

The Keys to Estimating Mobility in Urban Areas

Applying Definitions and Measures That Everyone Understands

A White Paper Prepared for the
Urban Transportation Performance Measure Study

by

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SUMMARY

MOBILITY MEASUREMENT CONSIDERATIONS

There are several keys to developing and applying mobility measures that are technically useful and generally understandable. Travel time measures are relatively easy to comprehend, but they have not always been used because of data concerns, mandated reporting practices, and other issues. Travel time and speed measures can serve many different uses, communicate to many different audiences, and enhance the ability of project analysis techniques to determine the most appropriate set of policies, programs, and projects for a situation. The important concepts identified in this paper are summarized below.

- Travel time and speed quantities are useful and understandable to a very broad audience and a wide range of uses. They also quantify the effect of the wide range of transportation improvements as well as the land use actions that are being pursued to improve mobility and provide travel and development choices in urban areas.
- Travel time and speed information do not have to be expensive or difficult to collect. There are a variety of automated data collection systems for roadway and transit systems that are being used to improve operations. Additional data collection can be concentrated on the locations with significant mobility problems. The remaining system can be sampled, and a range of analytical methods can be used to estimate travel time quantities.
- The process for selecting mobility measures should identify the decisions that will be made, the alternatives that will be studied, the audiences for the information, the accuracy level needed, and the data that are available or can be estimated. The goal of the mobility measure selection process is to select a set of measures that indicate progress toward the community's vision.
- Outcome measures such as "satisfaction of travelers and shippers with the trip time and cost" cannot be directly measured from system monitoring devices, but performance statistics can be calibrated to traveler satisfaction surveys. The system performance statistics can be updated much more frequently than surveys, in effect providing very useful user satisfaction information from the same data used to operate the system. Automated system monitoring processes provide a rich source of day to day performance information that cannot be replicated by user surveys.
- The concept of target travel conditions is the way to link the user satisfaction survey information with the system monitoring. A matrix of travel rates or travel times can be prepared to represent a community vision encompassing factors that can be seen as conflicting. Issues such as land use, economic development, mobility, environmental features, quality of life, and other concerns can be set against one another by interests opposed to any consensus. The process for getting to such a community consensus can begin with input obtained during long-range plan updates. The expectations for travel conditions vary depending on many factors (e.g., location within the urban

area, time of day) that can be included in the set of matrices. Planners, engineers, and other transportation professionals can then use the matrices to identify problem areas, systems, or time periods and prioritize actions to develop a set of projects, programs, and strategies that are targeted to achieving the community vision.

- There is a role for measures based on both free-flow conditions and “target” conditions. Free-flow conditions are good for comparisons in a national context. “Target” values for key performance measures can be used to identify trip patterns that take more time to complete or segments of the transportation system that are not providing the travel time and/or reliability that travelers expect, or the land use or environmental outcomes that neighborhoods desire.
- A complete set of mobility indicators includes an indicator of the variation in travel time. Reliability is a key component of user perception, and is especially important to freight movement and in just-in-time manufacturing processes.
- Travel Time Index, a ratio between the travel time in free-flow conditions or the posted speed limit and peak period conditions, can be used as a multimodal transportation system measure. It can be calculated for a range of area sizes, from individual facilities to corridors and regional systems. It can use information on travel time from continuous system monitors or from estimates developed from computer simulation models and empirical formulas.
- Travel delay and delay per capita are key components of any economic effect analysis. They are also easily communicated to non-technical audiences. They work best in roadway analyses but can be used in multimodal contexts.
- Evolution is the key to incorporating travel time and speed data into mobility measurements. The first steps may include direct travel time and speed measurement for important corridors, along with estimation procedures for the remainder of locations and modes. As more resources and more monitoring equipment become available, the direct data collection can be expanded. User satisfaction surveys can supplement travel speed information. This package of information can identify the threshold for target conditions, identify corridors that need improvement, and analyze alternatives.

The overriding conclusion from any investigation of mobility measures is that there is a range of uses and audiences. No single measure will satisfy all the needs, and no single measure can identify all aspects of mobility—there is no “silver bullet” measure. Mobility is complex and in many cases requires more than one measure, more than a single data source, and more than one analysis procedure. Mobility measures, when combined in a process to uncover the goals and objectives the public has for transportation systems, can provide a framework to analyze how well the land use and transportation systems serve the needs of travelers and businesses and provide the basis for improvement and financing decisions. Exhibit S-1 provides a quick reference to selected mobility measures discussed in more detail in this report.

Exhibit S-1. Quick Reference Guide to Selected Mobility Measures.

INDIVIDUAL MEASURES¹	
Delay per Traveler	$\frac{\text{Delay per Traveler (annual hours)}}{\text{Delay per Traveler (minutes)}} = \frac{\left(\frac{\text{Actual Travel Time} - \text{FFS or PSL Travel Time}}{\text{(minutes)}} \right) \times \text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicle)} \times \frac{250 \text{ weekdays}}{\text{year}} \times \frac{\text{hour}}{60 \text{ minutes}}}{\text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicle)}}$
Travel Time	$\text{Travel Time (person - minutes)} = \frac{\text{Actual Travel Rate (minutes per mile)} \times \text{Length (miles)} \times \text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicles)}}{\text{FFS or PSL Travel Rate (minutes per mile)}}$
Travel Time Index ²	$\text{Travel Time Index} = \frac{\text{Actual Travel Rate (minutes per mile)}}{\text{FFS or PSL Travel Rate (minutes per mile)}}$
Buffer Index ²	$\text{Buffer Index (\%)} = \left[\frac{\text{95th Percentile Travel Time (minutes)} - \text{Average Travel Time (minutes)}}{\text{Average Travel Time (minutes)}} \right] \times 100\%$
Planning Time Index ²	$\text{Planning Time Index (no units)} = \frac{\text{95th Percentile Travel Time (minutes)}}{\text{FFS or PSL Travel Time (minutes)}}$
AREA MOBILITY MEASURES¹	
Total Delay	$\text{Total Segment Delay (person - minutes)} = \left[\frac{\text{Actual Travel Time} - \text{FFS or PSL Travel Time}}{\text{(minutes)}} \right] \times \text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicle)}$
Congested Travel	$\text{Congested Travel (vehicle - miles)} = \sum \left(\frac{\text{Congested Segment Length (miles)} \times \text{Vehicle Volume (vehicles)}}{\text{(miles)}} \right)$
Percent of Congested Travel	$\text{Percent of Congested Travel} = \left[\frac{\sum_{i=1}^m \left(\left(\frac{\text{Actual Travel Time}_i - \text{FFS or PSL Travel Time}_i}{\text{(minutes)}} \right) \times \left(\frac{\text{Vehicle Volume}_i \times \text{Vehicle Occupancy}_i}{\text{(vehicles)} \text{ (persons/vehicle)}} \right) \right)}{\sum_{i=1}^n \left(\frac{\text{Actual Travel Rate}_i \times \text{Length}_i \times \text{Vehicle Volume}_i \times \text{Vehicle Occupancy}_i}{\text{(minutes per mile)} \text{ (miles)} \text{ (vehicles)} \text{ (persons/vehicle)}} \right)} \right] \times 100$ <i>(Each congested segment / All segments)</i>
Congested Roadway	$\text{Congested Roadway (miles)} = \sum \text{Congested Segment Lengths (miles)}$
Accessibility	$\text{Accessibility (opportunities)} = \frac{\sum \text{Objective Fulfillment Opportunities (e.g., jobs), Where}}{\text{Travel Time} \leq \text{Target Travel Time}}$

¹“Individual” measures are those measures that relate best to the individual traveler, whereas the “area” mobility measures are more applicable beyond the individual (e.g., corridor, area, or region). Some individual measures are useful at the area level when weighted by PMT (Passenger Miles Traveled) or VMT (Vehicles Miles Traveled).

²Can be computed as a weighted average of all sections using VMT or PMT).

Note: FFS = Free-flow speed, PSL = Posted speed limit.

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This is the second report of a research study that builds on past urban congestion reports. The goals of this new study are to examine the issue of mobility measurement and the presentation of information to a wide range of audiences. This report identifies a number of key issues and provides guidance on the state of the practice. Additional information developed in the course of the study with the help of the Steering Committee will improve this information.

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Disclaimer

The contents of this report reflect the interpretation of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the sponsoring departments of transportation or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation. In addition, this report is not intended for construction, bidding, or permit purposes. David L. Schrank, William L. Eisele, and Timothy J. Lomax (PE #54597) prepared this research report.

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LIST OF ACRONYMS

ATR	Automatic Traffic Recorder
AVI	Automatic Vehicle Identification
BI	Buffer Index
CBD	Central Business District
D2D	Door-to-door
DVMT	Daily Vehicle Miles Traveled
FFS	Free-flow Speed
FHWA	Federal Highway Administration
HCM	<i>Highway Capacity Manual</i>
HERS-ST	Highway Economic Requirements System—State Version
HOT	High-occupancy Toll Lane
HOV	High-occupancy Vehicle
IDAS	ITS Deployment Analysis System
ITS	Intelligent Transportation System
LOS	Level-of-service
LRT	Light Rail Transit
MAG	Maricopa Association of Governments
MMP	Mobility Monitoring Program
NCHRP	National Cooperative Highway Research Program
ODOT	Oregon Department of Transportation
PMT	Passenger Miles Traveled
PSL	Posted Speed Limit
PTI	Planning Time Index
TMC	Traffic Management Center
TRI	Travel Rate Index
TTI	Travel Time Index or Texas Transportation Institute
V/C	Volume-to-Capacity Ratio
VMT	Vehicle Miles Traveled
vphpl	Vehicles per hour per lane
WIM	Weigh-in-motion

QUICK REFERENCE GUIDE

Note that while all chapters build upon one another, each chapter also can “stand alone” on the topic and is written as such. To this end, references are included at the end of each chapter.

INTRODUCTION—Chapter 1

Overview of decision process for travelers and goods movement; transportation agency concerns and mobility measure needs.

OBJECTIVES FOR MEASURING MOBILITY—Chapter 2

The needs, uses, and audiences for mobility; definitions of congestion and mobility.

THE PROCESS OF MEASURING MOBILITY—Chapter 3

Description of a complete process from vision and goal definition, through measure selection, data collection, and improvement analysis.

SELECTING MOBILITY MEASURES—Chapter 4

Several key criteria that can be used to identify the correct set of mobility measures; the role of data collection concerns in the selection process; aspects of congestion and mobility that should be measured.

RECOMMENDED MOBILITY MEASURES AND DATA ELEMENTS—Chapter 5

Description of mobility measures and situations for their use.

DATA COLLECTION AND DATABASES—Chapter 6

Description of typical database contents and data collection procedures.

ILLUSTRATION OF MOBILITY MEASUREMENT—Chapter 7

Describes state-of-the-art examples of communicating mobility results.

APPLICATION AND INTERPRETATION OF CONGESTION MEASURES—Chapter 8

Demonstration of practical applications and interpretation of congestion measures described in the report. Spreadsheet is available for download and use for subsequent analyses.