Project Title: Using Truck GPS Data for Freight Performance Analysis in the Twin Cities Metro Area
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Task Due: 12/31/2013

TASK #5: IDENTIFY FREIGHT NODE, FREIGHT SIGNIFICANT CORRIDOR AND CONGESTION

Introduction

Truck bottlenecks delay truck freight shipment and delivery. Delays induced by bottlenecks could negatively impact a region's economy and productivity. As suggested by FHWA, reducing truck bottleneck is a major solution for increasing truck freight efficiency and reliability. This task generated truck performance measures, such as mobility, delay and reliability, using the results from truck GPS data analysis. The performance measures are used to identify key freight corridors and truck bottlenecks in the TCMA.

Bottleneck Identification Techniques

A few bottleneck identification techniques found in the literature are summarized as follows.

FHWA & Cambridge Systematics

This approach is the result of a federal program to identify freight bottlenecks [1]. The methodology for locating highway truck bottlenecks is as follows:

1. Locate highway segments with a high volume of traffic in proportion to the available roadway capacity (the volume-to-capacity ratio).
2. Determine truck volumes at these locations.
3. Calculate truck hours of delay by using queuing models. The bottleneck can then be ranked by hours of delay.

This approach has some limitations related to quality of the input data. Because much of the data are derived and do not directly account for real-world truck behavior.

American Transportation Research Institute (ATRI)

The ATRI approach [2, 3 & 4], completed in conjunction with the Federal Highway Administration (FHWA) Office of Freight Management and Operations, uses GPS data and free flow speeds on roadway segments as a base. The truck GPS data are used to calculate the average miles per hour below free flow speed on the segment of interest. This number is multiplied on an hour-by-hour basis by the number of trucks on that section of roadway. For each hour over the course of a day, "*vehicle population by hour*" is multiplied by "*Free Flow – Average MPH*" to result in an "*hourly freight congestion value*." The sum of the 24 hourly freight congestion values is used to produce the "*total freight congestion value*." This congestion value is used to rank the severity the bottlenecks.

Washington State

The Washington state approach takes full advantage of the high level of GPS data and roadway information available in Washington State. The bottleneck identification and ranking process developed for Washington State includes the following tasks [5]:

1. Separate the state's entire roadway network into analysis segments based on the locations of ramps /major intersections and, in some cases, roadway length.
2. Assign to each analysis segment the appropriate roadway attributes (speed limits, classification, etc.) along with heading information to determine travel direction.
3. Assign each probe truck's GPS location reads to the appropriate segments. Account for the truck's travel direction on the segment.
4. For segments with enough truck data, use the GPS truck's travel speeds averaged over time to quantify the reliability and overall performance of each segment and identify as bottlenecks locations where trucks are performing unreliably or slowly.
5. Rank the truck bottlenecks on the basis of a range of metrics, including averaged segment travel speeds, geographic location, and the segment's Freight Goods Transportation System (FGTS) category.

Our Approach

This study focuses on the key freight corridors in the Twin Cities Metro Area (TCMA). The bottleneck identification and ranking process developed for this task involves the following steps:

1. Segment the 38 key freight corridors in TCMA into 1-mile analysis segments.
2. Associate spatial attribute to the segments using GIS software. Assign to each analysis segment the appropriate roadway attributes (type of road, threshold speed, number of lanes, AADT, heading, etc.).
3. Geo-locate truck GPS point data and assign each probe truck's GPS location point to an appropriate roadway segment and corresponding travel direction.
4. Process the truck GPS data and generate performance measures through statistical analyses.
5. Quantify mobility and reliability performance measures of each roadway segment.
6. Identify segments as bottleneck locations where average truck speed is below target speed, unreliably or having significant delays.
7. Rank the truck bottlenecks on the basis of a range of metrics, including averaged segment travel speeds, delays, reliability, and geographic location.

Previous tasks (task #1 to #4) of this project focused on step 1 to 5 as described above. The rest of this report will focus on identifying and ranking truck bottlenecks in the TCMA.

Truck Performance Measures in TCMA

Performance measures of truck mobility, delay and reliability are discussed in this section. The performance measures were analyzed in the following three periods. These time periods are chosen in consistent with the annual transportation results scorecard published by MnDOT [6].

- AM Peak: 5 - 10AM
- Morning Off-Peak: 10AM - 2PM
- PM Peak: 2 - 7PM

<u>Freight Node & Freight Corridor</u>

Figure 1 displays the GIS map of Heavy Commercial Annual Average Daily Traffic (HCAADT) in TCMA. I-94, I-35W, I-494, and I-694 have the highest daily truck volume as compared to other corridors in the TCMA. Corridors in TCMA with HCAADT greater than 7500 vehicles are listed in Table 1.

Corridors in TCMA with HCAADT per lane greater than 1500 vehicles are listed in Table 2. Figure 2 illustrates the GIS map of HCAADT per lane in TCMA. I-94, I-35, I-494, State Highway 280, State Highway 65, and I-696 have higher truck activities than the other corridors in TCMA. I-94 between St. Cloud and Maple Grove, I-494 between Highway 55 and US Highway 212, I-35 in Burnsville, I-694 between State Highway 65, and I-35E near US Highway 52 and State Highway 55 have the highway daily truck volume per lane, as illustrated in Figure 2.

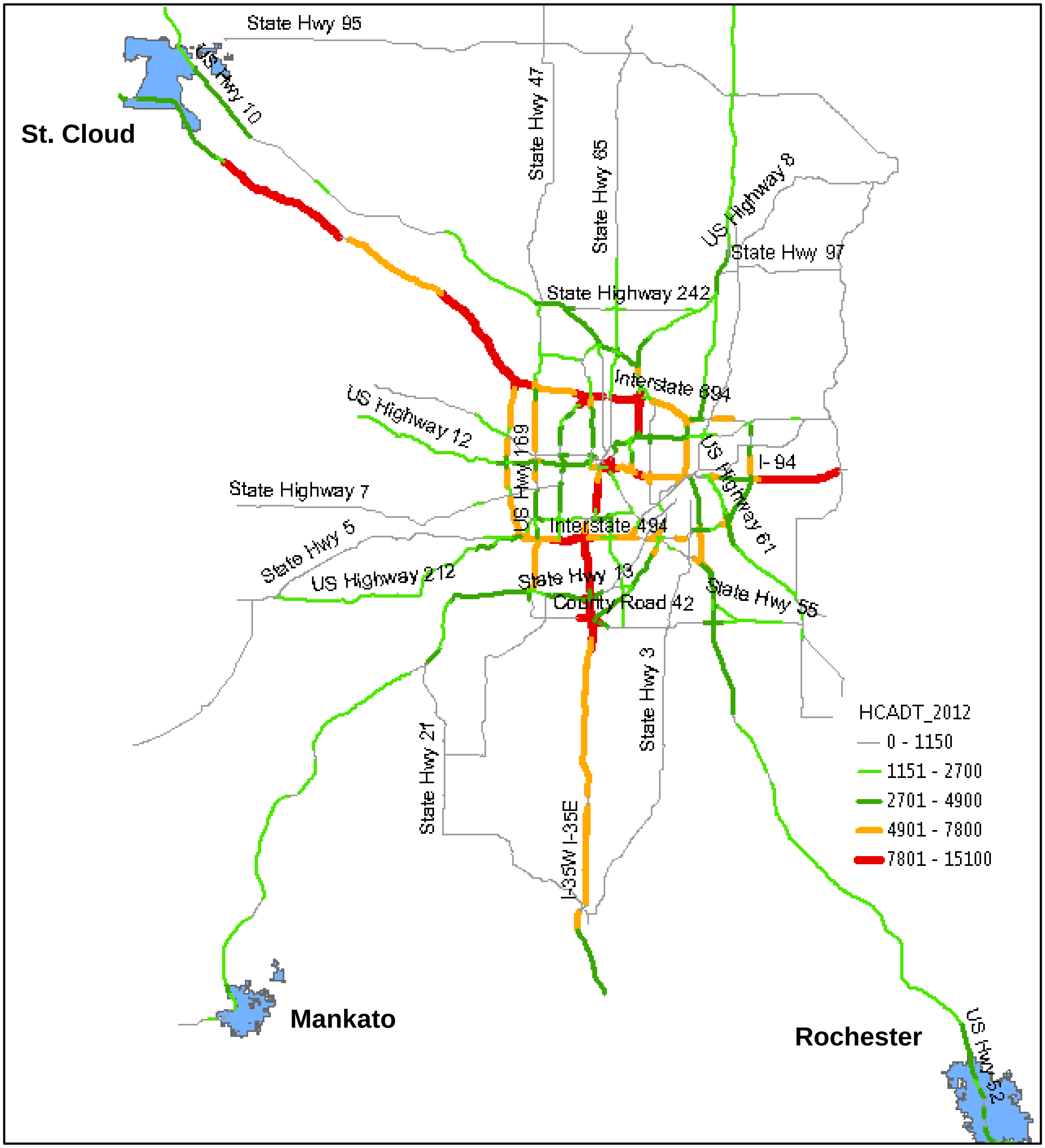

Figure 1 2012 Heavy Commercial Annual Average Daily Traffic (HCAADT) in TCMA

Table 1 Percentage of Miles by Route with HCAADT Greater than 7500

Rank	Route	Route Name	Route ID	% of Miles with HCAADT > 7500
1	94	I- 94	24	36.8%
2	280	State Highway 280	10	25.0%
3	694	Interstate 694	4	17.4%
4	35	I-35W	34	16.2%
5	65	State Hwy 65	26	13.6%
6	494	Interstate 494	6	9.3%
7	42	County Road 42	18	9.1%
8	51	State Hwy 51	21	8.3%
9	100	State Highway 100	7	6.3%
10	5	State Hwy 5	30	4.7%
11	13	State Hwy 13	38	2.3%
12	55	State Hwy 55	28	1.8%
13	35	I-35E	33	1.8%

Table 2 Percentage of Miles by Route with HCAADT per Lane Greater than 1500

Rank	Route	Route Name	Route ID	% of Miles with HCAADT Per Lane > 1500
1	94	I- 94	24	28.7%
2	694	Interstate 694	4	26.1%
3	18	County Road 18	20	25.0%
4	494	Interstate 494	6	16.3%
5	35	I-35W	34	15.4%
6	42	County Road 42	18	9.1%
7	35	I-35E	33	8.8%
8	55	State Hwy 55	28	3.6%
9	10	US Hwy 10	31	3.0%
10	52	US Hwy 52	29	2.3%
11	13	State Hwy 13	38	2.3%
12	65	State Hwy 65	26	1.7%
13	169	US Hwy 169	37	1.0%

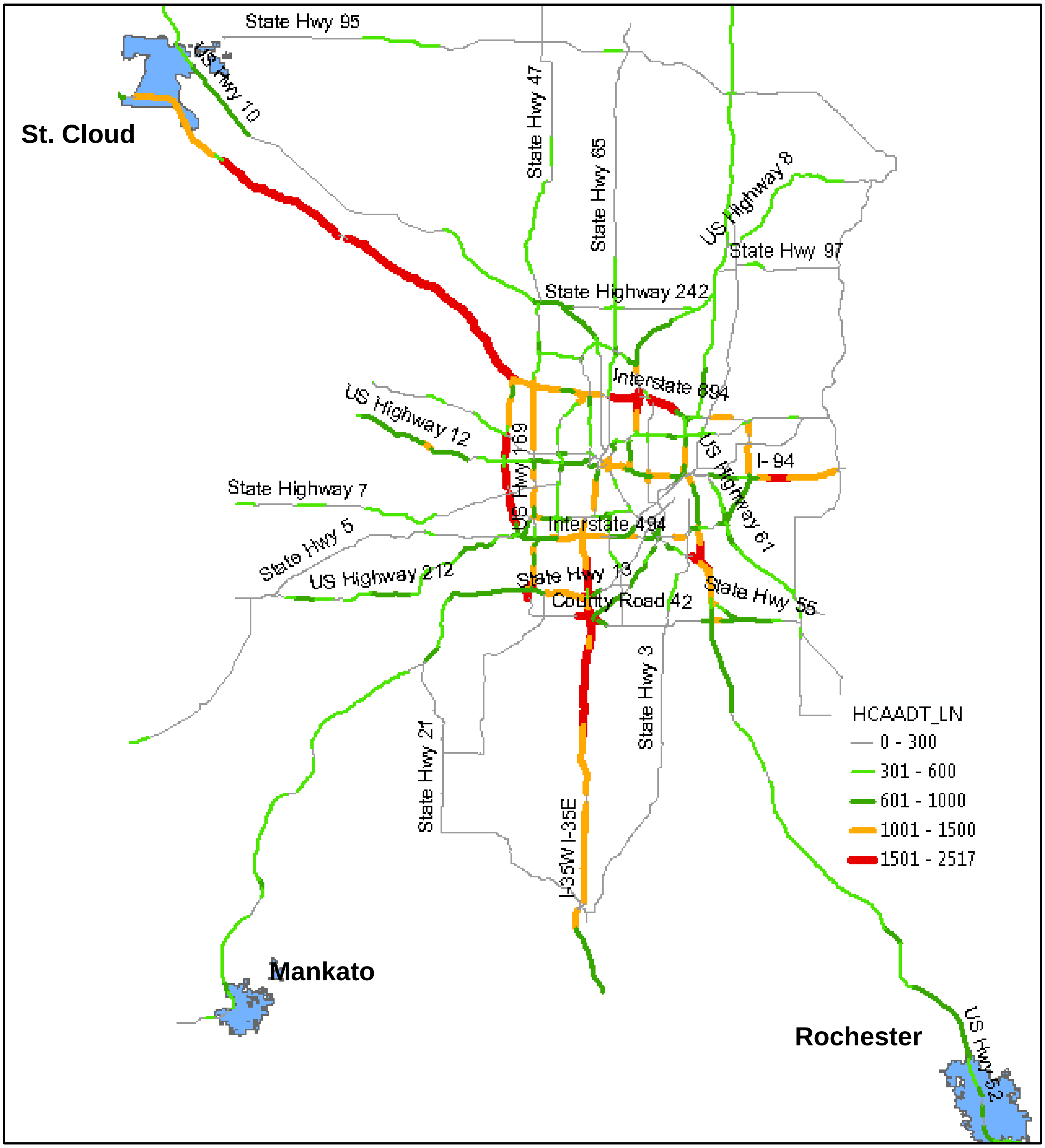

Figure 2 GIS Map of 2012 HCAADT Per Lane in TCMA

Corridor Target Speed in TCMA

Threshold speed for each corridor is selected using the target speed provided by MnDOT as displayed in Figure 3. In general, 45 MPH threshold speed (dark green) is used in the 7-county Twin Cities metro area. Threshold speed of 55 MPH or higher is used for corridors outside the metropolitan area. The target speeds are used to compute truck delay and reliability in the following sections.

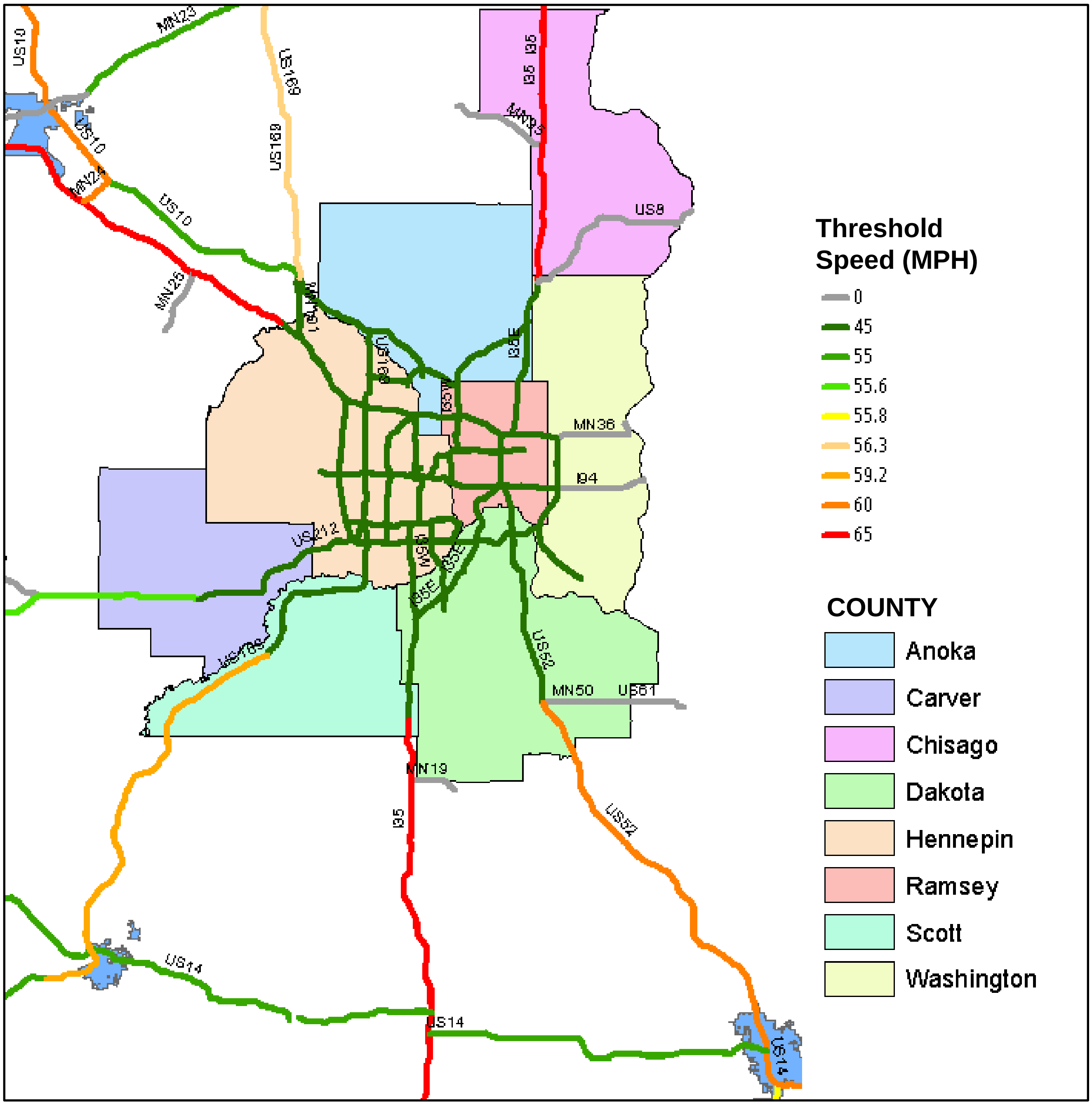

Figure 3 Corridor Target Speeds Specified by MnDOT in TCMA

Truck Mobility

MnDOT uses number of hours in peak periods with average speed below target speed in the annual mobility scorecard to measure mobility. Figure 4 displays the number of hours in AM peak period with average speed below 45 MPH. And, Figure 5 illustrates the number of hours in PM peak period with average speed below threshold speed.

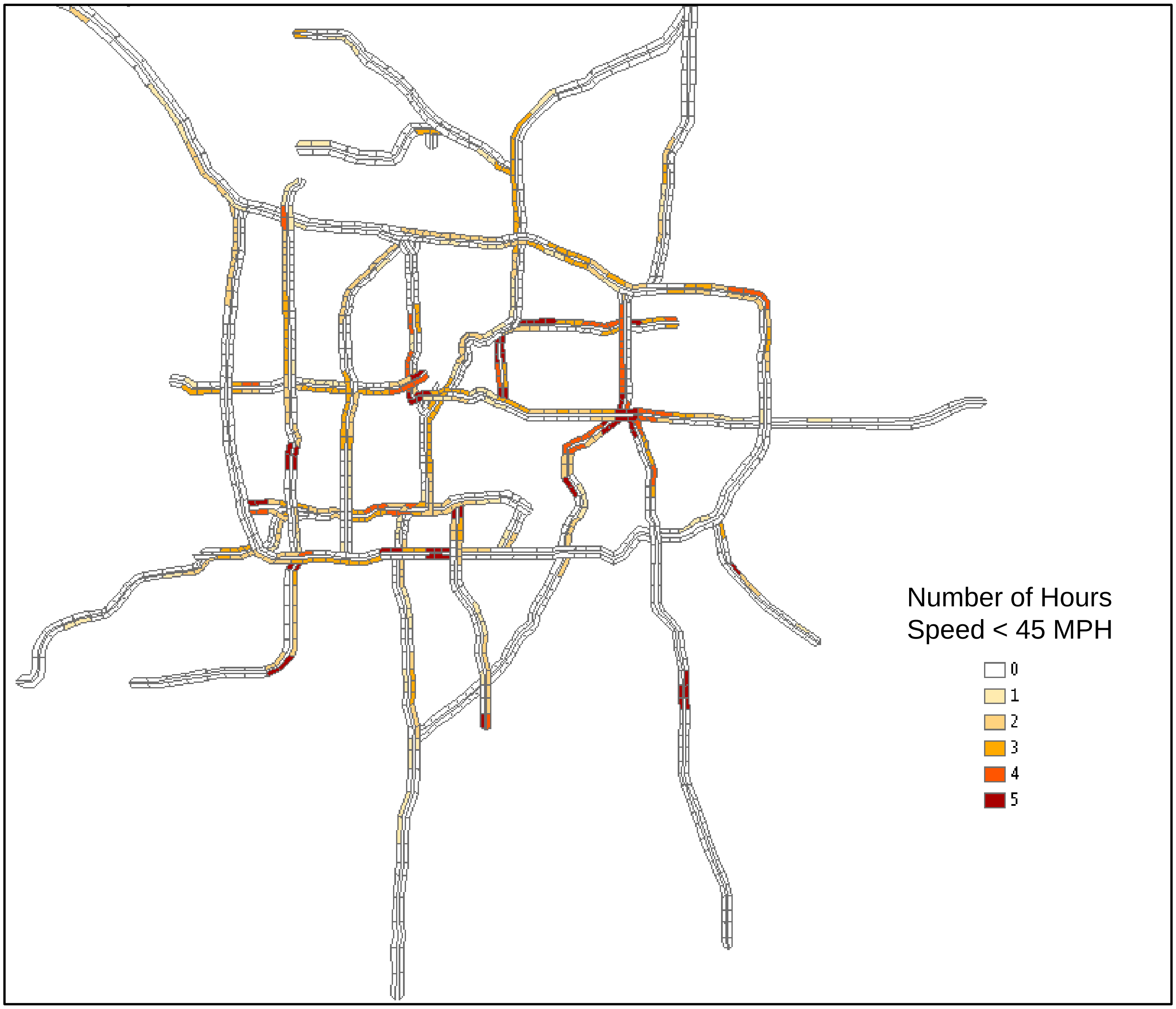

Figure 4 Number of AM Peak Hours with Average Speed Less than Threshold Speed

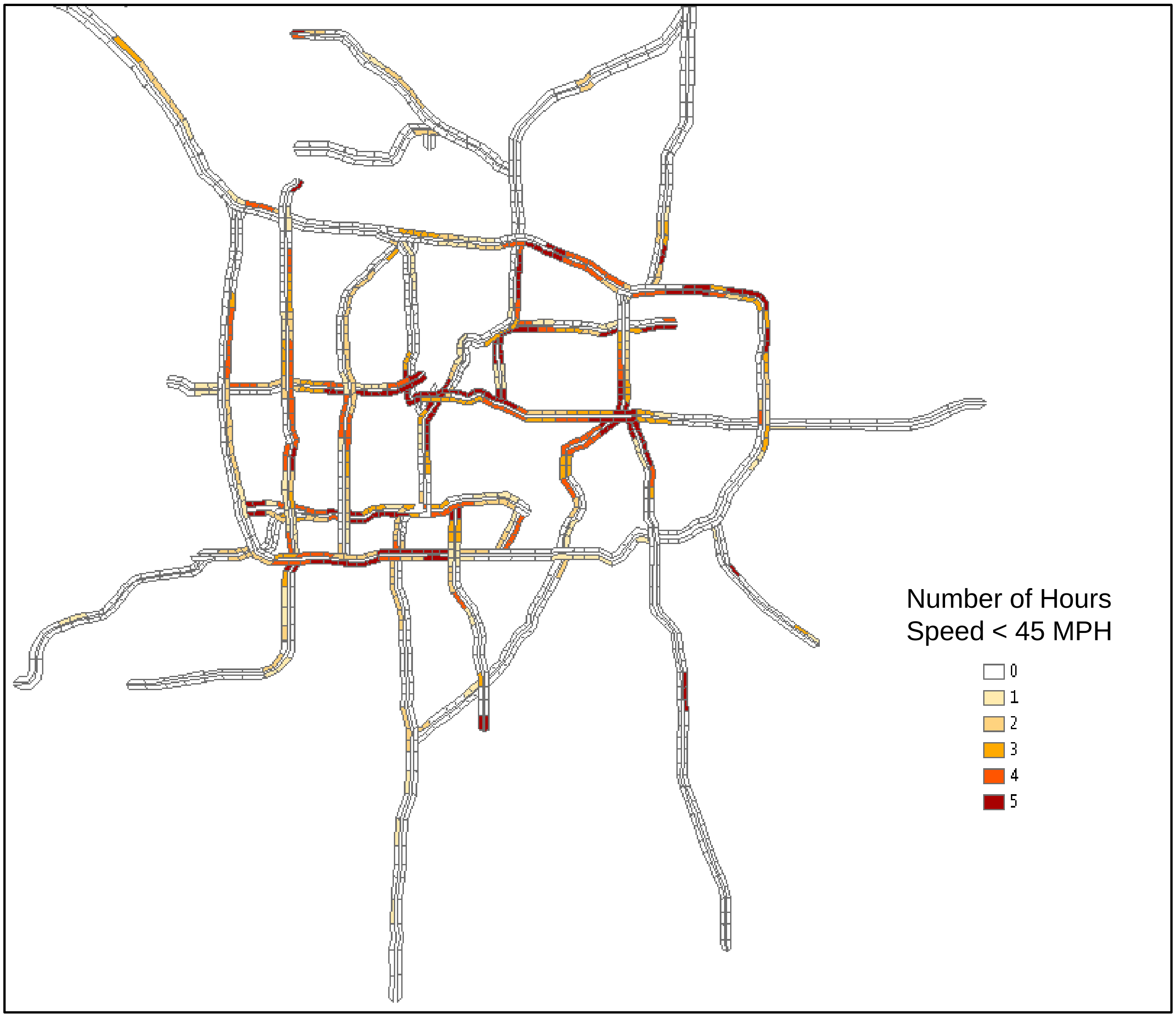

Figure 5 Number of PM Peak Hours with Average Speed Less than Threshold Speed

Truck Delay

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

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

Hours of truck delay in both AM and PM peak hours are illustrated in Figure 6 and 7, respectively.

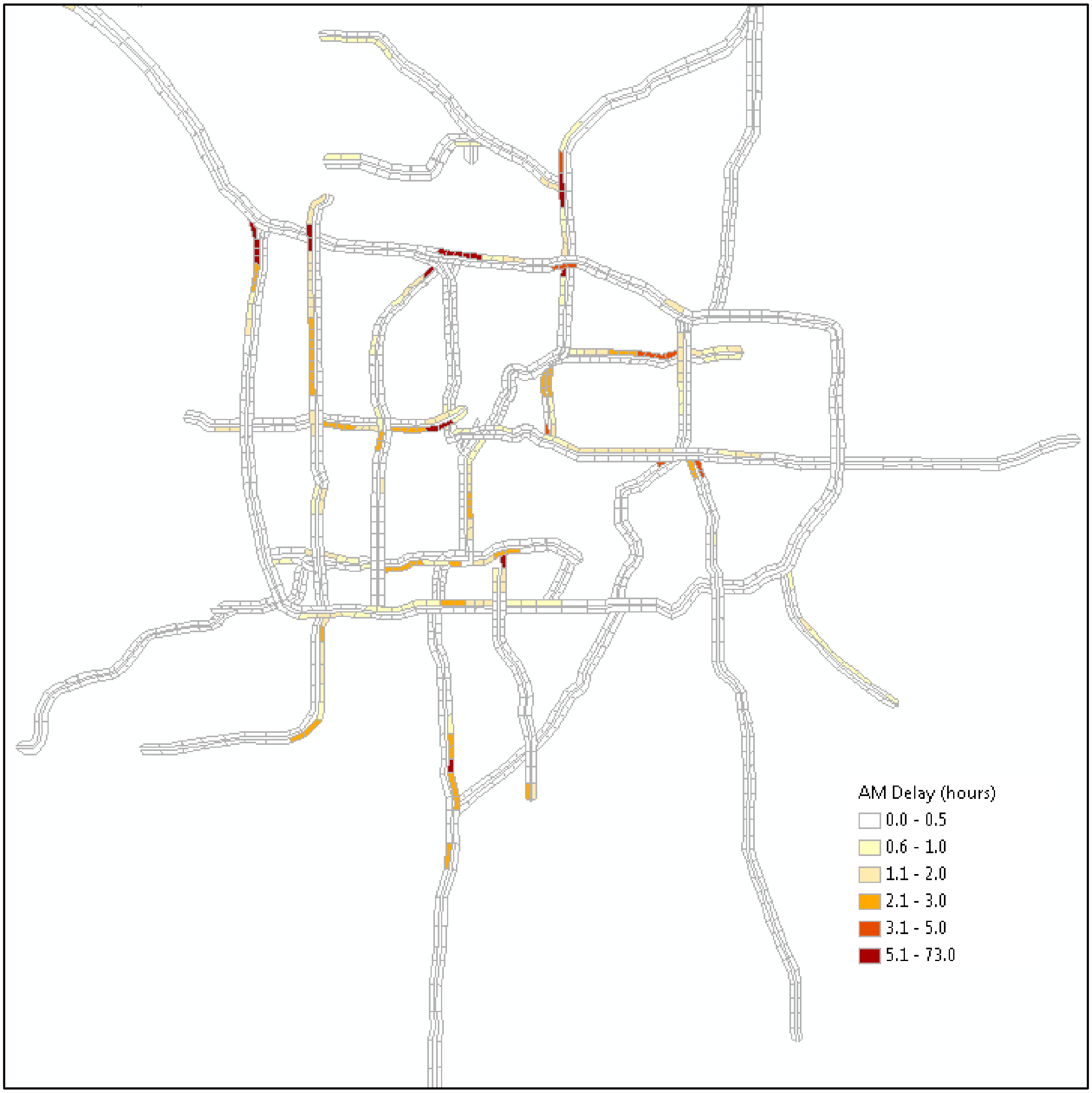

Figure 6 Map of Truck Delays in AM Peak

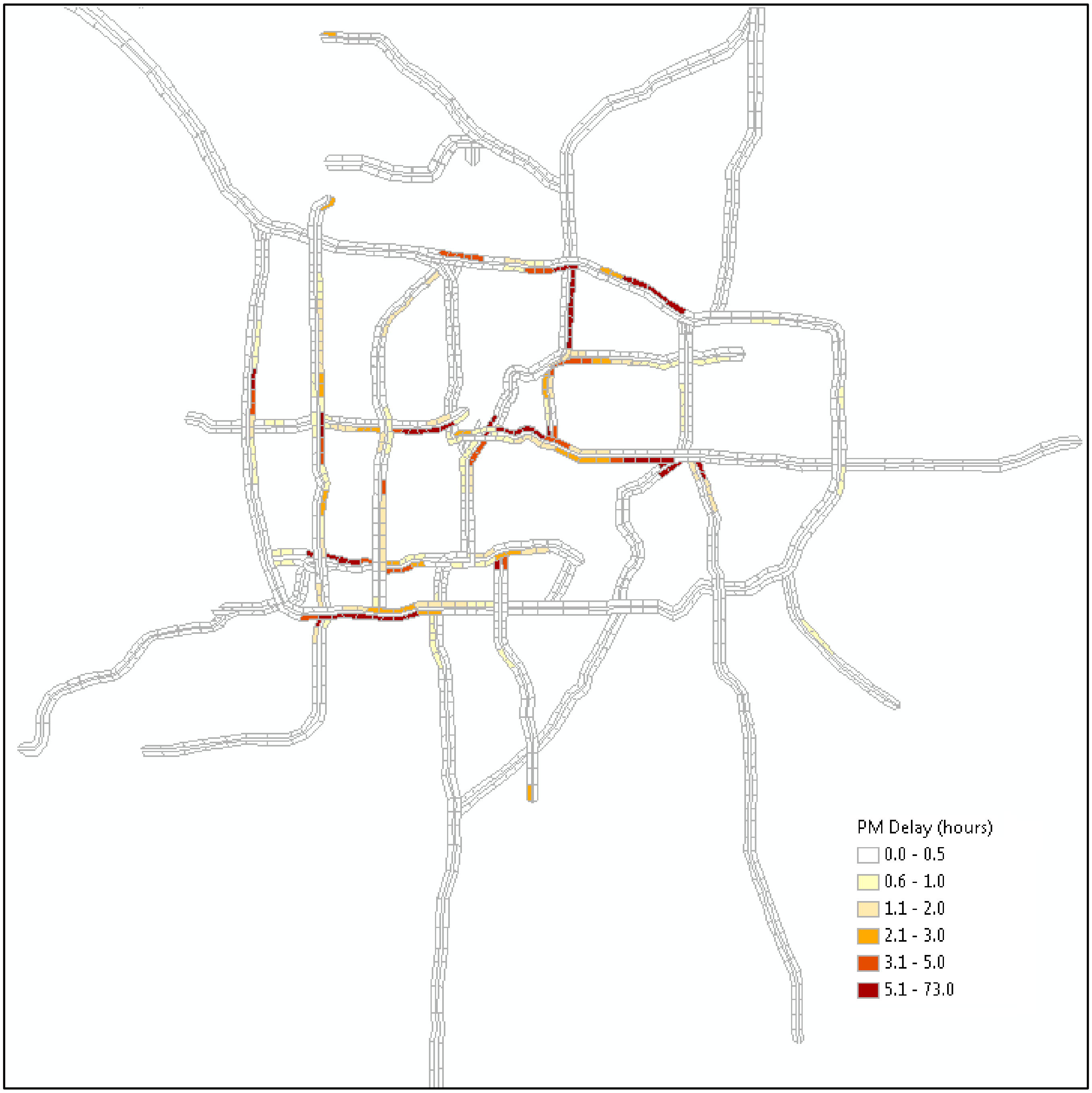

Figure 7 Map of Truck Delays in PM Peak

Truck Travel Time Reliability

An 80-percentile travel time reliability index, defined as equation (2), was used to compute the reliability of truck travel time.

$$RI_{80} = \frac{80^{th}\ percentile\ Travel\ Time}{Travel\ Time\ at\ MnDOT\ Specified\ Threshold\ Speed} \qquad \text{Eq. (2)}$$

The 80 percentile travel time reliability indices for all corridors in TCMA in both directions were plotted in Figure 8 and 9 for AM and PM peak hours, respectively. Travel time of a roadway segment is considered reliable, moderate reliable and unreliable using the following criteria.

- $RI_{80} < 1.5$ reliable
- $1.5 \leq RI_{80} < 2.0$ moderate reliable
- $RI_{80} \geq 2.0$ unreliable

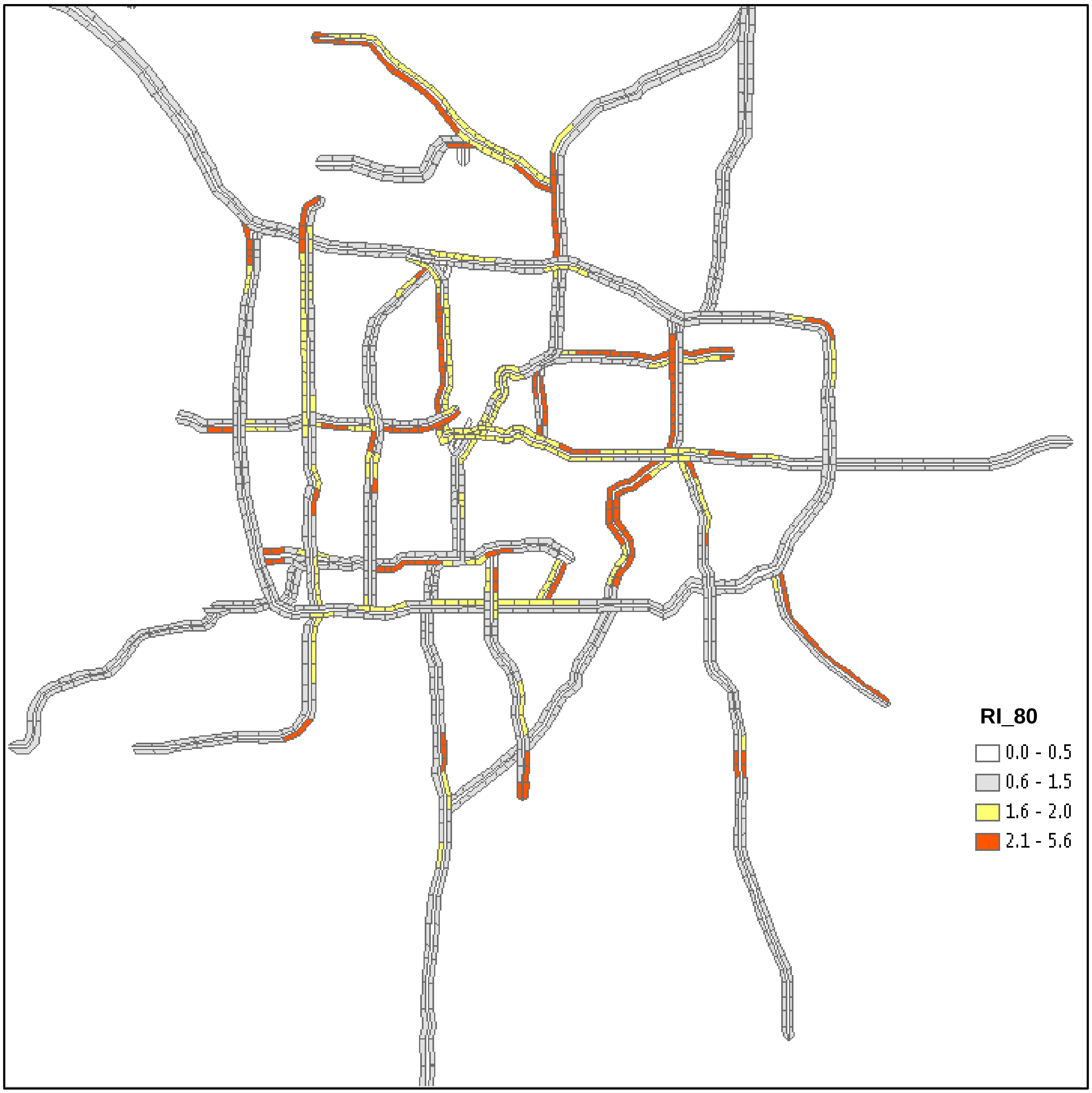

Figure 8 Truck Reliability Index in AM Peak

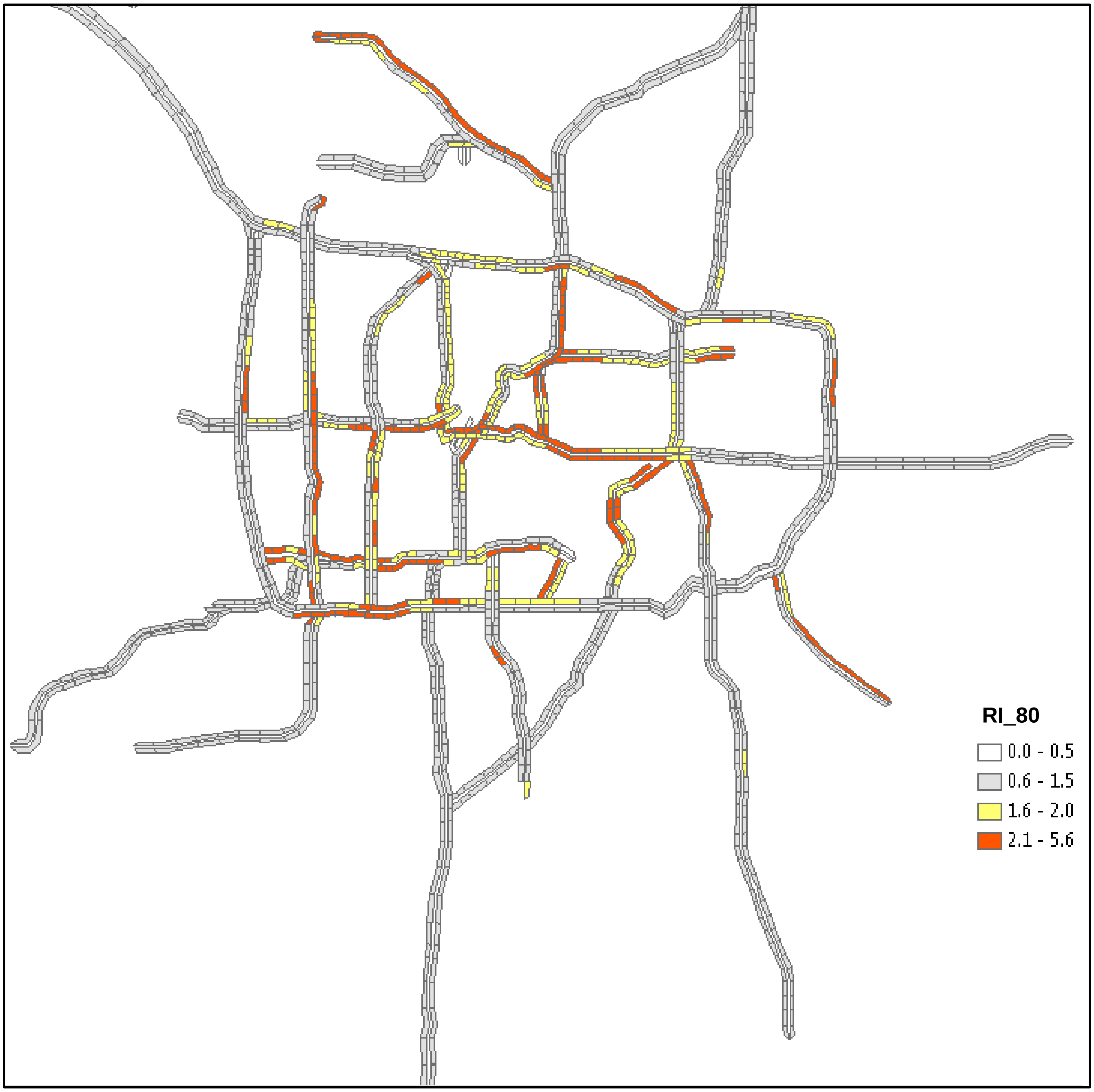

Figure 9 Truck Reliability Index in PM Peak

Truck Bottlenecks Identification

In addition to traffic volume to capacity ratio, highway interchange, lane drop, signal, and steep grade are typical factors contribute to traffic bottlenecks.

The research team first identifies truck bottlenecks by comparing the average truck delay per mile in the studied network. Table 3 listed 12 locations in TCMA with significant truck delays during the AM peak. A GIS map illustrating these locations (highlighted in aqua color) in AM peak period is displayed in Figure 10. Table 4 listed 18 locations in TCMA with significant truck delays during the PM peak. A GIS map illustrating these locations (highlighted in aqua color) in PM peak period is displayed in Figure 11. Most of the bottleneck locations are nearby an interchange.

Table 3 List of Truck Bottleneck in AM Peak (Based on Delay)

Rank	Location	Dir.	AM Peak Delay (hours) / Mile	AM Peak Reliability RI80	HCAADT	Number of Lanes	Length (miles)
1	I-494 S of I-94 (Maple Grove)	SB	13.18	2.5 - 4.36	5300	2	1.91
2	I-35W at Burnsville Pkwy	NB	10.67	3.46	10200	2	0.56
3	TH 169 at I-94	SB	8.76	2.65	3750	2	1.10
4	TH 100 at I-94	SB	8.34	2.05	2400	2	0.56
5	I-694 at I-94	WB	7.59	1.80	9000	3	1.83
6	I-394 at I-94	EB	6.43	3.15	4900	3	1.18
7	I-35W at US10	SB	5.74	2.5 - 2.68	5700	3	2.32
8	I-694 at I-35W	EB	3.92	1.80	12300	2	1.02
9	US52 at I-94	NB	3.8	2.93	5200	2	0.77
10	TH 280 at I94	SB	3.53	2.25	3250	2	0.43
11	TH 36 at I-35E	EB	3.37	2.65 - 3.01	2600	2	1.73
12	I-35E at I-94	SB	3.15	3.08	740	3	0.33

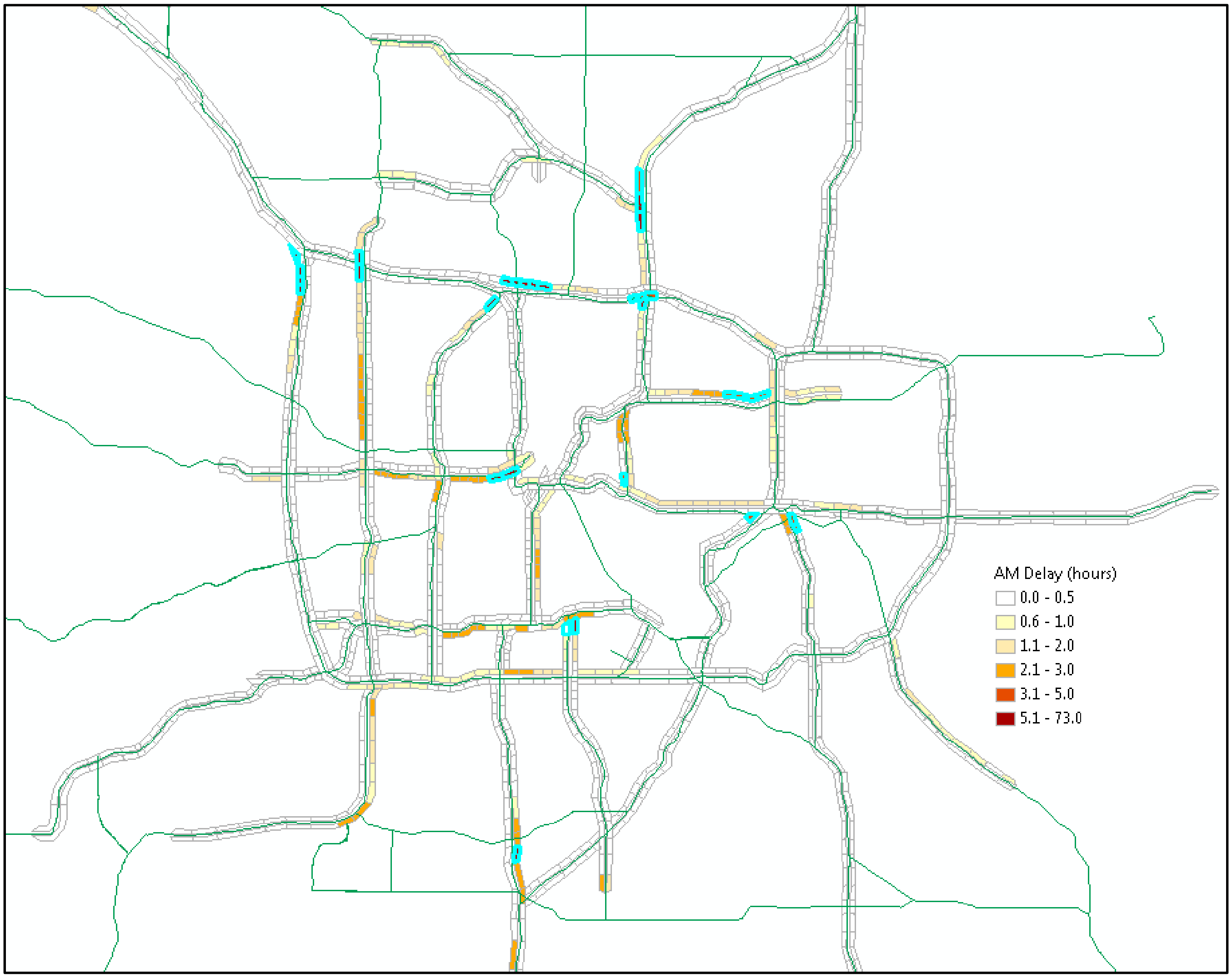

Figure 10 Map of Truck Bottleneck (Highlighted) with Delay ≥ 3 Hours in AM Peak

Table 4 List of Truck Bottleneck in PM Peak (Based on Delay)

Rank	Location	Dir.	PM Peak Delay (hours) / Mile	PM Peak Reliability RI80	HCAADT	Number of Lanes	Length (miles)
1	I-35W at I-694	NB	14.08	1.94 - 3.75	7700 - 8500	3	3.30
2	I-35W at I-94	SB	12.94	5.00	3250 - 8300	3	1.01
3	I-494 between I-35W & 169	EB	11.31	2.05 - 4.09	6900 - 9100	2	4.88
4	I-394 between TH 100 & I-94	EB	7.14	2.59 - 3.75	400	3	2.61
5	I-694 between I-35E & I-35W	WB	6.85	2.37 - 3.04	6700 - 7800	2	3.02
6	I-694 at I-35W	EB	6.81	1.58 - 2.18	9000 - 12300	2	2.25
7	TH 62 at TH 169	WB	6.41	2.81 - 5	2450	2	2.26
8	US52 at I-94	NB	6.40	4.33	4800 - 5200	3	0.75
9	I-94 at I-35W	WB	5.95	2.6 - 3.25	6600 - 6800	3	3.27
10	I-94 at I-35E	EB	5.88	2.84 - 3.21	6600 - 7100	4	2.67
11	I-494 at TH 55	NB	5.20	2.04 - 2.54	6300	2	1.93
12	I-35E at I-94	NB	5.15	3.27	740 - 810	3	0.96
13	TH 169 at I-394	NB	5.10	2.39 - 3	5000	2	2.20
14	I-696 at TH 100	WB	5.00	1.88	9000	3	1.83
15	I-35W at I-94	NB	4.07	2.45	3250 - 8300	4	1.25
16	TH 100 at TH 7	NB	4.00	3.55	3500	2	0.60
17	TH 36 at I-35W	EB	3.76	2.77	2550	2	1.69
18	TH 62 at TH 169	EB	3.26	3.23	2750	2	1.11

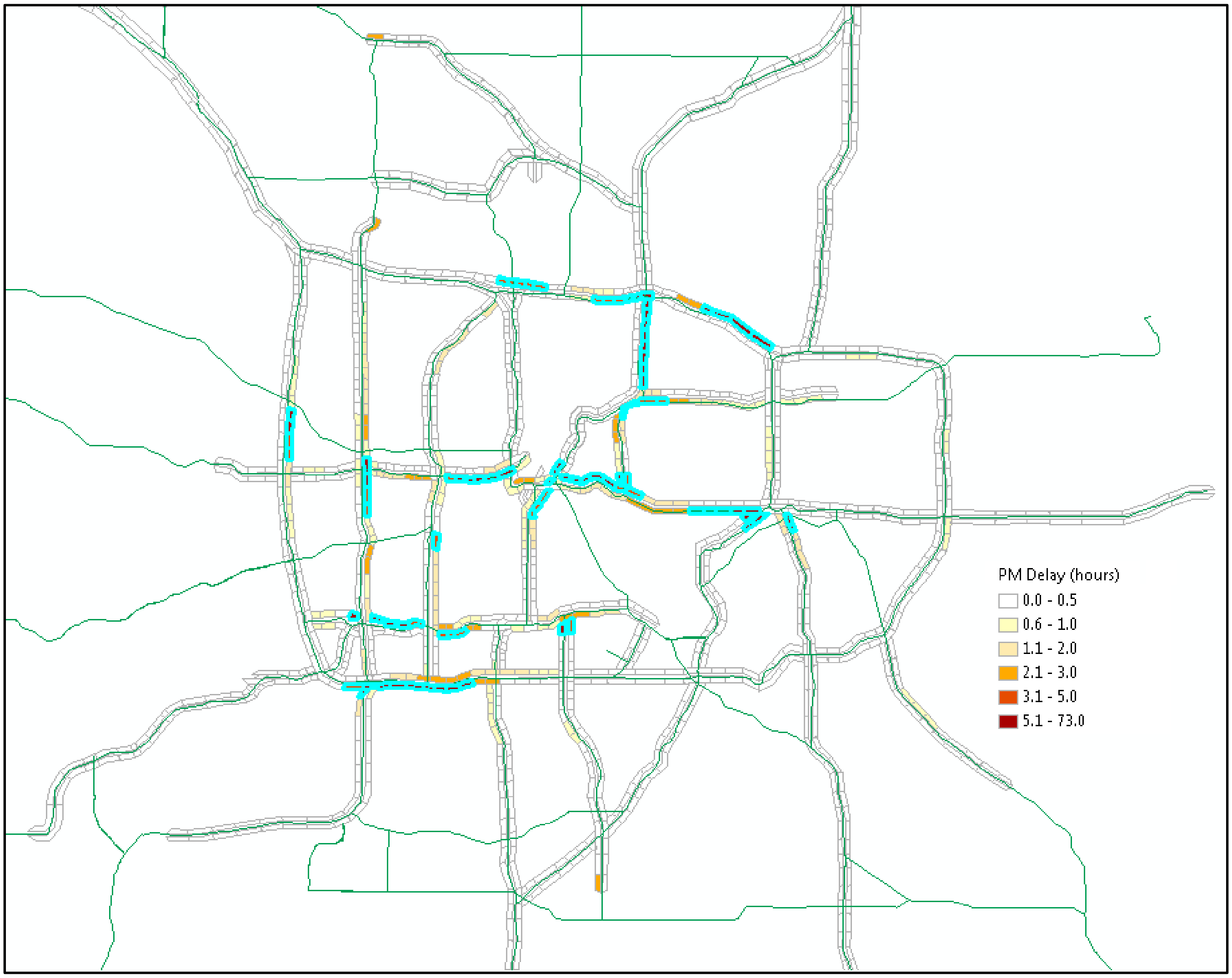

Figure 11 Map of Truck Bottleneck (Highlighted) with Delay ≥ 3 Hours in PM Peak

In addition to delay based approach, the research team also evaluated truck bottlenecks based on number of hours in peak period with speed less than threshold speed. Table 5 listed 15 locations in TCMA with significant truck delays during the AM peak. A GIS map illustrating these locations (highlighted in aqua color) in AM peak period is displayed in Figure 12. Table 5 listed 25 locations in TCMA with significant truck delays during the PM peak. A GIS map illustrating these locations (highlighted in aqua color) in PM peak period is displayed in Figure 13. Most of the bottleneck locations are nearby an interchange.

Table 5 List of Truck Bottleneck in AM Peak (Based on # of Hours below 45 MPH)

Rank	Location	Dir.	AM Peak Delay (hours) / Mile	AM Peak Reliability RI80	HCAADT	# of Lanes	Length (miles)	AM Peak Delay (hours)
1	TH 169 at I-94	SB	8.76	2.65	4150	2	1.09	9.55
2	I-394 at I-94	EB	4.55	2.35 3.15	1750 - 4750	3	1.92	8.74
3	TH 36 at I-35E	WB	3.01	2.49 - 3.08	2800	2	2.72	8.19
4	TH 280 at I-35W	NB	2.86	4.17	2700 - 3250	2	1.28	3.66
5	I-94 and I-35E common	WB / SB	1.77	1.79 - 3.08	6800	3	1.92	3.40
6	TH 280 at I-35W	SB	2.87	2.95	2700 - 3250	2	1.08	3.10
7	TH 36 at I-35W	WB	1.12	1.73 - 2.05	2950	2	1.63	1.83
8	I-494 at TH 77	WB	1.60	1.78	5800 - 6400	3	1.12	1.79
9	I-94 near Lowry Tunnel	WB	0.83	1.62 - 1.76	4000 - 6300	3	1.78	1.47
10	TH 169 S. of TH 7	NB	1.16	2.13	4850	2	1.11	1.29
11	TH 61 2.5 Mile S I-494	NB	1.65	2.41	3700	2	0.67	1.11
12	TH 62 at I-35W	EB	0.79	3.53	2250	2	1.14	0.90
13	I-494 at I-35W	WB	0.83	1.39	8800	3	1.06	0.88
14	TH 169 S. of TH 7	SB	0.68	1.45	4850	2	1.27	0.86
15	I-94 near Lowry Tunnel	EB	0.28	1.97 - 2.14	4000 - 6300	3	2.88	0.80

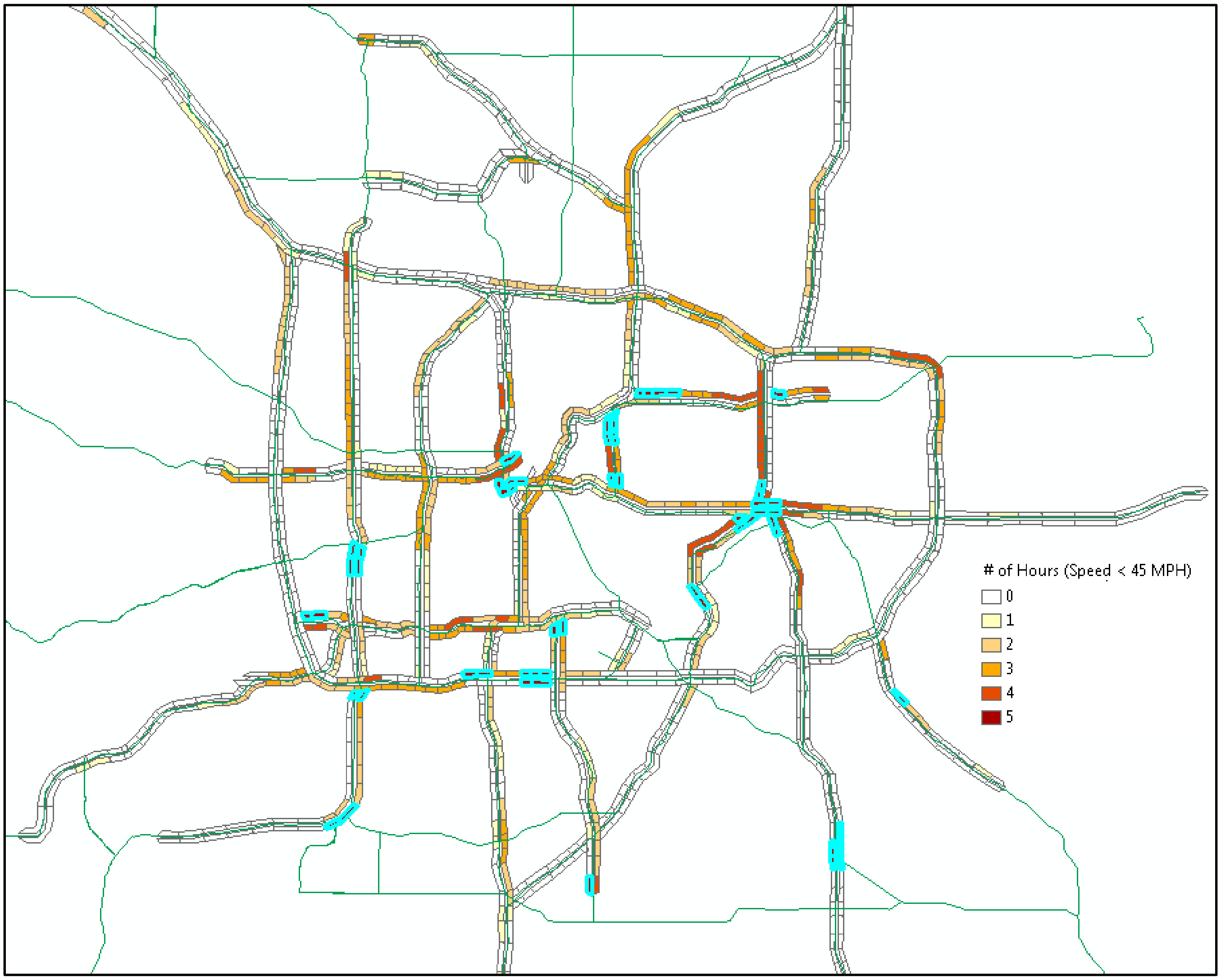

Figure 12 Map of Truck Bottleneck (Highlighted) with Average Speed ≤ 45 MPH for Over 5 Hours in AM Peak

Table 6 List of truck bottleneck in PM Peak (Based on # of Hours below 45 MPH)

Rank	Location	Dir.	PM Peak Delay (hours) / Mile	PM Peak Reliability RI80	HCAADT	# of Lanes	Length (miles)	PM Peak Delay (hours)
1	I-494 between I-35W & 169	EB	14.45	2.05 - 4.50	6800 - 9100	3	3.14	45.34
2	I-35W at I-694	NB	17.79	3 - 3.75	7200 - 8500	3	2.05	36.47
3	I-394 between downtown and TH 100	EB	4.96	1.93 - 3.75	2100 - 4200	3	4.78	23.69
4	I-94 between Lowry tunnel and TH 280	WB	4.51	2.35 - 3.25	4000 - 6300	3	5.02	22.63
5	I-35E at I-94	SB	5.32	1.50 - 22.5	6200 - 7900	3	2.4	12.76
6	I-35W at I-94	SB	6.79	1.98 - 5	3700 - 7100	3	1.84	12.48
7	I-694 at I-35W	WB	5.22	1.64	7300 - 11000	2	2.13	11.11
8	US52 at I-94	NB	3.94	2.42 - 4.33	4750 - 5200	3	2.18	8.59
9	I-35W at I-94	NB	3.04	1.61 - 2.45	8300	4	2.38	7.22
10	TH 36 at I-35W	EB	3.86	2.77	2550	3	1.78	6.87
11	I-94 at I-35E common	EB	2.98	1.87 - 2.84	6800	3	2.2	6.55
12	TH 62 between I-35W & TH 100	EB	2.01	3.00 - 3.28	2250 - 5200	2	2.81	5.65
13	TH 62 at TH 100	WB	3.40	2.04 - 2.81	2250 - 2450	2	1.65	5.62
14	I-35E at I-94	NB	2.63	1.56 - 3.27	6200 - 7900	3	1.89	4.97
15	I-494 between I-35W & 77	WB	1.41	1.55 - 2.14	6000 - 9000	3	3.25	4.60
16	TH 280 at I-35W	NB	2.75	3.30	2700 - 3250	2	1.28	3.52
17	TH 169 S. of TH 7	NB	2.75	2.5	4850	2	1.11	3.05
18	TH 280 at I-35W	SB	2.53	2.10 - 3.00	2700 - 3250	2	1.08	2.74
19	TH 77 at TH 62	NB	4.72	0	2000	2	0.53	2.50
20	TH 169 S. of I-494	SB	6.72	3.24	6000	2	0.34	2.29
21	TH 77 at TH 62	SB	5.38	0	2000	2	0.39	2.10
22	I-94 near Lowry Tunnel	EB	0.57	1.54 - 2.25	4000 - 6300	3	2.88	1.63
23	US52 at I-94	SB	1.76	1.73	4750 - 5200	2	0.92	1.62
24	I-694 at I-35W	EB	0.36	1.24 - 1.87	7300 - 11000	2	1.89	0.68
25	TH 169 S. of I-494	NB	0.86	1.67	6000	2	0.41	0.35

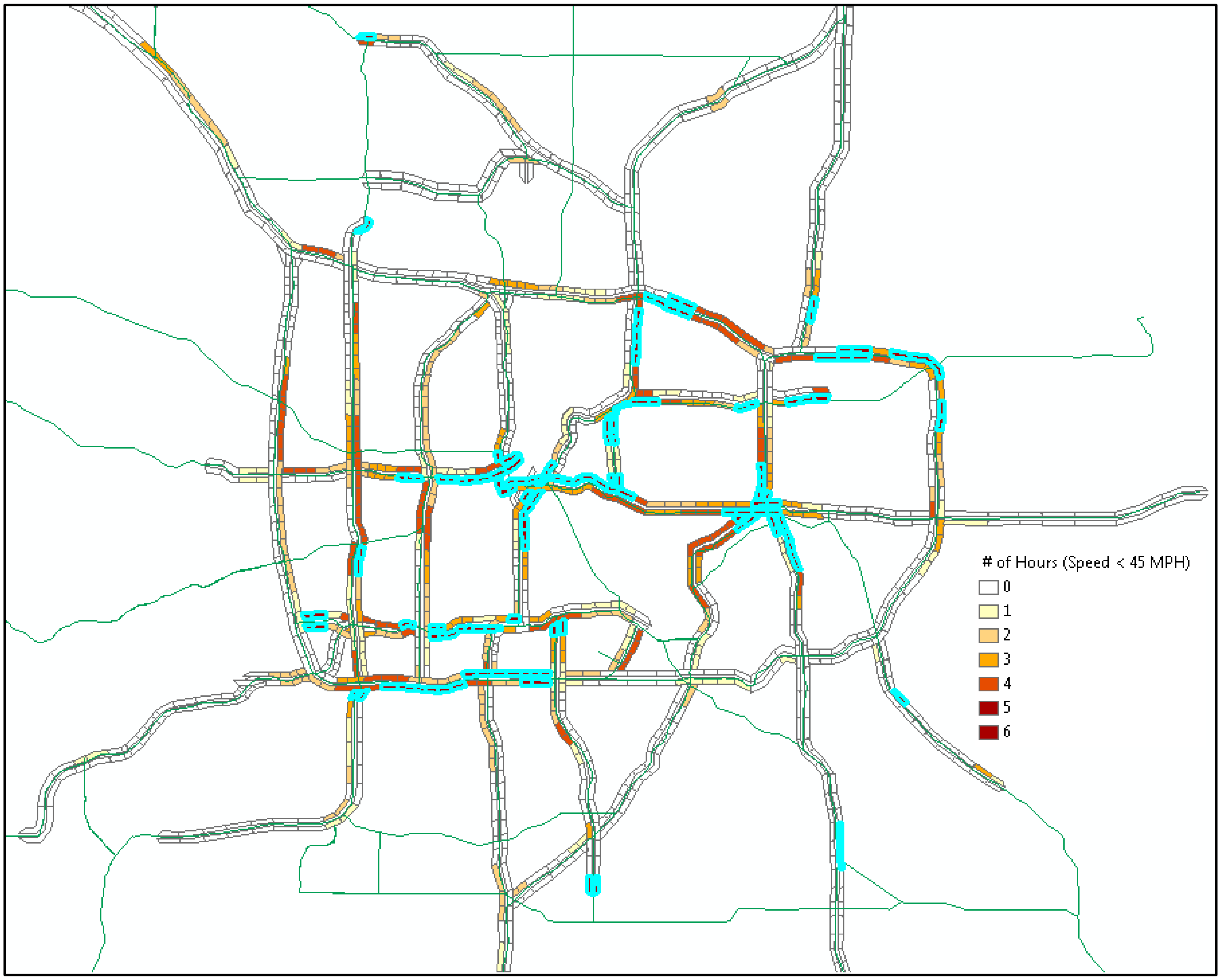

Figure 13 Map of Truck Bottleneck (Highlighted) with Average Speed ≤ 45 MPH for Over 5 Hours in PM Peak

Summary

Truck bottlenecks delay truck freight shipment and delivery. Delays induced by bottlenecks could negatively impact a region's economy and productivity. A few bottleneck identification techniques were briefly discussed. Highway interchange, lane drop, signal, and steep grade are typical factors contribute to traffic bottlenecks

This task generated truck performance measures, including mobility, delay and reliability, using the results from truck GPS data analysis. The performance measures were used to identify key freight corridors and truck bottlenecks in the TCMA. The research team first identified truck bottlenecks by comparing the average truck delay per mile in the studied network. In addition to delay based approach, the research team also evaluated truck bottlenecks based on number of hours in peak period with speed less than threshold speed. Both approaches listed over 12 locations in both AM and PM peak periods in the TCMA that cause truck delays.

References:

[1] Cambridge Systematics, (2005) An Initial Assessment of Freight Bottlenecks on Highways, A white paper prepared for Office of Transportation Policy Studies, http://www.fhwa.dot.gov/policy/otps/bottlenecks/, accessed December 2013.

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