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16. Abstract  <p>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.</p> <p>The overriding conclusion from any investigation of mobility and reliability 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 or reliability – there is no “silver bullet” measure. The problems are complex and in many cases require more than one measure, more than a single data source and more than one analysis procedure. Mobility and reliability performance 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.</p>					
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**USING TRAVEL TIME MEASURES TO ESTIMATE MOBILITY  
AND RELIABILITY IN URBAN AREAS**

by

Timothy J. Lomax, P.E.  
Research Engineer  
Texas Transportation Institute

and

David L. Schrank  
Assistant Research Scientist  
Texas Transportation Institute

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TEXAS TRANSPORTATION INSTITUTE  
The Texas A&M University System  
College Station, TX 77843-3135



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## ACKNOWLEDGMENTS

This is one of a series of research reports that build on past urban congestion studies. 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 in measuring mobility and reliability. Additional information developed in the course of the study with the help of the steering committee will improve this information.

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## TABLE OF CONTENTS

LIST OF FIGURES .....	ix
LIST OF TABLES .....	x
CHAPTER 1 — INTRODUCTION .....	1
CHAPTER 2 — OBJECTIVES FOR MEASURING MOBILITY AND RELIABILITY .....	3
Chapter Summary .....	3
Needs for Mobility Measures.....	3
The Importance of Reliability Statistics .....	4
Uses and Audiences .....	5
Definitions.....	7
A Word about Acceptable and Unacceptable Conditions.....	11
Implications for Defining Mobility.....	11
General Recommendation.....	11
CHAPTER 3 — THE PROCESS .....	15
Chapter Summary .....	15
Identify the Vision and Goals .....	15
Identify the Uses and Audiences.....	16
Develop a Set of Mobility Measures .....	16
Compare Potential Projects, Programs and Policies to Measures.....	16
Collect or Estimate Data Elements .....	16
Identify Problem Areas .....	17
Test Solutions.....	17
Implementing Mobility Measures.....	17
CHAPTER 4 — SELECTING MOBILITY AND RELIABILITY MEASURES .....	19
Chapter Summary .....	19
Choosing the Right Mobility Measure.....	19
What is the Ideal Mobility Measurement Process?.....	21
The Data Collection Issue.....	22
Calculating Reliability Statistics.....	24
Aspects of Mobility.....	24
Summarizing the Aspects of Mobility .....	26
Reliability Measurement Techniques .....	27
Statistical Range Measures .....	27

CHAPTER 5 — RECOMMENDED MEASURES .....	33
Chapter Summary .....	33
Basic Data Items .....	33
Other Data Elements .....	36
Basic Measures .....	36
Incorporating Reliability Measures.....	45
CHAPTER 6 — APPLYING THE MEASURES .....	47
Chapter Summary .....	47
The Right Measure for the Analysis Area .....	47
The Right Measure for the Type of Analysis.....	48
Using Acceptable Travel Condition Information .....	49
A Corridor Application.....	50
Using the Travel Rate Index for Urban Area Comparisons.....	51
Mobility Measure Example.....	51
CHAPTER 7 — USING TRAVEL TIME MEASURES TO ESTIMATE MOBILITY AND RELIABILITY IN URBAN AREAS .....	59
Lincoln-Lancaster County MPO Overview .....	59
Hidalgo County MPO Overview .....	59
Findings Regarding Data Collection.....	60
Data Analysis and Database Issues.....	61
Measures .....	61
Computer Modeling.....	62
Presentation.....	62
Summary.....	63
CHAPTER 8 — CONCLUDING NOTES.....	65
REFERENCES .....	67



## LIST OF FIGURES

Figure		Page
1	Desirable Role of Data Collection Issues in Measuring Mobility .....	22
2	The Components of Congestion.....	26
3	The Components of Mobility.....	27
4	Morning Peak-Period Operating Characteristics .....	54

## LIST OF TABLES

Table		Page
1	Mobility Measurement Needs.....	4
2	Applications of Mobility Analysis Methods.....	6
3	Example of Acceptable Travel Rate Value Matrix.....	35
4	Recommended Mobility Measures for Analysis Levels.....	48
5	Recommended Mobility Measures for Various Types of Analyses.....	49
6	Quick Reference Guide to Mobility Measures .....	52
7	Comparison of Delay Rate and Travel Rate Index Measures for Freeflow and Acceptable Travel Conditions.....	55
8	Corridor Mobility Measurement Example Using Freeflow Travel Conditions – Peak-Period Operations .....	56
9	Corridor Mobility Measurement Example Using Acceptable Travel Conditions – Peak-Period Operations .....	57

## CHAPTER 1 — INTRODUCTION

The persons and freight that move on the nation's transportation system have several factors that determine the basic parameters of the trip—departure time, route, travel mode and cost.

Improvements in the transportation system show up in:

- faster travel—due to more travel options or better travel conditions on the same facilities or modes;
- more reliable transportation—crashes and vehicle breakdowns are quickly moved so that they do not affect the system for long periods;
- more travel options—in terms of mode, route, time and cost; and
- cheaper travel options—including the value of time, environmental impacts and other factors in addition to out-of-pocket expenditures.

The travelers and freight carriers that move on the network are concerned with a package of these attributes that most closely optimizes their desires. Arriving at a destination on time and at a minimum cost can be thought of as a fairly typical goal; the choices made from that goal statement, however, are widely disparate. They are related to personal tastes, cost of the trip, trip purpose, mode availability and trip time.

Decisions that transportation agencies make about which projects and programs to select are also concerned with environmental impacts, quality of life in affected neighborhoods, safety, equity and a variety of other factors. The agencies must analyze the range of options and decisions and attempt to optimize the expenditure of limited transport funds to improve the system.

Developing a measure that relates all the traveler factors to the range of impacts and concerns that will govern urban decision-making, then, is not a narrow issue. This report is a step toward identifying the key concerns and charting a path that allows travelers, citizens and businesses to provide comments to professionals in ways that all groups can understand. The agencies, in turn, will get the benefit of guidance to improve the urban area transportation system or identify the key factors that make improvement an undesirable option for a particular portion of the system or specific policy or strategy.

Each chapter identifies research and practices that meet the needs of modal and multimodal analyses with travel time and speed-based measures. The paper emphasizes measures that can be presented and used by both technical and public audiences. Where compromises have been made for simplicity or data collection concerns, the ultimate measures or procedures are identified so that users can understand the path to the future as new models, procedures or technologies are developed. A brief discussion of some travel time data and analysis method applications is also included in this report.



## CHAPTER 2 — OBJECTIVES FOR MEASURING MOBILITY AND RELIABILITY

### 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 new definition of mobility is proposed—one 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 is satisfactory.

An analysis of transportation system performance measurement needs conducted in the National Cooperative Highway Research Program project “Quantifying Congestion” (*I*) 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 reexamines some of the conclusions and definitions developed in “Quantifying Congestion” (*I*) in relation to the needs of the urban mobility study.

### 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 are the data?” “Quantifying Congestion” (*I*) 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. The procedures used in these evaluations consider travel time, among other factors. 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) (2) measures. 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 late 21<sup>st</sup> 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.

Table 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.

**Table 1. Mobility Measurement Needs.**

GEOGRAPHIC SCOPE	}	Intersection/Interchange Facility Segment Route/Corridor Sector/Subregion Region State/Nation	LOCATION	}	Central Business District (CBD) Core CBD Fringe Central City Suburbs Suburban Fringe Seasonal/Resort Stadium, Arena or Sports Complex
TRANSPORTATION MODE		Roadways High-Occupancy Vehicle (HOV) or Bus-Only Lanes Carpools 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 Users and Uses)

Source: Reference (1)

## THE IMPORTANCE OF RELIABILITY STATISTICS

Many cities are coming to the realization that the peak hour or two during each commuting period will be congested for the foreseeable future. In addition to developing programs and projects to reduce the growth of congestion and provide mobility options, transportation agencies are concerned with improving the reliability of the transportation system. The increase in just-in-time (JIT) manufacturing processes has made a reliable travel time almost more important than a delay-free travel time for some segments of the US economy. JIT relies on the

transportation system to take advantage of low-cost labor and manufacturing plant development costs. Producing components in several manufacturing plants and bringing them together in one location at the same time to produce the final product can reduce total costs but requires a controlled environment of travel time and inventory control. If one component does not arrive due to improper product scheduling or due to traffic delays, an assembly line can be shut down, or costly building space has to be used for inventory storage rather than for manufacturing or assembly operations.

The importance of the reliability issue might also be illustrated in the way urban residents react to congestion. Travelers adjust their trip patterns and expectations to accommodate the usual levels of congestion. The places most likely to view mobility as the most important public policy concern are cities where congestion has rapidly increased over a few years. This is common to rapidly growing areas regardless of the beginning size or congestion level. Travelers perceive congestion in relative ways, and the stress of uncertainty is part of the phenomenon.

## **USES AND AUDIENCES**

The range of uses and potential audiences for mobility information are significant for the 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 are not always available.

Travel time and speed estimating procedures that produce information for technical uses and non-technical audiences are needed for alternatives analysis 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.

[Table 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.

**Table 2. Applications of Mobility Analysis Methods.**

Analysis Category	Type of Analysis Method			
	Point-Based 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	—	T	—	—
Analysis Period				
Existing Conditions	★	★	★	T <sup>1</sup>
Future Conditions				
Short range	★	★	★	T <sup>1</sup>
Long range	T	—	—	—
Analysis Scope and Scale				
Intersections	★	T	—	—
Single Roadway	T	★	T	—
Corridor	—	★	★	T
Subarea	—	—	★	★
Area wide	—	—	★	★

★ Application in most analyses.

T Limited application.

<sup>1</sup> Particularly when needed as base condition for analysis of future conditions.

Source: Reference (1)

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]) (2). 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 larger than short roadway segments. Some sampling process is useful to limit data collection requirements for large corridors, subareas 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 reexamine current practices of developing mobility information and analyzing potential improvement projects or programs. The broader perspective suggests that traditional roadway operating analysis procedures be complimented by direct travel time measurements and assessments, especially in the future.

**These needs indicate an evolutionary approach is required (I).** 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.

Researchers encourage direct collection of travel time and speed data 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.

## DEFINITIONS

Mobility definitions and measures should rely on concepts that are understood by the intended audience. Travel time is widely understood and used by professionals and the general public for a variety of analyses from current trip plans to long-range land use and business planning. This section presents several overlapping definitions of commonly used terms and develops a single definition that meets a broad range of needs and can be used with a variety of uses and audiences. Such issues as the physical ability to travel or availability of travel options are also connected to the definition of mobility, but this report will not develop measures for those aspects.

### Previous Definitions of Terms—“Quantifying Congestion” (I)

Revisiting definitions that provide a very specific delineation of terms that relate to mobility provides some perspective of the difficulties that have been encountered in communicating with general audiences. “Quantifying Congestion” (I) presented several useful and tightly constructed definitions which, nevertheless, may not meet the needs for analytical and presentation purposes. The recommended definitions at the end of this section attempt to reduce the confusion.

- **Past Definition—Mobility** is the ability of people and goods to move quickly, easily and cheaply to where they are destined at a speed that represents freeflow or comparably high-quality conditions (I).

Mobility in this definition is the extent to which a traveler can move freely – in both cost and travel speed terms. This definition can be applied to all modes and to person and goods movement. It can indicate performance of the system or of system elements. It can indicate efficiency using per lane-mile, per ton-mile, per vehicle or per person values. A freeway or street corridor that includes HOV lanes, bus priority treatments or a rail transit line will move more persons than a corridor without these treatments and, hopefully, at a better speed, indicating a high level of mobility.

The problem with this definition is that some professionals have used the “high-speed” element as an argument that this term is biased for road construction projects and against transit, bicycle or pedestrian treatments or a variety of land use pattern options. When used in this context, mobility becomes a “bad thing,” or at least an issue to question. And yet the public generally understands mobility as a “good thing” to have.

- **Past Definition—Accessibility** is the achievement of travel objectives within time limits regarded as acceptable (1).

This definition illustrates the general objective of travelers—reaching the destination in a time that is “not too long”(3). The traveler’s interest in questions such as “how much time will it take?” and “when should I leave?” are reflected in this definition.

If door-to-door travel time is the measure, the accessibility of different modes or routes can be analyzed together, as long as it is recognized that acceptability varies by mode. In addition, this definition of accessibility recognizes that travel needs might be satisfied if the transportation system is improved, if land use patterns are adjusted or additional travel modes or options are made available to travelers. For example, job accessibility can be enhanced either by improving transportation to and from activity centers or by relocating worksites and residences. Accessibility can measure the improvements resulting from the broad spectrum of urban initiatives on transportation and land use issues. It can also be used in relatively narrow, roadway-only analyses to identify the impact of improvements on the “market area” of travelers.

The significant problem is that the public does not readily understand the term “accessibility” as something that interests them. The measures that illustrate accessibility are relatively complicated and are more readily applicable to regional analyses than to corridors or individual bus routes or streets. The concept, however, is very valuable.

- **Past Definition—Congestion** is travel time or delay in excess of that normally incurred under light or freeflow travel conditions (1).
- **Past Definition—Unacceptable congestion** is travel time or delay in excess of an agreed-upon norm. The agreed-upon norm may vary by type of transportation facility, travel mode, geographic location and time of day (1).

The congestion definition does not attempt to define how much time delay is tolerable, since that varies in many ways. The definition relates to traveler expectations in that it uses travel time concepts as the basis for the definition. Traffic volumes, levels-of-service and ease of travel are

useful concepts and relate to travel time, but they are components, not the basis for how the public understands congestion. Travel time and speed are directly related to congestion.

The definition of unacceptable congestion was added by “Quantifying Congestion” (1) in recognition of the fact that travel times and speeds that are acceptable to travelers in one area or for one time period are unacceptable at other times, places or cities. Resolving the problem with the term congestion by developing a second definition, however, does not necessarily resolve the communication problem.

The public uses definitions of congestion that are close to both of these terms depending on the context. They recognize that auto trips in the peak hour in large cities are likely to encounter speeds that are slower than in the midday or evening. When they speak of desirable trip characteristics, freeflow speeds are mentioned, but when improvement options are discussed, there is often a recognition that the projects or programs needed to achieve freeflow speeds are more significant than the cost and environmental impact they are willing to support.

These four definitions seem to leave the profession with concepts that are not well understood by the public. There is also a general lack of agreement within the profession about which term or concept represents the goals of transportation improvements. Part of this problem is the natural variation in focus that comes from different sizes and shapes of urban areas. There also appears, however, to be a need for definitions that the public readily understands and that do not carry value judgments as to the best alternative or mode.

### **Definitions of Reliability**

Reliability and variability in transportation are being discussed for a variety of reasons. The two terms are related, but different in their focus, how they are measured and how they are communicated.

- **Reliability** is commonly used in reference to the level of consistency in *transportation service*.
- **Variability** might be thought of as the amount of inconsistency in *operating conditions*.

These concepts are both useful, but the term reliability may have a more “marketable” connotation for measurement purposes because it relates to an “outcome” of transportation – the quality of the service provided. Variability might be defined as the amount of change in a phenomenon. The traveling public and a variety of companies or product sectors use the term reliability in their goal statements, and it would seem this is the term that should be used with a performance measure.

Measures can be developed to relate the reliability/variability concept to “average measures” of mobility, and to identify differences in performance by time-of-day, assessing the methods to measure reliability for long and short trips, different trip purposes, trip locations, etc.

## **What Are We Trying to Measure?**

It will also be important to recognize that part of what is illustrated by reliability measures is due to explainable and regular factors. Holidays are typically periods when travel conditions vary from the average, whether they are widely observed days such as Thanksgiving or government employee holidays where daily traffic volume may only decline by a few percent. Reliability statistics collected from real-time traffic data collection devices will include these events as changes relative to the average conditions. They might appear as part of an unreliable or unpredictable system, but travelers and shippers will understand and be able to predict their occurrence much better than days when delay increases due to crashes or vehicle breakdowns.

One key difference in the way some measures are constructed is whether the variation in individual traveler behavior is being studied, or whether the variation from day-to-day of the average of all travelers is being examined. The former seems to be more interesting to social scientists studying the interaction between the behavior of travelers and the freedom of decision-making as determined by physical and operational constraints. Travel speed variation is greater in the off-peak periods when travelers are better able to choose their own speed. The latter version of the measurement goal is more likely to be interesting to sets of travelers or those interested in the variation in service quality provided to the users.

Trip planning decisions can be informed by data that are targeted for the expected variation in travel time at the traveler's usual departure time. Measures that might be useful would typically focus on specific trip patterns or corridors and specific hours of the day—area wide or sub-regional measures grouped in long time blocks would be less useful for this purpose. System or corridor evaluations, however, might be best identified with hour-to-hour, day-to-day and annual trend information. These might be less trip-specific and more amenable to average area-wide statistics. The effect of incident management programs could also be tracked with these sorts of measures. A set of descriptive statistics such as crash rates would also be required to identify some of the reason for variation in annual or corridor measures.

A single value or concept cannot really describe the effect of crashes for all travelers. Trips that enter a freeway downstream of an area where crashes frequently happen may actually see improved travel times on incident days. The bottlenecks that are created by incidents have a metering effect on downstream traffic volumes and, depending on the corridor data limits, incident days may appear to perform better than average days. Sorting out the incident locations and the magnitude of the effects will require a level of detail and study beyond the scope of area-wide analyses. If incident records are sufficiently detailed and electronically recorded, there may be ways to automate much of the analysis. Until then, the measures, data requirements and public understanding can be tested.

## **A WORD ABOUT ACCEPTABLE AND UNACCEPTABLE CONDITIONS**

The description of “acceptable” can be derived from citizen input at various public meetings, long-range planning discussions and similar functions. The “acceptable” conditions can be useful for a variety of analyses and measures. Acceptable conditions can be used in conjunction with accessibility to analyze the system, program and strategy improvements that might be enacted by transport and planning agencies. Many urban areas are examining land use and transportation changes as a way to achieve long-term community goals. Mobility problems can be identified as areas or system parts that do not provide “acceptable” travel time. And congestion can be defined in relative terms that match the perception of residents and travelers, as well as being measured on an absolute scale that indicates the time lost relative to freeflow operations.

The term “agreed-upon norm” from the “Quantifying Congestion” (*I*) definition can reflect travel speed, travel time or delay over a broad range. In smaller cities, outer suburbs of large metropolitan areas and rural areas, the expectations are for travel close to the speed limit or for rides on buses without crowded conditions. The expectations are usually different in the center of large areas, even if the desired conditions are for freeflow travel. The “norm” should be derived taking into account the expectation for each portion of the transportation system as influenced by community input and technical considerations. Geographic location, time period, mode and facility type will affect expectations, objectives and the agreed-upon norm, and therefore, the amount of acceptable congestion or the level of unacceptable mobility.

## **IMPLICATIONS FOR DEFINING MOBILITY**

Where past definitions of mobility have an element of high-speed travel, accessibility has a focus on “acceptable” travel conditions. Does the public understand this difference in terminology? Probably not. Does the public need to have separate ideas of accessibility and mobility? For the sake of simplicity in focusing the public on the problems and solutions in transportation and land use, again, probably not.

## **GENERAL RECOMMENDATION**

The general public does not require or use as many distinctions about congestion and mobility issues as the transportation profession has developed. The profession has attempted to separate definitions of these concepts from the judgment of the quality of the trip. A technical definition might refer to congestion as a roadway measure defining how slow the traffic moves and mobility as high-speed travel. The public simply perceives congestion as bad and mobility as good. And accessibility is perceived as a very long word!

Perhaps the best approach is to develop one definition that represents the target for both transportation professionals and the public. An example of the misunderstanding between these groups is the “professional” definition of mobility as high-speed movement. Those favoring public transportation or bicycle/pedestrian improvements often cite this as a negative characteristic. The term “automobility” (meaning mobility by automobile) might describe this situation more closely. The public, however, thinks of mobility as a “good thing” with several aspects including freedom of movement, ability to travel and ability to pay for the trip.

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 at a cost that is satisfactory.**
- **Congestion is the inability to reach a destination in a satisfactory time due to slow travel speeds and/or long travel distances.**

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. The definition 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, 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 optimal service due to travel demand/supply imbalance.
- Measuring “satisfactory” will not be as easy as counting cars, but it 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.

## Sources of Travel Time Variability

Reliability of travel service quality (and the variation in travel time or speed) can be traced to several factors:

- variability in demand volumes from day to day (special events or normal temporal variation),
- variability in physical capacity due to work zones and other non-fixed physical features (e.g., pavement condition),
- variability in operational capacity due to incidents, and
- variability in operational capacity due to adverse weather effects on driver behavior.

Essentially the terms “recurring” and “nonrecurring” congestion are misnomers; even without incidents or adverse weather, variability in traffic can cause some days to be congested and others to be uncongested. From a measurement perspective, it is important to capture not only the total variability and the total impact due to all of these factors – because that is what users experience – but also to account for the contribution of each of the factors to total variability in condition. Both total impact and the factors involved are important.

The solutions or remedial actions for various causes of reliability problems are different. A disaggregated description is useful to system operators who can target improvement strategies. For example:

- Weather-related traffic problems may be significant, but nothing can be done about the weather itself. The impacts of weather conditions, however, might be addressed by some strategies, and the need for them should be predictable within some range.
- The need for accident-related strategies is perhaps less predictable with regard to location, but knowing the impact and frequency of the problem will identify the level of commitment that might be reasonable.
- Construction and maintenance activity delay can be addressed in several stages of planning and implementation; data and measures about the effects can target high-priority corridors and trip patterns.

## Reliability Measure Overview

The choices for performance measures to indicate reliability in transportation service can be grouped into three broad categories. The differences are most apparent on the communication side of the issue, rather than the calculation end. Since the urban mobility study (4) and the mobility monitoring program (5) are most concerned with developing performance measures to improve the use and understanding of transportation statistics, the communication differences are highlighted.

- Statistical Range – This represents the most often theorized or conceptualized measures. It typically uses standard deviation statistics to present an estimate of the range of transportation conditions that might be experienced by travelers. The measures typically take the form of an average value plus or minus a value that encompasses the expectations for 68 percent to 95 percent of the trips (one or two standard deviations on each side of the mean). These usually appear as “variability” measures.
- Buffer Time Measures – These measures indicate the effect of irregular conditions in the form of the amount of extra time that must be allowed for travelers to achieve their destination in a high percentage of trips. The measures do not directly refer to the average trip time but could be presented as either a percentage of the average trip time or a value in minutes per mile or minutes of some typical or average trip. In practice, this might be thought of as “I need to allow enough time so that I am not late to work more than one day a month.” These measures usually illustrate “reliability.”
- Tardy Trip Indicators – These measures form answers the question “how often will a traveler be unacceptably late?” These measures also do not refer to the average travel time but use a threshold to identify an acceptable late arrival time. The time can be either a percentage of the trip time, an increased time in minutes above the average or some absolute value in minutes. These indicators usually measure “reliability.”
- Diagrams – While not a true performance measure, pictures of the reliability data can be even more effective than numbers in communicating to many audiences. The pictures may be for several of the measures in the other three categories, but they are worth noting separately.

Subsequent chapters discuss several measures for these broad concepts.



## CHAPTER 3 — THE PROCESS

### CHAPTER SUMMARY

Mobility measures and techniques for developing mobility information are parts of several processes and activities. The key steps in identifying the best mobility measure for any particular situation include the following:

- Identify the vision and goals.
- Identify the uses and audiences.
- Develop a set of mobility measures.
- Compare potential projects, programs and policies to the measures.
- Collect or estimate data elements.
- Identify problem areas.
- Test solutions.

Measuring mobility is a task performed in a variety of ways in several different types of analyses for many purposes. While the measures are often dictated by legislative or regulatory mandates, it is useful to view the selection of the measure or measures as an important task before the data are collected and the estimation or calculation procedures begin. This chapter identifies key elements necessary for a complete mobility analysis. As with any process, the continuous evaluation of the process will lead to improvement—it is important to compare the measures with the uses throughout the process and adjust the measures as necessary. It is also important to recognize that there are many processes that relate to mobility measurement. The steps outlined here are part of many of those processes.

### IDENTIFY THE VISION AND GOALS

The long-range transportation plan for an area ideally contains a description of the situation that the public wishes to create. As an important element of that plan, transportation facilities must be analyzed and improvements (if any) identified. In order for the selected programs and projects to move the area toward the vision, the measures must identify the proper type and scale of transportation improvements.

A similar line of thinking applies at the individual level (e.g., street, bus route, or demand management program). While the improvement options may not be as broad and the financial investment may not be as great, it is always instructive to think about possible outcomes before beginning the analysis. Not only will this ensure proper consideration of all options, but it will also lead to selection of measures that can fairly evaluate the range of alternatives.

It is this step where the expectations of the public and policy makers can be formulated into a set of statistics that can be used at the project or program evaluation level. The “agreed-upon

norms” (1) referred to in Chapter 2 can be used to make the link between broad outcome goals and the engineer, planner, economist, etc. who must evaluate the need for an improvement.

It is essential, therefore, that performance measures be consistent with the goals and objectives of the process in which they are being employed. Performance measures are key to controlling process outcome, whether the process is alternative selection, congestion management, growth management, or system optimization. For example, within congestion management, performance measures are used for problem identification and assessment, evaluation and comparison of alternative strategies, demonstration of effectiveness and ongoing system monitoring.

### **IDENTIFY THE USES AND AUDIENCES**

The analyses and potential targets of the measurement process must be determined before the proper mobility measures can be selected. The set of measures must be technically capable of illustrating the problems and the effect of the potential improvements. They must also be able to be composed into statistics that are useful for the variety of potential audiences. Increasing the flexibility of the measures may also improve the ability to use the information beyond the particular analysis. Corridor statistics may also satisfy annual reporting requirements, for example.

### **DEVELOP A SET OF MOBILITY MEASURES**

Many analyses, especially multimodal alternatives or regional summaries, require more than one measure to describe the problem. Analyses of corridor improvements might require travel time and speed measures to be expressed in person and freight movement terms. Some analyses are relatively simple, and it may be appropriate to use only one measure. Analyses of traffic signal timing where carpool and bus treatments are not part of the improvement options might not require person movement statistics—vehicle volume and delay information may be sufficient.

Poor selection of measures has a high probability of leading to poor outcomes (1). In contrast, goals and objectives that are measured appropriately can guide transportation professionals to the best project, program or strategy and can then check (using evaluation results) that the goals and objectives are best served by the solutions offered (6).

### **COMPARE POTENTIAL PROJECTS, PROGRAMS AND POLICIES TO MEASURES**

Before data collection begins, it is useful to revisit the selected measures and compare them to the possible improvements that may be evaluated and the uses and audiences. Will the measures illustrate the effect of the improvements? Are there aspects of the projects, programs or policies that will not be uncovered by the measures? Are the measures understandable to all the audiences? Are the uses of the measures appropriate, and will the procedures yield reliable information? These questions should be evaluated with prototype results of the analysis.

### **COLLECT OR ESTIMATE DATA ELEMENTS**

Data collection can proceed after an analysis of potential sources of information. The level of precision and statistical reliability must be consistent with the uses of the information and with

the data collection sources. Estimates or modeling processes may be appropriate additions to traffic count, travel time and speed data collection efforts. Statistical sampling procedures may be useful for wide-area analyses, as well as for validating models and adapting them to local conditions. Direct data collection may be used from a variety of sources including specific corridor studies, real-time data collection and annual surveys of travel time routes.

An area-wide travel monitoring program will consist of both travel speed data collection and estimated speed information obtained from equations or models. The directly collected data may be more expensive to obtain; statistical sampling techniques will decrease the cost and improve the reliability of the information. It may be possible to focus the data collection on a relatively small percentage of the roadway system that is responsible for a large percentage of the travel delay. Such a program would be supplemented with travel time studies on a few other sections of road and estimation procedures on the remainder of the system.

### **IDENTIFY PROBLEM AREAS**

The collected data and estimates can be used to develop measures that will illustrate the problem areas or situations. These should be compared to observations about the system to make a reasonableness check—the measures should identify well-known problem areas. The data will provide information about the relative size of the mobility problems so that an initial prioritization for treatment can be made.

### **TEST SOLUTIONS**

Testing the potential solutions against the mobility measures during the data collection process may improve the data collection effort and the ultimate results. After data collection and estimation is complete, testing the solutions for effect will be another chance to determine the need to modify mobility measures. Even after the analysis is complete, the measures should be evaluated before undertaking similar projects. Inconsistencies or irregularities in results are sometimes a signal that different procedures or data are required to produce the needed products.

### **IMPLEMENTING MOBILITY MEASURES**

The use of a set of mobility measures may mean more computer-based analyses, which might be perceived as a move away from direct measurement for some levels of analysis. This does not mean that travel time data will be less useful or less cost-effective to collect. On the contrary, direct measurement of travel time can be used to not only quantify existing conditions but also to calibrate wide-scale models of traffic and transportation system operation and to perform corridor and facility analyses. Incorporating the important process elements into a sequence of events leading up to a public discussion of alternative improvement plans might result in a series of steps like the following:

- Existing traffic and route condition data are collected directly.
- Measures are calculated.

- Results are compared to acceptable conditions that are determined from public comments during long-range plan discussion.
- Trip patterns, areas and modes that need improvement are identified.
- Solutions are proposed. Area-wide strategies should guide the selection of the type and magnitude of specific solutions.
- A range of the amount and type of improvements is tested.
- Mobility measures are estimated for each strategy or alternative.
- Measures are compared to corridor, subarea and regional goals.
- Individual mode or facility improvements that fit with the area-wide strategy are identified for possible inclusion in the plan, subject to financial analyses.

## CHAPTER 4 — SELECTING MOBILITY AND RELIABILITY MEASURES

### CHAPTER SUMMARY

The appropriate set of mobility measures will include several identifiable elements. This chapter identifies the important features as:

- relate to goals and objectives,
- clearly communicate results to audiences,
- include urban travel modes,
- are consistent and accurate,
- illustrate effect of improvements,
- apply to existing and future conditions,
- apply at several geographic levels,
- use person and goods movement terms, and
- use cost-effective methods to collect and estimate data.

The chapter also identifies the four aspects needed to identify mobility levels. Information about the time, location, level and reliability are needed to assess mobility for the range of analyses.

Given the wide range and diversity of available measures, it is important to have a clear basis for assessing and comparing mobility measures. Such an evaluation makes it possible to identify and separate measures that are useful for an analytical task from measures that are either less useful or inappropriate for certain analyses. It is important that every use of mobility measures be assessed in such a process. This chapter provides several considerations that can be used to identify the most appropriate mobility measure for a situation.

### CHOOSING THE RIGHT MOBILITY MEASURE

The ideal mobility measurement technique for any combination of uses and audiences will include the following features (*I*). These issues should be examined before data are collected and the analysis begins, but after the analyst has considered all reasonable responses to the problem or issue being studied. Having an idea of what the possible solutions are will produce a more appropriate set of measures.

- **Relate to goals and objectives**—The measures must indicate progress toward transportation and land use goals that the project or program attempts to satisfy. Measuring transportation and land use characteristics that are part of the desired future condition will provide a continual check on whether the area is moving toward the desired condition.

- **Clearly communicate results to audiences**—While the technical calculation of mobility information may require complicated computer models or estimation techniques, the resulting information should be in terms the audience can understand and find relevant.
- **Include urban travel modes**—Mobility is often a function of more than one travel mode or system. At least some of the measures should contain information that can be calculated for each element of the transportation system. The ability to analyze the system, as well as individual elements, is useful in the selection of alternatives.
- **Are consistent and accurate**—Similar levels of mobility, as perceived by travelers, should have similar mobility measures. This is important for analytical precision and also to maintain the perception of relevancy with the audiences. There should also be consistency between levels of analysis detail; results from relatively simple procedures should be similar to those obtained from complex models. One method for ensuring this consistency is to use default factors for unknown data items. Another method is to frequently check expected results with field conditions after an improvement to ensure that simple procedures—those that use one to three input factors—produce reasonable values.
- **Illustrate effect of improvements**—The improvements that may be analyzed should be consistent with the measures that are used. In relatively small areas of analysis, in smaller urbanized areas or portions of urban areas without modal options, this may mean that vehicle-based performance measures are useful. Using a broader set of measures will, however, ensure that the analysis is transferable to other uses.
- **Apply to existing and future conditions**—Examining the need for improvements to current operations is a typical use of mobility measures that can be satisfied with data collection and analysis techniques. Most analyses require the ability to relate future conditions (e.g., design elements, demand level, operating systems) to mobility levels.
- **Apply at several geographic levels**—A set of mobility measures should include statistics that can illustrate conditions for a range of situations from individual travelers or locations to subregional and regional levels. Using quantities that can be aggregated and averaged is an important element of this criterion.
- **Use person and goods movement terms**—A set of measures should include factors with units relating to the movement of people and freight. In the simplest terms, this means using units such as persons and tons. More complex assessments of benefits will examine the different travel patterns of personal travel, freight shipping and the intermodal connections for each.
- **Use cost-effective methods to collect and/or estimate data**—Using readily available data or data collected for other purposes is a method of maximizing the usefulness of any data collection activities. Focusing direct data collection on

significant problem areas may also be a tactic to make efficient use of data collection funding. Models and data sampling procedures can also be used very effectively.

## **WHAT IS THE IDEAL MOBILITY MEASUREMENT PROCESS?**

The best method to gather mobility information and user satisfaction data may be a survey conducted at the end of each trip. The survey would allow the traveler to rate the quality of the trip, both overall and for each facility or modal portion of the trip. Cost, time, and travel options could all be part of the survey. This would provide the transportation and land use professionals with a database they could match to system monitoring databases to identify potential causes of good and bad responses during the trip.

Freight shippers and manufacturers could be similarly surveyed about their use of the transportation system and its effect on their operations. These impacts may be more varied and require different surveying mechanisms. Processes such as just-in-time manufacturing and package delivery services have much different needs from the transportation system than some traditional activities. Just-in-time manufacturing is a method of delivering components to an assembly point at the moment they are required, rather than having a large inventory of parts on hand at the factory. This has benefits in reduced warehouse space, reduced financial burden of inventory, and other efficiency impacts. This process, as it is with package delivery services, places great reliance on the transportation system to provide a reliable travel time. Longer travel times are an important issue, but the assembly process can be adjusted to accommodate them; it is more difficult or less efficient to accommodate variable travel times.

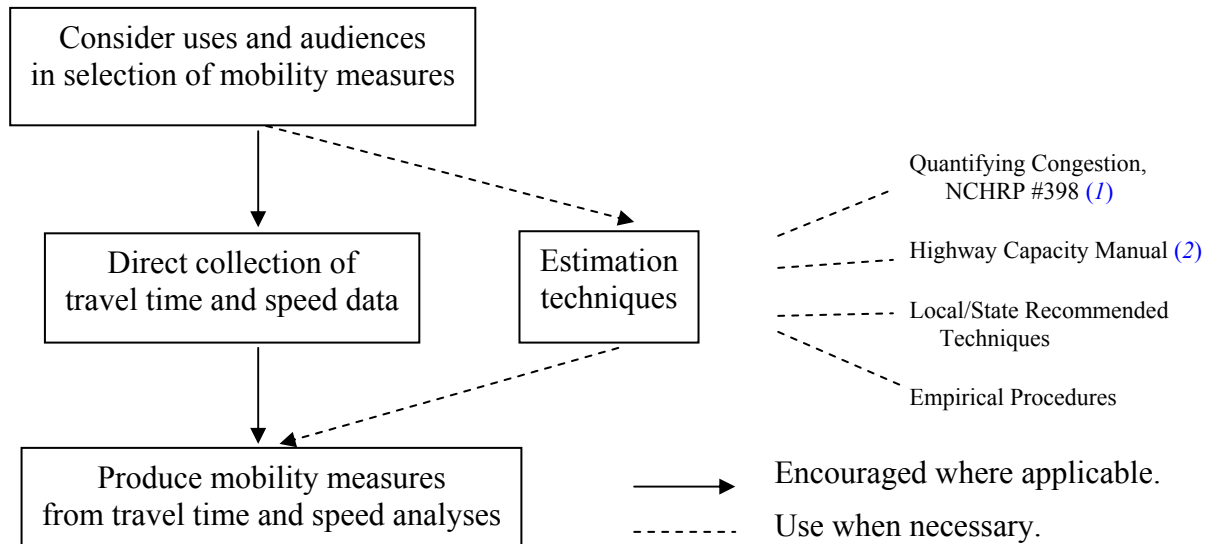
While surveys are certainly technologically possible now, and some are conducted, the amount of time needed to complete the survey could be longer than hurried travelers wish to take. If the method of obtaining the input and the time it would take could both be problems, does that make opinion gathering a bad idea? Not at all; the public—private citizens and businesses—pay for the transportation system and are the ultimate decision-makers about the worth of a project.

One significant problem, however, is that transport facilities exist in segments or corridors (even telecommunications move in corridors of cable or airwaves), and person trips (and electronic trips to some extent) are made from an origin to a destination. This requires measuring the performance of specific facilities or groups of facilities, in addition to the trip characteristics.

Focusing on individual facilities or modes, however, is not consistent with the manner in which most travelers make their choices. Door-to-door travel time is closer to the primary measure used by travelers and is best described with accessibility measures. Unfortunately, it is difficult to translate an accessibility measure like “population within 30 minutes travel time of a major activity center” into a procedure to evaluate signal improvements on an arterial street or alternative transit service option in a corridor. Accessibility measures do a very good job of explaining the differences in opportunities available to residents and travelers in areas of a city. The transportation and land use planning model required to calculate accessibility measures may not be sensitive enough to identify the improvement in travel conditions from relatively modest improvements. The planner and designer, likewise, need to communicate with the public and businesses who, while they are interested in the jobs and customers that may be within easy traveling distance, also wish to know how the travel time to their destinations will change.

## THE DATA COLLECTION ISSUE

Concerns about the cost and feasibility of collecting travel time data are frequently the first issue mentioned in discussions of mobility measures. **There are many ways to collect or estimate the travel time and speed quantities**; data collection should not be the determining factor about which measures are used. [Figure 1](#) makes the point that while the direct collection of data is the desirable method of obtaining travel speed information, the selection of the proper measures should be the first step. While it is not always possible to separate data collection issues from measure selection, this should be the goal.



Source: Reference (1)

**Figure 1. Desirable Role of Data Collection Issues in Measuring Mobility.**

Sampling procedures and estimation techniques can provide useful travel time information with limited data collection budgets. Advanced technologies already provide a significant improvement in travel time data, and the number of transportation analyses that use this real-time information is growing. As these systems are installed in cities, travel time information will be more available in at least some corridors. The inclusion of data issues in the Intelligent Transportation Systems (ITS) user services list will also make transportation professionals more aware of the range of travel time data sources.

Travel time and speed data can be collected on a sample set of roads, routes or modes in the analysis area. A strategic approach to sampling can be used—focus the travel time collection efforts on the problem or opportunity areas, and estimate travel conditions on the rest of the system with a combination of limited data collection and estimating procedures. Techniques such as this allow mobility assessment programs to be more effective and affordable, especially for annual monitoring purposes or for complex study areas. Specific procedures and recommendations for data collection are included in “Travel Time Data Collection Handbook,” an FHWA publication (FHWA PL-98-035) (7). The handbook can also be accessed on the



Internet at: [http://tti.tamu.edu/inside/hdv/ama/its\\_data/tt\\_book.stm](http://tti.tamu.edu/inside/hdv/ama/its_data/tt_book.stm) or from the Federal Highway Administration's Office of Highway Information Management.

The results of any estimate should be used with an allowance for the potential error that can be introduced when deriving such estimates. Travel time estimation procedures are most applicable for policy, programming or planning purposes—situations where the future is not known with precision but it is important to select between alternative actions. This selection process often calls for mixing direct data and estimates. In these cases, a separate estimate of the speed must be made for existing and future conditions. The future rate should be calculated using Eq. 1, which combines estimated travel rates for existing and future conditions with existing travel rates. This process reduces the error that would be induced by comparing actual rates to estimated rates—the difference may be related to the method used to obtain the estimate.

$$\text{Future travel rate} = \text{Existing travel rate} \times \frac{\text{Estimate of future conditions}}{\text{Estimate of existing conditions}} \quad (\text{Eq. 1})$$

Highway Capacity Manual (2) procedures are the basis for many national, state and local analytical processes. These count-based procedures are relatively detailed, with default factors provided when data are not available. The procedures and statistics have been developed for planning and operational analyses, and the products have not always been useful for communicating to audiences beyond transportation professionals. The HCM procedures have been developed from analysis of physical limitations of road systems at critical points. As such, the interaction between road sections that determines travel time along a congested road, as well as the spread of congested conditions beyond the peak hour, have not been a prominent aspect of HCM.

The incorporation of HCM procedures into computerized operations models has extended the usefulness of HCM to corridor and system analysis needs. Revisions to the basic products that are included in the improvements for the 2000 edition of the Highway Capacity Manual effort are also developing travel speed and delay estimates for all the key analytical procedures and encouraging computer models for corridor analyses. HCM-based procedures will always have a role in producing mobility measures, but the direct collection of travel time data can assist in calibrating computer models and estimation techniques.

Vehicle occupancy data may be important for some analyses where modal, ridesharing or other actions are being studied. The analysis may be able to use a set of regularly conducted studies in the urban area as a start for the analysis. Focused occupancy studies in locations where the average rate is likely to be different from the remainder of the urban area can be used to identify the effect of actions and assess locations where modal alternatives have been enacted. There may be many studies in an area where the use of general occupancy rates will be sufficient to adjust vehicle quantities to person values for economic analysis and presentation of results.

The key to developing good mobility measures is to recognize the interaction between elements of the transportation system. Changes in one mode, operating system/procedure or demand patterns can have effects that go beyond the original intent of the analysis. These potential effects should be considered in developing data collection plans.

## CALCULATING RELIABILITY STATISTICS

It is important to recognize that reliability measures are more widely discussed because there is access to much more detailed information from the point and segment detectors on many freeways and a few streets in the US. The travel speed and time information that is either obtained directly or estimated from such systems makes the variation in travel conditions much easier to study. All of the measurement concepts can be calculated or estimated in some way from the information that is collected by most traffic management centers. The mobility monitoring program research effort for FHWA focused on the freeway elements from 10 of these centers (5).

One decision that is required to operationalize some of these measures is to either decide on an average or representative trip length(s), or to develop statistics in length-neutral terms. The current presentation of average statistics using the travel time index (TTI) is a length-neutral measure, with an accompanying footnote that explains the relationship to trip travel time. Travel rate variation can be used as a length-neutral surrogate for trip time variation. Selecting a representative trip length might be more difficult and gives rise to concerns expressed in a form similar to “the average trip here is twice as long as that” which detracts from message clarity. Measures where trip time and length are integral, like accessibility measures, could continue to use variability statistics with units of minutes.

The time periods for analysis might also include several variations. Peak period might be most useful, but daily and peak-hour measures would present some interesting views, especially in corridors where congested time is expanding. Calculating the measures by direction would also give more detail into the causes and extent of the problems. Most archived databases can provide this disaggregated information with relatively little additional effort.

## ASPECTS OF MOBILITY

The proper set of mobility measures includes an assessment of what traveler concerns are characterized. This assessment can be drawn from experiences with measuring congestion in roadway systems. A set of four aspects of congestion was discussed at a Workshop on Urban Congestion Monitoring in May 1990 (8) as a way to begin formulating an overall congestion index. These four components provide a useful framework for mobility estimation procedures as well.

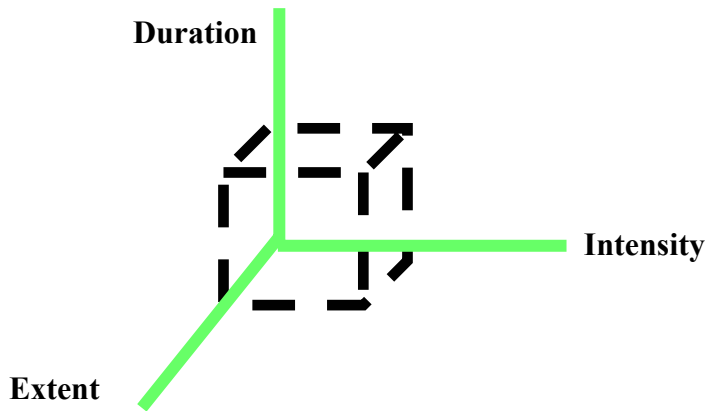
### Summarizing Congestion Effects Using Four General Components

While it is difficult to conceive of a single value that will describe all of the travelers’ concerns about congestion, there are four components that interact in a congested roadway or system (1,9). These components are duration, extent, intensity and variation. They vary among and within urban areas. Smaller urban areas, for example, usually have shorter duration than larger areas, but many have locations with relatively intense congestion.

The four components and measurement concepts that can be used to quantify them are discussed below. They use the definitions of congestion and mobility used in this report. Chapter 5 discusses the data elements and measures associated with each concept.

- **Duration**—This is defined as the length of time during which congestion affects the travel system. The peak hour has expanded to a peak period in many corridors, and mobility studies have expanded accordingly. The measurement concept that illustrates duration is the amount of time during the day that the travel speed indicates congested travel on a system element or the entire system. The travel speed might be obtained in several ways depending on data sources or travel mode being studied.
- **Extent**—This is described by estimating the number of people or vehicles affected by congestion and by the geographic distribution of congestion. Person congestion extent may be measured by person-miles of travel or person trips that occur during congested periods. The percent, route-miles or lane-miles of the transportation system affected by congestion may be used to measure the geographic extent of mobility problems.
- **Intensity**—The severity of congestion that affects travel is a measure from an individual traveler perspective. In concept, it is measured as the difference between the desired condition and the conditions being analyzed.
- **Variation**—This key mobility component describes the change in the other three elements. Recurring delay (the regular, daily delay that occurs due to high traffic volumes) is relatively stable. Delay that occurs due to accidents and vehicle breakdowns, however, is less easy to predict. The variation in travel time is a factor that conceptually can be measured as a standard deviation from the average travel time.

The relationship between the four components may be thought of as a three-dimensional box describing the magnitude of congestion. [Figure 2](#) illustrates three dimensions—duration, extent and intensity—of congestion. These present information about three separate issues: 1) how long is the system congested? 2) how much of the system is affected? and 3) how bad is the congestion problem? The variation in the size of the box from day to day is a measure of variability or reliability.



- † The volume of the box—Measure of the magnitude of congestion.
  - † Variation in volume of the box—Separate measure of congestion.
- Note: Smaller volume is “better.”

**Figure 2. The Components of Congestion.**

## SUMMARIZING THE ASPECTS OF MOBILITY

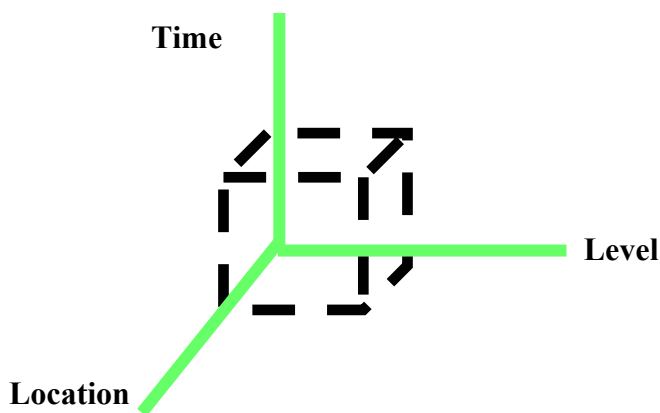
Developing a summary of mobility using concepts similar to those used for congestion will ensure that the appropriate measures are used. A similar typology uses different terms, a “positive” tone in the phrasing of the definitions and a slightly different orientation from congestion, but the aspects are basically the same. The image of a box is also appropriate to the description of the amount of mobility provided by a transportation and land use system.

- **Time**—The time that mobility is provided or available is an expression of the variation of mobility through the day, week or year. It can be a function of the existence of congestion or the presence of transit service, operational improvements or priority treatments. It can be measured as the times when travelers can get to their destinations in satisfactory travel times.
- **Location**—The places or trips for which mobility is available is an important aspect of measurement for transportation and land use analyses, as well as for other issues such as economic development and social equity. It can be described by accessibility maps and statistics and travel time contours that illustrate the areas that can be traveled to in a certain period of time. Descriptions of transit routes or special transportation services can also be used to identify locations where mobility is possible by more than private auto modes.
- **Level**—The amount of mobility provided is analogous to the intensity of congestion. The amount of time it takes to travel to a destination and whether this is satisfactory are the key elements of the level of mobility. It can be measured with travel rates or accessibility statistics.
- **Reliability**—The changing times, locations and levels of mobility are important characteristics for mobility measurement. This is particularly important to freight

movement operations that rely on the transportation system as an element of their productivity and to measuring the frustration level of travelers faced with an unexpected loss of mobility.

The total amount of mobility provided to travelers in an area is the volume of a box with axes of time, location and level. The reliability of the mobility provided to travelers and residents is the change in the volume of the box from time period to time period or from day to day. Figure 3 illustrates the description of mobility with the four aspects. These answer the key questions of travelers and residents: 1) when can I travel in a satisfactory time? 2) where can I travel in a satisfactory time? 3) how much time will it take? and 4) how much will my travel time vary from trip to trip?

Answering the key questions with measures of the four components of mobility will encompass the needs of residents and travelers as well as transportation and land use professionals.



- ⌈ Volume of the box—Amount of mobility provided.
  - ⌈ Change in volume of the box—Reliability of the mobility system.
- Note: Larger volume is “better.”

**Figure 3. The Components of Mobility.**

## **RELIABILITY MEASUREMENT TECHNIQUES**

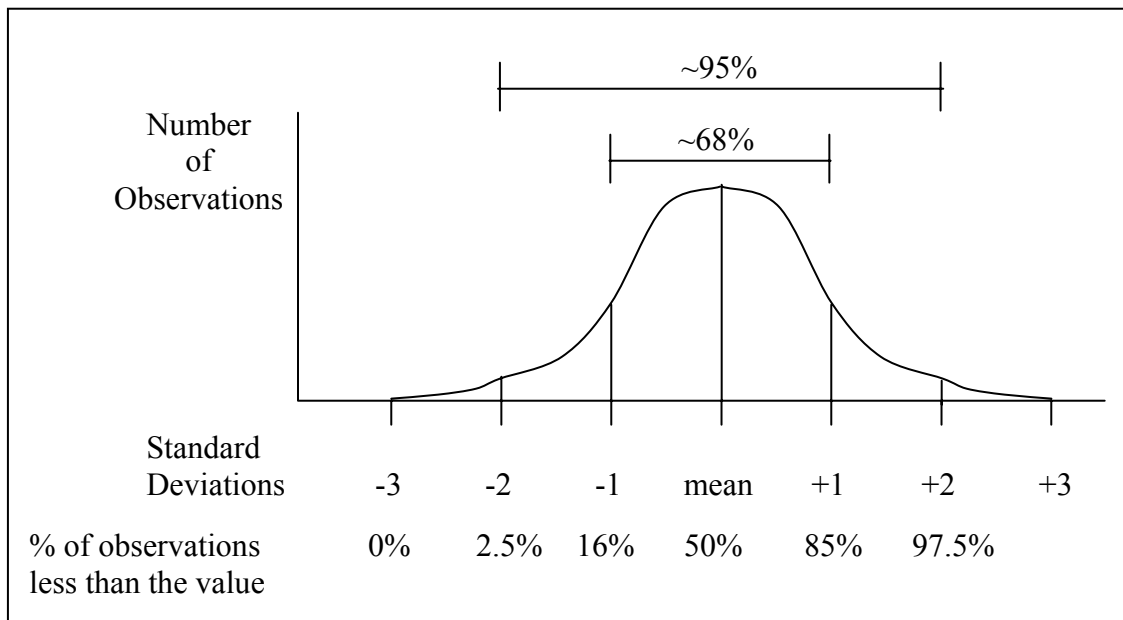
Drawing from research by the Texas Transportation Institute, Cambridge Systematics, Inc. and an excellent Master’s thesis by Dena Jackson (of Texas A&M University and the consulting firm of Reynolds, Smith and Hill in Florida) (10,11) the measure ideas represent those that are calculable or can be estimated for freeways from automatically collected data.

## **STATISTICAL RANGE MEASURES**

This type of measure is generally characterized by information presented in a relatively unprocessed format. The measures draw on concepts familiar to statisticians. They are not very complicated, but some are difficult to explain to non-statisticians. They can also be difficult to explain to individual travelers or to relate to trip decision-making.

A brief summary of the basics of a few statistical concepts is necessary to understand the measures. While these are not widely understood, and some of the subtleties are difficult to grasp, the ideas can be described so that non-technical audiences can relate to the measures. The standard deviation represents the amount of variation in the data. If the standard deviation is added to and subtracted from the average value, approximately 68 percent of the data values will be between those two values. (The 85th percentile used in setting speed limits is the value that contains all speeds below a value one standard deviation above the average). Two standard deviations above and below the average will encompass approximately 95 percent of the data.

The graph below shows these concepts using a “normal” (or balanced) distribution. Travel time distributions for a roadway, corridor or urban area are typically “log-normal”—the value does not go below zero and there is a longer tail to the right (high travel times). Most of the descriptions below assume a normal distribution for the ease of discussion. The differences will be somewhat important in preparing these measures if we decide to pursue them. For instance, the log of a value might be used in the calculation rather than the value itself. These do not affect the description of the measures or how they would be used.



*Travel Time Window* – The standard deviation of travel time or travel rate can be combined with the average for any of several measures to create a variation or reliability measure (*I*). This would take the form of a “plus or minus” type expression that would give the reader an idea of how much the travel time will vary (Eq. 2). Using one standard deviation will encompass 68 percent of the days, peak periods or whatever time period is chosen for analysis.

$$\text{Travel time window} = \text{Average travel time} \pm \text{standard deviation} \quad (\text{Eq. 2})$$

A multiplier can be applied to the standard deviation value to increase the number of trips described within the range of the interval. The concept of using the inter-quartile range (the difference between the 25<sup>th</sup> and 75<sup>th</sup> percentiles) might also be used in this measure.

This measure can be used for any mode of travel and can be used for a range of network sizes. Combining the different network portions or several modes is a process of weighting each segment by the number of users or the travel distance in person-miles.

*Percent Variation* – The average and standard deviation values can also be combined in a ratio form to produce a value the 1998 California Transportation Plan (10,12) calls percent variation (Eq. 3). This is a form of the statistical measure coefficient of variation. Analyzing travel time datasets using the coefficient of variation provides a clearer picture of the trends and performance characteristics than the standard deviation by itself.

$$\text{Percent variation} = \frac{\text{Standard deviation}}{\text{Average travel time}} \times 100\% \quad (\text{Eq. 3})$$

A factor of this type provides the ability to discuss the travel conditions of a variety of different trip lengths in a way similar to the travel rate index description of average travel conditions. The data can be presented for individual segments or corridors as well as for a combination of modes.

*Variability Index* – A view of the reliability issue that may have application beyond a single measure is illustrated in the variability index (10,13). The index is a ratio of peak to off-peak variation in travel conditions. The index is calculated as a ratio of the difference in the upper and lower 95 percent confidence intervals between the peak period and the off-peak period (Eq. 4). The interval differences (which represent two standard deviations above and below the average) in the peak are usually larger than in the off-peak, and the variability index value is therefore greater than 1.0.

$$\text{Variability index} = \frac{\text{Difference in peak - period confidence intervals (Upper 95 percent value - Lower 95 percent value)}}{\text{Difference in off - peak - period confidence intervals (Upper 95 percent value - Lower 95 percent value)}} \quad (\text{Eq. 4})$$

## Buffer Measures

The buffer time concept may relate particularly well to the way travelers make decisions. Conceptually, travel decisions proceed through questions such as, “how far is it?” “when do I need to arrive?” “how bad is the traffic?” “how much time do I need to allow?” “when should I leave?”. In the “time allowance” stage is an assessment of how much extra time has to be allowed for uncertainty in the travel conditions. This includes weather, incidents, construction zones, holiday or special event traffic or other disruptions or traffic irregularities. Comparing the real traffic conditions to those that occur on the average day or most frequently can relate the effect of uncertainty on decision-making.

*Buffer Time* – A measure that uses minutes of extra travel time needed to allow the traveler to arrive on time can be relatively easily calculated and give a good idea of the amount of uncertainty. The problem is defining an average trip that should be used as the base. Karl Wunderlich of Mitretek (14) is using a measure similar to this in evaluating the traveler information system in Washington DC with the HOWLATE computer simulation model and a network of trips.

A standard of “I can be late to work one day a month without getting into too much trouble” translates into using a 95<sup>th</sup> percentile level (one day out of 20 work days). The buffer time would be the difference between the average and the 95<sup>th</sup> percentile travel time as calculated from the annual average (Eq. 5).

$$\text{Buffer time (minutes)} = \text{95}^{\text{th}} \text{ percentile travel time for an average trip - (minutes)} - \text{Average travel time (minutes)} \quad (\text{Eq. 5})$$

*Buffer Time Index* – Using a percentage measure and the travel rate (rather than average travel time) can address the average trip concerns (Eq. 6). This can also be easily calculated with the real-time traffic monitoring data. The information would include an average of the segment-by-segment variation for a corridor, subarea or area of interest weighted by the amount of travel in each segment.

$$\text{Buffer time index (BTI)} = \frac{\text{95}^{\text{th}} \text{ percentile travel rate (minutes per mile)} - \text{Average travel rate (minutes per mile)}}{\text{Average travel rate (minutes per mile)}} \times 100\% \quad (\text{Eq. 6})$$

The measure would be explained as “a traveler should allow an extra BTI percent travel time due to variations in the amount of congestion delay on that trip.” The measure can be calculated from the real-time datasets either using roadway links combined into corridors or just the individual links.

### **Tardy Trip Indicators**

Where buffer time measures look at the trip time effects of unreliable system performance, another set of measures can represent the impact in the amount of late trips. If travelers only use the average trip time for their travel plans, they will be late to half their destinations and early to half (in round numbers). Prudent travelers allow for some time in addition to the average travel time because conditions fluctuate. If a value in minutes or percentage is chosen to represent some unacceptably late arrival interval, the data can be analyzed for the amount or percentage of trips that would be too slow relative to those expectations. A few methods to choose the interval are described in the following measures.

*Florida Reliability Method* – The Florida measure uses the standard deviation of travel time in the off-peak to estimate the limit of the expected travel time range (Eq. 7) (10,11,15). Travel times longer than the expected time would be termed “unreliable.” One adjustment that might be made for use with real-time monitoring systems is to use travel rate rather than travel time (Eq. 8). This would prevent trips that had long trip times from being graded unreliable, regardless of system condition. Using travel rate variations provides a length-neutral way of grading the system performance.



$$\text{Florida reliability statistic (percent of unreliable trips)} = 100 \text{ percent} - (\text{percent of trips with travel times greater than expected}) \quad (\text{Eq. 7})$$

$$= 100 \text{ percent} - (\text{percent of trips with travel times greater than the average for the time period plus the standard deviation for off - peak travel times}) \quad (\text{Eq. 8})$$

*On-Time Arrival* – A concept similar to the Florida method uses an acceptable “lateness threshold” of some percentage to indicate the percentage of trip travel times that can be termed reliable. This measure is used in a variety of travel modes and services and might be particularly useful in cross-modal comparisons. Estimating the trip characteristics would be difficult, but if the measure is simply calculated at the detector or segment level, the calculation should be relatively easy and the statistics interesting.

The urban mobility study report “The Keys to Estimating Mobility in Urban Areas” (15) suggested a threshold of 10 percent higher than the average travel time (or travel rate). This value has not been market-tested, but a 10 percent late arrival seems relatively conservative (Eq. 9).

Two concerns with the late arrival value are that 1) the value for acceptably late arrival may not vary linearly for all trips, and 2) it is not related only to trip duration. Being 10 percent late from a 16-hour overseas trip may not be as acceptable as being three minutes late for a 30-minute city trip. The amount of “acceptable lateness” is also a function of the previous activity and of the arriving activity. Being late may be more acceptable if the traveler is coming from an important activity, and it may be less acceptable if one is arriving at an important activity. Some testing of the acceptable lateness concept is certainly warranted, but the measure concept can be tested with an assumed value initially.

$$\begin{aligned} \text{On time arrival} &= 100 \text{ percent} - (\text{percent of travel rates greater than 110 percent of the average travel rate}) \\ &= 100 \text{ percent} - (\text{percent of daily peak-period travel rate averages that are greater than 110 percent of the average peak-period travel rate}) \end{aligned} \quad (\text{Eq. 9})$$

*Misery Index* – The negative aspect of trip reliability can be examined by the average number of minutes that the worst trips exceed the average (Eq. 10). This might be calculated by taking data from the worst 20 percent of the days and finding the average travel rate for just those trips. Comparing that to the average travel rate for all trips would give a measure of “how bad are the worst days?” The use of the 20 percent value might be explained as focusing on the worst day of the week.

$$\text{Misery index (MI)} = \frac{\text{Average of the travel rates for the longest 20 percent of the trips}}{\text{Average travel rate}} - \text{Average travel rate for all trips} \quad (\text{Eq. 10})$$



## CHAPTER 5 — RECOMMENDED MEASURES

### CHAPTER SUMMARY

Travel time and speed are key elements in assessing the performance of not only the transportation system, but of evaluating land use pattern changes as well. A wide range of mobility solutions is being pursued for a variety of reasons. This chapter describes the quantities and measures that illustrate the effect on travel time. It also identifies the data elements needed to estimate or calculate the measures. Key measures and data items include:

- travel time,
- travel rate,
- acceptable travel time or travel rate,
- accessibility measures,
- total delay, and
- travel rate index.

The calculation and use of each measure or data item is described; subsequent chapters illustrate the application of the measures.

Developing a system of mobility measures should be initiated only after an examination of the uses and audiences to be served, and after full consideration of program goals and objectives and the nature of likely solutions. This chapter illustrates a system of travel time-based measures to estimate mobility levels. These procedures are useful for roadway systems, other person and freight movement modes, and transportation improvement strategies and programs. Although a number of analyses may not benefit from a broad focus, the user should consider the way that measures might be used before selecting the appropriate set of mobility measures.

The following sections describe techniques for measuring mobility on various portions of a transportation network (*I*). Examples are used to illustrate the application of the basic measures to typical situations of system evaluation. Single mode and multimodal systems are integrated in the examples. Travel time, travel speed and delay measures should be the foundation for mobility measurement. Many of the definitions used in this chapter were included in “Quantifying Congestion” (*I*). The examples in this chapter are meant to emphasize the application of measures to multimodal mobility estimation, the basis for many of the conclusions in “Quantifying Congestion” (*I*).

### BASIC DATA ITEMS

This section describes the basic data elements used to define mobility measures. The units are noted for typical urban analyses.

**Travel time** (in minutes) is the time required to traverse a segment or complete a trip. Times may be measured directly using field studies or can be estimated using empirical relationships

with traffic volume and roadway characteristics, computer network models or the intended effects of improvements.

**Segment or trip length** (in miles) is the distance associated with the travel time. Length can be measured directly with a vehicle odometer or scaled from accurate maps but is typically an established item in a transit or roadway inventory database.

**Average speed** (in miles per hour) for a segment can be used to calculate travel rate or travel times if field data are not readily available.

**Actual travel rate** (in minutes per mile) is the rate at which a segment is traversed or a trip is completed (Eq. 11). Travel rates may be determined directly using travel time field studies, or can be estimated using transit schedules or empirical relationships between traffic volume and roadway characteristics.

$$\begin{aligned} \text{Travel rate} \\ (\text{minutes per mile}) &= \frac{\text{Travel time (minutes)}}{\text{Segment length (miles)}} \\ &= \frac{60}{\text{Average speed (mph)}} \end{aligned} \tag{Eq. 11}$$

**Person volume** is the number of people traversing the segment being studied. The person volume can be collected for each travel mode or estimated using average vehicle occupancy rates for types of vehicles.

**Freight volume** is the amount of goods moved on a transport segment or system. It can be measured in units of ton-miles, or it can be estimated from truck percentages. Freight volume may be particularly important in analyses dealing with travel time reliability due to the sensitive nature of “just-in-time” manufacturing processes and goods delivery services.

**Person-miles of travel** is the magnitude of travel on a section of the transportation system or on several elements of the system. It is a particularly useful measure in corridor and area-wide analyses where total travel demand is used in calculations. Eq. 12 indicates it is the product of distance and person volume. Person volume can also be estimated as the product of vehicle volume and average vehicle occupancy.

$$\text{Person-miles of travel (PMT)} = \text{Person volume} \times \text{distance (miles)} \tag{Eq. 12}$$

**Acceptable travel time** (in minutes) is the time that indicates a system or mode is operating according to locally determined performance goals. It focuses on the “door-to-door” trip time from origin to destination. The acceptable travel time can be differentiated by the purpose of the travel, the expectation for each mode within the transportation system and the time of day. It should be influenced by community input, particularly on the issue of the balance between transportation quality, economic activity, land use patterns and environmental issues.

**Acceptable travel rate** (in minutes per mile) is the maximum rate (slowest speed) at which a segment is traversed or a trip is completed without experiencing an unacceptable level of mobility. The acceptable travel rate should be based on factors that reflect the role and expectation of each portion of the transportation system, and should also be influenced by community input. As a minimum, the acceptable travel rates might include information such as included in [Table 3](#). This is similar to the process used by many states and cities where a target level-of-service is used to determine the need for additional transportation improvements.

**Table 3. Example of Acceptable Travel Rate Value Matrix.**

Area Type	PEAK PERIOD					
	Acceptable Travel Rates (minutes per mile)					
	Freeway Mainlane	Freeway HOV Lane	Major Street	Bus on Street	Rail in Street	Bike
Central Business District	1.7	1.0	5.0	7.0	6.0	6.0
Central City/ Major Activity Center	1.5	1.0	3.0	5.0	4.5	5.5
Suburban	1.33	1.0	2.4	4.0	4.0	5.0
Fringe	1.2	0.9	2.0	3.5	3.0	4.0

Area Type	OFF-PEAK PERIOD					
	Acceptable Travel Rates (minutes per mile)					
	Freeway Mainlane	Freeway HOV Lane	Major Street	Bus on Street	Rail in Street	Bike
Central Business District	1.5	0.9	3.0	5.0	4.5	5.0
Central City/ Major Activity Center	1.0	0.9	2.5	4.0	4.0	4.5
Suburban	1.0	0.9	2.0	3.5	3.5	4.0
Fringe	1.0	0.9	1.5	3.0	2.5	4.0

Source: Reference ([1](#))

*Note: These rates should reflect a consensus of input from technical and non-technical groups. An informational packet should include data on the relationship between economic development, environmental impact, land use and transportation system choices. It should also identify current operating conditions for facilities in each matrix cell, so that comparisons can be made.*

For both the peak and off-peak periods, the acceptable travel rates for several modes of travel are included. The area types are used to match the expectations of travelers with the environmental, social and economic concerns that might be exhibited in each area. The rates are for illustration only, and more area types and modes can be developed, but the table provides a view of the information needs.

In practice, there will also be a need for a corridor average value. This would be used as the target for facility, operating or program improvements. The facility/mode acceptable travel rates can be used for evaluation, but improvement strategies should be based on corridor-level decisions.

## **OTHER DATA ELEMENTS**

There are several other factors that may be needed to perform mobility analyses. This section describes some concepts that may be useful for mobility measure calculation.

**Hourly volumes**, expressed in vehicles or persons, may be very useful for the peak-period or 24-hour periods. Many roadway and transit analyses focus on the peak hour, but in most large cities this is not enough information to assess the mobility situation or to analyze alternatives. A range of improvements including demand management, advanced traveler information systems and high-occupancy vehicle lanes have an effect on other hours in the peak-period. Projects implemented in congested corridors often have no effect on peak-hour travel conditions, but they will affect travel speed in the hours before and after the peak hour. Hourly volumes can be obtained from recording traffic counters and from transit passenger load studies.

**Daily volume variation** is the variability in person or vehicle volume from day to day. These data are particularly important in analyses that examine mobility levels on particularly heavy volume days (e.g., Fridays, days before holidays) or days/time periods with different travel patterns (e.g., special events, weekends).

**Incident rate** is the number of accidents and vehicle breakdowns that occur on roadway segments and transit routes. This information is used in analyses of the variation in mobility level. Reliability of transport systems is a particular concern in analyses of incident management programs, value pricing projects and freight movement studies.

**Weather information** can explain a significant amount of the variation in travel conditions. Snow, ice, fog and rain can be noted in a database used for mobility analyses.

**Peak-direction hourly travel demand and volume** are two measures of person or vehicle travel used in system analyses. The two may be the same for uncongested corridors. Demand is higher than volume in congested corridors, however, and the “excess” volume travels on the main route in hours adjacent to the peak hour and on alternate routes. Improvements to primary routes or travel modes may result in higher traffic volumes in the peak hour that can be predicted if demand is estimated.

## **BASIC MEASURES**

Travel time, speed, and rate quantities are somewhat more difficult to collect and may require more effort than the traffic volume counts that currently provide the basis for most roadway analysis procedures. Travel speed-related measures can, however, be estimated as part of many analysis processes currently used. The ultimate implementation of a set of time-related mobility measures in most urban areas will probably rely on some estimating procedures. These measures may include current HCM-based analysis techniques, vehicle density measures taken from detectors in the pavement or from aerial surveys or relationships that estimate travel rate or speed

from generally available volume and roadway characteristics such as suggested in this report. The use of estimating procedures will be particularly important in setting policy and the prioritization of transportation improvement projects, pavement design, responding to developer requests for improvement and many other analyses.

This section describes the measurements that form the basis for the mobility analyses illustrated in subsequent sections of this report. The mobility aspects and geographic areas that can be analyzed with the measure are noted for each factor. This activity illustrates the flexibility of mobility measures. The application of the mobility measures will often satisfy two of the three “axis aspects” (level, location and time) in [Chapter 4](#).

**Accessibility** is the expression of the ability of travelers to reach the desired destination. It is typically calculated for individual locations as the number of travel objectives that can be reached within an acceptable travel time. One acceptable travel time is used for each type of objective (or travel purpose), mode of transportation and time of day. The acceptable time disregards distance and thereby ignores speed in much the same way that travelers use time and not speed to determine their trip decisions. Travel objectives can be represented by employment (jobs), housing, shopping, community services, or other destinations of interest. Percentages can be calculated by dividing accessible objectives by the corresponding total (e.g., percentage of total jobs). Weighted averages or the median value can be derived for a corridor or region. More complex formulations based on trip distribution model formulations are possible.

<p><b>Mobility Aspect</b>—Level, Location, Time</p> <p><b>Geographic Area</b>—Subarea, Region</p>
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Accessibility is most readily calculated using transportation planning computer networks and demographic data for a corridor or region ([Eq. 13](#)). It has been extensively used for assessing relative quality and equity in transit service, but it can be applied to any mode. The strongest feature of accessibility is that it is particularly useful in examining the impact of changes to the transportation network and land use patterns.

$$\text{Accessibility (opportunities)} = \frac{\sum \text{Objective fulfillment}}{\text{Opportunities (e.g., jobs), where Travel time} \leq \text{acceptable travel time}} \quad (\text{Eq. 13})$$

Accessibility is difficult to explain as a numerical quantity and is best illustrated using maps. The map can either be used to present existing conditions, future trends or the results of improvements to either transportation or land use systems. Improvements or alternative arrangements can also be examined by identifying the differences compared to existing conditions or the base case. The map can clearly identify the area affected and the magnitude of the effect of transportation or land use actions. Maps can be used to compliment other mobility statistics but are not typically used by themselves, no matter how persuasive the differences that are illustrated or strong the conclusions.

**Person-hours (or person-minutes) of travel** is a very effective measure of the effect of both transportation improvements and land use changes. While it is not an easily communicated value in the absence of some comparative information, as a trend measure, it can be very effective. This measure can identify the achievement of mobility goals by altering the transportation or land use systems. It can be used at a range of levels of analysis, and its use is similar to the use of travel delay. Shorter trips or better transportation system elements are depicted positively in this measure.

.....  
**Mobility Aspect**—Level  
**Geographic Area**—Section,  
 Corridor, Subarea, Region  
 .....

The **difference in travel time** (in minutes) can be used as a basic measure. It can be used to compare door-to-door travel times by different modes or a combination of modes. A common use of comparison by travelers is for determining mode or route choice, or time of departure. Acceptable travel time values can be combined with travel time statistics to evaluate alternative transportation and land use configurations. The mobility measures will evaluate both the transportation system and the arrangement of land uses. Travel time statistics are responsive to the trip length reduction that may occur when residential, commercial and office land uses are intermingled. Travel time is also useful in assessing the economic impact of mobility improvements.

.....  
**Mobility Aspect**—Level,  
 Location  
**Geographic Area**—Section  
 .....

**Travel rate** is the rate of motion (in minutes per mile) for a specified roadway segment or vehicle trip. It is a basic measure for many analyses as well as being a data item. It is the inverse of speed (multiplied by a conversion factor) and is calculated by dividing the segment travel time by the segment length. While this quantity is not readily understood by all the audiences for mobility measures, it is extremely useful for intermediate calculations and is more directly related to the quantity used by travelers in their trip planning (travel time) than the speed of the trip.

.....  
**Mobility Aspect**—Level,  
 Location, Time  
**Geographic Area**—Section,  
 Corridor  
 .....

This measure can be averaged for a facility, geographic area or mode, unlike travel speed, which is difficult to use directly in formulas and spreadsheets. The standard deviation can be calculated to obtain estimates of trip time reliability and can be compared to a target value representing an acceptable level of mobility. Ratios of travel rate values are also used in other mobility measures.

**Total delay** (in person- or vehicle-hours) for a transit or roadway segment is the sum of time lost due to congestion. Delay can be expressed as a value relative to freeflow travel or relative to acceptable or target conditions. Total delay in a corridor or an urban area is calculated as the sum of individual segment delays. This quantity is used as an estimate of the impact of improvements on transportation systems. The values can be used to illustrate the effect of major improvements to one portion of a corridor that affects several other elements of the corridor transportation system, either by improving travel rate or by drawing person travel away from portions of the system that do not perform well. The quantity is particularly useful in economic or benefit/cost analyses that use information about the magnitude of the mobility improvement for cost-effectiveness decisions.

.....  
**Mobility Aspect**—Level,  
 Location  
**Geographic Area**—Section,  
 Corridor, Subarea, Region  
 .....



$$\begin{aligned}
 \text{Total (person-hours)} &= \left[ \frac{\text{Actual travel time (minutes)} - \text{Acceptable travel time (minutes)}}{60 \text{ minutes}} \right] \\
 &\times \frac{\text{Person volume (persons)}}{60 \text{ minutes}} \times \text{hours} \\
 &\times \text{Delay rate} \times \text{person volume} \\
 &\times \text{segment length}
 \end{aligned}
 \tag{Eq. 14}$$

**Delay per person** (in daily person-minutes or annual person-hours) can be used to reduce the travel delay value to a figure that is more useful in communicating to non-technical audiences. It can normalize the impact of mobility projects that handle much higher demand than other alternatives. Delay for the primary route or road in these alternatives may be higher due to this higher volume, but this also indicates the need to examine the facilities or operations included in the “before “ case. To the extent possible, the initial analysis should include as much of the demand that might move to the improved facility, route or road.

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**Mobility Aspect**—Level,  
 Location  
**Geographic Area**—Subarea,  
 Region  
 .....

**The delay rate** (in minutes per mile) is the rate of time loss for vehicles operating in congested conditions on a roadway segment or during a trip (Eq. 15). It is calculated as the difference between the actual travel rate and the acceptable travel rate. The delay rate can also be calculated as the difference (in minutes) between the actual travel time and the acceptable travel time divided by the segment length (in miles). The quantity can be used to estimate the difference between system performance and the expectations for those system elements, which is the key to prioritizing alternative improvements.

.....  
**Mobility Aspect**—Level,  
 Location  
**Geographic Area**—Section,  
 Corridor  
 .....

$$\begin{aligned}
 \text{Delay rate (minutes per mile)} &= \frac{\text{Actual travel rate (minutes per mile)} - \text{Acceptable travel rate (minutes per mile)}}{\text{Trip or segment length (miles)}} \\
 &= \frac{\text{Acceptable travel time} - \text{Actual travel time}}{\text{Trip or segment length (miles)}}
 \end{aligned}
 \tag{Eq. 15}$$

**The corridor mobility index** is a measure of the mobility level provided by transportation facilities in a corridor in relation to a recognized operating standard. The measure is calculated as the product of passenger volume and average speed (in miles per hour) for a particular route, divided by the standard value (Eq. 16). In practice, this standard could be a freeway or street lane operating at peak efficiency with a typical urban vehicle occupancy rate. The measure combines two desirable

.....  
**Mobility Aspect**—Level,  
 Location  
**Geographic Area**—Corridor,  
 Subarea, Region  
 .....

transportation system attributes—speed of travel and the number of persons being moved. It is important to use speed in this measure because the index increases as either desirable quantity increases.

The corridor mobility index does not, however, directly address the reduction in travel time that might result from land use changes and should be used only as a transport system measure. The index does provide a relative value that can be used to compare alternative transportation improvements (e.g., high-occupancy vehicle treatments) to traditional improvements such as additional freeway lanes.

Calculating the optimum facility value is relatively simple. For instance, a freeway lane operating at high speed and volume might have a volume of 2,100 vehicles per hour at 50 mph. With an occupancy rate of 1.2 persons per vehicle the optimum facility value would be approximately 125,000. A similar value can be calculated for an arterial street lane using a capacity of between 1,600 and 1,800 vehicles per hour, 50 to 60 percent green time and operating speeds between 20 mph and 25 mph (e.g., a value of approximately 20,000 to 25,000).

Eq. 17 can be used for calculating the average person volume for a long corridor. Calculating the corridor mobility index (CMI) for a peak period requires the analyst to decide how many hours are used to calculate the optimum facility value (which is an hourly value). The orientation of the index is to compare to ideal speed and volume characteristics. If the roadway is not fully loaded for some portion of the peak period, however, a value less than the number of hours might be used so that an artificially low corridor value is not created (e.g., use 2.5 times the optimum facility value for a three-hour peak).

$$\text{Corridor mobility index} = \frac{\text{Person volume (persons)} \times \text{Average travel speed (mph)}}{\text{Normalizing value (e.g., 25,000 for streets or 125,000 for freeways)}} \quad (\text{Eq. 16})$$

$$\text{Person volume} = \frac{\text{Person-miles of travel}}{\text{Lane-miles of facility}} \quad (\text{Eq. 17})$$

The **travel rate index (TRI)** appears to fit the needs of agencies and travelers alike. Related measures, such as travel speed and delay, are common components of system comparisons, and travelers use expected travel time for a variety of decisions.

The TRI reflects travelers' perceptions of travel time on the roadway, transit facility or other transport network element. This comparison can be based on the travel time increase from either freeflow conditions or to the target (or acceptable) conditions. Thus, the same index could be applied to various system elements with different freeflow speeds. The travel rate measure appears to be an excellent candidate to serve as the basis for this calculation. Travel rate (in minutes per mile) is a direct indicator of the amount of travel time, which makes it relevant to travelers. The travel rate index in Eq. 18 compares measured travel rates to freeflow conditions.

Index values can be related to the general public as an indicator of the length of extra time spent in the transportation system.

$$\text{Travel rate index} = \frac{\left( \frac{\text{Freeway travel rate}}{\text{Freeway freeflow rate}} \times \frac{\text{Freeway peak-period}}{\text{Freeway VMT}} \right) + \left( \frac{\text{Principal arterial street travel rate}}{\text{Principal arterial street freeflow rate}} \times \frac{\text{Principal arterial street peak-period}}{\text{Principal arterial street VMT}} \right)}{\left( \frac{\text{Freeway peak-period}}{\text{Freeway VMT}} + \frac{\text{Principal arterial street peak-period}}{\text{Principal arterial street VMT}} \right)} \quad (\text{Eq. 18})$$

The measure can be averaged for streets, freeways, bus and carpool lanes, bus and rail transit, bicycle facilities and even sidewalks. All of these system elements have a freeflow travel rate and, when crowded, the travel rate increases. (Theoretically, the index could even be used to measure Internet service conditions). A corridor value can be developed using the number of persons using each facility or mode to calculate the weighted average of the conditions on adjacent streets, freeways, HOV lanes, bus routes and/or rail transit lines. The corridor values can be computed for hourly conditions and weighted by the number of travelers or vehicle-miles traveled (VMT) to estimate peak period or daily index values.

One difficulty with the index can be summarized as “we do not have a rateometer in our cars, we have a speedometer.” Travel rate is unfamiliar to the general public. It has an inverse relationship to speed, which can be confusing, but when the index is explained in a simple footnote indicating comparison to the travel time in freeflow conditions, the concept is not difficult to grasp. The public and businesses make mode, route and departure time decisions based on travel time concerns more than on a speed value; the travel rate is consistent with this decision-making approach.

The use of a continuous numerical scale will adjust a shortcoming in the level-of-service technique that uses letter grades. Letter grades are easy to communicate, but the calculation procedures can produce some discontinuities where the next letter grade is only 10 vehicles from the volume being used for analysis. This “jump” in grade produces somewhat artificial differences between alternatives; these might be remedied with a numerical scale.

The travel rate index measure can be applied to the measurement of more than one mode and can extend the “reach” of summary mobility statistics. Individual modes or routes can be evaluated, but it is particularly useful for corridor, subarea and regional analyses. The measure generally indicates the intensity of mobility problems, although there is also a duration component when the TRI is calculated for a consistent peak-period time. Larger TRI values are only possible for areas where mobility problems exist for more than one peak hour in the morning and evening. These attributes are similar to the roadway congestion index and other area-wide measures.

A system-based travel rate measure can also reflect the effect of new land use arrangements and increases in non-motorized travel modes. For most areas in the near term, including these “green” options will not have much effect on the area-wide index if the index uses the amount of

person travel as the method of averaging conditions across modes. The effect of new land use arrangements will not be noticed on an area-wide scale until the new approaches are a significant portion of the land use. The index may have its application in future analyses that illustrate the effect of different development strategies.

The peak period should be the basic period of analysis, but depending on the type of improvement alternative or issue being examined, the full day may also be an appropriate time period for analysis. Peak-hour information might be useful in relatively uncongested areas, but if slow speeds extend beyond one hour (or are projected to extend beyond an hour in the future), a longer time period is probably appropriate. In some cases daily traffic volume information might be used to estimate peak-period conditions. Expressing values in terms of daily averages should not, however, result in significant problems being obscured by freeflow travel over other portions of the day.

### **Freeflow or Acceptable Conditions?**

National or statewide comparisons of travel conditions will be the most frequent use of freeflow conditions as the “standard.” Analyses of system adequacy, the need for improvements or time-series analyses conducted in a corridor or area can benefit from comparisons using “acceptable” conditions.

Freeflow conditions will not be the goal of most large urban transportation improvement programs, but using them provides one consistent benchmark relevant for year-to-year and city-to-city comparisons. The “attainment of goals” standard might also be used at the national or state level but more often during a discussion of planning and project prioritization techniques.

The use of an “acceptable” or “target” travel rate can improve the guidance provided to system planners and engineers. If the target travel rates are a product of public discussion, they will illustrate the balance that the public wishes to have between road space, social effects, environmental impacts, economic issues and quality of life concerns. Areas or system elements where the performance is worse than the target can be the focus of more detailed study. A corridor analysis, for instance, might indicate a problem with one mode, but the solution may be to improve another mode or program that is a more cost-effective approach to raising the corridor value to the target.

Using target travel rates for local analyses provides the public input on priorities and concerns that might otherwise require extensive opinion surveys. The input is available to the agency staff level where projects and programs are developed, so alternative improvements can be quantitatively compared to the targeted conditions. The amount of corridor or area-wide person travel that occurs in conditions worse than the locally determined targets can be used to monitor progress toward transportation goals and identify problem areas.

The target travel condition (representing the compromise of financial, environmental, design, social or other concerns) can be incorporated in either of the following two ways. In each scenario, the area analyses would be performed using the person travel volume to weight each travel mode/facility condition in relation to the amount of travel on that system.

- **Scenario 1**—Adjust the travel rate index so that a value below 1.0 indicates the desirable conditions. The travel rate used in the bottom term of the calculation would not always be the freeflow travel rate and may represent different conditions for modes or facilities in the same corridor.
- **Scenario 2**—Develop the travel rate index with freeflow travel rates; use target TRI values in excess of 1.0 to indicate areas where less than freeflow travel rates are acceptable. The presentation of this method would be more complicated in that the targets would have to be communicated, but in doing so, the trade-off that results in less than freeflow travel speed as the acceptable condition are obvious to all viewers.

### **Relationship to Door-to-Door Travel Time Measures**

The measure of system performance that is closest to the concern of travelers is door-to-door travel time; for the travel rate index to be as useful as possible, it should relate to this measure as closely as possible. The method for this can be a periodic assessment of traveler satisfaction with the door-to-door travel time for corridors and the urban area. Calibrating the user view of system performance with measures that can be more readily collected from existing data sources is the key to the efficient and effective presentation of mobility information. Periodic updates of the surveys can be used to adjust corridor and area-wide presentations. Ten pairs of origin-destination trip patterns, for example, could be used to show the change in travel time. The information for these key travel patterns can be updated daily, monthly or annually with system-monitoring equipment. Every five years, the key patterns could be reexamined for relevance to the existing and future land use development patterns and transportation system.

Using acceptable, or target, conditions as the comparison standard provides the basis for a map or table showing system deficiencies in a way that is readily understood. A map showing the acceptable (or target) travel rates on the system links would accompany such a presentation. This approach could also be easily used in a multimodal analysis, with a target travel rate for the corridor. Future travel rates for the corridor can be changed by improving a facility or service, or by shifting travel to other modes/facilities. The “acceptable” comparison standard would be broader than simply a congestion or mobility measure since it would directly incorporate the idea that the goal for a corridor is not always high-speed travel. It could be used in conjunction with an area-wide planning effort to relate the link speeds used in estimating the travel rate index to the outcome measures of door-to-door trip satisfaction.

### **Impact on Data Collection**

One outcome of a move to the travel rate index would be the ability to include directly collected travel time data from the various transportation system elements. Many areas do not collect this information, but the initial statistics can be developed from estimates of travel speed. As travel time studies are conducted, however, the actual data can be used to replace the estimates in the index, as well as to improve the estimation processes. The information derived from systems that automatically collect and analyze travel speed over sections of freeways provide a significant resource for the travel rate index calculation. Current research may also develop a method for reliably estimating system travel time from detectors that obtain speed for only one point on the roadway (e.g., in-pavement detector loops).

## INCORPORATING RELIABILITY MEASURES

The variation in travel time as a key element of user perception of the system has been not been measured very frequently due to lack of useful and updated information. Incident delay has been discussed as a relatively significant portion of urban travel delay. Existing urban mobility study (4) procedures use an incident ratio to estimate the effect of incidents on travel delay. The information available to transportation system operators, however, will make this type of data more available in the future. The travel rate index can use this type of information with the addition of a plus/minus component, indicating the variation in peak-period travel conditions relative to the standard—whether that is freeflow or some target speed.

It seems appropriate to track several reliability performance measures. There is no single agreed-upon measure, and no customer/user market research has been performed. Even for these measures, it is not certain what level of reliability or variability (e.g., 85 percent, 90 percent, 95 percent) should be examined. The measures that look the most promising or may provide some good material for other analyses are:

- Percent variation – The amount of variation is expressed in relation to the average travel time in a percentage measure. The traveler would multiply the average travel time by the percent variation to get the time needed to be on-time 85 percent of the time (one standard deviation above the mean). Higher values indicate less reliability, and a percent value is distance/time neutral.
- Buffer time index – This measure was developed from the HOWLATE program – the amount of extra time needed to be on-time 90 percent or 95 percent of the time (late one or two days per month). Indexing the measure provides a time- and distance-neutral measure, but the actual minute values could be used by individual traveler or for particular trips.
- On-time arrival – This estimates the percentage of time that an on-time arrival is achieved based on some acceptable lateness threshold. A value in excess of the travel rate mean—possibly 10 percent or 15 percent—is used to identify the threshold, and the on-time arrival is the percent of trips that would arrive before that time (travel faster).
- Misery index – This measure seeks to measure the length of delay of only the worst trips. The average travel rate is subtracted from the upper 10 percent, 15 percent or 20 percent of travel rates to get the amount of time beyond the average for some amount of the slowest trips.

These measures, along with graphs and exhibits, should give us a good idea of the type of information that can be provided to the public and agencies to evaluate the reliability component of system performance. It is also appropriate to consider some common variations of the descriptions of each of the above measures. The issue of percentiles or confidence intervals will also be addressed as researchers develop the measures. Perhaps a mix will be useful, or possibly using only one approach is appropriate.

For national comparisons of examining system performance trends, a day-to-day comparison seems appropriate. Calculating the amount of variation in travel conditions from day to day is a very useful measure of system reliability that matches to several key traveler and shipper decisions. For local purposes, where individual trip planning is also an issue, it will be useful to also include reliability in travel conditions over time within an hour or for the peak period. Some measures will also be calculated with the variation in five-minute data across the locally defined peak period. This twin approach of both national and local focus is a strong point of the real-time data analysis process and strengthens the information provided to a wide range of customers without a large incremental effort beyond a “basic approach.”





## CHAPTER 6 — APPLYING THE MEASURES

### CHAPTER SUMMARY

Some mobility measures can be used for a variety of analyses, while others have limited application. This chapter summarizes several characteristics of mobility measures: 1) the areas that are best analyzed with the measure, 2) the mobility aspects that it describes and 3) the types of analytical needs that it may address. Data for a sample corridor are used to illustrate the use of the analysis of mobility measures. Acceptable travel condition information is used to show how to include concerns about community vision, quality of life and transportation improvement needs. The travel rate index is used as the summary measure of multimodal mobility.

In general, mobility measurement requires at least an intensity measure and a magnitude measure. For mobility levels to be completely described, some measurement of the four aspects of system monitoring must be present. Location, time, level and reliability are key concepts. This chapter shows which mobility measures to use for a range of analyses and presents a sample application for a multimodal corridor.

The increased emphasis placed on congestion and mobility at the local, state and national levels has changed mobility measures and the way they are applied. **It is important to recognize that past procedures may remain useful but may need to be modified.** They provide historic trend information for congestion or mobility levels and, with some minor modifications, may continue to serve transportation uses in the new era of measurement needs. But the decision information and process is often very different, and the measures used for public communications are also not the same.

### THE RIGHT MEASURE FOR THE ANALYSIS AREA

[Table 4](#) summarizes the mobility measures that should be used for several types of analysis and for different size areas or modal combinations (1,3). Individual traveler measures such as travel rate and the travel rate index are very useful for analysis up to the corridor level. At higher levels of analysis, magnitude statistics such as delay and accessibility are useful, but there is also a role for communication methods such as the travel rate index. The following sections include examples of the application of these measures to situations based on the level of analysis.

Most mobility studies should be conducted at geographic areas larger than individual locations and short sections of roadway. In relatively small areas, the studies will typically be limited to near-term analysis of operational improvements where new modes or facilities are not realistic options, and even the operational improvements will be limited. These analyses may proceed using Highway Capacity Manual-type procedures. Total delay, delay per person and travel time difference are most useful for intersections or individual locations due to problems identifying the length needed for the rate-based measures.

Larger scale analyses, where more detailed analytical tools are used and a wider choice of improvement options is considered, are more frequently identified as mobility studies. The analysis and presentation of mobility data can be accomplished by travel time, travel rate, index, total delay and accessibility as primary measures. Secondary measures may also be used for cumulative analyses of several improvements and estimation of benefits.

**Table 4. Recommended Mobility Measures for Analysis Levels.**

Analysis Area	Mobility Measures							
	Travel Time	Travel Time Difference	Travel Rate	Delay per Person	Total Delay	Corridor Mobility Index	Accessibility	Travel Rate Index
Individual locations	S	S		P	P			
Short roadway sections	P	P	P	P	P			P
Long roadway sections, transit routes or trips		S	S	P	P			P
Corridors			S	S	P	S	S	P
Subareas			S		P	S	P	P
Regional networks			S		P	S	P	P
Multimodal analyses		P	S	S	P	P	P	P

Note: P = Primary mobility measure

S = Secondary mobility measure

Note: Measures with delay components can be calculated in relation to freeflow conditions or a set of acceptable (or target) conditions.

Source: Adapted from References (1 and 3)

Mobility for larger areas of analysis, such as long roadway sections and corridors, can be quantified with some individual statistics if the roadways are of the same type, but if both freeways, streets and/or other travel modes are included, cumulative statistics and the travel rate index are very appropriate. Index statistics become useful at this higher level of analysis when multiple roadways and large numerical values make interpretation of relative conditions difficult.

### THE RIGHT MEASURE FOR THE TYPE OF ANALYSIS

The recommended uses in Table 5 are another illustration of how the mobility measures vary by the scope of the analysis, but not by mode or facility included in the analysis (1,3). Travel time and speed measures and the data and estimating techniques used to create them are very flexible analysis tools. When combined with person and freight movement quantities, they illustrate a range of mobility situations. Different values will be used for acceptable travel rate or acceptable travel time depending on the facility type or travel mode, but the calculation and application of the measures is identical.

While it is difficult to cover every type of mobility analysis, [Table 5](#) illustrates recommended measures for many common types of studies and information requirements. As with [Table 4](#), the analyses where small areas are analyzed or quick answers are needed use simple measures. More complex analyses, those that typically cover larger areas or multiple modes and those targeting non-technical audiences, use index measures and summary statistics.

**Table 5. Recommended Mobility Measures for Various Types of Analyses.**

Uses of Mobility Measures	Mobility Measures							
	Travel Time	Travel Time Difference	Travel Rate	Delay per Person	Total Delay	Corridor Mobility Index	Accessibility	Travel Rate Index
Basis for government investment or policies					P	S	P	P
Basis for national, state, regional policies and programs				S	P		P	P
Information for private sector decisions	P		P	S	S			P
Measures of land development impact	P	S	P	P	P		P	P
Input to zoning decisions	P	P	P				P	P
Inputs for transportation models	P		P					
Inputs for air quality and energy models	P		P	P				
Identification of problems	P	P	P	P	S			P
Base case (for comparison with improvement alternatives)		P		S	P	P	P	P
Measures of effectiveness for alternatives evaluation			P	P	P	P	P	P
Prioritization of improvements				P	P		S	P
Assessment of transit routing, scheduling, stop placement	P	P	P	P	S			P
Assessment of traffic controls, geometrics, regulations	P		P					
Basis for real-time route choice decisions	P	S	P	P				P

Note: P = Primary mobility measure  
S = Secondary mobility measure

Source: Adapted from Reference (1)

## USING ACCEPTABLE TRAVEL CONDITION INFORMATION

Chapters 2 and 5 introduced the concept of acceptable travel conditions and how they can provide the information needed to assist decisions about transportation system improvements—whether a facility or program needs to be improved and by how much—in relation to other community goals. In a typical application what constitutes an acceptable condition would be developed with input from citizens, businesses, decision-makers and transportation professionals. They represent the crucial link between 1) the vision that the community has for its transportation system, land uses and its “quality of life” issues and 2) the improvement

strategies, programs and projects that government agencies and private sector interests will implement.

One aspect of the community vision can be measured in door-to-door travel time—a primary measure used by travelers and best expressed in accessibility measures. Unfortunately, it is difficult to translate an accessibility measure like “population within 30 minutes travel time of a major activity center” into a procedure to evaluate the need for improvements to a mode, program or route. The transportation and land use planning model required to calculate the accessibility measure may not be sensitive enough to identify the improvement in travel conditions.

The acceptable travel condition values connect accessibility measures with smaller scale analyses. The acceptable travel time and travel rate conditions identify when the citizens believe improvements should be made. The conditions that citizens find unacceptable will be a mix of economic development, transportation and quality of life considerations. The acceptable condition values are desirably the result of a process that is integrated with the development of the long-range plan, but they must be reasonable and realistic, since the mobility assessment must reflect public perception as well as technical analysis. This process is a different approach to the project-by-project interaction that most agencies have with the public and may include different factors than those typically discussed during long-range plan development. The values can, however, be interpreted from existing input processes as a way to begin the assessment; refinement can take place as transportation projects are discussed and the public’s opinion is identified, and through sessions specifically designed to develop acceptable travel condition information as it relates to the community vision.

Urban areas should approach the use of acceptable travel rates with a corridor and system strategy. The acceptable targets may be developed for every mode or facility as a way to identify individual performance levels, but the key application will be as a corridor or system target. Individual facility “deficiencies” can be addressed through improvements to that mode or route or by other travel mode improvements, strategies or policies. For example, the freeway mainlanes may not provide acceptable travel rates, but if an HOV lane is successful in moving a large number of people at low travel rates (high speeds), the average travel rate for the corridor, when weighted by person volume, may achieve the target value.

## **A CORRIDOR APPLICATION**

The example in this chapter is for a corridor, but it combines several levels of analysis from roadway or route sections to a corridor assessment. Regional analyses can be thought of as a combination of corridor evaluations. The example is focused on using the appropriate measure to identify the performance of a road, route or facility. For many alternative improvements, the corridor level is the appropriate area for selecting the type of improvement and evaluating the effectiveness of the actions. Subarea or regional analyses are also useful and needed to develop system plans, but the analytical steps are similar to the corridor assessment presented here. Many local and statewide project funding decisions are based on individual section cost-effectiveness considerations, but there is a growing recognition that corridor analyses are an excellent method for evaluating, prioritizing and funding improvements.

The example depicts peak-period conditions, but the same procedures can be used for peak hour, daily or annual analyses. Weighting the different modes and sections of roadway using person volume provides the multimodal analysis capability needed to compare several alternative travel improvements and can illustrate the effect of land use pattern changes as well. Peak periods should be the analysis period, particularly when future congestion will extend beyond the peak hour. In these cases, there may be a reduction in the length of time and a decline in the number of people affected by corridor mobility levels that are below acceptable conditions, even when there is no change in peak-hour congestion.

## **USING THE TRAVEL RATE INDEX FOR URBAN AREA COMPARISONS**

A separate issue for the urban mobility study comparisons of cities and trend analyses is which target value to use—freeflow conditions, some moderate level of congestion or local mobility targets? While this issue is under study, the corridor example illustrates two of these approaches.

- Freeflow conditions—The uncongested travel rate provides a consistent measure of the conditions in an area that can be used for time series comparisons and for city-to-city comparisons. A standard benchmark may improve the understanding of general audiences and be useful for analyzing system conditions over time. A value based on the speed limit can also be used, although that is less desirable than a measure of roadway conditions.
- Acceptable conditions—A range of values based on local expectations might reflect the fact that most large cities have moved away from a focus on relieving peak-hour roadway congestion to a broader set of goals including shortening the peak period and improving the operational reliability of the system.

Experience with the roadway congestion index indicates that the notion of the congestion problem as a relative issue is well understood. Reporters, policy-makers and the public in relatively small cities understand that their “severe traffic problems” may not be perceived as problems in larger areas. The experience suggests that areas may be able to use information about both the freeflow and target value concepts, but that subject will be studied in more detail. The example includes both statistics to provide an idea of the decision process and the information that may be needed and might be produced.

## **MOBILITY MEASURE EXAMPLE**

The measures presented in [Chapter 5](#) are used to evaluate a corridor consisting of two streets with transit operations and a freeway with an HOV lane. Individual modes are analyzed, and facility analyses are used to “build-up” to corridor measures. The corridor measures could be used to develop subarea or regional statistics. Analyzing all facilities in an area requires summary statistics, but individual facility/route/mode quantities also provide information depending on the type of improvements or area being studied. [Table 6](#) shows a summary of the measures used in the example.

**Table 6. Quick Reference Guide to Mobility Measures.**

<b>INDIVIDUAL MEASURES</b>	
TRAVEL RATE (minutes per mile)	$= \frac{\text{Travel time (minutes)}}{\text{Segment length (miles)}} = \frac{60}{\text{Average speed (mph)}}$
DELAY RATE (minutes per mile)	$= \frac{\text{Actual travel rate (minutes per mile)}}{\text{Acceptable travel rate (minutes per mile)}}$
RELATIVE DELAY RATE	$= \frac{\text{Delay rate}}{\text{Acceptable travel rate}}$
DELAY RATIO	$= \frac{\text{Delay rate}}{\text{Actual travel rate}}$
CORRIDOR MOBILITY INDEX	$= \frac{\text{Passenger volume (persons)} \times \text{Average travel speed (mph)}}{\text{Optimum facility value* (person - mph)}}$ <small>*125,000 - freeways 25,000 - streets</small>
TRAVEL RATE INDEX	$= \frac{\left( \frac{\text{Travel rate}}{\text{Freeflow rate}} \times \frac{\text{Peak period}}{\text{VMT}} \right)_{\text{Freeway}} \times \left( \frac{\text{Travel rate}}{\text{Freeflow rate}} \times \frac{\text{Peak period}}{\text{VMT}} \right)_{\text{Principal Arterial Street}}}{\left( \frac{\text{Freeway peak period}}{\text{VMT}} + \frac{\text{Principal arterial street peak period}}{\text{VMT}} \right)}$
BUFFER TIME INDEX	$= \frac{95^{\text{th}} \text{ percentile travel rate (minutes per mile)} - \text{Average travel rate (minutes per mile)}}{\text{Average travel rate (minutes per mile)}} \times 100$
<b>TOTAL MOBILITY MEASURES</b>	
ACCESSIBILITY (to opportunities)	= The sum of the number of jobs, shops or other travel objectives that are within the acceptable travel time of each origin
TOTAL DELAY (vehicle-minutes)	$= \left[ \frac{\text{Actual travel time (minutes)}}{\text{Acceptable travel times (minutes)}} \right] \times \text{Vehicle volume (vehicles)}$
CONGESTED TRAVEL (person-miles)	$= \text{Sum of all} \left( \frac{\text{Congested segment length (miles)}}{\text{Person volume}} \right)$
CONGESTED ROADWAY (miles)	= Sum of all congested segment lengths (miles)

The underlying evaluation framework is for trip pattern analysis—identifying how well the transportation system gets travelers to where they are going—but the calculation and analysis methods are based on identifying corridors or sections of corridors that impede mobility. Useful summaries of conditions can be presented as either (or both) relative to the acceptable measures for area-wide studies, or relative to an absolute value such as freeflow travel.

The results of this analysis can identify areas and subareas where some type of improvement is needed. The effect of a broad range of construction, operation, policy or land use pattern changes can be identified with a set of mobility measures. Pricing actions that affect demand and travel patterns can also be identified if they change travel time and mobility.

Figure 4 illustrates a corridor with a freeway and two parallel streets. All three roadways and the transit operating on them serve the same basic travel pattern in the morning peak period—toward the central business district. The example statistics include typical operating information that might be available for an analysis: vehicle volume, person volume and travel rate. The statistics are averages or totals for the morning peak period. A more precise estimate of the mobility levels in the corridor can be created using similar values for each hour of the peak period. And a complete analysis would include the evening peak period, and possibly a midday peak. Some areas might require weekend or holiday travel information if there are mobility concerns during those times.

Specific corridor characteristics include:

- The congested Central Freeway has a well-used high-occupancy vehicle lane in the median.
- North Street has bus routes using the regular traffic lanes with no particular priority. North Street is relatively uncongested on the suburban end and relatively slow speed on the downtown end.
- South Street has a light-rail transit (LRT) line in the median. The LRT is very well patronized and has a modest amount of priority treatment so that its travel rate is near the vehicles in the street.

Table 7 illustrates an initial comparison that can provide information on one aspect of the mobility level in the corridor. The individual facilities are evaluated using the travel rate information and two standards—freeflow and acceptable travel conditions.

The delay rate (difference between the travel rate and the standard) represents the minutes lost per mile of travel. It is a calculation step toward estimating corridor delay, but it also illustrates the time penalties for each road/mode/facility. The North Street bus routes, the South Street LRT and the Central Freeway mainlanes have the most improvement need in relation to freeflow travel. When the acceptable rates are examined, however, the bus routes are performing reasonably well, with three of the five sections operating at or better than the target travel rates. Every section of the LRT is meeting or exceeding the acceptable targets.

Distance						
Section Number	1	2	3	4	5	
Volume	3,980	4,790	5,780	7,980	8,980	North Street
# Lanes	4 Lanes	4 Lanes	4 Lanes	6 Lanes	6 Lanes	
Travel Rate (minutes/mile)	2.0	2.0	4.0	3.0	4.0	
Persons	672	672	1,020	1,296	1,368	Bus Routes on North Street
Travel Rate (minutes/mile)	3.0	3.0	4.5	4.0	4.5	
Volume	16,520	16,520	26,280	33,060	37,560	Central Freeway
# Lanes	6 Lanes	6 Lanes	6 Lanes	8 Lanes	8 Lanes	
Travel Rate (minutes/mile)	2.0	2.0	3.5	3.5	3.5	
Persons	10,700	10,700	10,700	10,700	10,700	Central FWY HOV Lane
Travel Rate (minutes/mile)	1.0	1.0	1.0	1.0	1.0	
Volume	3,400	3,400	4,790	4,990	5,390	South Street
# Lanes	4 Lanes	4 Lanes	4 Lanes	4 Lanes	4 Lanes	
Travel Rate (minutes/mile)	2.5	2.5	3.0	3.0	3.0	
Persons	4,050	4,050	4,752	5,076	5,400	LRT in Median of South Street
Travel Rate (minutes/mile)	3.5	3.5	3.5	4.0	3.5	

**Figure 4. Morning Peak-Period Operating Characteristics.**



**Table 7. Comparison of Delay Rate and Travel Rate Index Measures for Freeflow and Acceptable Travel Conditions.**

Facility and Measure	Section Number and Comparison Standard											
	1		2		3		4		5		Weighted Average	
	Freeflow <sup>1</sup>	Acceptable <sup>2</sup>	Freeflow <sup>1</sup>	Acceptable <sup>2</sup>	Freeflow <sup>1</sup>	Acceptable <sup>2</sup>	Freeflow <sup>1</sup>	Acceptable <sup>2</sup>	Freeflow <sup>1</sup>	Acceptable <sup>2</sup>	Freeflow <sup>1</sup>	Acceptable <sup>2</sup>
North Street												
Delay Rate (minutes/mile)	0	1.0	1.0	0	2.0	1.0	1.0	0	2.0	1.0	1.1	0.1
Travel Rate Index	1.0	0.7	1.5	1.0	2.0	1.3	1.5	1.0	2.0	1.3	1.6	1.0
North Street Bus												
Delay Rate (minutes/mile)	1.0	-1.0	2.0	0	2.6	0.6	2.0	0	2.6	.6	2.1	0.1
Travel Rate Index	1.5	0.8	2.0	1.0	2.3	1.2	2.0	1.0	2.3	1.2	2.0	1.0
Central Freeway												
Delay Rate (minutes/mile)	1.0	0.5	2.0	1.5	2.5	2.0	2.5	2.0	2.5	2.0	2.2	1.7
Travel Rate Index	2.0	1.3	3.0	2.0	3.5	2.4	3.5	2.4	3.5	2.4	3.2	2.1
Central HOV												
Delay Rate (minutes/mile)	0	0	0	0	0	0	0	0	0	0	0	0
Travel Rate Index	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
South Street												
Delay Rate (minutes/mile)	0.5	-0.5	0.5	-0.5	1.0	0	1.0	0	1.0	0	0.8	-0.2
Travel Rate Index	1.3	0.8	1.3	0.8	1.5	1.0	1.5	1.0	1.5	1.0	1.4	0.9
South Street LRT												
Delay Rate (minutes/mile)	1.5	-0.5	1.5	-0.5	1.5	-0.5	2.0	0	2.0	0	1.7	-0.3
Travel Rate Index	1.8	0.9	1.8	0.9	1.8	0.9	2.0	1.0	2.0	1.0	1.9	0.9

<sup>1</sup>Freeflow travel rates—Freeway and HOV Lane = 1 minute per mile; Street and LRT = 2 minutes per mile; Bus = 2.5 minutes per mile

<sup>2</sup>Acceptable travel rates—Freeway = 1.5 minutes per mile; HOV = 1.0 minutes per mile; Street = 3.0 minutes per mile; Bus and Rail = 4.0 minutes per mile

Table 8 presents further comparisons for freeflow conditions.

**Table 8. Corridor Mobility Measurement Example Using Freeflow Travel Conditions – Peak-Period Operations.**

Facility Combination	Travel Time (hours)	Average Travel Rate (minutes/mile)	Daily Delay (person-hours)	Delay Rate (minutes/mile)	Corridor Mobility Index	Travel Rate Index
North Street and Bus Routes	5,600	3.2	117,000	1.2	0.6	1.6
South Street and LRT	6,400	3.2	148,000	1.2	0.7	1.6
Central Freeway and HOV Lane	22,000	2.0	822,000	1.6	0.7	2.6
All Facilities	34,000	2.2	1,087,000	1.4	0.7	2.3

Note: Freeflow travel rates—Freeway and HOV Lane = 1 minute per mile; Street and LRT = 2 minutes per mile; Bus = 2.5 minutes per mile.

- Travel time and delay can be used in cost-effectiveness analyses and in comparison to improvement alternatives for the facilities and the corridor. Both of these quantities, by virtue of their size, illustrate the importance of the Central Freeway mainlanes and HOV lane to travelers in the corridor.
- The average travel rate can be used to compare target conditions for roadway elements and as an illustration of overall corridor travel rate, but it does not include a specific mention of the target or standard comparison condition.
- The delay rate indicates the amount of delay per mile and shows the two streets as having more travel time deficiency per mile than the freeway corridor. This is the result of the large number of travelers on the HOV lane traveling at very low travel rates (high speeds).
- The corridor mobility index relates the speed and person movement to a optimum operating condition for a street or a freeway lane. Values equal to or greater than 1.0 indicate operations at very good levels; all facilities have approximately the same performance level.
- The travel rate index indicates the amount of extra time to travel to a destination than it does in the off-peak. Rather than speed, the index uses travel rate, a quantity closer to the time value used by travelers to plan their trips. The streets benefit, in relation to the freeway, from the higher travel rates (lower speed) during the off-peak period. The longer street travel time in the off-peak provides a larger number for the bottom term of the travel rate index than that of the freeway. The travel rate index for the streets indicate they come closer to providing off-peak travel time than the freeway/HOV lane combination. Freeway corridor travelers take 160 percent longer to travel this section than during uncongested operations. Corridor travelers, on average, take 130 percent longer to travel than in the off-peak.

- The street TRI values are better than the respective transit operations (Table 7), but the HOV lane operation substantially improves the freeway TRI (in Tables 7 and 8, from 3.2 to 2.6), despite having only 27 percent of the persons moved on the freeway/HOV lane in the peak period.

Table 9 presents the mobility statistics relative to the expectations for each portion of the corridor.

**Table 9. Corridor Mobility Measurement Example Using Acceptable Travel Conditions – Peak-Period Operations.**

Facility Combination	Travel Time (hours)	Average Travel Rate (minutes/mile)	Daily Delay (person-hours)	Delay Rate (minutes/mile)	Corridor Mobility Index	Travel Rate Index
North Street and Bus Routes	5,600	3.2	22,000	0.1	0.7	1.0
South Street and LRT	6,400	3.2	-23,000	-0.2	0.7	0.9
Central Freeway and HOV Lane	22,000	2.0	562,000	1.2	0.9	1.8
All Facilities	34,000	2.2	561,000	0.9	0.8	1.6

Note: Acceptable travel rates—Freeway = 1.5 minutes per mile; HOV = 1.0 minutes per mile; Street = 3.0 minutes per mile; Bus and Rail = 4.0 minutes per mile.

- The average travel rate, travel time and corridor statistics are not calculated relative to an acceptable condition—those values are the same as in the freeflow condition. These measures can be used for comparisons to acceptable conditions if “acceptable” values are developed for each measure.
- Delay declines significantly from the freeflow conditions, and does not exist in the South Street section of the corridor. This delay might be thought of as a calculation of unacceptable delay or delay that travelers may perceive as “undesirable.”
- The delay rate indicates the travelers on the freeway are likely the only ones that can perceive a gap between their travel conditions and the acceptable conditions. This obviously means that while there is not an absence of delay, the street corridors operate close to the standards defined for them. This observation can be used to test any set of acceptable conditions for reasonableness—peak-period travelers who use the two streets for a substantial portion of their trip should respond that their trip time is close to acceptable.

- The travel rate index indicates the freeway corridor travelers take 80 percent longer to travel this section of their trip than is considered acceptable, while the street corridor users are traveling near the expected times. The corridor average is 60 percent longer.
- Despite the poor showing in the travel rate index, travelers in the freeway corridor travel at lower travel rates (faster speeds) than motorists or transit riders on the streets. While this is somewhat of a contradiction, it reflects the higher expectations from facilities that cost more to build and maintain, and which have the potential for greater economic, social and environmental impact.

## **CHAPTER 7 — USING TRAVEL TIME MEASURES TO ESTIMATE MOBILITY AND RELIABILITY IN URBAN AREAS**

This project used metropolitan planning organizations (MPOs) as test subjects to show the benefits and challenges of using travel time data. A guidebook for using travel time measures to estimate mobility was developed and observations about the usefulness of travel time information were collected from the MPOs. The Lincoln-Lancaster County MPO and the Hidalgo County MPO served as examples.

### **LINCOLN-LANCASTER COUNTY MPO OVERVIEW**

The Lincoln-Lancaster County MPO in Nebraska uses its travel time data for studies of subareas of the city as well as for area-wide planning efforts. The analysis method, data collection and measures were developed as a joint agreement between the citizens and Lincoln-Lancaster County MPO professional staff. The staff wanted a prioritization scheme that could be used in a computerized and systematic format. Residents did not like typical roadway capacity calculations, finding them too complicated and difficult to replicate with their own resources. The information used to compile travel time studies and the resulting products fit both the communities' needs and the staff analytical needs.

Travel time measures are used to evaluate the need for more detailed study of high-priority corridors. Problems are identified using a “trigger speed” of 18 mph. When collected speeds fall below this threshold, further study is used to identify the source of the problem and potential remedies. When the average speed falls below 16 mph, the corridor segment improvement alternative (approved by the public) is selected for the six-year capital improvements program.

The travel speed information was also used in a revalidation of the planning model speeds. Maximum and minimum speeds were developed for a matrix of area types and functional road classes. The maximum speed was estimated from the average midday speeds. Most of these were close to the 1995 model speeds that had been used. Peak-period speeds were used to estimate the minimum speeds. Most of the minimum speeds in the 1995 model were found to be too high for current conditions. More information on the city and county use of travel time and speed information can be found on the planning department website:

<http://interlinc.ci.lincoln.ne.us/city/plan/>

### **HIDALGO COUNTY MPO OVERVIEW**

While a project report from the Hidalgo County MPO in Texas was never received and some project tasks were not performed, there are several outcomes that can guide the implementation of travel time measures. The Hidalgo County MPO has been very active in collecting and using travel speed data since 1995. More than 500 miles of road have been surveyed using in-vehicle travel time data collection techniques. This represents a significant resource for decision-making and trend analysis, much more than for a typical area of this size. The database and data collection activities also represent a commitment to travel time and speed data collection that is not found in areas with populations many times the size of Hidalgo County. In a significant way,

the Hidalgo County MPO provides a valuable peer resource and study site for entities interested in performing travel speed studies.

Additional information regarding the congestion management system can be found at the Hidalgo County MPO's website: <http://www.lrgvdc.org>

## **FINDINGS REGARDING DATA COLLECTION**

The Hidalgo County and Lincoln-Lancaster MPOs conducted travel time data collection for several years. Included in this review are some findings from their experiences.

- **Reduce the sampling rate and frequency for uncongested road sections.** Other data, such as traffic counts and number of lanes, can be used to identify road sections that are likely uncongested. These roads can be surveyed every three to five years rather than annually. If traffic growth or usage patterns change and congestion is detected, the frequency can be increased. Most areas that perform travel speed studies spend too much effort on uncongested road sections the first few years.
- **Reduce the sampling rate and frequency on minor roads.** From a transportation problem and improvement perspective, minor roads are not as significant a problem as major streets and freeways. Data collection and analysis resources could be more efficiently used by focusing on problem areas. Stratifying the road systems into areas that should be surveyed annually, those that can be surveyed every two years, and those that can be surveyed less frequently can provide the same amount of information with lower cost. Lincoln-Lancaster County MPO did this to great effect in its model update process.
- **Use the travel speed data to assist in developing local estimation procedures and in calibrating the transportation-planning model.** Travel speed estimation procedures are used both as post-processors of travel model output, and as mechanisms to allow the travel models to distribute traffic to roadways. The “target market” for improved speed estimation procedures seems to be more aligned with the post-processor function. The methods to estimate speeds from model outputs would not only improve communication abilities with the general public, they would also provide a metric for comparing no-build alternatives with additional lanes, operational improvements, land use strategies, or other capacity enhancements.
- **Recognize value of investment costs.** Travel time and speed data collection was relatively costly but provided a significantly improved dataset than if estimating equations alone were used. Almost 500 miles of freeways and streets were used in the first several travel time and speed studies in Hidalgo County. This included every major road and some minor roads. The Lincoln study sampled 28 percent of the area's road miles with a basic “three runs per direction” data collection level. Important corridors were sampled with greater frequency and coverage. Interstate and major arterials represented 50 percent of the sample data collection. Both of these resulted in the ability to communicate with the public and gave a comprehensive quality to the information.

- **Collect data for relevant time periods.** Four time periods appear to be a good division of the day for the purposes of data collection. Morning peak, midday, evening peak, and after hours provides information for decisions and evaluation. This breakdown also helps connect the traveler’s experience with the datasets. Atypical days or runs are noted and not included with the averages.
- **Archive data.** Use of archived data from traffic operations centers was not part of the study, but their use does appear to be a significant resource for data collection efforts in the future. The reliability measurements provided from the automated data collection databases will add a significant amount of information and provide documentation of the improvements from several operational improvement strategies.

## DATA ANALYSIS AND DATABASE ISSUES

Two types of data usage approaches are common—area-wide or corridor analyses. The data analysis steps for each are relatively similar. The types of measures, the level of aggregation, and the database design might also vary, but many uses can be supported if an inclusive design process is used from the start. Hidalgo County’s study (and other travel time studies including Corpus Christi, which is discussed in a separate technical memorandum) is focused on updating its congestion management system and supporting the project funding decisions made from that. The Lincoln County work was for the similar but somewhat more detailed purpose of corridor level analyses. Some other relevant guidelines include:

- The speeds are weighted by travel amounts or road distance to get averages. If the objective is to replicate user experiences, weighting by travel distance or trips is preferable.
- Lincoln and Hidalgo County are among the cities/MPOs that use varying targets of acceptable speed according to functional class. These targets are very useful in setting targets for improvement. They do require a process to get the speeds that residents and travelers find acceptable. This approach might be incorporated into the public involvement process during the long-range plan update.
- The analyses were relatively simple. Spreadsheet or simple database programs are typically used and the datasets are not too large unless continuously collected data are used.

## MEASURES

Researchers chose the case study sites for their experience with travel speed data and measures. Hidalgo, Corpus Christi, and Lincoln among several areas used average speed as a base measure when the study began. Even though this does not have a direct relationship with travel time, speed is easily understood. Other observations include:

- The “acceptable speed” concept applies to different types of roadway, roads in different parts of the city, and various modes of travel. Similar concepts are used in

conjunction with levels-of-service; converting to speed should be relatively easy if the public and decision-makers endorse the idea.

- Lincoln uses a target speed for high-priority corridors. The target speed triggers a study of potential solutions. The follow-up study is not restricted to using car speed measures or recommending auto-only solutions. A multimodal set of solutions and measures can be employed.
- Hidalgo now uses a ratio of standard travel time to actual travel time calculated as the Congestion Index. A value of 0.74 or less is considered congested with the travel time at the speed limit representing the standard time.
- Travel speed measures are used in Lincoln for both corridor studies and area-wide transportation improvement program prioritization processes. The level-of-service criteria used in several decision-making elements use travel speed as the descriptor.

## **COMPUTER MODELING**

The travel time surveys can be used to update the lookup tables for freeflow travel speeds. At the validation stage, travel speeds in the important corridor segments can be used to identify model accuracy. There are also a variety of other potential implementation issues:

- Travel times between locations can verify that speeds on road segments are accurate.
- Collected data can improve congested travel speed prediction methodologies.
- Travel speed estimation processes can be used to evaluate alternative projects in a shorter time than it takes to generate a new travel network model. Using both the model and field data to calculate delay will provide a context for comparisons between the two methods.
- Other computer modeling-related issues might be tested by Texas Department of Transportation for Hidalgo County's model in the future. Several suggestions were provided during the project scoping meeting between the Texas Transportation Institute and the Texas Department of Transportation's Transportation Planning Program staff.

## **PRESENTATION**

Most MPOs and large projects have public involvement programs that use graphics to communicate results. Travel time and speed studies can provide the basis for many excellent graphic displays. Typical presentations used in the case study cities include maps with speed ranges noted by colors placed on the streets. Some of the more detailed maps show speed values next to the streets. The following list describes potential graphics for presentations.

- Isochronal maps—"topographic" lines that show the distance away from a starting point that can be achieved after a certain travel time—are good methods of presenting information about travel to and from major activity centers.



- Travel time data can be used to support the development of accessibility maps and measures. While a difficult concept to communicate, accessibility (e.g., the number of jobs within 30 minutes of a residential area) can be presented for alternative improvement projects. Areas that gain access can be shown for a combination of projects, or for individual modal improvements.
- Speed and travel time variation during the day can illustrate the extent and duration of typical congestion. If automated data archiving is present, the day-to-day variation can be displayed and reliability statistics prepared.

## **SUMMARY**

The travel time and speed measures used in system evaluation and project analyses are very useful and popular with a variety of audiences. Hidalgo County MPO finds that its annual congestion report is its most popular public involvement item. The Lincoln-Lancaster MPO uses travel speed data and measures because the public understands them and the MPO can collect its own travel speed data.

We recommend that decision-makers use travel speed and time data in evaluating congestion and mobility issues. The congestion management systems and transportation improvement programs are likely targets for travel speed measures. The measures have proven useful in both technical and public information purposes, and we recommend that MPOs put data into audience-friendly presentations for use in public involvement and communication programs.



## **CHAPTER 8 — CONCLUDING NOTES**

This report is designed as a guide to applying travel time related data to a variety of transportation analyses. Several measures are discussed, and the relative merits for several situations are defined. Calculation procedures are presented and recommendations for the use of the measures are included.

Typical objectives for travel time data collection and analysis are discussed. The process for considering the data and measures is also outlined. Summaries of case studies are also included to show some of the applications for the measures.



## REFERENCES

1. Quantifying Congestion - Final Report and User's Guide National Cooperative Highway Research Program Project 7-13, National Research Council, NCHRP Report 398, 1997.
2. *Highway Capacity Manual—Special Report 209, Third Edition*. Transportation Research Board, National Research Council, 1994.
3. Ewing, R. *A Unified Set of Transportation Performance Measures*, Florida Atlantic University, n.d.
4. Urban Roadway Congestion Annual Report, 1998. Sponsored by Departments of Transportation in California, Colorado, Kentucky, Minnesota, New York, Oregon, Pennsylvania, Texas and Washington, 1998. (<http://mobility.tamu.edu>).
5. Lomax, T., Turner, S., and Margiotta, R. *Monitoring Urban Roadways in 2000: Using Archived Operations Data for Reliability and Mobility Measurement*. Texas Transportation Institute and Cambridge Systematics Inc. December 2001. (<http://mobility.tamu.edu/mmp>).
6. Deen, Thomas B., and Pratt, Richard. "Evaluating Rapid Transit." In *Public Transportation* by Editors George E. Gray and Lester A. Hoel, Second Edition, Prentice Hall, 1991.
7. Turner, Shawn M., Eisele, William L., Benz, Robert J., and Holdener, Douglas J. *Travel Time Data Collection Handbook*, Report No. FHWA-PL-98-035. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., March 1998.
8. Pisarski, Alan E. *Summary and Recommendations of the Workshop on National Urban Congestion Monitoring, 1990*, Report No. FHWA-PL-90-029. U.S. Department of Transportation, Federal Highway Administration and Office of Highway Information Management, Washington, D.C., September 1990.
9. Guinn, C. R. *Travel Time Empirical Study*. Preliminary Report No. 8. Planning and Research Bureau, New York State Department of Transportation, Albany, New York, June 1967.
10. Jackson, D. *Reliability as a Measure of Transportation System Performance*. Unpublished Master's Thesis, Texas A&M University, College Station, Texas, December 2000.
11. Shaw, T., and McLeod, D. *Mobility Performance Measures Handbook*. Florida Department of Transportation, Systems Planning Office, Tallahassee, Florida, July 1998.
12. Booz-Allen & Hamilton, Inc. *1998 California Transportation Plan: Transportation System Performance Measures: Final Report*. California Department of Transportation, Transportation System Information Program, Sacramento, California, August 1998.

13. Albert, L.P. *Development and Validation of an Areawide Congestion Index Using Intelligent Transportation Systems Data*. Unpublished Master's Thesis, Texas A&M University, College Station, Texas, May 2000.
14. Wunderlich, K. Preliminary Results from HOWLATE: DC Travel Reliability Study. Mitretek Systems, April 2000.
15. The Keys to Estimating Mobility in Urban Areas: Applying Definitions and Measures That Everyone Understands. Sponsored by Departments of Transportation in California, Colorado, Kentucky, Minnesota, New York, Oregon, Pennsylvania, Texas and Washington, 1998. (<http://mobility.tamu.edu>)