Project Title: Using Truck GPS Data for Freight Performance Analysis in the Twin Cities Metro Area
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Task Due: 7/31/2013

TASK #3 PROCESS TRUCK GPS DATA AND DERIVE PERFORMANCE MEASURES

1. Introduction

The objective of this task is to develop a data analysis methodology, process raw probe vehicle data, and derive performance measures to assess the mobility and reliability of trucks traveling along the key freight corridors in the Twin Cities Metro Area (TCMA). First, truck GPS raw data received from American Transportation Research Institute (ATRI) is summarized in the following section. Second, a list of studied corridors in TCMA, the data processing methodology and analysis results are presented. Processed probe vehicle speed and volume percentage by hour are compared to the data collected from a Weigh-In-Motion (WIM) station. Lastly, freight performance measures, such as truck delay, cost of delay, and travel time reliability are derived and discussed. Additional data description, processing and analysis results are included in Appendices.

2. Probe Vehicle GPS Data from ATRI

As part of the data sharing agreement between the UMN and ATRI, the research team received three different sets of truck GPS data as summarized and listed in Table 1. Dataset A and C contain probe vehicle spot speed and latitude-longitude location information. Dataset B does not include vehicle spot speed information. Dataset A has a positioning accuracy less than 3 meters. At 95% probability, the GPS positioning accuracy of dataset B and C is about 150 and 58 meters, respectively. Corresponding tolerance is used to merge raw GPS point to a nearest roadway. Due to data privacy concerns, the vehicle ID is masked or encrypted. In addition, the vehicle ID in dataset B rotates every 15 days and the vehicle ID in dataset C changes every 24 hours. The estimated GPS pinging rate for dataset A, B and C are about 10, 22 and 1 minute with standard deviations of 15, 28, and 5 minutes, respectively. A list of ATRI truck GPS data fields for each dataset is included in Appendix A.1.

Table 1 Summary of ATRI GPS Data

Data Set	DS-A	DS-B	DS-C
Time Zone	GMT/UTC	GMT/UTC	GMT/UTC
Spot Speed?	Yes	No	Yes
Static ID?	Yes	Rotates every 15 days	Rotates every 24 hours
Data Accuracy	Within <3 meters	Within 124-134 meters at 90% probability and 129-150 meters at 95% probability.	Within 13-56 meters at 90% probability and 15-58 meters at 95% probability.
Snap Tolerance Used	**50 m**	**150 m**	**50 m**
2012 Number of Truck Trips	**29,555**	**69,063**	**66,632**
2012 Raw Data Size	40,500,081	4,840,339	28,290,687
2012 Snapped	12,287,134	1,246,536	8,593,449
2012 Snapped Percentage %	**30.3%**	**25.8%**	**30.4%**
Average (SD) Sampling Time	**10 (15) min**	**22 (28) min**	**1 (5) min**

3. Key Freight Corridors

Thirty eight (38) key freight corridors in the Twin Cities Metro Area (TCMA), as illustrated in Figure 1, were selected for this study. This study also includes 4 major corridors that connect the metropolitan area to regional freight centers in St. Cloud, Mankato, and Rochester. List of each freight corridor ID referred in the data processing and analysis, and its corresponding route description is tabulated in Appendix A.2.

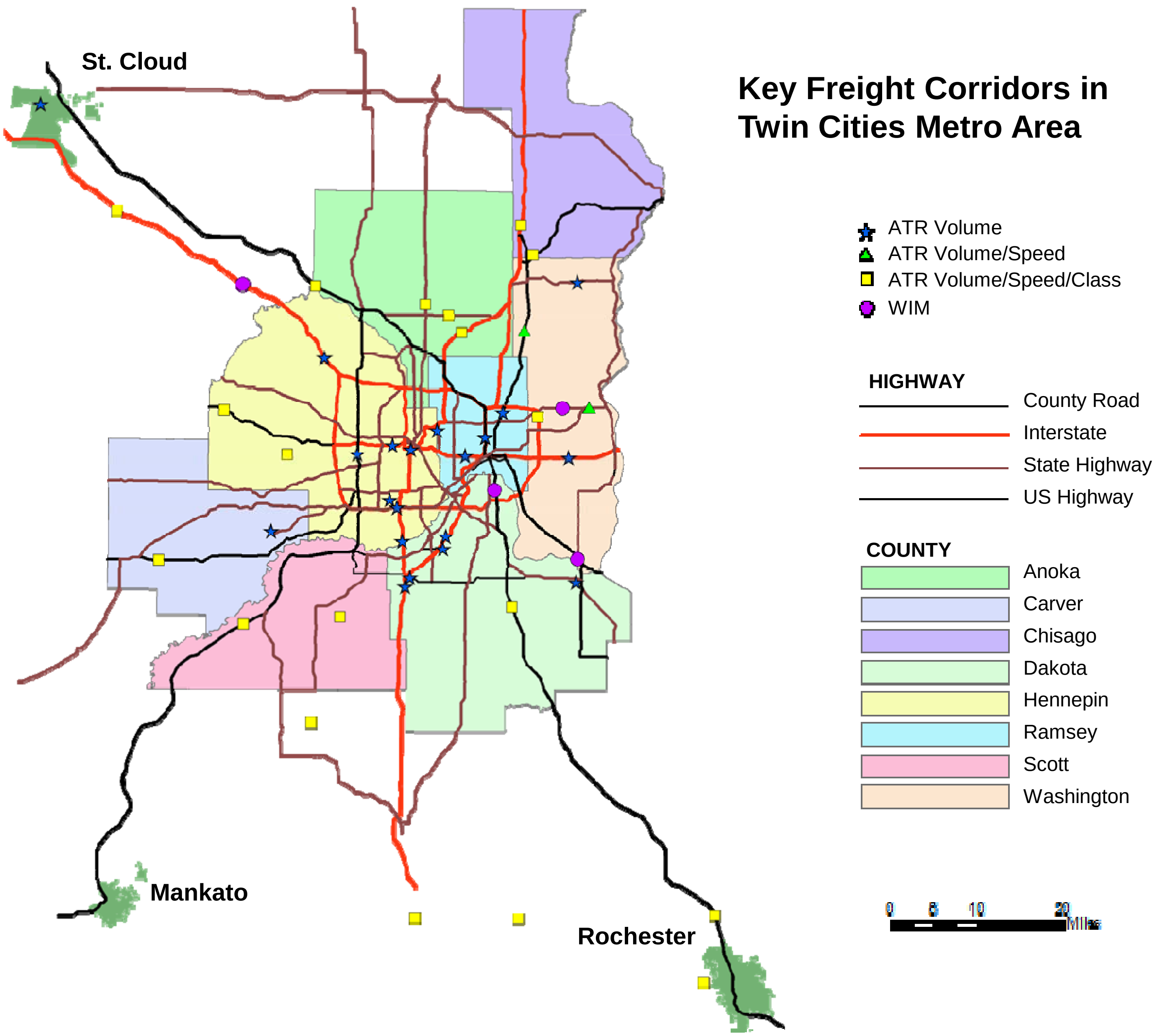

Figure 1 Key Freight Corridors in Twin Cities Metro Area

4. Data Processing Methodology

A route geo-spatial database of 38 key freight corridors in the TCMA was prepared using the ArcGIS[1] software (http://www.esri.com/software/arcgis). The geographic information system (GIS) roadway network data was

[1] ArcGIS is a GIS developed by ESRI (www.esri.com) for working with maps and geographic information.

imported to an open source Structured Query Language (SQL) object-relational database, called *PosgreSQL* (http://www.postgresql.org/). In addition, a spatial database extension, call *PostGIS* (http://postgis.net/), for PostgreSQL database was included to support geographic objects analysis and allow location queries to be executed in the SQL environment.

After importing the raw truck GPS data from each dataset into the PostgreSQL database, several SQL scripts were developed to locate nearest roadway segments for all GPS latitude-longitude points and compute linear referencing measurements and distances. Individual vehicle trip speed was then computed by grouping vehicle ID and sorting the location data by time. Average vehicle space mean speed of a network segment is calculated by dividing the linear distance difference over time difference between two consecutive GPS data points within the same trip. Vehicle spot speed was also included for later data analysis. Processed data does not meet the speed filtering parameters (potential anomalies) are stored in a separate database for later truck stop location and stop duration analyses. The data processing and analysis flowchart was presented in Figure 2.

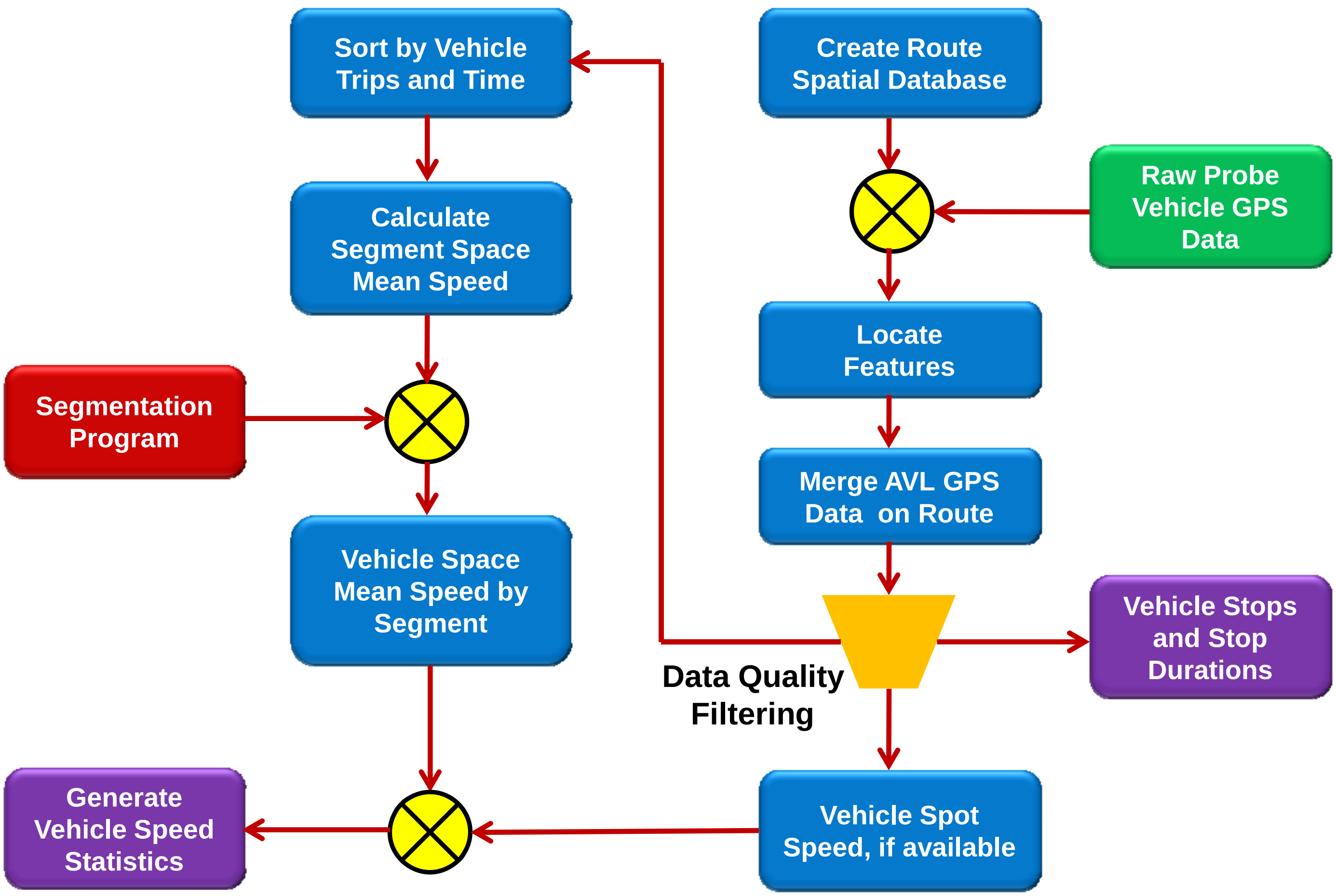

Figure 2 Data Processing and Analysis Flowchart

Truck speed variations by location and by hour of day were analyzed. Speed and volume variations at specified mile marker were analyzed to compare the changes over the hour of day. Computed truck speed versus the general traffic speed gathered by state DOTs were compared to evaluate the speed difference between trucks and passenger vehicles. Raw truck GPS data did not pass through the data quality filter were trucks that might stop for service or rest. Public truck rest locations or facility along the key corridors in the TCMA and their stop durations were also derived to evaluate truck parking activity and service availability.

5. Data Analysis

Data proximity, spot vs. processed speed (or space mean speed), comparisons of speed and hourly volume percentage between probe vehicles and WIM stations were discussed and presented as follows. Positive direction is defined as the direction along a route where mile post increases. And the negative direction is the direction along a route where mile post decreases. Bar charts of number of probe vehicle data points by route in both directions are included in Appendix A.3.

5.1 Data Proximity Analysis

Due to GPS data accuracy and the accuracy of road network GI S data, collected GPS data points distribute along a roadway as illustrated in Figure 3. As shown in the bar charts of data proximity by route in Appendix A.4, most of raw data from dataset A and C are, in average, 20 meters away from roadway centerline. In average, most GPS points from Dataset B are about 70 meters away from roadway.

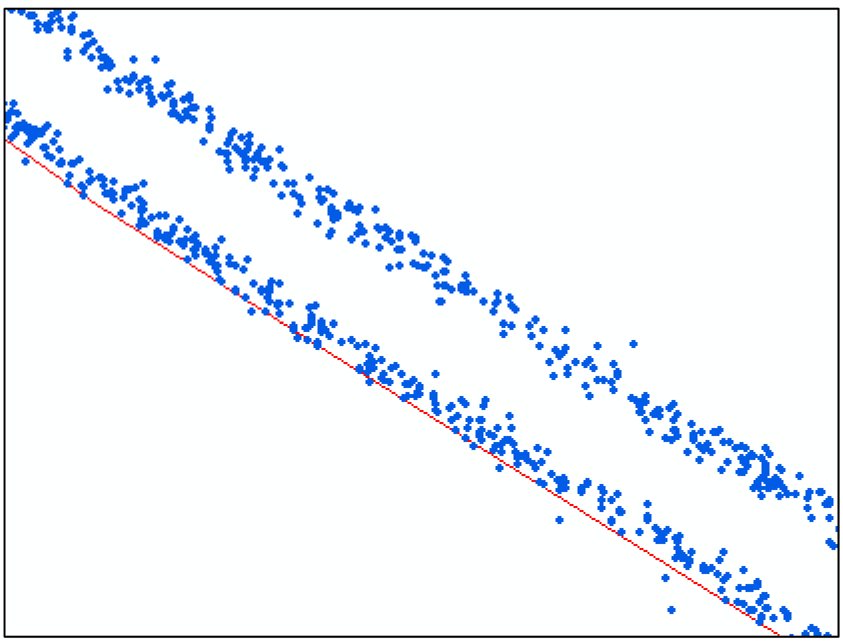

Figure 3 Example of GPS Data Point Cloud

5.2 Comparisons of Processed Probe Vehicle Results and WIM data

There are four Weigh-In-Motion (WIM) stations in the TCMA. The WIM sensor records individual vehicle speed, classification, and weight information. It's an ideal source to validate processed probe vehicle data. 12-month of WIM data from all four stations were received from MnDOT. Both passenger vehicles (class 2) and heavy commercial vehicles (class 9 and above) were analyzed and compared with processed results from probe vehicle data. Descriptions of these four WIM stations and their corresponding 2011 HCAADT counts are listed in Table 2 as follows. WIM station #37 is discussed in the following section. Additional data analysis results of WIM station #36, 40 and 42 are presented in Appendix B.

Table 2 Description of WIM stations

WIM ID	36	37	40	42
Route Name	MN 36	I-94	US 52	US 61
County Name	Washington	Wright	Dakota	Washington
City Name	Lake Elmo	Otsego	West St Paul	Cottage Grove
Direction	EB	WB	NB	SB
Mile Post	15	200	127	119
WIM Location Description	.7 mi W of CSAH17 Lake Elmo Ave N) in Lake Elmo	1.2 mi NW of CSAH19 (La Beaux Ave) in Otsego	0.5 mi N of CSAH14 in West St. Paul	0.4 mi S of TH95 (Manning Ave S), S of Cottage Grove
WIM Type	VOLUME/SPEED/CLASS/WEIGHT			
Route ID	5	24	29	27
Roadway Segment ID	15	59	81	16
Linear Ref Direction	1	1	1	-1
2011 HCAADT	1100	6900	4400	1750

5.3 Spot vs. Space Mean Speed

Spot speed is the instantaneous vehicle speed captured by the GPS unit. Processed speed (or space mean speed) is the average vehicle speed calculated based on two consecutive vehicle GPS locations. Dataset A and C have spot speed information while dataset B does not have spot speed information. Spot speed at mile post 200 on I-94 is analyzed and compared with space mean speed as an example.

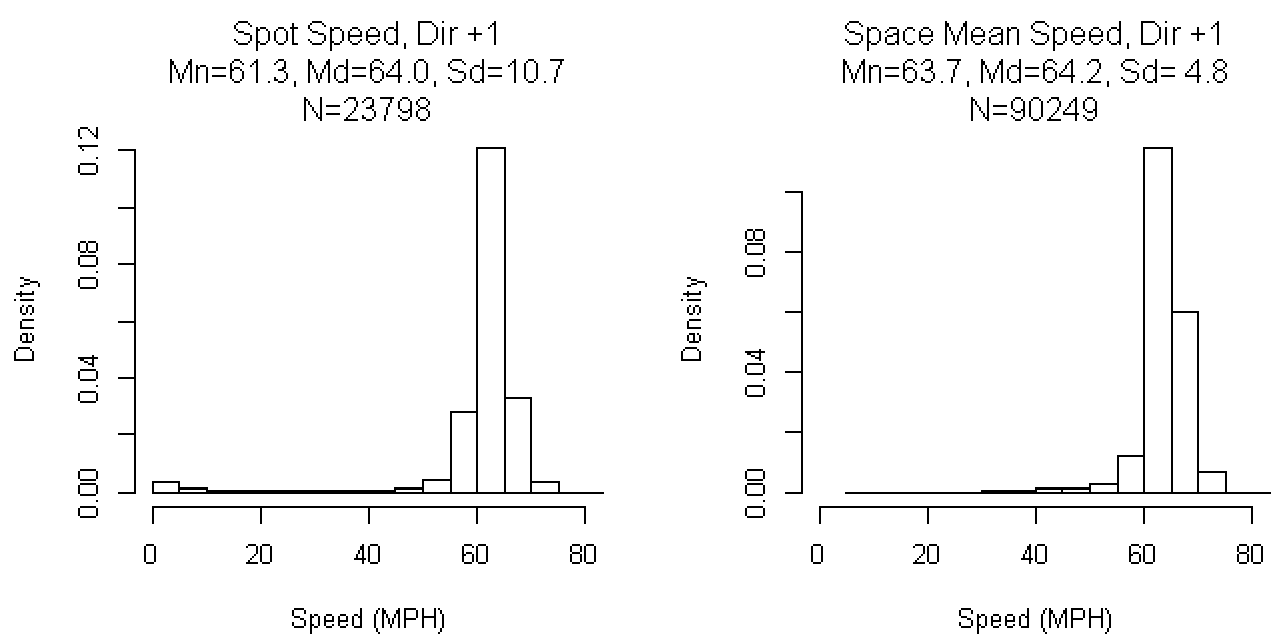

Figure 4 Spot vs. Space Mean Speed on Route I-94 at Mile Post 200
(In Increasing Mile Post Direction)

The histogram of probe vehicle spot speed and space mean speed are displayed in Figure 4 and 5 in both directions. In the increasing mile post direction (positive direction), the median of spot speed and space mean speed are 64.0 and 64.2 MPH, respectively. The distribution of average spot speed in positive direction is 61.3 MPH, 2.4 MPH lower than the average space mean speed at the same location. Similarly, the median of spot speed and space mean speed in the decreasing mile post direction (negative direction) are 64.0 and 64.5 MPH, respectively. The distribution of average spot speed in negative direction is 62.7 MPH, 1.7 MPH lower than the average space mean speed at the same location. In general, the standard deviation of spot speed is about twice as large as the processed speed in both directions.

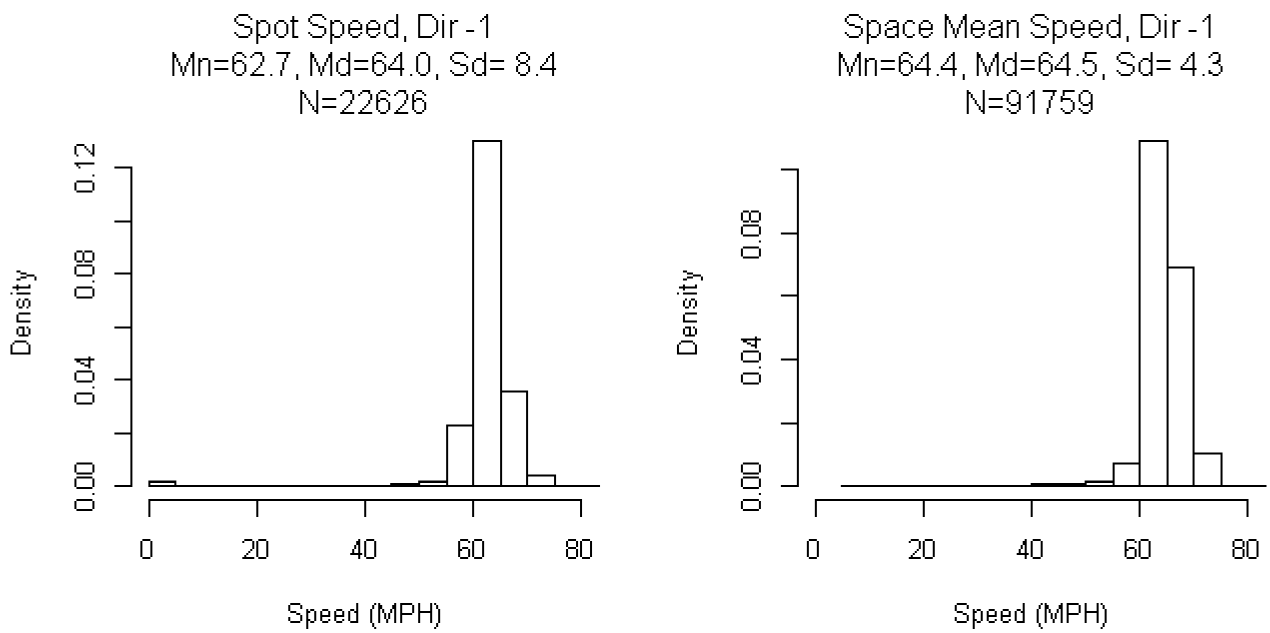

Figure 5 Spot vs. Space Mean Speed on Route I-94 at Mile Post 200
(In Decreasing Mile Post Direction)

6. Speed and Volume Comparisons

A one mile segment (I-94 WB Otsego, route ID 24, segment ID 59, mile post 200) where WIM station #37 is located is presented and discussed in this section. Additional analyses and comparisons at WIM #36, #40, and #42 are included Appendix B.

6.1 Probe Vehicle vs. WIM Speed Comparisons

Probe vehicle speed at mile post 200 on I-94, where the WIM station #37 is located, are compared with speed collected by WIM #37 in 2012. The histogram of probe vehicle speed and WIM speed are displayed in Figure 6. The average probe vehicle speed at WIM37 location is 63.2 MPH while the WIM station recorded an average heavy commercial vehicle speed is 65.7 MPH. Similarly, the median speed of probe vehicles at WIM37 location is 64 MPH, 1 MPH lower than median speed from WIM37 station. The distribution of probe vehicle speed has a slightly larger standard deviation (6.5 MPH) than the speed (5.8 MPH) from WIM. The probe vehicle spot and median speeds by hour on weekdays are compared with WIM speeds as plotted in Figure 7.

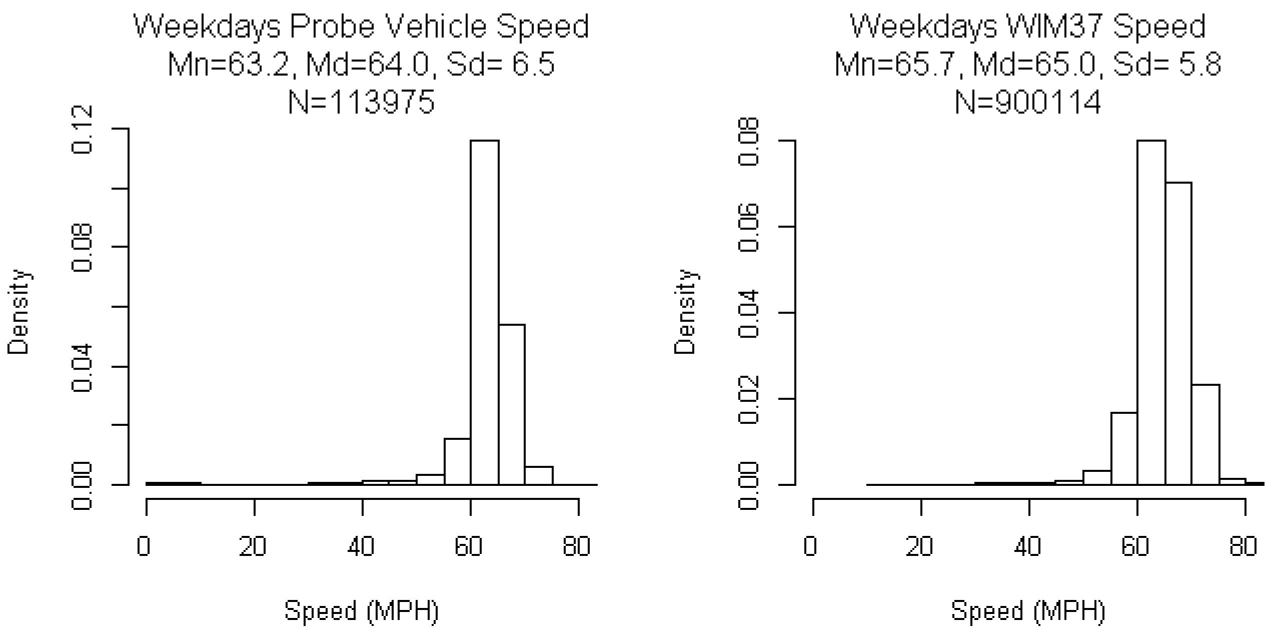

Figure 6 Probe Vehicle Speed vs. WIM Speed at WIM#37

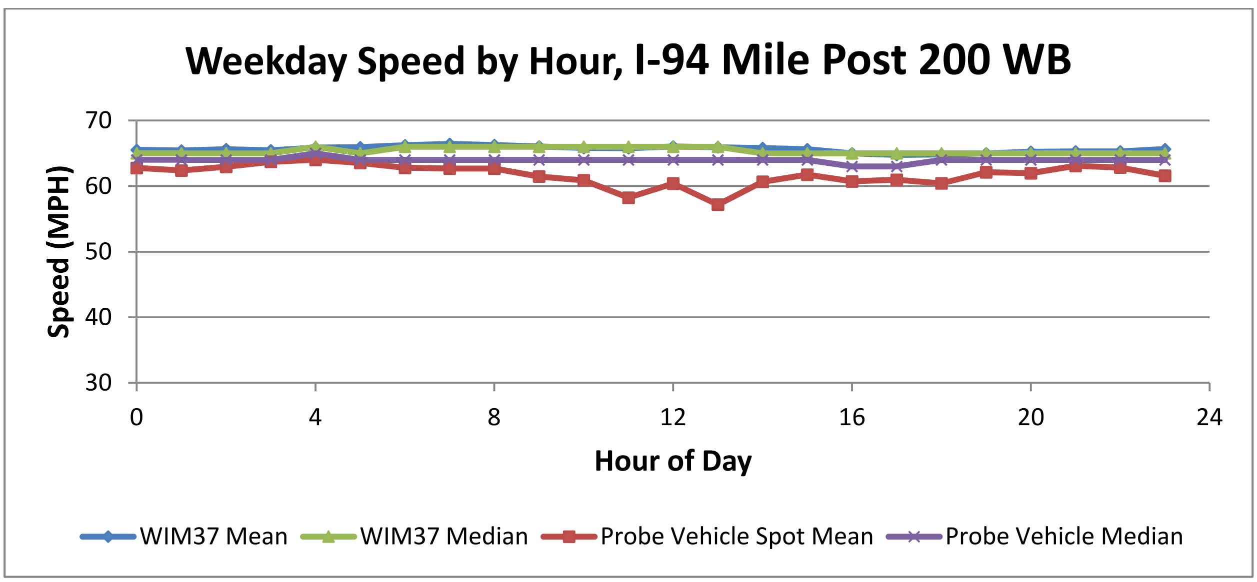

Figure 7 Probe Vehicle Median Speed vs. WIM Speed by Hour at WIM#37

Figure 8 displays the hourly comparison of probe vehicle speed with the speed from passenger vehicles and heavy commercial vehicles collected by WIM #37 in 2012. Average speed of passenger vehicles is about 70 MPH at this roadway segment. The average truck speeds measured from WIM and probe vehicles are about 65 and 63 MPH, respectively. The average standard deviation of speed measured from WIM for both passenger and trucks are pretty close (6.1 and 5.6 MPH, respectively) while the average standard deviation of probe vehicle speed is about 7.6 MPH, slightly higher than the WIM speeds.

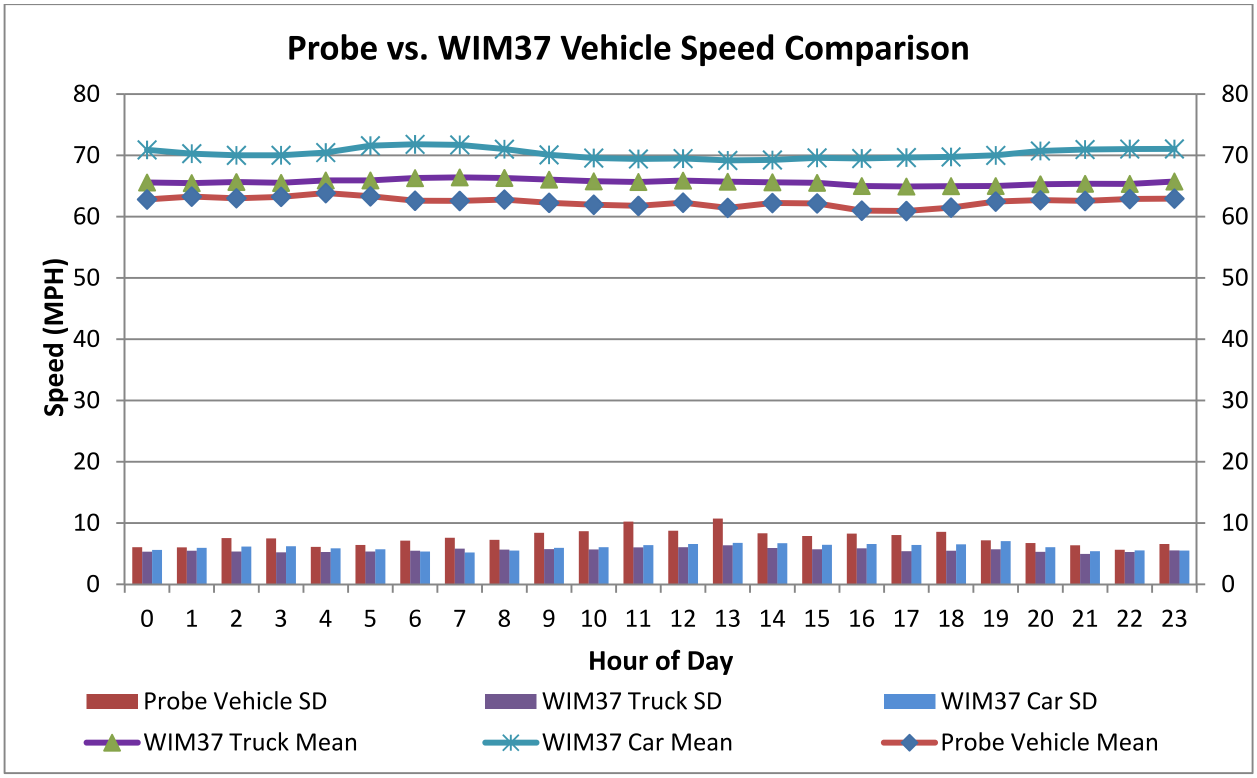

Figure 8 Probe Vehicle Speed vs. WIM Speed by Hour at WIM#37

6.2 Speed Comparison by Month and Hour

Figure 9 displays the average hourly and monthly speed variation from WIM station #37 in 2012. The average speed decreases slightly in the PM peak hours.

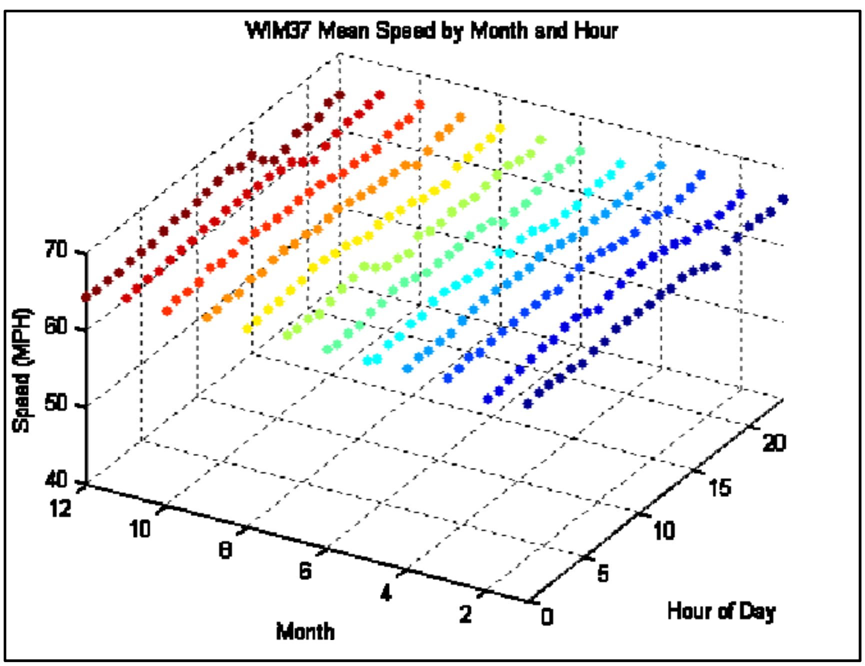

Figure 9 WIM37 Heavy Vehicle Mean Speed by Month and Hour

Figure 10 displays the average hourly speed variation from probe vehicle data at WIM station #37 in 2012. The average speed computed from probe vehicle has larger variations than those from WIM data..

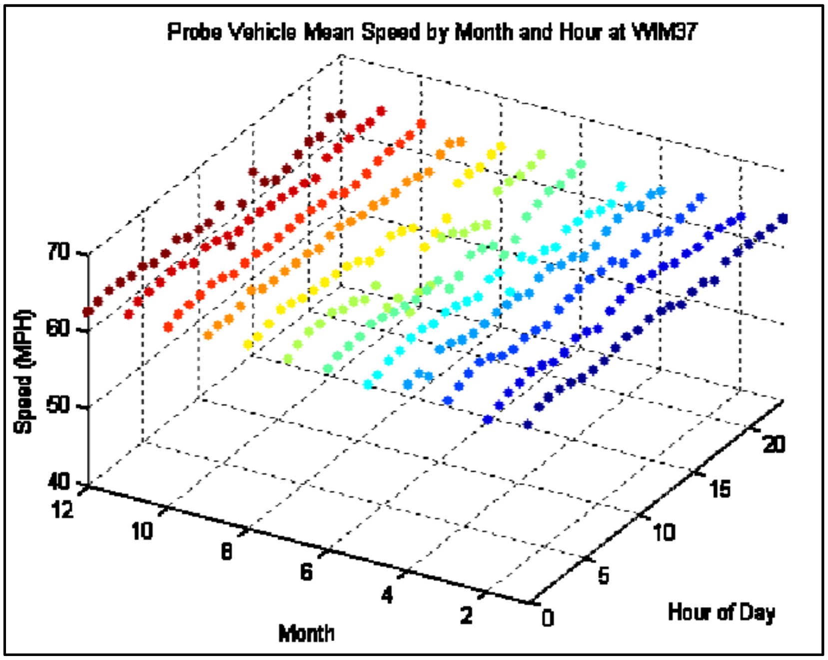

Figure 10 Probe Vehicle Mean Speed by Month and Hour at WIM37

6.3 Probe Vehicle vs. WIM Volume Percentage Comparisons

Hourly volume percentage is selected to verify the truck volume variations in a weekday. Figure 11 illustrates the volume variations from probe vehicle and WIM37 data. The probe vehicle spot volume percentage uses only the vehicle counts from spot speed data excluding the derived space mean speed data points. The hourly volume variation of probe vehicles follows closely to the curve from WIM37 station as shown in Figure 11.

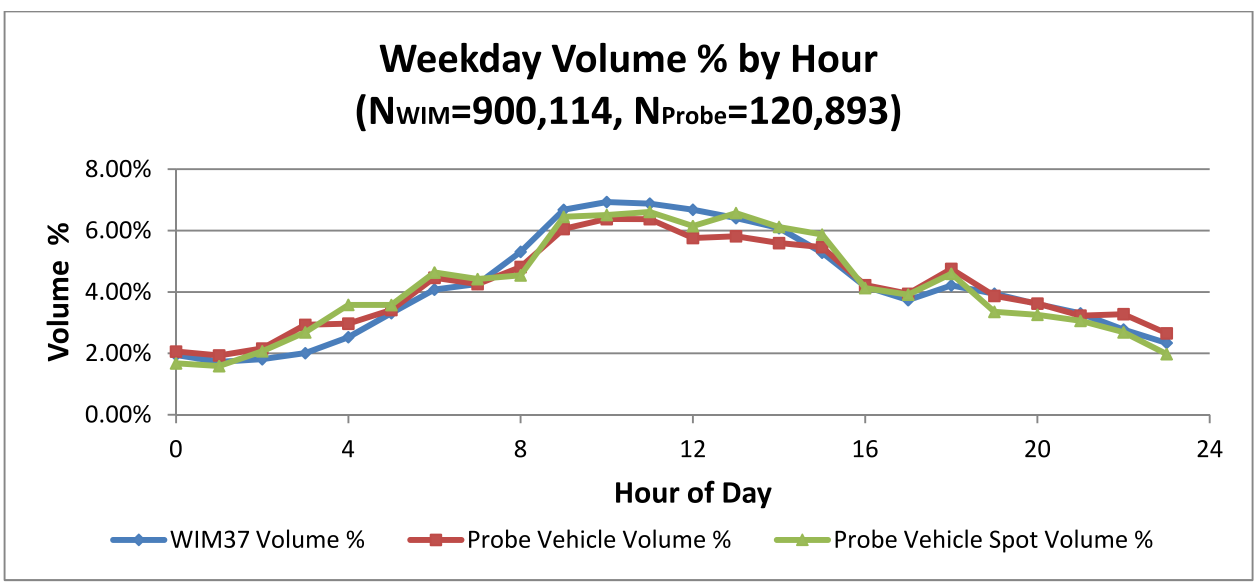

Figure 11 Probe Vehicles vs. WIM Volume Percentage by Hour at WIM#37

7. Performance Measures

Truck mobility, delay and reliability measures are discussed in this section. Threshold speed for each corridor is selected using the target speed provided by MnDOT as illustrated in Figure 12. In general, 45 MPH threshold speed is used in the core of the TCMA and 55 MPH or higher is used for corridors outside the metropolitan area.

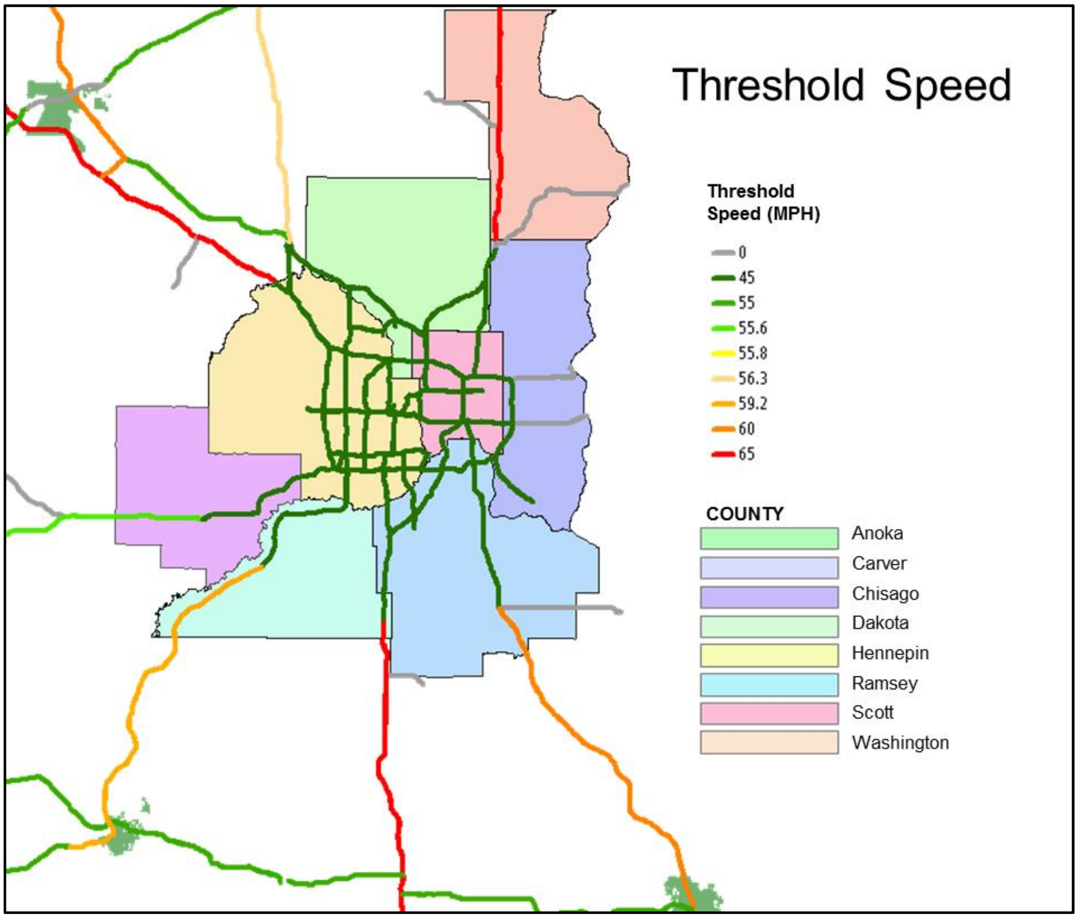

Figure 12 Threshold Speed in TCMA

7.1 Truck Mobility

Freeway system congestion is one of the mobility measures reported in MnDOT's annual transportation results scorecard (http://www.dot.state.mn.us/measures/pdf/2011_Scorecard_10-19-12.pdf). Similarly, percent of freight corridor miles with average speed below 45 MPH in AM or PM Peak is measured as listed in Table 3. Figure 13 and 14 illustrate the location and direction of segments with speed less than 45 MPH during AM and PM peak hours, respectively. Figure 15 and 16 display the GIS map of average truck speed in AM and PM peak hours.

Table 3 Percent of Miles in TCMA below 45 MPH during AM/PM Peak in 2012

Time Period (2012 Weekdays TCMA)	AM Peak 5-10 AM	PM Peak 2-7 PM
# of Miles with Average Speed < 45 MPH	96	147
Total Miles of RTMC Stations in TCMA	774	774
Percentage of Miles < 45 MPH	**12.4%**	**19.0%**

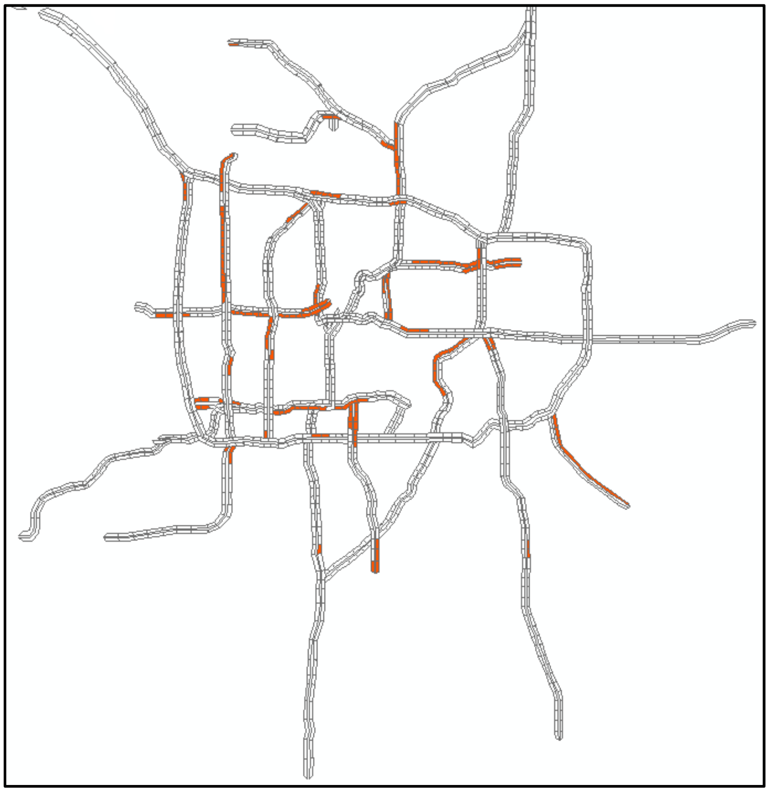

Figure 13 GIS Map of Truck Speed Less Than 45 MPH during AM Peak (5-10 AM) in 2012

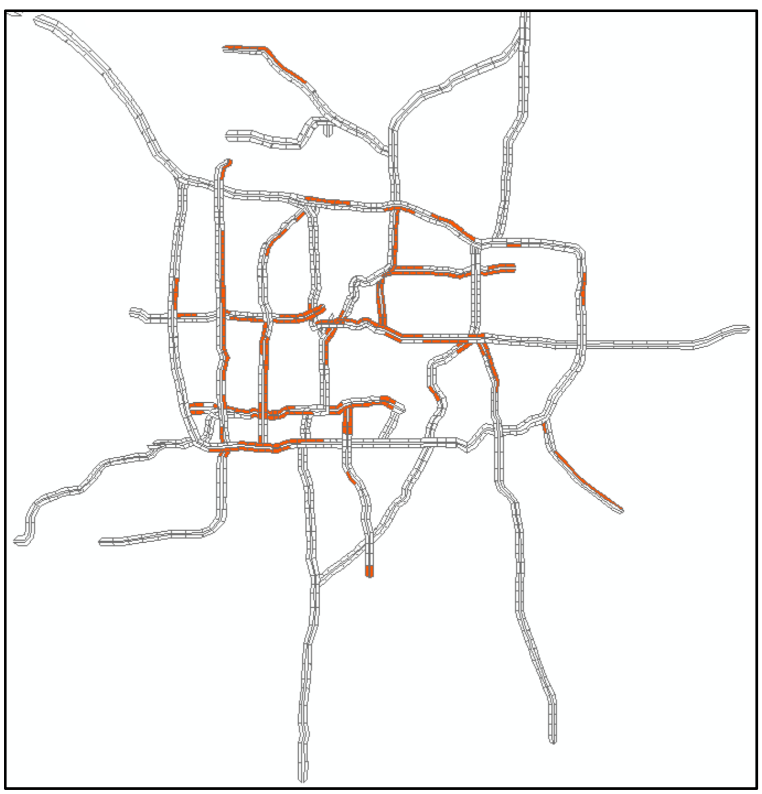

Figure 14 GIS Map of Truck Speed Less Than 45 MPH during PM Peak (2-7 PM) in 2012

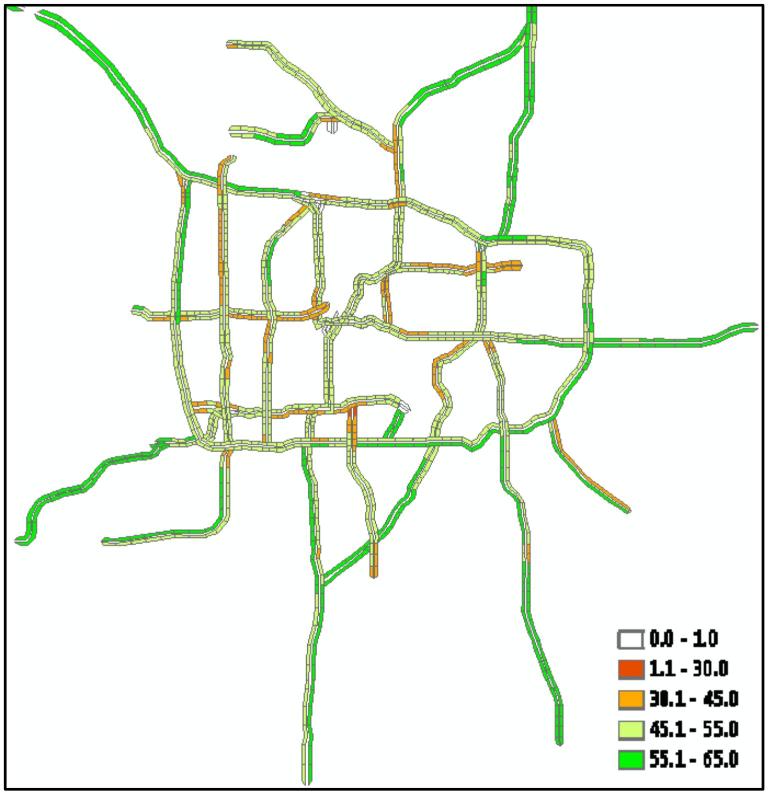

Figure 15 GIS Map of Truck Speed during AM Peak (5-10 AM) in 2012

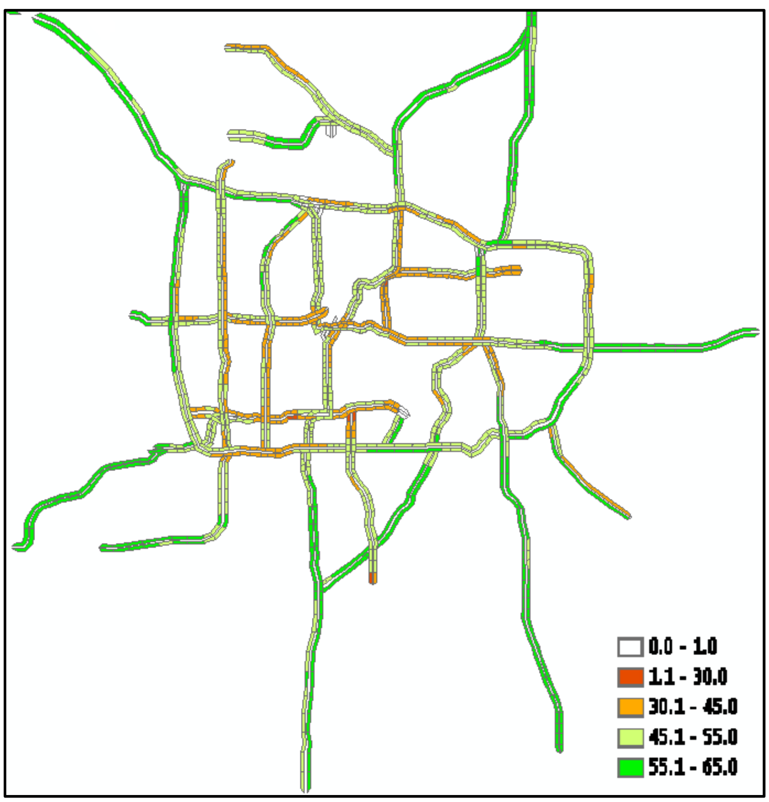

Figure 16 GIS Map of Truck Speed during PM Peak (2-7 PM) in 2012

7.2 Truck Daily Delay

Daily truck delay of each roadway segment can be calculated using the following equation (1). The 2012 HCAADT data published by MnDOT is used for the truck delay calculation.

$$\sum_{Segment} \sum_{Hour} \left(\frac{Segment\ Length}{Travel\ Speed} - \frac{Segment\ Length}{Threshold\ Speed} \right) \times HCAADT_{Segment} \qquad \text{Eq. (1)}$$

Average truck delay of two corridors (I-694 and I-494) was analyzed and computed using 45 MPH threshold speed. The results are displayed in Figure 17 and 18 for both corridors, respectively. Figure 17 illustrates the daily truck delay in hours between highway 252 (mile post 0) and I-94/I-494 interchange (mile post 23) in Oakdale. The blue bars are the truck delay in eastbound and the red bars are the delay for westbound truck traffic. Corresponding average truck speed at each mile post is also plotted for both eastbound (blue line with the square mark) and westbound (red line with the diamond mark) directions. Majority of the daily truck delay occurs between highway 252 and I-35E. Daily truck delay in eastbound is about 21 hours and 44 hours in westbound.

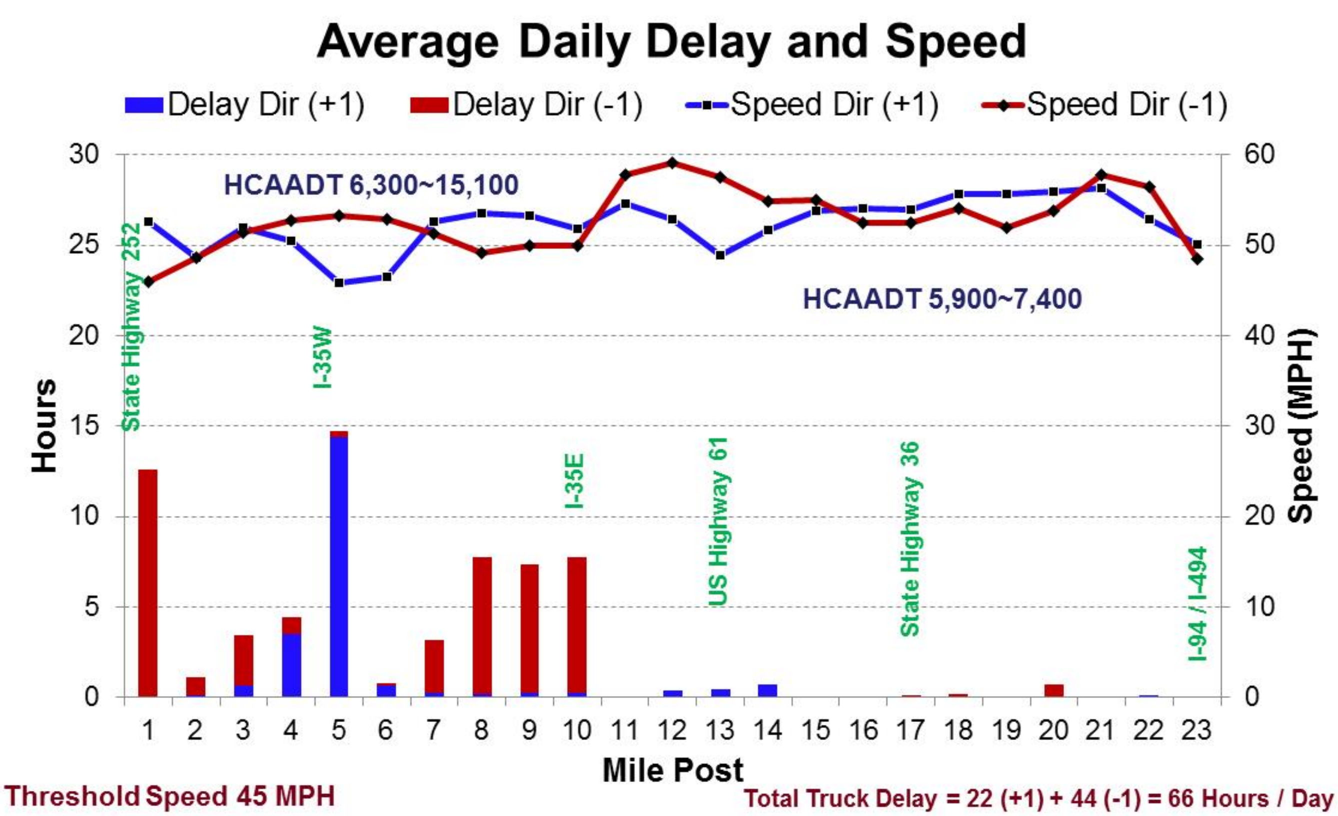

Figure 17 Average Daily Truck Delay and Speed on I-694

Figure 18 illustrates the daily truck delay in hours between I-94/I-494 interchange (mile post 43) in Maple grove and interchange of I-94/I-494 (mile post 0) in Woodbury. The blue bars are the truck delay in westbound and the red bars are the delay for eastbound truck traffic. Corresponding average truck speed at each mile post is also plotted for both eastbound (red line with the diamond mark) and westbound (blue line with the square mark) directions. Majority of the daily truck delay occurs from I-94 to I-394 and from highway 212 to highway 77. Daily truck delay is about 95 hours in eastbound and 37 hours in westbound. Figure 19 and 20 display the GIS map of average truck delay during AM and PM peak hours.

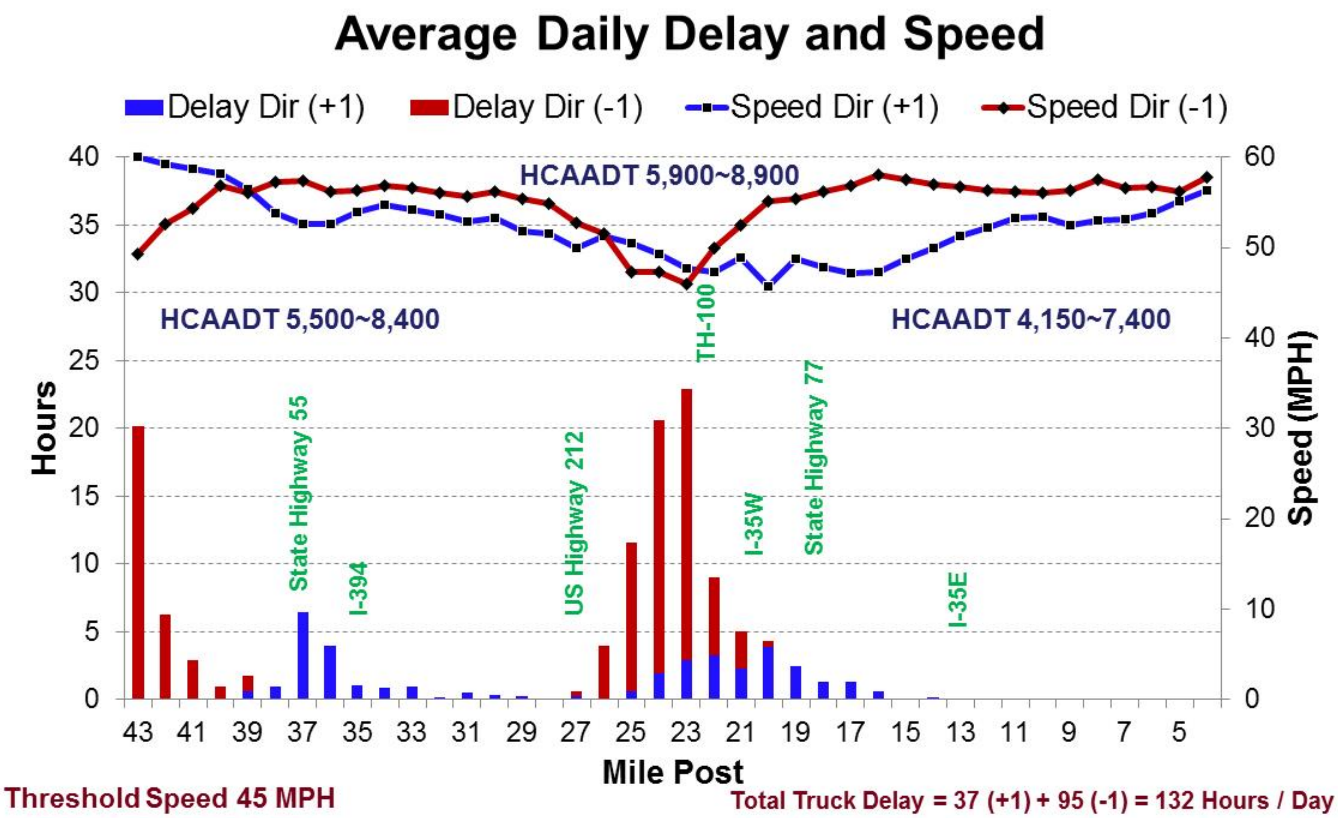

Figure 18 Average Daily Truck Delay and Speed on I-494

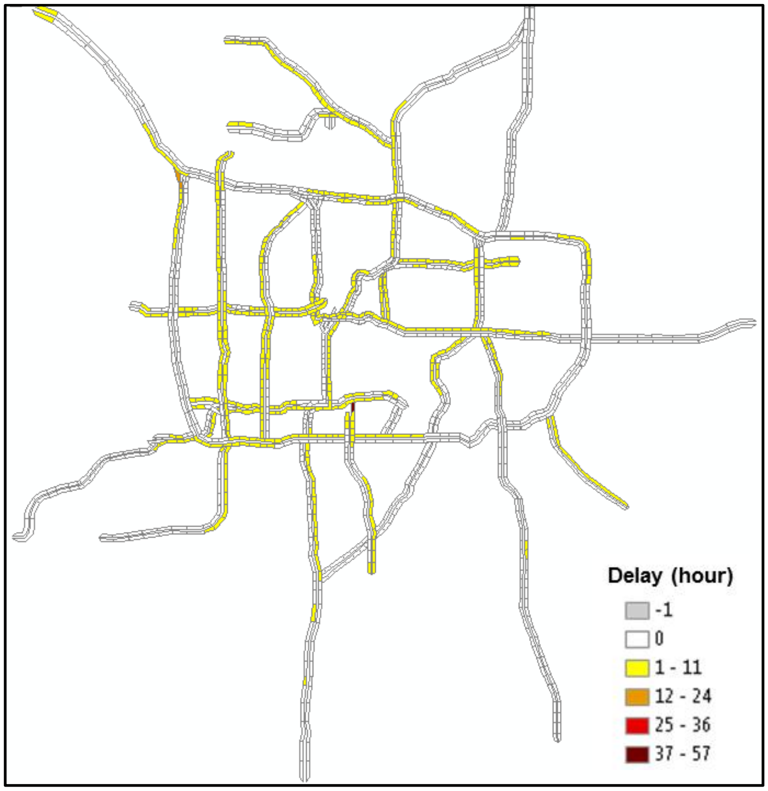

Figure 19 GIS Map of Truck Delay during AM Peak (5-10 AM) in 2012

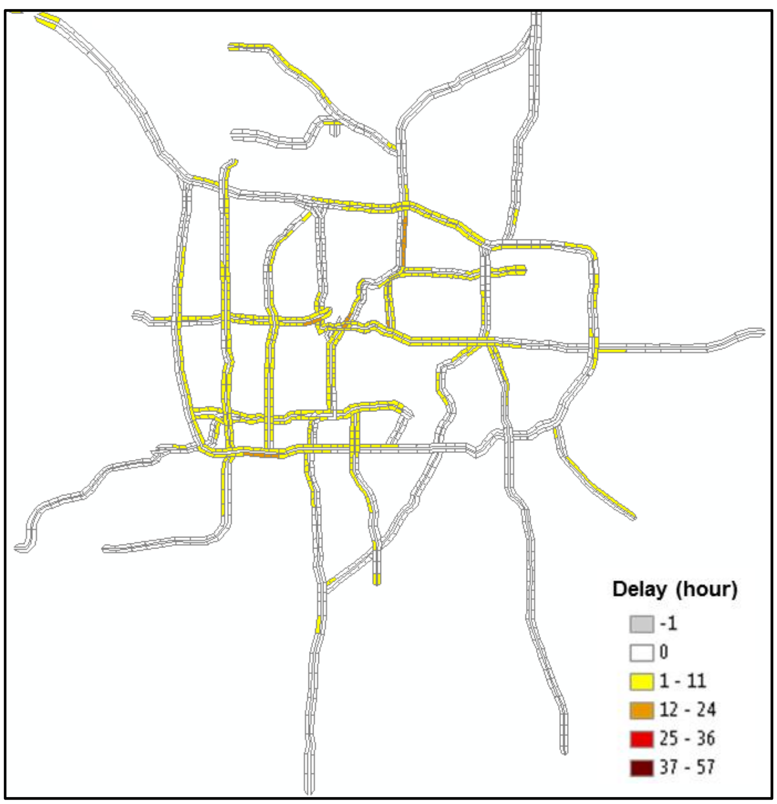

Figure 20 GIS Map of Truck Delay during PM Peak (2-7 PM) in 2012

7.3 Delay Cost

The cost of truck congestion includes truck delay cost and wasted fuel cost. The total cost of truck delay can be computed using equation (2) as follows.

$$Truck\ Delay\ Cost = (Delay\ Cost\ per\ Hour) \times (Total\ Truck\ Delay) \quad \text{Eq. (2)}$$

The hourly cost of average truck delay is $88 according to the 2012 Urban Mobility Report (Schrank et al., 2012). In a report titled "An Analysis of the Operational Costs of Trucking: A 2012 Update", the ATRI recommends using $68.21 hourly cost for average truck operation cost. The wasted fuel cost can be computed using equation (3) as follows.

$$Wasted\ Fuel\ Cost = (Excess\ Fuel\ Consumed) \times (Truck\ VMT\ \%) \times (Diesel\ Price/Gallon) \quad \text{Eq. (3)}$$

7.4 Travel Time Reliability Index

An 80-percentile travel time reliability index can be defined as equation (4).

$$RI_{80} = \frac{80^{th}\ percentile\ Travel\ Time}{Travel\ Time\ at\ MnDOT\ Specified\ Threshold\ Speed} \quad \text{Eq. (4)}$$

The 80 percentile travel time reliability indices, as defined in equation (4), for I-694 in both directions at I-35W were plotted in Figure 21. During the 24-hour period, the travel time is less reliable (larger index value) during AM peak (5-10 AM) and PM peak (2-7 PM) hours. Figure 21 indicates that the eastbound travel time in this 1-mile segment is less reliable than the westbound travel time.

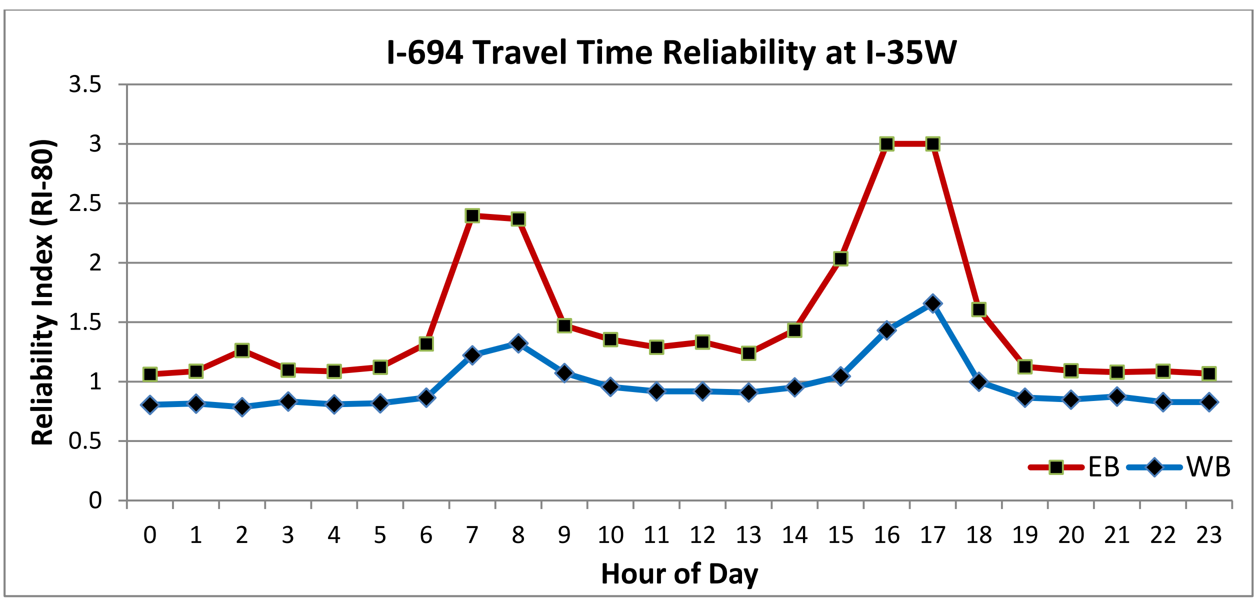

Figure 21 Hourly Travel Time Reliability on I-694 at I-35W

The 80 percentile travel time reliability indices for I-494 in both directions at highway 100 were plotted in Figure 22. During the 24-hour period, the travel time is less reliable (larger index value) during AM peak (6-9 AM) and significant less reliable from 2 PM to 7 PM. Figure 22 indicates that the travel time reliability in both directions before noon are relatively close. However, in the PM peak hour, the eastbound travel time in this 1-mile segment is about twice less reliable than the westbound travel time.

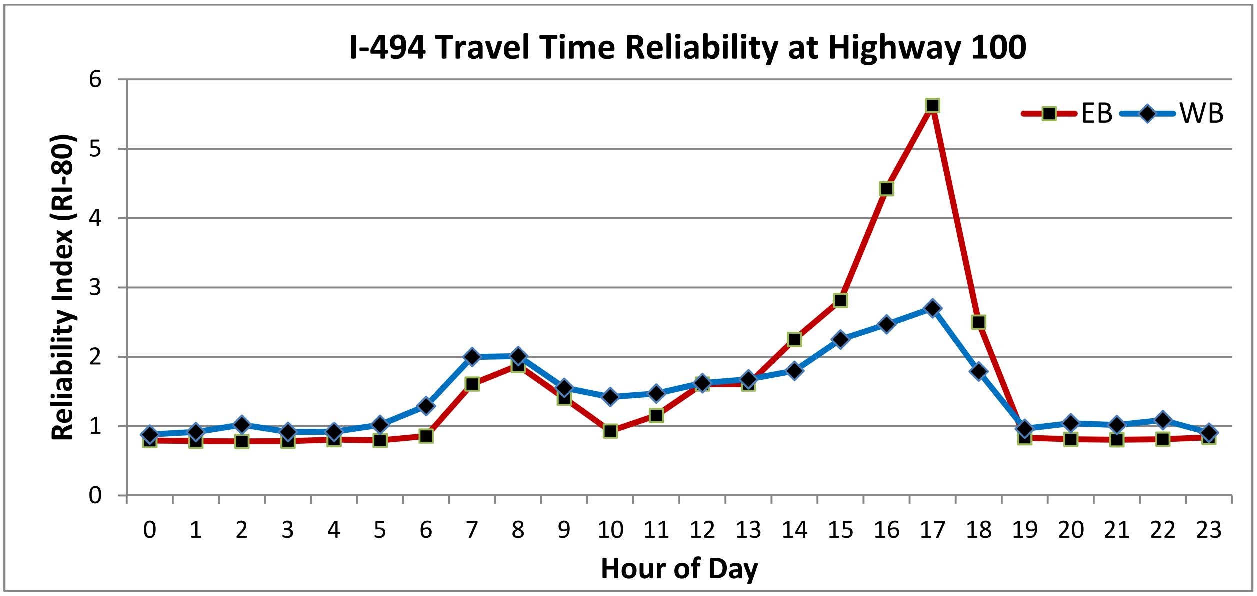

Figure 22 Hourly Travel Time Reliability on I-494 at Highway 100

In addition to evaluating the travel time at a specific roadway segment, Figure 23 illustrates the travel time reliability along I-694 in both directions during AM peak hour (5-10 AM). The reliability indices in both directions are similar between milepost 7 and 15. The travel time in westbound is less reliable than that in eastbound from milepost 20 (highway 5) to milepost 15 (McKnight Rd.) as shown in Figure 22.

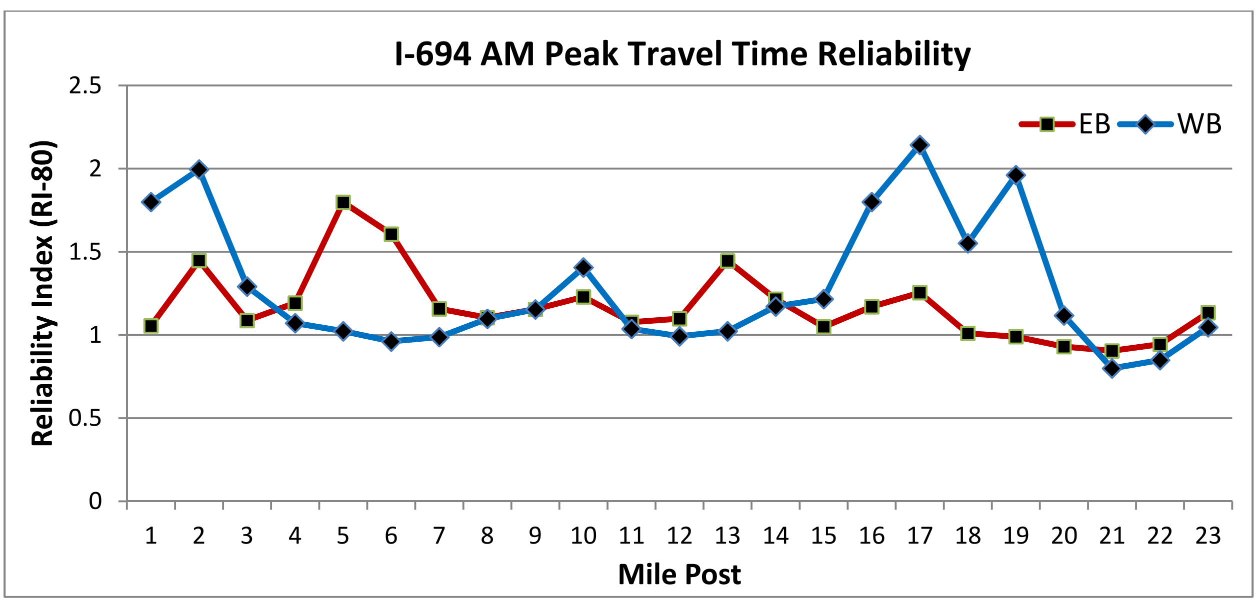

Figure 23 I-694 AM Peak Travel Time Reliability

Similarly, Figure 24 illustrates the travel time reliability along I-694 in both directions during PM peak hour (2-7 PM). The reliability indices in both directions along this corridor in the PM peak hours vary quite significantly by location. Westbound travel time from milepost 21 to 18 and from 11 to 6 is less reliable than the other locations. The eastbound travel time from milepost 3 to 7 and from 11 to 15 has larger variations than the other segments.

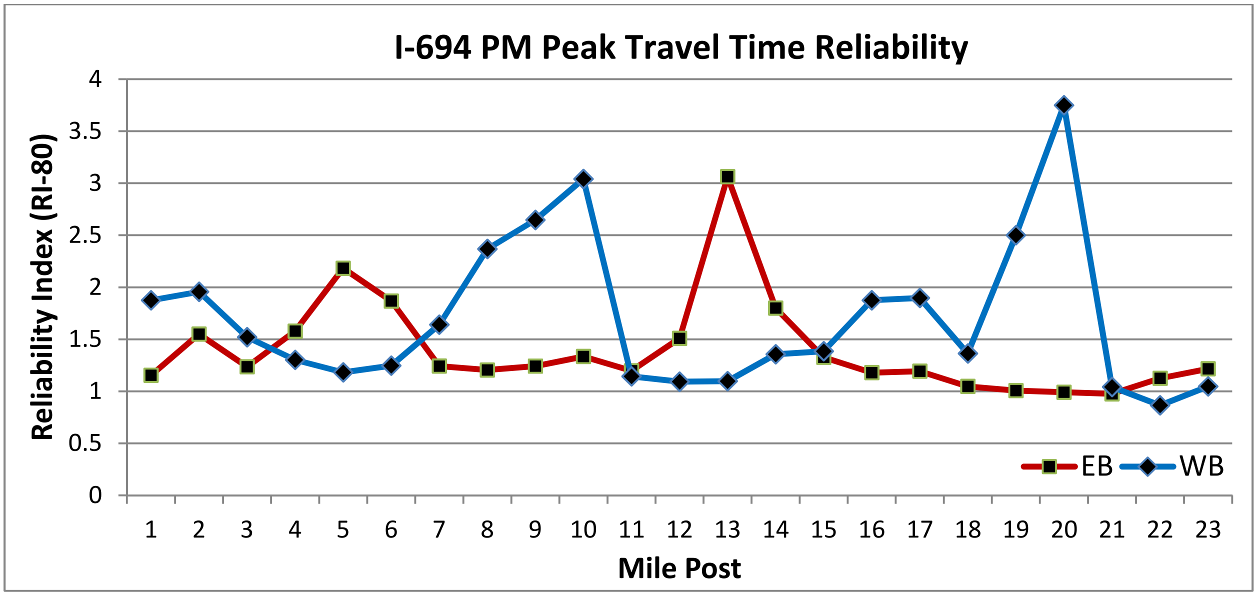

Figure 24 I-694 PM Peak Travel Time Reliability

Figure 25 and 26 illustrate the travel time reliability in TCMA for both AM and PM peak hours. Higher reliability index value represents less reliable travel time.

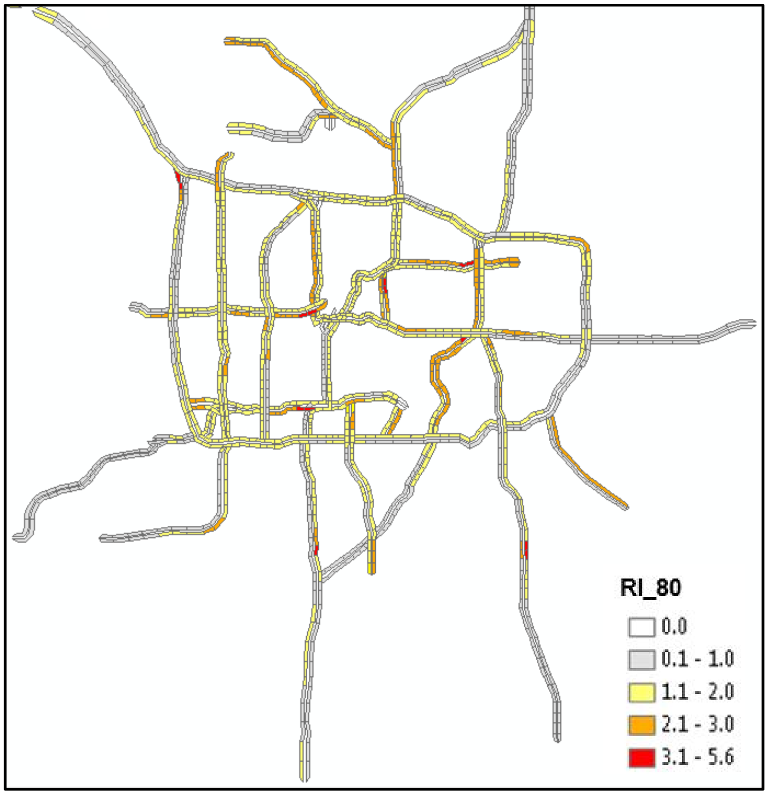

Figure 25 GIS Map of Truck Travel Time Reliability during AM Peak (5-10 AM) in 2012

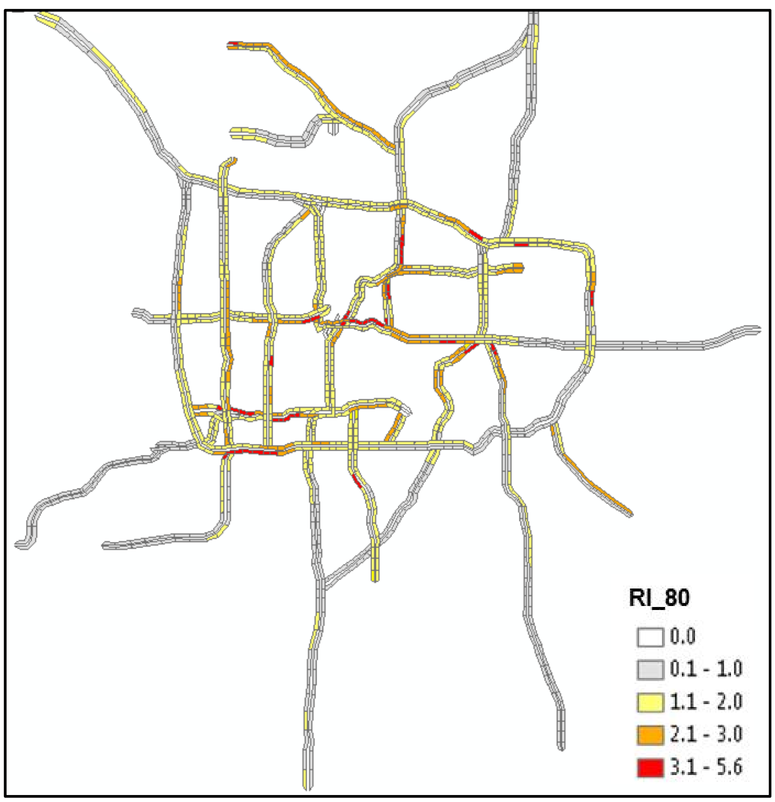

Figure 26 GIS Map of Truck Travel Time Reliability during PM Peak (2-7 PM) in 2012

References

Schrank, D., Eisele, B., and Lomax, T., (2012). TTI's 2012 Urban Mobility Report Powered by INRIX traffic data, Texas A&M Transportation Institute, College Station, Texas. http://tti.tamu.edu/documents/mobility-report-2012.pdf, accessed July, 2013.

ATRI, (2012). An Analysis of the Operational Costs of Trucking: A 2012 Update, Arlington, VA. http://atri-online.org/2012/09/17/an-analysis-of-the-operational-costs-of-trucking-a-2012-update/, accessed July, 2013.

Appendix A: Data Descriptions

A.1 Truck GPS Data Fields

Table A.2 ATRI Truck GPS Dataset

Data Field	DS-A	DS-B	DS-C
1	truckid	truckid	readdate
2	readdate	readdate	latitude
3	speed	latitude	longitude
4	heading	longitude	speed
5	latitude		truckid
6	longitude		

A.2 Route Data

Table A.1 List of Routes

Route ID	Interstate	Highway No.	Highway Name	Length (m)
1	N	242	State Highway 242	8314.91
2	N	610	State Highway 610	468.69
3	N	252	State Highway 252	6599.55
4	Y	694	Interstate 694	3041.47
5	N	36	State Highway 36	16002.52
6	Y	494	Interstate 494	9033.50
7	N	100	State Highway 100	11128.01
8	Y	394	Interstate 394	1460.40
9	N	12	US Highway 12	26542.60
10	N	280	State Highway 280	5341.15
11	N	7	State Highway 7	4082.93
12	N	62	State Highway 62	3778.53
13	N	110	State Highway 110	2221.52
14	N	212	US Highway 212	2418.68
15	N	77	State Highway 77	3718.24
16	N	32	County Road 32	1675.38
17	N	101	County Road 101	3528.21
18	N	42	County Road 42	9184.11
19	N	316	State Highway 316	19.52
20	N	18	County Road 18	4939.27
21	N	51	State Hwy 51	12772.62
22	N	97	State Hwy 97	20652.74
23	N	95	State Hwy 95	203475.19
24	Y	94	I- 94	217983.03
25	N	8	US Highway 8	35601.66
26	N	65	State Hwy 65	93901.44
27	N	61	US Highway 61	98029.82
28	N	55	State Hwy 55	88518.58
29	N	52	US Hwy 52	4049.13
30	N	5	State Hwy 5	138375.39
31	N	10	US Hwy 10	160722.09
32	N	47	State Hwy 47	94114.98
33	Y	35	I-35E	182949.10
34	Y	35	I-35W	186840.93
35	N	3	State Hwy 3	74925.82
36	N	21	State Hwy 21	61771.60
37	N	169	US Hwy 169	167515.58
38	N	13	State Hwy 13	69792.16

A.3 Truck GPS Data Distribution by Route

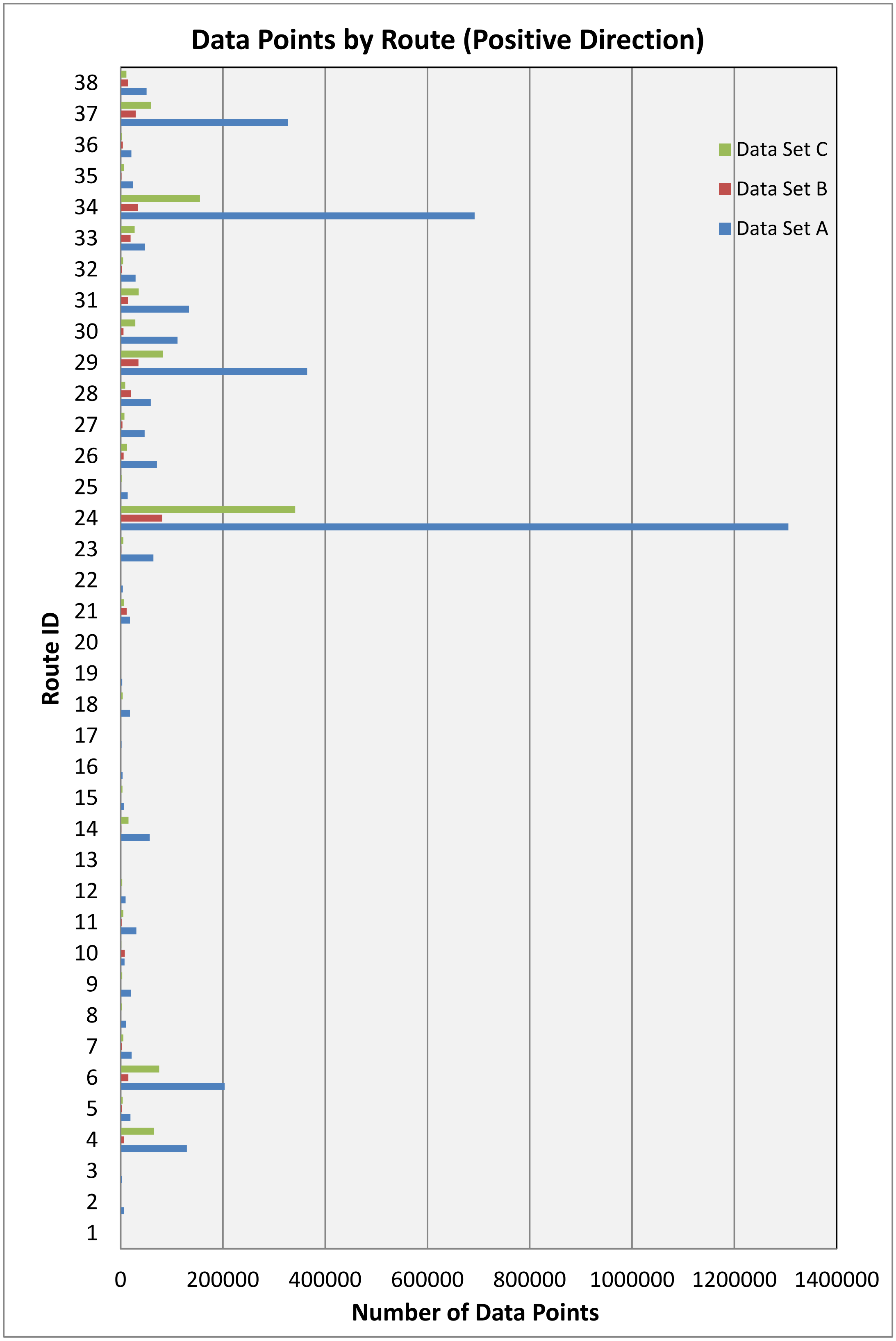

Figure A.1 GPS Point Distribution by Route (Positive Direction)

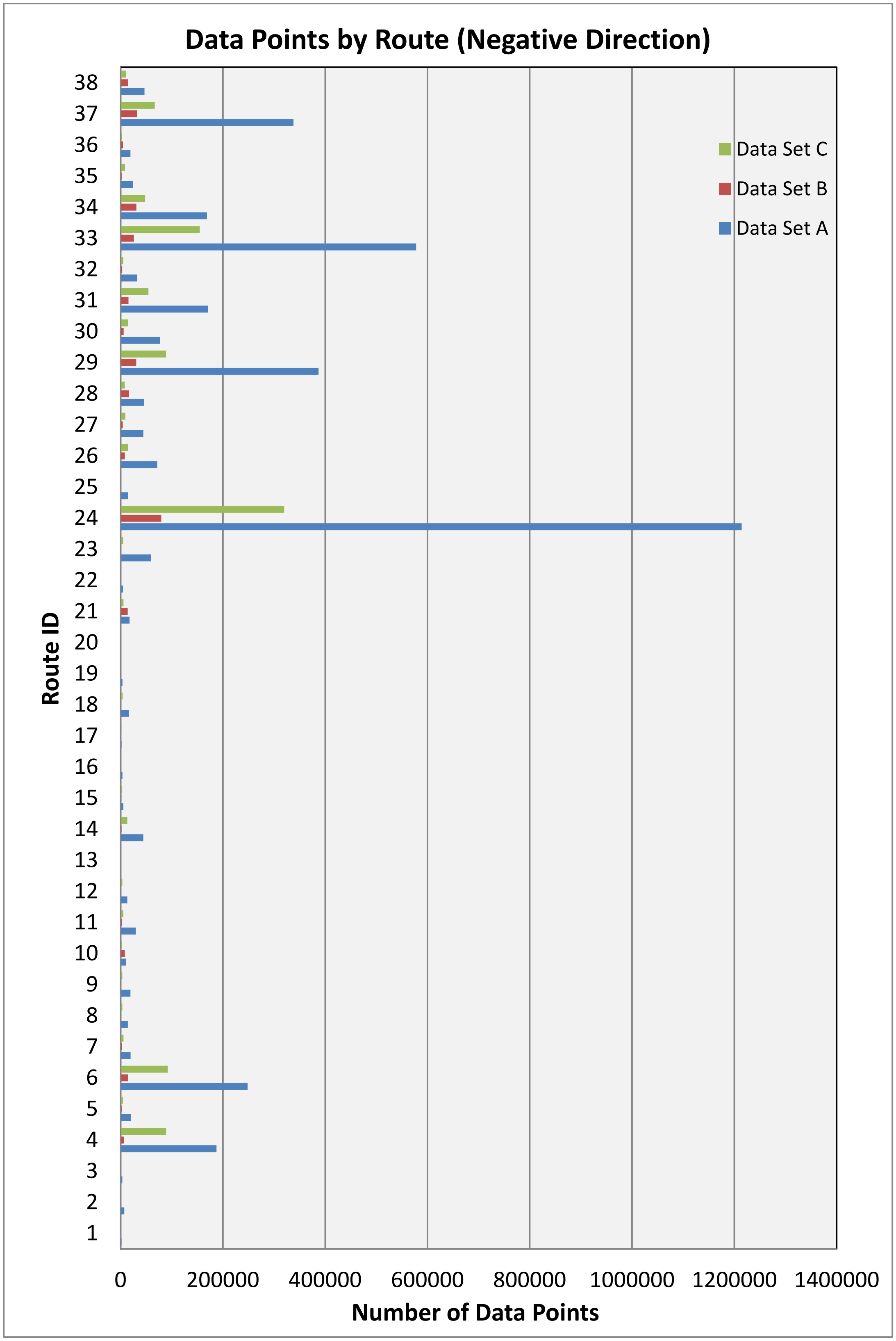

Figure A.2 GPS Point Distribution by Route (Negative Direction)

A.4 Data Proximity by Route

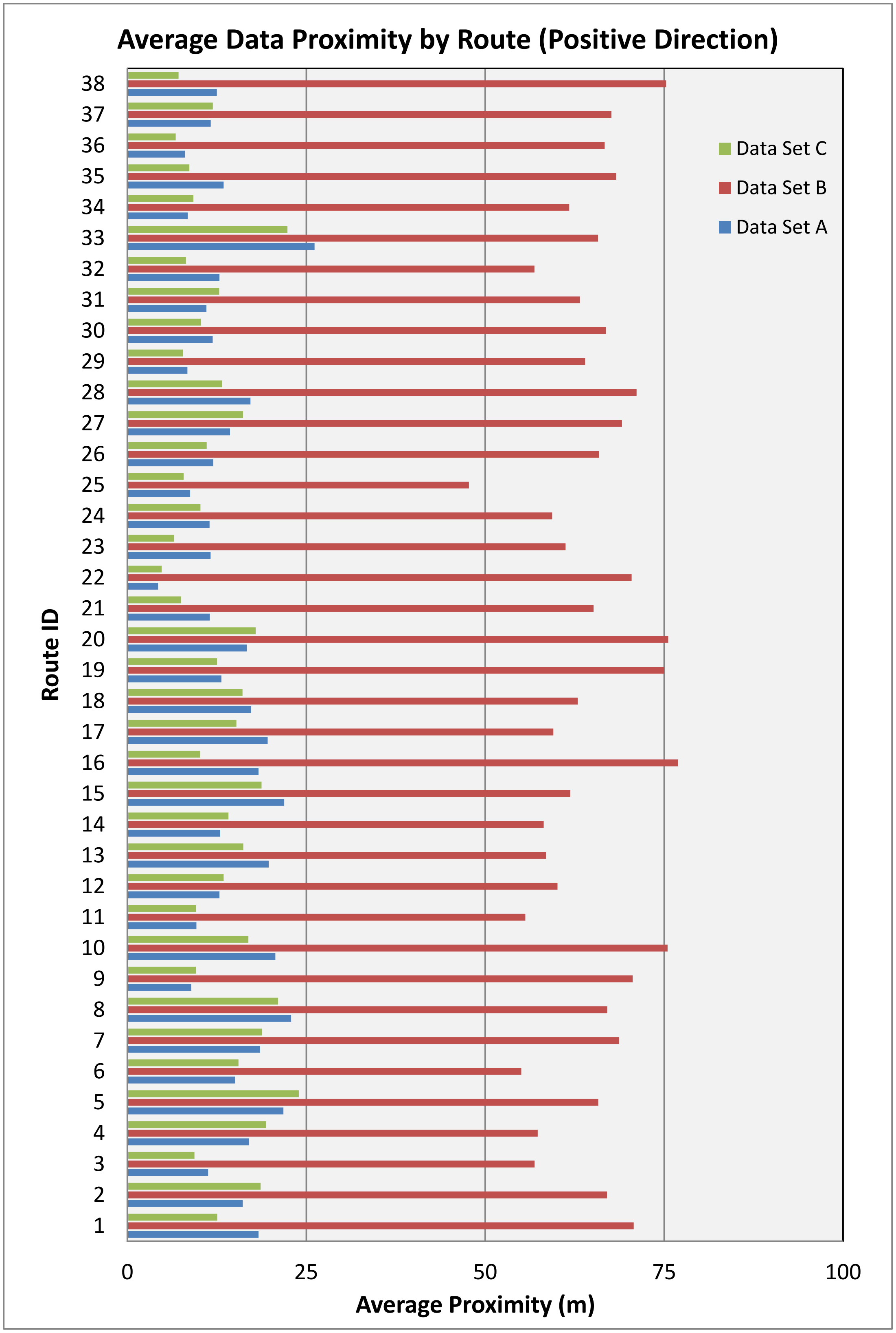

Figure A.3 Data Proximity by Route (Increasing Mile Marker Direction)

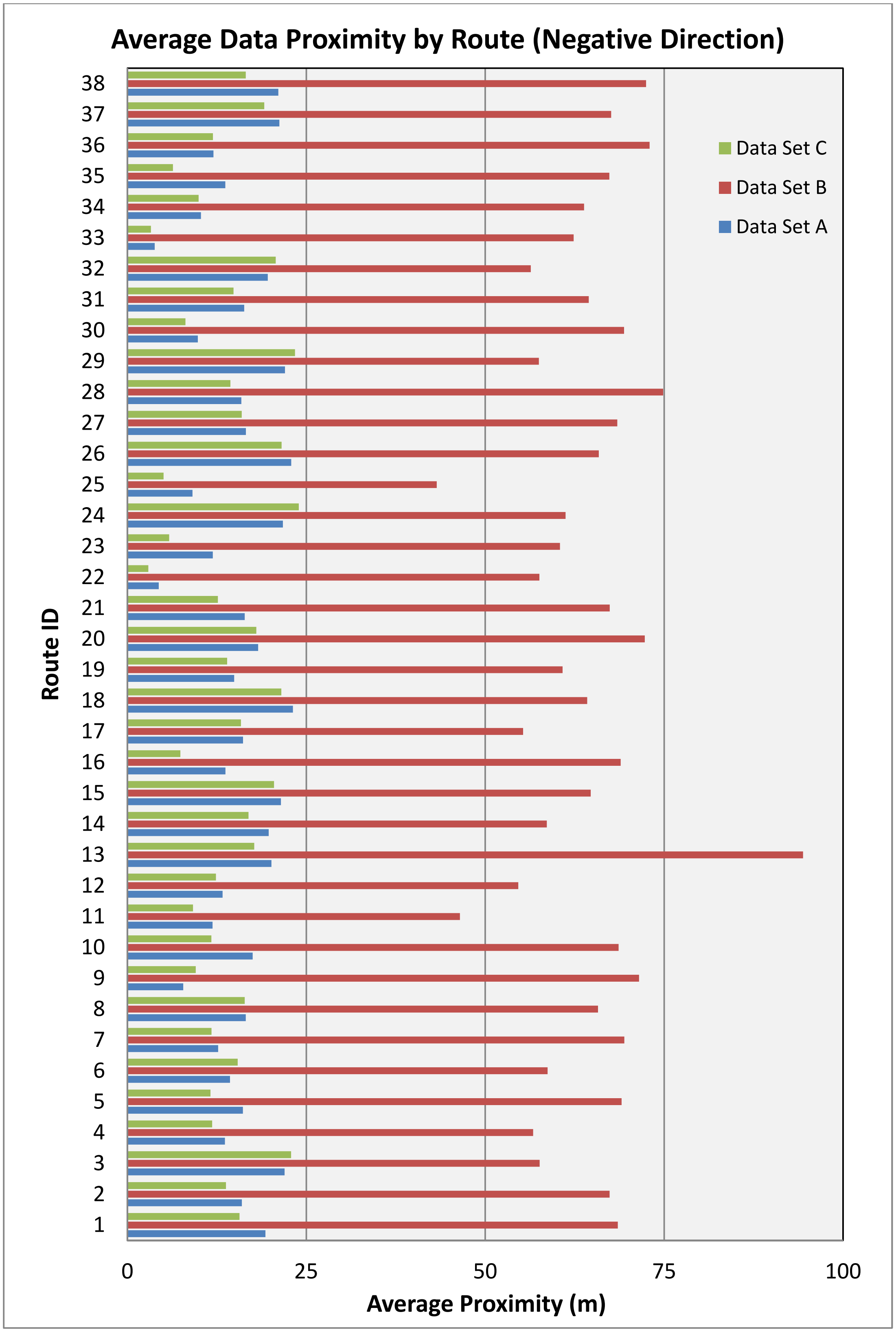

Figure A.4 Data Proximity by Route (Decreasing Mile Marker Direction)

Appendix B Data Analysis and Comparison

B.1 Point vs. Space Mean Speed Comparisons

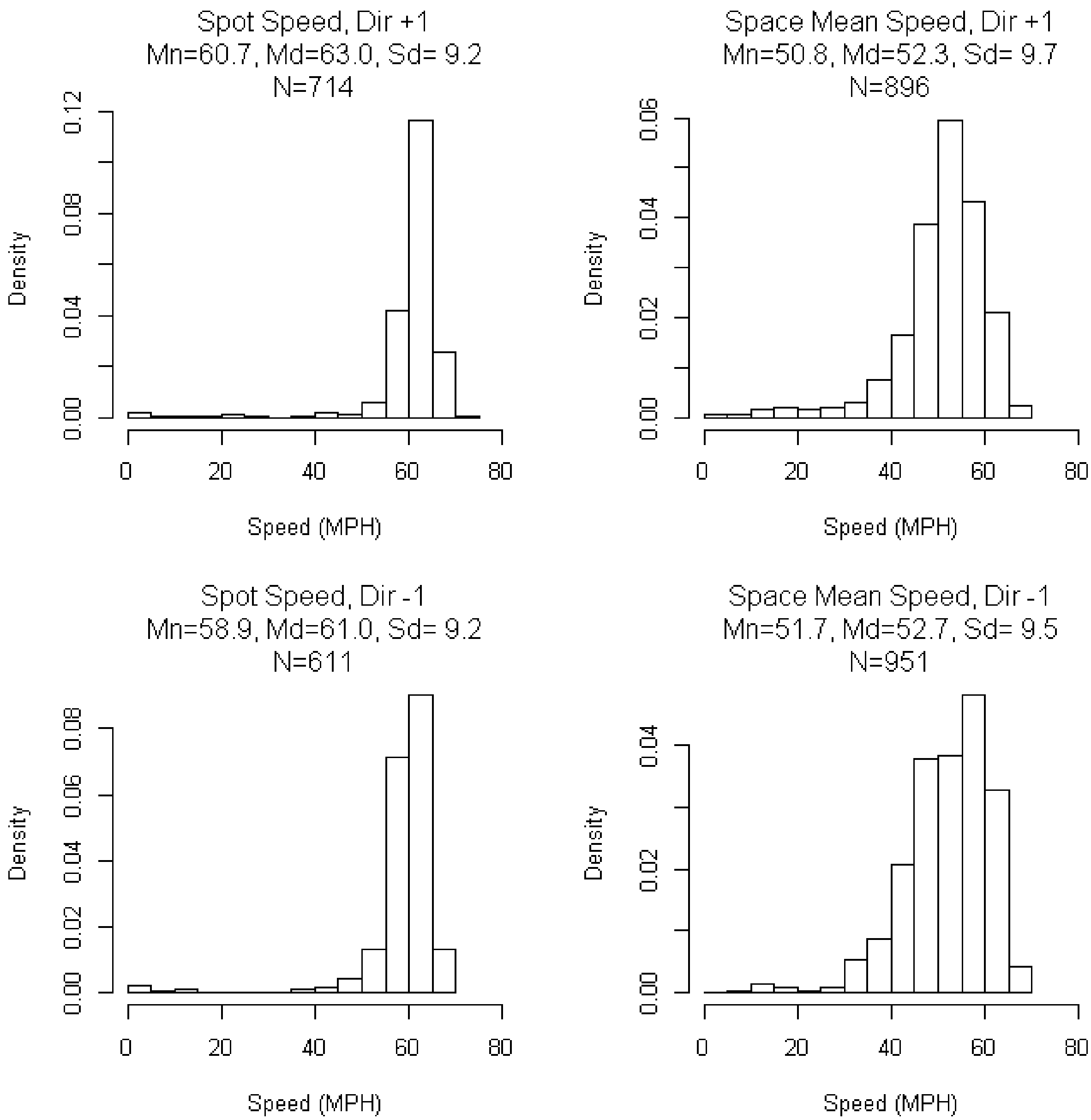

Figure B.1 Point Speed vs. Space Mean Speed on Route State Highway 36 at Mile Post 15
(Nearby Lake Elmo, WIM#36)

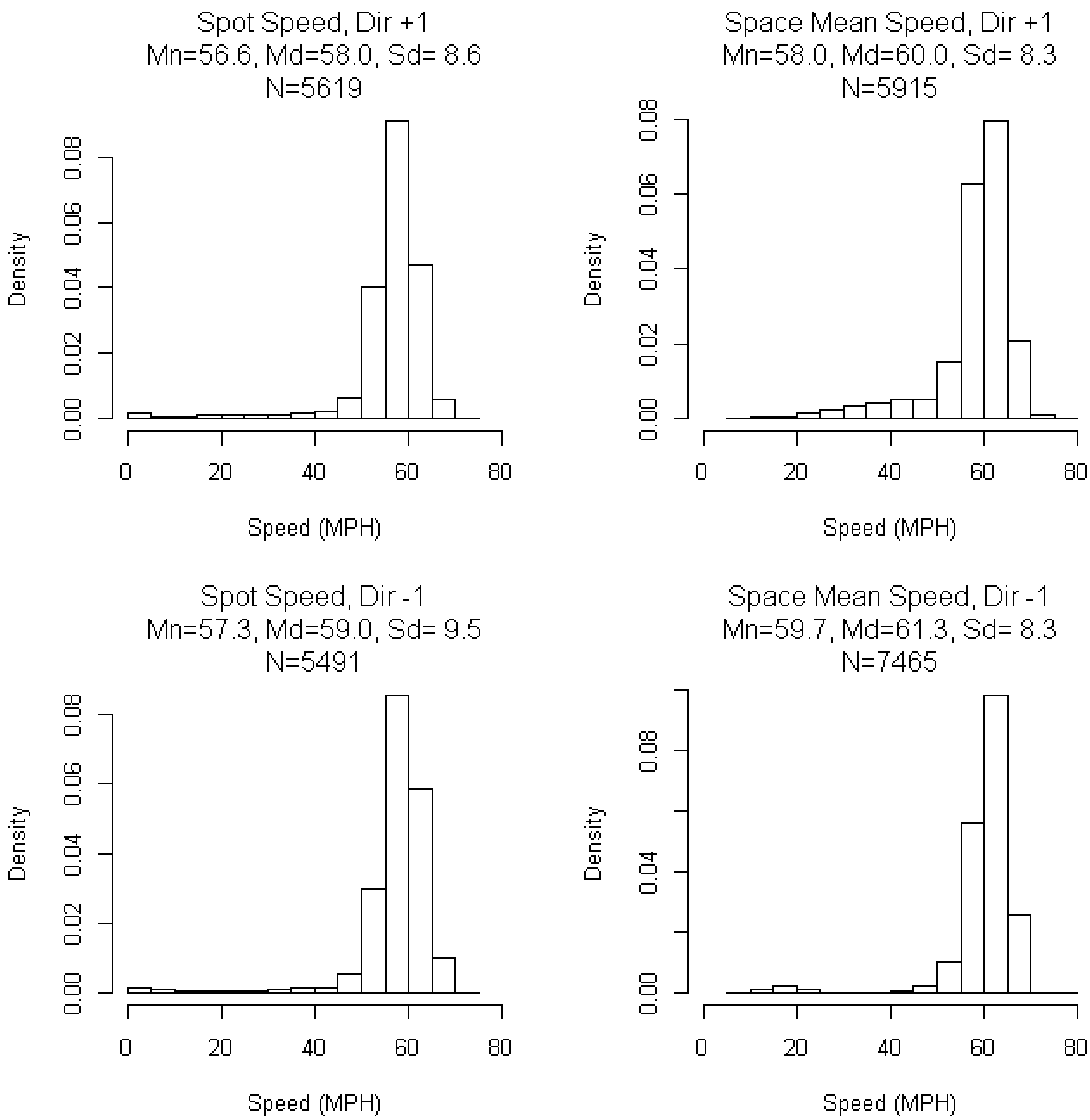

Figure B.2 Point Speed vs. Space Mean Speed on Route U.S. Highway 52 at Mile Post 81
(Nearby CSAH14 in West St. Paul, WIM#40)

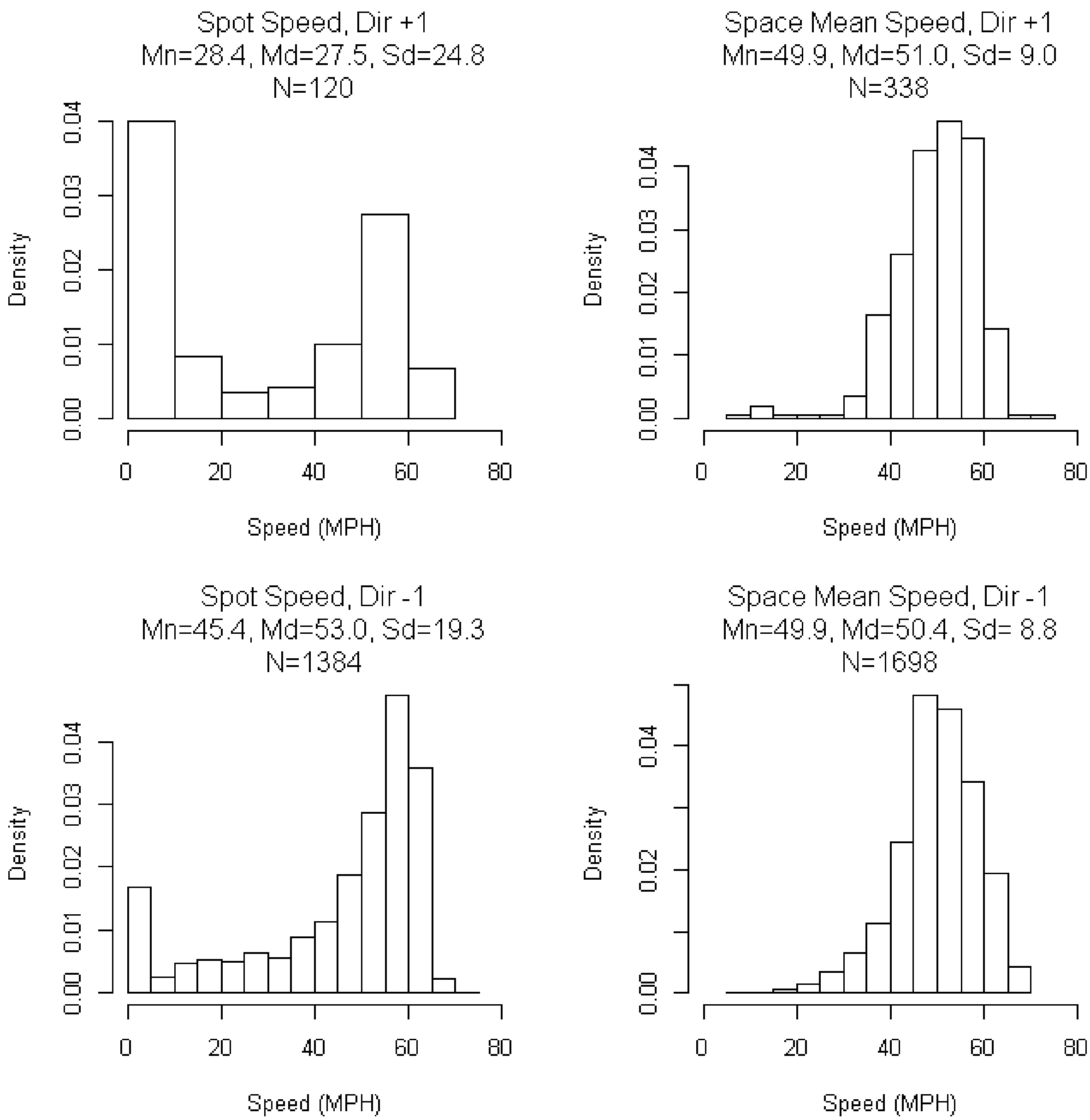

Figure B.3 Point Speed vs. Space Mean Speed on Route U.S. Highway 61 at Mile Post 16
(South of TH95 in Cottage Grove, WIM#42)

B.2 Probe Vehicle vs. WIM Speed Comparisons

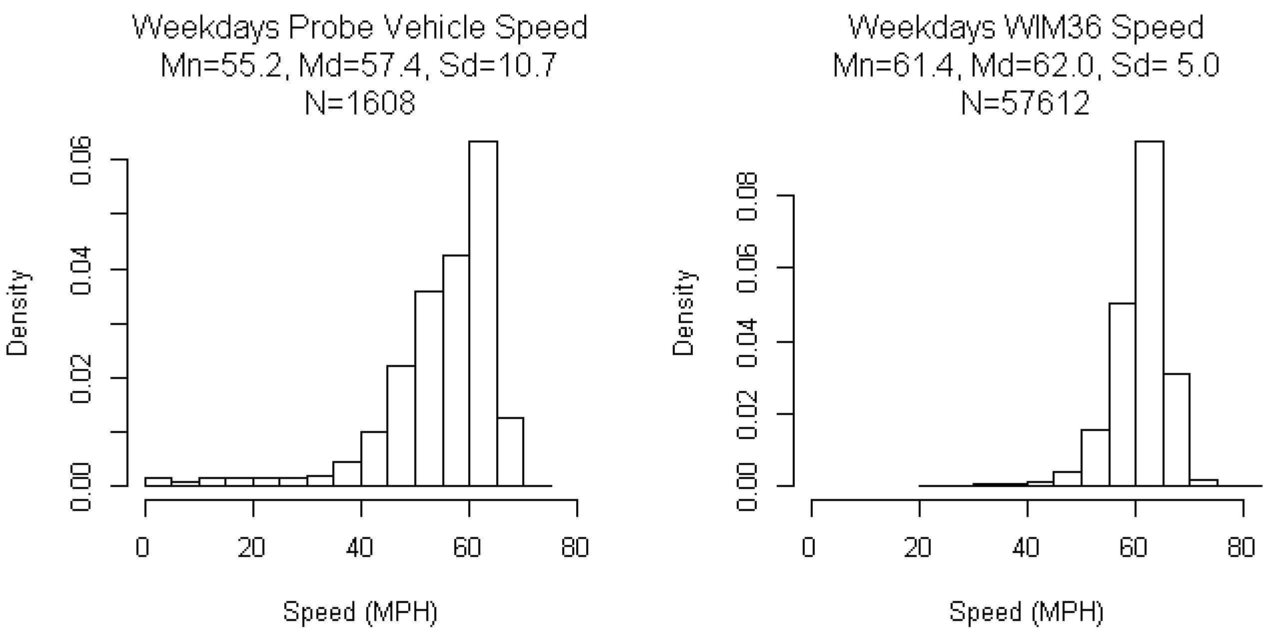

Figure B.4 Probe Vehicle Speed vs. WIM Speed at WIM#36

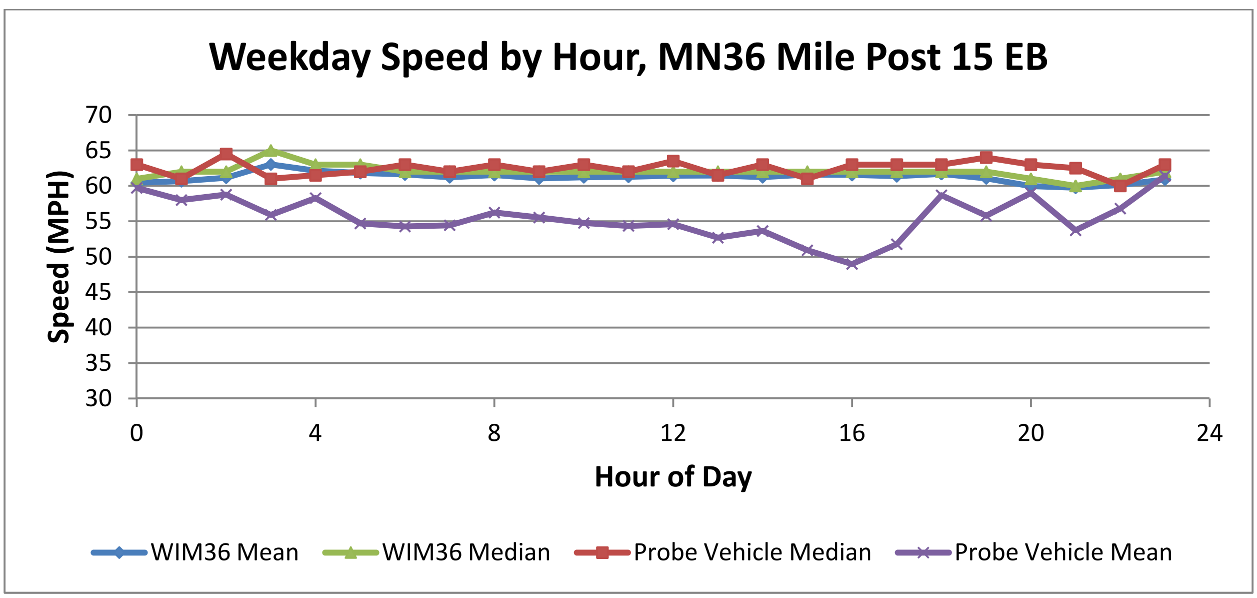

Figure B.5 Probe Vehicle Median Speed vs. WIM Speed by Hour at WIM#36

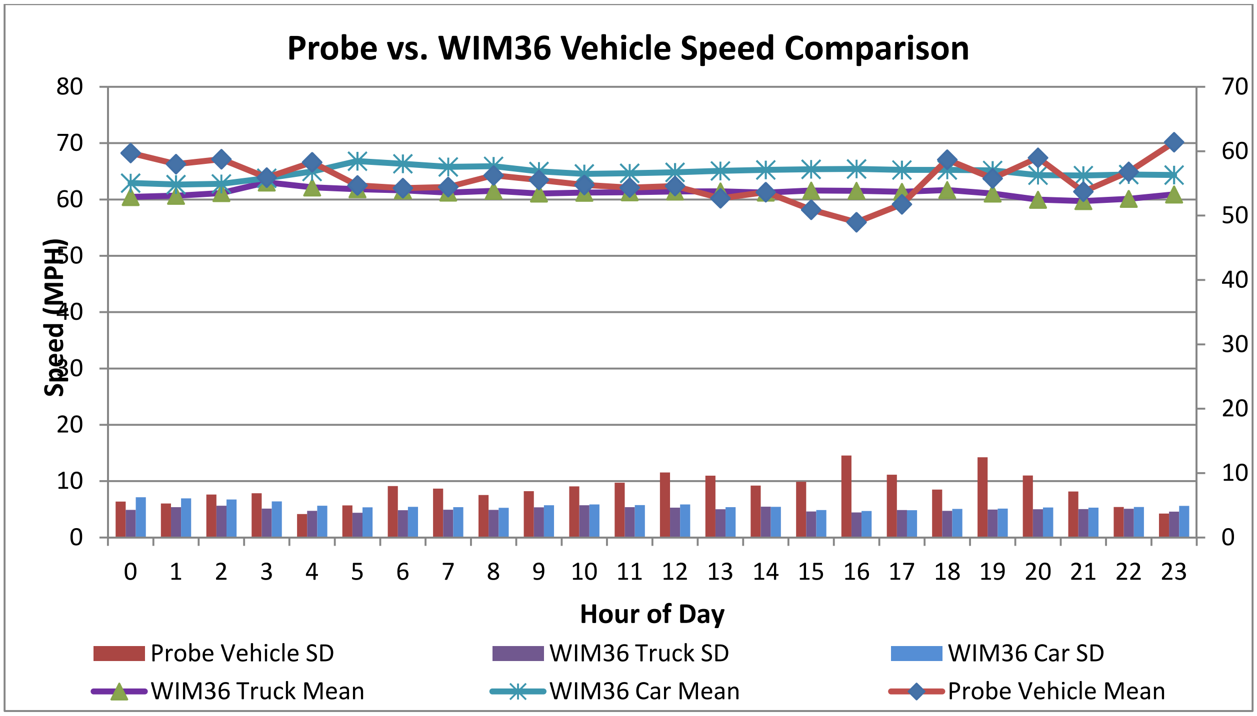

Figure B.6 Probe Vehicle Speed vs. WIM Speed by Hour at WIM#36

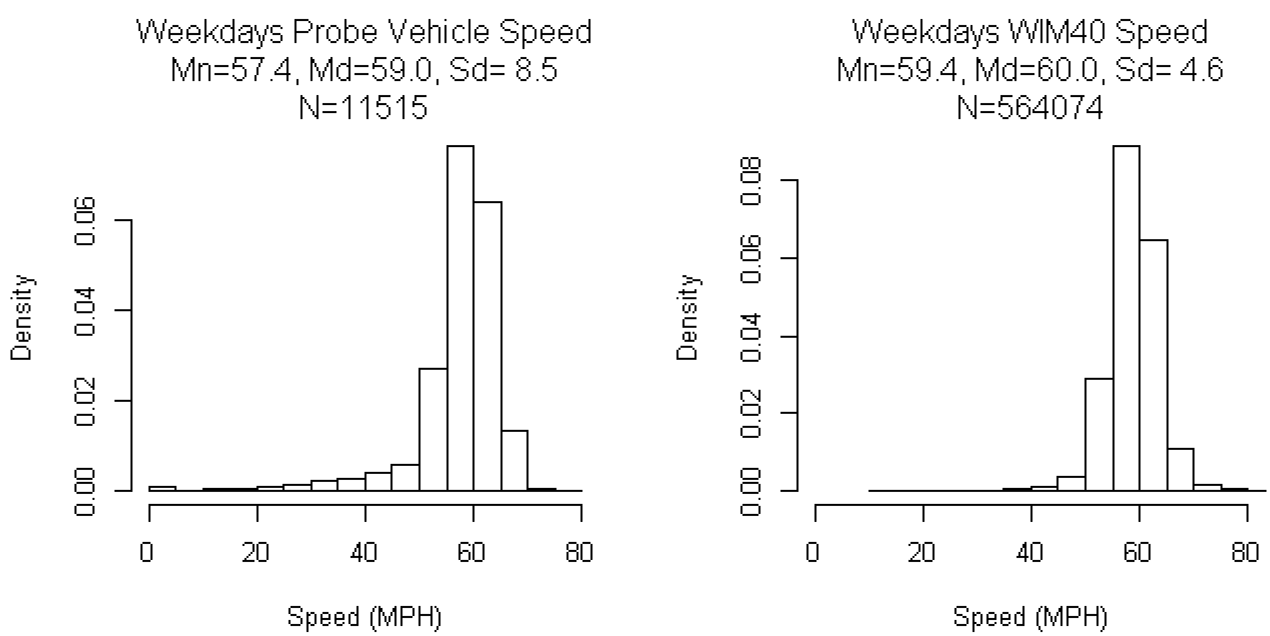

Figure B.7 Probe Vehicle Speed vs. WIM Speed at WIM#40

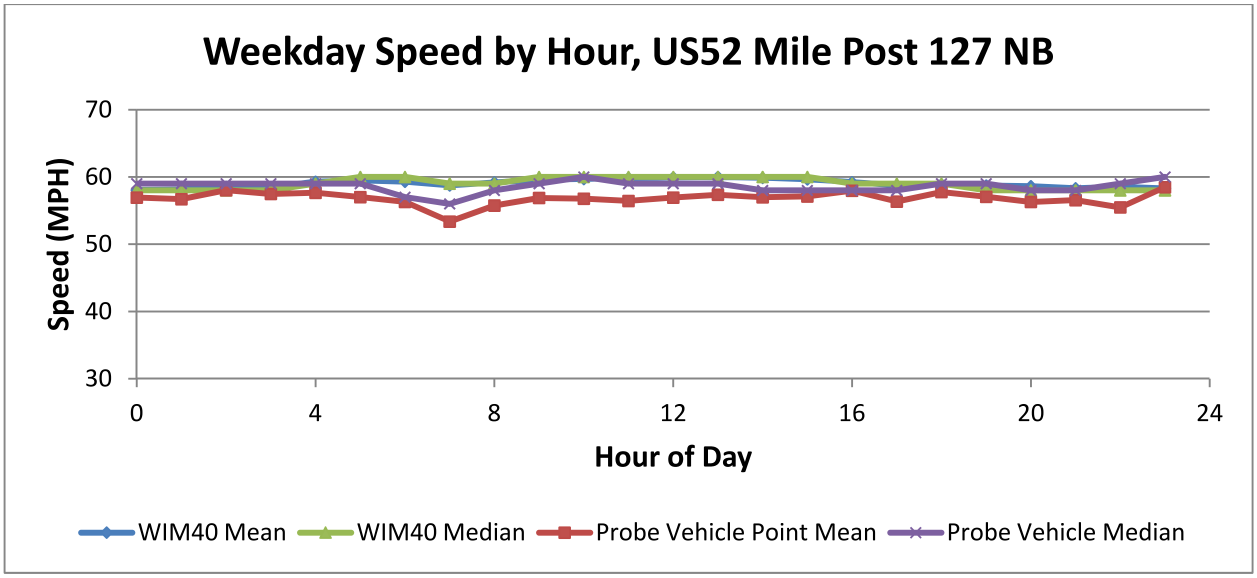

Figure B.8 Probe Vehicle Median Speed vs. WIM Speed by Hour at WIM#40

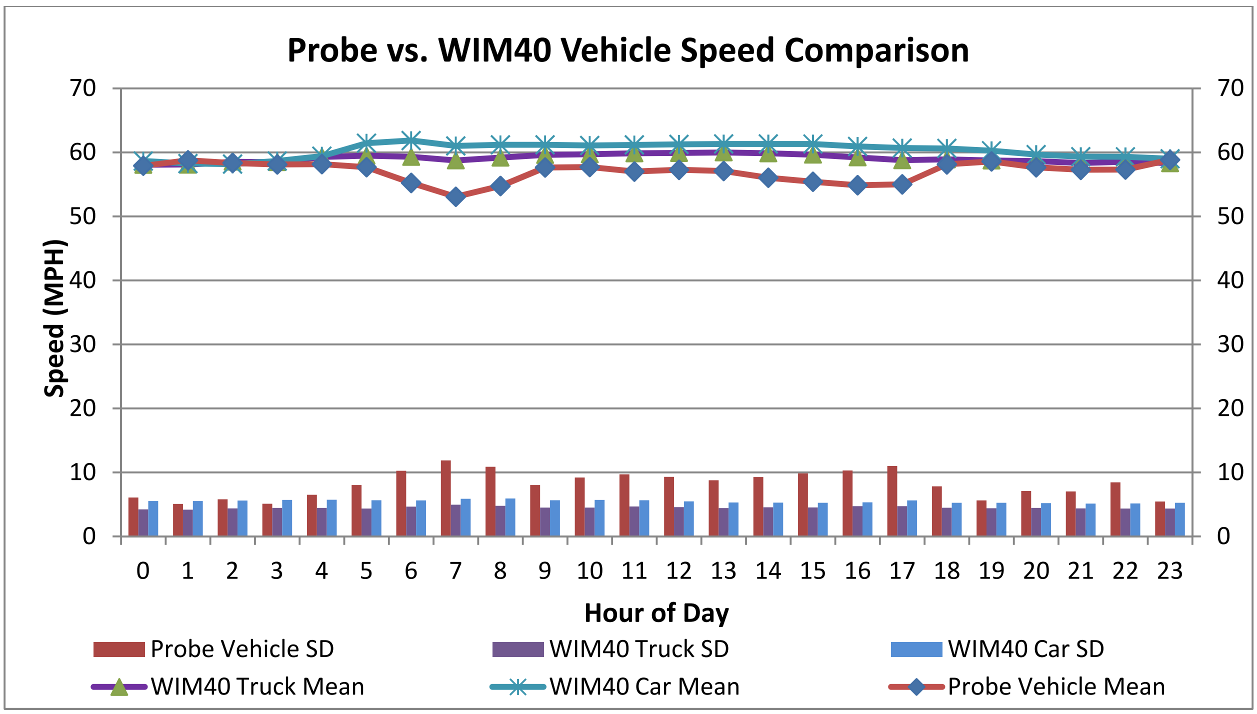

Figure B.9 Probe Vehicle Speed vs. WIM Speed by Hour at WIM#40

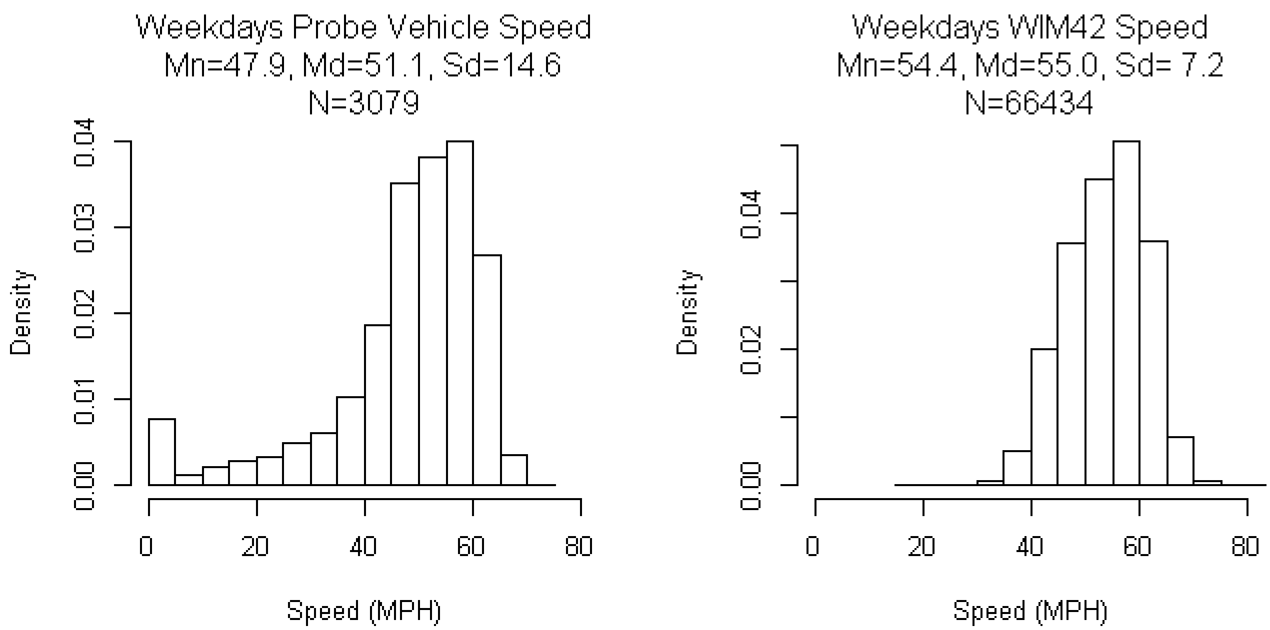

Figure B.10 Probe Vehicle Speed vs. WIM Speed at WIM#42

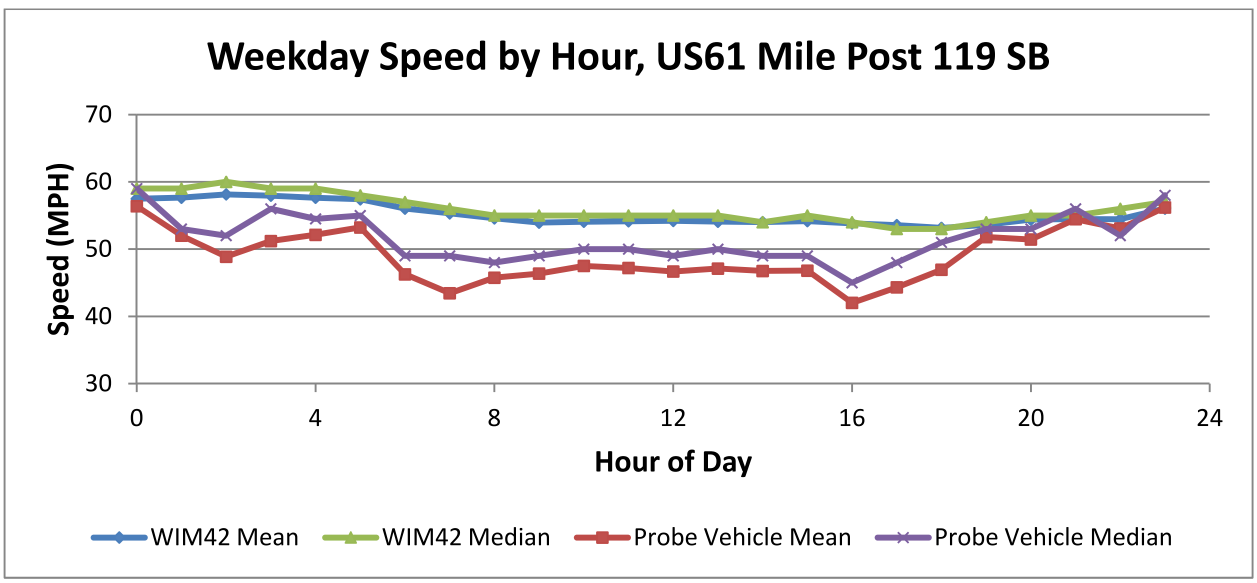

Figure B.11 Probe Vehicle Median Speed vs. WIM Speed by Hour at WIM#42

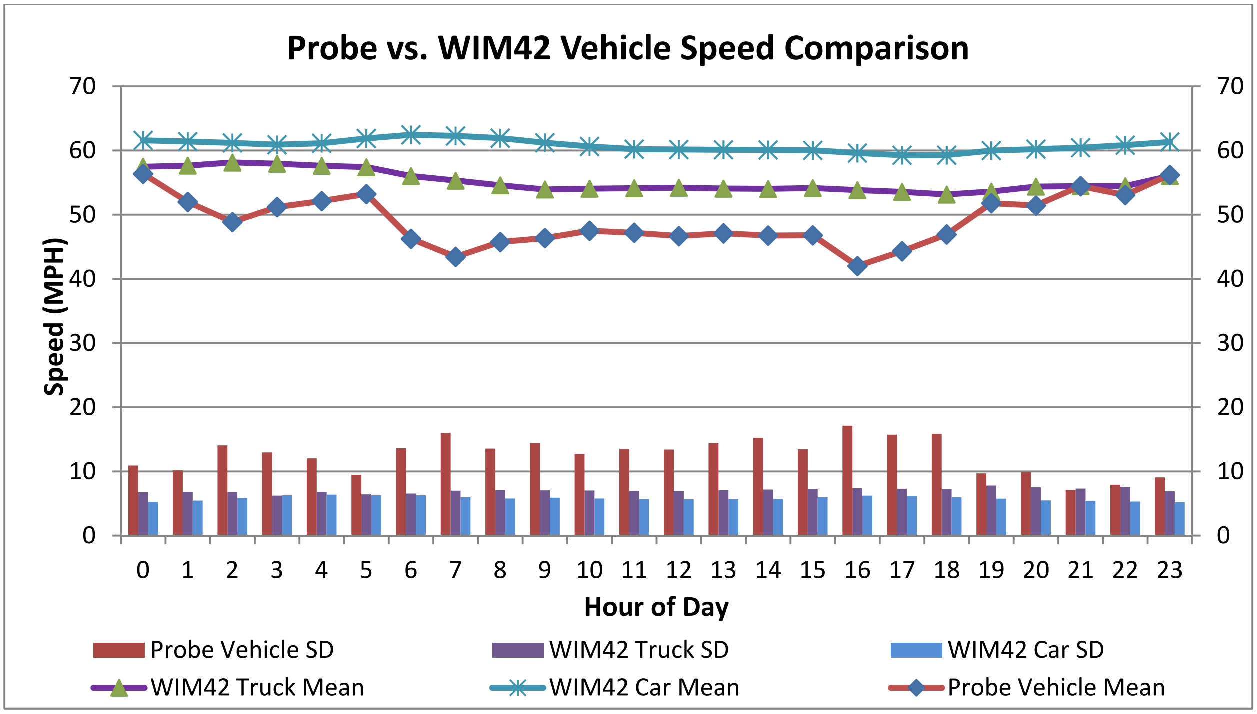

Figure B.12 Probe Vehicle Speed vs. WIM Speed by Hour at WIM#42

B.3 Probe Vehicle vs. WIM Heavy Vehicle Speed by Month and Hour

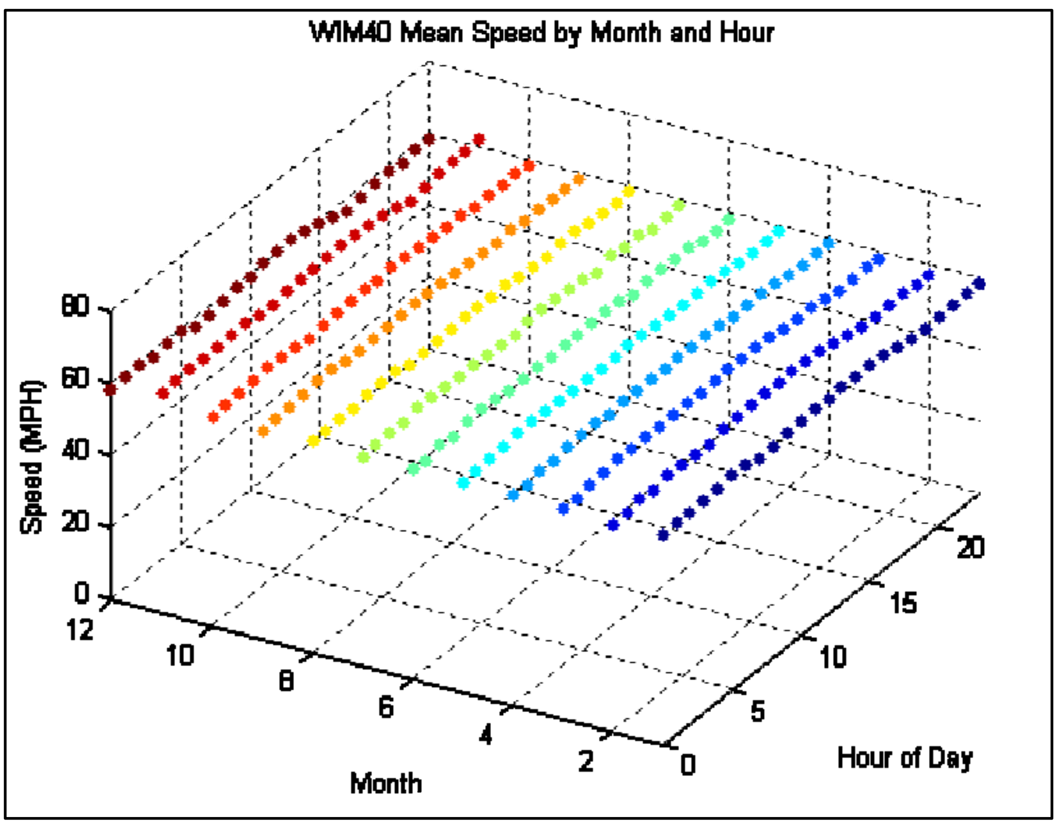

Figure B.13 WIM40 Heavy Vehicle Mean Speed by Month and Hour

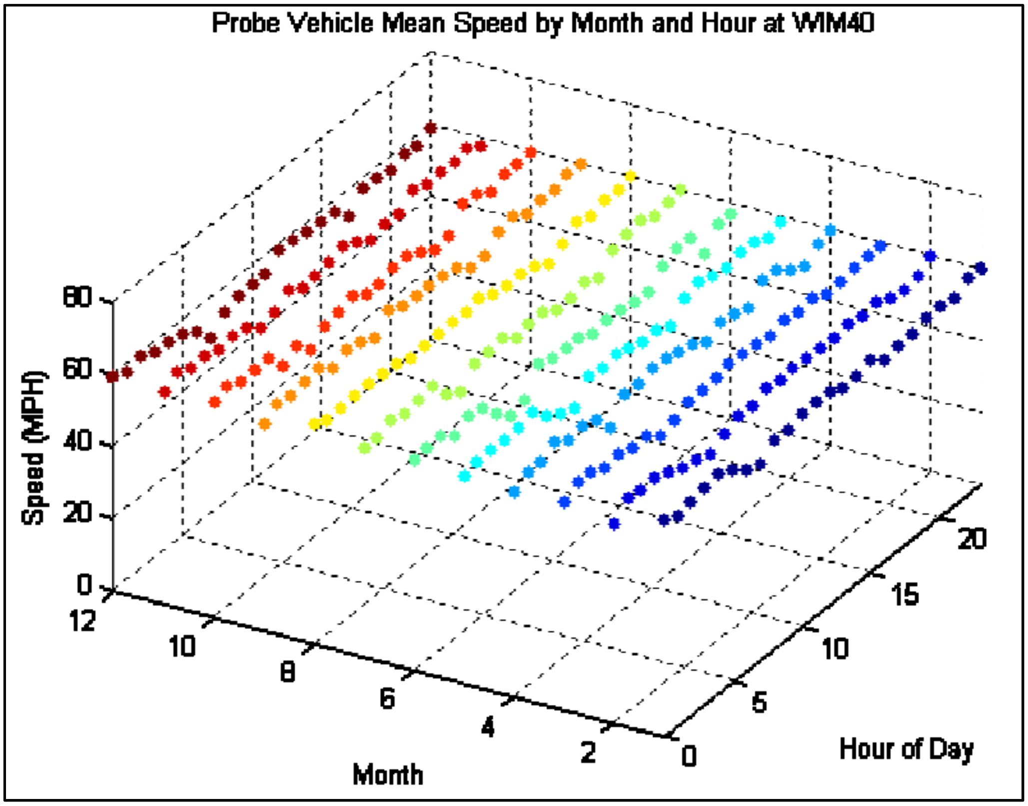

Figure B.14 Probe Vehicle Mean Speed by Month and Hour at WIM40

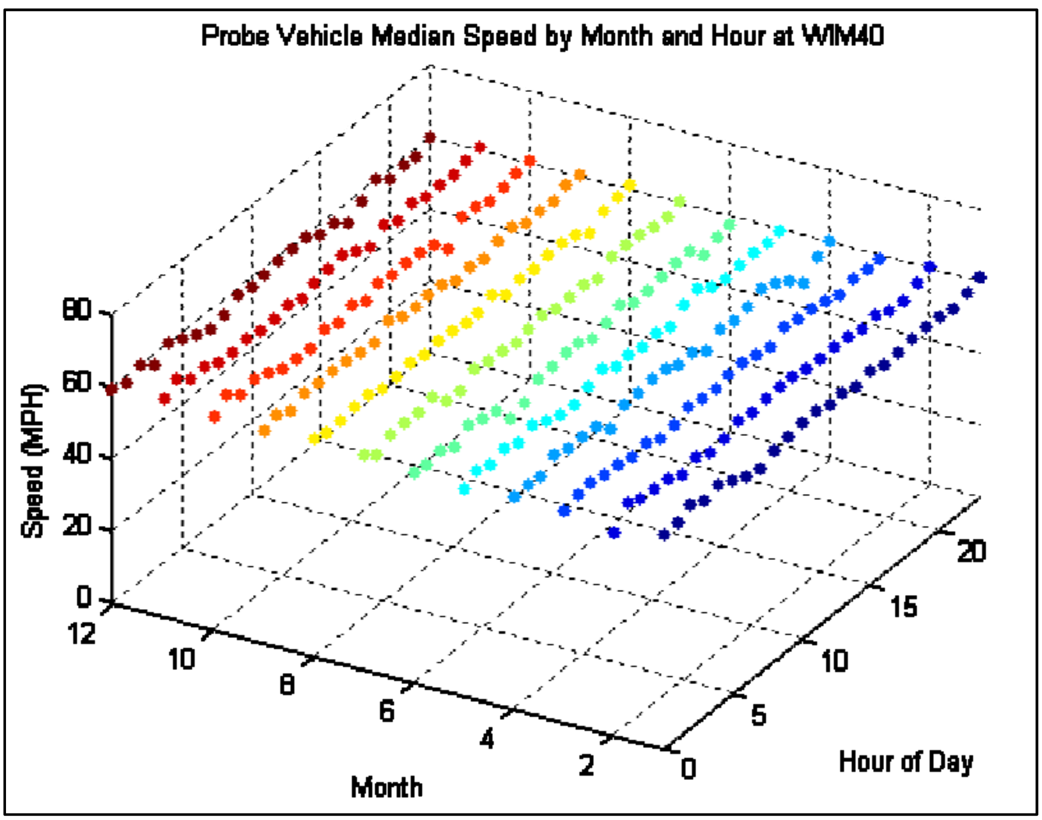

Figure B.15 Probe Vehicle Median Speed by Month and Hour at WIM40

B.4 Probe Vehicle vs. WIM Volume Percentage Comparisons

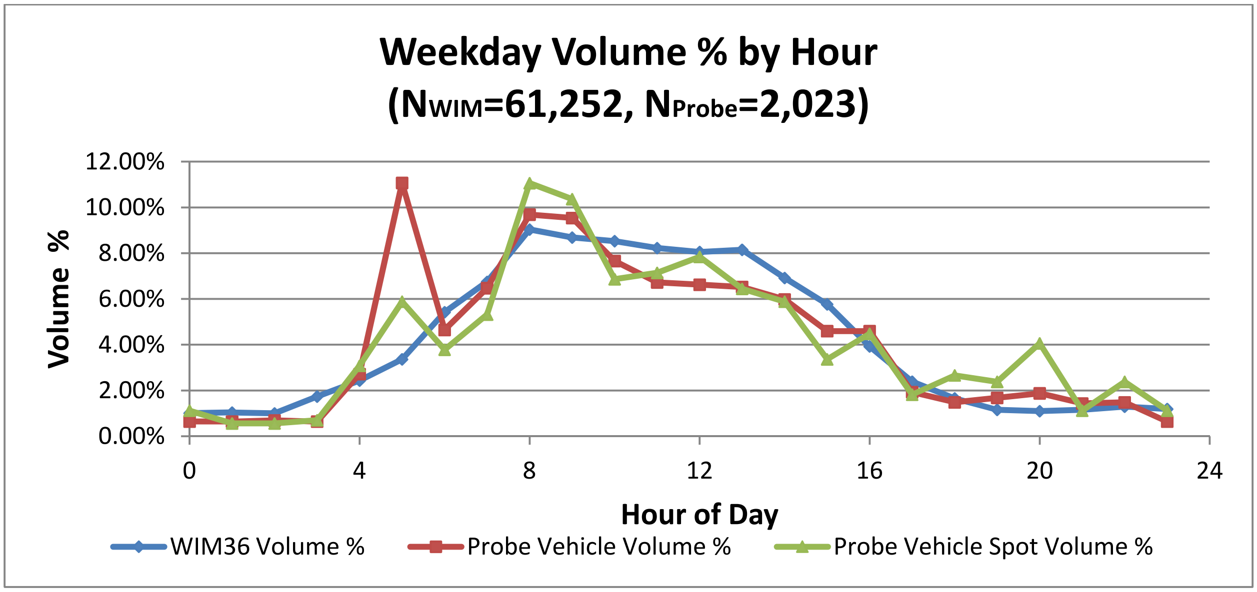

Figure B.16 Probe Vehicle vs. WIM Volume % by Hour at WIM#36

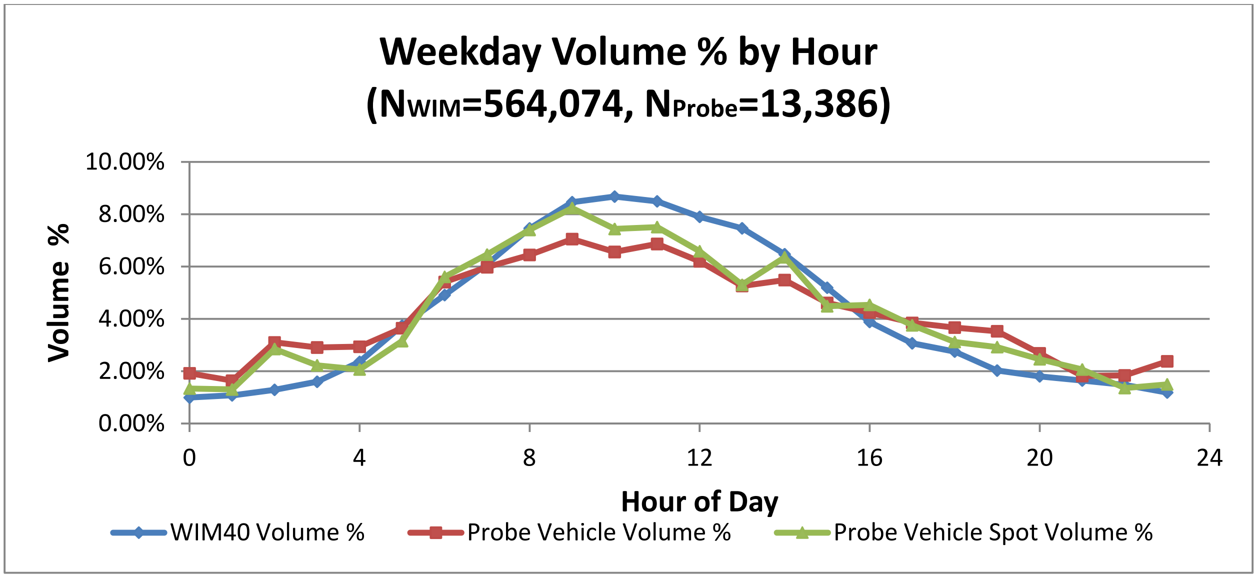

Figure B.17 Probe Vehicle vs. WIM Volume % by Hour at WIM#40

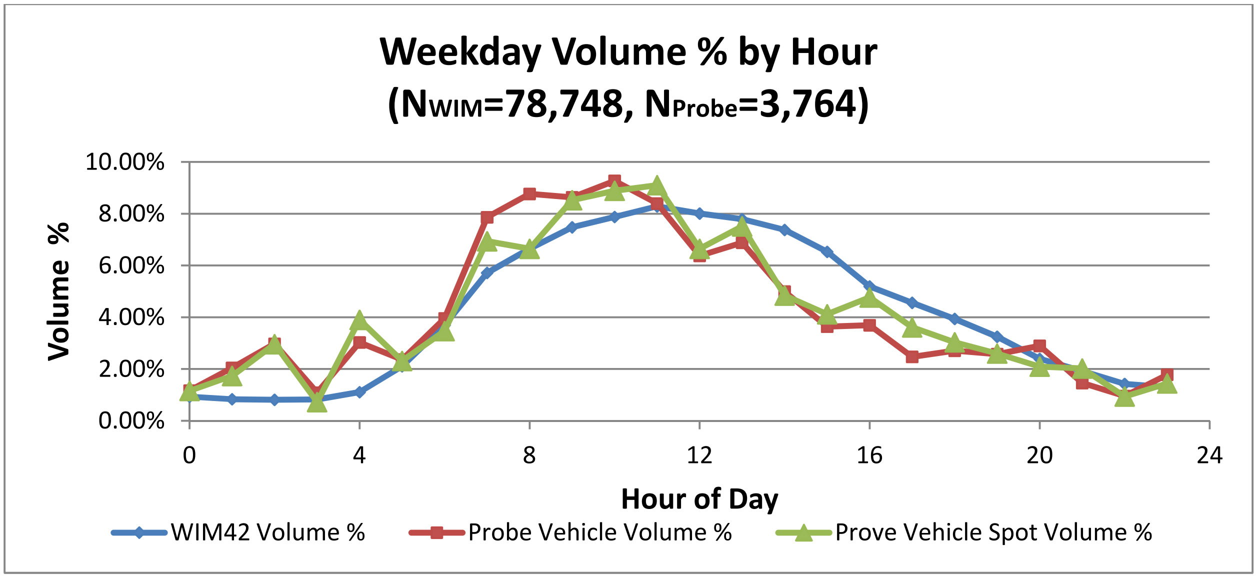

Figure B.18 Probe Vehicle vs. WIM Volume % by Hour at WIM#42