

Using Ground Truth Geospatial Data to Validate Advanced Traveler Information Systems Freeway Travel Time Messages

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ABSTRACT

The Oregon Department of Transportation (ODOT) maintains an extensive freeway surveillance, management, and traveler information system in the Portland metropolitan area. The statewide advanced traveler information system (www.tripcheck.com) provides traveler information across the state. Currently ODOT can calculate and report travel times for key freeway corridors using the existing surveillance infrastructure. Travel times can be reported via the TripCheck website and via variable message signs along the freeways. Additionally, Portland State University (PSU), working with ODOT and other regional transportation agencies, has developed PORTAL (www.portal.its.pdx.edu), a new transportation data archive that includes a means of automatically generating freeway travel time estimates using the ODOT data. This paper describes the preliminary results of an evaluation of ODOT's travel time reporting capabilities by comparing the ODOT travel time estimates with probe vehicle travel times. PSU students were employed to traverse eighteen directional corridor links in vehicles equipped with global positioning system (GPS) sensors in a variety of traffic conditions. The evaluation includes the development of a statistical bound on the validity of the current travel time algorithm used by the ODOT Region 1 Traffic Management Operations Center (TMOC). Recommendations will also be provided for the addition of new data collection instrumentation in the region.

INTRODUCTION

ODOT's Region 1 TMOC gathers data from 436 inductive loop detectors that make up the Portland region's Advanced Traffic Management System (ATMS). These detectors generate data (count, occupancy and speed) that are used in the day-to-day management of the regional transportation system. Once congested areas and incidents are identified, travelers can be alerted and rerouted using Advanced Traveler Information Systems (ATIS) and variable message signs (VMS).

ATIS, a critical component of regional intelligent transportation systems (ITS), have numerous applications and are deployed in an effort to improve and enhance the performance of transportation systems in terms of efficiency and safety. A primary application of ATIS is to provide the public with estimates of travel times between strategic points and along critical freeway segments and arterials. Most ATIS, such as ODOT's TripCheck, rely on existing freeway surveillance infrastructure for the data used to generate these estimates.

There is a certain degree of error inherent to the process of automatically generating travel time estimates from loop detector data. First, individual detectors and/or stations periodically malfunction and report inaccurate data or none at all. Second, detectors are

located at varying densities along individual freeway segments, leading to differing levels of interpolation. Third, the possibility exists that, subsequent to thorough analysis, the algorithm used by ODOT to calculate travel times could be improved upon.

The research described in this paper documents the preliminary results of an evaluation of the accuracy of ODOT's travel time estimates by comparing them with probe vehicle travel times representing "ground truth." The following section summarizes the preliminary analysis that was conducted to aid in the development of the data collection plan. The next section documents the experimental design process that was used to further define the specifics of the data collection effort. We then summarize the data collection and subsequent data analysis processes. Finally, the paper discusses some of the preliminary findings gleaned from the research conducted to date.

REGIONAL TRAVELER INFORMATION

TripCheck offers a variety of features designed to improve travel both within Oregon in general and with a particular emphasis on the Portland metropolitan region. Most significant among these is a color-coded speed map of Portland freeways that displays up-to-date average speeds for individual highway segments. Roadway incident maps, images from over 130 roadway cameras, localized weather information, statewide road condition reports, and a mileage calculator are all available to the TripCheck user as well.

In addition to TripCheck, ODOT has installed and maintains a number of variable message signs within the Portland area. These VMS display a variety of messages pertaining to freeway conditions, and three of them currently report estimated travel times on key corridors. The locations of the three VMS currently in operation are shown below in Table 1.

Table 1. Current VMS Locations

Sign ID	Milepost	Location
1	285.26	I-5 NB at Wilsonville
2	291.00	I-5 NB at Carmen
8	298.38	I-5 SB at Terwilliger



Figure 1. TripCheck Speed Map

PORTAL DATA ARCHIVE

In an effort to encourage the retention and subsequent utilization of ITS-generated data, the United States Department of Transportation (USDOT) revised the National ITS Architecture in 1999 to include the Archived Data User Service (ADUS). ADUS is designed to promote “the unambiguous interchange and reuse of data and information throughout all functional areas.” ADUS stipulates that ITS data be collected and archived for historical and secondary uses, as well as being made readily available (3).

In cooperation with ODOT and other regional partners, the Portland Regional Transportation Archive Listing (PORTAL) was inaugurated in July 2004 by way of a direct fiber-optic connection between ODOT and PSU. This data archive, developed at PSU, ingests and archives 20-second data provided by ODOT’s network of loop detectors. As part of a significant effort in the early stages of this project, an area of PORTAL was customized to compute the travel time on each of the eighteen identified freeway segments using a travel time algorithm identical to the one employed by ODOT’s TMOC. An image of this section is provided below in Figure 2.

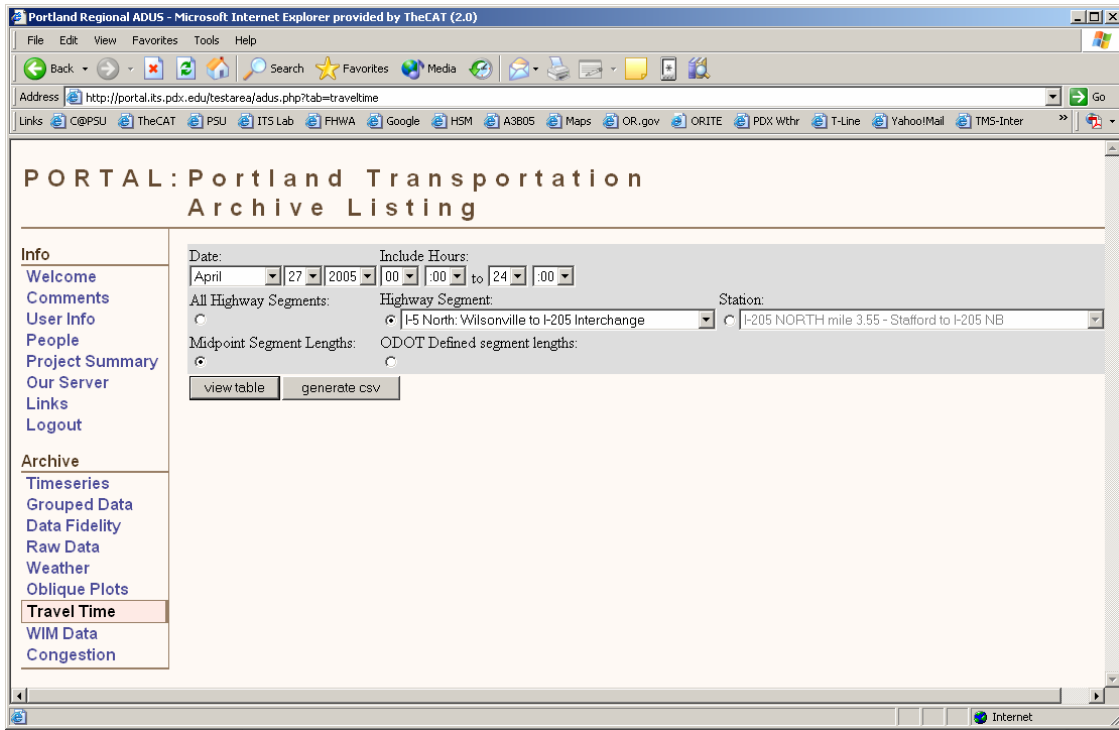


Figure 2. Portal Travel Time Measurement Interface

The PORTAL travel time area is capable of producing travel time estimates using either a traditional midpoint segment method or using a modified midpoint method currently employed on select freeway segments by ODOT. According to the traditional midpoint method, an influence area is assigned to an individual detector based on the locations of the midpoints between that detector and the next stations upstream and downstream. For the purposes of this study, therefore, traffic conditions attributed to a particular detector represent the conditions on the section of freeway extending from halfway to the next downstream station to halfway to the next upstream station. In the event that no ‘next’ station exists, the detector’s influence is extended to the end of the segment in question. Once these influence areas have been defined, their length can be easily calculated because each detector is linked to a specific position (milepost) along the freeway. At the inception of this study, ODOT provided the research team with a spreadsheet containing these milepost locations. PORTAL then combines these lengths with speed data generated by the loop detectors to calculate estimated travel times. Figure 3 below provides a visual representation of this method.



Figure 3: Loop detector influence areas as defined by the midpoint method

In addition to the traditional midpoint method outlined above, ODOT also uses a modified version on several freeway segments for which travel times are periodically reported by way of VMS. The three VMS that currently report travel times display comparisons for alternate routes to identical destinations. If the traditional midpoint method were used, these routes would tend to consist of one or more detector influence areas as well as fractions thereof. Therefore, in order to obtain accurate travel time estimates, ODOT has manually established the bounds of the routes in question for the purpose of VMS reporting.

METHODOLOGY

In consultation with agency staff from the ODOT Region 1 TMOC, eighteen directional freeway links were identified for analysis. Traffic patterns and the availability of loop detector data were taken into account in the selection of these links, and it was understood that maintenance or construction activities could lead to situations where one or more links would not be valid sources for data within the project timeline. These links are shown below in Table 2.

Table 2. Directional Freeway Links Identified for Analysis

Freeway Link	Freeway	Freeway Link Name
1	NB I-5	Wilsonville to I-205 Interchange
2		I-205 Interchange to 217 Interchange
3		217 Interchange to I-405 Interchange
4		I-84 Interchange to Interstate Bridge
5	SB I-5	Interstate Bridge to I-84 Interchange
6		I-405 Interchange to 217 Interchange
7		217 Interchange to I-205 Interchange
8	NB 217	I-5 Interchange to US26 Interchange
9	SB 217	US26 Interchange to I-5 Interchange
10	NB I-205	I-5 Interchange to Oregon City
11		Oregon City to I-84 Interchange
12	SB I-205	I-84 Interchange to Oregon City
13	EB I-84	I-5 Interchange to I-205 Interchange
14	WB I-84	I-205 Interchange to I-5 Interchange
15	EB US26	Helvetia to 217 Interchange
16		217 Interchange to 405
17	WB US26	I-405 Interchange to 217 Interchange
18		217 Interchange to Helvetia

Experimental Design

The intent of the experimental design task was to define the number of data collection runs, the number of days of data collection, and probe vehicle headways required to complete sufficient data collection for a statistically valid study. The experiment has been designed to meet these goals:

- Statistical comparison - using the probe vehicle data as “ground truth”, the experiment will produce estimates of the statistical bounds on the validity of the travel time estimates produced by the TMOC method
- Provide recommendations for improving travel time algorithms and estimates
- ***Determine the effect of added instrumentation*** - a survey of existing loop detector stations will be made along with an assessment of bottleneck locations in order to conduct sensitivity analyses toward estimating the potential for improving travel time estimates

As background for developing the data collection plan and sample size analysis, an analysis was performed on one week (April 4 - April 8) of predicted travel times from the PORTAL data for each of the 18 identified freeway links to identify travel time trends. The raw data were reviewed in an effort to isolate pertinent trends, and a scatter plot was prepared for each link for a visual representation. These data were used to estimate sample size and develop a data collection plan and times that will be able to capture the travel conditions required. A sample of these plots is shown in Figure 4.

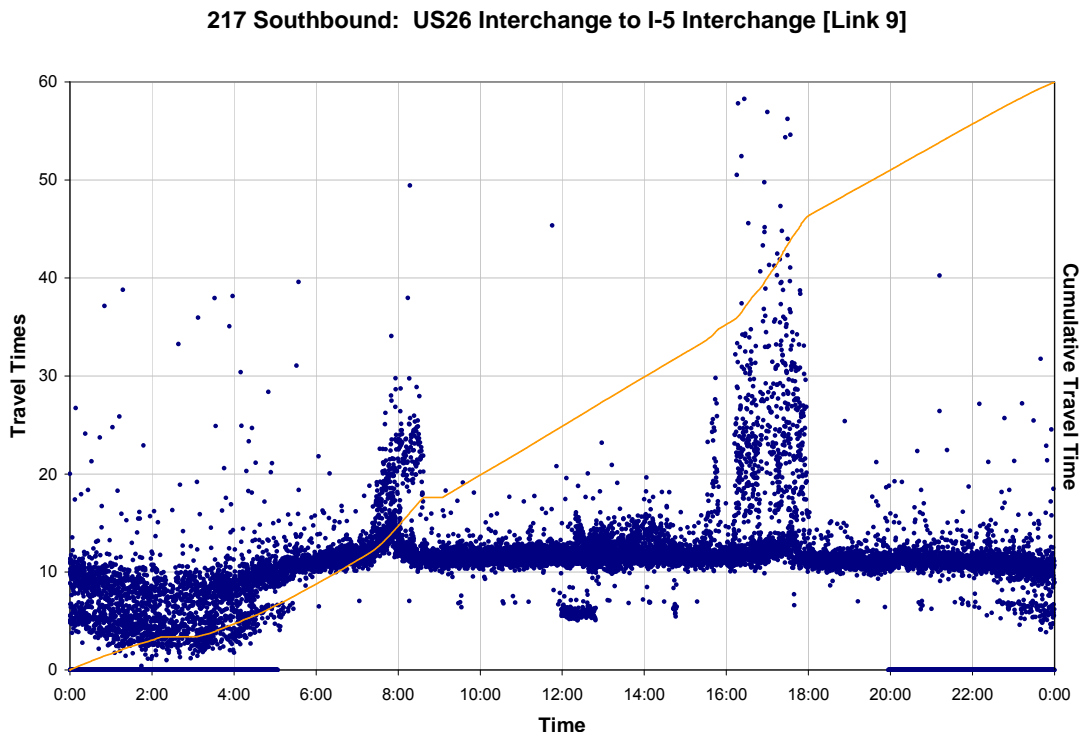


Figure 4. Scatter Plot of Travel Times, PORTAL April 4-8, 2005

Sample Size Analysis

In order to minimize costs associated with the data collection effort, an analysis was undertaken to determine the minimum number of runs needed on each freeway link in order to obtain statistically significant results. The statistical estimation of the sample size n is typically based on specifying levels of confidence and acceptable. The permitted error E is expressed as

$$E = Z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$$

where

n = minimum sample size

$Z_{\alpha/2}$ = standard normal curve area to its right equals $\alpha/2$ for a confidence level of $1 - \alpha$

σ = standard deviation of population

E = maximum error of the estimation

Often this estimation is performed based on prior information or an initial sample leading to a random variable having a t -distribution with $(n - 1)$ degrees of freedom. At the same level of confidence of $(1 - \alpha)100\%$, the new equation is written upon solving for n as

$$n = \left(t_{\alpha} \frac{\sigma}{E} \right)^2$$

where

s = estimate standard deviation of random samples

t_{α} = t distribution statistic (used instead of $Z_{\alpha/2}$ when dealing with random samples or small sample size)

E = maximum error of the estimation

For this research, estimates of the mean travel speed (equivalent to travel time) were made and the standard deviation of the travel speed was calculated based on link length and travel time. This was done for one hour in the AM peak (7:30-8:30) and one hour in the PM peak (16:30-17:30). These times were chosen because they were the data collection periods most likely to reflect traffic conditions transitioning from free-flowing to congested. This calculation was performed for both the 20-second data and the travel times aggregated to 5-minute averages. The allowable error E recommended by ITE for travel time studies is between 3 and 5 mi/h. For example, on Link 3 in the AM period

Mean speed = 37.42 mi/h

Standard Deviation = 4.82 mi/h

α = 0.05 (corresponds to 95% level of confidence)

E = \pm 3 mi/h

Since the statistic t_{α} is a function of n , an iterative procedure is needed to solve for n . As a result, $n \approx 5$ runs.

Required Number of Runs

Based on the analysis of PORTAL data described above, the number of runs required on each of the directional links to make a statistically valid comparison of travel times at two statistical confidence levels (90% and 95%) was calculated. It was determined that most links would require between five and ten runs. For links requiring additional runs, it was decided that the number of needed runs would be recalculated based on the travel time handbook and the recommendations of the ITE manual on traffic engineering studies.

Data Collection Plan

The preliminary analysis represented by Figure 4 was used to inform the process of creating a data collection plan. The intent of the project was to collect data during the transitions from freely-flowing to congested, and from congested to freely-flowing, traffic conditions whenever feasible. The scatter plot for each link was analyzed to determine the appropriate peak period for data collection as well as approximating the times when traffic condition transitions occur. Data collection routes were then designed to collect the required number of samples for each link while minimizing wasted travel. In accordance with the Federal Highway Administration's *Travel Time Data Collection Handbook* (<http://www.fhwa.dot.gov/ohim/start.pdf>), drivers would be instructed to follow standard probe vehicle instructions such that the data would represent the behavior of a "typical" driver.

- Data to be collected by groups of probe vehicles separated by 5-7 minute headways

DATA COLLECTION

As an initial step in the data collection phase, one probe vehicle run was conducted on each of the eighteen directional freeway links for preliminary analysis. This analysis focused on a section of I-5 northbound from Wilsonville to I-405 that contains three of the identified links. In Figure 5, the probe vehicle trajectory is represented as a solid line. The total estimated travel time was calculated by summing the estimated PORTAL travel times for each directional link at the time the probe vehicle entered the first link. This is shown as a dashed line, and the travel time estimates for entrances 3 minutes before and 3 minutes after are shown as dashed lines as well. In Figure 6, the probe vehicle trajectory is represented by a dark solid line and the predicted travel times are shown for each link based on the time of the probe vehicle's entrance. Note that the scale on the x-axis represents the time of day and is presented in minutes. In later reports, similar graphs will be prepared for each of the probe vehicle runs in order to demonstrate the comparison of the probe vehicles to the PORTAL or TMOC travel time estimates.

I-5 Northbound 02/18/2005: Trial Run Versus Hypothetical Trajectories

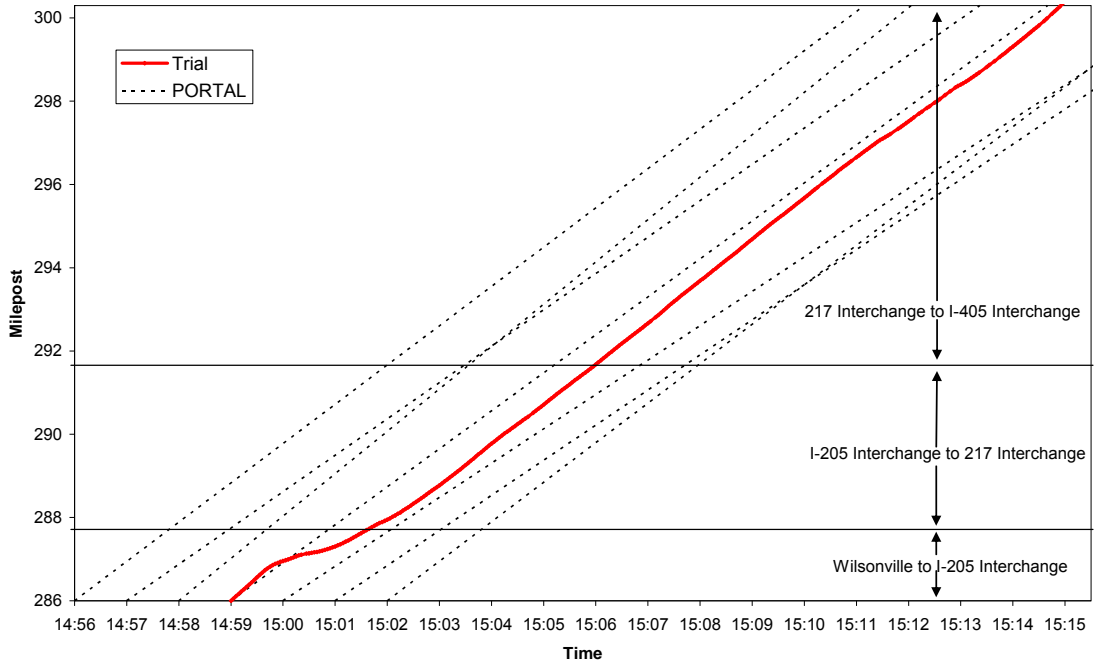


Figure 5. Probe Vehicle Trajectory and Portal Estimated Travel Times

I-5 Northbound 02/18/2005: Trial Run Versus Detector Data

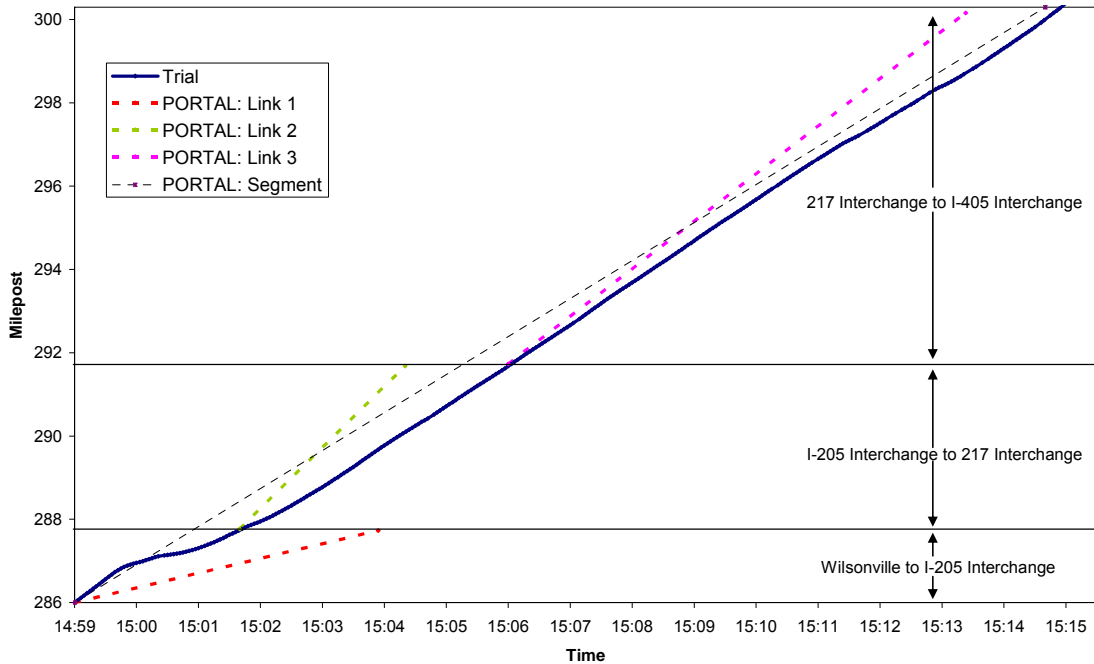


Figure 6. Sample Probe Vehicle Trajectory and Portal Travel Time Estimates

Probe Vehicle

ITS-GPS has been used extensively in research projects conducted at the Intelligent Transportation System Lab at Portland State University. ITS-GPS equipped probe vehicles were deployed to validate the Frontier Travel Time system which reads and matches license plates of passing vehicles to estimate corridor travel time.² ITS-GPS devices recorded location (latitude and longitude) at three-second intervals, making it possible to map each vehicle's location and speed as a trajectory between camera locations.

Loop Detector

Using the TransPort Portal data archive developed at PSU, the 20-second loop detector data will be processed for the same days, times and corridors as the probe vehicle data as established in the work plan. Using sound techniques for assigning influence areas to each detector site, travel times will be determined at 20-second level of resolution. Efforts in this task will compare travel times calculated here with travel times calculated using the same algorithm as the TMOC.

DATA COMPARISON

Using the results of the data analyses conducted, a statistical comparison will be developed in order to reveal the reliability of the travel times calculated from the loop detector data compared to the actual probe vehicle travel times. Using the probe vehicle data as "ground truth", the Contractor will provide statistical bounds on the validity of the travel time calculations using the probe vehicle method and the TMOC method. The Contractor will provide recommendations for improving travel time algorithms and estimates.

EFFECT OF ADDED INSTRUMENTATION

Using the results from previous tasks, a survey of existing loop detector stations will be made along with an assessment of bottleneck locations. The Contractor will analyze the potential for increasing data gathering instrumentation, and will conduct sensitivity analyses toward estimating the potential for improving travel time estimates.

CONCLUSIONS

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