A Travel Time Study

Using GPS

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Table of Contents

INTRODUCTION

A travel time study was initiated this year with the purpose of improving the link travel time and speed data in the travel demand model. It was also expected that the travel time data will highlight locations with significant delay and will serve as a base for future reference for the roadway network performance. No such study has been conducted in the area for at least three decades. After a literature review of travel time studies using a float vehicle and float vehicle with Global Positioning Systems (GPS) techniques, it was decided to use GPS for the travel time study. A previously purchased GPS receiver was available and could be used for this study.

A pilot project was undertaken with an objective to see if the GPS receiver was still useable and to estimate the resources needed for post processing of field data. A procedure manual for conducting this study was prepared and comments were solicited from the WVDOT and ODOT. It was learned that GPS for travel time has not been used in Ohio or West Virginia prior to this study. The scope of the project includes a systemwide study including all interstates, US, state routes and roadways classified as arterials and higher in Belmont County, Ohio and Ohio and Marshall Counties in West Virginia.

A float vehicle technique with a vehicle mounted GPS antenna was utilized for this study. The float vehicle technique is useful in obtaining average travel time for the run. The GPS datalogger recorded position coordinates every two seconds and field data was post processed to obtain average travel time and average speed for all runs. Three runs were made for each route.

Four routes, I-70, I-470, WV86 and a portion of WV88 were traversed and GPS data was collected. This report presents the data and analysis for the four routes. Due to a limited window of evening peak from 3:30 to 6:00 p.m. on school days and one GPS receiver, only a few routes can be studied each year. Therefore, this will be an ongoing project until data for all qualifying routes is acquired. Due to the novelty of using GPS for travel time, several issues surfaced and had to be addressed. Significantly more than expected time was spent on resolving these issues. However, due to this experience, many more routes can be traversed next year.

This report documents results of the initial effort his year. It presents the travel time and speed data for the routes studied and explains the GPS issues encountered and resolved.

SCOPE OF THE STUDY

The study area encompasses Belmont County, Ohio and Ohio and Marshall Counties in West Virginia. All interstate, US and state routes are planned to be included. All other roads classified as arterials or above will also be included.

Travel time data is being collected during the PM peak (3:30 - 6:00 p.m.). Each route will be traversed a minimum of three times on different school days. After the first three runs, a determination will be made if additional runs are needed for a sample size for 95% level of confidence as per ITE procedures. Additional runs, if needed may be undertaken based on the available resources.

This year four routes, I-70, I-470, WV86 and a part of WV88 are studied and presented in this report.

METHODOLOGY

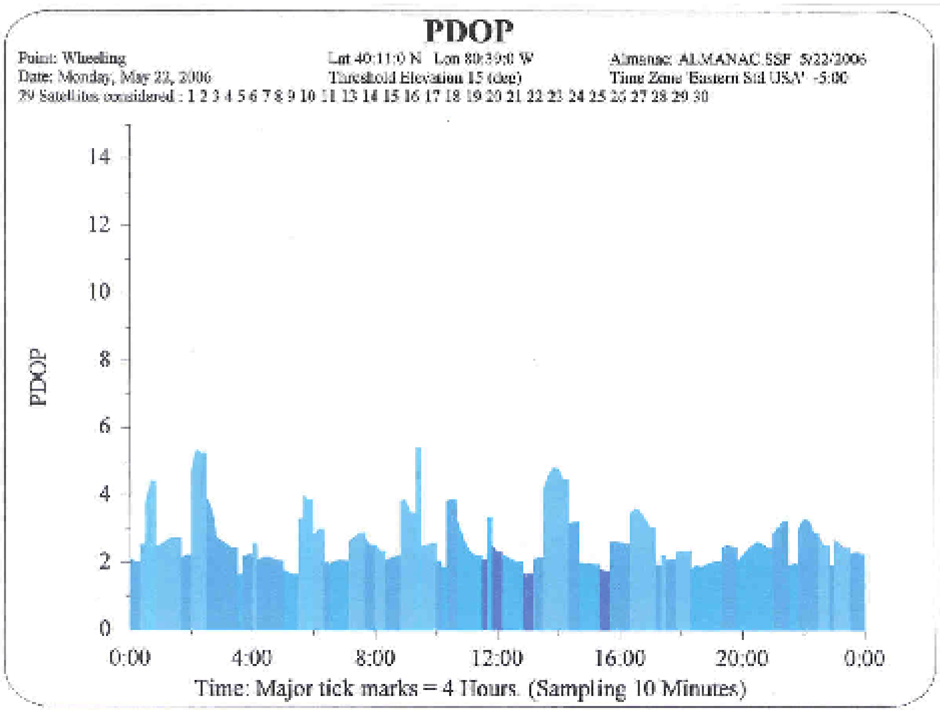
A float vehicle with mounted GPS antenna was used in this study. The float vehicle is used to approximate average travel speed for each run. The driver attempts to pass as many vehicles as pass it and generally floats with the existing traffic. The procedures for this technique are well documented in the literature and are not elaborated here.

The GPS antenna and the datalogger used in the study are shown in Figure I below. The antenna has a built-in magnetic mount. The antenna was mounted on the roof of the vehicle before every run and connected to a handheld datalogger using a cable. The cable was passed through the passenger side window and the datalogger was operated by the passengers in the vehicle. The datalogger and receiver used is GeoExplorer3 by Trimble Navigation. GeoExplorer3 is a 12 channel receiver capable of achieving 1 meter accuracy.

FIGURE I
GPS EQUIPMENT

Based on the weather forecast, availability of GPS satellites was determined using the "Quick Plan" software module from the Trimble Corporation's Pathfinder Office software. Quick Plan software facilitates preplanning so windows without satellite locks can be minimized. Of particular interest was PDOP. [1] Satellite availability windows with PDOP less than 6 were picked and run start time was selected based on available windows within 3:00 to 6:00 p.m. Generally there was approximately one half hour of bad GPS window on certain days. A sample PDOP graph is included as Figure II.

FIGURE II



The receiver settings were checked before each run. The settings were PDOP less than 5; Signal to noise ratio (SNR) Less than 6; Elevation Mask at 15°; minimum satellites at 4 and log between features at 2 seconds. In addition, units, datum, coordinates and data dictionary were verified. Vehicle was driven to the start point and features were logged. Linear features were collected and segmented at visible control points. If satellite lock was lost, at a control point, that point was missed and the first control point after the lock was obtained again was recorded. The missed point was added during the post processing. If the loss occurred for a significant time, then that section of the route was traversed again after the run was complete. At the end of run, the data file was closed and a new file was started for the other direction. The second file was closed at the end of that run. The data was brought back to the office for post processing.

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[1]Position Dilution of Precision (PDOP) is an indication of the current satellite geometry. Location of each satellite relative to all other satellites in the constellation is used in the calculation. The higher the PDOP, the lower the accuracy of the logged positions.

POST PROCESSING

The data was downloaded from the datalogger and displayed. A differential correction was done using relevant files from the base station in Morgantown, West Virginia. The corrected data files were exported to the GIS in ARC/INFO format. Previously obtained orthophotos for the area were used to overlay the GPS data. Validity of control points, entered in the field, was ascertained and data was inspected for usability. Each run was inspected separately, after all three runs for a route were complete. Further processing was necessary for combining the travel time for averaging. The runs were combined by assigning a line identification number to the arc representing a segment on the road. The same segment on each run got the same identification number. The runs were then combined on this line identification number and average segment travel time and speed were computed. The average travel time and speed data for each route is presented first and post processing issues are discussed later.

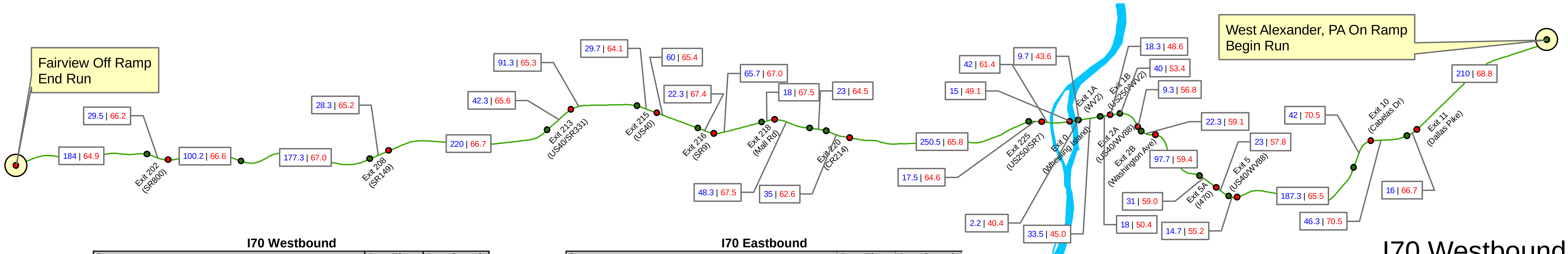
INTERSTATE 70

Interstate 70 runs were conducted on May 9th, May 22nd and May 24th. The eastbound runs started at the Fairview on ramp in Ohio and ended at the West Alexander off ramp in Pennsylvania. All on and off ramps were entered. The west bound runs started at West Alexander and ended at Fairview. The data for I-70 is presented in Figure III, IV(a) and IV(b) on pages 5, 6, and 7.

The graphs in Figure IV(a) and Figure IV(b) are derived from data presented in Figure III. Generally on the Ohio side the observed speed in both directions is within 5 MPH of the posted speed limit of 65 MPH. A sharp drop from 65 MPH to 45 MPH around the Wheeling Tunnels and the Fort Henry Bridge is reflected in the observed speed. Even at the reduced speed limit, the observed speed is slightly higher than the posted speed. The observed speed on the section of I-70 posted for 55 MPH, is also around 60 MPH. It is only on the 70 MPH section in West Virginia where speed is consistently below the posted speed. In this section, the westbound speed is higher than the eastbound speed probably due to the grades of the Dallas Pike hill. Overall, irrespective of the consistent speed limit in Ohio and significant variation in West Virginia, the observed speed generally does not fluctuate more than 5 MPH from the posted speed limit. No delays were observed on the mainline, however, ramps will be studied separately in the future to determine delays related to ramp intersections.

INTERSTATE 470

For Interstate 470 runs, the datalogging started and ended at the Elm Grove interchange in West Virginia and the Mall Road interchange in Ohio. The I-70 split at both ends was recorded while in motion. The I-470 runs were done on April 12th, May 8th and May 18th. The results of I-470 runs are presented in Figure V, VI(a) and VI(b) on pages 8 and 9. The posted speed limit on I-470 in West Virginia is 55 MPH, while it is 65 MPH in Ohio. The terrain is hilly and involves over 5% grade between US250 and I-70 in West Virginia. The speeds however are higher than the posted speed in both directions.



I70 Westbound

I70 Westbound

Segment	Avg. Time	Avg. Speed
West Alexander, PA On Ramp - Dallas Pike Off Ramp	210.0	68.8
Dallas Pike Off Ramp - Dallas Pike On Ramp	16.0	66.7
Dallas Pike On Ramp - Cabelas Dr Off Ramp	46.3	70.5
Cabelas Dr Off Ramp - Cabelas Dr On Ramp	42.0	70.5
Cabelas Dr On Ramp - US40/WV88 Off Ramp	187.3	65.5
US40/WV88 Off Ramp - US40/WV88 On Ramp	14.7	55.2
US40/WV88 On Ramp - I470 Off Ramp	23.0	57.8
I470 Off Ramp - US40/WV88 On Ramp	31.0	59.0
US40/WV88 On Ramp - Washington Ave Off Ramp	97.7	59.4
Washington Ave Off Ramp - Washington Ave On Ramp	22.3	59.1
Washington Ave On Ramp - US40/WV88 Off Ramp	9.3	56.8
US40/WV88 Off Ramp - US40/WV88 On Ramp	40.0	53.4
US40/WV88 On Ramp - US250/WV2 Off Ramp	18.3	48.6
US250/WV2 Off Ramp - US250/WV2 On Ramp	18.0	50.4
US250/WV2 On Ramp - WV2 Off Ramp	33.5	45.0
WV2 Off Ramp - US40/WV2 On Ramp	9.7	43.6
US40/WV2 On Ramp - WV2 On Ramp	2.2	40.4
WV2 On Ramp - Wheeling Island Off Ramp	15.0	49.1
Wheeling Island Off Ramp - US250/SR7 Off Ramp	42.0	61.4
US250/SR7 Off Ramp - US250/SR7 On Ramp	17.5	64.6
US250/SR7 On Ramp - CR214 Off Ramp	250.5	65.8
CR214 Off Ramp - CR214 On Ramp	35.0	62.6
CR214 On Ramp - I470 On Ramp	23.0	64.5
I470 On Ramp - Mall Rd Off Ramp	48.3	67.5
Mall Rd Off Ramp - Mall Rd On Ramp	18.0	67.5
Mall Rd On Ramp - SR9 Off Ramp	65.7	67.0
SR9 Off Ramp - SR9 On Ramp	22.3	67.4
SR9 On Ramp - US40 Off Ramp	60.0	65.4
US40 Off Ramp - US40 On Ramp	29.7	64.1
US40 On Ramp - US40/SR331 Off Ramp	91.3	65.3
US40/SR331 Off Ramp - US40/SR331 On Ramp	42.3	65.6
US40/SR331 On Ramp - SR149 Off Ramp	220.0	66.7
SR149 Off Ramp - SR149 On Ramp	28.3	65.2
SR149 On Ramp - US40 On Ramp	177.3	67.0
US40 On Ramp - SR800 Off Ramp	100.2	66.6
SR800 Off Ramp - SR800 On Ramp	29.5	66.2
SR800 On Ramp - CR114 Off Ramp	184.0	64.9

I70 Eastbound

Segment	Avg. Time	Avg. Speed
Fairview On Ramp - SR800 Off Ramp	180.3	66.7
SR800 Off Ramp - SR800 On Ramp	25.7	64.5
SR800 On Ramp - US40 Off Ramp	104.3	66.4
US40 On Ramp - SR149 Off Ramp	177.0	67.2
SR149 Off Ramp - SR149 On Ramp	29.0	68.7
SR149 On Ramp - US40/SR331 Off Ramp	217.7	67.7
US40/SR331 Off Ramp - US40/SR331 On Ramp	34.0	68.9
US40/SR331 On Ramp - US40 Off Ramp	94.3	64.1
US40 Off Ramp - US40 On Ramp	29.3	66.4
US40 On Ramp - SR9 Off Ramp	61.7	65.9
SR9 Off Ramp - SR9 On Ramp	17.0	62.0
SR9 On Ramp - Mall Rd Off Ramp	95.0	63.1
Mall Rd Off Ramp - Mall Rd On Ramp	15.0	62.9
Mall Rd On Ramp - Banfield Rd On Ramp	17.3	65.3
Banfield Rd On Ramp - I470 Interchange Off Ramp	21.3	65.2
I470 Interchange Off Ramp - CR214 Off Ramp	30.0	67.1
CR214 Off Ramp - CR214 On Ramp	22.3	70.1
CR214 On Ramp - US250/SR7 Off Ramp	247.8	65.6
US250/SR7 Off Ramp - US250/SR7 On Ramp	21.8	59.9
US250/SR7 On Ramp - Wheeling Island On Ramp	43.0	56.6
Wheeling Island On Ramp - WV2 Off Ramp	17.3	44.8
WV2 Off Ramp - US250/WV2 Off Ramp	37.8	47.4
US250/WV2 Off Ramp - US250/WV2 On Ramp	18.8	57.6
US250/WV2 On Ramp - Washington Ave Off Ramp	18.8	54.0
Washington Ave Off Ramp - Washington Ave On Ramp	22.7	58.2
Washington Ave On Ramp - WV88 Off Ramp	23.5	58.0
US40/WV88 Off Ramp - US40/WV88 On Ramp	17.7	56.8
US40/WV88 On Ramp - US40/WV88 Off Ramp	108.3	59.2
US40/WV88 Off Ramp - I470 Interchange On Ramp	21.3	54.3
I470 Interchange On Ramp - US40/WV88 Off Ramp	22.0	59.0
US40/WV88 Off Ramp - US40/WV88 On Ramp	16.3	60.1
US40/WV88 On Ramp - Cabelas Dr Off Ramp	223.0	64.0
Cabelas Dr Off Ramp - Cabelas Dr On Ramp	43.0	63.7
Cabelas Dr On Ramp - Dallas Pike Off Ramp	18.5	66.9
Dallas Pike Off Ramp - Dallas Pike On Ramp	24.7	68.4
Dallas Pike On Ramp - West Alexander, PA Off Ramp	221.2	64.1

Figure III

Off Ramp
On Ramp
Travel Time | Speed

I70 Eastbound

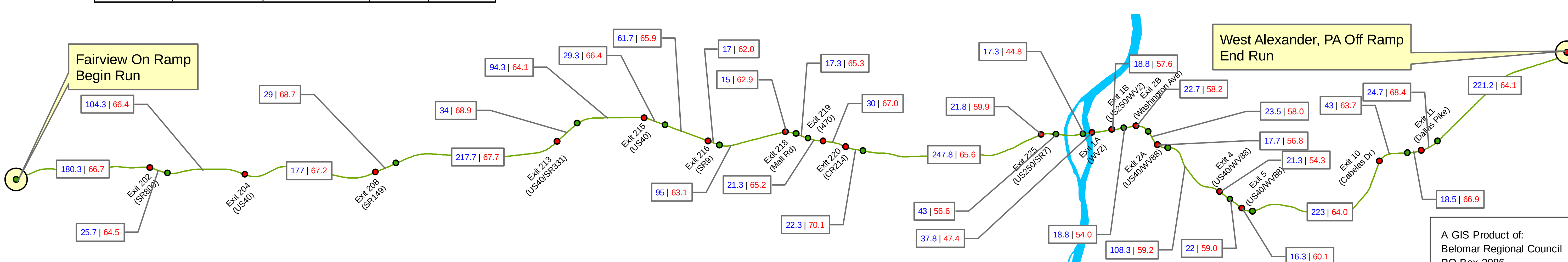


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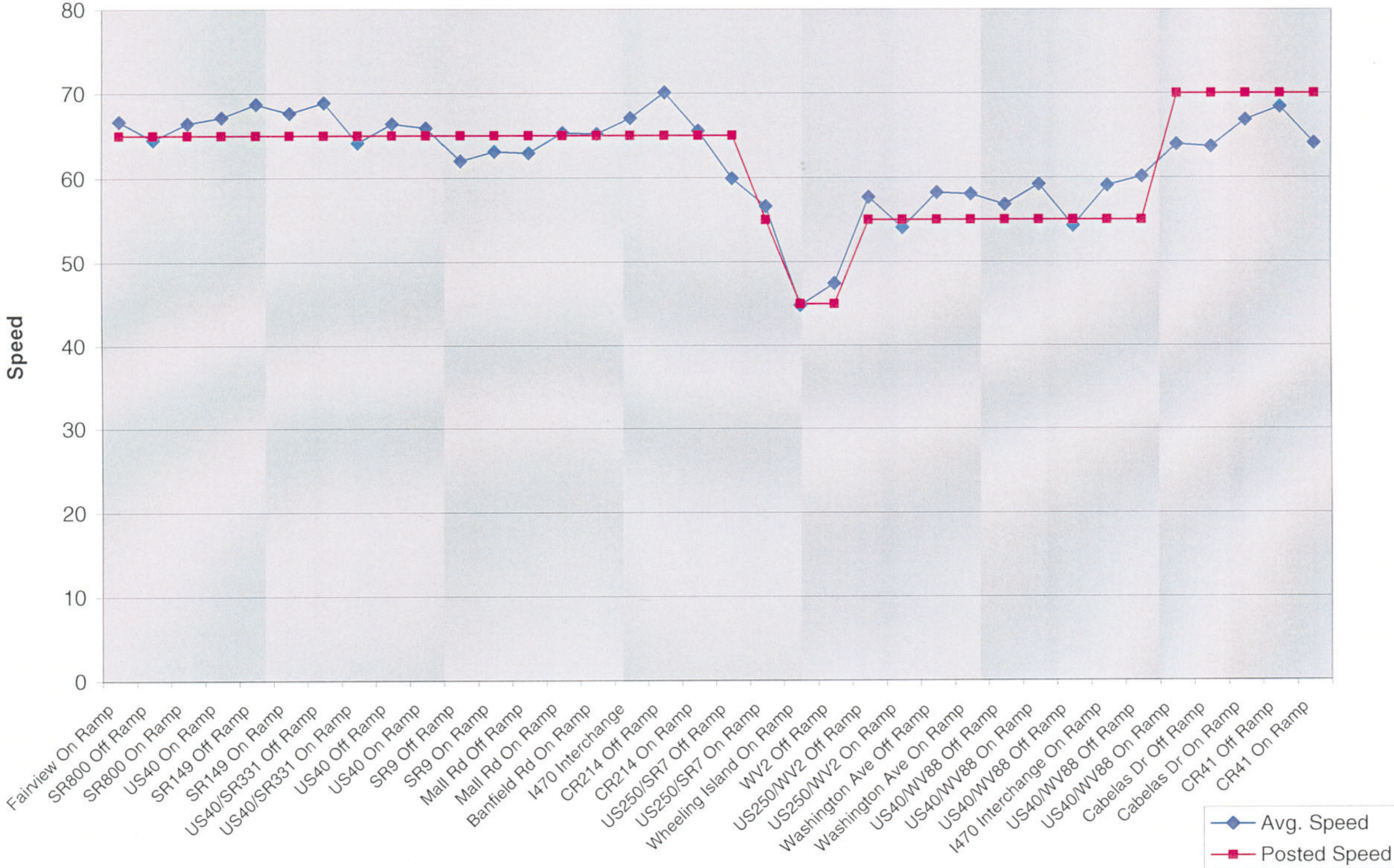
Figure IV (a)
I70 Eastbound Observed vs. Posted Speed



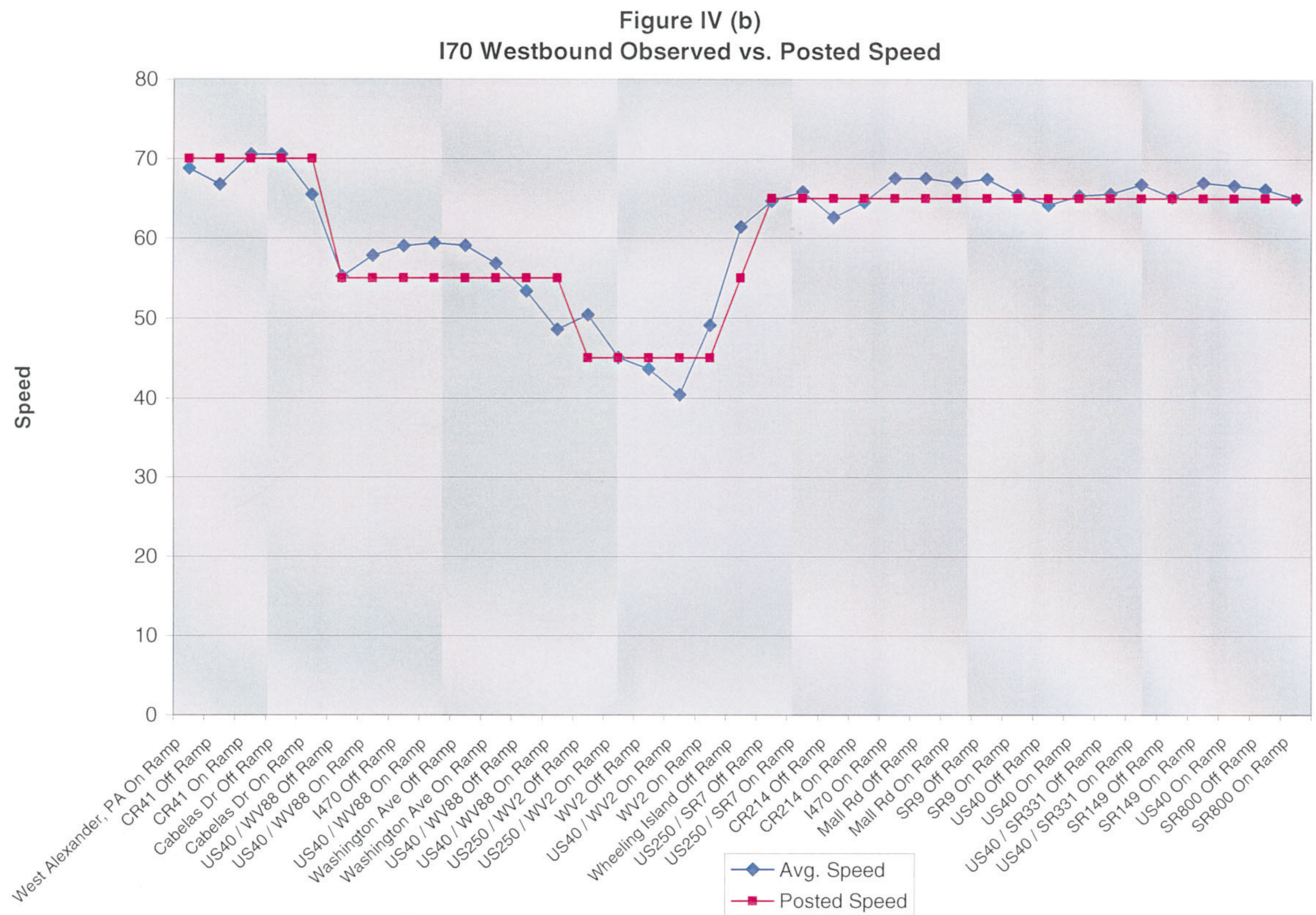
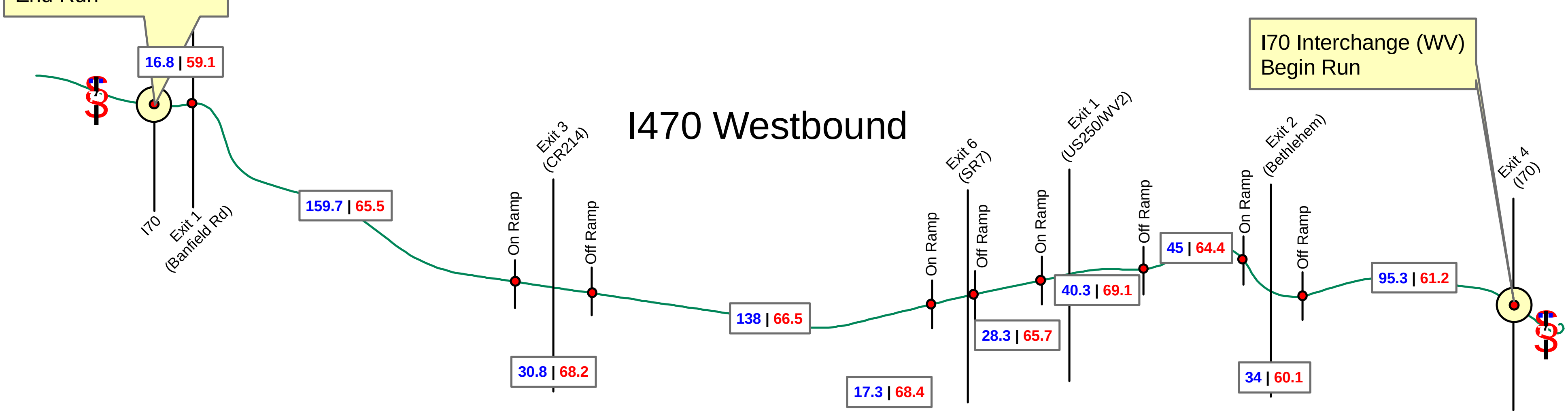


Figure IV (b)
I70 Westbound Observed vs. Posted Speed
Speed
80
70
60
50
40
30
20
10
0
West Alexander, PA On Ramp
CR41 Off Ramp
CR41 On Ramp
Cabelas Dr Off Ramp
Cabelas Dr On Ramp
US40 / WV88 Off Ramp
US40 / WV88 On Ramp
I470 Off Ramp
US40 / WV88 On Ramp
Washington Ave Off Ramp
Washington Ave On Ramp
US40 / WV88 Off Ramp
US40 / WV88 On Ramp
US250 / WV2 Off Ramp
US250 / WV2 On Ramp
WV2 Off Ramp
US40 / WV2 On Ramp
WV2 On Ramp
Wheeling Island Off Ramp
US250 / SR7 Off Ramp
US250 / SR7 On Ramp
CR214 Off Ramp
CR214 On Ramp
I470 On Ramp
Mall Rd Off Ramp
Mall Rd On Ramp
SR9 Off Ramp
SR9 On Ramp
US40 Off Ramp
US40 On Ramp
US40 / SR331 Off Ramp
US40 / SR331 On Ramp
SR149 Off Ramp
SR149 On Ramp
US40 On Ramp
SR800 Off Ramp
SR800 On Ramp
Avg. Speed
Posted Speed

Figure V



I470 Westbound

Segment	Avg. Time	Avg. Speed
I70 Interchange - Bethlehem Off Ramp	95.3	61.2
Bethlehem Off Ramp - Bethlehem On Ramp	34.0	60.1
Bethlehem On Ramp - US250/WV2 Off Ramp	45.0	64.4
US250/WV2 Off Ramp - US250/WV2 On Ramp	40.3	69.1
US250/WV2 On Ramp - SR7 Off Ramp	28.3	65.7
SR7 Off Ramp - SR7 On Ramp	17.3	68.4
SR7 On Ramp - CR214 Off Ramp	138.0	66.5
CR214 Off Ramp - CR214 On Ramp	30.8	68.2
CR214 On Ramp - Banfield Rd Off Ramp	159.7	65.5
Banfield Rd Off Ramp - I70 Interchange	16.8	59.1

I470 Eastbound

Segment	Avg. Time	Avg. Speed
I70 Interchange - CR214 Off Ramp	165.3	67.3
CR214 Off Ramp - CR214 On Ramp	28.7	67.7
CR214 On Ramp - SR7 Off Ramp	141.2	68.1
SR7 Off Ramp - SR7 On Ramp	18.3	65.1
SR7 On Ramp - US250/WV2 Off Ramp	27.3	63.4
US250/WV2 Off Ramp - US250/WV2 On Ramp	40.8	63.9
US250/WV2 On Ramp - Bethlehem Off Ramp	54.8	58.7
Bethlehem Off Ramp - Bethlehem On Ramp	25.8	57.6
Bethlehem On Ramp - I70 Interchange	92.0	62.6

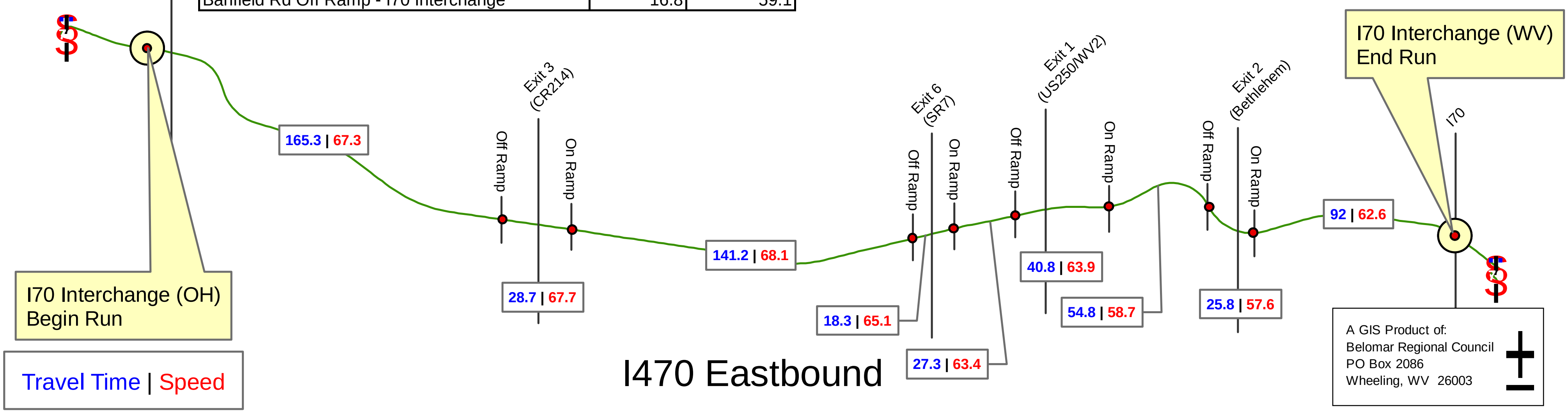


Figure VI (a)

I470 Eastbound Observed vs. Posted Speed

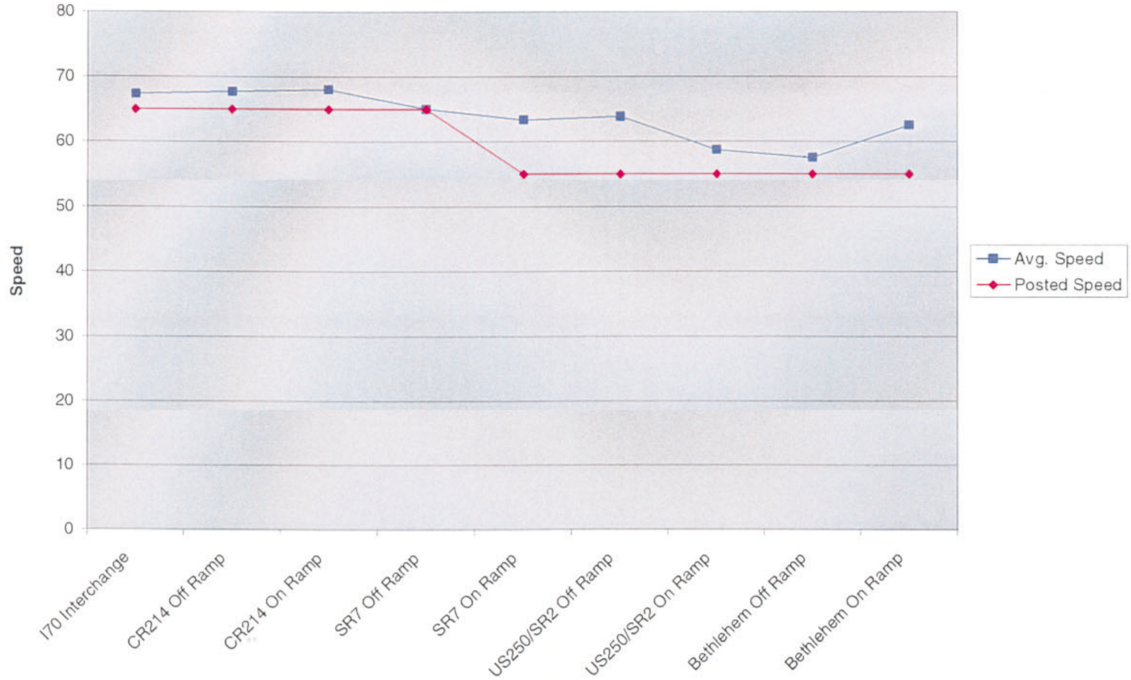
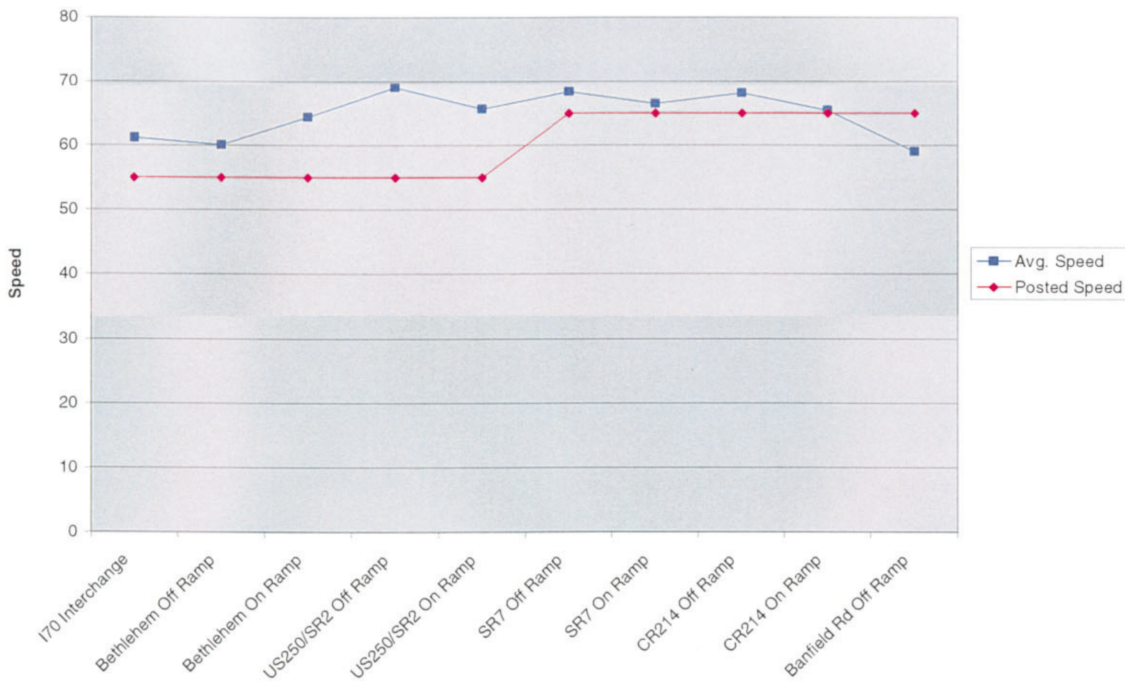


Figure VI (b)

I470 Westbound Observed vs. Posted Speed



In Ohio the observed speed is within 5 MPH of the posted speed. The variation from the posted speed is significant in West Virginia. On the up and downhill slope of the Bethlehem hill, speed variation is noticeable. Westbound between I-70 and the Bethlehem off ramp the uphill grade marginally reduces the speed before it goes up again peaking at the bottom of the hill at the US250 off ramp (7% grade). Eastbound experience is also similar. From US250 on ramp to Bethlehem off ramp speed declines at a faster rate and picks up again on the downhill slope east of the exit.

WV86

The start and endpoints for this run as shown in Figures VII(a) and VII(b) on pages 11 and 12 were WV88 and US250. There were only limited controlled points along this run. Due to the presence of "T" intersections, the number of segments in both directions is not identical. For "T" intersection, a control point was added only in the applicable direction. Also shown in the table is line-id, a field used to accumulate and average data from all runs. The speeds are lower immediately north of US250 in Glen Dale. These sections are posted for 25 MPH. Posted speed limit varies from a low of 25 MPH to a high of 45 MPH. Higher speeds are north of the Glen Dale corporation line. Since points where posted speed change occurred were not recorded, a direct comparison between posted and observed speed limits could not be made. Generally speaking, observed speed was within 5 miles of the posted speed and was generally lower than the posted speed due to the hilly terrain involving horizontal and vertical curves.

WV88

WV88 runs from the Brooke County line south to US40, follows US40 to Kruger Street in Elm Grove where it separates and proceeds south through Bethlehem and terminates at US250 in Marshall County. The section between the Brooke County line and US40 had a one lane restriction and was not studied this year. However, in studying WV86, a large section of WV88 through Bethlehem was being traversed to get to WV86. Therefore, it was decided to collect WV88 without control points. The objective was to see if GPS data collected without control points will lend to quicker and efficient post processing than the data being collected otherwise. Two approaches were used. In the first approach a new file was started at the intersection of US40, WV88 and Kruger Street. This file was closed at WV86 and a new file was started for WV86. After the WV86 run was completed, yet another file was opened to log GPS data from WV86 south to US250 on WV88. At US250, the file was closed. A new file was opened for the trip back to collect data for WV88 northbound. It was expected that for southbound WV88 two separate files could be combined, while for northbound direction only one file would be used. No control points were entered along the way. These files were not post processed til all runs were completed. Two lessons were learned from these experimental runs. The data could be collected with only one person in the vehicle since no control points were added in the field and datalogger automatically recorded positions every two seconds. Secondly, the post processing in light of issues encountered, was more efficient and it also saved on dead time and mileage reimbursement.

Out of two approaches used for WV88 only one worked. The file that was started at US250 and ended at Kruger Street was useable while the files ending and starting at WV86 did not have enough overlap

Figure: VII(a)

WV 86 NORTHBOUND

WV86 NORTHBOUND (starts at us250)

line-id	cross st	ttave	spdave
1	Washington Ave	13.167	21.07
2	Jefferson Ave	10.667	28.09
3	Madison Ave	7.500	28.70
4	CR 8/1	194.500	37.57
5	CR 2/4	258.167	40.22
6	WV 88	78.000	31.95

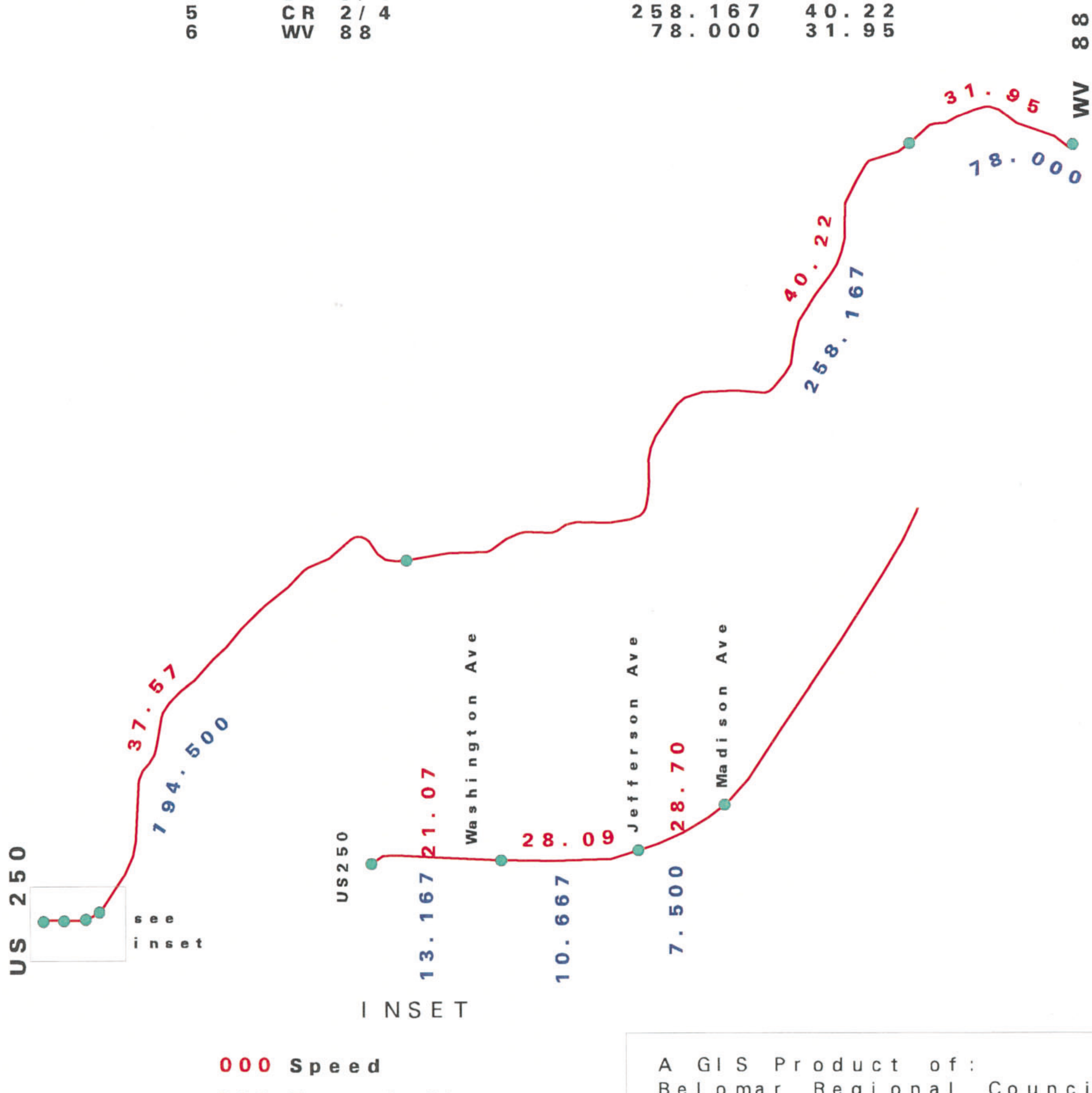


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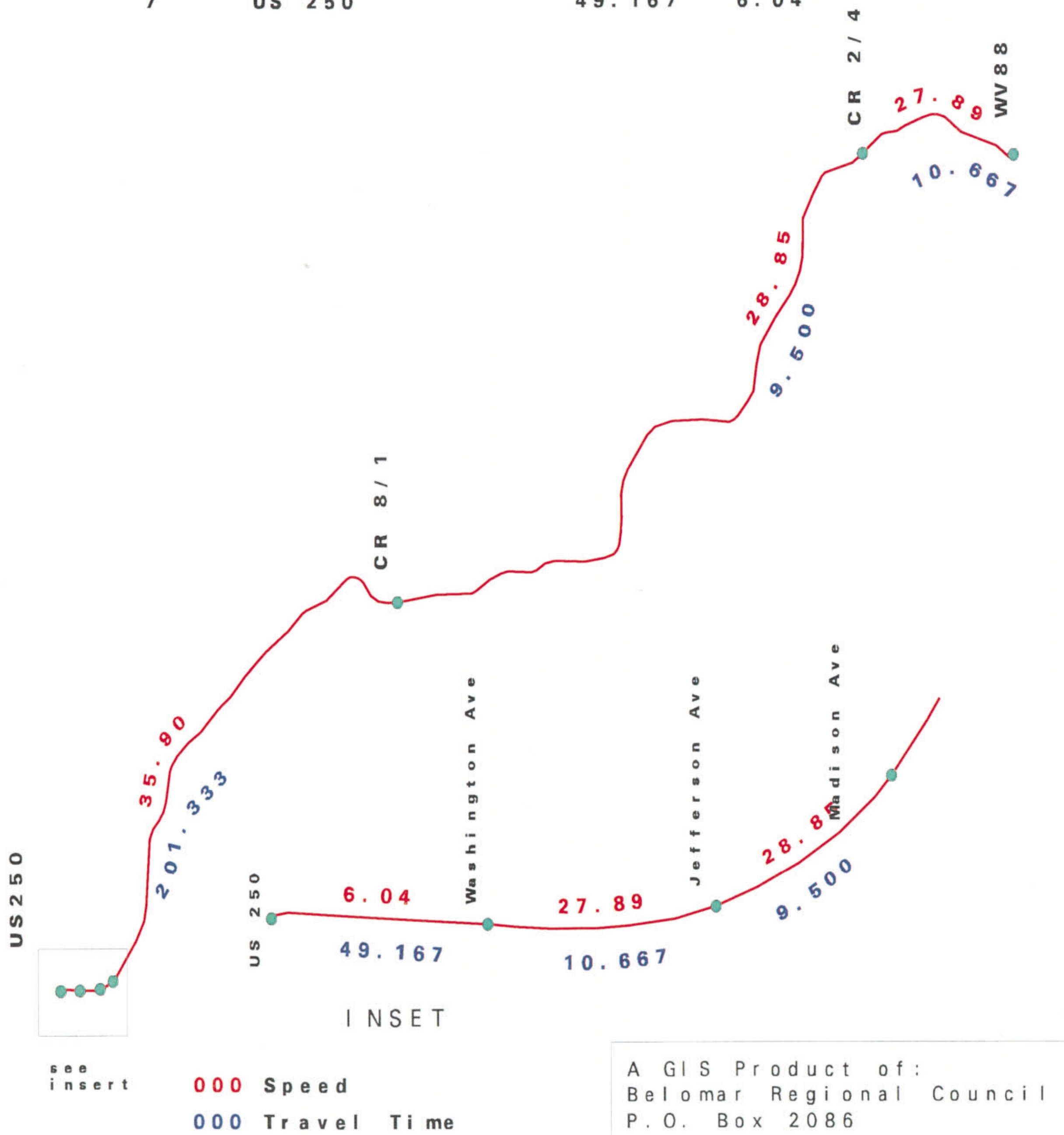
Figure: VII(b)

WV 86 SOUTHBOUND

WV86 SOUTHBOUND (starts at wv88)

line-id	cross st	ttave	spdave
1	CR 1	41.000	25.21
2	CR 2/4	47.500	30.52
3	CR 8/1	272.500	38.00
4	Madison Av	201.333	35.90
5	Jefferson Ave	9.500	28.85
6	Washington Ave	10.667	27.89
7	US 250	49.167	6.04



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as well as time sequence in both files was different. It was possible to overcome time sequence issues, but it was felt that data quality will be compromised due to a lack of overlaps. Therefore, the data from US250 north to Kruger Street is presented in one direction only.

As shown in Figure VIII on page 14, speeds vary significantly on this roadway. It is consistent with the posted speed limits that vary from a low of 25 MPH to a high of 50 MPH. A stop delay is also experienced at the signalized intersection at US40/Kruger Street. Stop delay is reflected in the lowest speed on this segment.

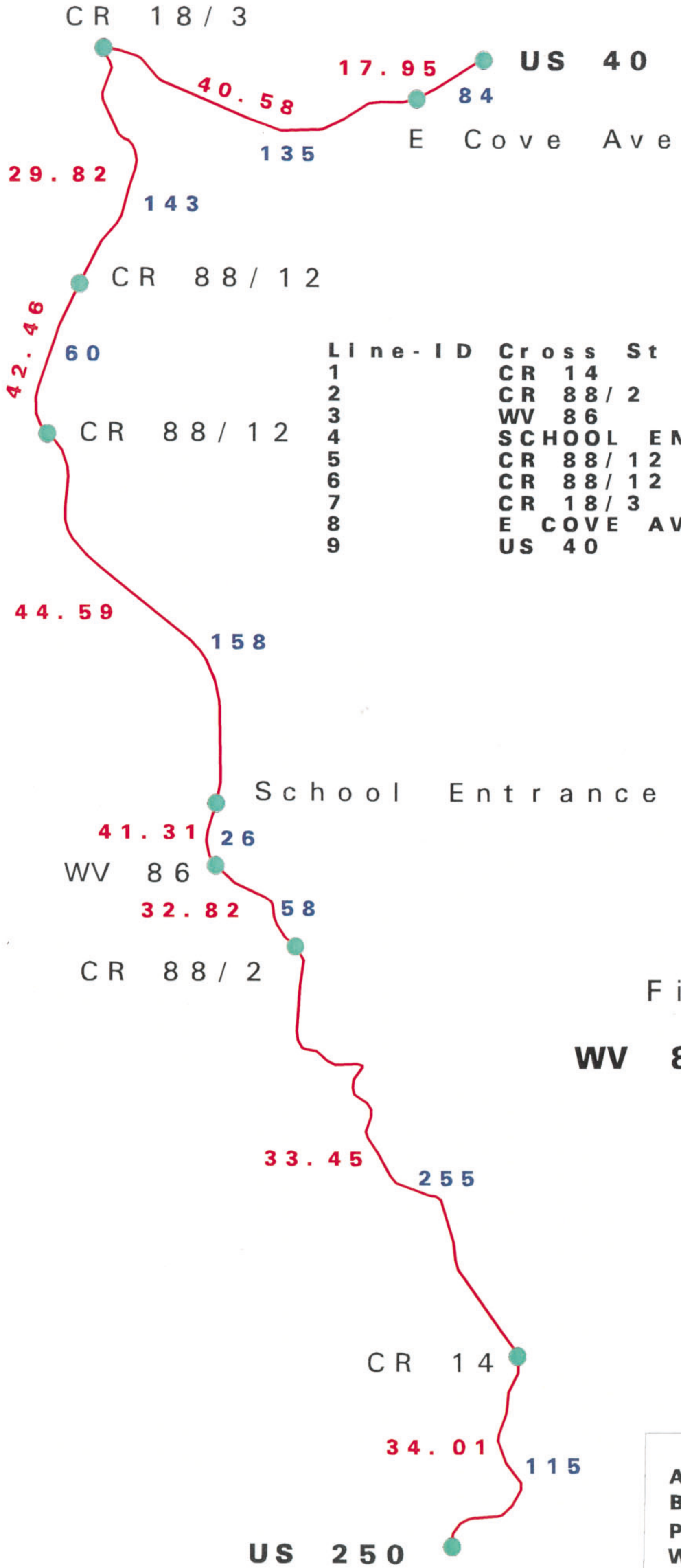
POST PROCESSING ISSUES

Several post processing issues surfaced that were not experienced during a pilot run before this project was initiated. It was expected that the segment start and end time could be calculated by an in-house software routine developed for the pilot. However, in averaging travel time for multiple runs, it was necessary that segment lengths be nearly consistent. In instances where satellite lock was lost or control points from different runs were not within reasonable distance, the field entered point had to be moved to a different position for consistency. A point spread for three runs on a single point is shown in Figure IX(a) on page 15. The points where needed were moved within 1 second of each other. The points to be moved were selected by overlaying the GPS data on orthophotos in West Virginia and a combination of orthophotos and roadway centerline data in Ohio.

The roadway centerlines for West Virginia became available when this project was near completion, so were used only partially. One of the advantages of a roadway centerline (or a statewide transportation layer) is shown in Figure IX(a). In adjusting node (control point) positions; if a reliable node was available from a base layer (such as SAMB's centerlines), all nodes could be repositioned at the reference node. The benefits of such an approach are far reaching and have statewide implications. For example a statewide travel time dataset can be developed this way with MPOs collecting the data and eliminating duplication of effort.

The orthophotos in West Virginia were available in Universal Transverse Mercator projection. The projection of raster image data is important in that image conversion from one projection to another is not easily accomplished within the installed GIS software. On the other hand, vector data can be converted easily. This raised a dilemma for Ohio side as the imagery for Belmont County is available in Ohio State plane coordinates only. Considerable time was spent on this issue. Finally the vector data was converted to Ohio State plane coordinates processed and then converted back to UTM grid for processing of West Virginia data.

The GPS data was collected as a linear feature. This caused problem when vehicle was stationary or moving at lower speeds (<5 MPH). This effect is shown in Figure IX(b) and IX(c) on page 15. At signalized intersection on Kruger Street multiple points were recorded at a short distance. Too many points over short distance distorted the linear feature. This does not affect the travel time as shown by points 247722 and 247798. Any number of points can occur between these two points without affecting the run time for the segment. The run time value can only change based on the value of two outside points



Line-ID	Cross St	AVETT	AVESPD
1	CR 14	114.667	34.01
2	CR 88/2	255.333	33.45
3	WV 86	58.333	32.82
4	SCHOOL ENT	25.667	41.31
5	CR 88/12	157.667	44.59
6	CR 88/12	60.333	42.46
7	CR 18/3	142.667	29.82
8	E COVE AVE	135.333	40.58
9	US 40	84.000	17.95

Figure: VIII

WV 88 NORTHBOUND

000 Travel Time

000 Speed

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Figure: IX(a)

Node Registration

Figure: IX(b)

Stop Delay at Kruger St

WV88 Leg

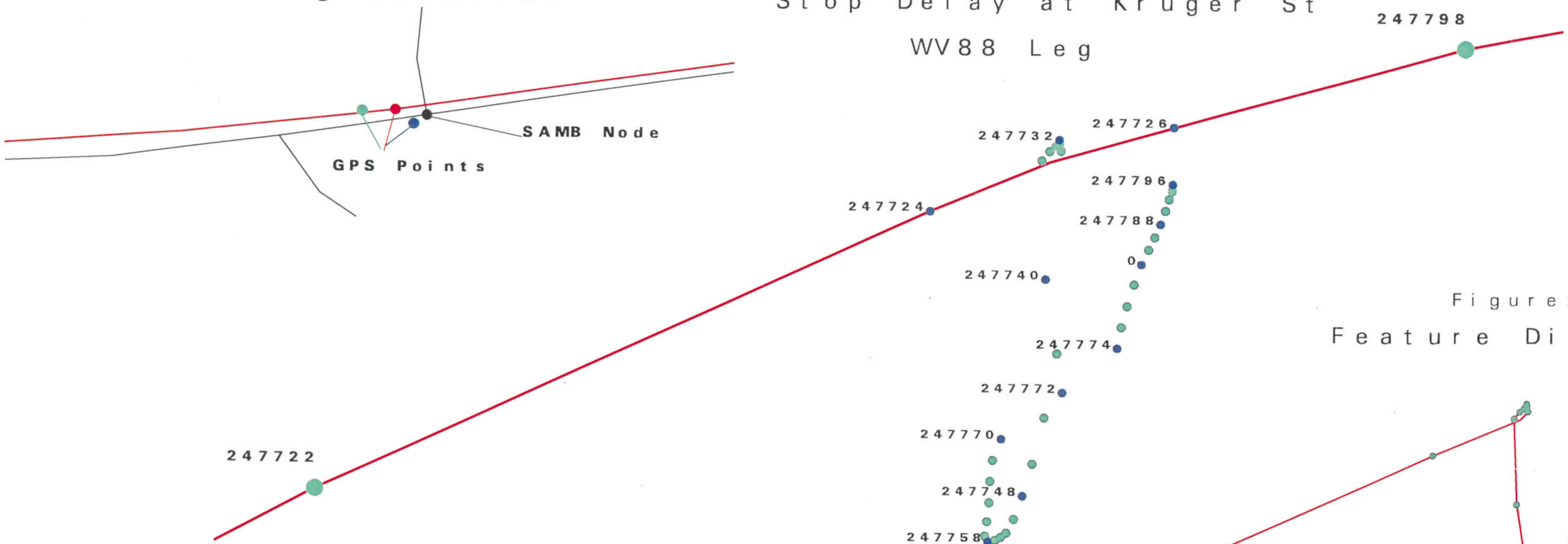


Figure: IX(c)

Feature Distortion

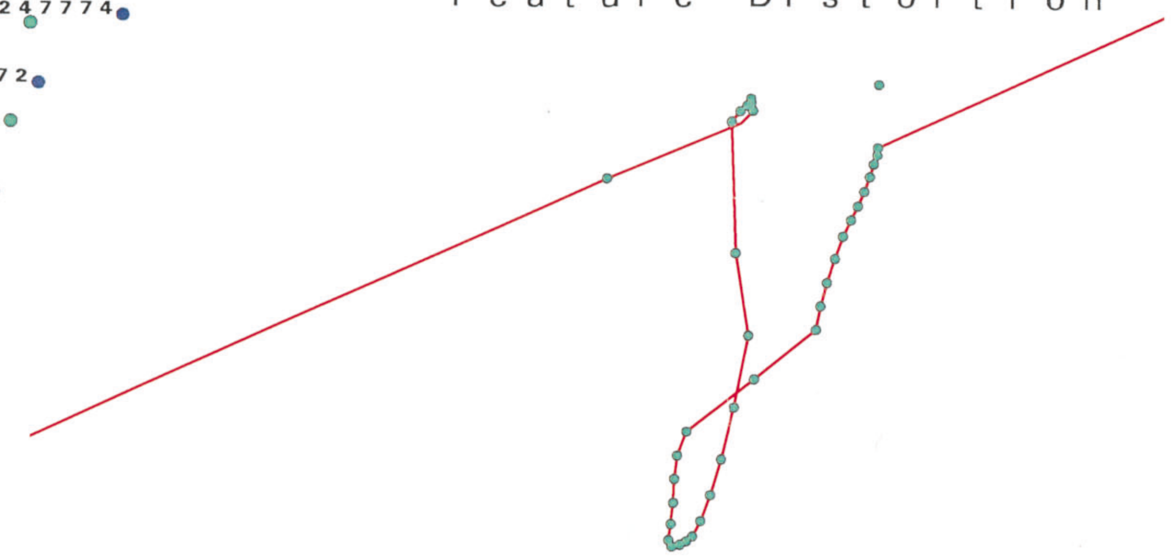
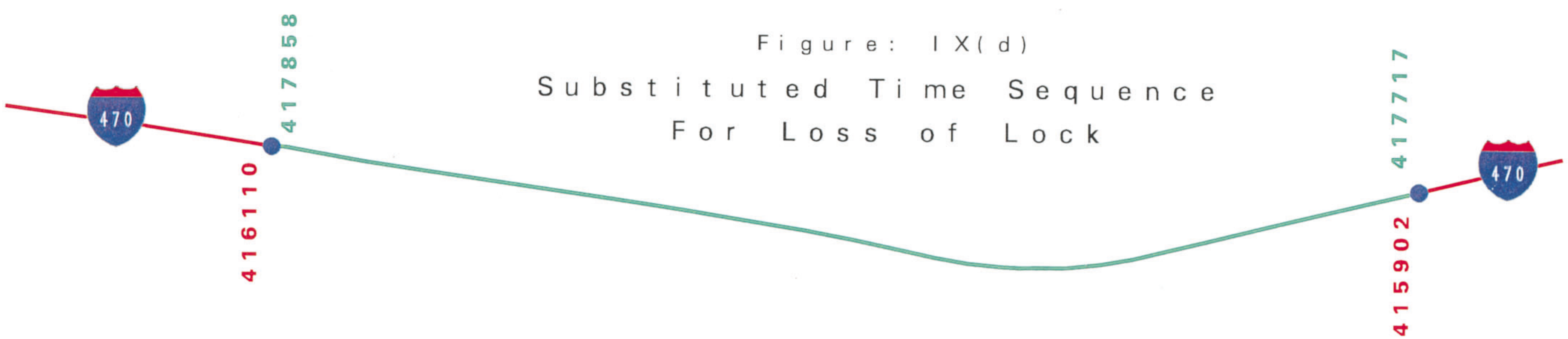


Figure: IX(d)

Substituted Time Sequence

For Loss of Lock



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irrespective of number of points within the segment. However, the length of the feature is affected by this distortion and affects the speed calculation.

An advantage of these additional points is that the stop delay can be calculated separately from the run time. The affect of additional length due to stop delay may be eliminated if only position data is collected. The feature (or roadway centerline) can be created during the post processing and segmentation can be done using procedures used in this study for WV88. The portion of distorted line feature was deleted so it would not factor in the speed calculation. At least one route will be studied, next year where only position data is collected in the field and linear feature (roadway) is generated as post processing.

Occasionally, GPS lock is lost and gaps in the data are visible. These gaps can be filled in many different ways. As shown in Figure IX(d) on page 15, on I-470 westbound for the third run, lock was lost between SR7 on ramp and CR214 off ramp. After the run was completed, another pass was made at this section. The data obtained during this pass was then used to bridge the gap in the original run.

CONCLUSIONS

The GPS technology has been used successfully for travel time elsewhere in the country. After collecting travel time data for more than 1,100 miles of roadway, the Hampton Roads MPO in Virginia concluded:

> "Among the benefits of collecting travel time data with a GPS-equipped vehicle are simple and trouble-free data collection, an easy interface for linking the data to the GIS, and efficiency in terms of time and manpower. Limitations include inability to collect data inside tunnels and under dense foliage. In the latter case, runs have to be made in the fall or winter months after leaves have fallen."

In this report an attempt is made to highlight technical issues that affect data collection and a final product produced by using GIS software is presented. The lessons learned will improve data collection and post processing for additional routes next year. One technique of collecting only positions in the field and generating roadway feature as a step in post processing still remains to be tested. In spite of this, it is concluded that the GPS data can be collected with only one person in the vehicle and segmented in the office during post processing. This process does not require selection of control points before the run and control points can be selected visually from the orthophotos or roadway centerlines.

A statewide transportation layer is very critical in avoiding duplication of efforts at local, regional and state level. All GPS data is referenced to an image source or a base layer (e.g., roadway centerlines), if this base layer is a statewide layer (e.g. transportation layer) then a statewide dataset is an automatic outcome of this effort.

The stop delay data can be separated from the run time data and used for addressing operational issues at intersections.

Finally, it can be concluded that GPS can be used for travel time studies. It can be efficient and advantages of digital spatial data with time stamp for each position are too numerous to mention. Even though data collection is more accurate, efficient and requires less man hours, the post processing requires significant time commitment. From start to generation of the final product (a travel time table), GPS requires more time than the traditional stop watch techniques. However, the usability, flexibility and applicability of GPS data outweighs any advantage of stop watch methods.