Developing and Implementing Statewide Operations Performance Measures in the State of Oregon: Methodology and Application for Using HERS-ST and Archived Real-time Data

by

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ABSTRACT

Many state or regional transportation agencies have an interest in implementing operations performance measures. The Oregon Department of Transportation (ODOT) recently sponsored research performed by the Texas Transportation Institute (TTI) to identify performance measures that are sensitive to operational treatments and to test a methodology for quantifying these measures statewide. Operations performance measures will help ODOT in the identification of transportation needs related to operations programs and to evaluate benefits of operations programs. The methodology, which uses Highway Economic Requirements System—State Version (HERS-ST) and archived real-time data (when available), was successfully tested on several corridors. It provides the flexibility of incorporating different operational treatments that reduce travel delay. It also allows for adjusting the delay reduction percentages for a given operational treatment to reflect local conditions if studies are available for a specific corridor(s).

This paper describes the work performed by TTI and ODOT to develop the measures, test the methodology on case study corridors and suggest additional analysis and data enhancements to improve the methods prior to statewide implementation. This research effort identified numerous data elements that could be further analyzed with sensitivity analysis, inventoried, calibrated, and/or quality controlled to fine-tune the methodology output. Updates to HERS-ST that would enhance the methodology are also discussed.

The experiences documented in this research will prove valuable to any state DOT or regional transportation agency that is investigating statewide or regional implementation of operations performance measures. In particular, the research identifies issues with typical traffic data sources and what may be necessary to update them for use in a statewide methodology such as the one presented here. Necessary sensitivity analyses are also identified.

INTRODUCTION AND PROJECT OBJECTIVES

Many state or regional transportation agencies have an interest in implementing operations performance measures. The Oregon Department of Transportation (ODOT) recently began an effort to develop a set of statewide operations performance measures and a methodology to implement the measures. Operations performance measures will help ODOT in the identification of transportation needs related to operations programs and to evaluate benefits of operations programs. The Texas Transportation Institute (TTI) assisted in developing the measures and methodology, which is described in this paper. ODOT assembled a Technical Advisory Committee (TAC) made up of individuals from ODOT sections of traffic management, transportation planning and analysis, transportation data, traffic operations, and internal audit/performance measures. The TAC also included individuals from the metropolitan planning organization (MPO) in Portland (Metro) and the Eugene/Springfield area (Lane Council of Governments), academia, and the local Federal Highway Administration (FHWA) office. The TAC provided valuable comment and direction to the effort as there was representation from all areas within ODOT as well as transportation agencies external to ODOT—all agencies that have a high interest in operations performance measures and methods to estimate them.

The project had three goals:

1. To identify a small set of mobility performance measures that serve the needs of operations performance measures.
2. To develop, test and document methods for implementing these measures at a system and corridor level so that ODOT staff are able to fully implement the measures and methodology statewide.
3. To make recommendations for future improvements to data gathering and measures estimation to improve the measures' accuracy, geographic precision, and sensitivity to operations programs.

The implementation of the measures and methodology will allow ODOT decision-makers to compare operations program benefits with other programs (e.g. safety, bridge, maintenance). The project provides the operations program with a process for estimating benefits, and this will help the program to identify places for additional study and investment. Finally, these methods will help define the return on operational investments. TTI developed a spreadsheet of computations for each test corridor to illustrate the application of the methodology and performance measure estimation.

This paper describes the work performed by TTI and ODOT to develop the measures, test the methodology on case study corridors and suggest additional analysis and data enhancements to improve the methods prior to statewide implementation. The experiences documented in this research will prove valuable to any state DOT or regional transportation agency that is investigating statewide or region-wide implementation of operations performance measures. In particular, the research identifies issues with typical traffic data sources and what may be necessary to update them for use in a methodology such as the one presented here.

DEFINITION OF OPERATIONS PERFORMANCE MEASURES

The TAC had five desired criteria for the operations performance measures selected for the study. These criteria are as follows:

1. They should address state transportation policies such as the 1999 Oregon Highway Plan. The Oregon Highway Plan defines policies and investment strategies for the state highway system for the next 20 years (*1*).
2. They should be applicable to urban and rural settings.
3. They should be applicable at the transportation system level or a transportation corridor level.
4. They should allow ODOT to identify the location and relative magnitude of problems, the affects on travelers, and the effects of proposed operations programs.
5. They should be calculable using existing data and should be improvable incrementally with improving data collection efforts and calculation methods.

The TAC agreed upon six primary measures that are described in this paper and quantified in the methodology application. The measures are

1. Travel Time Index (TTI)
2. Travel Delay
3. Buffer Index (BI)
4. Volume-to-capacity Ratio (V/C)
5. Travel Time
6. Speed

These measures are described in more detail below. Additional discussion of the measures can be found elsewhere (*2-4*).

Travel Time Index (TTI)

The Travel Time Index is a comparison between the travel conditions in the peak period to free-flow conditions. The measure can be averaged for freeways and arterial streets using the amount of travel on each portion of the network. An average corridor value can be developed using the number of persons using each facility type (or modes) to calculate the weighted average of the conditions on adjacent facilities. The corridor values can be computed for hourly conditions and weighted by the number of travelers to estimate peak-period or daily index values.

The Travel Time Index in Equation 1 compares measured travel rates to free-flow conditions for any combination of freeways and arterial streets. Index values can be related to the general public as an indicator of the length of extra time spent in the transportation system during a trip. Vehicle travel or person travel (measured in miles traveled on each part of the system) can be used as the weighting factor. Equation 1 illustrates a relatively simple version of the calculation using vehicle-miles of travel (VMT), but person miles could also be used, as could a value of time calculation that incorporates person and freight travel. The value in Equation 1 indicates the ratio of peak travel time to free-flow travel time. The peak-period value is calculated as a weighted average for all travel (VMT) in the time period of interest.

$$\text{Travel Time Index} = \frac{\left(\dfrac{\text{Freeway Travel Rate}}{\text{Freeway Free-flow Rate}} \times \text{Freeway Peak Period VMT}\right) + \left(\dfrac{\text{Principal Arterial Street Travel Rate}}{\text{Principal Arterial Street Free-flow Rate}} \times \text{Principal Arterial Street Peak Period VMT}\right)}{\left(\text{Freeway Peak Period VMT} + \text{Principal Arterial Street Peak Period VMT}\right)} \qquad (1)$$

Travel Delay

Travel delay estimates the hours of extra time spent traveling as a result of congestion. It has the same attributes as the Travel Time Index because both measures are calculated in the same way—relative to a free-flow speed. Travel delay, however, may be more applicable in areas that target dense development patterns because it includes the distance traveled. The most basic form of travel delay is shown in Equation 2 as the difference between the actual and free-flow period travel times. When measured with ITS data, the actual travel time for a specific corridor can be calculated from the speed data. To obtain a system-level calculation, several corridors (freeway and arterial) can be summed to get the total delay in hours. Using a delay measure of hours per mile of road, hours per 1,000 miles traveled or hours per 1,000 travelers might be more meaningful to agencies at the corridor level, but the public may not understand these measures as it is difficult to relate to key decisions or travel experience. At the system/area level, annual hours of delay per person or per traveler might be readily understood and useful for agency evaluation purposes as well. It is sometimes desirable to calculate delay relative to some acceptable or target speed or travel time. This might allow the recognition of the inevitable nature of some congestion, while providing a way to target severe congestion problems.

$$\begin{matrix}\text{Delay}\\ \text{(hours)}\end{matrix} = \left[\begin{matrix}\text{Actual}\\ \text{Travel Time}\\ \text{(minutes)}\end{matrix} - \begin{matrix}\text{Acceptable}\\ \text{Travel Time}\\ \text{(minutes)}\end{matrix}\right]\left[\frac{1\ \text{hour}}{60\ \text{minutes}}\right] \qquad (2)$$

Buffer Index (BI)

The Buffer Index (BI) expresses the amount of extra "buffer" time needed to be on-time for 95 percent of the trips (e.g., late for work on one day per month). It is a measure of trip reliability. Indexing the measure provides a time and distance neutral measure, but the actual minute values could be used by an individual traveler for a particular trip length. With ITS data, the index is calculated for each road or transit route section and a weighted average is calculated using vehicle-miles or more desirably person-miles of travel as the weighting factor (Equations 3 and 4).

For each section of roadway or transit route…

$$\text{Buffer Index} = \left[\frac{\begin{array}{c}\text{95th Percentile Travel Rate}\\ \text{(in minutes per mile)}\end{array} - \begin{array}{c}\text{Average Travel Rate}\\ \text{(in minutes per mile)}\end{array}}{\begin{array}{c}\text{Average Travel Rate}\\ \text{(in minutes per mile)}\end{array}} \times 100\% \right] \tag{3}$$

$$\begin{array}{c}\text{Weighted Average}\\ \text{of Buffer Index for}\\ \text{Several Sections}\end{array} = \frac{\left(\text{VMT}_{\text{section 1}} \times \text{BI}_{\text{section 1}}\right) + \left(\text{VMT}_{\text{section 2}} \times \text{BI}_{\text{section 2}}\right) + \ldots}{\text{VMT}_{\text{section 1}} + \text{VMT}_{\text{section 2}} + \ldots} \tag{4}$$

The calculations consist of calculating the average and 95th percentile travel time for each section of roadway for each combination of days and time periods. The Buffer Index values of each road section can be calculated and then combined to calculate the Buffer Index for a corridor or area. Vehicle-miles (or person-miles) of travel are used to weight each section Buffer Index value (Equation 4).

The Texas Transportation Institute (TTI) has been investigating the relationship between the Travel Time Index and Buffer Index where real-time ITS data are available from numerous cities in the 2002 Mobility Monitoring Program (MMP) (*3*). A second-order polynomial best-fit line and corresponding prediction intervals have been calculated for the conditions of 3-lanes or less and 4-lanes or more by direction on freeways. For illustration purposes, Figure 1 shows the scatter-plot of the available data by city for 3-lanes or less in one direction, including Portland data. The Texas Transportation Institute continues to investigate the relationship between the TTI and BI on freeways as more data become available. There are far fewer locations with real-time data on arterial facilities than freeway locations. The research team has identified some data in Houston as well as some potential data in Colorado, Michigan, and Minneapolis that might be useful in the future to develop future relationships between TTI and BI on signalized facilities.

Volume-to-Capacity Ratio

The volume-to-capacity ratio (V/C) measures the relative levels of volume and capacity for a section of roadway. V/C has been recognized in the 1999 Oregon Highway Plan as a mobility standard by highway classification and type. V/C does not directly measure how the individual traveler is affected by congestion, and it can be difficult to communicate to the general public for this reason. It estimates the relationship between the physical infrastructure (supply) and traffic volume (demand).

Travel Time and Speed

At the initial TAC meeting, the suggestion was made to add travel time and speed to the measures used in the study. Travel time will be added as it shows the affect of land use and transportation service improvements. Average speed will also be added because it is easy for audiences to understand. The measures of travel time and speed will be readily available due to the computation of the other four operations performance measures.

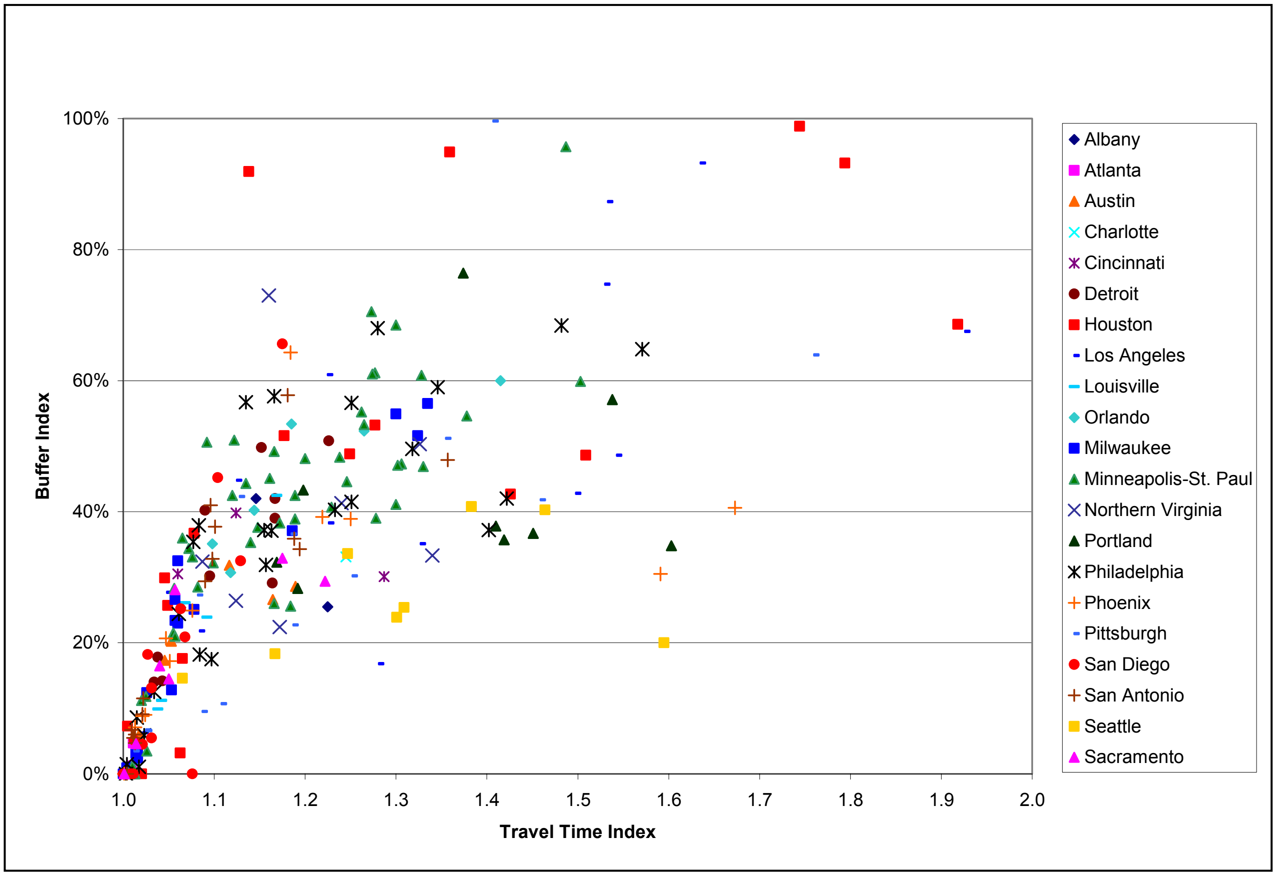

FIGURE 1 Urban areas with freeway sections having 3 or less lanes.

DESCRIPTION OF HERS-ST AND ODOT DEFICIENCY ANALYSIS HISTORY

Description of HERS-ST

The Highway Economic Requirements System—State Version (HERS-ST) is a highly sophisticated highway deficiency analysis model that allows states to identify long-term investment needs and performance, and to evaluate the impacts of alternative highway investment levels on the state highway system (*5*). The HERS-ST model simulates highway condition and performance levels and identifies deficiencies through the use of engineering principles. The model then identifies a set of alternative improvements to correct each deficiency and determines a benefit-to-cost ratio for each potential improvement. Subsequently, the most economically attractive improvement for each deficiency is accepted, the improvement implemented based on available funding, and the resulting improved performance condition for each section is re-evaluated and output by the model.

The HERS-ST model is an enhanced version of the HERS model which has been used by FHWA since 1995 to provide estimates of investment requirements for the nation's highway system in the biennial Condition and Performance (C&P) Report to Congress (*6*). The structure of HERS-ST is identical to the national version of HERS, and the input requirements for both make use of the highway section dataset in the Highway Performance Monitoring System (HPMS) format. The user-friendly Graphical User Interface (GUI) and certain input/output features are the primary difference that distinguishes HERS-ST from HERS-National. For this study, HERS-ST was used to obtain speed and delay estimates to which subsequent delay reduction was applied for operational improvements.

ODOT Deficiency Analysis History

ODOT has made extensive use of the deficiency analysis models for over a dozen years for planning analysis, beginning with the Highway Performance Monitoring System Analytical Process (HPMSAP or AP) in the early 1990's. Most recently, Oregon used the AP model to provide supporting data for Corridor Plans (1993-1996), the

Roads Finance Study (1992-1993), the Oregon Transportation Initiative (1996), and the Oregon Highway Plan (1997-1999).

During the data analysis process for the 1999 Oregon Highway Plan, the Planning Section began using a customized version of HERS modeling software, known as HERS-OR, to develop the modernization needs for the study. ODOT has been an active participant in the HERS-ST Developer's Group.

Oregon has used the HERS-ST model in several non-traditional deficiency analysis studies. The capacity analysis FORTRAN code was rewritten in Visual Basic (VBA) so that the HERS-ST capacity analysis could be utilized for ODOT's Congestion Management System (CMS) as a stand-alone procedure used outside the formal HERS-ST environment. In the same manner, the free-flow speed (FFS) calculations within HERS-ST were rewritten in R-code to facilitate the capture of free-flow speeds for passenger cars and trucks independently on each roadway section. Additionally, a value of travel time report was developed using the equations from HERS-ST to estimate the hourly value of time for drivers, passengers, and freight in Oregon.

The purpose of the study upon which this paper is based was to develop operation performance measures (OPM) based on internal HERS-ST calculations for the existing system condition. The operations performance measures study was not concerned with future analysis, which identifies deficiencies and evaluates defined funding budget constrains (i.e., analysis for which HERS-ST is typically used).

METHODOLOGY FOR MEASURE CALCULATION INCLUDING ARCHIVED REAL-TIME DATA AND HERS-ST

As illustrated in Figure 2, the methodology begins by identifying the roadway sections for analysis. The methodology is applicable to freeways, rural highways, and signalized arterial sections. The results of the roadway section analysis for a given performance measure can be weighted together by VMT for the corridor, regional or system estimates. If ITS data are available and reliable, they provide the ability to directly measure free-flow speed and operating speed for the roadway section of interest. Methods for quality control and analyzing ITS data have been documented as part of the Mobility Monitoring Program (*3*).

If ITS data are not present, and for statewide consistency, HERS-ST can be used to estimate the section-by-section free-flow speed (FFS). HERS-ST computes FFS internally as a function of pavement roughness, maximum allowable speed on the curve, and the posted speed limit. The speed model is further described in Chapter 4 of the HERS-ST Technical Manual (*7*). HERS-ST estimates incident delay either through a queuing procedure or as a function of internally-estimated crash rates depending upon the facility type. Recurring delay is estimated through section-by-section capacity-based computations. For a majority of facility types, delay is internally computed for three periods/directions—1) peak period, peak direction, 2) peak period, counter-peak direction, and 3) the off-peak period. Delay is allocated to these periods/directions as a function of HPMS-like inputs such as AADT, number of through lanes, K (peak hour) and D (directional) factors, and shoulder widths. For signalized arterials, the number and type of intersections are also considered in the delay computation. The interested reader can find the equations for delay in Appendix F of the HERS-ST Technical Report (*7*). The result is the "baseline" delay indicated in Figure 2. HERS-ST computes an average effective speed given the delay estimate and the free-flow speed. Speeds for each of the three periods in each direction are computed in this manner.

"Credit" for operational treatments is then applied to the delay estimates obtained from HERS-ST. The operational treatments include surveillance cameras, ramp metering, freeway service (incident) patrols, and signal progression. The delay reduction factors are the same as those used in the TTI Urban Mobility Report for these operational treatments, and they are applied to either the recurring and/or incident delay (*8*). Table 1 shows the percent delay reduction tables by congestion level for the operational improvements. On a section-by-section basis, "credit" for any combination of these operational treatments can be given for the congestion level observed (ADT/lane). The adjusted delay, along with the FFS, can then be used to obtain the new peak-period speed with the operational treatments present. From this speed information, with and without the operational treatments, the subsequent performance measures can be obtained. V/C is estimated using the capacity estimate output by HERS-ST. It should be noted that any operational treatments could be added to the methodology if the delay reduction by congestion level can be estimated.

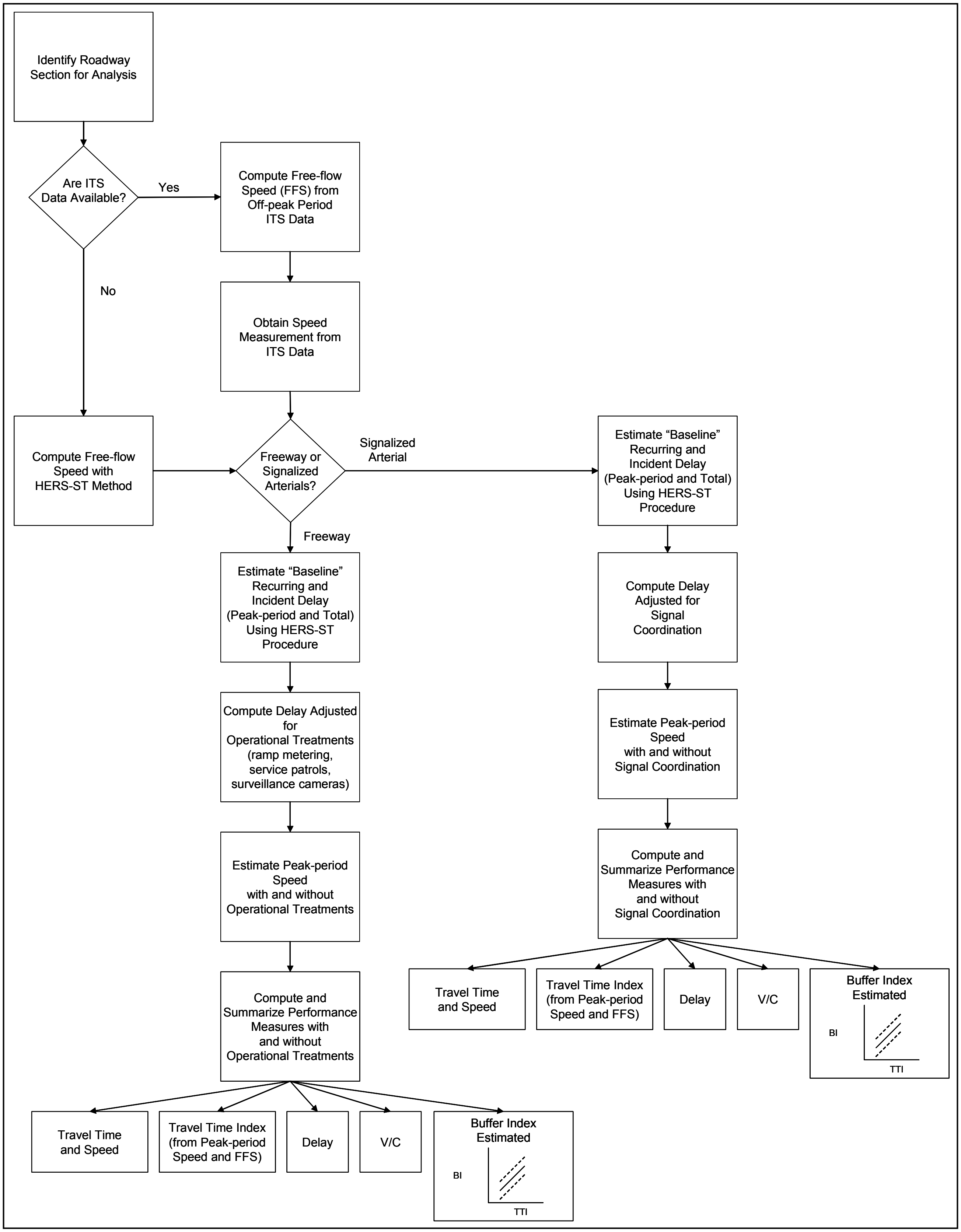

FIGURE 2 Methodology to estimate statewide operational performance measures.

TABLE 1 Delay Reduction Benefits of Operational Treatments (Adapted from Reference *8*)

Ramp Metering (reduces freeway recurring and incident delay)					
Ramp Metering	**Congestion Level[1]**				
	Uncongested	**Moderate**	**Heavy**	**Severe**	**Extreme**
No ramp meters	0	0	0	0	0
Isolated, pre-timed, centrally controlled or traffic responsive (recurring/incident)	0	peak=0 off-peak=0	peak=5.6 off-peak=0	peak=11.0 off-peak=7.3	peak=12.4 off-peak=11.6

Surveillance Cameras (reduces freeway incident delay)					
Surveillance Cameras	**Congestion Level[1]**				
	Uncongested	**Moderate**	**Heavy**	**Severe**	**Extreme**
No cameras	0	0	0	0	0
Coverage amount					
25%	0	2.5	3.0	3.5	3.5
50%	0	2.5	3.0	3.5	4.0
75%	0	3.0	3.5	4.0	4.5
100%	0	3.0	3.5	4.0	5.0

Service Patrols (reduces freeway incident delay)						
Service Patrols	**Patrol Cycle (miles each vehicle covers)**	**Congestion Level[1]**				
		Uncongested	**Moderate**	**Heavy**	**Severe**	**Extreme**
No patrols		0	0	0	0	0
If 100% of the system is covered	More than 10 miles	0	18	21	24	28
	Less than 10 miles	0	25	28	31	35

Signal Progression (reduces principal arterial recurring and incident delay)						
Signal Progression	**Signal Density (signals per mile)**	**Congestion Level[2]**				
		Uncongested	**Moderate**	**Heavy**	**Severe**	**Extreme**
No coordination	–	0	0	0	0	0
Traffic actuated	Less than 3 per mile	0	0.5	0.5	0.5	0.3
	3 to 6 per mile	0	2.2	2.1	1.9	1.5
	More than 6 per mile	0	2.1	2.1	1.5	1.1
Progressive (centralized or real-time)	Less than 3 per mile	0	1.0	1.0	0.9	0.7
	3 to 6 per mile	0	5.0	4.8	4.5	3.6
	More than 6 per mile	0	6.1	6.0	4.6	3.1

[1]Freeway congestion levels: Below 15,000 ADT/lane (Uncongested), 15,000 to 17,500 ADT/lane (Moderate), 17,501 to 20,000 ADT/lane (Heavy), 20,001 to 25,000 ADT/lane (Severe), and over 25,000 ADT/lane (Extreme)
[2]Principal arterial congestion levels: Below 5,500 ADT/lane (Uncongested), 5,501 to 7,000 ADT/lane (Moderate), 7,001 to 8,500 ADT/lane (Heavy), 8,501 to 10,000 ADT/lane (Severe), and over 10,000 ADT/lane (Extreme)

OREGON TEST CORRIDORS AND AVAILABLE DATA

The methodology for performance measure development was tested on four corridors: an urban transportation system, an urban limited access/expressway corridor, an urban signalized arterial corridor, and a rural corridor. It is important to note that the primary intent of testing the methodology on the four corridors is to identify the necessary data elements, applicable factors, and to demonstrate the process. The activities were not focused on getting the "correct answer" for the performance measures in a given corridor. Therefore, improvements to data elements and measure estimation from the test corridors are the primary results (see project objective 2 and 3 in the first section of this paper).

Table 2 summarizes the characteristics of the corridors selected for testing the methodology as well as the available data for each location. It identifies the case study corridor locations, project limits and the available data for use in the project. The corridors in the Portland area have incident data available through the Advanced Traffic Management System (ATMS) while the other corridors have incident data summarized in the computer-aided dispatch (CAD) system. Where available, speed data sources for comparison to the HERS-ST model estimates are shown in Table 2. These include the ITS data along I-5 and automatic traffic recorder (ATR) speed data along the

Bend Parkway and the Salmon River Highway. Straight-line charts and video logs were obtained for all of the corridors to assist in locating cross-streets, geometry, ramp location and other specific features along the corridors. Archived weather data are also available from the weather station at milepost 72 along US 26, which is approximately 2 miles west of the I-5 corridor. Crash data were obtained for all the corridors.

TABLE 2 Characteristics of Oregon Test Corridors

Corridor Type	Location	Limits (length)	Primary Available Data
Urban Transportation System	I-5 (Portland)	MP 293.11 to 299.77 (6.7 miles)	• ATMS incident information • Nearby weather station • Straight-line charts and video log • Speed and volume (ramp meter data from mainline and ramps) • Crash data • HERS-ST/HPMS-like data inputs
	Barbur Boulevard (99W) (Portland)	MP 1.33 to 7.81 (6.5 miles)	• ATMS incident information • Straight-line charts and video log • Crash data • HERS-ST/HPMS-like data inputs
Urban Limited Access/ Expressway Corridor	Bend Parkway (US97) (Bend)	MP 133.86 to 141.26 (7.4 miles)	• CAD incident information • Speed and volume (2 ATR stations) • Straight-line charts and video log • Crash data • HERS-ST/HPMS-like data inputs
Urban Signalized Arterial	Powell Boulevard (US26) (Portland)	MP 0.75 to 2.95 (2.2 miles)	• ATMS incident information • Straight-line charts and video log • Crash data • HERS-ST/HPMS-like data inputs
Rural Corridor	Salmon River Highway (ORE 18) (Lincoln City to Valley Junction)	MP -0.41 to MP 24.07 (24.5 miles)	• CAD incident information • Speed and volume (ATR station) • Straight-line charts and video log • Crash data • HERS-ST/HPMS-like data inputs

TEST CORRIDOR FINDINGS

This section describes the findings of the methodology application on each test corridor. The focus is on the findings for each test corridor related to the analysis and suspicious data rather than the actual values of performance measures that were computed. The data and procedural findings should be most valuable to state or local areas that might be interested in implementing a similar process. They are the focus of this paper.

It is important to note that some of the reported roadway inventory information appeared suspect for some sections along the test corridors. For example, freeway ADT/lane values along I-5 up to 33,000 per lane were found. Similarly, ADT/lane values over 10,000 were found along the signalized arterial Powell Boulevard. These values were later found to be the result of erroneous data coding. This point is made to clarify that the performance measures were calculated and the methodology was developed using these roadway inventory data inputs. The data values would require further screening and investigation prior to statewide implementation of such a methodology. These values do not negate the validity of the methodology approach, but rather point to the importance of data quality and review prior to application.

After applying the methodology to the case studies, it was generally found that the methodology using HERS-ST appears to be a promising technique to obtain operational performance measures. The sections below identify key findings for each test corridor. They primarily relate to improving the data sources, and they allude to the need for additional sensitivity analysis. The findings are expected to be typical of what many state and local implementers would likely find in doing a similar analysis and review of data sources.

Urban Transportation System (I-5 and Barbur Boulevard)

I-5 and Barbur Boulevard were investigated together to test a system application because they are parallel facilities. The following highlight the key findings of the application of the data elements and methodology on the urban transportation system (I-5 and Barbur Boulevard).

Data Element Observations

1. As indicated earlier in this section, there were some suspiciously high ADT/lane sections along I-5.
2. The archived real-time ITS data were found to contain -999 values for speed and volume at times throughout the entire day along the I-5 corridor. Typically, 10 to 30 percent of the data were removed for suspicious combinations of speed and volume or because of these negative values. According to the system documentation, the negative values occur when the 15-minute period is malfunctioning. On-going research by Portland State University has noted that the negative values also occur when there is a zero count. Therefore, it is not clear exactly what causes the negative values, and when.
3. With the ITS data, it is also not clear how the data are aggregated in the field from the 20-second polling cycle to 15-minutes. For example, speeds must be weighted by the number of vehicles in each polling cycle to obtain an accurate measure of the speed over a 15-minute period. Volumes should also be factored-up when they are missing in a polling period, and it is not clear if this is occurring. Meta data (data about the data) would be useful to assist the analyst in understanding the quality of each 15-minute aggregation of data.
4. The average speed by ramp meter station and 15-minute period of time were averaged across the 2002 data year. It was found that speeds sometimes did not decrease in the peaks and/or were found to be relatively similar throughout the day. This would indicate a possible calibration error in the data.
5. The HERS-ST results were compared to the ramp meter data and the VMT and ADT/lane values were approximately 17 percent different (HERS-ST higher). The data questions above may constitute some of the differences in these values. For example, the number of lanes could be incorrect in some cases for the HERS-ST data. The ITS data may be missing some data because the -999 speed and volume data were removed. It is also important to note the very different origins of the two types of data—modeled (HERS-ST) and real-time (ITS). ITS data only measure those vehicles that are present on the roadway, and some travelers may not take the trip if there is an incident or they may find an alternate route. This differs from modeled data that can include a higher demand than experienced on the roadway.

Methodology Observations

1. The methodology included a delay reduction for incident patrols, surveillance camera, and ramp metering on I-5 along with signal progression along the signalized Barbur Boulevard. The delay computed by HERS-ST was used as a "base" delay (see Figure 2) to which the delay reduction factors were applied.
2. Free-flow speed was computed as lower than the peak-period speed for a few sections along I-5. This indicates either an error in the R-code used to compute the FFS or perhaps an error in the HERS-ST software that does not check for this possibility.
3. Delay was focused around the signalized intersection locations on Barbur Boulevard because HERS-ST does a section-by-section analysis. However, it is believed that for the entire corridor the results are more intuitive because there is relatively low delay on the non-signalized sections. This suggests that the HERS-ST model is likely more adequate for corridor analysis and estimates rather than for particular sections. This is particularly true for signalized sections. This is intuitive given the original purpose for which HERS was developed.

Urban Limited Access/Expressway Corridor (Bend Parkway)

The Bend Parkway was selected for the urban limited access/expressway corridor. The key findings of the methodology application are noted as follows:

1. The primary data element observation was related to the automatic traffic recorder (ATR) data. ATR data were obtained for 51 days for comparison to the HERS-ST methodology. The speed and volume estimates from HERS-ST and the ATR were fairly similar although they were from different years. To ensure an accurate comparison, the ATR would need to be calibrated and all geometric conditions would need to be coded into HERS-ST as they appear in the field. ATR data are a good source of speed data, and ODOT is relatively unique in its collection of speed data from ATRs. They provide a valuable source of speed data. It was noted that there was relatively low variability in the ATR data obtained from the Bend Parkway. Either this is a relatively low-variability corridor or perhaps there is a need to calibrate the ATRs.

2. The primary methodology observation related to operational improvements of service patrols and actuated signals. The maximum ADT/lane along the Bend Parkway was around 9,000 and benefits for service patrols are not realized until the ADT/lane values are over 15,000 (start of "Moderate" congestion level in Table 1). Delay reduction benefits for actuated signals were provided in the vicinity of signalized intersections. The delay reduction benefits were too small to indicate a change in the peak-period speed due to the operational treatments. However, the methodology showed how the delay reduction could be applied on a section-by-section basis.

Urban Signalized Arterial (Powell Boulevard)

Similar difficulties that had been identified along previous case study locations were found along Powell Boulevard. These included the following:

1. The primary data element observation was a few sections that had ADT/lane values that were suspiciously high. The ADT/lane values were as high as 25,000 for some of the unsignalized sections. This indicates either an incorrect number of lanes or an ADT volume that is too high or some combination of both.
2. The methodology observation to note is that delay reduction benefit was given for actuated signals. As with the Bend Parkway, the delay reduction benefit was not substantial enough to indicate a change in the peak-period speed.

Rural Corridor (Salmon River Highway)

The final corridor was the rural corridor along the Salmon River Highway, and key data and methodology findings are as follows:

<u>Data Element Observations</u>

1. ATR speed data were obtained for the corridor over a two-week period. Low variability was again observed in the data, and again it would be valuable to ensure the ATR is calibrated as it could be a valuable data source.
2. An investigation of the K and D factors along this corridor was performed to identify changes to these values for holidays and weekends compared to weekdays. It would appear that the K and D factors could be updated to reflect differences for different travel periods. Further analysis of the K and D factor would be necessary for a more thorough sensitivity analysis.

<u>Methodology Observations</u>

1. Delay reduction benefit was given for the presence of roving patrols that provide motorist assistance. A recent evaluation of rural incident patrols was used to identify the percent reduction due to the patrols (*9*). This illustrated the ability to incorporate local knowledge and studies into the methodology. The delay reduction was too small to indicate a change in the 24-hour or peak-period speed; therefore, the performance measures remain unchanged due to the presence of the operational treatments. However, the methodology was found useful for the analysis.
2. One reason for the lack of an observable difference in the performance measures after the application of the delay reduction factors is because the corridor is relatively uncongested. It would appear that the relatively low travel levels are adequately handled during the incident conditions; therefore, relatively low values of incident delay are realized on each section.

As indicated previously, it was generally found that the methodology using HERS-ST appears to be a promising technique to obtain operational performance measures. However, there is a need to further investigate data quality issues as well as additional sensitivity analysis to better understand HERS-ST. These items are noted in the next section.

RECOMMENDATIONS AND SUMMARY OF LESSONS LEARNED FROM METHODOLOGY APPLICATION

In general, the methodology provides a framework for estimating operations performance measures given operational treatments. It should be noted that for this analysis, the methodology included the effects of the existing operational treatments on the test corridors. The methodology could also be used to estimate the affect of future operational treatments. There are some improvements to both the input data elements and the methodology, and these items are noted in this section.

Data Improvement Areas to Enhance Methodology

HPMS-like Data—The analysis discovered several locations where the ADT/lane values seemed suspiciously high. A need was identified to review the databases from which the ADT and number of lanes data elements are located. The TAC also indicated an interest in revisiting traffic factors (K factor, D factor). It was suggested that an urban model could possibly be considered to obtain the K and D factors. There was discussion at the final project meeting that the input data along the study corridors could be cleaned up and re-run through HERS-ST.

ATRs—Oregon is relatively unique in obtaining speed data from ATRs. This study was assisted by obtaining ATR data in two places along the Bend Parkway and at one location along the Salmon River Highway. ODOT expressed interest in identifying additional ATR locations, ensuring they are calibrated, and identifying whether speed data can be obtained. It was noted that ODOT is doing an upgrade of ATR stations and some of the new stations can measure speed. The speed data can be used to calibrate or validate the estimates produced in this study.

Weigh-in-Motion (WIM) Stations—ODOT is working with the ODOT Motor Carrier Division to get their WIM data. This would also provide a source of data for calibrating or validating the estimates from this study.

Incident Data—Incident data for each of the study corridors were obtained and reviewed for analysis. The primary and secondary route designated in the ATMS incident data often had numerous ways of identifying a given road. Review of the data dictionary for the ATMS (Portland-area) incident management data indicates that the confirm time, primary milepost, secondary milepost, number of lanes affected, and estimated end time are not required data elements. Requiring these elements, as well as standardizing road names, would help ensure the most important incident data elements are included. Though the data are less extensive, the incident data in the CAD database include these data elements as time received, dispatch time, arrival time, and clear time as well as including the location of the incident by milepost.

Ramp Meter (ITS) Data—There is a need to better understand what constitutes a -999 speed and volume value. It is not clear to what extent this may be caused by equipment malfunction, incomplete 20-second polling data within the 15-minute period, or as a result of zero counts. It is also not clear how the data are being aggregated from the 20-second polling cycle to the 15-minute period level. Investigation of the 15-minute average speeds by station across the year had limited variability and indicated the need for calibration in some places. It was suggested at the TAC meeting that a communication overload may result in controllers not being polled every 20 seconds and, therefore, an error is reported. A need for meta-data (data about the data) along with each 15-minute data element to allow the analyst to understand the quality of the data being used was also identified.

Other data sources—This study also initiated discussion about what other data sources would be useful and where they may be located. There was discussion about the need to inventory where the different types of sensors (WIM, ATR, ITS, traffic signals) are located.

Further Analysis to Improve Methodology

Several analysis steps were discussed by the TAC that could be performed to improve the methodology. These are discussed as follows.

Weekend and Weekday Factors and HPMS Data—The study identified an interest in obtaining weekend and weekday factors, particularly along rural locations where there may be substantial differences. This was briefly investigated for the Salmon River Highway, and the D factor was found to be different for the weekend and weekday analysis. Sensitivity analysis in HERS-ST is necessary to investigate these differences further.

Local Conditions and Updated Factors—There is a need to obtain additional travel time and speed data to calibrate the model and the spreadsheet. It is possible that local knowledge and/or studies of specific corridors may suggest higher or lower delay reduction factors for different operational treatments. There may also be local knowledge of percent green time for signalized corridors in specific areas also. While the framework for the methodology is solid, it can be fine-tuned with local knowledge of this sort.

Data Quality Control—This study identified the need for necessary work to improve the quality of data sources such as the real-time ITS data and the incident data. Work is underway at Portland State University that is investigating the aggregation of data from the 20-second polling cycle to the 15-minute level. The need for cleaning and more consistently logging the ATMS incident data was also identified.

Longer Sections in HERS-ST—The TAC indicated that it would be useful to investigate the affect of longer sections of road on the output statistics. This would be a sensitivity analysis to identify how lengths of double or triple the current sections affect the delay values produced by HERS-ST because it performs a section-by-section analysis. This would be particularly useful for the affect of different influence areas for signalized intersections.

HERS-ST Needs to Improve Methodology

Several updates to HERS-ST that would enhance the methodology were identified as a result of this research. One TAC member noted that the next version of HERS-ST will output peak-period and off-peak period delay for a majority of facility types, rather than just 24-hour delay. It will also output the data on a section-by-section level, which will not require multiple sections to be batched. A batching process was required in this study. This included writing a program that would run each section of input to obtain output on each section. Obtaining peak-period and off-peak period VMT would also allow for weighting performance measure estimates for the corridor.

There is still a need for HERS-ST to output free-flow speed, although it may be easier to estimate correctly with the peak-period and off-peak period delay being output. It would also be beneficial if HERS-ST allowed the user to input local crash rate data into HERS-ST. Finally, it would be helpful if the presence of some of the operational effects could be incorporated directly into the HERS-ST model thus allowing HERS-ST to output speed and delay information with and without operational treatments present.

Additional Observations for Statewide Application

Keeping a Consistent Speed in the Statewide Application—Any statewide performance measure analysis should keep a consistent source of speed data (and subsequently computed performance measures) because this value will change over time, and it is important to understand the extent that this measure(s) is changing due to the measurement versus due to operational improvements. For example, if HERS-ST is the source for the measures, then the "HERS-ST Speed" should be kept from year-to-year as a data element. When supplemental speed information is available, they can be kept in the database next to the HERS-ST speed. There may even be speeds from more than one other source if different studies or local knowledge might be available. Other speed sources might include the real-time ITS data, floating car studies, ATR, etc. This would provide the opportunity to see trends not only in operational performance from year to year, but to also see how these speed values may differ by data source. This would allow for the calibration of the HERS-ST values with any other data sources that might be present.

Possible "Beta" Version Before Final Distribution—There were some concerns expressed by the TAC that unreliable data may be indicating that there is an operational problem (rather than an actual problem). To ultimately get a statewide methodology in place, identifying and fixing data issues such as those identified in this report are an inevitable part of the start-up process. It might be possible that the statewide implementation of the estimation procedures could be performed over a year or two or three and the results could be identified as "beta" or "prototype" to allow a review of the process over years and to allow for calibration of the results across years, and at different geographic locations, based on local knowledge or studies before the final "roll-out."

DISCUSSION AND CONCLUSIONS

The experiences documented in this research will prove valuable to any state DOT (or local transportation agency) that is investigating statewide or region-wide implementation of operational performance measures. In particular, the research identifies issues with typical traffic data sources and what may be necessary to update them for use in a methodology as presented here.

Many states or regional transportation agencies have an interest in implementing operations performance measures. ODOT recently sponsored research by the Texas Transportation Institute to identify performance measures that are sensitive to operational treatments and to test a methodology for quantifying these measures statewide. The methodology, which uses HERS-ST and real-time (ITS) data (when available), was successfully tested on several corridors and provides the flexibility of incorporating different operational treatments that reduce delay. It also allows for adjusting the delay reduction percentages for a given operational treatment to reflect local conditions if studies are available for a certain corridor(s).

The operational performance measures identified for this effort are the Travel Time Index, Buffer Index, Travel Delay, V/C ratio, Speed, and Travel Time. Figure 2 of this paper illustrates a methodology for quantifying these measures using archived real-time (ITS) data when they are available and reliable as well as using HERS-ST for estimating the measures. When real-time data are available, the performance measures can be quantified directly. However, in the absence of these data, and for statewide consistency, HERS-ST appears to be a useful method to provide a "baseline" recurring and incident delay to which delay reduction factors can be applied. After the delay reduction factors have been applied on a section-by-section basis by ADT/lane for the existing operational treatments, the adjusted delay, along with the free-flow speed can be used to compute the speed (and subsequent performance measures) when operational treatments are present. This paper explains that delay reduction factors currently used in TTI's Urban Mobility Report were used to compute the delay reduction. Along one corridor (Salmon River Highway), local knowledge from a recent research effort was used for the delay reduction. This demonstrates the flexibility of the methodology to local studies. The methodology and approach presented here is anticipated to be valuable to states and regional areas interested in tracking operations performance measures.

This research effort identified numerous data elements that could be reviewed, inventoried, calibrated, updated, and/or cleaned to fine-tune the methodology output. The data sources include the HPMS-like data used as an input to HERS-ST, ATRs, ramp meter (ITS) data, WIM, and incident records. This paper described unique issues identified with each of these data sources, and how they could be improved to facilitate the methodology. Additional sensitivity analyses within HERS-ST that could improve the methodology were also identified. Finally, updates to HERS-ST that could improve the methodology are identified. All of the insights into data issues and future analysis needs illustrate typical expectations that any state or region might encounter when performing a similar effort.

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