

Evaluation of Freeway Travel Time Estimates



Final Report

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The Oregon Department of Transportation

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Executive Summary

The Oregon Department of Transportation's (ODOT) advanced traffic management system (ATMS) in the Portland metropolitan area is capable of computing estimated travel times for key freeway segments. The estimated travel times are currently relayed to travelers using variable message signs (VMS) located at key locations along the metro freeways. At this time, ODOT is considering reporting computed travel times on additional dynamic signs as well as disseminating travel times using other mechanisms such as the 511 phone system and the TripCheck web site. Prior to investing additional resources towards expanding the dissemination of travel times to Portland travelers, ODOT expressed interest in researching and understanding the accuracy of the current travel time calculations.

Travel time estimations created by real-time processing of freeway loop detector data have been compared with travel times recorded by probe vehicles simultaneously driving on predetermined freeway routes. In general, the statistical analysis revealed that the travel time predictions by the ATMS perform very well. Only some locations did not result in statistically valid results suggesting that the calculated travel times were the same as the probe vehicle times.

One target result of this project was some recommendations of those locations where additional detectors would improve travel time predictions. A methodology was followed that resulted in identifying seven locations that would likely have a significant impact on improving travel time predictions. A brief recap of the process of identifying these locations is summarized as follows:

- Analysis of the probe data compared to the PORTAL data, as well as traffic engineering fundamentals, resulted in the following initial conclusions:
 - Increased detection will most benefit locations and times where recurring congestion occurs;
 - The greatest benefits of increased detection will be during steady state congestion conditions, as opposed to the periods where congestion is beginning or clearing;
 - Situations where incidents are occurring will only benefit from increased detection if the detection happens to be right near the incident, and then the benefits (of increased detection) will be marginal as incident conditions are so unpredictable.
- With the conclusion drawn that increased detection will best address those areas where steady state recurring congestion tends to occur, visual analysis of PORTAL reports of average traffic speeds recorded during the time of this project identified 13 stretches of road where recurring congestion appears to be an issue.

1. I-205 NB at MP 9
2. Hwy 217 NB at MP 2.5-4.5
3. Hwy 217 NB at MP 6-6.5
4. Hwy 217 SB at MP 0 - .5
5. Hwy 217 SB at MP 2-6
6. Hwy 217 SB at MP 6-7
7. Hwy 26 EB at MP 65-67 (displayed in the example plot above)
8. Hwy 26 EB at MP 69-74 (displayed in the example plot above)
9. Hwy 26 WB at MP 67-74
10. I-5 NB at MP 296-300
11. I-5 NB at MP 305 to State Line
12. I-5 SB at MP 306-307
13. I-84 EB at MP 0-3.5

- Building upon the 13 stretches of roads identified as candidates for increased detection, the next step was to examine the current detector spacing and locations along the 13 corridors identified above. A rule of thumb for this analysis was that any locations where detectors were 1 mile or less apart were seen as having adequate detector spacing. By searching for detector spacing gaps of 1 mile or more within the candidate areas, the following seven locations were concluded as having the best potential for impact in improving travel time estimations:

1. Hwy 217 NB at MP 3.2
2. Hwy 26 EB at MP 70
3. Hwy 26 WB at MP 69
4. Hwy 26 WB at MP 70
5. I-5 NB at MP 298.5
6. I-5 SB at MP 306.5
7. I-84 EB at MP 2.0

1. Project Overview

1.1 Background

The Oregon Department of Transportation's (ODOT) advanced traffic management system (ATMS) in the Portland metropolitan area is capable of computing estimated travel times for key freeway segments. The estimated travel times are currently relayed to travelers using variable message signs (VMS) located at key locations along the metro freeways. At this time, ODOT is considering reporting computed travel times on additional dynamic signs as well as disseminating travel times using other mechanisms such as the 511 phone system and the TripCheck web site.

Prior to investing additional resources towards expanding the dissemination of travel times to Portland travelers, ODOT expressed interest in researching and understanding the accuracy of the current travel time calculations. Therefore, this research project evaluated the travel time reporting capabilities of the ODOT ATMS in the Portland metropolitan area.

1.2 Project Goals

The goals of this research project are summarized as follows:

- Goal #1: To evaluate the travel time estimating and reporting capabilities of the ODOT ATMS given the current configuration of loop detectors, the current algorithms and system configurations.
- Goal #2: To preliminarily identify the locations where additional traffic monitoring devices would benefit the travel time calculations.

1.3 Project Approach

Travel time estimations created by real-time processing of freeway loop detector data have been compared with travel times recorded by probe vehicles simultaneously driving on predetermined freeway routes. The probe vehicles utilized global positioning system (GPS) sensors to accurately record location data as the vehicles traveled along the routes.

The primary research involved four key activities:

1. Creating a laboratory environment in which to ingest the loop detector data and run the ODOT TMC algorithms to compute the same estimated travel times generated by ODOT for display on the DMS signs.
2. Collecting actual travel time information by employing probe vehicles to drive the freeways during the period of time at which the loop detector data is analyzed.
3. Combining the probe travel time data and estimated travel time data in order to compare the accuracy of the estimated times, and to view those individual segments where the estimated times differed significantly from the probe data.
4. Statistical analysis of the results to determine the accuracy of the travel time calculations.

1.3.1 Loop Detector Ingest and Analysis

The laboratory environment to support the ingest and analysis of loop data was created within the TransPort PORTAL developed at Portland State University (PSU). The PORTAL collects and archives 20-second loop detector data provided by ODOT. As part of a significant effort earlier in this project, PSU customized an area of PORTAL to compute the travel time on each of the 18 identified freeway segments using the exact travel time algorithm that is used within the ODOT TMOC. This application can produce travel time estimates used in the TMOC either using a traditional midpoint segment method or using the modified midpoint method currently used by ODOT. A screen shot of this area in PORTAL is shown below in Figure 2. Note that this feature is currently only available in the testing area of PORTAL.

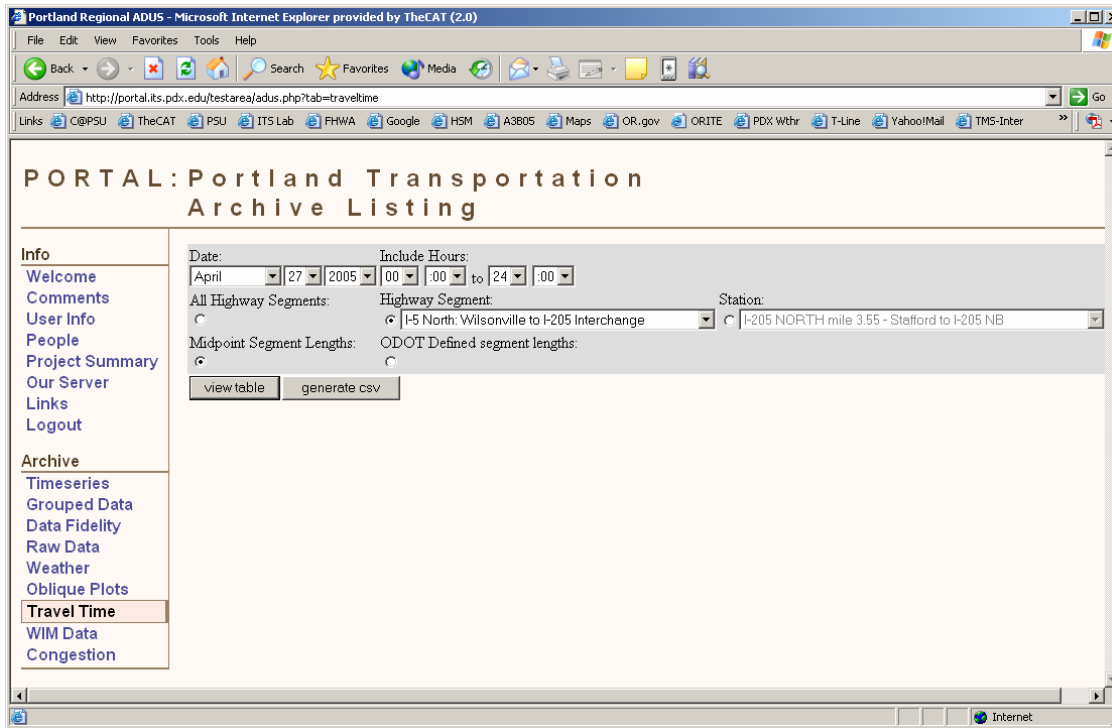


Figure 1- PORTAL Travel Time Measurement Interface

1.3.2 Probe Vehicle Data Collection

To facilitate data collection during the project, drivers were employed to traverse 18 directional corridor links in vehicles equipped with global positioning system (GPS) sensors in a variety of traffic conditions. This evaluation included the development of a statistical bound on the validity of the current travel time algorithm collection instrumentation in the region.

1.3.3 Combining Probe Vehicle Data with Loop Detector Data

Researchers at PSU extracted the data from the probe vehicle collection devices and the PORTAL center to assemble data for each segment that represented near simultaneous readings for actual observed travel times as well as computed travel times. The results of these activities are plots illustrating the computed and observed travel times for each segment over multiple runs, and provide a very visual view on where the calculations differ (physically) from the observed times.

1.4 Current ODOT Use of Predicted Travel Times

Currently, ODOT reports estimated travel times to travelers by displaying ranges of travel times on VMS displays at key locations along the freeways. Before detailed analysis of the accuracy of travel time prediction, it is important to understand the ranges of values reported to travelers. There are three locations where travel times are reported using VMS: I-5 at Wilsonville, I-5 at Carmen Road, and I-5 at Terwilliger. The time ranges presented to the destinations are presented below.

Table 1 – Summary of Travel Time Ranges Presented on VMS Displays

Location	Travel Time Ranges Presented (in minutes)			
I-5 NB at Wilsonville to Hwy 217	8-10	10-13	13+	
I-5 NB at Carmen to Hwy 26	8-10	10-12	12-15	15+
I-5 NB at Carmen to I-405	10-12	12-15	15+	
I-5 SB at Terwilliger to I-205	10-12	12-15	15+	

It is important to note that in events where travel times are significantly longer than free flow (e.g. over 13 minutes or 15 minutes) the system no longer gives a range, but instead indicates that the time is more than 13 or 15 minutes.

2. Summary of Test Area

The following map is a representation of the major freeways in the Portland, Oregon metropolitan area. This will serve as a graphical reference for the data collection test segments that are mentioned throughout the following sections and the corresponding segment tables for this project.



Figure 2 - Illustrated Map of the Test Area

2.1 Summary of Test Segments

The test area was defined by a series of test segments. The results of analyses on each test segment will be presented in later sections. This section contains a summary table describing each segment to assist in understanding the results presented in later sections.

Table 2 - Test Segment Summary

Segment Number	Road Name	From	To	Segment Length
1	Northbound Interstate 5	Wilsonville Interchange	Interstate 205	1.75 miles
2	Northbound Interstate 5	I-205 Interchange	217 Interchange	3.93 miles
3	Northbound Interstate 5	217 Interchange	I-405 Interchange	8.62 miles
4	Northbound Interstate 5	I-84 Interchange	Interstate Bridge	7.5 miles
5	Southbound Interstate 5	Interstate Bridge	I-84 Interchange	7.19 miles
6	Southbound Interstate 5	I-405 Interchange	217 Interchange	8.07 miles
7	Southbound Interstate 5	217 Interchange	I-205 Interchange	3.26 miles
8	Northbound 217	I-5 Interchange	US26 Interchange	5.95 miles
9	Southbound 217	US26 Interchange	I-5 Interchange	7.07 miles
10	Northbound I-205	I-5 Interchange	Oregon City	6.7 miles
11	Northbound I-205	Oregon City	I-84 Interchange	9.53 miles
12	Southbound I-205	I-84 Interchange	Oregon City	23.34 miles
13	Eastbound Interstate 84	I-5 Interchange	I-205 Interchange	3.59 miles
14	Westbound Interstate 84	I-205 Interchange	I-5 Interchange	12.33 miles
15	Eastbound US 26	Helvetia	217 Interchange	2.44 miles ¹
16	Eastbound US 26	217 Interchange	I-405 Interchange	6.11 miles
17	Westbound US 26	I-405 Interchange	217 Interchange	8.08 miles
18	Westbound US 26	217 Interchange	Helvetia	0.6 miles ²

¹ Due to construction, data collection could not be completed for US-26 eastbound between Helvetia and the 217 interchange.

² Due to construction, data collection could not be completed for US-26 westbound between the 217 interchange and Helvetia.

3. Experimental Design

The intent of the experimental design task was to define the number of data collection runs, the number of days during which data would be collected, and probe vehicle headways required to complete sufficient data collection for a statistically valid study.

The experiment has been designed to meet the following goals:

- *Statistical comparison.* Using the probe vehicle data as “ground truth”, the experiment developed 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 was made along with an assessment of bottleneck locations in order to conduct sensitivity analyses toward estimating the potential for improving travel time estimates.

3.1 Sample Size Analysis

For this travel time study, a minimum sample size was desired to minimize the data collection cost and fit within the budgetary constraints. However, as output from this sample size determination was also a valuable resource to statistically ensure the level of confidence and reliability of such data, it became important to execute a number of travel time collection runs to determine a statistically permitted level of error from the sample size. In general, the statistical estimation for the sample size n is based on specifying the probability statements about level of confidence that the error is most 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, the estimation is done based on prior information or an initial sample which led 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 morning peak timeframe of 7:30AM to 8:30AM and one hour in the afternoon peak timeframe of 4:30PM to 5:30PM. These hours were chosen because they were the most likely times PSU would be collecting travel time information where travel was transitioning from free-flowing to congestion. These calculations were made 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 peak morning 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.

3.2 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. Only the 95% level is reported in Table 2.

Table 3 - Computed Number of Runs Required for the Statistically Valid Sample

Freeway Link	Freeway Link Name	AM/PM	Required Number of Samples @ 95%		Planned Number of Samples
			+3 MPH	+5 MPH	
1	Wilsonville to I-205 Interchange	PM	15+	10	None
2	I-205 Interchange to 217 Interchange	AM	10	5	5
3	217 Interchange to I-405 Interchange	AM	9	5	5
3	217 Interchange to I-405 Interchange	PM	15+	8	8

4	I-84 Interchange to Interstate Bridge	PM	5	3	5
5	Interstate Bridge to I-84 Interchange	PM	11	5	5
5	Interstate Bridge to I-84 Interchange	AM	6	4	5
6	I-405 Interchange to 217 Interchange	PM	10	5	5
6	I-405 Interchange to 217 Interchange	AM	15+	10	10*
7	217 Interchange to I-205 Interchange	PM	15+	9	10*
8	I-5 Interchange to US 26 Interchange	AM	4	3	5
9	US 26 Interchange to I-5 Interchange	PM	7	4	5
10	I-5 Interchange to Oregon City	PM	15	7	5
11	Oregon City to I-84 Interchange	PM	9	5	5
12	I-84 Interchange to Oregon City	PM	4	3	5
13	I-5 Interchange to I-205 Interchange	PM	6	4	5
14	I-205 Interchange to I-5 Interchange	AM	15+	15+	10*
15	Helvetia to 217 Interchange ³	AM	14	7	As needed
16	217 Interchange to I-405	AM	4	3	5
17	I-405 Interchange to 217 Interchange	PM	10	5	5
18	217 Interchange to Helvetia ⁴	PM	15+	15+	As needed

3.3 Data Collection Plan

The data collection routes were designed to minimize wasted travel and collect the required number of samples for each link. The intent was to collect data during the transition from freely-flowing to congested conditions, and from congested to freely-flowing conditions, if feasible.

In accordance with the Federal Highway Administration’s Travel Time Data Collection Handbook (<http://www.fhwa.dot.gov/ohim/start.pdf>), drivers were to follow standard probe vehicle instructions, so that data would be representative of a “typical” driver.

³ Due to construction, data collection could not be completed for US-26 eastbound between Helvetia and the 217 interchange.

⁴ Due to construction, data collection could not be completed for US-26 westbound between the 217 interchange and Helvetia.

PSU agreed to contact Region 1 staff prior to the beginning of extensive data collection, in an effort to ensure that construction projects would not be interfering with the loop detector system.

Table 4 - Data Collection Routes

Route	Start	Path	Number of vehicles	Headway between Probes
1	AM	I-84 WB from the I-84/I-205 jct. to I-5 jct then I-5 SB to OR217 NB to US26 EB	5 vehicles / 1 run	5-7
2	AM	I-5 SB from Interstate Bridge past I-84 interchange and returning I-5NB to Interstate Bridge on same route	5 vehicles / 1 run	5-7
3	PM	US-26WB from PSU to OR-217 SB to I-5 SB to the Stafford Rd interchange returning on I-5 NB to Interstate Bridge	5 vehicles / 1 run	5-7
4	PM	I-84EB from PSU to I-205SB to I-5 jct to I-5 SB to the Stafford Road interchange I-5 NB to I-205NB	5 vehicles / 1 run	5-7

3.4 Configuring PORTAL to Estimate Link Travel Times

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. 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, gathers and archives 20-second data provided by ODOT’s network of loop detectors. The TransPort PORTAL developed at PSU collects and archives 20-second loop detector data provided by ODOT. The ODOT data contains speed, volume, and occupancy counts for each station.

The PORTAL web interface was configured to calculate travel times from the 20-second loop detector data specifically for use in this research. A screen capture of that interface is shown in Figure 1. Each loop detector station on the freeway network and its influence area were provided by ODOT and included in the PORTAL database. The influence area of a detector station is defined by two ways in PORTAL:

- midpoint method
- modified midpoint method (ODOT)

In the 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. In the event that no 'next' station exists, the detector's influence is extended to the end of the segment in question. Figure 3 provides a visual representation of this method. In addition to the midpoint method outlined above, ODOT has modified the influence areas of certain detectors on the I-5 corridor from Wilsonville to I-405 to better reflect observed travel times based on the know bottleneck areas and detector coverage. These modified travel times also used by ODOT to display travel times on reported by way of VMS. There are currently three VMS (presented in Table 1) that currently report travel times display comparisons for alternate routes to identical destinations.

Travel time estimates are made by averaging the detector speeds across all lanes for each 20 second interval and dividing by the distance of the influence area to determine the average travel time on that link. Both the midpoint and the modified midpoint method assume that traffic conditions at one point in space (detector) can be extrapolated to accurately represent the travel time of the entire link.



Figure 3 - Loop Detector Influence Areas as Defined by the Midpoint Method

A map file was prepared by dynamically segmenting the influence areas of each detector to the highway network. The influence areas of each detector were that were assembled to produce the travel time estimates for each link are identified and shown in Figure 4.

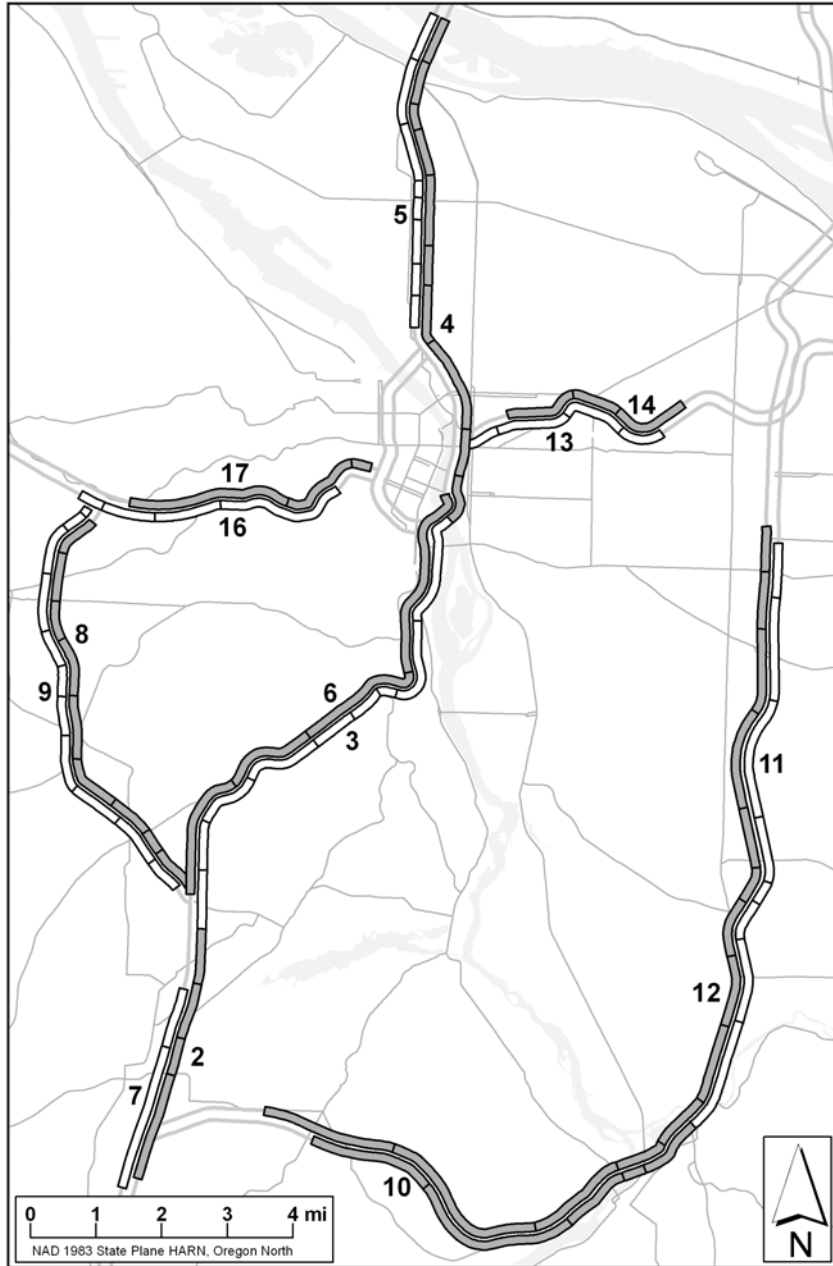


Figure 4 - Directional Freeway Segments and Detector Influence Areas (Midpoint Method)

4. Summary of Tests and Results

Section 4 documents the tests and results of the data analysis that was conducted to compare the accuracy of ODOT’s travel time estimates by comparing them with probe vehicle travel times that can be assumed to represent “ground truth.” The section contains the following subsections:

- Probe data collection summary
- Data reduction
- Travel time comparisons
- Data analysis summary
- 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.

4.1 Probe Data Collection Summary

Probe vehicles were deployed along strategic routes to validate the method currently used by ODOT in the estimation of travel times along specified freeway corridors. Probe vehicle data were collected using ITS-GPS, a software application designed for use with Palm handheld computers equipped with GPS devices. ITS-GPS was developed and has subsequently been used extensively in research projects conducted at the Intelligent Transportation System Lab at Portland State University.

- All data were used in the analysis including preliminary data, separate test runs, and designed data collection plan.
- Vehicles left starting location with lead times of 4-5 minutes between departures
- Probe vehicle instructions were standard (see work plan)
- 87 data runs were collected
- Approximately 904 minutes (15 hours) of probe vehicle runs were documented.

For some links, the number of runs performed differs from the number of runs identified in the data collection plan. The following table summarizes the runs and explains those events that resulted in a fewer number of runs conducted for some links:

Table 5 – Data Collection Summary

Link	Time (mins)	Planned Runs	Runs	Reason for not collecting planned runs
LK 2 - I-5 NB	31.15	5	8	
LK 3 - I-5 NB	58.60	5-8	6	Within planned range
LK 4 - I-5 NB	89.90	5	5	
LK 5 - I-5 SB	29.95	5	4	One probe vehicle lost data due

				to ITS-GPS device
LK 6 - I-5 SB	101.95	5-10	9	
LK 7 - I-5 SB	25.15	10*	5	As stated, data reexamined after probe data collected and sample was sufficient to compare statistically
LK 8 - OR-217 NB	149.85	5	7	
LK 9 - OR-217 SB	30.45	5	4	One probe vehicle lost data due to ITS-GPS device
LK 10 - I-205 NB	57.55	5	4	One probe vehicle lost data due to ITS-GPS device
LINK 11 - I-205 NB	9.40	5	1	Incomplete instructions to probe drivers resulted in probes leaving route at wrong location
LK 12 - I-205 SB	73.85	5	4	One probe vehicle lost data due to ITS-GPS device
LK 13 - I-84 EB	60.50	5	11	
LK 14 - I-84 WB	57.95	10*	8	As stated, data reexamined after probe data collected and sample was sufficient to compare statistically
LK 16 - US 26 EB	68.45	5	7	
LK 17 - US 26 WB	59.50	5	4	One probe vehicle lost data due to ITS-GPS device
Totals	904.2		87	

4.2 Data Reduction

All probe data collected, for both the preliminary analysis and for the runs described in the data collection section, were assembled and prepared for further analysis. For each probe vehicle run, the data from the Palm handheld units were downloaded to a local PC for further analysis. The probe vehicle travel time runs were imported and displayed on the ODOT highway network. Any data that were not spatially accurate or contained errors were discarded. A total of 87 number probe vehicle runs were collected.

The log files were configured to record position, speed, and time every three seconds during the entire period that the ITS-GPS software was operating. The probe vehicle data files were appended to add a unique number for each record in the data file. Each probe vehicle data collection run was then added to the highway map using the recorded latitude and longitude of each record. The map was then visually inspected to identify the nearest probe vehicle record that represented when the probe vehicle entered and exited the freeway link for analysis. A representation of this technique is shown in Figure 5. The probe vehicle records that correspond to each link were extracted and placed in separate spreadsheets for further analysis.



Figure 5 - Sample Probe Vehicle Travel Path Plotted on Highway Network

For each time period that the probe vehicles collected data, the corresponding travel times for the midpoint method and the ODOT modified method were downloaded from PORTAL. These data contained the estimated travel in twenty second intervals for each link. At the nearest 20-second time interval that the probe vehicle entered the link, the PORTAL travel estimate for 1 and 3 minutes earlier were extracted. At all instances, the probe vehicles times were rounded down to match the nearest 20-second interval. The reason for extracting travel time estimates for 1 and 3 seconds earlier were to assess whether inclusion of short term past data could add to the accuracy of the travel time estimates.

For some freeway sections, this visual inspection of the probe vehicle travel path on the map revealed that that some of the travel times calculated by PORTAL included sections of influence areas that were not traversed by the probe vehicles, particularly at interchanges. In these cases, the influence area that was not traversed by the probe vehicle was removed from the link analysis, shortening the link to only included influence areas traversed by the probe. This was done by extracting the travel time estimate for that detector's influence area and subtracting it from the total travel time estimate. In the same manner, the probe vehicle records were extracted for further analysis. This was possible because the PORTAL interface includes both travel time estimates for each link and also allows each detector to be assembled into the link.

4.3 Travel Time Comparisons

Probe travel times were compared to six estimates of travel time for each of the 15 links and:

- Midpoint – the travel time calculated using the midpoint method at the nearest 20-second interval when the probe vehicle first enters the link.
- ODOT – the travel times estimated by the influence area lengths defined by ODOT at the nearest 20-second interval when the probe vehicle first enters the link.
- Midpoint - 1 minute - an average of travel times for 1 minute before the nearest 20-second interval when the probe enters the link (i.e. if probe enters the link at 16:10:00, then the average of times at 16:09:00, 16:09:20, 16:09:40, 16:10:00)
- Midpoint - 3 minute - an average of travel times for 3 minutes before the nearest 20-second interval when the probe enters the link
- ODOT - 1 minute - an average of travel times for 1 minute before the nearest 20-second interval when the probe enters the link
- ODOT - 3 minute - an average of travel times for 3 minutes before the nearest 20-second interval when the probe enters the link

Summary statistics for each comparison were calculated that included the average travel time for each method, the standard deviation, sample size, the 95% confidence interval, the average difference between probe and comparison travel time, the percent error, and the maximum and minimum difference in the travel time estimates. Two summary plots were created, showing the average travel time and the confidence interval for the probe and six comparison method and the average difference and minimum and maximum travel time differences. A sample of these plots is shown in Figures 6 and 7. The complete summary statistical sheets for data analysis are included in full detail in Appendix A.

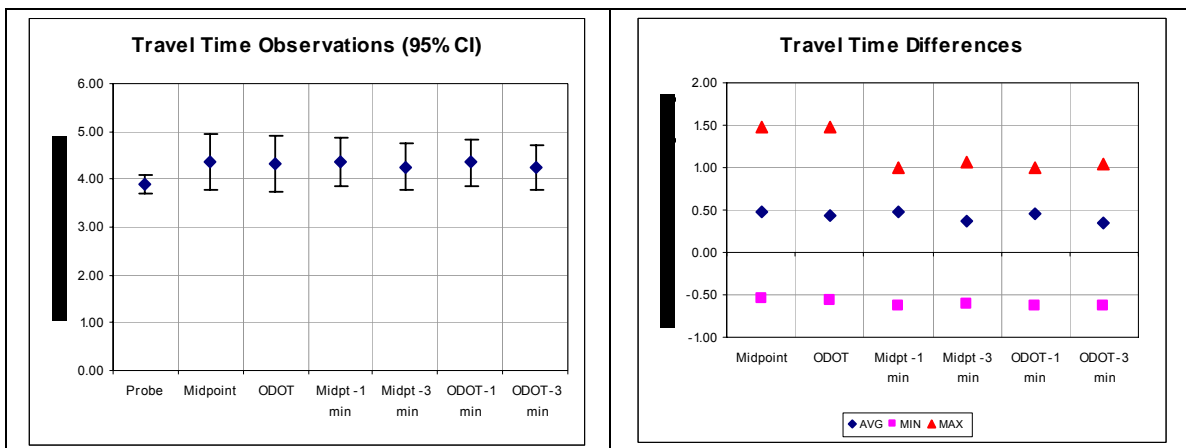


Figure 6 - Sample Link Summary Plots – Travel Time Observations and Differences

In addition, plots for each of the 87 probe runs were created that show the probe vehicle trajectories and the estimated trajectories for the nearest 20 second interval when the probe vehicle entered the link, as well as estimated trajectories for 1, 2, and 3 minutes on either side of the nearest interval. These plots clearly show when the probe vehicles was traveling in congested or free flow conditions.

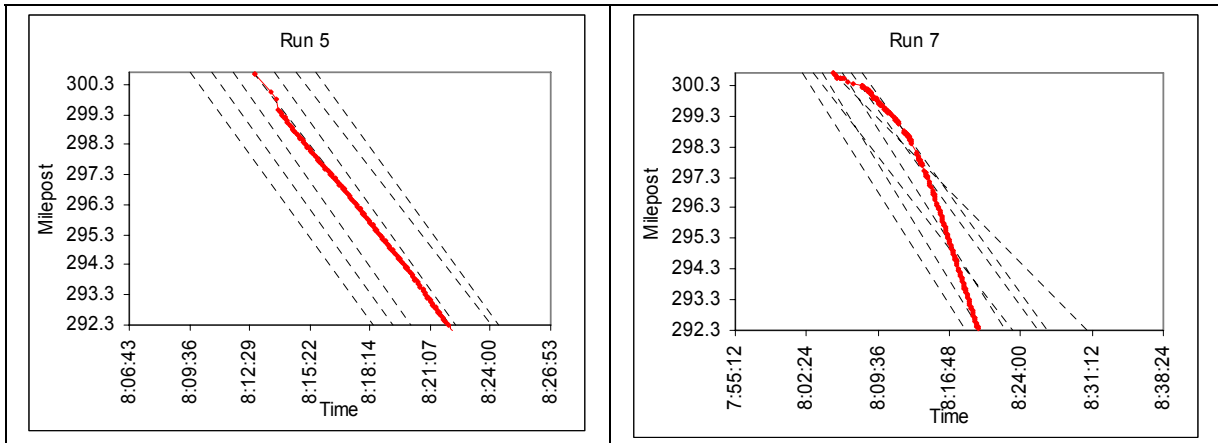


Figure 7: Sample Link Trajectory Plots – Probe Vehicle and Estimated Trajectories

4.4 Data Summary

- The following table shows the average probe time and average difference of the probe travel times and the midpoint and ODOT travel estimates from detectors.
- The difference is shown in decimal minutes.
- The percent error gives an idea of the magnitude of the error and the confidence interval is calculated as described in the paired t-test section.

Table 6 - Data Analysis Summary

Link	Highway	MP From	MP To	Average Probe Time	Average Difference		Percent Difference	
					Midpt	ODOT	Midpt	ODOT
2	I-5 NB: I-205 Intchg to 217 Intchg	287.85	291.78	3.89	0.48	0.42	12%	11%
3	I-5 NB: OR-217 Intchg to I-405 Intchg	291.78	300.40	9.77	0.37	-1.02	4%	-10%
4	I-5 NB: I-84 Intchg to Interstate Bridge	300.40	308.38	17.98	0.71	0.68	4%	4%
5	I-5 SB: Interstate Bridge to Going St SB	308.38	303.50	7.49	0.53	0.53	7%	7%
6	I-5 SB: I-405 Intchg to 217 Intchg	300.71	292.30	11.33	1.22	6.35	11%	56%

7	I-5 SB: OR-217 Intchg to I-205 Intchg	290.82	287.66	4.16	-1.38	-1.38	-33%	-33%
8	OR-217 NB: I-5 Intchg to US-26 Intchg	7.20	0.26	21.41	-4.70	-5.90	-22%	-28%
9	OR-217 SB: US-26 Intchg to I-5 Intchg	0.11	6.89	7.61	-0.20	0.75	-3%	10%
10	I-205 NB: I-5 Intchg to Oregon City	3.22	10.25	14.39	1.05	-1.15	7%	-8%
12	I-205 SB: I-84 Intchg to Oregon City	19.79	2.48	18.46	0.30	2.34	2%	13%
13	I-84 EB: I-5 Intchg to I-205 Intchg	0.31	3.69	5.50	0.17	2.05	3%	37%
14	I-84 WB: I-205 Intchg to I-5 Intchg	4.17	1.21	7.24	0.44	0.44	6%	6%
16	US 26 EB: 217 Intchg to I-405 Intchg	68.93	73.32	9.78	1.93	1.93	20%	20%
17	US 26 WB: I-405 Intchg to 217 Intchg	74.08	69.70	14.88	-9.60	-9.68	-65%	-65%

The ODOT and Midpoint calculations for Link 6 differ by a large amount (as shown in the table above). Examination of the data (contained in Appendix A) reveals that runs 7, 8, and 9 were the runs that produced significant difference in travel times along link 6. During these three runs, a major incident was occurring along link 6 seriously restricting travel within the first influence area. The effects of this event were to the extent that the Midpoint calculated travel time to travel one mile was approximately 6.77 minutes. Therefore, an adjustment for the ODOT adjusted algorithm that increased the influence area #1 of Link 6 by one mile would immediately add an additional 6.77 minutes to the travel time. An increase by two miles would add over 13 minutes to the travel time. Therefore, it is easy to understand how the ODOT and Midpoint calculations can differ by such a significant amount when a segment's length is extended and that segment has such a significant event (in this case resulting in calculated speeds of 8.85 MPH). This further validates the decision by ODOT to not post values for travel times when they exceed a high threshold (typically 13 or 15 minutes).

4.5 Statistical Comparison

Each of the travel time estimates were compared to the probe vehicle travel times for statistical validity. The paired t-test was used since the probe travel times and the estimated travel times can be considered a paired sample. The power of this test is greater than a simple test of means. The paired t-test tests the hypothesis that the average of the differences between each paired sample is zero. The null hypothesis is that the probe and calculated travel times are equal. The alternate hypothesis is that the probe and calculated travel times are not equal. Therefore, if the null hypothesis is accepted, it can be statistically concluded that the probe and calculated travel times are equal. The null and alternative hypotheses are stated as:

$$H_O : \mu_d = 0$$

$$H_A : \mu_d \neq 0$$

where:

$$\mu_d = \mu_1 - \mu_2$$

- $H_O =$ null hypothesis
- $H_A =$ alternative hypothesis
- $\mu_d =$ difference in means between the two populations

The t-test statistic is calculated as:

$$t^* = \frac{\bar{X}_d - \mu_d}{\frac{s_d}{\sqrt{n_d}}}$$

- $\bar{X}_d =$ average of sample differences
- $s_d =$ standard deviation of sample differences
- $n_d =$ sample size

And the confidence interval for the mean difference μ_d :

$$\bar{X}_d \pm t_{\alpha/2} \left(\frac{s_d}{\sqrt{n_d}} \right)$$

The p-value of the hypothesis as calculated by Microsoft Excel TTEST function is shown in the table. If the p-value is less than the test level α then the null hypothesis is rejected. In this comparison, a significance level of 95% was used ($\alpha = 0.05$). If the p-value is greater than 0.05 then the null hypothesis is accepted and the travel times compared can be considered equal. The smaller the p-value, the more contradictory the data is to H_o - meaning smaller p-values indicate less reliability in the statistical significance of the data.

In addition to the statistical calculations on the data, the following observations were made on the probe vehicle runs:

- Only one data collection was run on link 11, and due to problems encountered with the PORTAL travel times calculated during the time of the run, no values are reported.

- All probe vehicles on Link 8 on 05/04/05 encountered an incident on OR-217NB (near Greenburg Rd., ~ MP 4.85) that was the cause of the unusually long travel times on that day. A multi-vehicle crash was reported, but there were no longer any lane blockages by the time the probe vehicles arrived. Only one of the vehicles involved remained, and it had been moved to the shoulder.
- All probe vehicles on Link 17 also encountered an incident on US-26WB just west of the tunnel. The nature of the incident was unclear – a probe vehicle observed two vehicles and an ambulance stopped in the left-hand lane, but there was no sign of a crash. Only the right-hand lane was open. Detector data is not complete, and PORTAL data is missing some values.
- Cells shaded gray indicate that travel times are statistically different.
- There does not appear to be a consistent pattern in the accuracy of travel time estimates by including the (-1) and (-3) intervals in the estimates.
- In most cases, averages of (-1) and (-3) intervals decreases the error range (but not in all cases) and increased the statistical significance of the tests.

Table 7 – P-Value – Statistical Significance

P- Value -Statistical Significance						
Link Number	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
LINK 2 - I-5 NB	0.073	0.103	0.034	0.071	0.038	0.079
LINK 3 - I-5 NB	0.272	0.012	0.214	0.202	0.010	0.035
LINK 4 - I-5 NB	0.651	0.665	0.545	0.287	0.560	0.301
LINK 5 - I-5 SB	0.470	0.470	0.503	0.256	0.503	0.256
LINK 6 - I-5 SB	0.435	0.095	0.676	0.605	0.052	0.045
LINK 7 - I-5 SB	0.009	0.009	0.021	0.016	0.021	0.016
LINK 8 - OR-217 NB	0.016	0.011	0.012	0.024	0.009	0.011
LINK 9 - OR-217 SB	0.381	0.040	0.199	0.159	0.146	0.205
LINK 10 - I-205 NB	0.532	0.460	0.277	0.040	0.896	0.965
LINK 12 - I-205 SB	0.537	0.020	0.478	0.731	0.003	0.003
LINK 13 - I-84 EB	0.273	0.070	0.518	0.402	0.098	0.077
LINK 14 - I-84 WB	0.736	0.736	0.754	0.530	0.754	0.530
LINK 16 - US 26 EB	0.026	0.026	0.009	0.012	0.009	0.012
LINK 17 - US 26 WB	0.013	0.013	0.014	0.012	0.013	0.011

Table 8 – Statistical Significance

Statistical Significance						
Link Number	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
LINK 2 - I-5 NB	YES	YES	NO	YES	NO	YES
LINK 3 - I-5 NB	YES	NO	YES	YES	NO	NO
LINK 4 - I-5 NB	YES	YES	YES	YES	YES	YES
LINK 5 - I-5 SB	YES	YES	YES	YES	YES	YES
LINK 6 - I-5 SB	YES	YES	YES	YES	YES	NO
LINK 7 - I-5 SB	NO	NO	NO	NO	NO	NO
LINK 8 - OR-217 NB	NO	NO	NO	NO	NO	NO
LINK 9 - OR-217 SB	YES	NO	YES	YES	YES	YES
LINK 10 - I-205 NB	YES	YES	YES	NO	YES	YES
LINK 12 - I-205 SB	YES	NO	YES	YES	NO	NO
LINK 13 - I-84 EB	YES	YES	YES	YES	YES	YES
LINK 14 - I-84 WB	YES	YES	YES	YES	YES	YES
LINK 16 - US 26 EB	NO	NO	NO	NO	NO	NO
LINK 17 - US 26 WB	NO	NO	NO	NO	NO	NO

5. Assessment of Results

The intent of this section is to assess the results, and to the extent possible offer recommendations on candidate locations for the placement of new detectors.

5.1 *Assessment of Travel Time Prediction for Various Situations*

Stepping away from purely looking at the statistics of the problem, it is useful to first examine the possible situations that vehicles may encounter while traveling along a route after receiving a travel time report. The ODOT and PORTAL travel time algorithms compute instantaneous travel times using the current readings for all detectors along the route. Currently, ODOT presents this information to the travelers using a VMS sign that is visible as the vehicle approaches the roadway segment. Therefore, one of the following scenarios will occur with each trip:

1. The vehicle enters the route during congestion free (essentially free flow) conditions and the route remains congestion free for the duration of the vehicle's trip;
2. The vehicle enters the route during a period where congestion (recurring or non-recurring) is present on part or all of the route, and this congested state remains for the vehicle's travel along the route;
3. The vehicle enters the route during a period where congestion (recurring or non-recurring) is present and the congestion clears while the vehicle is traveling along the route; or
4. The vehicle enters the route during congestion free conditions, and congestion begins while the vehicle is on the route.
5. The vehicle encounters a traffic situation caused by a serious non-recurring incident, significantly reducing the travel speeds.

Each of these five situations will now be analyzed, using examples from data collection runs whenever possible.

Situation 1: Free-flowing conditions for the entire trip

For 'Situation 1' type events, the travel time is computed and reported at nearly the exact time the vehicle enters the route. The system essentially remains in steady state condition, and most often the velocity, occupancy and speed of the freeway will follow the established speed-flow diagrams.

Free flow conditions were experienced by the majority of probe vehicles collecting the data. The plots contained in the Appendix clearly identify those runs that encountered free flow conditions as the probe vehicle follows a nice consistent slope, typically near to the speed limit (i.e. a range of 50-60 miles per hour).

The ODOT/PORTAL calculated travel times performed very well for routes with free flowing conditions, and it can be concluded that the given spacing of detectors is adequate to report free flow conditions accurately to travelers.

Situation 2: Congestion encountered along the entire trip

For Situation 2 types of events, one or more detectors along the route measure slow speeds and the result is an estimated travel time that represents congestion conditions on part of or the entire link. The figure below illustrates Run 9, where the probe vehicle was traveling along Link 6 (I-5 Southbound from the I-405 Interchange to Hwy 217). It is apparent from this plot that congestion is occurring along the first influence area (roughly from the start of the link to Milepost 298) as the vehicle covers approximately three miles in seven minutes. The horizontal dashed line plotted just below Milepost 299.3 represents the location of the detector that predicted the travel time along the first influence area. At the time the probe vehicle passes the detector, the slopes of both the probe plot and the estimated plots are very similar, verifying that the congestion conditions were still in effect when the probe passed the detector location. Visual observation notes that the probe vehicle slope increases at a location that is roughly 80% of the distance along the first influence area, and quickly assumes a slope that is similar to the slope of the second influence area. Therefore, an additional detector location that would shorten the first influence area may have resulted in a transition to the slope shown in the second influence area sooner, and therefore decreased the estimated travel time to bringing the estimated and final travel times closer. However, the accuracy of the prediction for this run was very good, and found to be statistically valid.

The results of this analysis suggest that the ODOT detector configurations perform adequately under congested conditions that remain consistent throughout the time the vehicle is traveling the route. The congested conditions experienced by this run are indicative of recurring congestion where the vehicle speeds are somewhat consistent and average roughly 30 MPH, as opposed to incident conditions where vehicles encounter stop and go conditions. In addition, while the calculated travel time on this route was accurate, it should be noted that the roughly 2.5 mile length of the first influence area is a long area, and the travel time prediction would have likely improved with a shorter influence area.

To summarize, scenarios under congestion perform well with the current ODOT configurations, but increased detection would improve the estimations further.

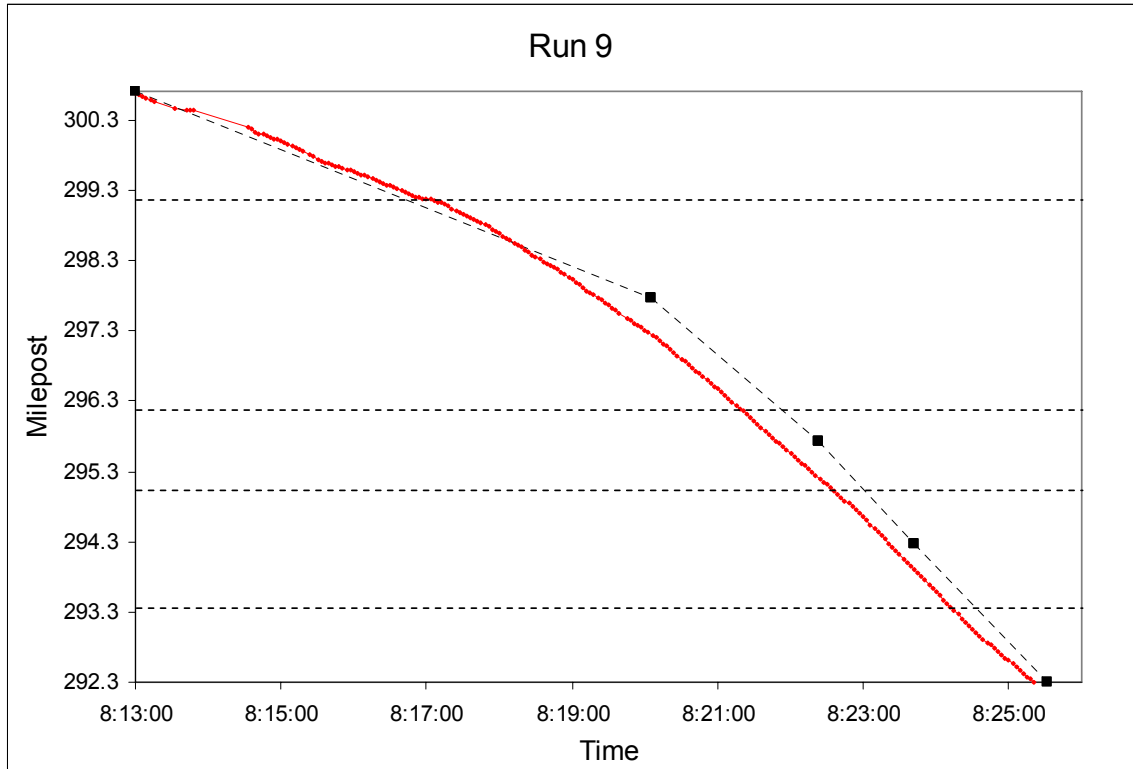


Figure 8 – Probe Vehicle Run along I-5 SB from I-405 to HWY 217
(dashed horizontal lines represent detector locations –solid horizontal lines represent influence area bounds)

Situation 3: Congestion upon entry that clears during the trip

In situations where one or more influence areas are experiencing congestion at the moment information is presented to the travelers, and then the congestion clears in subsequent detector readings, the risk is that the system will report longer travel times than the travelers will experience.

Run #8, illustrated below, covers the same freeway segment as illustrated in Figure 9 above (I-5 from I-405 to Hwy 217). Upon close examination of this plot, the detector reporting conditions for the first influence area has detected slow vehicle speeds that closely match the speed of the probe vehicle for roughly the initial 8 minutes. However, the probe vehicle speed significantly increases prior to reaching the first detector station, and is reporting higher speeds at the detector location than were recorded at that detector during the initial speed detection. The situation strongly suggests that the congestion along the first influence area cleared after the time at which the detector readings were taken and the vehicle entered the route and before the probe vehicle reached the location of the first detector station. The probe vehicle eventually settles in to a very similar speed (slope) as the detectors reporting along influence areas 2, 3, and 4.

The conclusions drawn from this experience are as follows:

- Additional detection prior to the first detector (just after Milepost 299.3) would not have improved the predictions for this run.
- Additional detection between the first and second detectors may have improved the accuracy of the estimation, however only if the additional detector was downstream of the congestion. Still, the additional detectors would have no impact on reducing the divergence in travel times caused by the congestion clearing (after the initial readings were recorded and before the vehicle reached the first detector).
- The impacts of congestion clearing are experienced very quickly by vehicles along the route (as the capacity of the roadway allows vehicles to accelerate to the speed limit very quickly), and therefore the clearing of an event will likely have a dramatic difference in the actual travel time versus a predicted time when the congestion was still in effect.

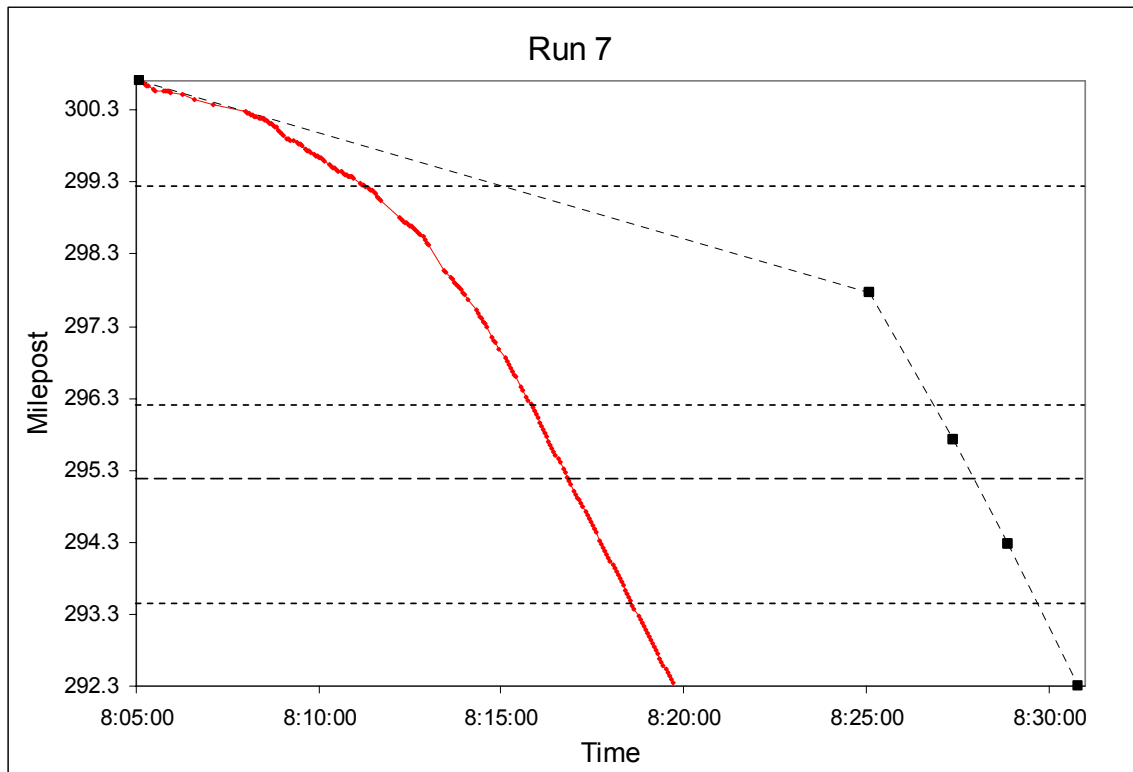


Figure 9 – Probe Vehicle Run along I-5 SB where congestion appears to clear during the run (dashed horizontal lines represent detector locations –solid horizontal lines represent influence area bounds)

Situation 4: Free flowing traffic upon entry becomes congested during the trip

Situations where the conditions along a route do not show congestion when the travel time calculation is performed and the vehicle starts the trip, but where congestion builds during the time of the trip, present a different type of challenge. Figure 11 below illustrates the probe vehicle run and the calculated travel times for a stretch of I-5 Southbound from Interstate Bridge to Going Street. Close examination of the probe vehicle trajectory shows a slowing of travel speed at approximately Milepost 317.5. At the location where the speed of the probe vehicle slows the probe and calculated travel times are nearly the same. However, the probe lines and the estimated lines quickly diverge and illustrate nearly a 2 minute travel time difference over the next mile.

In this example, once the probe vehicle's speed increases again (with the assumption that it has cleared the location of congestion), the speed of the probe vehicle is faster than the estimated speed for each of the remainder of the influence areas along the route. When this observation is considered with the fundamentals of traffic flow, any time congestion slows a stretch of freeway it restricts the flow of vehicles downstream. When that congestion frees or when the vehicles clear the area of congestion, there is typically excess capacity downstream and therefore vehicles' speeds will be higher. This possibly explains why the probe travels faster downstream than measured by the detectors at the start of the run, when there was no significant congestion along the route.

The plot below suggests that when the travel times were calculated there was some slowing and congestion along the second influence area, however not as significant as the probe vehicle encountered.

Conclusions about situations where congestion builds after the travel time is estimated are as follows:

- New congestion restricting vehicle speeds will cause predicted and actual travel times to quickly diverge.
- Additional detectors will not compensate for speed changes encountered after the estimations were performed, however increased detection along the route will cause the overall accuracy to increase because of shorter influence zones being better able to predict the general conditions.
- Similar to how new congestion causes a slow down to occur that was not measured by the detectors before the run began, the slow down will likely cause downstream vehicle speeds to be faster than those measured before the trip began, having the effect of reversing the diverging paths of the probe vehicle run and the calculated run.
- In summary, congestion occurring after the detector readings were taken will cause divergence regardless of the number of detector stations, and will likely not see a drastic improvement with increased detector deployments.

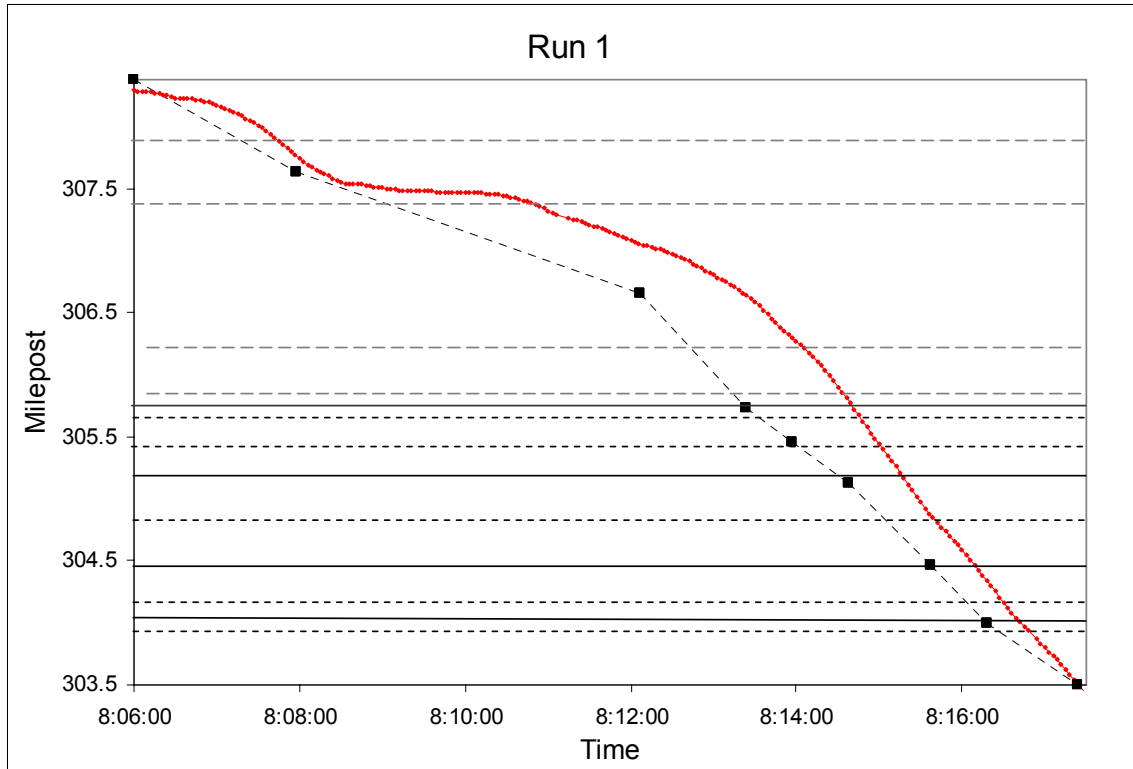


Figure 10 – Results of Run 1 Illustrating Situation #4
(dashed horizontal lines represent detector locations –solid horizontal lines represent influence area bounds)

Situation 5: The presence of an incident that seriously affects traffic flow

In cases where an incident significantly reduces the speed along a route, often the speed is reduced so tremendously that the detectors may often give erroneous data. Every probe run that generated incidents produced results that suggested the predicted travel time was not equal to the probe’s time. These results are consistent with discussions with Mn/DOT traffic operators, where detectors are located every ½ mile. Even with ½ mile density, incidents are difficult for the prediction to properly report travel times.

Therefore, for scenarios where incidents occur, it is generally accepted that the travel times will be off. ODOT respects this currently by not specifying minutes of travel time over 15 minutes (but rather reporting ‘greater than 15 minutes’). Additional detection would help, but only if it were near the incident (upstream and downstream).

5.2 Assessment of Improved Instrumentation or Modified Algorithms

Travel time estimation and prediction can be improved by at least two approaches, identified as follows:

- Improved instrumentation, consisting of increased detectors or more strategically placed detectors; and
- Modified algorithms to compute travel times using existing detector data.

5.2.1 *Improved Instrumentation*

One approach to determining the ideal number and location of detectors is to assume that increased detection will always improve the accuracy of travel time estimation and to deploy as many detectors as financially feasible. Essentially, it is correct that increased detection will improve the accuracy (and certainly not hurt the accuracy); however, the more challenging question is ‘to what extent will increased detection improve the accuracy?’ The preceding section outlined conclusions about different scenarios experienced by travelers. The following four points regarding increased detection were presented:

- For travel along routes experiencing steady state free flow conditions that remain in effect for the duration of a trip, the current ODOT configuration of detectors and algorithms performs adequately, and increased detection would be improving on already adequate results.
- For travel along routes experiencing steady state congestion conditions that remain in effect from before the travel time calculations were performed until after the vehicle completes the route, the current ODOT configuration of detectors performs adequately in most situations, and increased detection will continue to improve this. The most dramatic benefit of increased detection will be at a location where recurring congestion is common and where the termination point of the congestion is a known location (i.e. where the freeway drops a lane and congestion is frequent, a detector immediately downstream will significantly increase accuracy.
- For travel along routes experiencing congestion that clears while the vehicle is traveling along the route, the ODOT configuration does not perform well, and increased detection will only have a marginal impact.
- For travel along routes where congestion begins after the travel time calculations are performed and before the vehicle completes the route, the ODOT configuration appears to perform well with the limited sample set along a stretch of well instrumented detectors, but only after the probe vehicle diverges significantly from the estimated travel time and then rejoins it by encountering faster speeds downstream of the location of congestion.
- For travel along routes with an incident occurring, the current ODOT configuration does not perform well. Increased detection will improve this so long as the detectors are located near the locations of the incidents, which typically is not possible to predict.

Therefore, additional detectors for the Portland metropolitan area would be recommended for those locations where recurring congestion that lasts a substantial time during peak hours occurs. In addition, any locations that are prone to incidents should be considered for additional detectors.

5.2.2 *Effects of Modified Algorithms*

The ODOT midpoint and adjusted algorithm calculations are very straightforward algorithms for computing travel times. Each detector serves as a single point to represent speeds along an entire influence area. This section presents three options for modifying the algorithms:

- Consideration of historic data;
- Averaging across detector stations; and
- Utilizing t-1 or t-3 data.

Consideration of historic data

One adjustment to the ODOT algorithms could be to include some weighted averaging where the current reading at a detector station is combined with readings from the same detector station at the same time during previous commute days (for example using values from the three previous days, or maintaining a running average of each detectors average reading at a given time by factoring in each new day's readings).

The advantages of this algorithm modification would include the following:

- The travel time estimations would be less sensitive to significant changes in travel times caused either by congestion or by incidents. For example, if today's reading at 5:00 P.M. by a detector shows a speed of 5MPH, although that detector location has an average of 30MPH during that timeframe, then the factoring of historic data may result in a reported speed of 10MPH. If the situation begins to improve very quickly, a computed travel time closer to the average travel time would be a better estimate. Therefore, this algorithm modification might avoid the presentation of travel times that vary significantly from the normal times, because in reality the system may return to normal before the vehicle completes the route.
- The second benefit of this approach would be that in the case where detector data is temporarily unavailable from a detector, the historic data could be used to estimate the travel time. This would require a decision to use historic data when current data is not available.

Averaging across detector stations

A second potential algorithm modification is an approach used by the Minnesota Department of Transportation. Rather than utilizing one detector speed to estimate the speed along an entire influence area, Mn/DOT divides an influence area into three sub-sections. The middle sub-section is described by the speed of the detector located in the middle of the influence area. The sub-section on either side of the middle sub-section reports a speed that is the average of the detector reading for that influence area, and the reading from the detectors in the neighboring influence areas. In effect, this is recognition that if a vehicle is traveling 10 MPH at one detector, and then 20 MPH at the next detector, there is not a point at which the vehicle instantaneously changes speed, but rather a range, and this is accounted for by averaging the two detectors for this middle range (sub-section).

Use of t-1 or t-3 minute reporting cycles

The calculations performed in this study also included calculated travel times for both the midpoint and modified ODOT approaches if the current detector readings are combined with reading from 1 or 3 minutes prior. As presented above, this tends to dampen the impacts of changing speeds and has the effect of not causing one reading to make such a drastic difference.

5.3 *Interpreting the Results against ODOT's Goals for this Study*

Revisiting the original goals for this study, ODOT is currently reporting travel times along key sections of I-5 (Northbound near Wilsonville, Northbound at Carmen, and Southbound at Terwilliger), and was hoping to understand the accuracy of travel time estimations along these routes. In addition, ODOT is considering posting travel times on VMS along additional freeways. Finally, ODOT is considering disseminating travel times using the TripCheck website or the 511 phone system. Recommendations are presented below for each of these considerations:

Locations where VMS currently display travel time estimations

The probe runs for these locations suggest that the travel time estimations are accurate, especially during steady state free-flow or congested conditions. During incidents or major events that cause congestion the travel time estimates may be off, however the ODOT VMS display does not specify any travel times above 15 minutes. Locations along I-5 where recurring congestion occurs should be considered for additional detection. While this will generally tighten up the accuracy of the estimates, it is not expected that this will have much impact on those periods where congestion is building or clearing. Nor will it greatly improve the accuracy during incidents.

Another option that ODOT should consider is adopting a modified algorithm similar to the Mn/DOT algorithm to allow a smoother transition from one detector to another.

One link (Link 7) of I-5 did not conclude that the probe travel time and estimated travel time were statistically the same. The plots of the 5 runs along this link (shown in the Appendix) illustrate that one run had a significant change in the slope of the probe vehicle that slowed the vehicle tremendously. The remainder of the runs was much more accurate. Again, such a change of slope (assumed to be caused by congestion occurring after the estimation is calculated) would not be improved by additional sensors.

Additional Locations Where VMS Displays May Be Located

The additional links around the Portland metropolitan area performed well, with the exception of Hwy 26 and Hwy 217. As explained earlier in this report, the probe vehicle runs all encountered incident events along these routes. Therefore, the results of runs without incidents have demonstrated that the general performance of travel time estimations is adequate to display travel times on additional VMS signs. However, additional data collection or observations along Hwy 26 and Hwy 217 should be performed to verify these stretches. Additional detectors would have marginal impacts on the travel time accuracy, but again is likely to have little impact on those periods where congestion is building or clearing.

Dissemination of Travel Times on TripCheck and 511

Unlike VMS signs immediately upstream of a route, Internet and telephone dissemination of travel times adds an additional layer of complexity. Earlier, this section illustrated how significant an impact a change in steady state conditions after the travel time is reported to travelers can have (either by congestion building or clearing). Travelers viewing travel times on the Internet or calling 511 may not travel the route for several to many minutes after receiving the travel time prediction. While the information presented to travelers on the Internet and phone system will be useful when understood to be a snapshot in time, it is recommended that ODOT consider using different algorithms when computing the travel times to be presented on 511 and/or the Internet, as follows:

- The consideration of historic data will allow for a smoothing effect, and allow ODOT to factor in some predictive aspect to the travel time reporting. For example, at 4:15PM the travel time along a route may be calculated to be 16 minutes. However, the historic travel time for this route at 4:30 may average 19 minutes. Combining the current travel time prediction, with an average value for what the travel time is over the immediate future may allow ODOT to present a time that is closer to what the traveler will experience when they reach the route.
- The consideration of heuristics may also allow ODOT to present a travel time with predictive qualities. For example, if the travel time for a route is computed as 12 minutes, and the previous calculation (20 seconds prior) was 11 minutes, and the next prior calculation (40 seconds prior) was 10 minutes. A simple

heuristic algorithm examining trends in travel times, as well as other factors such as time of day will allow the travel time to be assumed to be increasing, and may be presented to the caller as '12-15 minutes'.

- ODOT might consider an adjusted reporting strategy for 511 and the Internet, such as “travel times over the next half hour along I-5 from Wilsonville to 217 are expected to be 12-15 minutes”. This might help travelers understand if there is a difference in the travel time reported on the phone and the VMS signs.

5.4 Conclusions on the Benefits of Increased Detectors

To summarize the results and conclusions developed earlier in this report, increased detection will have the most significant impact on the accuracy of travel time predictions for trips where steady state congestion occurs over the duration of the route at the time the vehicle travels. The ultimate scenario would be to have a detector immediately after the location where congestion clears (or begins), to capture the new vehicle speed as close to the location where it occurs as possible. While this ultimate scenario is not possible using fixed location detectors, any increase in detection will narrow the distance from the location of speed change to the detector.

Therefore, ODOT's travel time estimations would benefit the most by deploying additional detectors at locations where recurring congestion is likely, and especially if the bounds of congestion can be reasonably predicted (i.e. where a lane drops, or a merge causes congestion but clearing occurs just after the location). Section 6 of this report presents locations of recurrent congestion in the Portland area to assist in this analysis.

6. Understanding the Locations of Recurring Congestion

6.1 Identifying Links where Recurring Congestion Occurs as Potential Sites for Additional Detectors

As a concluding task in this project, the PORTAL system was queried to generate graphs illustrating the locations where speeds are reduced on a recurring basis. These locations are presented in Appendix 2 to assist ODOT in assessing the recommendations for additional sensors (i.e. where recurring congestion occurs). For purposes of this study, locations of congestion were determined by colors representing slow traffic (e.g. light green, yellow or red). In the example illustrated below, two general stretches of the road (Hwy 26 EB) are represented by a pattern of light green and/or yellow and red coloration: from MP 65-67 and 69-74. Similar visual observations of the remaining roadway sections produced the complete list of candidate stretches of road provided below.

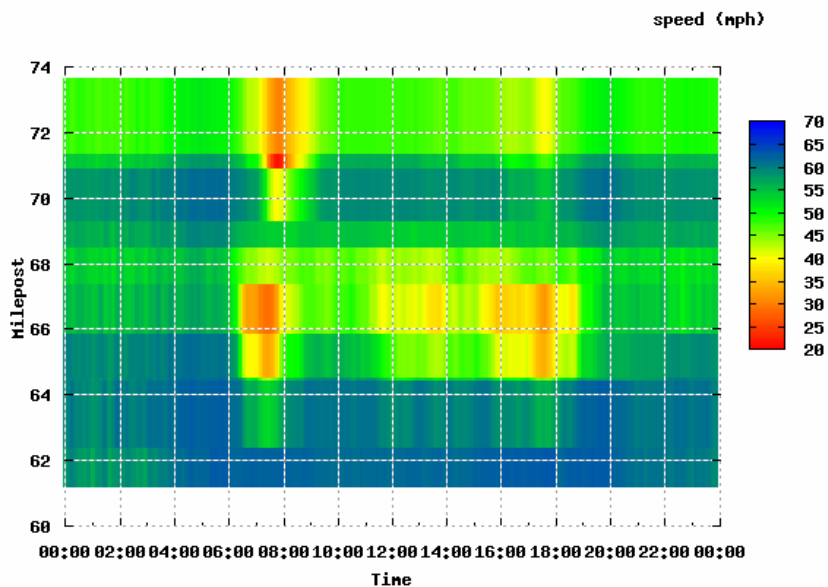


Figure 11 – Average Travel Speeds Reported Along Hwy 26 EB

The plots of the speed trends for each roadway are included in Appendix B; however, a high-level summary of those stretches of roads that may be considered to have the most significant recurring congestion are as follows:

- I-205 NB at MP 9
- Hwy 217 NB at MP 2.5-4.5
- Hwy 217 NB at MP 6-6.5

- Hwy 217 SB at MP 0 - .5
- Hwy 217 SB at MP 2-6
- Hwy 217 SB at MP 6-7
- Hwy 26 EB at MP 65-67 (displayed in the example plot above)
- Hwy 26 EB at MP 69-74 (displayed in the example plot above)
- Hwy 26 WB at MP 67-74
- I-5 NB at MP 296-300
- I-5 NB at MP 305 to State Line
- I-5 SB at MP 306-307
- I-84 EB at MP 0-3.5

6.2 *Analysis of Existing Detectors to Narrow Potential Sites for Additional Detectors*

By examining each of the links identified above against the locations of existing detectors, many of the locations above can be eliminated, or the stretches of roads narrowed. As a preliminary elimination strategy, the above locations were compared against existing detectors, and the following locations represent locations within the stretches of roads identified above that would benefit by increased detector density, most often identified by stretches of road between detectors of length one mile or longer.

- Hwy 217 NB at MP 3.2
- Hwy 26 EB at MP 70
- Hwy 26 WB at MP 69
- Hwy 26 WB at MP 70
- I-5 NB at MP 298.5
- I-5 SB at MP 306.5
- I-84 EB at MP 2.0

In summary, the analysis of the probe vehicle runs concluded that the situations that stand the most benefit by additional detectors are those with recurring congestion that lasts for the duration of the trip. By examining plots of locations of recurring congestion, a series of 13 stretches of roadways were identified as potential candidates to be areas where recurring congestion occurs. By examining the current detection along these 14 stretches of roadway, and eliminating those stretches that already have good coverage of detectors (i.e. 1 mile or less distance between detectors), 7 locations were identified as likely candidates for additional detectors.

6.3 Sensitivity Analysis of Sample Locations of Recommended Detection

Using a plot of Hwy 26 EB where individual detector reports of speeds are plotted against the probe vehicle trajectory, the following plot illustrates the calculated travel time (under existing detection conditions), and the probe vehicle results.

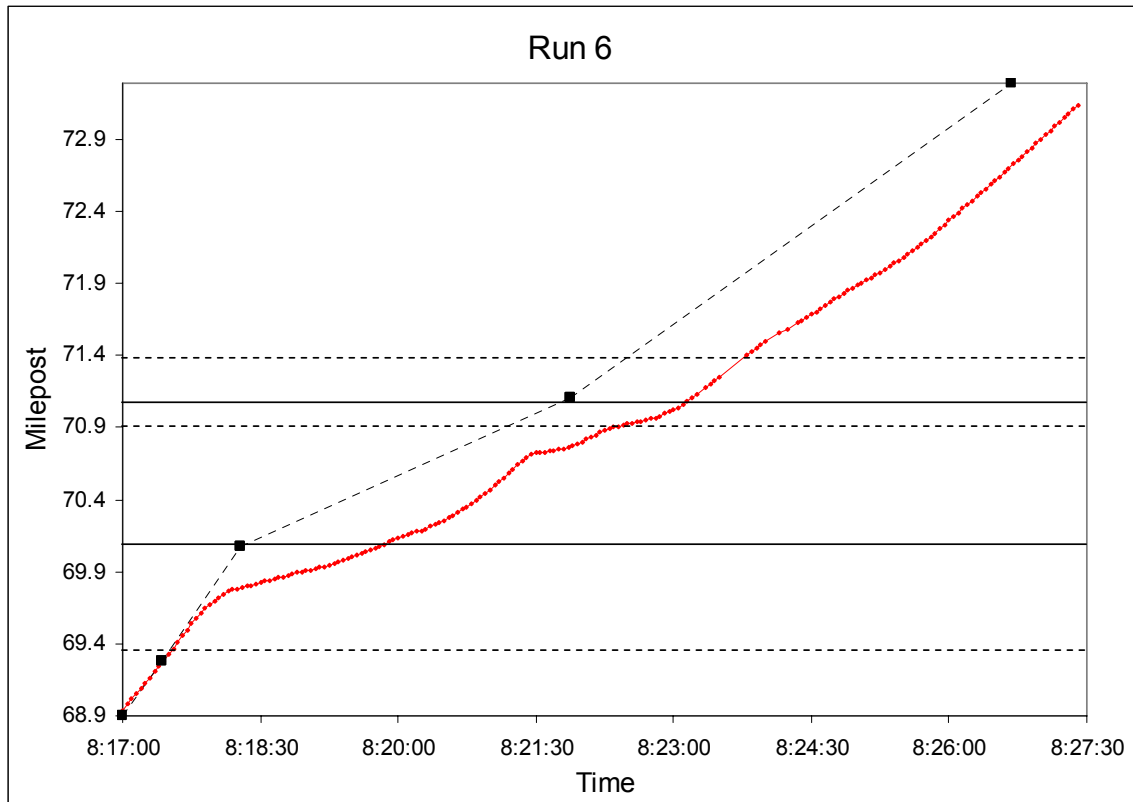


Figure 12 – Highway 26 Eastbound – Travel Time and Probe Vehicle Results

To perform a sensitivity experiment, if we follow the recommendation above for this link and simulate the addition of a detector at MP 70, and make some assumptions as follows:

- Assume that the new simulated detector at MP 70 would also report the same speed (slope) as the probe vehicle recorded while passing MP 70 (remembering that this is to address steady state congestion conditions).
- Assume that the other readings are the same as presented in Figure 12

The illustration below is a graphical estimation of the impacts on travel time if there were an additional detector at MP 70. The impacts would be an earlier conversion to the slope followed by the probe vehicle when it slowed down upon reaching MP 69.7. The blue bolded horizontal dotted lines in the graph below represent the location of the new detectors. The blue bolded horizontal lines represent an estimate of the travel times that would have been calculated by PORTAL with the additional detector.

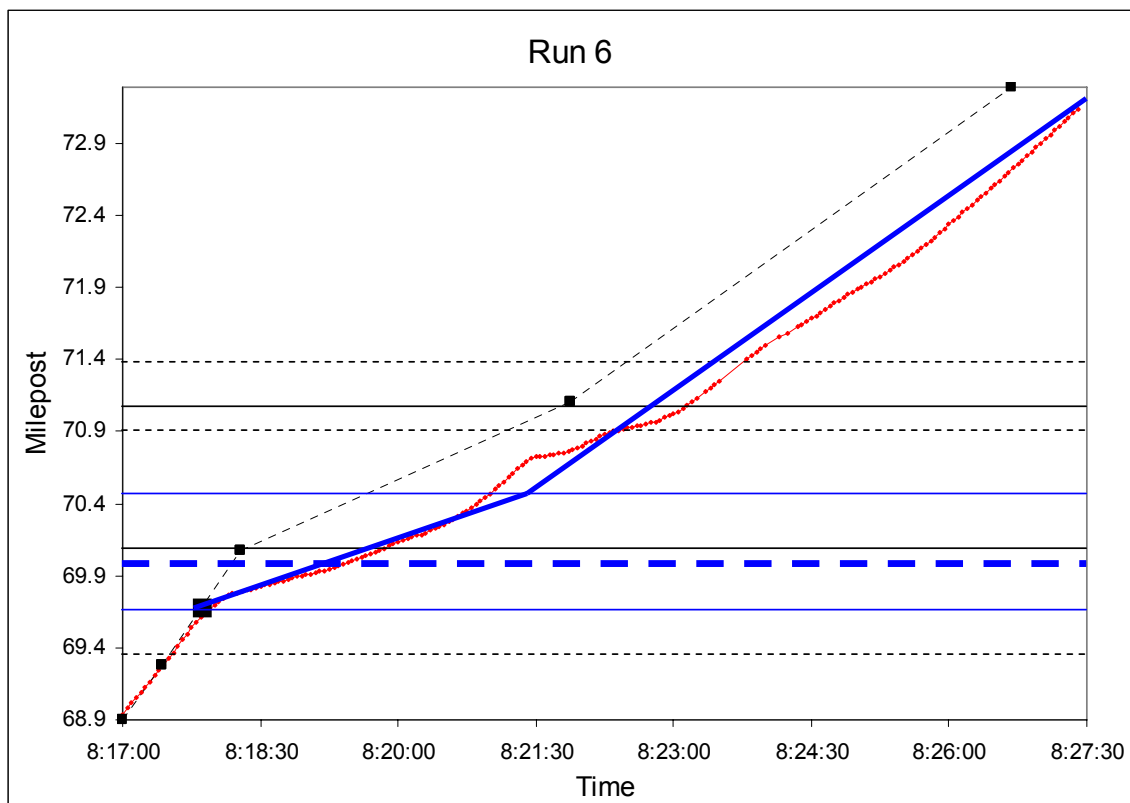


Figure 13 – Illustration of Estimated Impacts of Additional Detectors on Link 16 (horizontal dashed lines represent detectors – horizontal solid lines represent the bounds of the influence areas)

Figure 13 above illustrates graphically that the impacts of an additional detector on Hwy 26 EB at MP 70 would have resulted in a travel time calculation that more closely resembles the actual time encountered by the probe vehicles, with the stated assumptions above. Therefore, based on this data run, the recommended additional detectors appear to make a significant impact on travel time predictions in areas with recurrent congestion.

7. Conclusions

The ODOT Travel Time Estimation Project was intended to assess the current performance of the detectors and algorithms currently employed by the ODOT ATMS to predict travel times.

In general, the statistical analysis revealed that the travel time predictions by the ATMS (recreated within PORTAL for this project) perform very well. Only some locations did not result in statistically valid results suggesting that the calculated travel times were the same as the probe vehicle times.

One target result of this project was some recommendations of those locations where additional detectors would improve travel time predictions. A methodology was followed that resulted in identifying seven locations that would likely have a significant impact on improving travel time predictions. A brief recap of the process of identifying these locations is summarized in this section.

7.1 Determining which Situations will Benefit from Increased Detection

Analysis of the probe data compared to the PORTAL data, as well as traffic engineering fundamentals, resulted in the following initial conclusions:

- Increased detection will most benefit locations and times where recurring congestion occurs;
- The greatest benefits of increased detection will be during steady state congestion conditions, as opposed to the periods where congestion is beginning or clearing;
- Situations where incidents are occurring will only benefit from increased detection if the detection happens to be right near the incident, and then the benefits (of increased detection) will be marginal as incident conditions are so unpredictable.

7.2 Identifying the Locations Where Recurring Congestion Occurs

With the conclusion drawn that increased detection should be used to address those areas where steady state recurring congestion tends to occur, visual analysis of PORTAL reports of average traffic speeds recorded during the time of this project identified 13 stretches of road where recurring congestion appears to be an issue.

- I-205 NB at MP 9
- Hwy 217 NB at MP 2.5-4.5

- Hwy 217 NB at MP 6-6.5
- Hwy 217 SB at MP 0 - .5
- Hwy 217 SB at MP 2-6
- Hwy 217 SB at MP 6-7
- Hwy 26 EB at MP 65-67 (displayed in the example plot above)
- Hwy 26 EB at MP 69-74 (displayed in the example plot above)
- Hwy 26 WB at MP 67-74
- I-5 NB at MP 296-300
- I-5 NB at MP 305 to State Line
- I-5 SB at MP 306-307
- I-84 EB at MP 0-3.5

7.3 *Narrowing the Candidate Locations for Increased Detection*

Building upon the 13 stretches of roads identified as candidates for increased detection, the next step was to examine the current detector spacing and locations along the 13 corridors identified above. A rule of thumb for this analysis was that any locations where detectors were 1 mile or less apart were seen as having adequate detector spacing. By searching for detector spacing gaps of 1 mile or more within the candidate areas, the following seven locations were concluded as having the best potential for impact in improving travel time estimations:

- Hwy 217 NB at MP 3.2
- Hwy 26 EB at MP 70
- Hwy 26 WB at MP 69
- Hwy 26 WB at MP 70
- I-5 NB at MP 298.5
- I-5 SB at MP 306.5
- I-84 EB at MP 2.0

Appendix A – Statistical Data

I-5 Northbound: I-205 Interchange to I-405 Interchange

MP 287.85 300.40

Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	04/08/05	16:02:18	14.85	20.92	16.48	19.41	16.97	15.98	14.65
2	04/28/05	16:34:39	13.85	14.22	12.93	13.86	13.57	12.66	12.40
3	05/04/05	17:06:30	13.45	14.90	13.52	14.99	14.92	13.67	13.61
4	05/04/05	16:59:48	13.25	14.99	13.73	14.87	14.76	13.62	13.43
5	05/04/05	17:24:57	14.00	15.58	14.48	15.32	15.39	14.12	14.23
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7									
8									
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10									
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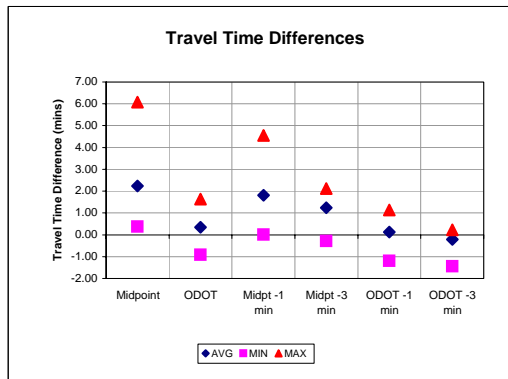
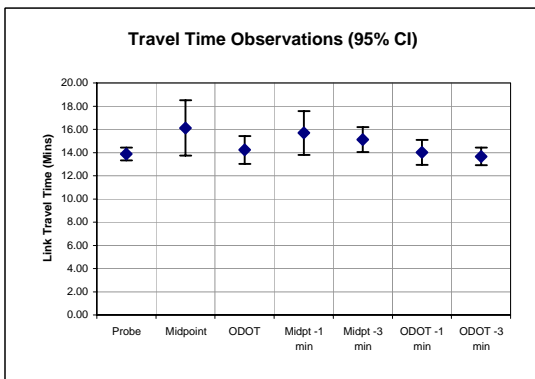
Difference from Probe Times

Run	Probe	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1		6.07	1.63	4.56	2.12	1.13	-0.20
2		0.37	-0.92	0.00	-0.28	-1.19	-1.45
3		1.45	0.07	1.54	1.47	0.21	0.15
4		1.74	0.48	1.62	1.51	0.37	0.18
5		1.58	0.48	1.32	1.39	0.12	0.23
6							
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Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	13.88	16.12	14.23	15.69	15.12	14.01	13.66
Std. Deviation	0.62	2.73	1.38	2.15	1.23	1.22	0.86
Sample Size	5	5	5	5	5	5	5
95% Confidence Interval	0.54	2.39	1.21	1.88	1.08	1.07	0.75
TT - CI 95%	13.34	13.73	13.02	13.80	14.04	12.93	12.91
TT + CI 95%	14.42	18.51	15.43	17.57	16.20	15.08	14.42
Average Difference		2.24	0.35	1.81	1.24	0.13	-0.22
Percent Error		16.15%	2.51%	13.02%	8.95%	0.92%	-1.56%
95% CI Difference		2.74	1.14	2.07	1.12	1.04	0.88
Percent Error- CI 95%		-3.59%	-5.70%	-1.92%	0.90%	-6.58%	-7.89%
Percent Error + CI 95%		35.89%	10.71%	27.95%	16.99%	8.42%	4.78%
Min Difference		0.37	-0.92	0.00	-0.28	-1.19	-1.45
Max Difference		6.07	1.63	4.56	2.12	1.13	0.23

Results of the Paired T-Test

P-value		0.0855	0.4439	0.0728	0.0367	0.7500	0.5328
Significance	0.05	YES	YES	YES	NO	YES	YES



I-5 Northbound: I-205 Interchange to Interstate Bridge

MP 287.85 308.38

Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	04/08/05	16:02:18	44.60	55.36	50.90	49.78	45.93	46.37	43.61
2	05/04/05	17:06:30	28.55	28.34	26.92	28.85	31.82	27.50	30.47
3	05/04/05	16:59:48	28.95	33.44	32.12	35.39	31.30	34.09	29.93
4	05/04/05	17:24:57	28.70	30.29	29.18	29.65	29.05	28.43	27.87
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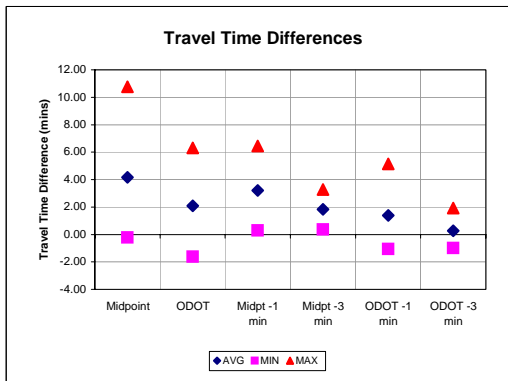
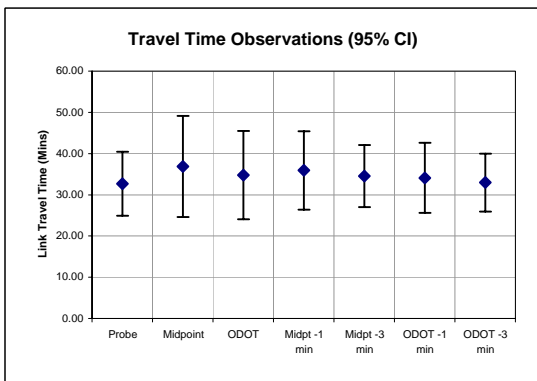
Difference from Probe Times

Run	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	10.76	6.30	5.18	1.33	1.77	-0.99
2	-0.21	-1.63	0.30	3.27	-1.05	1.92
3	4.49	3.17	6.44	2.35	5.14	0.98
4	1.59	0.48	0.94	0.35	-0.27	-0.83
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Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	32.70	36.86	34.78	35.92	34.53	34.09	32.97
Std. Deviation	7.94	12.51	10.96	9.69	7.70	8.68	7.18
Sample Size	4	4	4	4	4	4	4
95% Confidence Interval	7.78	12.26	10.74	9.49	7.54	8.51	7.04
TT - CI 95%	24.92	24.60	24.04	26.42	26.98	25.58	25.93
TT + CI 95%	40.48	49.12	45.52	45.41	42.07	42.60	40.01
Average Difference		4.16	2.08	3.22	1.83	1.39	0.27
Percent Error		12.71%	6.36%	9.83%	5.59%	4.26%	0.83%
95% CI Difference		7.65	5.46	4.85	2.01	4.40	2.25
Percent Error- CI 95%		-10.69%	-10.34%	-5.01%	-0.55%	-9.19%	-6.06%
Percent Error + CI 95%		36.11%	23.06%	24.68%	11.73%	17.71%	7.71%
Min Difference		-0.21	-1.63	0.30	0.35	-1.05	-0.99
Max Difference		10.76	6.30	6.44	3.27	5.14	1.92

Results of the Paired T-Test

P-value		0.1822	0.3121	0.1255	0.0627	0.3876	0.7277
Significance	0.05	YES	YES	YES	YES	YES	YES



Link 2 - I-5 Northbound: I-205 Interchange to 217 Interchange

MP 287.85 291.78 Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	02/18/05	15:04:06	3.30	2.75	2.74	2.67	2.69	2.66	2.68
2	04/08/05	16:02:18	4.05	4.08	4.07	4.37	4.36	4.36	4.35
3	04/08/05	17:35:33	3.85	4.44	4.10	4.47	4.37	4.40	4.34
4	04/28/05	16:34:39	3.95	4.12	4.11	4.21	4.02	4.20	4.02
5	05/04/05	17:06:30	3.85	4.52	4.51	4.57	4.45	4.56	4.44
6	05/04/05	16:59:48	4.00	4.30	4.29	4.71	4.51	4.70	4.50
7	05/04/05	17:24:57	3.95	5.43	5.42	4.95	5.01	4.94	5.00
8	05/04/05	17:29:45	4.20	5.32	5.31	4.95	4.65	4.95	4.65
9									
10									
11									

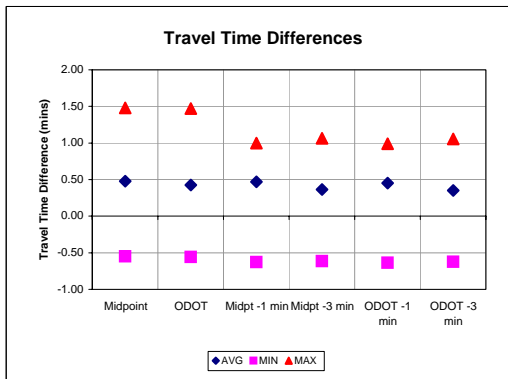
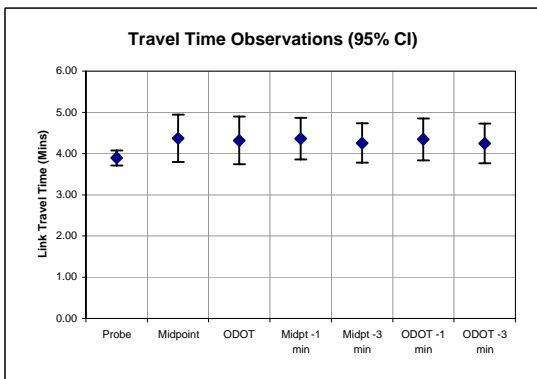
Difference from Probe Times

Run	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	-0.55	-0.56	-0.63	-0.62	-0.64	-0.63
2	0.03	0.02	0.32	0.31	0.31	0.30
3	0.59	0.25	0.62	0.52	0.55	0.49
4	0.17	0.16	0.26	0.07	0.25	0.06
5	0.67	0.66	0.72	0.60	0.71	0.59
6	0.30	0.29	0.71	0.51	0.70	0.50
7	1.48	1.47	1.00	1.06	0.99	1.05
8	1.12	1.11	0.75	0.45	0.74	0.44
9						
10						
11						

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	3.89	4.37	4.32	4.36	4.26	4.34	4.25
Std. Deviation	0.27	0.83	0.83	0.73	0.69	0.73	0.69
Sample Size	8	8	8	8	8	8	8
95% Confidence Interval	0.18	0.58	0.58	0.51	0.48	0.51	0.48
TT - CI 95%	3.71	3.79	3.74	3.85	3.78	3.84	3.76
TT + CI 95%	4.08	4.95	4.90	4.87	4.74	4.85	4.73
Average Difference		0.48	0.42	0.47	0.36	0.45	0.35
Percent Error		12.23%	10.91%	12.01%	9.34%	11.57%	9.04%
95% CI Difference		0.53	0.54	0.42	0.40	0.42	0.40
Percent Error- CI 95%		-1.47%	-2.83%	1.21%	-1.05%	0.81%	-1.35%
Percent Error + CI 95%		25.93%	24.66%	22.80%	19.73%	22.33%	19.43%
Min Difference		-0.55	-0.56	-0.63	-0.62	-0.64	-0.63
Max Difference		1.48	1.47	1.00	1.06	0.99	1.05

Results of the Paired T-Test

P-value		0.0727	0.1026	0.0339	0.0712	0.0385	0.0786
Significance	0.05	YES	YES	NO	YES	NO	YES



LINK 3 - I-5 Northbound: OR-217 Interchange to I-405 Interchange

MPs 291.78 300.40

Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	04/08/05	16:06:27	10.70	11.50	9.36	12.53	13.81	10.15	10.89
2	04/28/05	16:38:39	9.85	9.60	8.38	9.42	9.58	8.27	8.37
3	05/04/05	17:10:24	9.55	9.36	8.12	9.42	9.86	8.33	8.69
4	05/04/05	17:03:51	9.20	10.75	9.32	10.09	9.69	8.84	8.53
5	05/04/05	17:08:57	9.30	9.86	8.72	10.23	10.21	8.98	9.03
6	05/04/05	17:28:57	10.00	9.75	8.60	9.92	9.90	8.81	8.77
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8									
9									
10									
11									

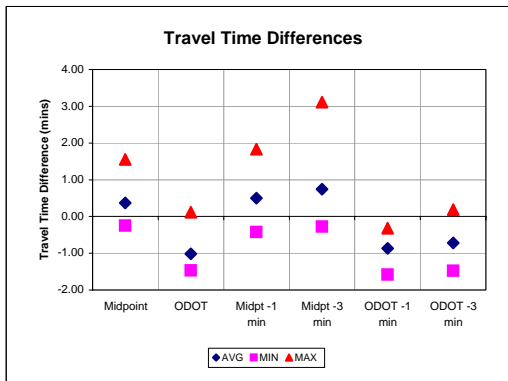
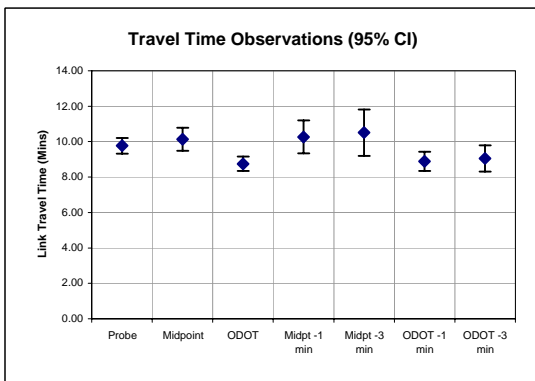
Difference from Probe Times

Run	Probe	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1		0.80	-1.34	1.83	3.11	-0.56	0.19
2		-0.25	-1.47	-0.43	-0.27	-1.58	-1.48
3		-0.19	-1.43	-0.14	0.30	-1.23	-0.86
4		1.55	0.12	0.89	0.49	-0.36	-0.67
5		0.56	-0.58	0.93	0.90	-0.32	-0.28
6		-0.25	-1.40	-0.08	-0.10	-1.19	-1.23
7							
8							
9							
10							
11							

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	9.77	10.14	8.75	10.27	10.51	8.89	9.05
Std. Deviation	0.55	0.82	0.50	1.16	1.63	0.68	0.93
Sample Size	6	6	6	6	6	6	6
95% Confidence Interval	0.44	0.66	0.40	0.93	1.31	0.54	0.74
TT - CI 95%	9.33	9.48	8.35	9.34	9.20	8.35	8.30
TT + CI 95%	10.21	10.79	9.15	11.19	11.81	9.44	9.79
Average Difference		0.37	-1.02	0.50	0.74	-0.87	-0.72
Percent Error		3.79%	-10.41%	5.12%	7.58%	-8.93%	-7.38%
95% CI Difference		0.77	0.68	0.90	1.30	0.55	0.64
Percent Error- CI 95%		-4.10%	-17.39%	-4.13%	-5.69%	-14.61%	-13.98%
Percent Error + CI 95%		11.68%	-3.43%	14.38%	20.86%	-3.25%	-0.79%
Min Difference		-0.25	-1.47	-0.43	-0.27	-1.58	-1.48
Max Difference		1.55	0.12	1.83	3.11	-0.32	0.19

Results of the Paired T-Test

P-value		0.2719	0.0122	0.2139	0.2020	0.0099	0.0346
Significance	0.05	YES	NO	YES	YES	NO	NO



LINK 4 - I-5 Northbound: I-84 Interchange to Interstate Bridge

MP 300.40 308.38

Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	04/08/05	16:17:12	29.70	30.82	30.76	29.77	31.75	29.71	31.70
2	05/04/05	17:20:00	15.05	12.01	11.99	13.13	13.33	13.11	13.31
3	05/04/05	17:13:09	15.60	21.01	20.98	21.71	18.16	21.68	18.13
4	05/04/05	17:18:18	14.90	13.30	13.28	13.11	15.36	13.08	15.33
5	05/04/05	17:39:00	14.65	16.32	16.29	17.18	15.89	17.12	15.85
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8									
9									
10									
11									

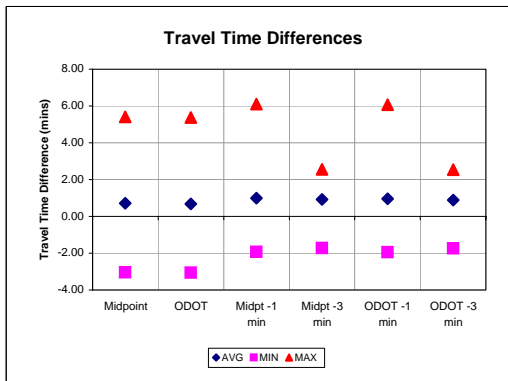
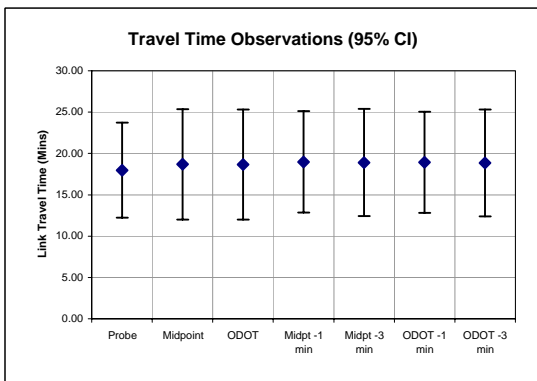
Difference from Probe Times

Run	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	1.12	1.06	0.07	2.05	0.01	2.00
2	-3.04	-3.06	-1.92	-1.72	-1.94	-1.74
3	5.41	5.38	6.11	2.56	6.08	2.53
4	-1.60	-1.62	-1.79	0.46	-1.82	0.43
5	1.67	1.64	2.53	1.24	2.47	1.20
6						
7						
8						
9						
10						
11						

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	17.98	18.69	18.66	18.98	18.90	18.94	18.87
Std. Deviation	6.56	7.61	7.60	7.00	7.39	6.98	7.38
Sample Size	5	5	5	5	5	5	5
95% Confidence Interval	5.75	6.67	6.66	6.13	6.48	6.12	6.47
TT - CI 95%	12.23	12.02	12.00	12.84	12.42	12.82	12.40
TT + CI 95%	23.73	25.36	25.32	25.11	25.38	25.06	25.33
Average Difference		0.71	0.68	1.00	0.92	0.96	0.89
Percent Error		3.96%	3.78%	5.55%	5.12%	5.33%	4.92%
95% CI Difference		4.05	4.04	4.19	2.08	4.19	2.07
Percent Error- CI 95%		-18.57%	-18.71%	-17.78%	-6.46%	-17.96%	-6.61%
Percent Error + CI 95%		26.49%	26.27%	28.87%	16.70%	28.61%	16.45%
Min Difference		-3.04	-3.06	-1.92	-1.72	-1.94	-1.74
Max Difference		5.41	5.38	6.11	2.56	6.08	2.53

Results of the Paired T-Test

P-value		0.6511	0.6649	0.5453	0.2871	0.5598	0.3015
Significance	0.05	YES	YES	YES	YES	YES	YES



LINK 5 - I-5 Southbound: Interstate Bridge to Going St SB

308.38 303.50

Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	04/28/05	8:06:00	11.50	11.40	11.40	10.50	12.06	10.50	12.06
2	04/28/05	8:36:45	7.45	9.86	9.86	12.31	10.57	12.31	10.57
3	04/28/05	8:59:21	5.35	4.99	4.99	5.72	5.93	5.72	5.93
4	04/28/05	9:18:15	5.65	5.80	5.80	5.42	5.45	5.42	5.45
5									
6									
7									
8									
9									
10									
11									

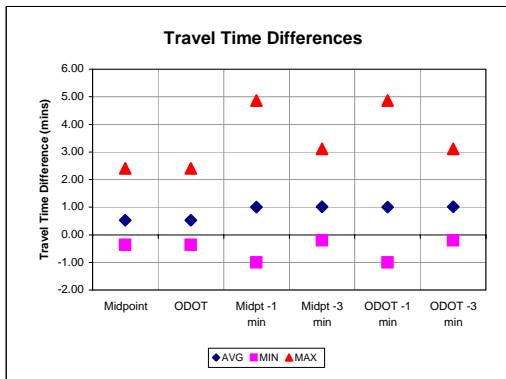
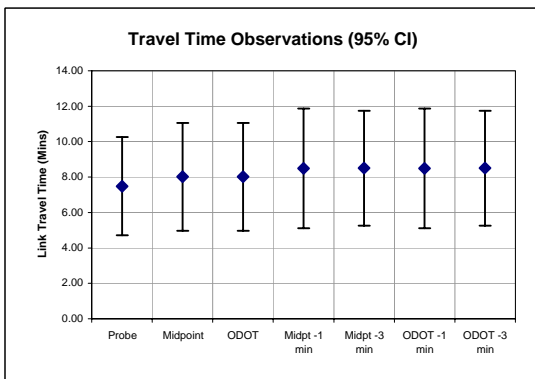
Difference from Probe Times

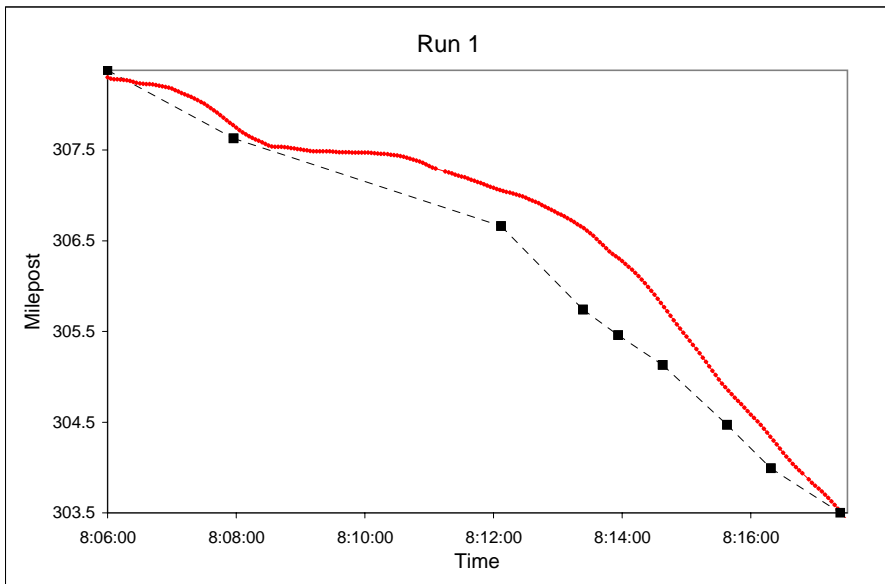
Run	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	-0.10	-0.10	-1.00	0.56	-1.00	0.56
2	2.41	2.41	4.86	3.12	4.86	3.12
3	-0.36	-0.36	0.37	0.58	0.37	0.58
4	0.15	0.15	-0.23	-0.20	-0.23	-0.20
5						
6						
7						
8						
9						
10						
11						

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	7.49	8.01	8.01	8.49	8.50	8.49	8.50
Std. Deviation	2.83	3.10	3.10	3.45	3.31	3.45	3.31
Sample Size	4	4	4	4	4	4	4
95% Confidence Interval	2.77	3.04	3.04	3.38	3.24	3.38	3.24
TT - CI 95%	4.71	4.97	4.97	5.10	5.26	5.10	5.26
TT + CI 95%	10.26	11.06	11.06	11.87	11.75	11.87	11.75
Average Difference		0.53	0.53	1.00	1.02	1.00	1.02
Percent Error		7.01%	7.01%	13.35%	13.56%	13.35%	13.56%
95% CI Difference		2.03	2.03	4.19	2.30	4.19	2.30
Percent Error- CI 95%		-20.06%	-20.06%	-42.64%	-17.22%	-42.64%	-17.22%
Percent Error + CI 95%		34.08%	34.08%	69.33%	44.34%	69.33%	44.34%
Min Difference		-0.36	-0.36	-1.00	-0.20	-1.00	-0.20
Max Difference		2.41	2.41	4.86	3.12	4.86	3.12

Results of the Paired T-Test

P-value		0.4702	0.4702	0.5032	0.2556	0.5032	0.2556
Significance	0.05	YES	YES	YES	YES	YES	YES





LINK 6 - I-5 Southbound: I-405 Interchange to 217 Interchange

MP 300.71 292.30

Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	04/08/05	16:59:06	12.70	9.04	11.27	9.01	9.36	11.54	11.84
2	05/04/05	8:04:09	10.20	9.13	12.01	9.42	10.22	12.14	12.79
3	05/04/05	7:58:24	9.40	9.35	12.04	9.90	9.23	12.42	11.79
4	05/04/05	8:05:30	9.30	9.04	11.26	9.05	9.62	11.43	12.22
5	05/04/05	8:12:42	9.50	9.38	11.78	8.78	8.93	11.49	11.60
6	05/04/05	8:15:39	9.30	9.04	11.82	9.47	9.15	12.14	11.81
7	05/18/05	8:05:06	14.60	25.71	40.76	19.79	19.83	30.47	30.37
8	05/18/05	7:52:33	14.60	19.75	30.15	17.44	17.07	26.15	25.46
9	05/18/05	8:13:00	12.35	12.53	18.05	13.91	16.22	20.33	24.08
10									
11									

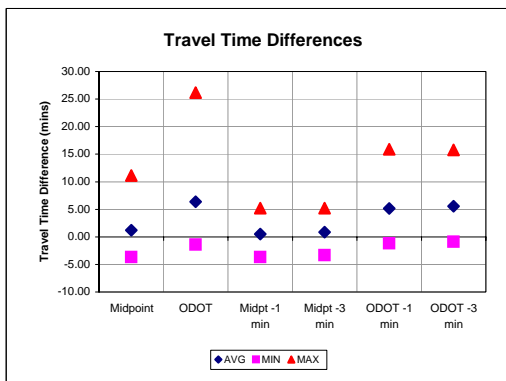
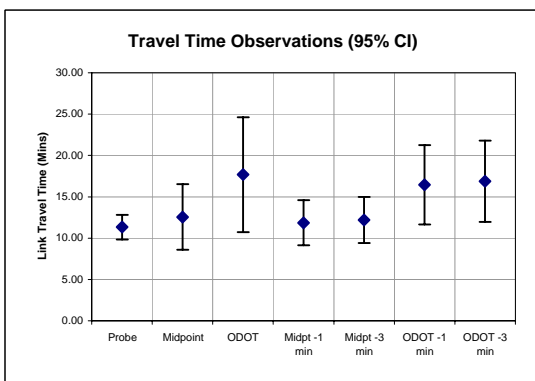
Difference from Probe Times

Run	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	-3.66	-1.43	-3.69	-3.34	-1.16	-0.86
2	-1.07	1.81	-0.78	0.02	1.94	2.59
3	-0.05	2.64	0.50	-0.17	3.02	2.39
4	-0.26	1.96	-0.25	0.32	2.13	2.92
5	-0.12	2.28	-0.72	-0.57	1.99	2.10
6	-0.26	2.52	0.17	-0.15	2.83	2.51
7	11.11	26.16	5.19	5.23	15.87	15.77
8	5.15	15.55	2.84	2.47	11.55	10.86
9	0.18	5.70	1.56	3.87	7.98	11.73
10						
11						

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	11.33	12.55	17.68	11.86	12.18	16.45	16.88
Std. Deviation	2.26	6.06	10.63	4.17	4.26	7.36	7.51
Sample Size	9	9	9	9	9	9	9
95% Confidence Interval	1.48	3.96	6.94	2.73	2.79	4.81	4.90
TT - CI 95%	9.85	8.59	10.74	9.14	9.39	11.65	11.98
TT + CI 95%	12.80	16.51	24.63	14.59	14.97	21.26	21.79
Average Difference		1.22	6.35	0.54	0.85	5.13	5.56
Percent Error		10.81%	56.10%	4.73%	7.52%	45.25%	49.05%
95% CI Difference		3.34	6.78	1.92	1.99	4.24	4.37
Percent Error- CI 95%		-18.69%	-3.78%	-12.23%	-10.02%	7.85%	10.46%
Percent Error + CI 95%		40.31%	115.97%	21.69%	25.07%	82.66%	87.65%
Min Difference		-3.66	-1.43	-3.69	-3.34	-1.16	-0.86
Max Difference		11.11	26.16	5.19	5.23	15.87	15.77

Results of the Paired T-Test

P-value		0.4350	0.0948	0.6756	0.6053	0.0523	0.0450
Significance	0.05	YES	YES	YES	YES	YES	NO



Station	Influence Area	
	start	end
Hood Ave SB	300.71	297.76
Spring Garden St SB	297.76	295.72
Capital Hwy SB	295.72	294.27
ORE 99W SB	294.27	292.30

Midpoint	run	Hood		Spring Garden		Capital Hwy		ORE 99W	
		In	Out	In	Out	In	Out	In	Out
	7	8:05:06	8:25:07	8:25:07	8:27:24	8:27:24	8:28:54	8:28:54	8:30:48
	8	7:52:33	8:06:10	8:06:10	8:08:20	8:08:20	8:10:10	8:10:10	8:12:19
	9	8:13:00	8:20:05	8:20:05	8:22:23	8:22:23	8:23:43	8:23:43	8:25:32

ODOT	run	Hood		Spring Garden		Capital Hwy		ORE 99W	
		In	Out	In	Out	In	Out	In	Out
	7	8:05:06	8:39:55	8:39:55	8:41:34	8:41:34	8:42:18	8:42:18	8:45:52
	8	7:52:33	8:16:14	8:16:14	8:17:48	8:17:48	8:18:41	8:18:41	8:22:43
	9	8:13:00	8:25:20	8:25:20	8:26:59	8:26:59	8:27:38	8:27:38	8:31:03

LINK 7 - I-5 Southbound: OR-217 Interchange to I-205 Interchange

MP 290.82 287.66

Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	04/08/05	15:47:03	3.70	2.25	2.25	2.40	2.35	2.40	2.35
2	04/08/05	17:14:39	6.80	4.42	4.42	3.65	3.69	3.66	3.69
3	05/04/05	16:53:24	3.80	2.36	2.35	2.27	2.28	2.27	2.28
4	05/04/05	16:46:54	3.30	2.42	2.42	2.40	2.26	2.40	2.26
5	05/04/05	16:51:30	3.20	2.47	2.47	2.36	2.29	2.35	2.29
6	05/04/05	17:11:00	4.35	0.00	0.00	1.14	1.81	1.14	1.81
7									
8									
9									
10									
11									

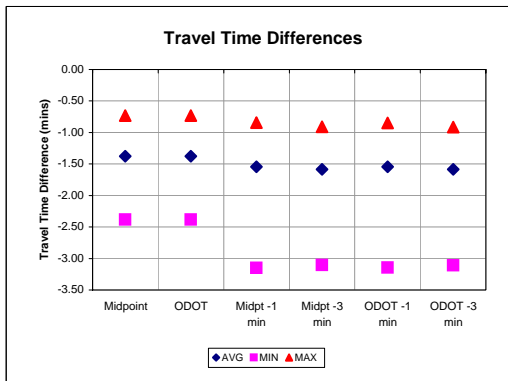
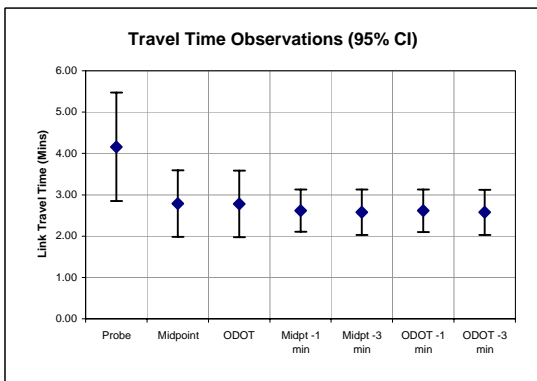
Difference from Probe Times

Run	Probe	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1		-1.45	-1.45	-1.30	-1.35	-1.30	-1.35
2		-2.38	-2.38	-3.15	-3.11	-3.15	-3.11
3		-1.44	-1.45	-1.53	-1.52	-1.53	-1.52
4		-0.88	-0.88	-0.90	-1.04	-0.90	-1.04
5		-0.73	-0.73	-0.84	-0.91	-0.85	-0.91
6		-4.35	-4.35	-3.21	-2.54	-3.21	-2.54
7							
8							
9							
10							
11							

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	4.16	2.78	2.78	2.61	2.58	2.61	2.58
Std. Deviation	1.50	0.92	0.92	0.58	0.63	0.58	0.63
Sample Size	5	5	5	5	5	5	5
95% Confidence Interval	1.31	0.80	0.81	0.51	0.55	0.51	0.55
TT - CI 95%	2.85	1.98	1.98	2.10	2.03	2.10	2.03
TT + CI 95%	5.47	3.59	3.59	3.12	3.12	3.13	3.12
Average Difference		-1.38	-1.38	-1.55	-1.58	-1.55	-1.58
Percent Error		-33.08%	-33.12%	-37.18%	-38.07%	-37.18%	-38.10%
95% CI Difference		1.67	1.67	1.34	1.10	1.34	1.09
Percent Error- CI 95%		-73.24%	-73.27%	-69.45%	-64.39%	-69.42%	-64.41%
Percent Error + CI 95%		7.08%	7.02%	-4.90%	-11.74%	-4.93%	-11.78%
Min Difference		-2.38	-2.38	-3.15	-3.11	-3.15	-3.11
Max Difference		-0.73	-0.73	-0.84	-0.91	-0.85	-0.91

Results of the Paired T-Test

P-value		0.0090	0.0090	0.0211	0.0161	0.0210	0.0161
Significance	0.05	NO	NO	NO	NO	NO	NO



LINK 8 - OR-217 NB: I-5 Interchange to US-26 Interchange

MP 7.2 0.26

Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	05/04/05	8:07:51	30.65	21.43	19.85	25.15	24.91	23.72	23.39
2	05/04/05	8:14:51	30.45	26.39	24.39	28.00	27.12	26.37	25.41
3	05/04/05	8:22:15	30.65	23.72	21.51	25.71	24.86	23.87	23.20
4	05/04/05	8:25:00	30.70	21.62	20.15	22.93	30.72	21.33	29.04
5	05/18/05	8:19:45	8.85	7.80	7.43	7.68	7.82	7.31	7.44
6	05/18/05	8:07:12	9.75	7.71	7.32	7.87	7.93	7.46	7.52
7	05/18/05	8:25:24	8.80	8.31	7.89	8.07	7.88	7.70	7.50
8									
9									
10									
11									

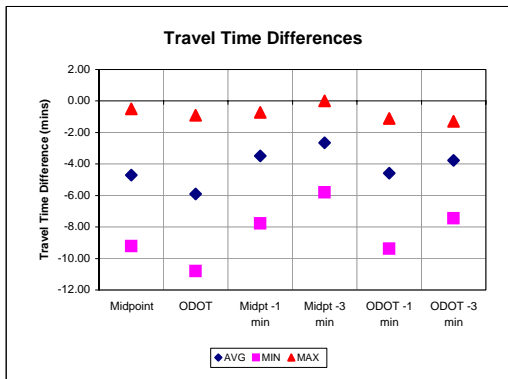
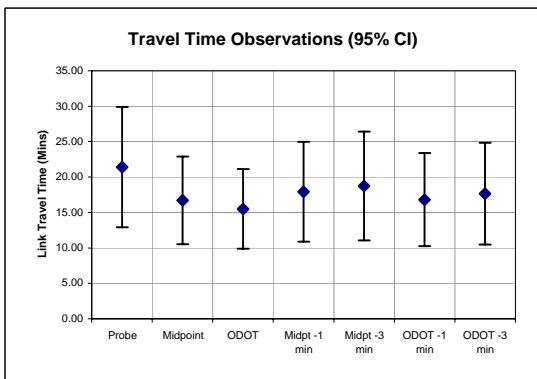
Difference from Probe Times

Run	Probe	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1		-9.22	-10.80	-5.51	-5.75	-6.93	-7.26
2		-4.06	-6.06	-2.45	-3.33	-4.08	-5.04
3		-6.93	-9.14	-4.95	-5.79	-6.78	-7.45
4		-9.08	-10.55	-7.77	0.01	-9.37	-1.66
5		-1.05	-1.42	-1.17	-1.03	-1.54	-1.41
6		-2.04	-2.43	-1.88	-1.82	-2.29	-2.23
7		-0.49	-0.91	-0.73	-0.92	-1.11	-1.30
8							
9							
10							
11							

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	21.41	16.71	15.51	17.91	18.75	16.82	17.64
Std. Deviation	11.49	8.37	7.59	9.51	10.35	8.85	9.69
Sample Size	7	7	7	7	7	7	7
95% Confidence Interval	8.51	6.20	5.62	7.04	7.67	6.56	7.18
TT - CI 95%	12.90	10.51	9.88	10.87	11.08	10.26	10.47
TT + CI 95%	29.92	22.91	21.13	24.96	26.42	23.38	24.82
Average Difference		-4.70	-5.90	-3.49	-2.66	-4.59	-3.76
Percent Error		-21.94%	-27.57%	-16.32%	-12.43%	-21.42%	-17.58%
95% CI Difference		3.44	4.02	2.42	2.18	2.93	2.56
Percent Error- CI 95%		-38.02%	-46.33%	-27.64%	-22.61%	-35.09%	-29.53%
Percent Error + CI 95%		-5.86%	-8.80%	-5.00%	-2.25%	-7.75%	-5.63%
Min Difference		-9.22	-10.80	-7.77	-5.79	-9.37	-7.45
Max Difference		-0.49	-0.91	-0.73	0.01	-1.11	-1.30

Results of the Paired T-Test

P-value		0.0157	0.0114	0.0124	0.0244	0.0086	0.0114
Significance	0.05	NO	NO	NO	NO	NO	NO



LINK 9 - OR-217 SB: US-26 Interchange to I-5 Interchange

MP 0.11 6.89 Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	05/04/05	16:44:00	7.35	7.27	8.19	7.14	7.08	8.00	7.94
2	05/04/05	16:37:21	7.65	7.00	7.81	7.11	7.05	7.98	7.91
3	05/04/05	16:42:33	7.00	7.27	8.19	7.14	7.08	8.00	7.94
4	05/04/05	16:59:06	8.45	8.11	9.25	7.40	7.31	8.33	8.24
5									
6									
7									
8									
9									
10									
11									

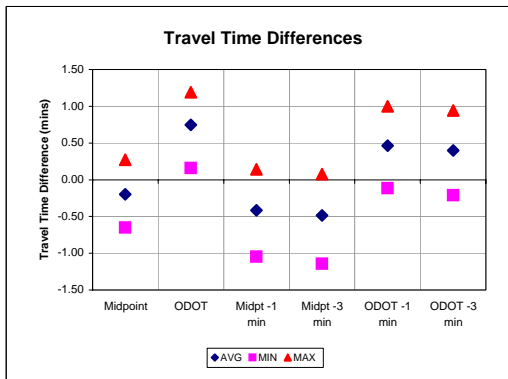
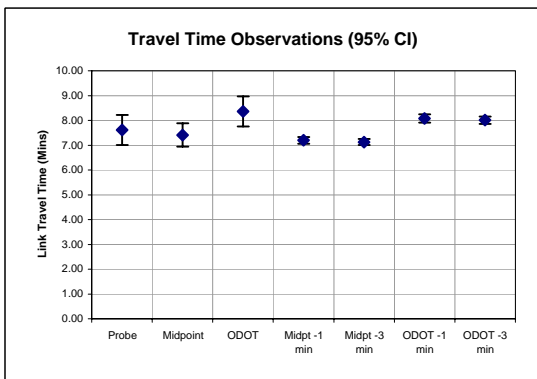
Difference from Probe Times

Run	Probe	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1		-0.08	0.84	-0.21	-0.27	0.65	0.59
2		-0.65	0.16	-0.54	-0.60	0.32	0.26
3		0.27	1.19	0.14	0.08	1.00	0.94
4		-0.34	0.80	-1.05	-1.14	-0.12	-0.21
5							
6							
7							
8							
9							
10							
11							

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	7.61	7.41	8.36	7.20	7.13	8.08	8.01
Std. Deviation	0.62	0.48	0.62	0.14	0.12	0.17	0.15
Sample Size	4	4	4	4	4	4	4
95% Confidence Interval	0.61	0.47	0.61	0.13	0.12	0.17	0.15
TT - CI 95%	7.01	6.94	7.75	7.06	7.01	7.91	7.86
TT + CI 95%	8.22	7.88	8.97	7.33	7.25	8.24	8.16
Average Difference		-0.20	0.75	-0.41	-0.48	0.46	0.40
Percent Error		-2.63%	9.82%	-5.45%	-6.36%	6.08%	5.22%
95% CI Difference		0.62	0.68	0.80	0.83	0.76	0.78
Percent Error- CI 95%		-10.79%	0.85%	-16.02%	-17.20%	-3.84%	-5.08%
Percent Error + CI 95%		5.53%	18.79%	5.11%	4.48%	16.00%	15.51%
Min Difference		-0.65	0.16	-1.05	-1.14	-0.12	-0.21
Max Difference		0.27	1.19	0.14	0.08	1.00	0.94

Results of the Paired T-Test

P-value		0.381	0.040	0.199	0.159	0.146	0.205
Significance	0.05	YES	NO	YES	YES	YES	YES



LINK 10 - I-205 NB: I-5 Interchange to Oregon City

MP 3.22 10.25

Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	05/18/05	17:17:42	14.45	11.44	9.49	12.74	15.17	10.29	11.91
2	05/19/05	17:24:12	15.35	16.70	14.85	17.63	19.11	15.02	15.30
3	05/20/05	17:24:57	14.55	18.75	16.07	16.80	18.95	14.60	15.42
4	05/21/05	17:48:00	13.20	14.88	12.53	22.41	18.75	16.75	14.75
5									
6									
7									
8									
9									
10									
11									

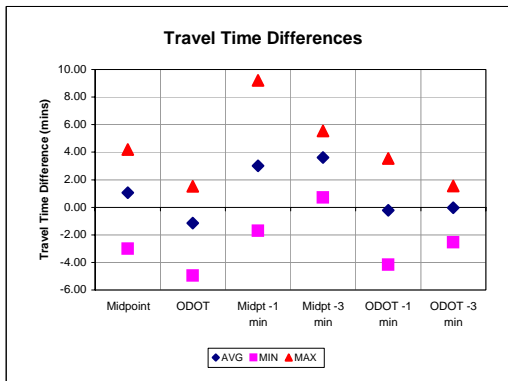
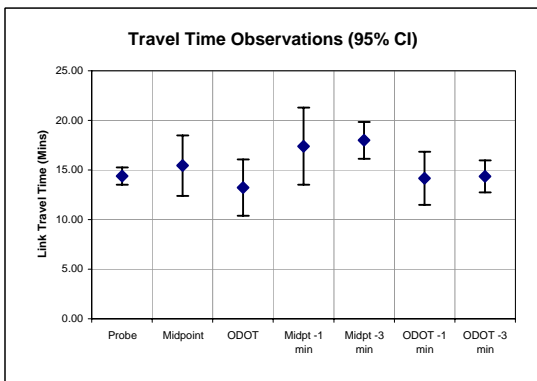
Difference from Probe Times

Run	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	-3.01	-4.96	-1.71	0.72	-4.16	-2.54
2	1.35	-0.50	2.28	3.76	-0.33	-0.05
3	4.20	1.52	2.25	4.39	0.04	0.87
4	1.68	-0.67	9.21	5.55	3.55	1.55
5						
6						
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Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	14.39	15.44	13.24	17.40	17.99	14.16	14.34
Std. Deviation	0.89	3.10	2.90	3.97	1.89	2.74	1.65
Sample Size	4	4	4	4	4	4	4
95% Confidence Interval	0.87	3.04	2.84	3.89	1.85	2.69	1.62
TT - CI 95%	13.52	12.40	10.40	13.51	16.14	11.47	12.73
TT + CI 95%	15.26	18.48	16.07	21.28	19.85	16.85	15.96
Average Difference		1.05	-1.15	3.01	3.61	-0.22	-0.04
Percent Error		7.33%	-8.01%	20.90%	25.07%	-1.56%	-0.30%
95% CI Difference		4.76	4.34	7.22	3.29	5.01	2.85
Percent Error- CI 95%		-25.78%	-38.16%	-29.28%	2.23%	-36.41%	-20.09%
Percent Error + CI 95%		40.45%	22.14%	71.08%	47.90%	33.29%	19.49%
Min Difference		-3.01	-4.96	-1.71	0.72	-4.16	-2.54
Max Difference		4.20	1.52	9.21	5.55	3.55	1.55

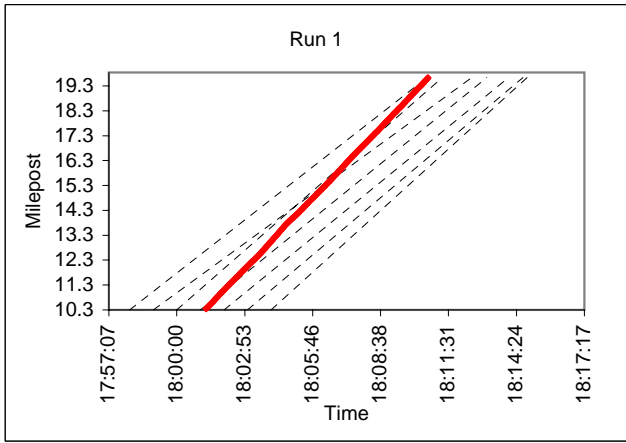
Results of the Paired T-Test

P-value		0.532	0.460	0.277	0.040	0.896	0.965
Significance	0.05	YES	YES	YES	NO	YES	YES



LINK 11 - I-205 NB: Oregon City to I-84 Interchange

ODOT MODIFIED



LINK 12 - I-205 SB: I-84 Interchange to Oregon City

MP 19.79 2.48 **Travel Times (minutes)**

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	05/18/05	16:40:12	17.80	19.38	21.62	18.54	18.33	20.78	20.52
2	05/18/05	16:47:33	18.65	18.35	20.20	18.37	18.52	20.44	20.58
3	05/18/05	16:49:21	18.25	18.15	19.98	18.78	18.60	20.70	20.59
4	05/18/05	17:11:21	19.15	19.17	21.41	18.98	18.72	21.11	20.73
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9									
10									
11									

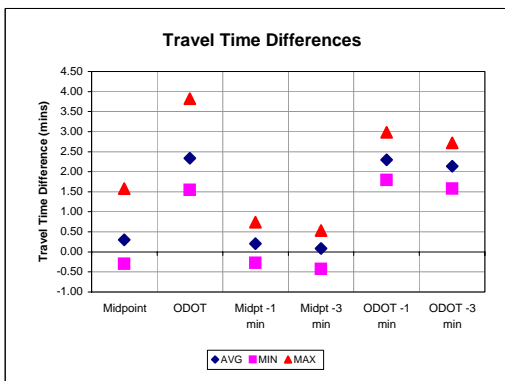
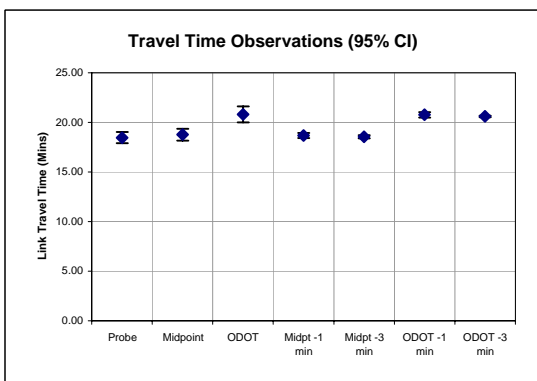
Difference from Probe Times

Run	Probe	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1		1.58	3.82	0.74	0.53	2.98	2.72
2		-0.30	1.55	-0.28	-0.13	1.79	1.93
3		-0.10	1.73	0.53	0.35	2.45	2.34
4		0.02	2.26	-0.17	-0.43	1.96	1.58
5							
6							
7							
8							
9							
10							
11							

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	18.46	18.76	20.80	18.67	18.55	20.76	20.60
Std. Deviation	0.58	0.60	0.83	0.26	0.16	0.28	0.09
Sample Size	4	4	4	4	4	4	4
95% Confidence Interval	0.56	0.59	0.82	0.26	0.16	0.27	0.09
TT - CI 95%	17.90	18.17	19.99	18.41	18.38	20.49	20.52
TT + CI 95%	19.03	19.35	21.62	18.93	18.71	21.03	20.69
Average Difference		0.30	2.34	0.21	0.08	2.30	2.14
Percent Error		1.62%	12.67%	1.11%	0.45%	12.44%	11.59%
95% CI Difference		1.37	1.64	0.81	0.70	0.85	0.79
Percent Error- CI 95%		-5.82%	3.78%	-3.26%	-3.33%	7.82%	7.31%
Percent Error + CI 95%		9.07%	21.57%	5.48%	4.23%	17.06%	15.86%
Min Difference		-0.30	1.55	-0.28	-0.43	1.79	1.58
Max Difference		1.58	3.82	0.74	0.53	2.98	2.72

Results of the Paired T-Test

P-value		0.537	0.020	0.478	0.731	0.003	0.003
Significance	0.05	YES	NO	YES	YES	NO	NO



LINK 13 - I-84 EB: I-5 Interchange to I-205 Interchange

MP 0.31 3.69 **Travel Times (minutes)**

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	05/04/05	7:29:27	3.80	3.75	4.40	3.39	3.40	4.04	4.07
2	05/04/05	7:29:30	3.75	3.75	4.40	3.39	3.40	4.04	4.07
3	05/04/05	7:29:33	3.75	3.75	4.40	3.39	3.40	4.04	4.07
4	05/18/05	7:20:42	3.60	3.44	4.02	3.77	3.84	4.48	4.62
5	05/18/05	7:22:12	3.65	3.50	4.06	3.61	3.76	4.21	4.47
6	05/18/05	7:25:03	3.60	3.74	4.34	3.69	3.66	4.34	4.26
7	05/18/05	16:23:00	10.10	10.82	15.67	10.12	10.62	14.57	15.43
8	05/18/05	16:32:33	8.35	10.53	15.14	11.57	11.18	16.62	15.73
9	05/18/05	16:33:03	9.45	9.40	13.66	10.83	10.91	15.71	15.43
10	05/18/05	16:55:24	7.00	6.98	9.68	8.39	8.23	11.46	11.14
11	05/04/05	7:33:27	3.45	2.71	3.29	3.43	3.46	4.04	4.12

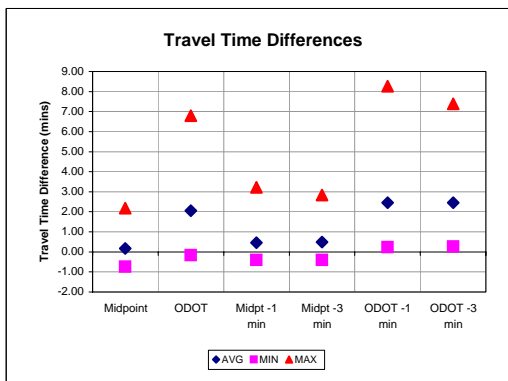
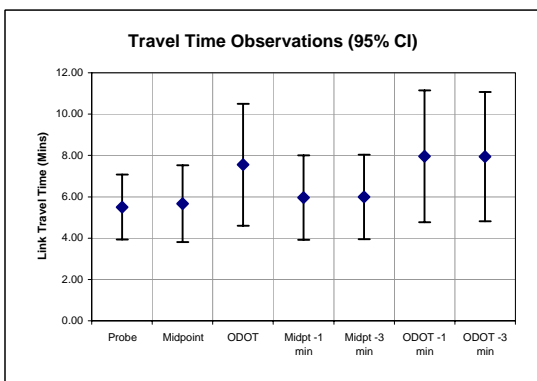
Difference from Probe Times

Run	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	-0.05	0.60	-0.41	-0.40	0.24	0.27
2	0.00	0.65	-0.36	-0.35	0.29	0.32
3	0.00	0.65	-0.36	-0.35	0.29	0.32
4	-0.16	0.42	0.17	0.24	0.88	1.02
5	-0.15	0.41	-0.04	0.11	0.55	0.81
6	0.14	0.74	0.09	0.06	0.74	0.66
7	0.72	5.57	0.02	0.52	4.47	5.33
8	2.18	6.79	3.22	2.83	8.27	7.38
9	-0.05	4.21	1.37	1.46	6.26	5.98
10	-0.02	2.68	1.39	1.23	4.45	4.14
11	-0.74	-0.16	-0.02	0.01	0.58	0.67

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	5.50	5.67	7.55	5.96	5.99	7.96	7.95
Std. Deviation	2.66	3.15	4.98	3.46	3.45	5.40	5.29
Sample Size	11	11	11	11	11	11	11
95% Confidence Interval	1.57	1.86	2.94	2.05	2.04	3.19	3.12
TT - CI 95%	3.93	3.81	4.61	3.91	3.95	4.76	4.82
TT + CI 95%	7.07	7.53	10.50	8.01	8.03	11.15	11.07
Average Difference		0.17	2.05	0.46	0.49	2.46	2.45
Percent Error		3.09%	37.29%	8.37%	8.89%	44.68%	44.49%
95% CI Difference		0.50	1.62	0.74	0.66	1.94	1.81
Percent Error- CI 95%		-6.03%	7.90%	-5.17%	-3.19%	9.44%	11.50%
Percent Error + CI 95%		12.21%	66.68%	21.91%	20.97%	79.92%	77.47%
Min Difference		-0.74	-0.16	-0.41	-0.40	0.24	0.27
Max Difference		2.18	6.79	3.22	2.83	8.27	7.38

Results of the Paired T-Test

P-value	0.273	0.070	0.518	0.402	0.098	0.077
Significance	0.05	YES	YES	YES	YES	YES



LINK 14 - I-84 WB: I-205 Interchange to I-5 Interchange

MP 4.17 1.21 Travel Times (minutes)

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	05/04/05	7:47:00	8.35	3.49	3.49	3.40	3.47	3.40	3.47
2	05/04/05	7:56:21	6.10	7.46	7.46	5.59	5.20	5.59	5.20
3	05/04/05	8:03:18	6.20	3.18	3.18	3.23	3.23	3.24	3.23
4	05/04/05	8:05:30	6.90	7.77	7.77	4.89	4.18	4.89	4.18
5	05/18/05	7:52:12	7.55	8.40	8.40	8.83	8.15	8.83	8.16
6	05/18/05	7:40:51	7.70	14.34	14.34	16.31	11.29	16.31	11.29
7	05/18/05	8:00:57	8.55	11.34	11.34	11.17	8.68	11.17	8.68
8	05/04/05	7:54:30	6.60	5.48	5.48	8.39	8.54	8.38	8.53
9									
10									
11									

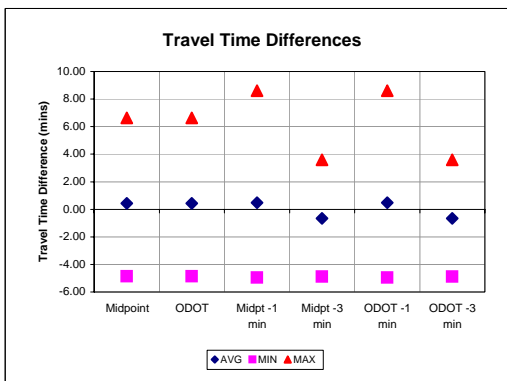
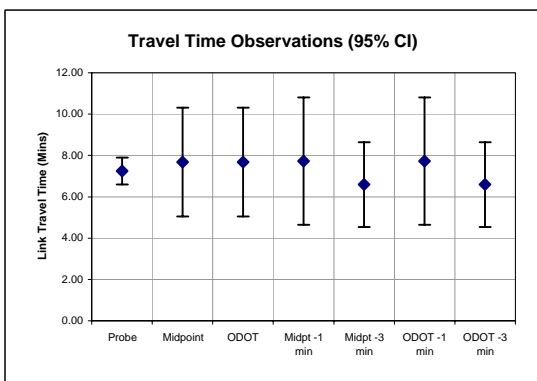
Difference from Probe Times

Run	Probe	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1		-4.86	-4.86	-4.95	-4.88	-4.95	-4.88
2		1.36	1.36	-0.51	-0.90	-0.51	-0.90
3		-3.02	-3.02	-2.97	-2.97	-2.97	-2.97
4		0.87	0.87	-2.01	-2.72	-2.01	-2.72
5		0.85	0.85	1.28	0.60	1.28	0.60
6		6.64	6.64	8.61	3.59	8.61	3.59
7		2.79	2.79	2.62	0.13	2.62	0.13
8		-1.12	-1.12	1.78	1.94	1.78	1.93
9							
10							
11							

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	7.24	7.68	7.68	7.72	6.59	7.72	6.59
Std. Deviation	0.94	3.80	3.80	4.45	2.96	4.45	2.96
Sample Size	8	8	8	8	8	8	8
95% Confidence Interval	0.65	2.63	2.63	3.08	2.05	3.08	2.05
TT - CI 95%	6.59	5.05	5.05	4.64	4.54	4.64	4.54
TT + CI 95%	7.89	10.31	10.31	10.81	8.65	10.81	8.65
Average Difference		0.44	0.44	0.48	-0.65	0.48	-0.65
Percent Error		6.06%	6.06%	6.64%	-9.00%	6.64%	-9.00%
95% CI Difference		2.96	2.96	3.48	2.33	3.48	2.33
Percent Error- CI 95%		-34.78%	-34.78%	-41.46%	-41.20%	-41.46%	-41.19%
Percent Error + CI 95%		46.90%	46.90%	54.74%	23.20%	54.73%	23.19%
Min Difference		-4.86	-4.86	-4.95	-4.88	-4.95	-4.88
Max Difference		6.64	6.64	8.61	3.59	8.61	3.59

Results of the Paired T-Test

P-value		0.736	0.736	0.754	0.530	0.754	0.530
Significance	0.05	YES	YES	YES	YES	YES	YES



LINK 16 - US 26 EB: 217 Interchange to I-405 Interchange

MP 68.93 73.32 **Travel Times (minutes)**

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1	02/18/05	16:35:24	4.45	4.71	4.71	4.80	4.76	4.80	4.76
2	05/04/05	8:39:57	10.20	12.95	12.95	12.94	13.11	12.94	13.11
3	05/04/05	8:52:03	11.65	12.00	12.00	11.88	11.81	11.88	11.81
4	05/04/05	8:58:39	9.45	11.11	11.11	13.10	13.55	13.10	13.55
5	05/04/05	8:58:42	10.80	12.50	12.50	12.59	13.15	12.59	13.15
6	05/18/05	8:17:00	10.40	15.78	15.78	14.94	15.70	14.94	15.70
7	05/18/05	8:34:15	11.50	12.92	12.92	14.67	13.92	14.67	13.92
8									
9									
10									
11									

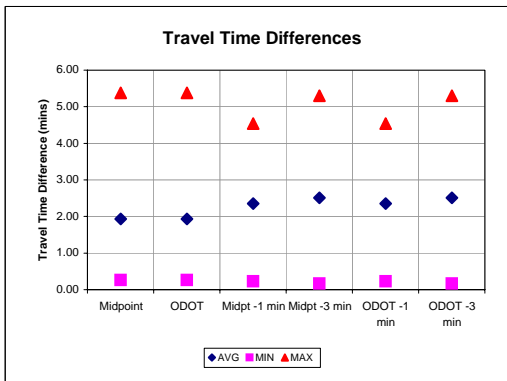
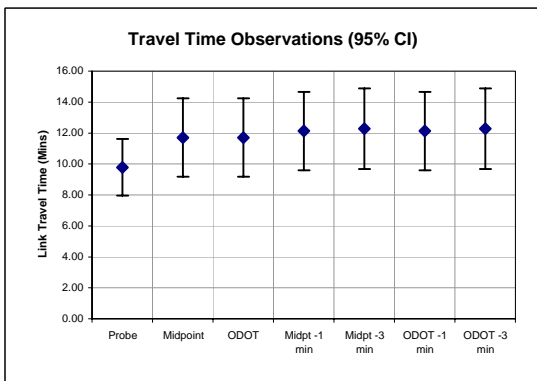
Difference from Probe Times

Run	Probe	Midpoint	ODOT	Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
1		0.26	0.26	0.34	0.31	0.34	0.31
2		2.75	2.75	2.74	2.91	2.74	2.91
3		0.35	0.35	0.23	0.16	0.23	0.16
4		1.66	1.66	3.65	4.10	3.65	4.10
5		1.70	1.70	1.79	2.35	1.79	2.35
6		5.38	5.38	4.54	5.30	4.54	5.30
7		1.42	1.42	3.17	2.41	3.17	2.41
8							
9							
10							
11							

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1 min	Midpt -3 min	ODOT -1 min	ODOT -3 min
Average	9.78	11.71	11.71	12.13	12.28	12.13	12.28
Std. Deviation	2.47	3.41	3.41	3.42	3.52	3.42	3.52
Sample Size	7	7	7	7	7	7	7
95% Confidence Interval	1.83	2.52	2.52	2.53	2.61	2.53	2.61
TT - CI 95%	7.95	9.19	9.19	9.60	9.68	9.60	9.68
TT + CI 95%	11.61	14.23	14.23	14.66	14.89	14.66	14.89
Average Difference		1.93	1.93	2.35	2.51	2.35	2.51
Percent Error		19.75%	19.75%	24.04%	25.63%	24.04%	25.63%
95% CI Difference		1.61	1.61	1.52	1.72	1.52	1.72
Percent Error- CI 95%		3.26%	3.26%	8.53%	8.00%	8.53%	8.00%
Percent Error + CI 95%		36.24%	36.24%	39.55%	43.26%	39.55%	43.26%
Min Difference		0.26	0.26	0.23	0.16	0.23	0.16
Max Difference		5.38	5.38	4.54	5.30	4.54	5.30

Results of the Paired T-Test

P-value		0.026	0.026	0.009	0.012	0.009	0.012
Significance	0.05	NO	NO	NO	NO	NO	NO



LINK 17 - US 26 WB: I-405 Interchange to 217 Interchange

Run	Date	Start Time	Probe	Midpoint	ODOT	Average			
						Midpt -1	Midpt -3	ODOT -1	ODOT -3
						min	min	min	min
1	05/04/05	16:29:45	12.45	5.13	5.10	5.45	5.53	5.37	5.43
2	05/04/05	16:22:06	13.60	5.46	5.36	5.88	5.70	5.71	5.54
3	05/04/05	16:27:03	13.40	5.39	5.34	5.43	5.41	5.33	5.32
4	05/04/05	16:37:45	20.05	5.12	5.00	5.30	5.76	5.29	5.68
5									
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8									
9									
10									
11									

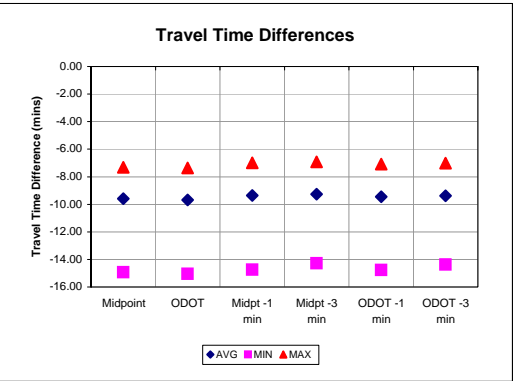
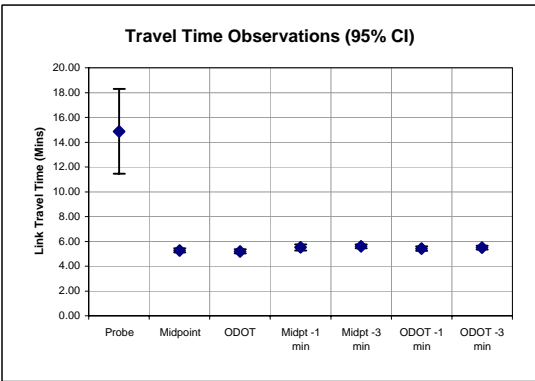
Difference from Probe Times

Run	Midpoint	ODOT	Midpt -1	Midpt -3	ODOT -1	ODOT -3
1	-7.32	-7.35	-7.00	-6.92	-7.08	-7.02
2	-8.14	-8.24	-7.72	-7.90	-7.89	-8.06
3	-8.01	-8.06	-7.97	-7.99	-8.07	-8.08
4	-14.93	-15.05	-14.76	-14.29	-14.76	-14.37
5						
6						
7						
8						
9						
10						
11						

Summary Statistics	Probe	Midpoint	ODOT	Average			
				Midpt -1	Midpt -3	ODOT -1	ODOT -3
	min	min	min	min	min	min	min
Average	14.88	5.28	5.20	5.52	5.60	5.42	5.49
Std. Deviation	3.49	0.18	0.18	0.25	0.16	0.19	0.15
Sample Size	4	4	4	4	4	4	4
95% Confidence Interval	3.42	0.17	0.17	0.25	0.16	0.19	0.15
TT - CI 95%	11.46	5.10	5.03	5.27	5.45	5.23	5.34
TT + CI 95%	18.29	5.45	5.37	5.76	5.76	5.61	5.64
Average Difference		-9.60	-9.68	-9.36	-9.27	-9.45	-9.38
Percent Error		-64.54%	-65.04%	-62.92%	-62.34%	-63.54%	-63.09%
95% CI Difference		5.68	5.73	5.76	5.37	5.67	5.35
Percent Error- CI 95%		-102.74%	-103.59%	-101.65%	-98.46%	-101.69%	-99.06%
Percent Error + CI 95%		-26.33%	-26.49%	-24.20%	-26.22%	-25.39%	-27.12%
Min Difference		-14.93	-15.05	-14.76	-14.29	-14.76	-14.37
Max Difference		-7.32	-7.35	-7.00	-6.92	-7.08	-7.02

Results of the Paired T-Test

P-value	0.013	0.013	0.014	0.012	0.013	0.011
Significance	0.05	NO	NO	NO	NO	NO



Appendix B – Plots for Speed Trends

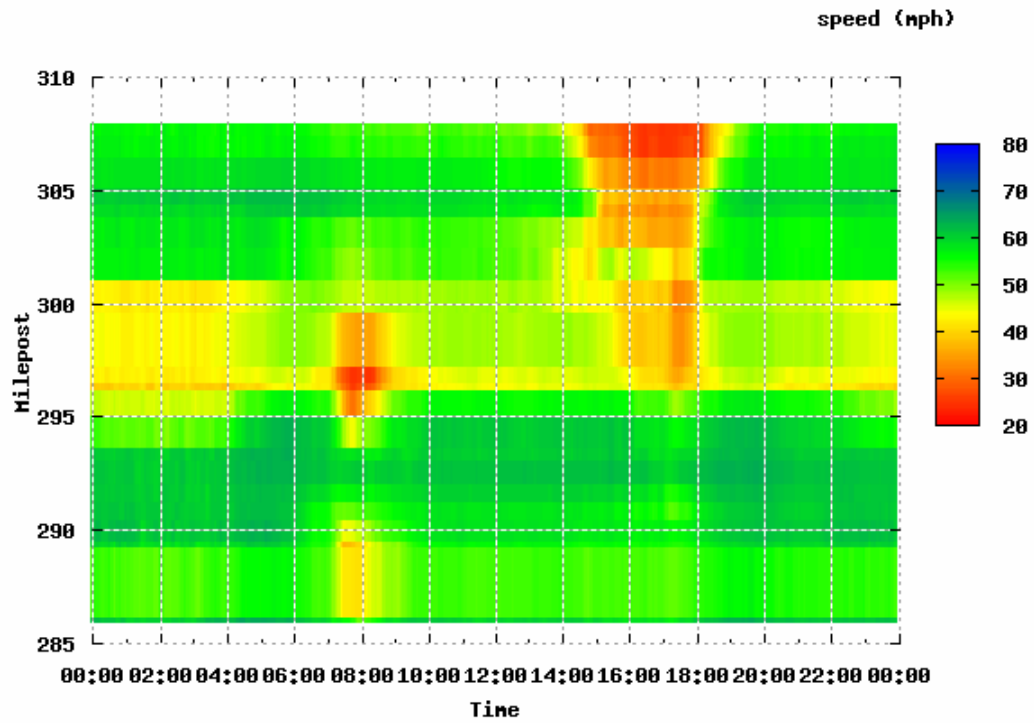


Figure B.1 - I-5 Northbound

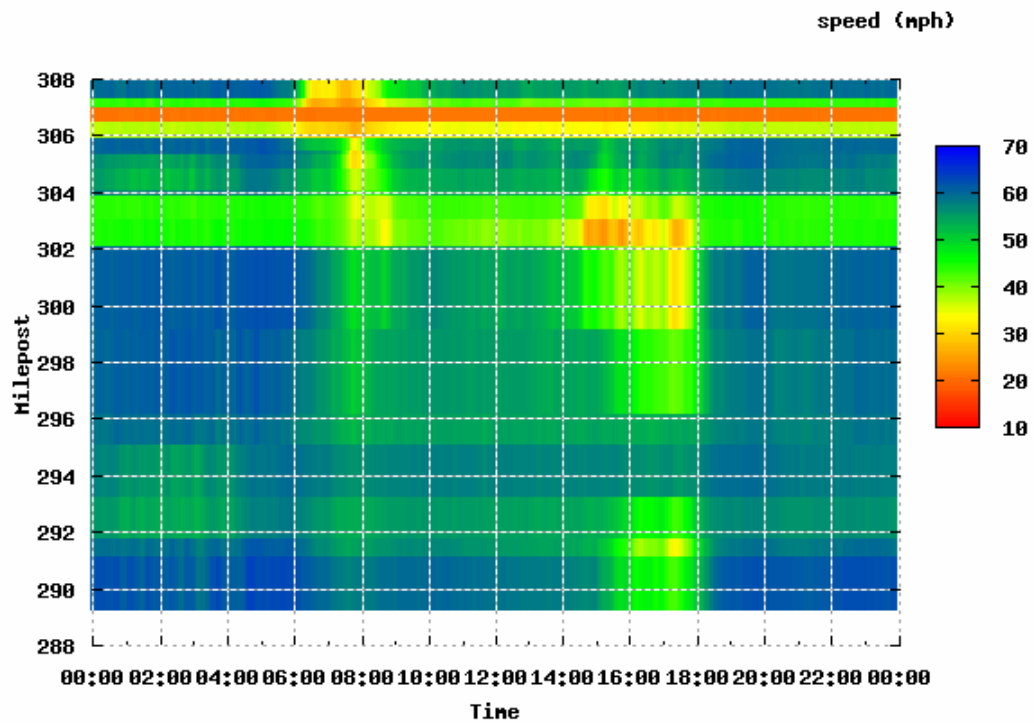


Figure B.2 - I-5 Southbound

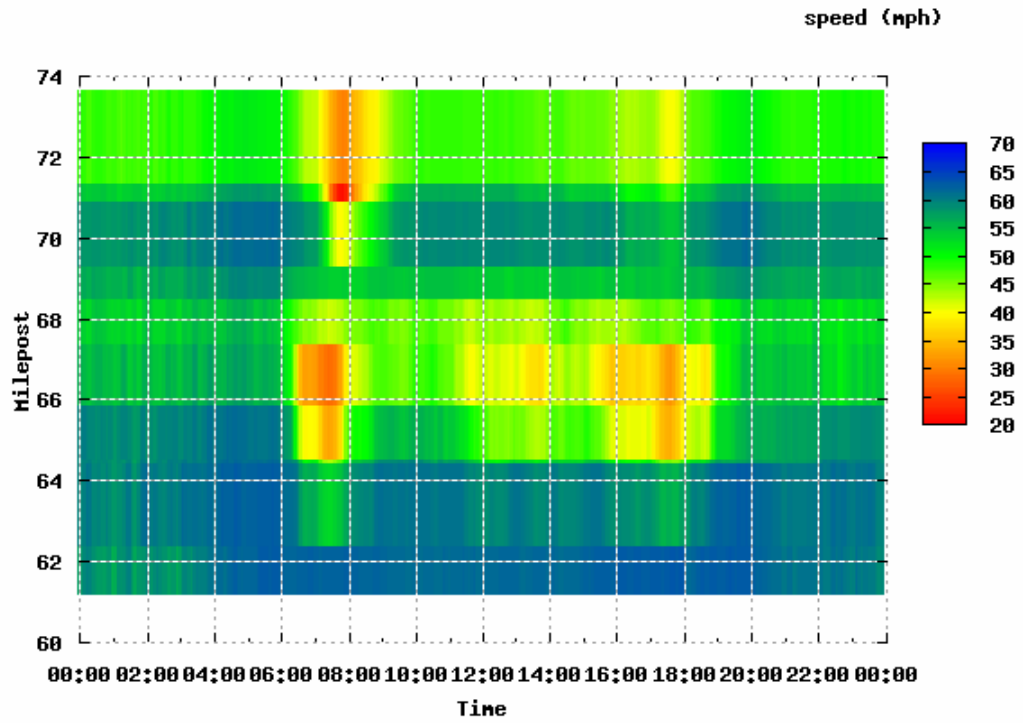


Figure B.3 - US 26 Eastbound

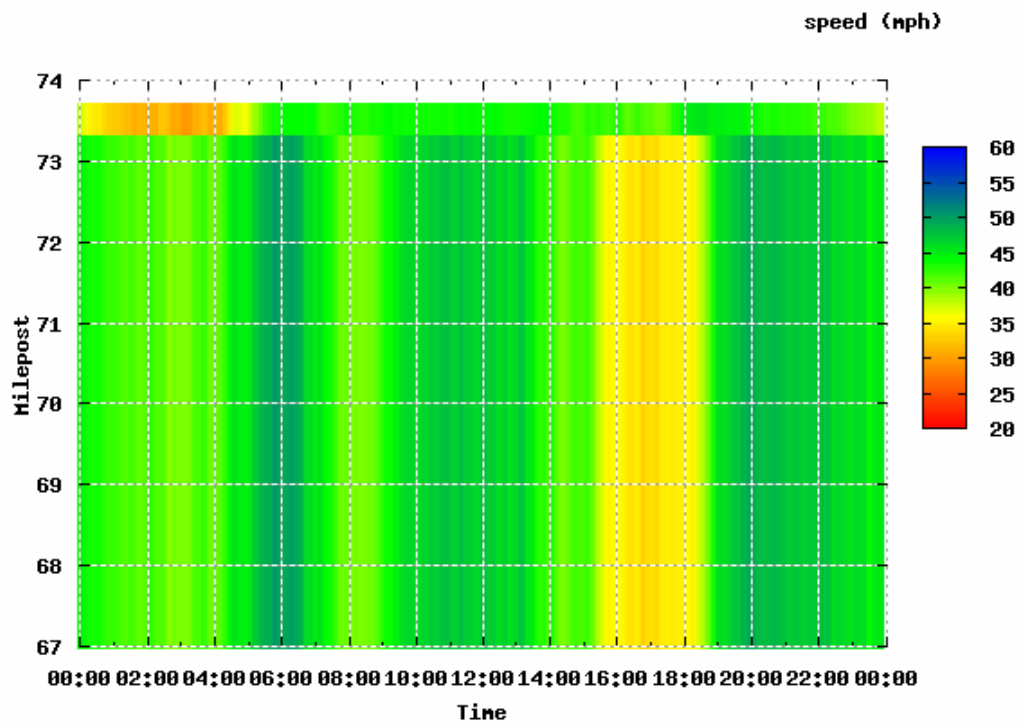


Figure B.4 - US 26 Westbound

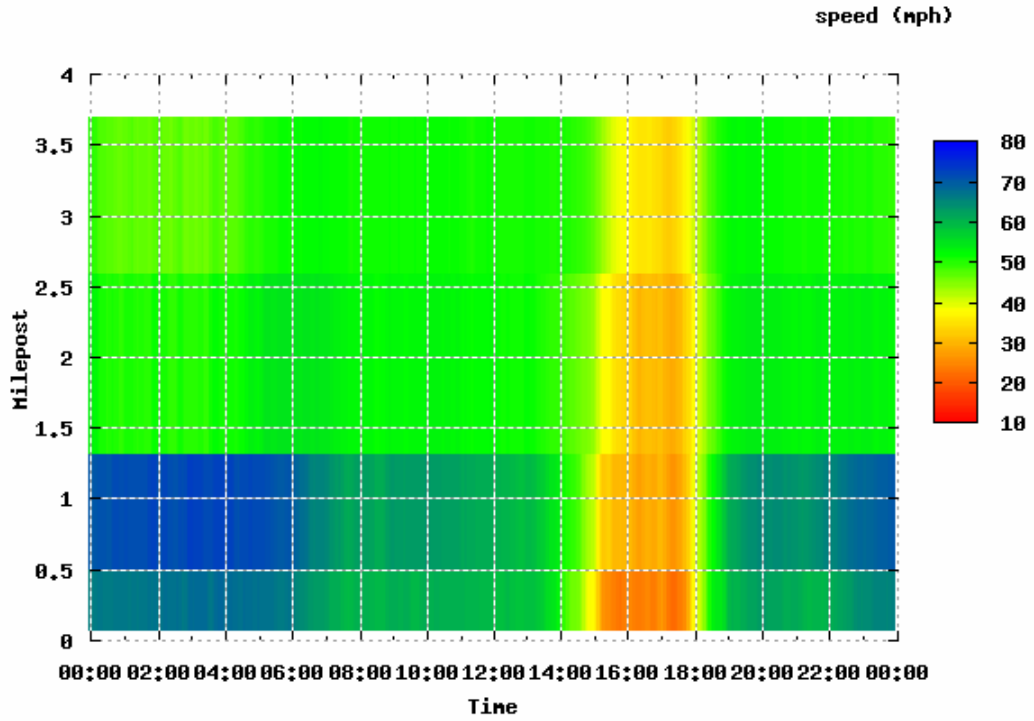


Figure B.5 - I-84 Eastbound

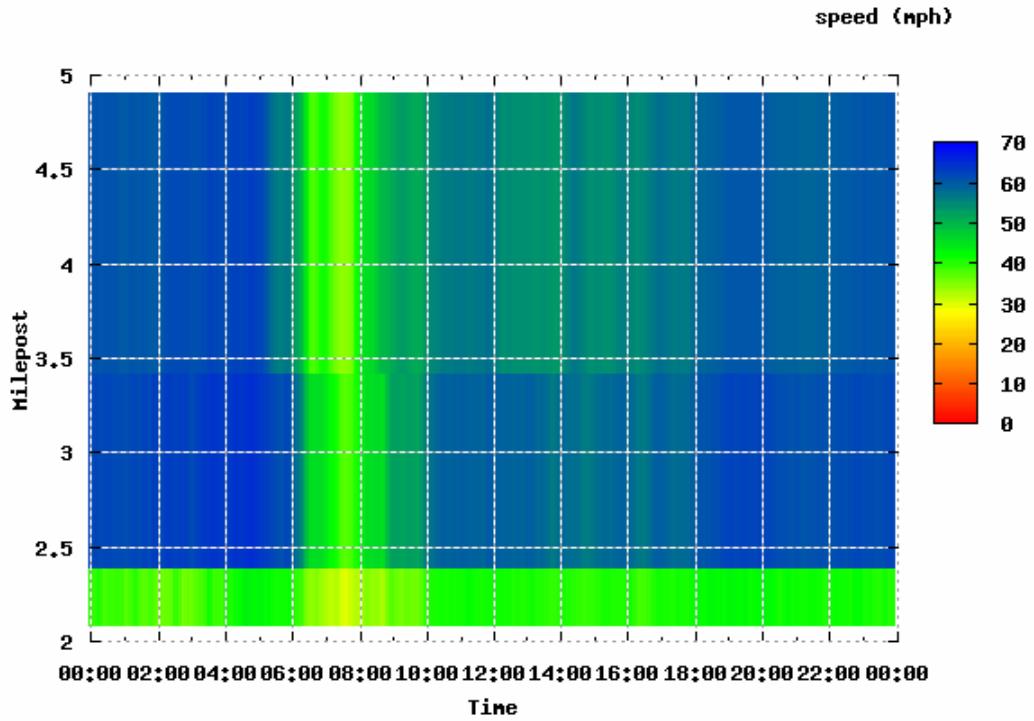


Figure B.6 - I-84 Westbound

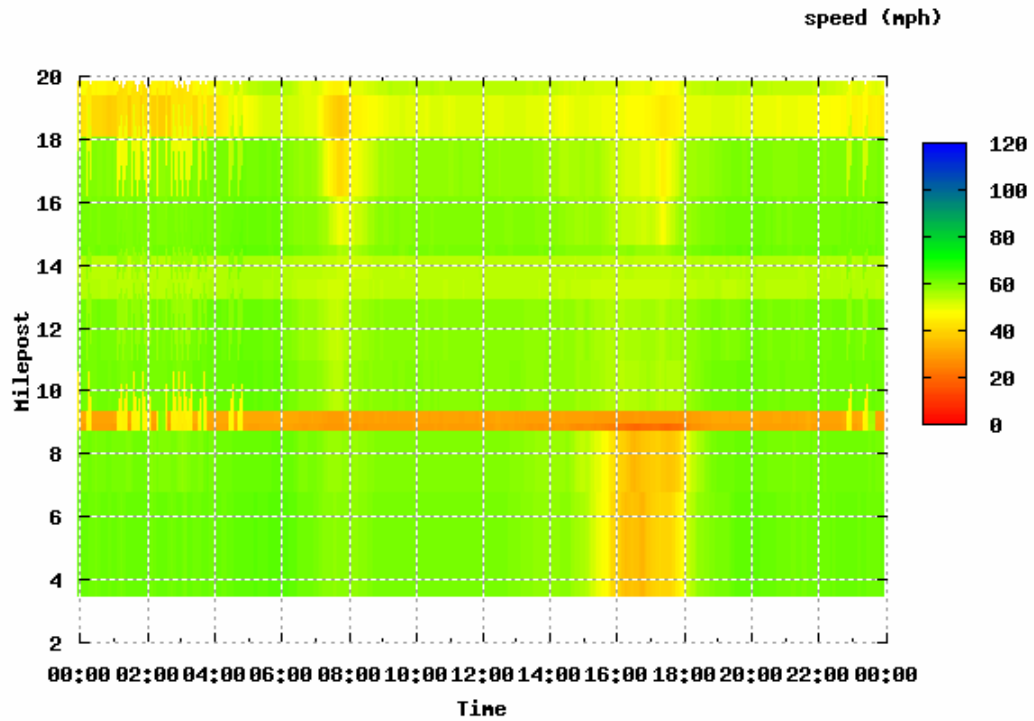


Figure B.7 - I-205 Northbound

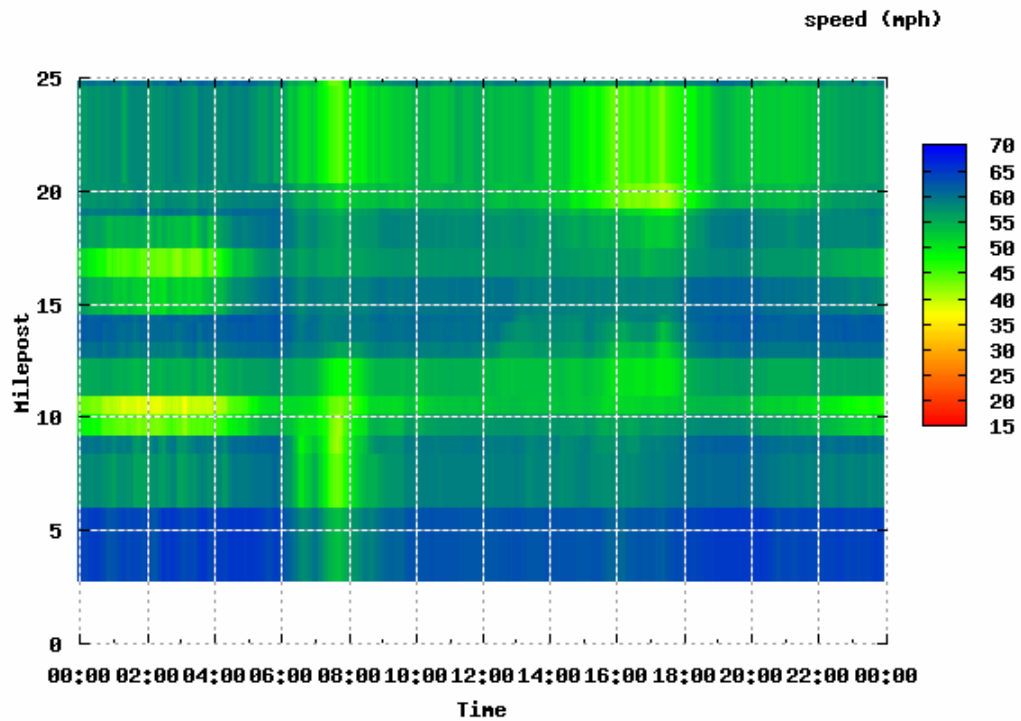


Figure B.8 - I-205 Southbound

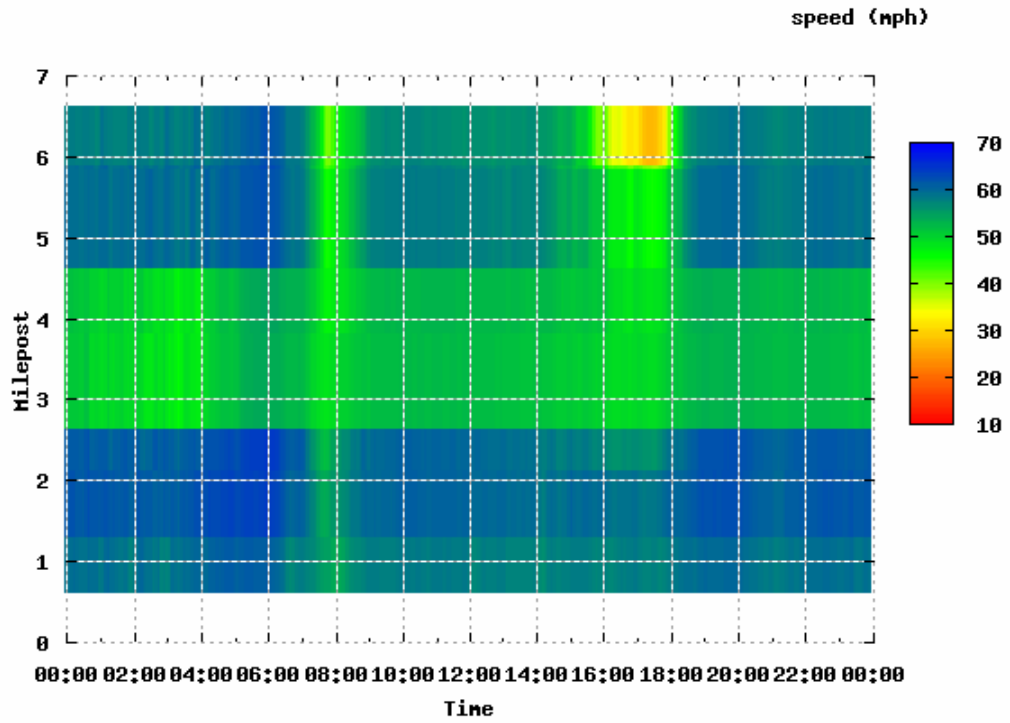


Figure B.9 - OR-217 Northbound

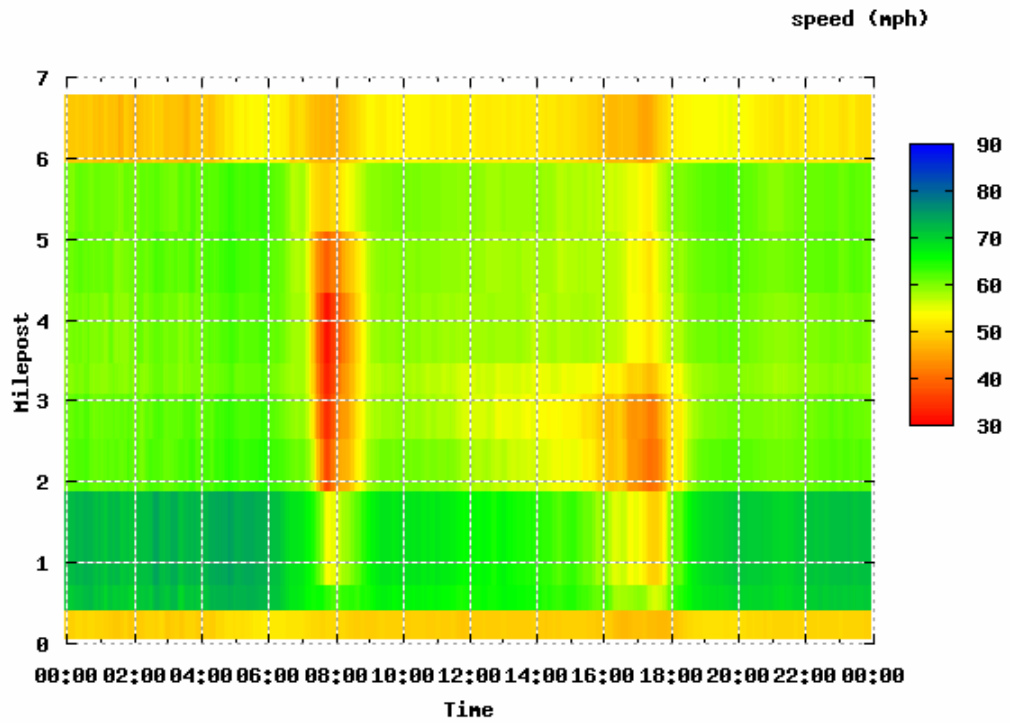


Figure B.10 - OR-217 Southbound