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16. Abstract

This report describes the results of research on the use of intelligent transportation system (ITS) data in calculating mobility performance measures for ITS operations. The report also describes a data quality control process developed for the TransGuide® detector data in San Antonio. The TransLink® research team concluded that quality control is necessary to ensure the accuracy and integrity of data collected by traffic management centers, and that it is desirable to implement quality control procedures as close to the data collection source as possible (i.e, local controller). Based upon this, we recommend that basic quality control checks (such as those shown in this report) be incorporated into standard practice for traffic management centers in Texas.

The report presents performance measures for three levels of analysis: point/link, facility, and system. The performance measures can easily be calculated using speed and volume data currently collected by nearly all traffic management centers in Texas. The report also presents useful displays of performance measures that can be used to identify and illustrate traffic problems and the effects of improvements. We recommend that operations staff at selected traffic management centers experiment with using the recommended performance measures as an operations planning tool.

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ITS DATA QUALITY CONTROL AND THE CALCULATION OF MOBILITY PERFORMANCE MEASURES

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The United States Government and the state of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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- Mr. Derrick Bailey – for overall project and data management support.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

Performance measures are a critical element in the operation of intelligent transportation systems (ITS) because they help transportation operators and managers identify how well their efforts meet stated or implied goals and objectives. Performance measures also provide insight into what strategies or tactics can be used in the future to further improve system performance. Performance measures are particularly desirable in ITS and operations, a transportation specialty in which incremental improvements may lead to similar sustained gains in system performance.

This brief report describes the results of TransLink® research focused on demonstrating the use of archived ITS data in calculating mobility performance measures for ITS operations. The research used archived data publicly available from the TransGuide® traffic management center in San Antonio to calculate and display performance measures that can be used in traffic management and operations. Before presenting the performance measures and examples of their display, the report describes a data quality control process developed for the specific instance of TransGuide detector data.

CHAPTER 2. QUALITY CONTROL FOR ITS DATA

At a minimum, quality control for data collected by ITS should consist of "flagging" erroneous or suspect data as close to the data source as possible. For traffic condition data collected by various sensors or detectors, the quality control should ideally be performed on the local controller that aggregates individual vehicle actuations and communicates to the central traffic management system. If computational resources are not available in the field to perform quality control, it could be performed with the central traffic management software once the data has been received. The following paragraphs summarize TTI research on conducting quality control on ITS data at two distinct locations: 1) in the field on a local controller; and 2) in the traffic management center once the data has been received.

QUALITY CONTROL TECHNIQUES AT LOCAL CONTROLLERS

Numerous quality control algorithms can be applied at the local controller level to provide better information about erroneous or suspect data. Quality control algorithms at the local controller that have been reported in the literature include the following:

- comparing detector on-times to a station/location average (*1*);
- setting threshold values for a combination of volume and occupancy (*2*);
- comparing differences in volume and occupancy between each loop in double-loop speed trap configuration (*3*);
- computing the sum of vehicle storage rates for a freeway section (*4*); and,
- comparing detector on-times between upstream and downstream detectors (*5*).

TTI researchers chose to develop and test a quality control algorithm that calculated an individual vehicle length based upon detector on-times. The algorithm was tested by sending inductance loop detector actuations to an industrial computer in a field cabinet. The algorithm was not implemented on a controller at this time because of its experimental nature. Early results from this vehicle length quality control algorithm are promising. The algorithm is quite simple and requires only basic information (i.e., detector on-time) available from nearly any type of traffic detector. Additional details on the testing of this controller are available in a forthcoming technical report.

QUALITY CONTROL TECHNIQUES AT THE TRAFFIC MANAGEMENT CENTER

Quality control techniques may be performed at the traffic management center if no quality control is performed on local controllers. Even if basic quality control is performed at the controller level, additional checks that compare detector data to upstream/downstream locations and historical locations are desirable at the traffic management center.

The researchers recommend the following quality control checks for implementation in the traffic management center environment. Nearly all of the quality control can be automated. Most of these quality control checks are oriented to point detector data in which volume, occupancy, and speed are collected at regular intervals (typically 20 to 60 seconds).

- **Check regularity of polling cycle –** This step ensures that the elapsed times between data reports are approximately equal to the reported polling cycle. For example, the reported polling cycle may be 30 seconds, but poll server overload causes elapsed times significantly greater than 30 seconds. The easiest way to check the regularity of the polling cycle is to sort the data records by detector and time, then compute the elapsed time between subsequent data records. There may be some minor variation between each polling cycle, but this variation is typically no more than ± 2 or 3 seconds. Simple time-series charts can illustrate situations where the polling cycle has irregular patterns.

- **Check for physically impossible data values or combinations of values –** This step checks the reasonableness of data values at the data record level. Table 1 contains basic quality control rules developed for TransGuide system data in San Antonio, which currently uses 20-second polling cycles in gathering data from local controllers. Similar quality control rules could be developed for TxDOT Advanced Traffic Management Software (ATMS) implementations, in which the system controller unit (SCU) uses 1-minute polling cycles to collect detector data.

- **If possible, assess the accuracy of traffic monitoring equipment –** This step gathers information about the expected accuracy of the data collection equipment and corresponding data, and must be conducted outside of the real-time environment. The accuracy of detectors should be tested prior to acceptance from construction contractors, and should also be periodically tested during routine maintenance activities.

Table 1. Quality Control Check Rules for 20-Second TransGuide Loop Detector Data.

Scenario Number	20-Second Record Value			Condition
	Speed (mph)	Volume (vehicles)	Occupancy (percent)	
Single-Loop Detectors (speed not available [e.g., "-1"], typically only exit and entrance ramps)				
1	-1	0	0	**good data** - no vehicle(s) present.
2	-1	0	OCC>95	**good data** - vehicle stopped over loop.
3	-1	1<VOL<17	OCC>0	**good data** - vehicle(s) present.
4	-1	0	1 <OCC<95	**CAUTION** - single vehicle over loop at end of reporting period. This vehicle should be included in the next reporting period.
5	-1	>0	0	**good data** - occupancy value truncated to integer value.
6	-1	VOL>17	>0	**CAUTION** - high volume count may be caused by loop chatter OR a long reporting period of 2-3 minutes. Check elapsed time since previous detector report.
Double-Loop Detectors (typically only freeway mainlanes)				
7	0	0	0	**good data** - no vehicle(s) present.
8	0	0	OCC>95	**good data** - vehicle stopped over loop.
9	>0	1<VOL<17	>0	**good data** - vehicle(s) present.
10	0	0	1<OCC<95	**CAUTION** - single vehicle over loop at end of reporting period. This vehicle should be included in the next reporting period.
11	0	>0	0	**CAUTION** - single vehicle between double loops in speed trap configuration and occupancy value truncated to nearest integer. This vehicle's speed should be averaged into the next reporting period average speed.
12	0	>0	>0	**CAUTION** - single vehicle between double loops in speed trap configuration. This vehicle's speed should be averaged into the next reporting period average speed.
13	>0	0	0	**CAUTION -** single vehicle finishing traversal of speed trap in second reporting period (see #11 and #12).
14	>0	>0	0	**good data** - occupancy value truncated to integer value.
15	>0	0	>0	**CAUTION -** cause unknown.
16	>0	VOL>17	>0	**CAUTION** - high volume count may be caused by a chatter OR a long reporting period of 2-3 minutes. Check elapsed time since previous detector report.
17	no values reported			**missing data -** no data reported by server.

CHAPTER 3. CALCULATION AND DISPLAY OF MOBILITY PERFORMANCE MEASURES

The mobility performance measures described in this section fall into three basic levels of detail/analysis: point/link, facility, and system. The following sections are organized around these three different levels of detail for performance measures. Each section describes several recommended measures that best characterize transportation performance for the given level of detail. These recommended performance measures have universal applicability to nearly all transportation analyses at this level of detail. The report presents several other possible measures that may be useful in certain types of analyses.

The data requirements for all of the performance measures in this report are very basic and are currently collected (or can be estimated) nearly everywhere that ITS has been deployed. The required data elements are:

- vehicle travel time and/or speed,
- vehicle volume per unit time, and
- definition of the transportation network (e.g., links and facilities).

The following data elements are typically estimated but can easily be replaced with locally collected data:

- vehicle occupancy (typically assumed to be 1.20 persons per vehicle), and
- congestion threshold (typically assumed to be less than 55 mph).

All of the performance measures presented and displayed in this report are calculated from these five basic data quantities. The calculation of the measures in the remainder of this chapter has been presented in TTI Report 1752-2 *(6)*.

POINT/LINK MEASURES

Table 2 summarizes point/link mobility performance measures suggested for use with ITS data. Figures 1 through 3 illustrate useful graphic displays of these performance measures.

Table 2. Summary of Point/Link Mobility Performance Measures.

Description

Point/link mobility measures characterize the performance of a specific location or short section of the transportation system. The location or section is just one of many such components of an individual traveler's trip.

When/Where to Use these Measures

Point/link-based measures are most useful to transportation professionals, who may use these measures to identify location-specific traffic problems (e.g., weaving area on a freeway) or measure the impact of isolated improvements (e.g., an isolated ramp meter). Travelers and other non-technical audiences should be able to relate these measures to specific problem locations along freeways or arterial streets.

Recommended Measures

- average speed (miles per hour) or travel time (minutes)
- travel time (minutes) or speed reliability (miles per hour)
- total vehicle or person throughput (vehicles or persons per unit time)
- vehicle or person delay (vehicle- or person-hours)

Other "Specialized" Measures

- person movement speed (person-mph/lane)
- vehicle flow rate (vehicles per hour per lane)

Useful Measure Displays

There are numerous ways to display point/link mobility performance measures. Basic tabular displays can be used to present the above measures over time and at different locations. The following, though, are some examples of useful graphic displays:

Figure 1 – chart of vehicle throughput, speed, and reliability by time of day, example from Seattle, Washington
Figure 2 – chart of morning and evening peak hour average weekday speeds, example from San Antonio, Texas
Figure 3 – map display of peak hour (or peak period) speed (or travel time), example from San Antonio, Texas

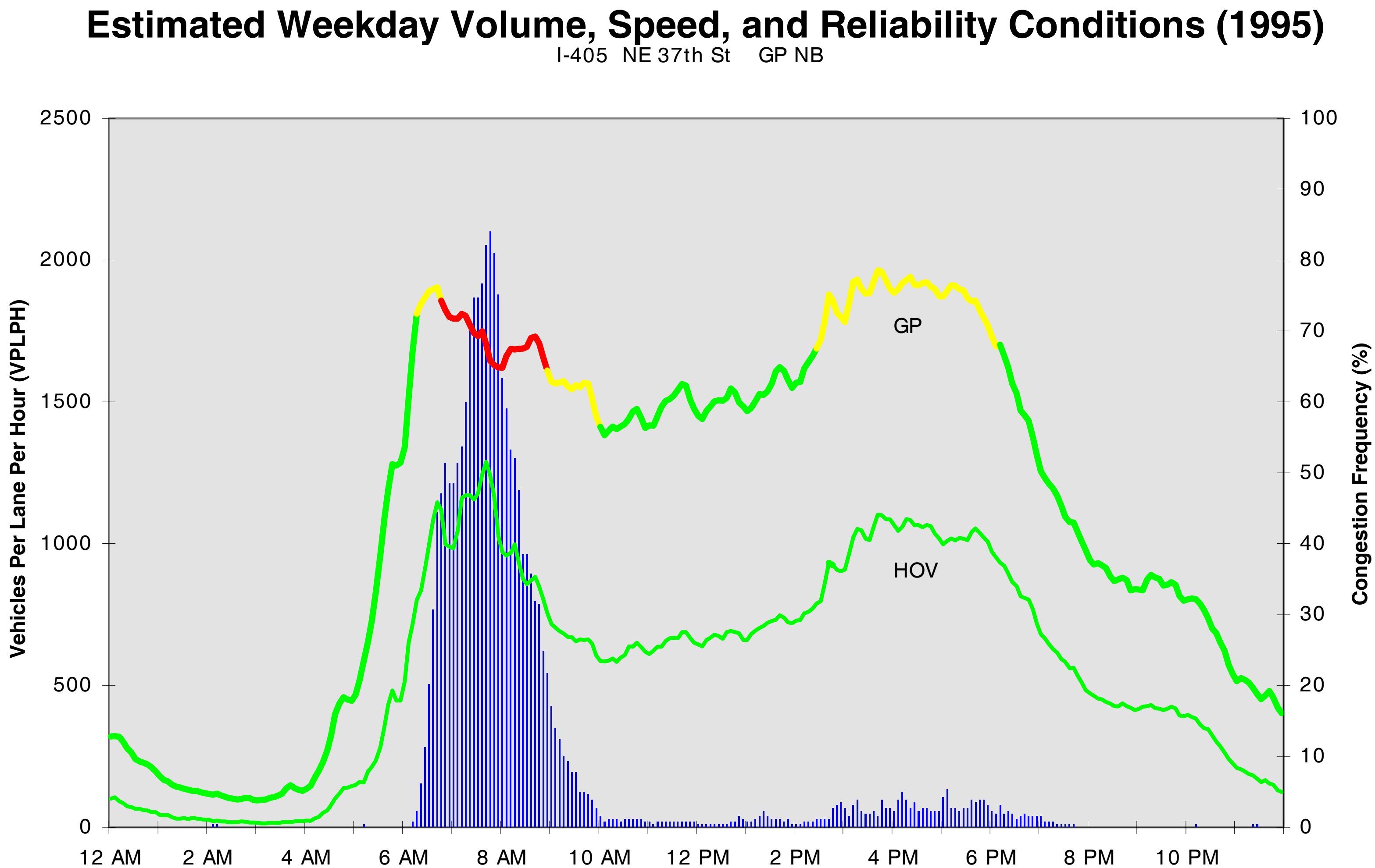

Figure 1. Average Weekday Volume, Speed, and Reliability for General Purpose and High-Occupancy Vehicle Lanes on I-405 in Seattle, Washington. (Chart courtesy of Mark Hallenbeck, Washington State Transportation Center)

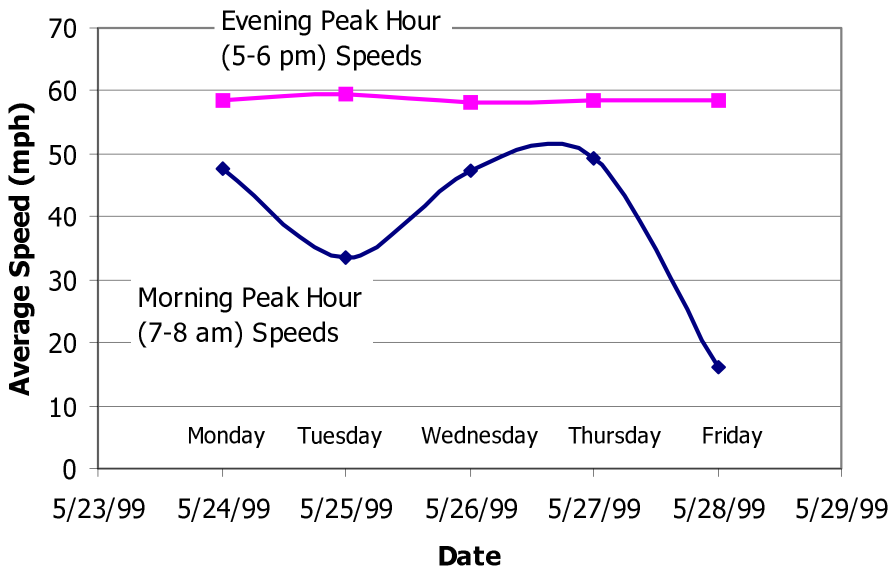

Figure 2. Average Peak Hour Speeds on I-35 Northbound just South of I-10, San Antonio. (TransGuide Detector ID# 0035N-152.590)

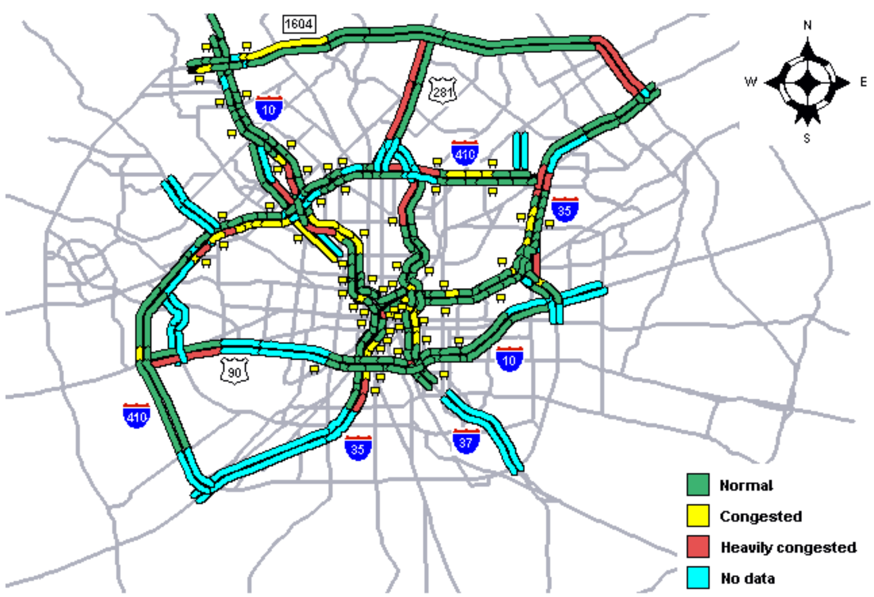

Figure 3. Real-Time Map Display That Could Also Illustrate Peak Hour/Period Speeds.
(Image courtesy of TransGuide web site, http://www.transguide.dot.state.tx.us/Traffic/ccmap.php)

FACILITY MEASURES

Table 3 summarizes facility mobility performance measures suggested for use with ITS data. Figures 4 and 5 illustrate useful graphic displays of these performance measures.

Table 3. Summary of Facility Mobility Performance Measures.

Description Facility measures characterize performance of a significant length of a transportation facility. A facility can constitute a substantial component of an individual traveler's trip.
When/Where to Use these Measures Transportation professionals may use facility measures to identify the impacts of facility-based improvements (e.g., courtesy patrol, facility-wide traffic control). Travelers and other non-technical audiences should be able to relate to these measures if a significant portion of the specific facility is part of their trip.
Recommended Measures • average travel time (minutes) or speed (miles per hour) • travel time (minutes) or speed reliability (miles per hour) • total vehicle or person delay (vehicle- or person-hours) • total and congested person-miles of travel (PMT) • total and congested person-hours of travel (PHT) • % of congested roadway (miles, lane-miles)
Other Measures to Consider • person movement speed (person-mph/lane) • congestion severity index (vehicle-hours of delay per 1,000 VMT) • lane-mile duration index (lane-mile-hours of delay)
Useful Measure Displays There are numerous ways to display point/link mobility performance measures. Basic tabular displays can be used to present the above measures over time and at different locations. The following, though, are some examples of useful graphic displays: Figure 4 – chart of daily speed contours for a facility by time of day, example from San Antonio, Texas Figure 5 – chart of average annual speed contours for facility by time of day, example from Seattle, Washington Figure 6 – chart of average facility speeds for different days and times of the day, example from Orlando, Florida

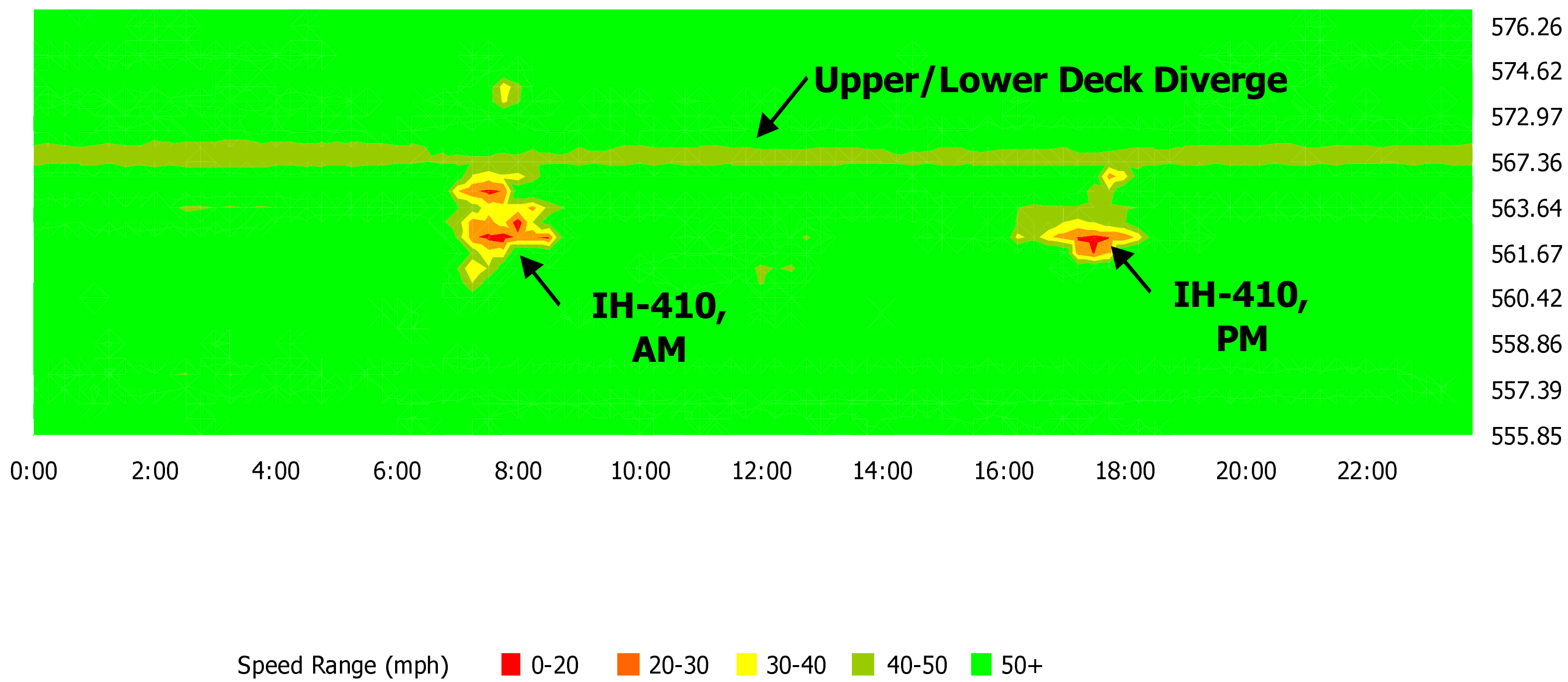

Figure 4. Example of Speed Contour Chart for I-10 Eastbound, San Antonio (October 28, 1999).

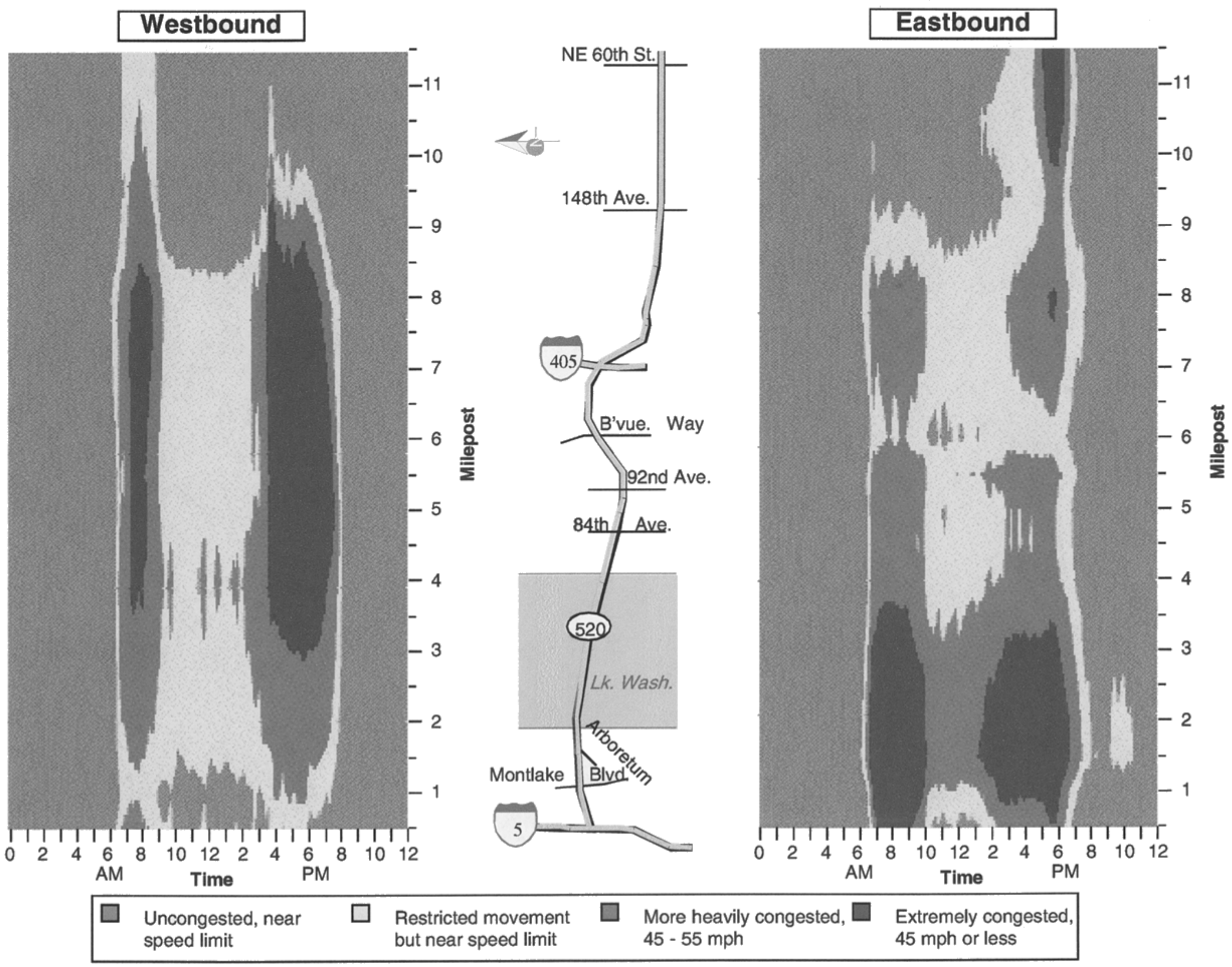

Figure 5. Example of Speed Contour Chart for SR 520 in Seattle, Washington (1997 Weekday Average) (7).

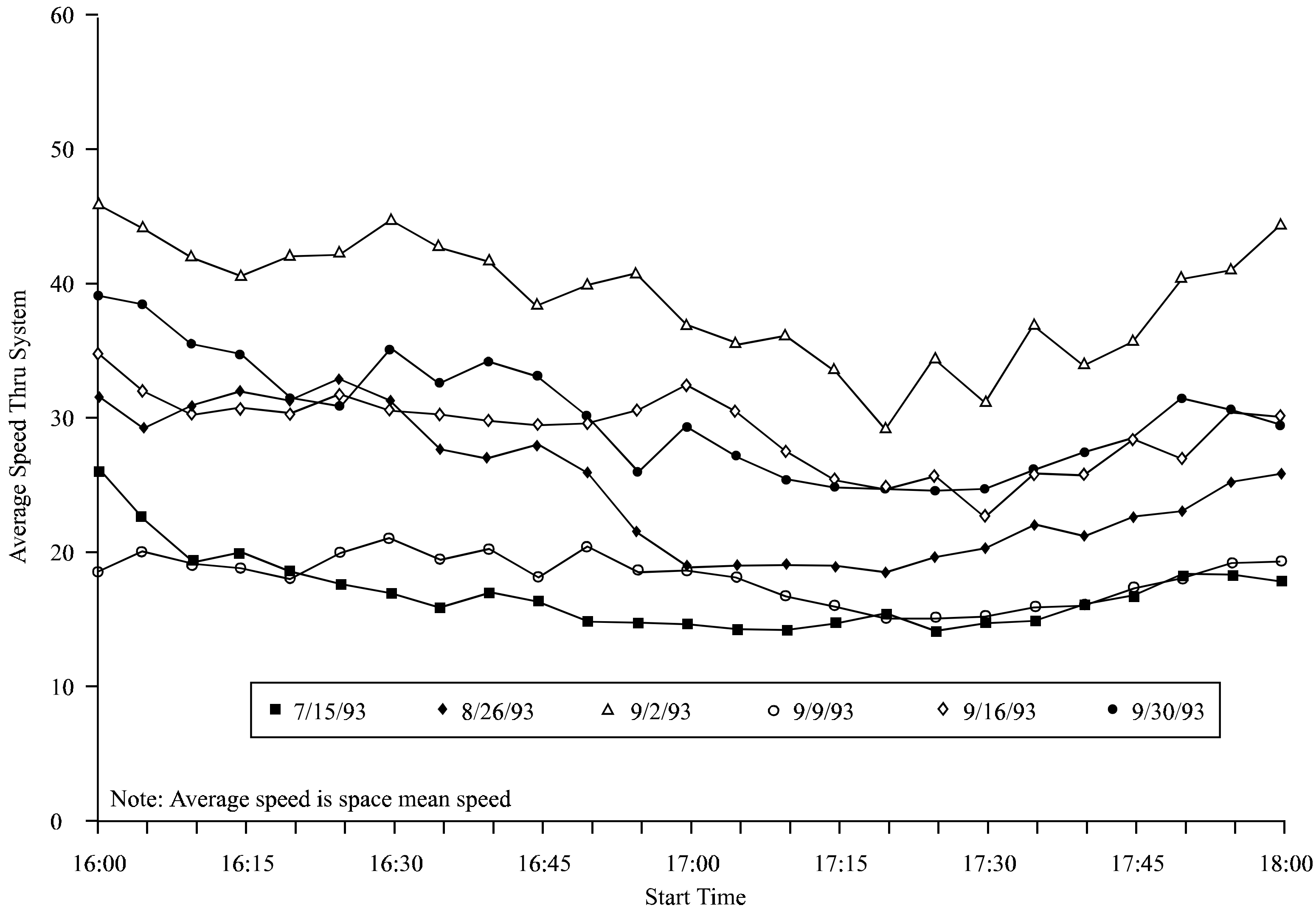

Figure 6. Example of Facility Speeds for Different Days and Departure Times for I-4 in Orlando, Florida.

(Figure courtesy of Rich Margiotta, Cambridge Systematics)

SYSTEM MEASURES

Table 4 summarizes system mobility performance measures suggested for use with ITS data. Figures 6 and 7 illustrate useful graphic displays of these performance measures.

Table 4. Summary of System Mobility Performance Measures.

Description System mobility measures characterize performance of an entire modal or multi-modal transportation system within defined political boundaries.
When/Where to Use these Measures System mobility measures are most useful to policy and decision-makers who may influence planning and/or programming of the transportation system in a particular region. They may also be useful to transportation professionals who wish to measure the impact of area-wide transportation improvements (e.g., regional traveler information, ozone alert days, etc.). System mobility measures may not correlate with travelers' experiences in the region depending upon their regular pattern of trips or commutes; however, some travelers may use a system measure to compare their travel experiences in one city to another city.
Recommended Measures • travel rate index • system reliability (variability of or confidence intervals for system measures) • total vehicle or person delay (vehicle- or person-hours) • total and congested person-miles of travel (PMT) • total and congested person-hours of travel (PHT) • % of congested travel (PMT, PHT) • % of congested roadway (miles, lane-miles)
Other "Specialized" Measures • congestion severity index (vehicle-hours of delay per 1,000 VMT) • lane-mile duration index (lane-mile-hours of delay) • system congestion index (current person-hours delay per PMT/ annual average person delay-previous year)
Methods of Display There are several ways to display system mobility performance measures. Basic tabular displays can be used to present the above measures over time and at different locations. The following are some useful graphic displays: Figure 7 – chart of daily travel rate index for a month, example from San Antonio, Texas Figure 8 – chart of system reliability (travel rate index confidence intervals), example from San Antonio, Texas Figure 9 – chart of travel time contours from downtown, example from Atlanta, Georgia

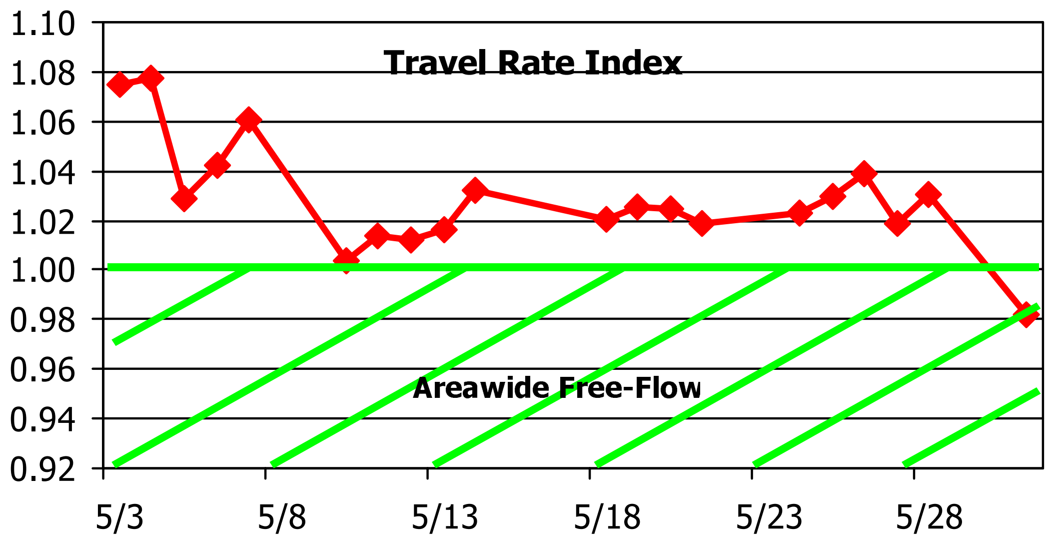

Figure 7. Travel Rate Index for all TransGuide Freeways in San Antonio (May 1999).

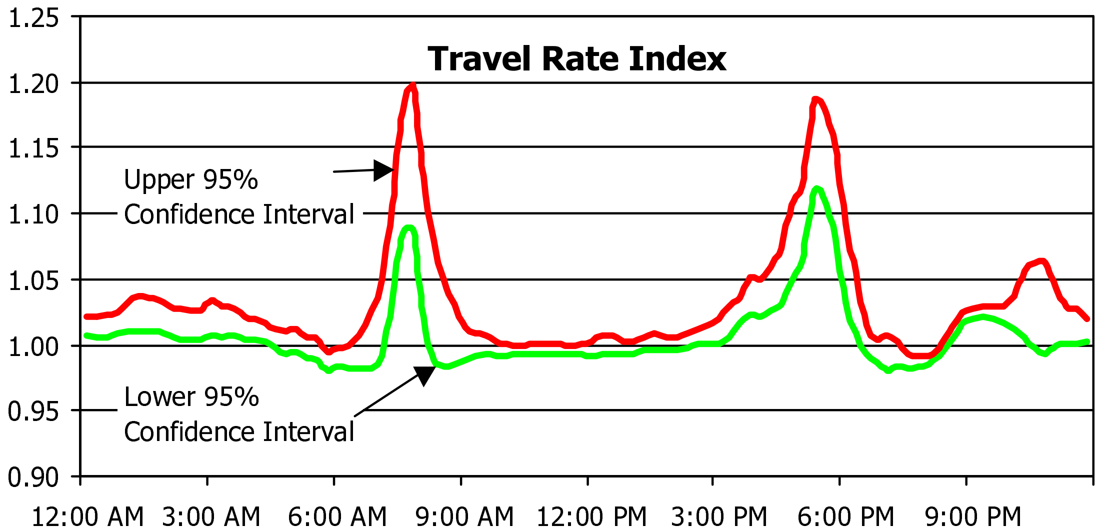

Figure 8. System Reliability (Variability of Travel Rate Index) of all TransGuide Freeways in San Antonio (May 1999).

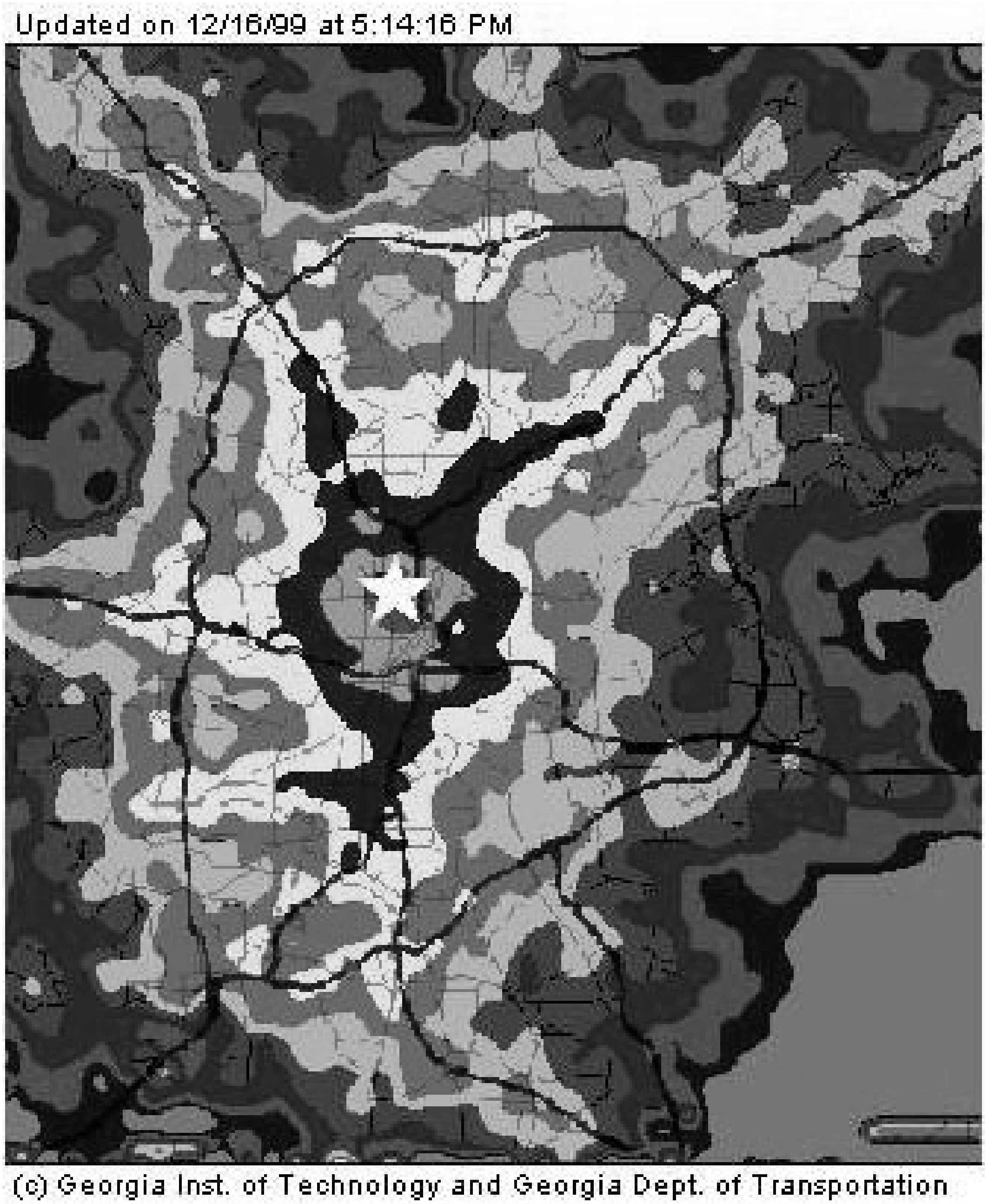

Figure 9. Example of Travel Time Contours Illustrating Mobility from Downtown Atlanta, Georgia.
(Image courtesy of Georgia Tech web site, http://traffic.ce.gatech.edu/datawarehouse/)

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

The TransLink research team provides the following conclusions:

- **Quality control is necessary to ensure the accuracy and integrity of data collected by traffic management centers.** It is desirable to implement quality control procedures as close to the data collection source as possible (i.e, local controller). Numerous quality control algorithms exist for checking loop detector data at the local controller level. TTI researchers have performed preliminary tests on a controller-based algorithm that uses estimated vehicle length, and the test results appear promising. TTI researchers have also developed some simple quality control rules for screening TransGuide detector data that can be applied after the data has been gathered from local controllers.

- **Performance measures are desirable to measure system performance and improve transportation operations.** This report presents performance measures for three levels of analysis: point/link, facility, and system. The performance measures can easily be calculated using speed and volume data currently collected by nearly all traffic management centers in Texas. The report also presents useful displays of performance measures that can be used to identify and illustrate traffic problems and potential improvements.

- **Performance measures generated from archived ITS data are already being used by operations personnel for a variety of applications.** Three common examples are given below, although many more potential applications exist.

  1. TranStar generates an annual report of ITS benefits for decision-makers in the TranStar partner agencies and other elected officials (*8*). The TranStar annual report includes the measure of vehicle delay, which is calculated using travel time data originally collected by the automatic vehicle identification (AVI) system for traffic monitoring.

  2. The Washington State Department of Transportation (WsDOT) recently evaluated a new ramp metering algorithm using travel time-based performance measures and charts similar to those shown in Figures 4 and 5 of this report (*9*). WsDOT also uses these performance measures to evaluate the operational effectiveness of HOV lanes and make decisions about alternative HOV operating schemes (see Figure 1) (*10*).

  3. The California Department of Transportation (Caltrans) is developing a Performance Measurement System (PeMS) that they plan to use as the basis for planning and programming operations improvements (*11*). PeMS calculates numerous travel time-based performance measures from detector data currently collected in the Los Angeles and Orange County districts.

The TransLink research team makes the following recommendations:

- **Standard practices for traffic management centers should incorporate basic quality control checks (such as those shown in this report).** These quality control checks may be most easily implemented in the software at the traffic management center; however, consideration should also be given to including similar quality control checks on all local controllers.

- **Operations staff at selected traffic management centers should experiment with using the recommended performance measures as operations planning tools.** The experiment could provide evidence of the usefulness of performance measures in improving operations.

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