**13 Planning of Traffic and Movement**

# Using Archived ITS Data to Improve Regional Performance Measurement and Travel Demand Forecasting

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## ABSTRACT

In the Portland metropolitan region, Metro is a unique elected regional government and also the metropolitan planning organization (MPO). Metro engages in some of the most advanced travel demand forecasting and transportation planning efforts in the U.S., and also provides targeted transportation performance measurements to its 1.3 million residents in three counties and 25 cities in the Portland, Oregon, region. Portland State University has partnered with Metro over the past several years to assist in improving the performance reporting and travel demand modeling by providing linkages to real-time freeway surveillance data through a new regional data archive—PORTAL (the Portland Oregon Regional Transportation Archive Listing). The objective of this paper is to describe how, working closely with Metro, the PSU research team has developed new performance metrics that can be directly incorporated into Metro's annual transportation system reporting. In addition, the paper will describe how the regional travel demand forecasting model has been improved using real-time freeway flow and speed data for the Highway 217 Corridor Study. By updating the Metro route assignment algorithm with recent, measured speed/flow data and developing new travel time/delay functions, the model has been shown to produce more realistic freeway travel characteristics. As more intelligent transportation systems (ITS) data become available, these examples can be extended to other cities and regions in the future.

## INTRODUCTION

In cooperation with the Oregon Department of Transportation (ODOT) and other regional partners, the Portland Regional Transportation Archive Listing (PORTAL, located at http://portal.its.pdx.edu) was recently inaugurated via a direct fiber optic connection between ODOT and Portland State University (PSU). In July 2004, the data archive "went live," receiving 20-second data from the 436 inductive loop detectors comprising the Portland area's Advanced Traffic Management System (ATMS).

In early 2004, just prior to the inauguration of PORTAL, researchers at the Portland State University (PSU) Intelligent Transportation Systems (ITS) laboratory worked with Metro, the MPO for the Portland metropolitan area, to improve the volume delay functions used in the regional travel demand forecasting model. This specific experiment focused on Highway 217. ODOT provided one week of loop detector data from April 14, 2002 to April 20, 2002. This paper first discusses the volume delay functions previously used by Metro. This is followed by a description of the methodology for using the week of loop detector data to develop new volume delay functions that more accurately represent actual freeway conditions. The next section of the paper discusses new performance metrics developed by Metro and PSU researchers that can be directly incorporated into Metro's annual transportation system reporting.

## METRO TRAVEL DEMAND MODEL DESCRIPTION

Metro uses a typical four step model: trip generation, trip distribution, mode choice, and trip assignment. In the final step, the trips are iteratively distributed over the available transportation links until equilibrium is established. The trip assignment process relies upon a volume delay function, which is a specified relationship between the volume of vehicles on a link and the expected amount of time required to traverse that link.

Prior to working with PSU, Metro used standard volume-travel time relationships from the United States Bureau of Public Roads (BPR) *Traffic Assignment Manual (1,2).* The BPR, which later became the Federal Highway Administration, used these functions historically to make transportation decisions for the entire country. Regional variations in highway performance may exist which are not accounted for, and it is reasonable to assume that the characteristics of automobiles and the behavior of drivers have changed significantly since these functions were created.

Perhaps more importantly, recent developments in vehicle technology and transportation operations such as freeway ramp metering may have deeply altered the performance characteristics of vehicles on our highways. These original BPR functions modeled a steady degradation of highway speeds as the volume of traffic approaches capacity. Recent observations indicate that our current more efficient use of transportation facilities may cause speeds to remain much more consistent as volume increases, and there is evidence that highway capacities may have actually increased. The hope in this study was that ATMS data could serve the same role for highways that probe vehicle tests had for arterial roads and provide some model of road performance without relying on these theoretical relationships.

Metro worked closely PSU researchers to use archived loop detector data to improve the accuracy of the volume delay functions used for Highway 217 in the regional travel demand model. The previous volume delay functions used as model inputs for Highway 217 were modifications of the BPR function. The generalized BPR function has the following form:

$$f_{BPR}(x) = 1 + (x)^{\alpha} \qquad \text{where} \quad x = \frac{v}{c} \tag{1}$$

Metro used a slightly modified version of the BPR congestion function in their EMME/2 model:

$$f_{EMME/2}(x) = 1 + 0.15\left(\frac{v}{0.75c}\right)^{\alpha} \tag{2}$$

Setting equation 6 equal to equation 7 and solving for *x* results in:

$$x = \sqrt[\alpha]{0.15}\left(\frac{1}{0.75}\right)\left(\frac{v}{c}\right) \tag{3}$$

Metro used an alpha value of 7 to represent freeway segments in the model. When α = 7, solving for *x* in equation 3 results in:

$$x = 1.0168\left(\frac{v}{c}\right) \tag{4}$$

Equation 2 adequately represents the relationship between travel time and volume when the volume/capacity ratio is between 0 and 1. Realistically, volumes should not exceed the actual capacity of the road for an extended amount of time. However, during the trip assignment process, the function values for v/c ratios of 5 or greater are sometimes necessary in calculations to converge to an equilibrium trip assignment. With an alpha value of 7, equation 2 increases rapidly where volume/capacity is above 1. This causes inefficiencies in model convergence.

To address this inefficiency in model convergence, Metro used a conical volume delay function:

$$f_{CONICAL}(x) = 2 + \sqrt{\alpha^2(1-x)^2 + \beta^2} - \alpha(1-x) - \beta \tag{5}$$

where: $x = \frac{v}{c}$

and: $\beta = \frac{2\alpha - 1}{2\alpha - 2}$ (when α = 7, $\beta = \frac{13}{12} = 1.0833$)

Inserting $\beta = 1.0833$ and $x = 1.0168\left(\frac{v}{c}\right)$ into equation 5 results in:

$$f_{CONICAL}(x) = 2 + \sqrt{49(1 - 1.0168\frac{v}{c})^2 + 1.1735} - 7.1176\left(\frac{v}{c}\right) - 8.0833 \tag{6}$$

When volume/capacity is between 0 and 1, the conical function represented by equation 6 is very similar to the BPR function in equation 2. This similarity is shown in Figure 1. However, for values above 1, the BPR function increases much more rapidly. The conical function is superior because it has the desirable characteristics when volume/capacity is near and below 1, but has the advantage converging more efficiently due to the characteristics when volume/capacity > 1.

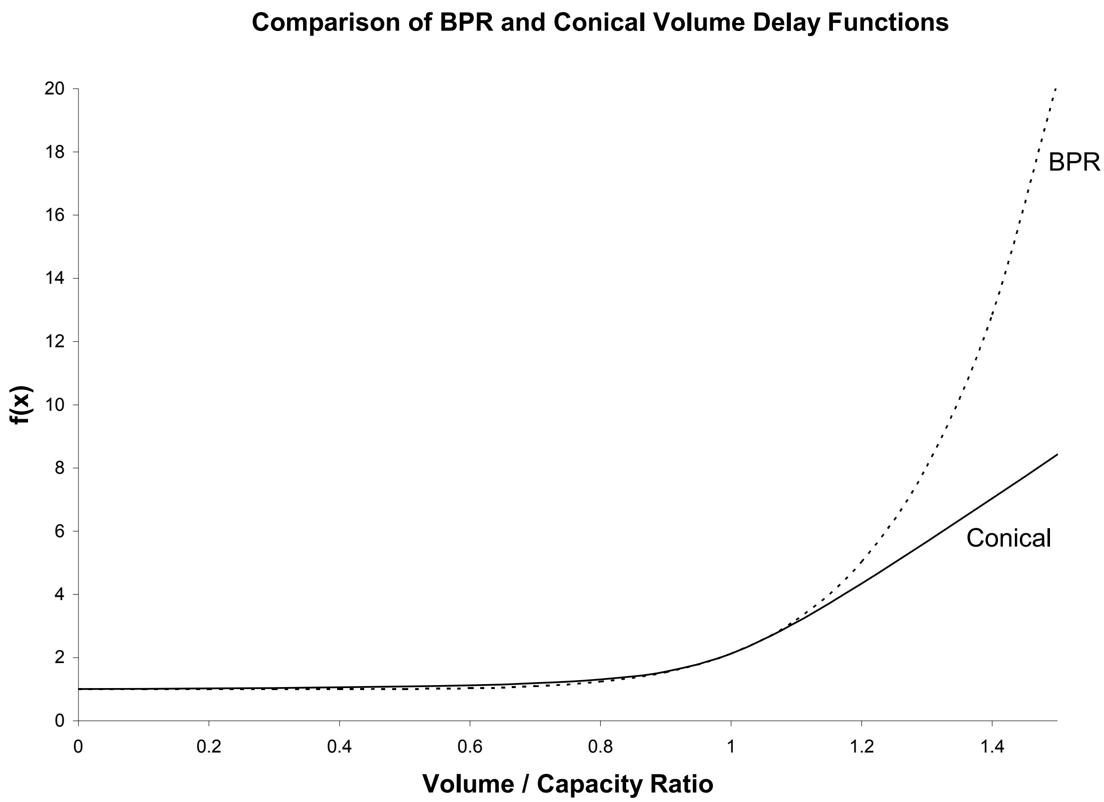


**FIGURE 1: Conical vs. BPR Volume Delay Functions**

Although the use of a conical volume delay function improves the convergence times of trip assignment, it does not necessarily accurately represent traffic characteristics on Highway 217. Regional variations in highway performance may exist which are not accounted for, and it is reasonable to assume that the characteristics of automobiles and the behavior of drivers have changed significantly since the BPR functions were devised. Metro therefore wanted to employ the use of loop detector data to create volume delay functions that more accurately reflected the actual road conditions.

## VOLUME AND CAPACITY VALIDATION

The study of Highway 217 occurred prior to the development of PORTAL. PSU researchers did not yet have access to a continuous stream of loop detector data. ODOT provided a week of loop detector data, from April 14, 2002 to April 20, 2002. These data were loaded into an Access database.

There were a number of known issues with loop detector data from the Portland area that had been uncovered by previous studies. For example, when no vehicles passed a detector during a 20 second sample period, the detector reported an error code rather than a zero volume. Since zero volume records were not necessary for this study, they were removed from the working data set. After performing some quality control checks, it was determined that the first and last loop detector stations along Highway 217 were reporting error codes or invalid data during most of the study period. Because of these errors, these stations were eliminated from the study. Figure 2 shows an aerial photo of the study area with the loop detectors ultimately used.

The volume counts for each remaining detector in the study area were validated by Metro staff. They compared these volume counts with separate ground counts performed by ODOT. The counts from the database fell within 10 percent of the ODOT counts. Metro determined that this was within an acceptable range for validation *(3)*.

The capacity of each segment was taken to be the maximum 15 minute flow on each segment. There is some question as to whether these values should be referred to as 'capacities' since this word has a strong pre-established meaning. However, the results of this process appear to be the maximum sustainable volume of traffic on a particular segment, beyond which a breakdown in flow occurs. This capacity definition was determined to be acceptable for the purposes of this study by Metro staff.

## DETERMINING INFLUENCE AREAS

The resulting database table contained a week of high resolution information about traffic on Highway 217, sampled at discrete points along the length of the highway. For the purpose of travel demand forecasting, these point measurements need to be extrapolated to lengths of highway that can be represented as links in the model. These representative segments are often referred to as the influence areas of the detectors. The lengths of these influence areas are important values because the loop detectors cannot directly provide travel time information; travel times must be estimated by dividing segment length by speed.

For this study, each detector was assumed to represent the traffic conditions on both the segment of road extending halfway to the next upstream station and the segment extending halfway to the next downstream station. Where no next station existed, the detector's influence extended to the end of the highway. The position and length of influence areas can be easily calculated because the database provides a table specifying the position along the road (milepost) of each detector. See Figure 3 for a visual representation of the defined segment influence areas for the detectors.

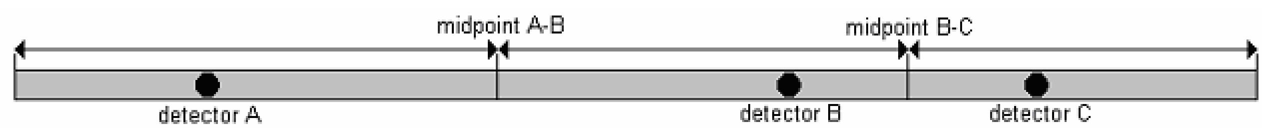


**Figure 3: Loop detector defined influence areas**

## PASSENGER CAR EQUIVALENCE ADJUSTMENT

Volumes in the travel demand model are expressed in passenger car equivalents (PCE). Real highway traffic consists of a mix of vehicle types, so the standard vehicle is taken to be a typical passenger car and all heavier, larger, or slower vehicles are represented as the number of passenger cars displaced by their vehicle type given the local terrain and road conditions. These larger vehicles tend to both occupy more roadway space and, particularly in hilly terrain, create downstream gaps in traffic which are left unfilled.

It is technically possible to classify vehicles by length using inductive loop detectors. Unfortunately, the firmware in the Portland area detectors are not yet programmed to perform this function, so vehicle classification information was not available with the same resolution as the rest of our data. Instead, ODOT State Highway Inventory Reports were used to estimate vehicle mix for this highway *(4)*. Data were available for from December 31, 2001 at milepost 3.02 in the southbound direction of Highway 217. Table 1 shows the results of these data.

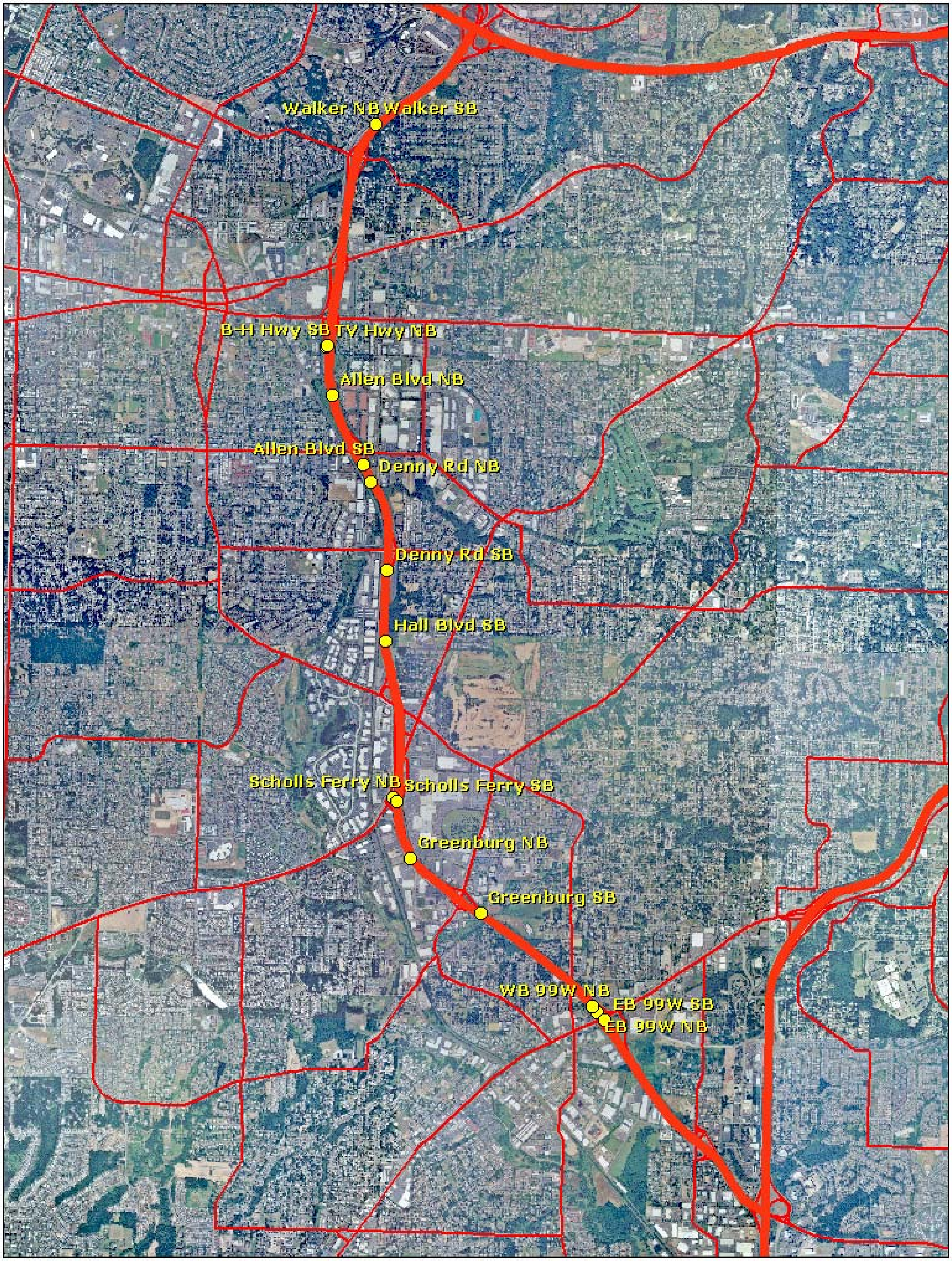


**FIGURE 2: Aerial photo of study area showing arterials, highways, and loop detectors**

**TABLE 1: Vehicle classification counts for Oregon Highway 217, December 31, 2001**

| Vehicle Class Code | Vehicle Class | Vehicle Class Volume | Daily Traffic Count | Vehicle Class Pct |
|---|---|---|---|---|
| | **Light Vehicles** | | | |
| 1 | Motorcycles | 427 | 115,301 | 0.37% |
| 2 | Passenger Cars | 93,416 | 115,301 | 81.02% |
| 3 | Other Two-Axle, Four-Tire Single Unit Vehicles | 12,429 | 115,301 | 10.78% |
| | **Total** | **106,272** | 115,301 | **92.17%** |
| | **Heavy Vehicles** | | | |
| 4 | Buses | 450 | 115,301 | 0.39% |
| 5 | Two-Axle, Six-Tire, Single-Unit Trucks | 4,105 | 115,301 | 3.56% |
| 6 | Three-Axle Single-Unit Trucks | 1,280 | 115,301 | 1.11% |
| 7 | Four or More Axle Single-Unit Trucks | 104 | 115,301 | 0.09% |
| 8 | Four or Fewer Axle Single-Trailer Trucks | 1,706 | 115,301 | 1.48% |
| 9 | Five-Axle Single-Trailer Trucks | 680 | 115,301 | 0.59% |
| 10 | Six or More Axle Single-Trailer Trucks | 208 | 115,301 | 0.18% |
| 11 | Five or fewer Axle Multi-Trailer Trucks | 173 | 115,301 | 0.15% |
| 12 | Six-Axle Multi-Trailer Trucks | 58 | 115,301 | 0.05% |
| 13 | Seven or More Axle Multi-Trailer Trucks | 265 | 115,301 | 0.23% |
| | **Total** | **9,029** | 115,301 | **7.83%** |

The study used a PCE of 1.2, from the Highway Capacity Manual for trucks traveling on level terrain (*5*). The overall heavy vehicle correction factor is:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)} \qquad (12)$$

Where:

$P_T$ = proportion of trucks (combinations plus single units) from inventory, expressed as a decimal

$E_T$ = passenger car equivalents

As shown in Table 1, 7.83 percent of all vehicles were heavy vehicles. When $P_T$ = 7.83 and $E_T$ = 1.2, equation 12 gives a PCE correction factor of 1.016. All vehicle counts in the data set were multiplied by this correction factor for consistency with other portions of the demand model.

## ANALYSIS

The trip distribution process in EMME/2 specifically requires functions relating the volume/capacity (V/C) ratio on a link to the travel time over that link. The first step to reaching this end goal of our analysis was to develop a relationship between PCE flow and travel time.

For each detector individually, all reported 20-second volume-speed pairs were grouped together regardless of time of observation. All volumes were then multiplied by a factor of 180 to convert the reported 20-second counts to equivalent hourly flows. A travel time was determined for each data point by dividing the segment length that the detector represented by the reported speed.

Because the 20-second volume figures are integer values, the equivalent hourly rates are naturally quantized to multiples of 180. The resulting flow – travel time pairs can therefore be sorted into about sixteen 'bins' based on these different hourly flows. For each of these bins, the average and standard deviation of the reported travel times was calculated and plotted. At this point in the study, flows were divided by an assumed capacity of 2400 vehicles per hour to allow presentation of the data in a form similar to that required by the demand model. The first of these plots is shown in Figure 4, including a regression curve derived from the data.

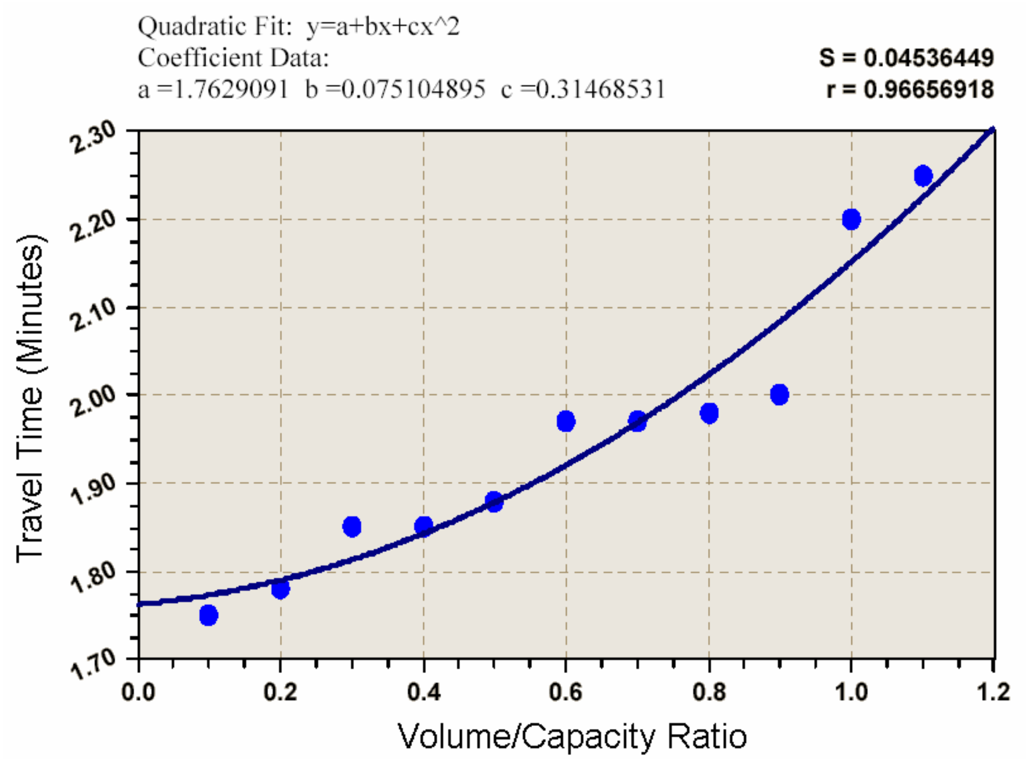


**FIGURE 4: Preliminary plot of V/C to travel time relationship at one detector assuming capacity of 2400 vehicles per hour.**

The use of true travel times based on the varying road segment lengths at different detector stations produced functions which were difficult to validate or compare with one another. To facilitate comparison, a normalized form of travel time was later used in which the inverse of the reported speeds was multiplied by 60, giving a result with units of minutes per mile. The resulting functions were more readily comparable, but could be converted to output true travel times by multiplying the normalized travel time by the segment length in miles.

## RESULTS

The resulting travel time vs. flow pairs were sorted into bins based on different hourly flows. For each of these bins, the average and standard deviation of the reported travel times were calculated and plotted. At this point, flows were divided by an hourly capacity to allow presentation of the data in a form similar to that required by the demand model. Figure 5 shows a plot of these data for a single detector on highway 217.

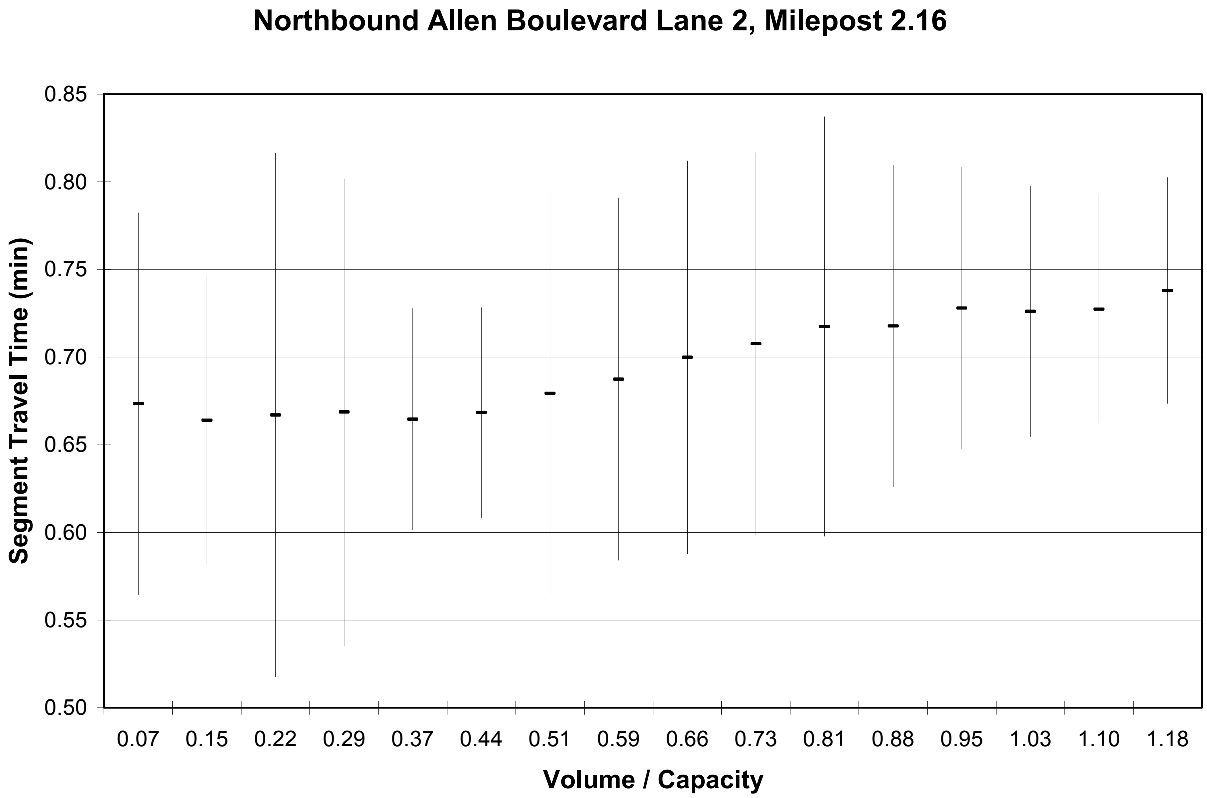


**FIGURE 5: Mean and Standard Deviation of travel time vs. volume/capacity ratio**

After plotting these data for each segment, Metro determined that there was some variation between the segments studied. They therefore decided to develop two third degree polynomial functions – a high and a low volume delay function. The resulting best fit functions have the following forms:

$$f_{HIGH} = 0.9664 + 1.2812x - 2.52x^2 + 2.5694x^3 \quad (7)$$

$$f_{LOW} = 0.9711 + 1.0624x - 2.8213x^2 + 2.6339x^3 \quad (8)$$

Figure 6 shows the above functions compared to the conical function described above.

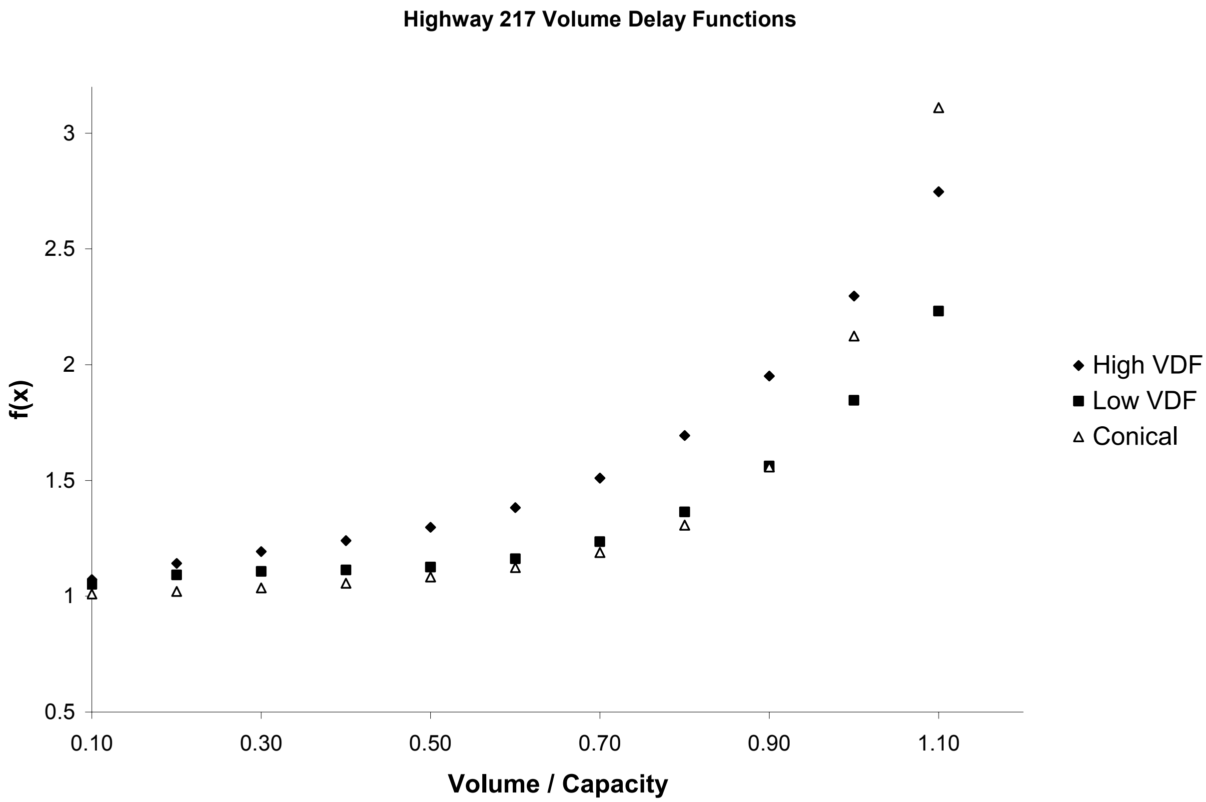


**FIGURE 6: Comparison of high and low volume delay functions to the conical function**

## METRO PERFORMANCE MEASURES

In March 2003, Metro released the *Performance Measures Report: An Evaluation of 2040 growth management policies and implementation (6)*. This marked the first explicit evaluation by Metro of Portland region's growth management polices. This report was developed to comply with Oregon State Law (ORS 197.301) which established nine performance measures which Metro must report to the Department of Land Conservation and Development a minimum of every two years *(6)*.

In part as a result of this recently passed Oregon State Law, Metro has an interest in working with PSU researchers to extract performance measures from PORTAL. In preparation for the 2004 Performance Measures Report, PSU provided Metro with two sample pieces of information from archived loop detector data. First was a color-coded map of average speeds for all Portland highways during the same peak period. The second item was a series of charts, one for each highway segment, showing the percentage of the time at each time of day that the segment fell below its acceptable level of service.

This study was also conducted prior to the full inauguration of PORTAL. This study used data from January 19, 2001 to January 30, 2001 and January 21, 2002 to January 30, 2002. Figures 7 and 8 show the average speed maps for the weekday PM peak for both 2001 and 2002. For purposes of this study, the PM peak period was defined as 4:30 to 5:30 PM.

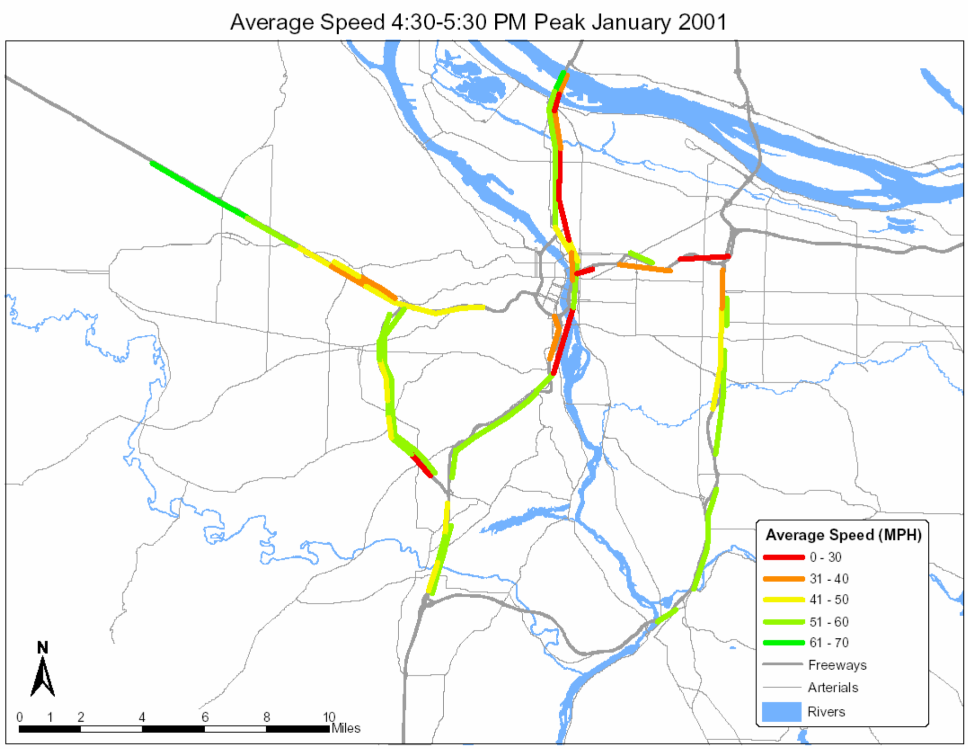


**FIGURE 7: Average PM Peak Speed, January 2001**

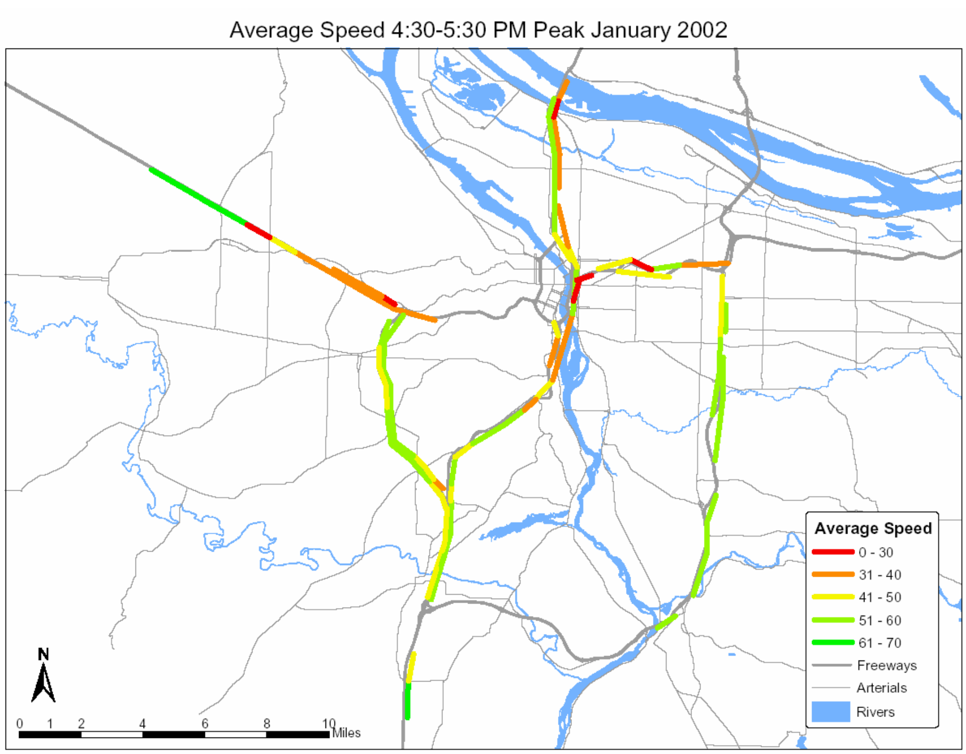


**FIGURE 8: Average PM Peak Speed, January 2002**

Figure 9 is a plot showing, at each time of day, the percentage of time that the segment on I-5 from Highway 217 to I-405 fell below its acceptable level of service of 30 MPH. Similar plots were created for each loop detector station in the freeway network.

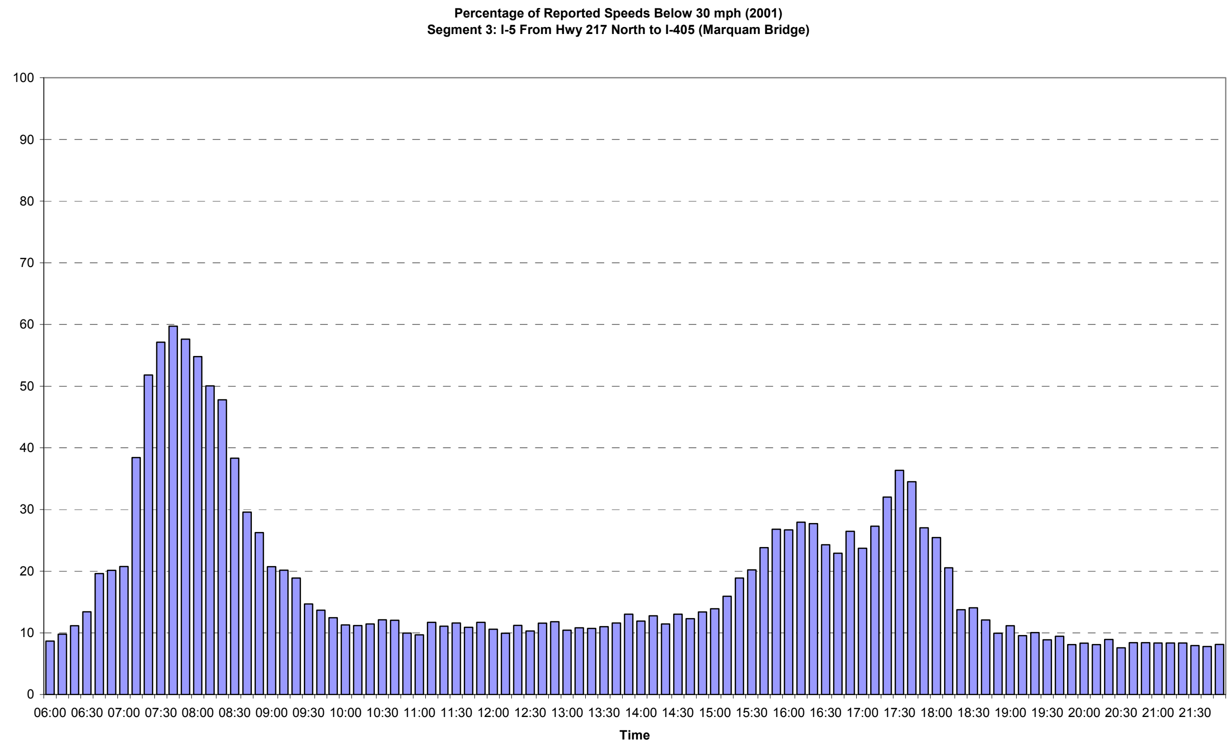


**FIGURE 9: Percentage of Reported Speeds Below 30 MPH, segment I-5 from Highway 217 North to I-405 (Marquam Bridge)**

## URBAN CONGESTION REPORTING

In 2002, the Federal Highway Administration identified urban congestion and performance metrics, which led to the establishment of a monthly Urban Congestion Report. This experimental report summarizes performance measures for ten cities in the U.S. For each city the following performance metrics are reported:

- Hours of Congested Travel
- Travel Time Index
- Buffer Index

Hours of congested travel is calculated by first determining the free flow travel speed, which is defined as the 15th percentile travel speed. A segment is considered congested if the travel time is 130% or greater than the free flow travel time. The Travel Time index is a measure of intensity of congested travel. It is the ratio between the average travel time and the free flow travel time. Buffer Index is a measure of congestion variability. It is defined as the ratio between the 95th percentile travel time and the free flow travel time for the segment.

PORTAL contains all the information necessary to calculate these performance metrics for the Portland region. A customized report page was developed on PORTAL specifically to extract this same information for the Portland region.

## CONCLUSION

Metro is pleased with the initial results of both the travel demand forecasting work and the performance measurements. PSU is currently working with Metro to develop new volume delay functions for the remaining freeway segments. Metro is also continuing their partnership with PSU to develop performance measures for the Portland region.

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