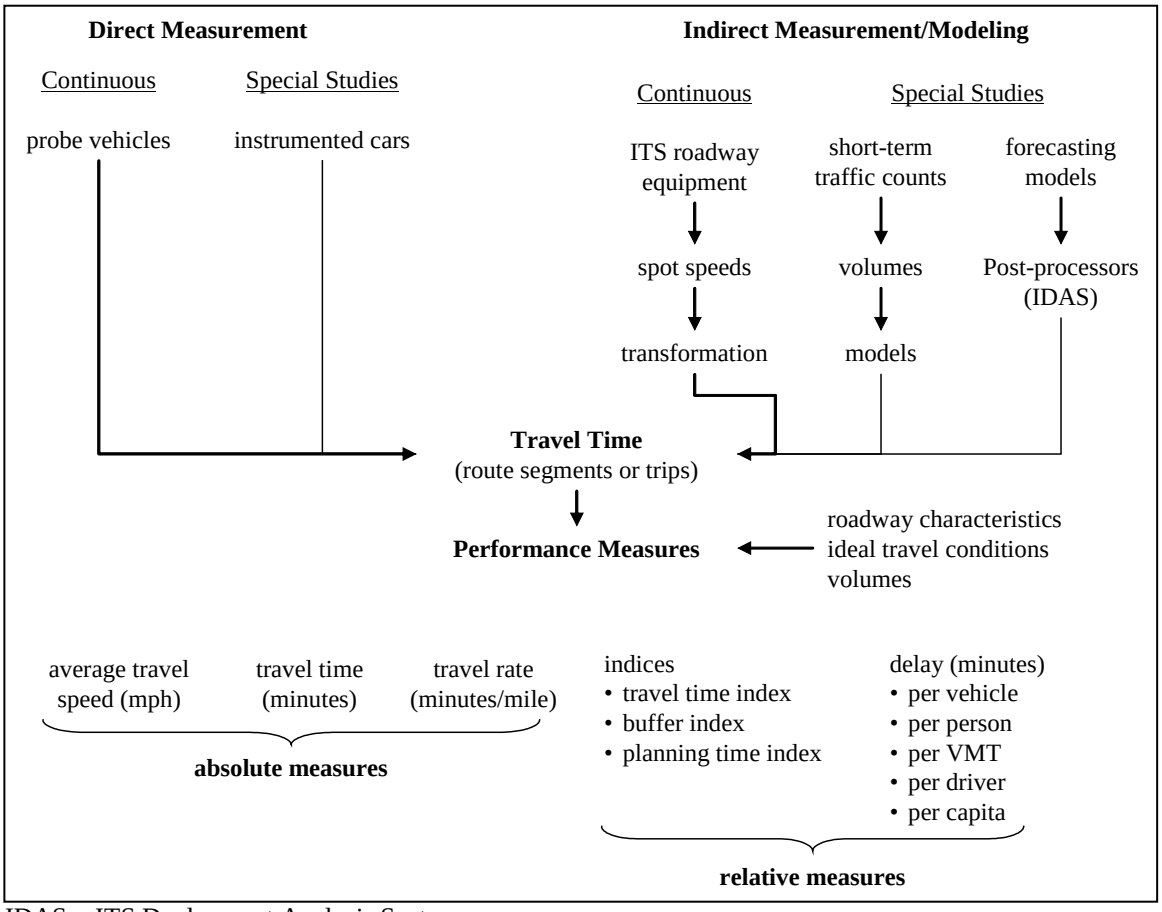
Principle 1	Mobility performance measures must be based on the measurement of travel time.
Principle 2	Multiple metrics should be used to report congestion performance.
Principle 3	Traditional HCM-based performance measures (Volume-to-Capacity Ratio [V/C] ratio and level of service) should not be ignored but should serve as supplementary, not primary, measures of performance in most cases.
Principle 4	Both vehicle-based and person-based performance measures are useful and should be developed, depending on the application. Person-based measures provide a "mode-neutral" way of comparing alternatives.
Principle 5	Both mobility (outcome) and efficiency (output) performance measures are required for congestion performance monitoring. Efficiency measures should be chosen so that improvements in their values can be linked to positive changes in mobility measures.
Principle 6	Customer satisfaction measures should be included with quantitative mobility measures for monitoring congestion "outcomes."
Principle 7	Three dimensions of congestion should be tracked with congestion-related performance measures: source of congestion, temporal aspects, and spatial detail.
Principle 8	The measurement of reliability is a key aspect of roadway performance measurement, and reliability metrics should be developed and applied. Use of continuous data is the best method for developing reliability metrics, but abbreviated methods should also be explored.
Principle 9	Communication of freeway performance measurement should be done with graphics that resonate with a variety of technical and nontechnical audiences.

Note: These principles relate to both passenger and freight mobility monitoring.
Source: NCHRP (*4*)

Foremost among these is the notion that ***congestion performance measures must be based on the measurement of travel time.*** Travel times are easily understood by practitioners and the public, and are applicable to both the user and facility perspectives of performance. Exhibit 2-5 shows how travel times can be developed from data, analytic methods, or a combination. Clearly, the best methods are based on direct measurement of travel times, either through probe vehicles or the more traditional "floating car" method. However, both of these have drawbacks: probe vehicles (e.g., toll tags and cellular telephones) currently are not widely deployed and the floating car method suffers from extremely small samples. Further, since many performance measures require traffic volumes as well, additional collection effort is required to develop the full suite of performance measures. Use of Intelligent Transportation System (ITS) roadway equipment addresses these issues, but this equipment does not measure travel time

directly; ITS spot speeds must be converted to travel times first. Other indirect methods of travel time estimation use traffic volumes as a basis, either those that are directly measured or developed with travel demand forecasting models.

Exhibit 2-5. Travel Time is the Basis for Defining Mobility-based Performance Measures.



IDAS = ITS Deployment Analysis System
Source: Turner et al. (*5*)

Exhibit 2-5 also shows how basic travel times can then be converted into a variety of performance measures using a few fundamental pieces of information about the environment where travel times were measured (roadway characteristics, "ideal" travel speeds, and traffic volumes). This implies that travel time-based performance measures are extremely similar in their basic nature, although some researchers have tended to exaggerate the differences. Travel time-based performance measures can be thought of as two types: 1) absolute measures and 2) relative measures. Relative measures require comparison to some base conditions, usually "free-flow" or posted speed limit conditions.

2.3 Defining Mobility

The challenge for transportation professionals is to develop a connection to the concepts people measure in their trip-making activity and derive measures that produce consistent evaluations. If the definition is flexible, mode neutral, and focused on providing a trip that meets the needs of the traveler, the discussion of whether improvements are needed and which to pursue can proceed on the merits of the project or program. While several precise definitions are useful, perhaps the following definitions meet a variety of needs.

- **Mobility is the ability to reach a destination in a time and cost that are satisfactory.**
- **Congestion is the inability to reach a destination in a satisfactory time due to slow travel speeds.**
- **Reliability is the level of consistency in transportation service (e.g., hour to hour and day to day).**

A definition of quick or cheap—presumably the desirable end of the mobility spectrum—would be relative to the expectations of the traveler for each trip. This has such considerations as:

- The speed of travel for a trip is not as important if the trip is short. Walking across the street to the sandwich shop does not have to be accomplished at 60 mph to satisfactorily achieve the travel objective.
- Paying a toll for a trip is not necessarily bad if the traveler believes the benefits outweigh the costs. If a toll brings travel conditions that are satisfactory and reliable, the desired mobility level can be achieved.
- The definition can be extended to travel by persons or freight using road, rail, air, water, or electronic forms of trip making.
- Mobility will be understood as good no matter which mode is used. Congestion will be defined as a characteristic that represents less than satisfactory service due to travel demand/supply imbalance.
- Measuring "satisfactory" will not be as easy as counting cars but will provide the profession with a better idea about the transportation goals of the public.

This definition of mobility may lack some precision in identifying the modes or travel patterns that are included, but it is simple and can be used with existing technologies and procedures. It can also be modified to describe individual pieces of the transportation system such as road mobility measures, transit system measures, or multimodal transportation mobility measures. And if transportation and planning agencies explore the input they receive from the public, a definition of "satisfactory" that is consistent with the opinions of their customers will become clear enough to be used for initial phases of project and program evaluation and prioritization. More specific determinations of public support will always occur as plans are updated or designs reviewed for specific projects.

2.4 References

1. *NCHRP Report 398*. Quantifying Congestion—Final Report and User's Guide. National Cooperative Highway Research Program Project 7-13, National Research Council, 1997.

2. *Highway Capacity Manual*. Transportation Research Board, National Research Council, 2000.

3. "Guide to Effective Freeway Performance Measurement." National Cooperative Highway Research Program Project 3-68, Amplified Work Plan, National Research Council, December 2003.

4. "Guide to Effective Freeway Performance Measurement (Version 1)," National Cooperative Highway Research Program Project 3-68, Interim Report, National Research Council, November 2004.

5. Turner, S.M., Margiotta, R., and Lomax, T. "Lessons Learned: Monitoring Highway Congestion and Reliability Using Archived Traffic Detector Data." U.S. Department of Transportation, Federal Highway Administration, September 2004.