SRF Consulting Group, Inc. | Engineers Planners Designers

Memorandum

SRF No. 11155

To: Mark Dierling, PE
SEH Inc.

From: Ryan Loos, PE

Date: August 6, 2018

Subject: 494: Airport to 169
Existing Traffic Conditions Memorandum

Introduction

Interstate (I)-494 is a major freeway corridor connecting communities to large employment and shopping centers at the Bloomington commercial strip along I-494 between TH 100 and 34th Avenue South, the Eden Prairie "Golden Triangle" business park located between United States Highway (US) 212, US 169, and I-494, the Eden Prairie Center Mall, Southdale Mall, the Mall of America, , and the Minneapolis-Saint Paul (MSP) International Airport. As the region has developed, highway traffic volumes have increased to the point that a number of segments along the corridors experience significant peak period congestion each day, including weekends.

The purpose of this memorandum is to document existing geometric, operational and reliability, and safety deficiencies that result in vehicle congestion and mainline queues. Congestion is expected to significantly increase by year 2040 as additional growth and development occur in the region and along the study corridors.

A number of resources were used to identify these deficiencies which include; the prior *I-494/TH 62 Congestion Relief Study*, the use of MnDOT's Regional Traffic Management Center (RTMC), the *Metropolitan Freeway System 2017 Congestion Report*, existing traffic and crash data made available through several MnDOT software programs (PeMS, Data Extract, Data Plot, MnCMAT, etc.).

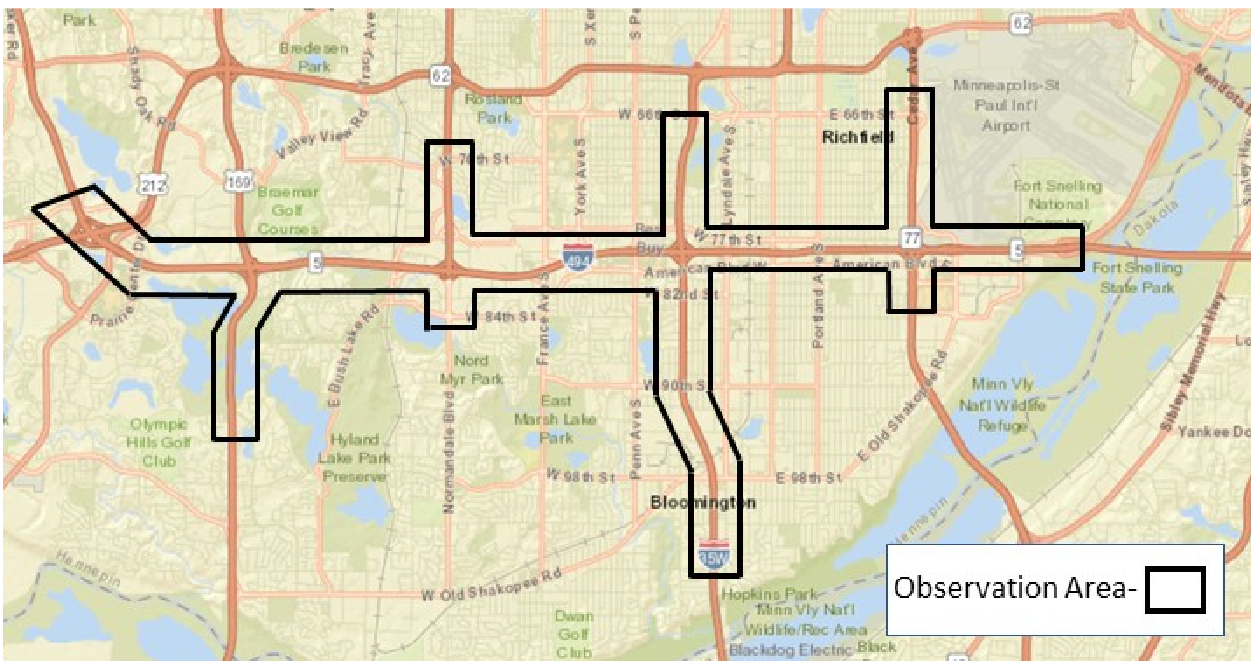
Understanding the existing operational issues along the I-494 south corridor is a critical component in determining the projects purpose and need and will aid in developing and evaluating potential future improvements.

Traffic Observations

SRF Staff visited MnDOT's Regional Traffic Management Center (RTMC) on April 25 and 26, 2018. These dates were chosen as they overlapped with turning movement count data collection activities occurring at the interchange intersection nodes. A tour of the facility and a tutorial was completed followed by a.m. and p.m. peak period observations. The closed caption freeway cameras located along the project corridor allowed staff to observe congestion including existing bottlenecks and mainline queueing while it developed.

Careful consideration was taken when selecting the geographical extents in which to make traffic observations. While the modeling limits are defined within the project scope, there may be areas outside of these limits that impact traffic operations within the study area. The areas observed are shown in Figure 1.

Figure 1. Traffic Observation Area



A.M. Peak Period Observations

A.M. peak period observations were conducted from 6:00 a.m. to 8:30 a.m. on Thursday, April 26, 2018. The following is a summary of observations made:

- Northbound I-35W to westbound I-494 queued back intermediately from 6:00 to 7:00 a.m., but cleared. This is a high heavy vehicle movement and queues mainly formed when there was a semi-tractor trailer moving slower on the loop. This movement would queue back to 86th Street at times.

- There was an incident on the right shoulder at the diverge of the northbound collector-distributor (CD) road from I-35W to westbound I-494 at 6:30 a.m. The incident slowed traffic down marginally, but queues did not develop.
- Westbound I-494 queued back from I-35W to Lyndale Avenue at 6:50 a.m. While northbound I-35W is added as an auxiliary lane, there is weaving occurs at this location due to the southbound I-35W on-ramp and Penn Avenue off-ramp downstream that causes congestion to the east.
- Northbound France Avenue to westbound I-494 on-ramp volume increases around 8:00 a.m. This additional volume merging onto I-494 is another cause of westbound congestion.
- Southbound I-35W ramp to westbound I-494 queued back onto I-35W mainline once westbound I-494 was congested. Queue extended as far south as 98th Street.
- An incident occurred at 6:45 a.m. that blocked the inside lane of eastbound I-494 at Stone Avenue. Another incident occurred later during the a.m. peak period, so for most of the a.m. peak observation period. These incidents metered eastbound traffic into the study area for most of the a.m. peak period.
- Eastbound I-494 congestion spilled back from the Penn Avenue on-ramp. The northbound France Avenue on-ramp and the lane drop to France Avenue also contributed to congestion continuing to build to the west of this location.
- Southbound TH 100 ramp to eastbound I-494 queues back onto TH 100 mainline to 70th Street. This is the result of the high volume making this movement (~1500 vehicles/hour).
- Eastbound I-494 operates as a 5-lane section where the TH 100 weave and buffer lane interact.
- Eastbound and westbound I-494 weave sections between East Bush Lake Road and TH 100 caused friction that resulted in slower speeds, especially in the eastbound direction due to the short weave distance.
- Eastbound Penn Avenue queued back onto I-494 at 8:40 a.m. for approximately one minute.
- Traffic on northbound TH 77 trying to get to westbound I-494 queues back on flyover due to ramp meter. There is also a lane drop after 12th Avenue where this traffic is required to merge in to mainline I-494 causing turbulence. Queues extend back to the lane drop at 24th Avenue.
- Isolated queues frequently develop at lane drop location at 24th Avenue.

P.M. Peak Period Observations

P.M. peak period observations were conducted from 2:30 p.m. to 6:00 p.m. on Wednesday, April 25, 2018. The following is a summary of observations made:

- Fatal crash in the eastbound direction of TH 212 west of Mitchell Road that resulted in traffic being metered to eastbound I-494 and westbound queues spilling back onto I-494 extending to TH 169 due to "rubber-necking".

- Eastbound I-494 congestion began at 2:45 p.m. due to the France Avenue on-ramp volume and off-ramp lane drop.

- Congestion on eastbound I-494 at 3:10 p.m. spilled back from the Penn Avenue on-ramp to France Avenue.

- Right lane congestion on eastbound I-494 to the west of I-35W. I-494 mainline traffic enters the auxiliary lane between Penn Avenue and I-35W prior to the gore point, which reduces the efficiency of the auxiliary lane.

- Eastbound I-494 congestion began at 4:15 p.m. at the Nicollet Avenue on-ramp merge point.

- I-35W northbound off-ramp to eastbound I-494 queued back to 82nd Avenue once the congestion from Nicollet Avenue reached the merge point.

- Eastbound I-494 congested conditions existed until TH 77 when a large volume exits to southbound TH 77. All of the vehicle making this movement need to weave over at least one lane with the 12th Avenue on-ramp traffic.

- Northbound France Avenue on-ramp merge to eastbound I-494 caused congestion to develop. The eastbound lane drop to France Avenue exacerbated the congestion.

- Southbound TH 100 to eastbound I-494 on-ramp queued back once the congestion from France Avenue reaches TH 100.

- Eastbound congestion on I-494 started to reduce at 5:00 p.m.

- Westbound I-494 congestion began at TH 100 due to the lane drop to northbound TH 100 and the traffic merging on from the two France Avenue on-ramps that needs to weave over.

- Westbound I-494 right-lane drops to the east of Portland Avenue. Traffic from TH 77 has to have merged by this point, which creates additional congestion.

- Westbound I-494 congestion spilled back to TH 5 and the northbound TH 77 to westbound I-494 became congested.

Congestion Causes

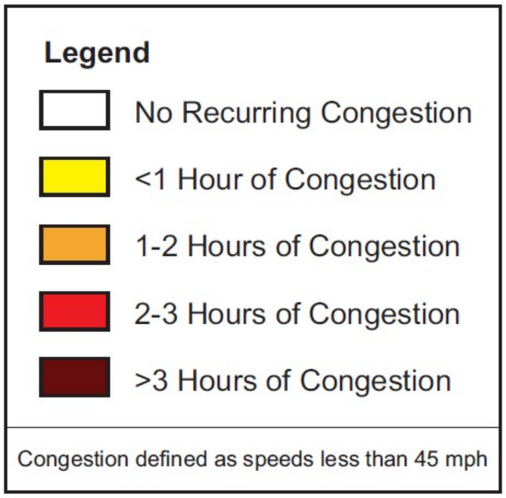
Data sources and existing operations analysis used to develop an understanding of the congestion causes affecting the study corridor is included the *System Problem Statement* technical memorandum completed as part of the *Congestion Management and Safety Plan Phase II* (2008) along with the *Metropolitan Freeway System 2017 Congestion Report* and information pulled from MnDOT's Data Extract and Data Plot programs.

MnDOT defines congestion as traffic flowing at speeds less than or equal to 45 miles per hour (MPH) in one or more lanes. Congestion is measured by two processes: surveillance detectors in roadways and field observations. MnDOT currently uses electronic surveillance systems in place throughout the I-494 study corridor.

A lack of roadway capacity (i.e., number of lanes) is not the only cause of recurring congestion. Often congestion may be caused by a downstream constraint, such as a large volume of entering or exiting traffic, a short weaving section, closely spaced interchanges, or a lane drop. The purpose of the existing operation assessment was to clearly identify the causes of congestion; development of solutions to the congestion causes will be accomplished as part of the alternative development stage of the study. These congestion causes will also be cross checked with other operational characteristics including safety, physical characteristics, and nonrecurring congestion. Nonrecurring congestion can be used to determine the influence of crashes, incidents, weather, and roadwork on study corridor operations.

Congestion Reports are freeway maps which display color coding corresponding to a certain number of hours of recurring congestion. The typical legend for congestion reports use a range of color coding; no color represents no recurring congestion while gradually moving to a dark color represents multiple hours of recurring congestion. An example of such a legend can be seen in Figure 2. As each congestion cause is discussed, a corresponding Congestion Report segment is presented using this legend. Data from the congestion reports was summarized using loop detector data from October 2017. Morning peak period congestion was aggregated from 5 to 10 A.M., and afternoon peak period data was aggregated from 2 to 7 P.M. More information can be found in the 2017 Metropolitan Freeway Congestion Report, available at http://www.dot.state.mn.us/rtmc/reports/congestionreport2017.pdf.

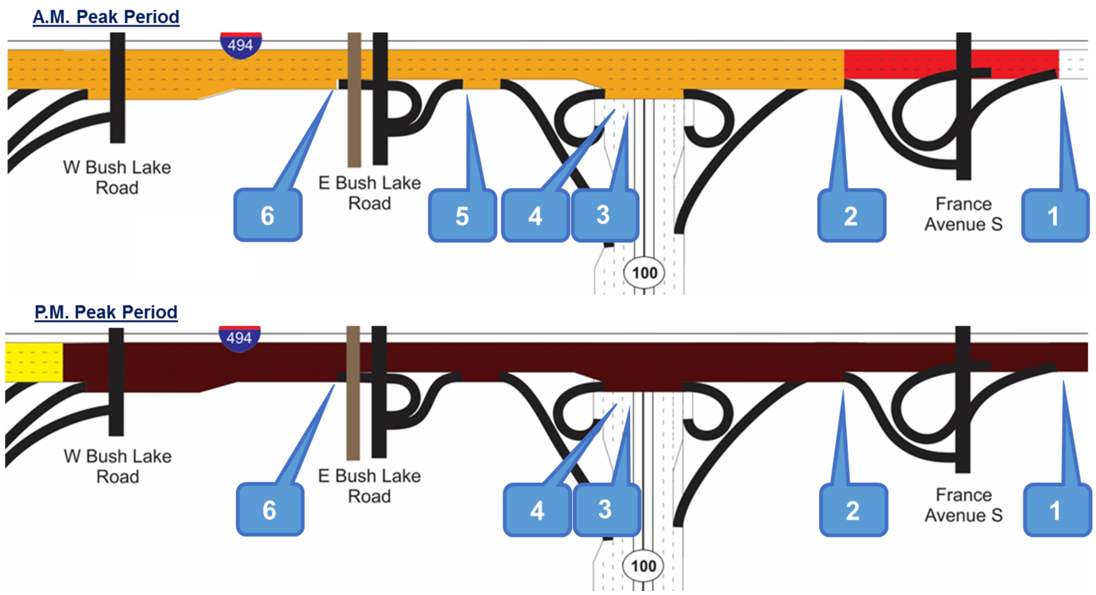
Figure 2. Congestion Report Legend Example



Often times segments of roadway experiencing congestion have multiple contributing issues. The analysis seeked to identify the primary cause in each of these instances, or the most downstream/first point of failure that started generating a bottleneck. Subsequent congestion causes upstream of the primary congestion point compound congestion issues. In the section below, primary congestion causes are identified as (Primary Cause of Congestion) after the congestion cause label.

Eastbound I-494

East Bush Lake Road to France Avenue



Congestion Cause 1 (Primary Cause of Congestion):

Entering traffic from France Avenue puts the eastbound I-494 mainline over capacity. This area is congested between two and three hours in the A.M. peak period, and more than three hours in the P.M peak period.

Congestion Cause 2:

The lane drop on eastbound I-494 at France Avenue does not carry a full lane's worth of traffic. The demand for the remaining three through lanes exceeds capacity. This area is congested between one and two hours in the A.M. peak period, and more than three hours in the P.M peak period.

Congestion Causes 3 and 4:

Entering traffic from southbound TH 100 combined with the substandard geometry of the buffer lane design and driver expectation to have to merge (from southbound TH 100) with mainline traffic instead of using the provided auxiliary lane is affecting the eastbound I-494 mainline operation. This area is congested between one and two hours in the A.M. peak period, and more than three hours in the P.M peak period.

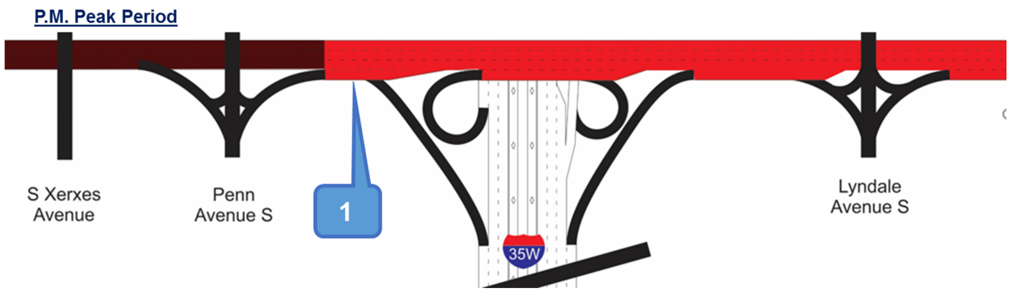
Congestion Cause 5 (A.M. Peak Period Cause Only):

Entering traffic from East Bush Lake puts the eastbound I-494 mainline over capacity, with a short weave distance to southbound TH 100 (350 feet). This area is congested between one and two hours in the A.M. peak period.

Congestion Cause 6:

The lane drop on eastbound I-494 at East Bush Lake Road does not carry a full lane's worth of traffic. The demand for the remaining three through lanes exceeds capacity. Additionally, vehicles have been observed using this lane to bypass queues and are merging in before the exit. This area is congested between one and two hours in the A.M. peak period, and more than three hours in the P.M peak period.

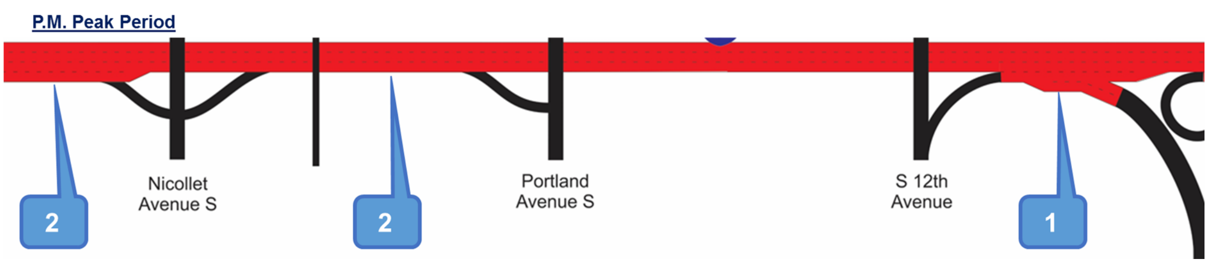
France Avenue to I-35W



Congestion Cause 1:

A combination of issues causes the congestion on eastbound I-494 heading into the I-35W interchange. There is a large amount of entering volume from Penn Avenue and an equally large exiting volume to southbound I-35W. The combination of entering and exiting volume downstreatm generates a large amount of weaving in this short 700 foot section section that is already near capacity. This area is congested between two and three hours in the P.M. peak period.

I-35W to TH 77



Congestion Cause 1 (Primary Cause of Congestion):

A combination of issues causes the congestion on eastbound I-494 heading into the TH 77 interchange. There is a large amount of entering volume from 12th Avenue and a larger exiting volume to southbound TH 77. The combination of entering and exiting volume downstreatm generates a large amount of weaving in this difficult section where exiting traffic has to make at least one lane change. Additionally, the volume exiting to southbound TH 77 is characterized by poor lane utilization with vehicles stacking in the right lane which occasionally backs up onto eastbound

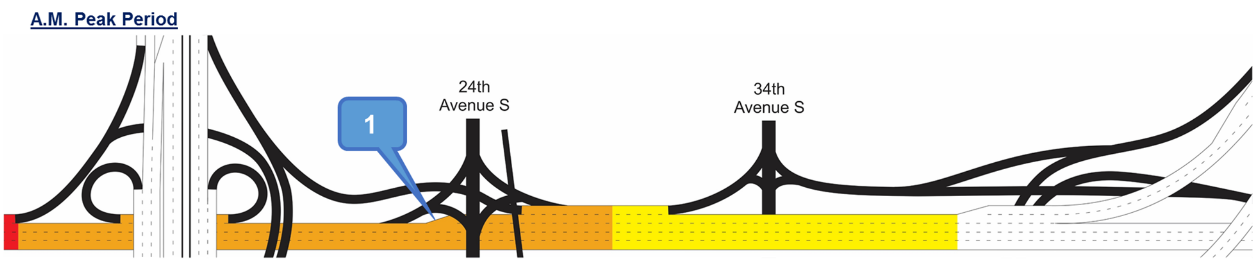
I-494, which affects mainline operation. This area is congested between two and three hours during the P.M. peak period.

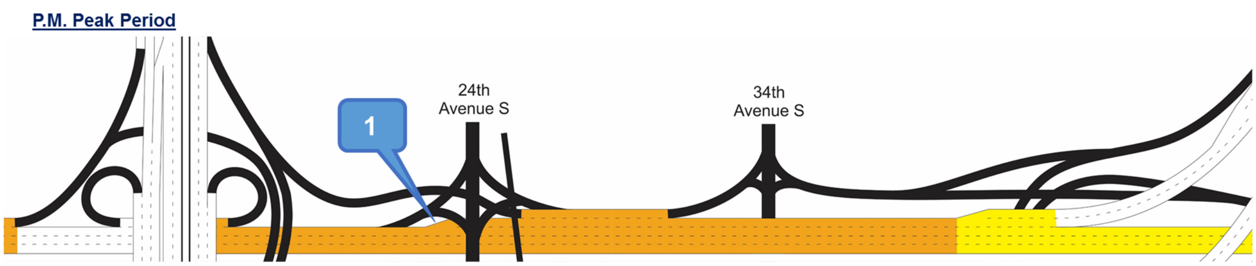
Congestion Cause 2:

Entering traffic and ramp to ramp weaving occurs between ramps of the interchanges of eastbound I-494 and I-35W, Lyndale Avenue, Nicollet Avenue, Portland Avenue, and TH 77. This area is congested between two and three hours during the P.M. peak period.

Westbound I-494

TH 5 to TH 77



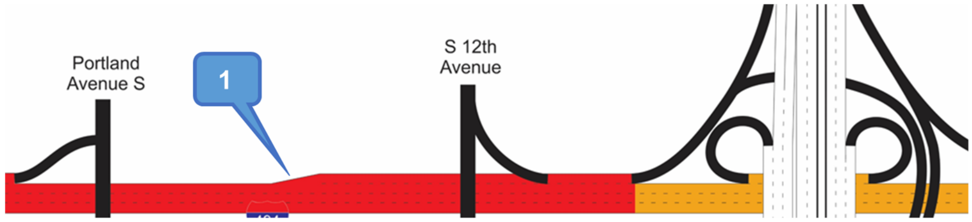


Congestion Cause 1:

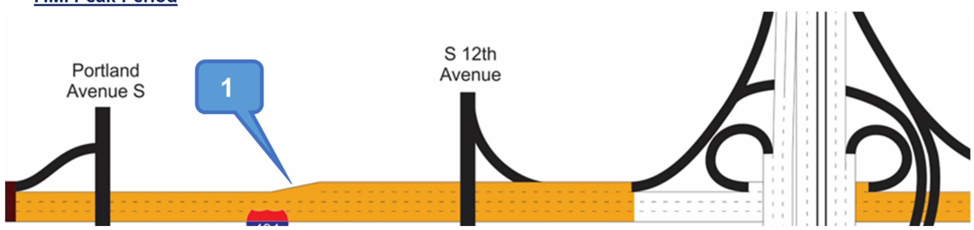
The lane drop on westbound I-494 after the 24th Avenue exit puts the mainline at capacity. This area is congested between one and two hours in the A.M. peak and P.M. peak periods.

TH 77 to Portland Avenue

A.M. Peak Period



P.M. Peak Period

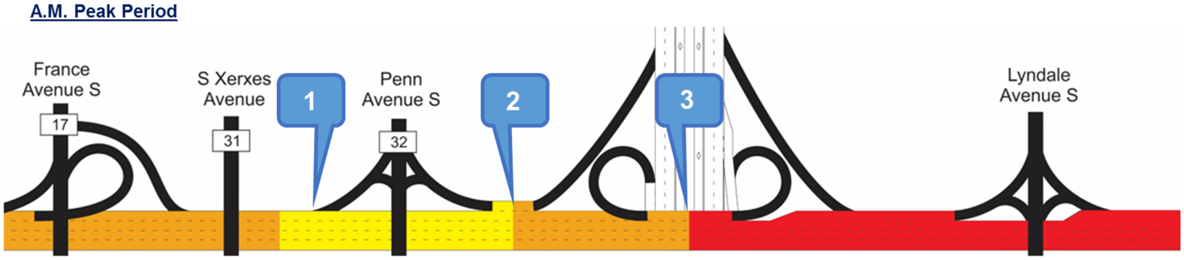


Congestion Cause 1:

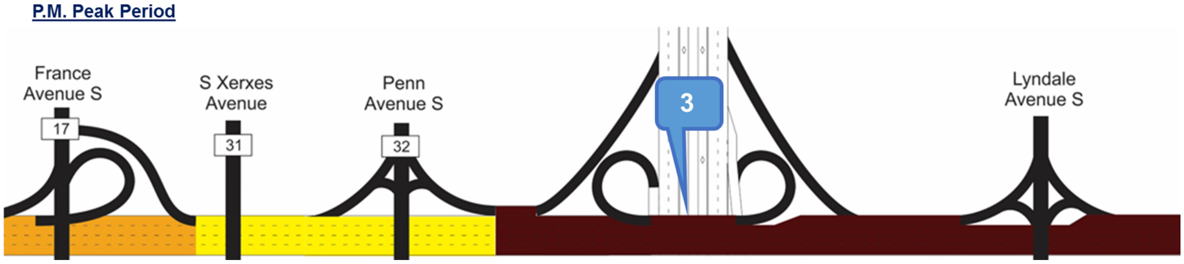
The lane drop on westbound I-494 after the 12th Avenue exit puts the mainline at capacity. All of the entering traffic from TH 77 has to merge by this point. This area is congested between two and three hours in the A.M. peak period, and one and two hours in the P.M. peak period.

Portland Avenue to Penn Avenue

A.M. Peak Period



P.M. Peak Period



Congestion Cause 1 (A.M. Peak Causes Period Only):

Entering traffic from Penn Avenue puts the westbound I-494 mainline over capacity. This area is congested less than one hour in the A.M. peak period.

Congestion Cause 2(A.M. Peak Period Cause Only):

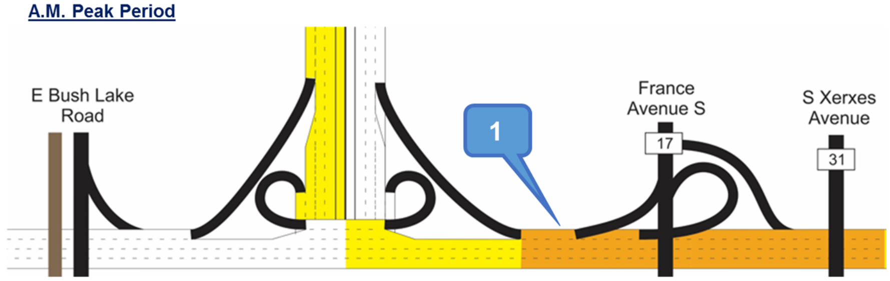
A combination of issues causes congestion on westbound I-494 between the Penn Avenue interchange and I-35W interchange. There is a large amount of entering traffic from southbound I-35W. Additionally there is a moderate amount of volume of traffic destined to exit to Penn Avenue. The combination of large entering volume, and immediately down stream exiting traffic generates a large amount of weaving in this section that has substantial number of lanes and volume. This area is congested between one and two hours in the A.M. peak period.

Congestion Cause 3 (Primary Cause of Congestion):

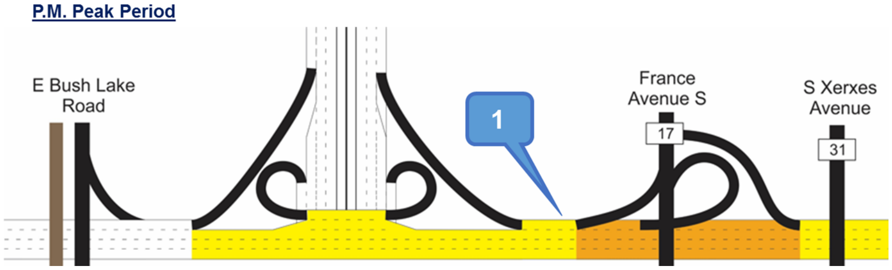
Ramp to ramp weaving occurs between the northbound I-35W entrance and the southbound I-35W exit creating an over-capacity weave segment between the interchange loops. There is also a high volume of trucks involved in this movement further compounding the issue. This area is congested between two and three hours in the A.M. peak period, and over three hours in the P.M. peak period.

France Avenue to TH 100

A.M. Peak Period



P.M. Peak Period



Congestion Cause 1:

A combination of issues causes the congestion on westbound I-494 near the TH 100 interchange. Entering traffic from France Avenue puts the westbound I-494 mainline over capacity. Additionally there is a large volume of traffic destined to exit for TH 100 northbound, after the exit for northbound TH 100 the mainline drops from four lanes to three. The combination of entering volume exceding mainline capacity, and large exiting volume downstreatm generates a large amount of weaving in this section that is already over capacity. This area is congested between one and two hours in the A.M. and P.M. peak periods.

Existing Safety Analysis

A crash safety analysis was performed on I-494 between TH 169 and TH 5 to identify interchanges and segments with above critical crash rates and additional trends for existing conditions. The analysis incorporated three years of crash data (2015-2017) from MnDOT's Minnesota Crash Mapping Analysis Tool (MnCMAT), which includes the location, start time, and severity of crashes.

Two separate analyses were completed, one focused on crashes within interchanges and another for the I-494 mainline segments between the interchanges. Methodologies for calculating the crash rates for each analysis and resulting conclusions are discussed in the following sections.

Methodology

The I-494 corridor between TH 169 and TH 5 was divided into 14 interchanges and 24 segments (12 in each direction). Interchanges generally run east/west from gore to gore and north-south to include all entrance and exit ramps along with a 100-foot buffer. Interchanges are assigned crashes along the I-494 mainline, entrance/exit ramps, as well as crashes along the cross street/freeway. Crash rates are calculated based on the number of crashes and number of vehicles entering the interchange annually (2016 Annual Average Daily Traffic (AADT) from each approach). These methodologies are consistent with MnDOT's 2015 Interchange Crash Toolkit.

The segments generally connect two adjacent interchanges and therefore, vary in length. In one case, between TH 77 and 24th Avenue, there was insufficient length (< 0.1 mile) between the interchanges to insert analysis segments. Crashes were assigned to either the TH 77 or 24th Avenue interchanges. Crash rates for I-494 mainline segments are calculated separately for each direction and include the number of crashes, directional AADT and the length of the segment. This allows the segments of varying lengths to be compared so long as the segment length is greater than 0.1 mile.

"Critical crash rate" is a metric used throughout this memorandum as a reference point for comparing the severity of crash rates. Critical crash rates are calculated separately for interchanges and segments and rely on an average system rate. For interchanges, the average system rate used was the statewide average crash rate from the 2015 Interchange Crash Toolkit (2013-2015 crash data). The average crash rates for segments came from the 2015"Sections Green Sheets" value for an urban freeway with three years of data.

As noted in the MnDOT Traffic Engineering Manual, Chapter 11, "critical crash rates provide a statistical threshold for screening sites. The critical rate is calculated by weighting the average crash rate for similar intersections or segments across Minnesota by the existing traffic volume. The critical CR is calculated at a 99.5% confidence interval (K = 2.576)."

Segment Crash Summary

The following two stacked bar charts break down the segment crash rates by crash type. The majority of crashes are rear end crashes, followed by sideswipe passing crashes, both of which are commonly caused by congestion. Note that segment lengths vary, so the absolute number of crashes for each segment is not reflective of the segment's crash rate.

Figure 1 - Eastbound Segment Crash Types

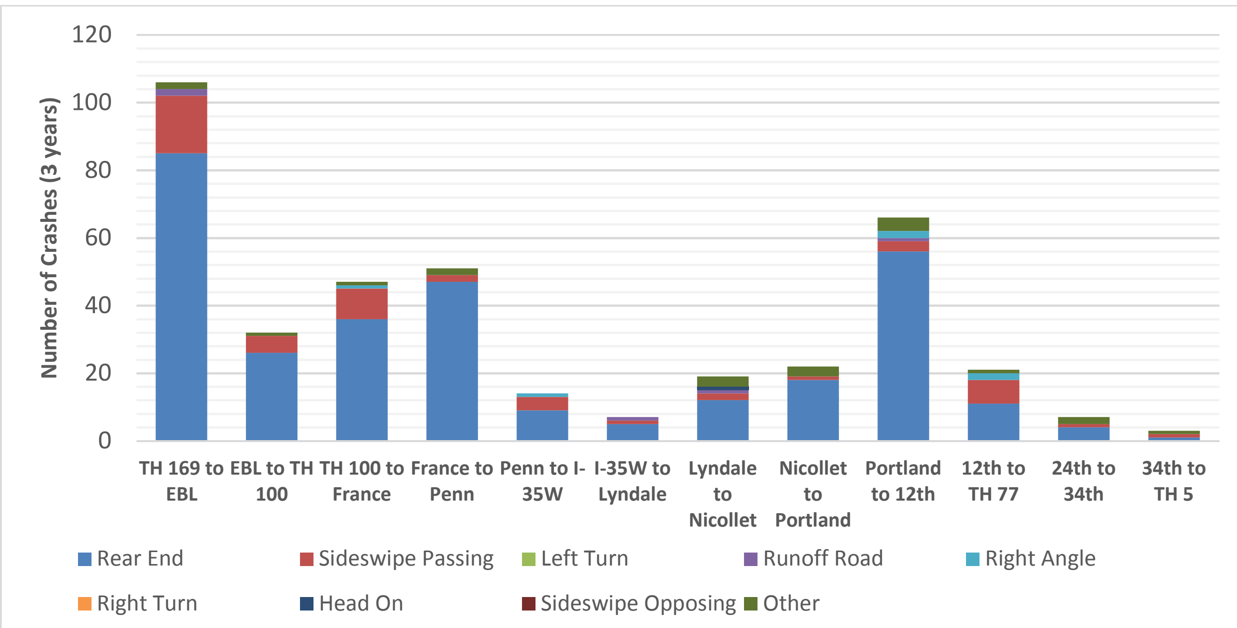
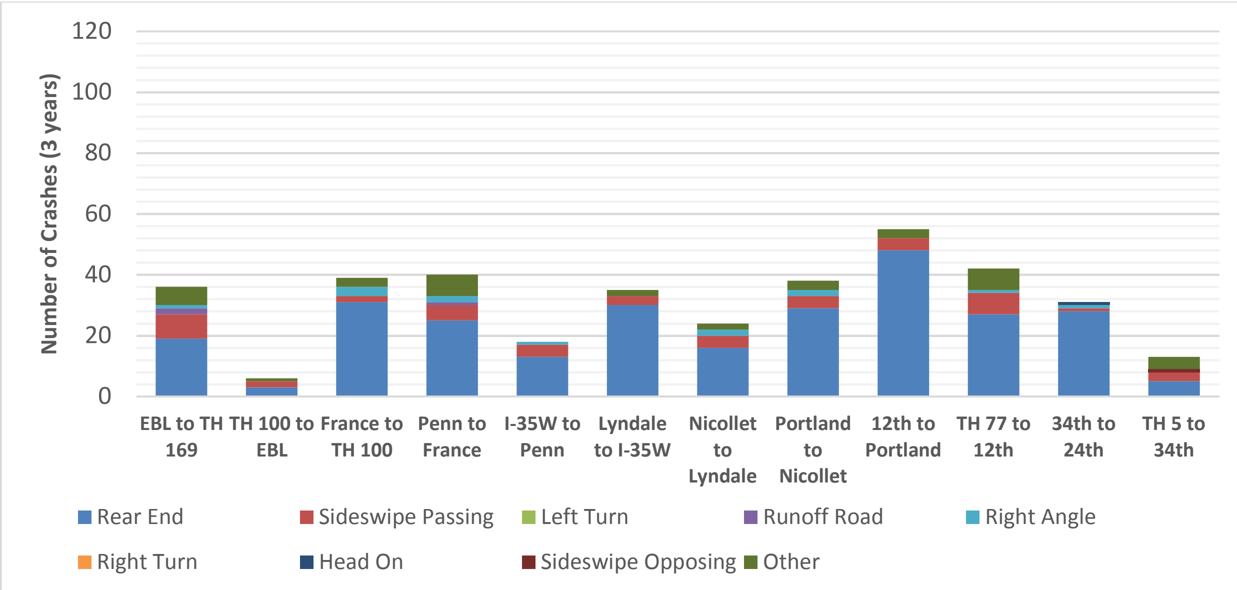


Figure 2 - Westbound Segment Crash Types



The following tables provide the number of crashes by severity, segment length, and resulting crash rate for each segment. The Green Sheet average crash rate for an urban freeway is 0.90 and the calculated segment critical crash rate is 1.79. Above critical crash rates are bolded in red.

Table 1 – Eastbound Segment Crash Summary

Segment	Length (Miles)	Crash Severity					Total Crashes	Crash Rate (per mil vehicles)
		K	A	B	C	PD		
TH 169 to EBL	1.0	-	-	2	14	90	106	1.3
EBL to TH 100	0.2	-	-	-	3	29	32	**2.2**
TH 100 to France	0.6	-	-	-	7	40	47	0.9
France to Penn	0.6	-	-	2	12	37	51	1.1
Penn to I-35W	0.1	-	-	1	1	12	14	1.2
I-35W to Lyndale	0.1	-	-	-	-	7	7	0.6
Lyndale to Nicollet	0.2	-	-	2	4	13	19	1.0
Nicollet to Portland	0.2	-	-	2	2	18	22	1.6
Portland to 12th	0.4	-	-	4	12	50	66	**2.3**
12th to TH 77	0.2	-	-	1	1	19	21	1.2
24th to 34th	0.3	-	-	1	-	6	7	0.4
34th to TH 5	0.2	-	-	1	1	1	3	0.2

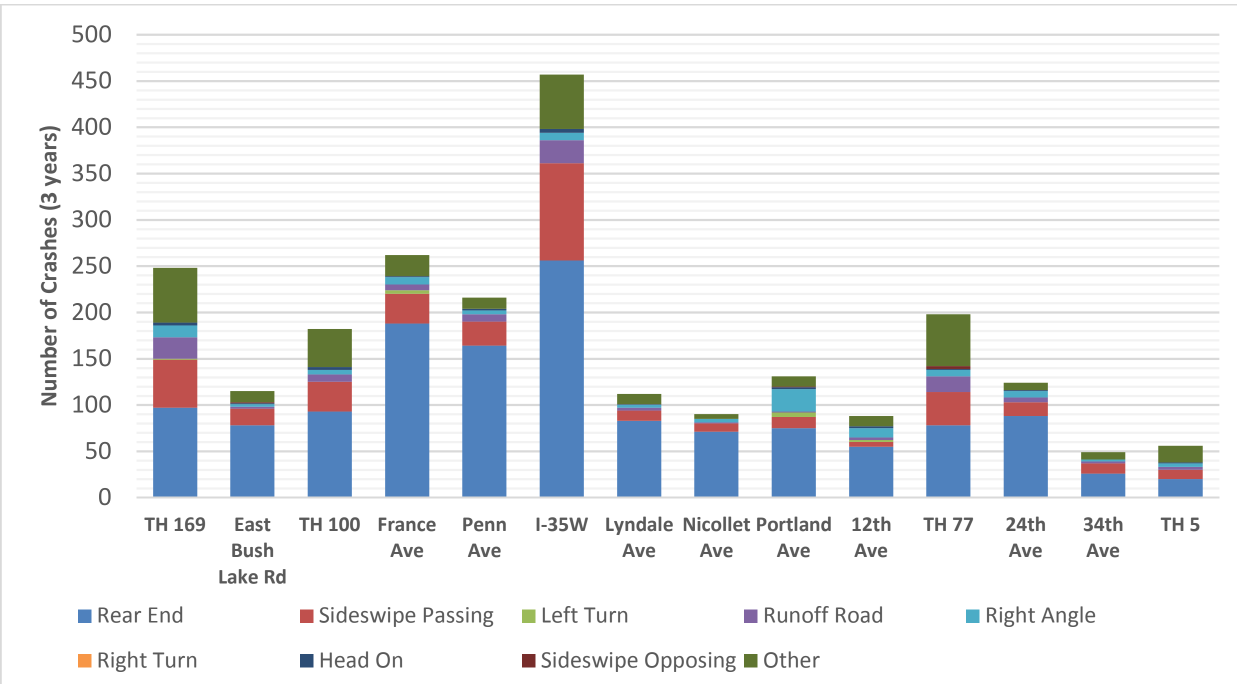
Table 2 - Westbound Segment Crash Summary

Segment	Length (Miles)	Crash Severity					Total Crashes	Crash Rate (per mil vehicles)
		K	A	B	C	PD		
TH 5 to 34th	0.2	1	-	1	2	9	13	0.8
34th to 24th	0.3	-	-	5	4	22	31	1.6
TH 77 to 12th	0.2	-	1	4	6	31	42	**2.3**
12th to Portland	0.4	-	1	4	8	42	55	**1.8**
Portland to Nicollet	0.2	-	-	2	3	33	38	**2.7**
Nicollet to Lyndale	0.2	-	-	-	1	23	24	1.2
Lyndale to I-35W	0.1	-	-	3	6	26	35	**3.0**
I-35W to Penn	0.1	-	-	-	3	15	18	1.3
Penn to France	0.6	-	-	2	9	29	40	0.8
France to TH 100	0.6	-	-	1	6	32	39	0.7
TH 100 to EBL	0.2	-	-	-	1	5	6	0.4
EBL to TH 169	1.0	-	-	3	6	27	36	0.4

Interchange Crash Summary

The following stacked bar chart summarizes the interchange crashes by type. Compared with the segments, there is a wider variety of crash types within the interchanges (greater proportion of non rear-end and sideswipe passing crashes). I-35W stands out with nearly double the number of crashes compared to the next highest at France Avenue.

Figure 3 - Interchange Crash Types



The following table provides the number of crashes by severity for each interchange along with the resulting crash rate. The statewide average intersection crash rate is 0.890, with a calculated critical crash rate of 0.936. Above critical crash rates are bolded in red.

I-35W and France Avenue have the greatest number of crashes and also the highest crash rates, accounting for the total number of vehicles entering the interchange.

Table 3 - Interchange Crash Summary

Interchange	Crash Severity					Total Crashes	Crashes on I-494 Mainline	Crash Rate (per mil vehicles)
	K	A	B	C	PD			
TH 169	1	1	16	19	211	248	109	1.0
East Bush Lake Rd	-	1	8	12	94	115	95	0.6
TH 100	-	-	13	19	150	182	91	0.8
France Ave	-	-	11	41	210	262	192	1.3
Penn Ave	-	1	6	43	166	216	173	1.0
I-35W	-	1	29	65	362	457	141	1.6
Lyndale Ave	-	1	9	14	88	112	91	0.6
Nicollet Ave	-	1	2	9	78	90	68	0.5
Portland Ave	-	0	10	27	94	131	82	0.9
12th Ave	-	1	7	24	56	88	63	0.6
TH 77	-	1	9	19	169	198	69	1.1
24th Ave	-	-	8	17	99	124	99	0.8
34th Ave	-	-	4	12	33	49	24	0.3
TH 5	-	1	6	8	41	56	33	0.4

Interchange crashes were reviewed to identify trends and possible causes. The following factors were analyzed for the five interchanges with above critical crash rates, including US 169, France Ave, Penn Ave, I-35W, and TH 77.

- Crash location – roadway direction, relation to interchange (mainline, ramps, etc.), and concentration based on latitude/longitude
- Road circumstance (road surface condition, congestion backup due to non-recurring incident, congestion backup, etc.)
- Driver contributing factor (following too closely, speeding, negligence, etc.)
- Driver pre-crash maneuver (moving forward, slowing, negotiating curve, etc.)

There were several specific locations within the five interchanges which generated a greater number of crashes. In most cases, these concentrations of crashes appear related to mainline congestion stemming from the I-494/I-35W interchange. Specifically, EB I-494 shows a high concentration of crashes just west of the Penn Ave bridge. Heading WB, the I-494 mainline experiences a high concentration of crashes between the I-35W exit ramps. Similarly, I-35W has high concentrations of crashes heading SB approaching the WB I-494 exit ramp and NB approaching the EB I-494 exit ramp and near the CD road.

The review of other crash parameters, including road circumstance, driver contributing factor, and driver pre-crash maneuver also suggests congestion as the greatest influence of crashes and not specific interchange-related geometrics. This aligns with the large prevalence of rear-end crashes along the entire corrido, but particularly in areas upstream of the I-494/I-35W interchange.

MnDOT's 2015 Interchange Crash Toolkit was also sorted by crash cost and it was found that three of the interchanges in this corridor were in the top 20 of interchange crash costs state-wide. I-35W, Penn Avenue, and France Avenue ranked seventh, thirteenth, and fourteenth, respectively.

Severe Crashes

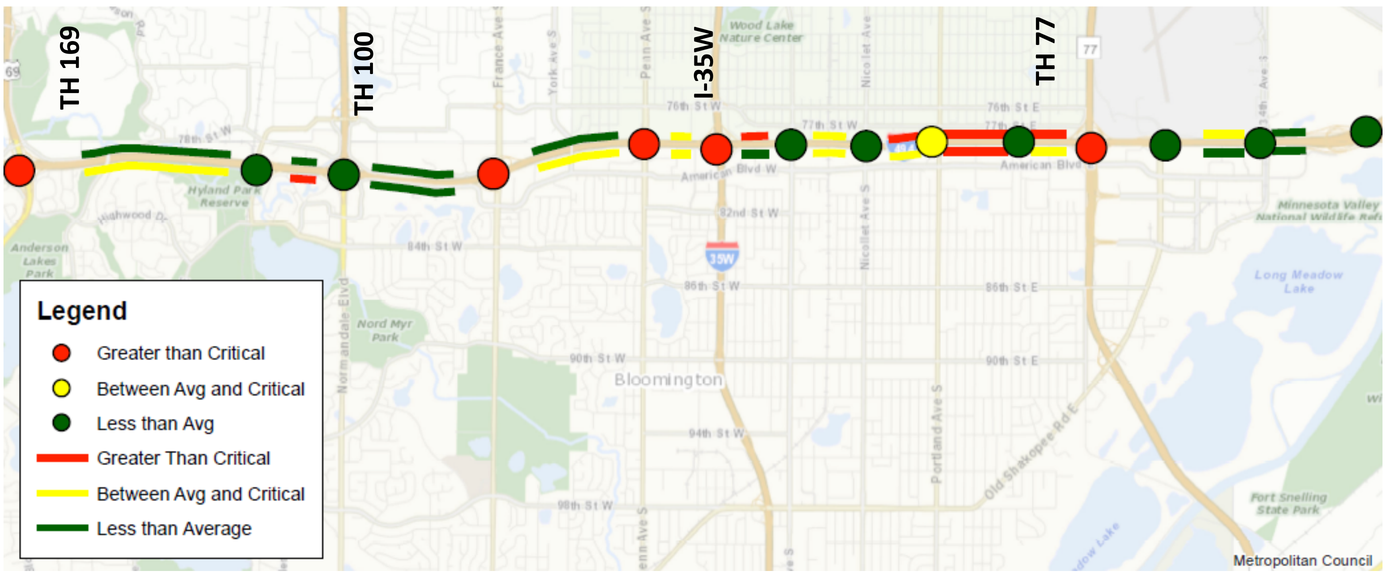
In the three years of analyzed crash data, there were 14 severe cashes, two being fatal and 12 type A crashes. The TH 169 interchange was the only interchange or segment to have more than one severe crash occurrence in the three years of data. One of the TH 169 severe crashes was caused by a driver operating in a careless/negligent manner with another having vision obstructed by sun or headlights. All but two of the 14 severe crashes were caused by careless/negligent operation, excessive speed, disregard for traffic signs, failure to yield, distraction, or following too closely. The cause of the other two severe crashes were noted as other or obscured vision.

Results Summary

Figure 4 provides a summary of the crash rates for each of the interchanges and segments. Crash rates are categorized as:

- Green – Less than Average
- Yellow – Between Average and Critical
- Red – Greater than Critical

Figure 4 – Crash Rates



Five of the 14 interchanges (~35%) have above critical crash rates, while six of the 24 segments (25%) are above critical. Crash rates on eastbound segments generally increase approaching interchanges and drop just downstream of the interchange. Westbound segments, on the other hand, have the highest crash rates between TH 77 and I-35W, with most other segments below average.

Safety Findings and Conclusions

The crash analysis of segments and interchanges along I-494 between TH 169 and TH 5 using three years (2015-2017) of MnCMAT crash data resulted in the following key findings:

- I-35W interchange has nearly double the amount of crashes than the next highest interchange on the corridor. While it has the highest entering volume, it's crash rate is still the highest by over 20%. In addition to serving as a congestion bottleneck, the I-35W interchange poses safety issues, including one severe crash in the three-year dataset.

- 35% of interchanges and 25% of segments exceed critical crash rates. The high percentage of above critical crash rates suggests safety issues exist corridor-wide.

- Eastbound crash rates are highest just upstream of system interchanges, largely from rear-end crashes. These mostly rear-end crashes are the result of the congestion bottlenecks at the interchanges. Improving operations at the interchanges should also help reduce crash rates.

- Westbound crash rates are highest between TH 77 and I-35W. This is the most congested westbound segment and sees varying queues stemming from the I-35W interchange. Similar to eastbound, these crashes are largely congestion caused by either end-of-queue or stop-and-go rear-end collisions.

- High concentration of severe crashes between Penn Avenue and TH 77. Given the recurring congestion in this area, this is a bit surprising, however, high speed differentials between lanes may occur during certain hours of the day, particularly in the shoulders of the peak periods.

Existing Reliability Analysis

Reliability is an emerging area of transportation evaluation that considers the variability in travel times that occur due to weather, crashes and other non-recurring conditions. Historical traffic measures often focus on average congestion but ignore variability. Travel time reliability is important because the more travel times vary on a given route, the earlier travelers must leave to ensure on-time arrival. A congested but consistent commute is easier to plan for than a less congested but unreliable commute. The purpose of the reliability analysis for this project is to understand the reliability measure of the corridor and the factors contributing to unreliable conditions.

This memorandum documents the reliability analysis conducted for the I-494 Bloomington Strip Project. Reliability results were developed using 2017 travel time, volume, crash, incident, short-term roadwork and weather data. This memorandum presents the data sources and methodology used in the analysis, and the results and key findings of the evaluation.

Data Sources

Data for the reliability analysis was obtained from a variety of sources. Travel time and volume data were obtained from MnDOT loop detectors. Weather data was obtained from the National Oceanic and Atmospheric Administration (NOAA). Crash data included Minnesota Department of Public Safety (DPS) crash records accessed through the Minnesota Crash Mapping Analysis Tool (MnCMAT) and records from the Regional Transportation Management Center's (RTMC) IRIS software. Incident and short-term roadwork data were also gathered from IRIS records. Short-term roadwork data generally includes maintenance operations which last less than one day.

Methodology

To fully understand travel time reliability under existing conditions, one year of travel time, volume, incident, crash, short-term roadwork and weather data was aggregated into 15-minute bins.

The corridor was divided into nine segments with five segments in the eastbound direction and four segments westbound. The segments are generally divided at system interchanges, beginning just downstream of the entrance ramps and continuing through the following system interchange to the beginning of the next segment. This is meant to capture the effects of interchange bottlenecks within the upstream segment.

I-494 Eastbound:

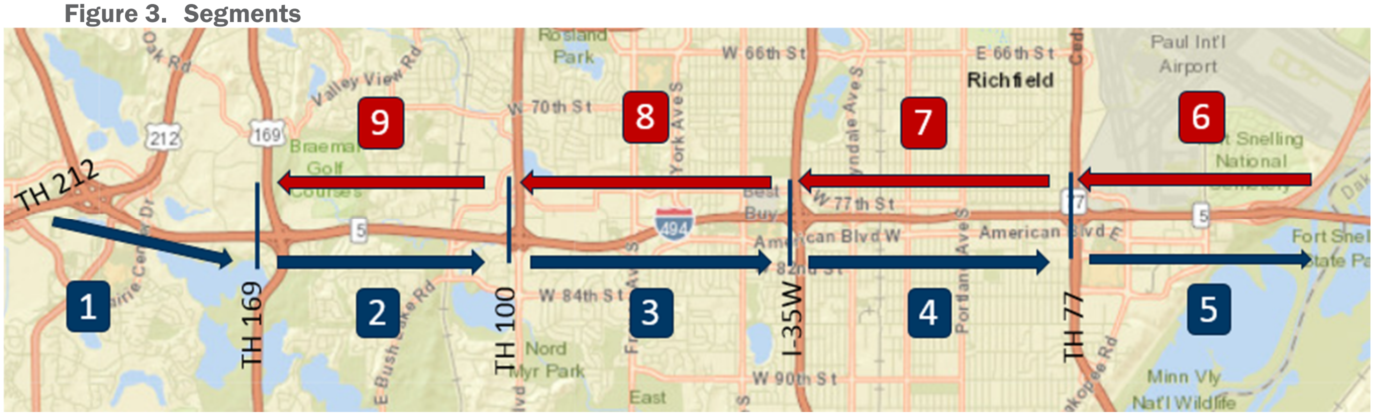
1. TH 212 to TH 169
2. TH 169 to TH 100
3. TH 100 to I-35W
4. I-35W to TH 77
5. TH 77 to TH 5

I-494 Westbound:

6. TH 5 to TH 77
7. TH 77 to I-35W
8. I-35W to TH 100
9. TH 100 to TH 169

The figure below shows the corridor segments.

Figure 3. Segments

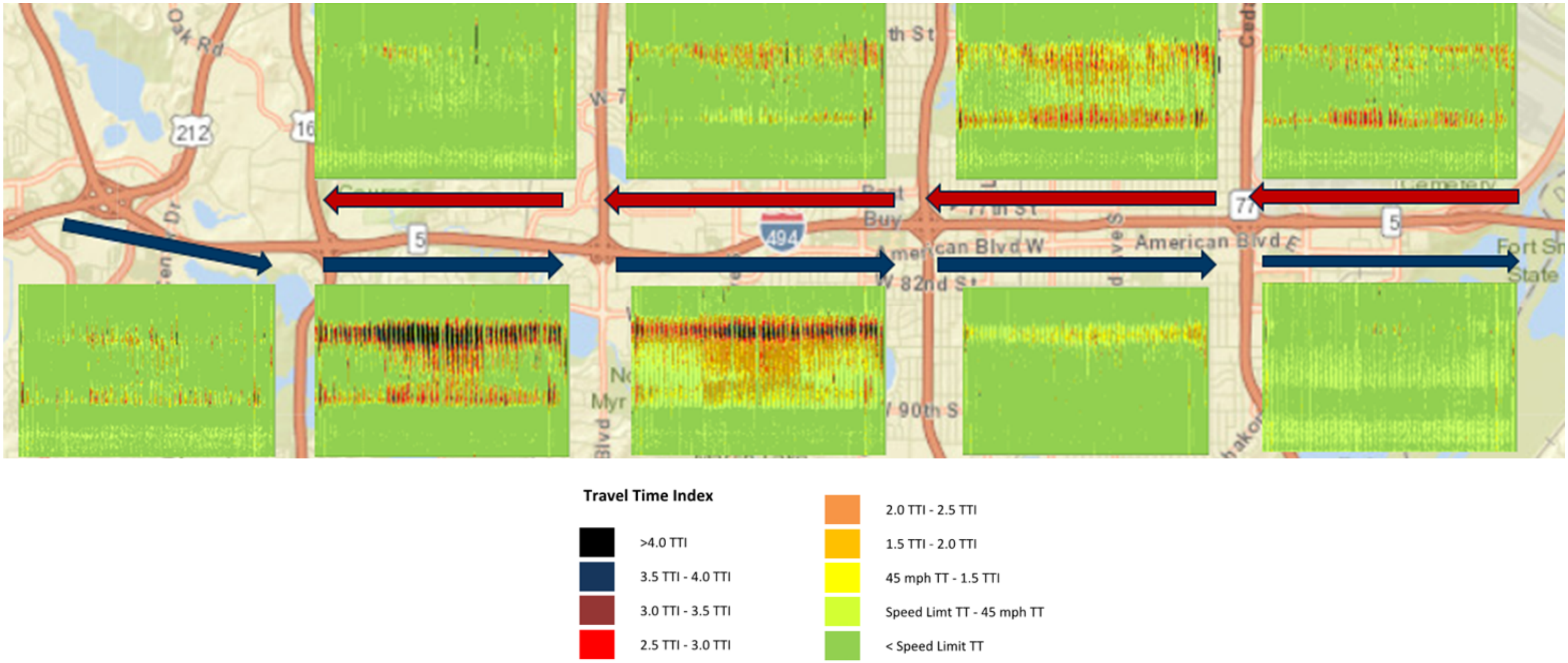


Results

Travel Time Heatmaps

Travel time heatmaps provide a visual representation of travel times along a segment every 15 minutes for an entire year. With time of day on the y-axis and day of year on the x-axis, the heatmaps provide a very useful overview of travel patterns on the segment. One can observe recurring peak period congestion, seasonal variations, and days affected by non-recurring factors. The heatmaps are color-coded by travel time index (TTI) which is the ratio of the observed travel time to the free-flow travel time. Travel time heatmaps are provided for each segment along the corridor in the following figure, with full size heatmaps available in the appendix.

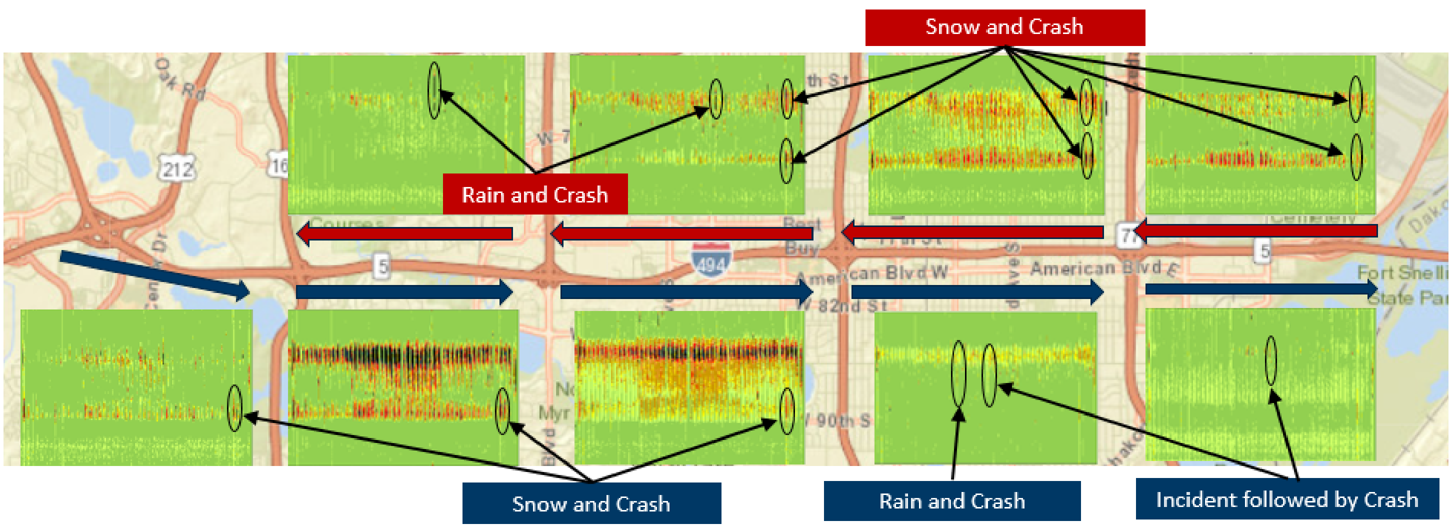
Figure 4. Travel Time Heatmaps



In both the eastbound and westbound directions, the I-35W interchange is the primary bottleneck, with congestion in both the AM and PM peak periods as well as midday in several segments. Downstream of I-35W, conditions are less congested, however, there is still recurring congestion leading up to the TH 77 interchange in the eastbound direction and TH 100 interchange in westbound. Several segments also show increased congestion during the summer months where TTIs over 1.5 span the midday, and most severe conditions in the peak periods grow in duration.

Severe non-recurring events can be observed across several segments from the travel time heatmaps. Several examples are illustrated below, such snow and rain events combined with crashes as well as an incident followed by a crash. These events are severe enough to cause congestion in upstream segments, particularly when combined with recurring peak period congestion as the segments lack the capacity to adapt to the non-recurring events without causing long queues.

Figure 5. Non-recurring Events Affecting Multiple Segments



Travel Time Thermometers

Travel time thermometers provide a representation of the typical variability in travel times experienced by a user along the corridor during peak periods. There are 20 increments for each thermometer representing percentiles ranging from the 2.5-th to 97.5-th with five percent increments. These increments were selected to represent 20 typical peak period commutes that may occur within one month (5 days/week times 4 weeks). For example, the 2.5-th percentile travel time represents the best monthly commute travel time, while the 97.5-th represents the worst. Half of an average user's commute travel times will be less than the 50-th percentile (median) and half will be longer. The travel times are color-coded based on their TTI. Travel time thermometers are provided for the AM (6:00-9:00) and PM (15:00-18:00) peak periods for each segment along the corridor in the following figure, with full size thermometers available in the appendix.

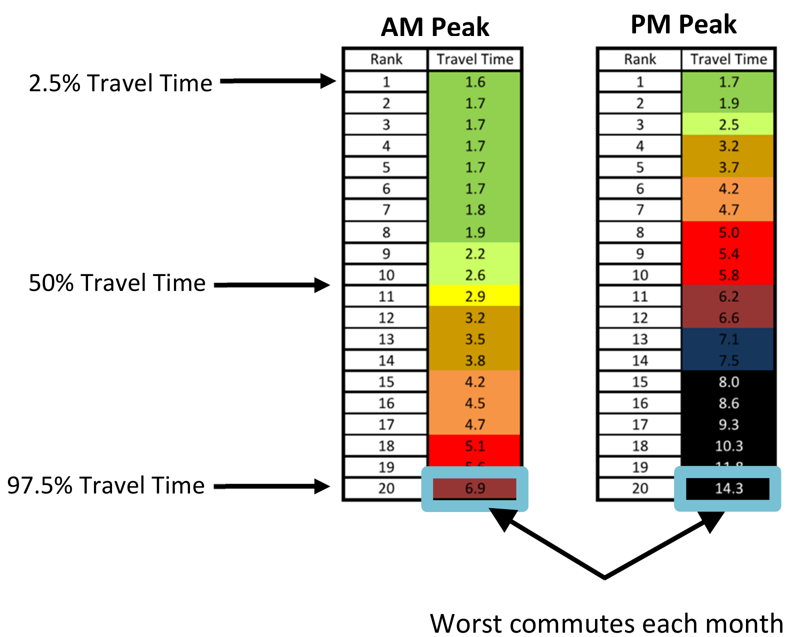
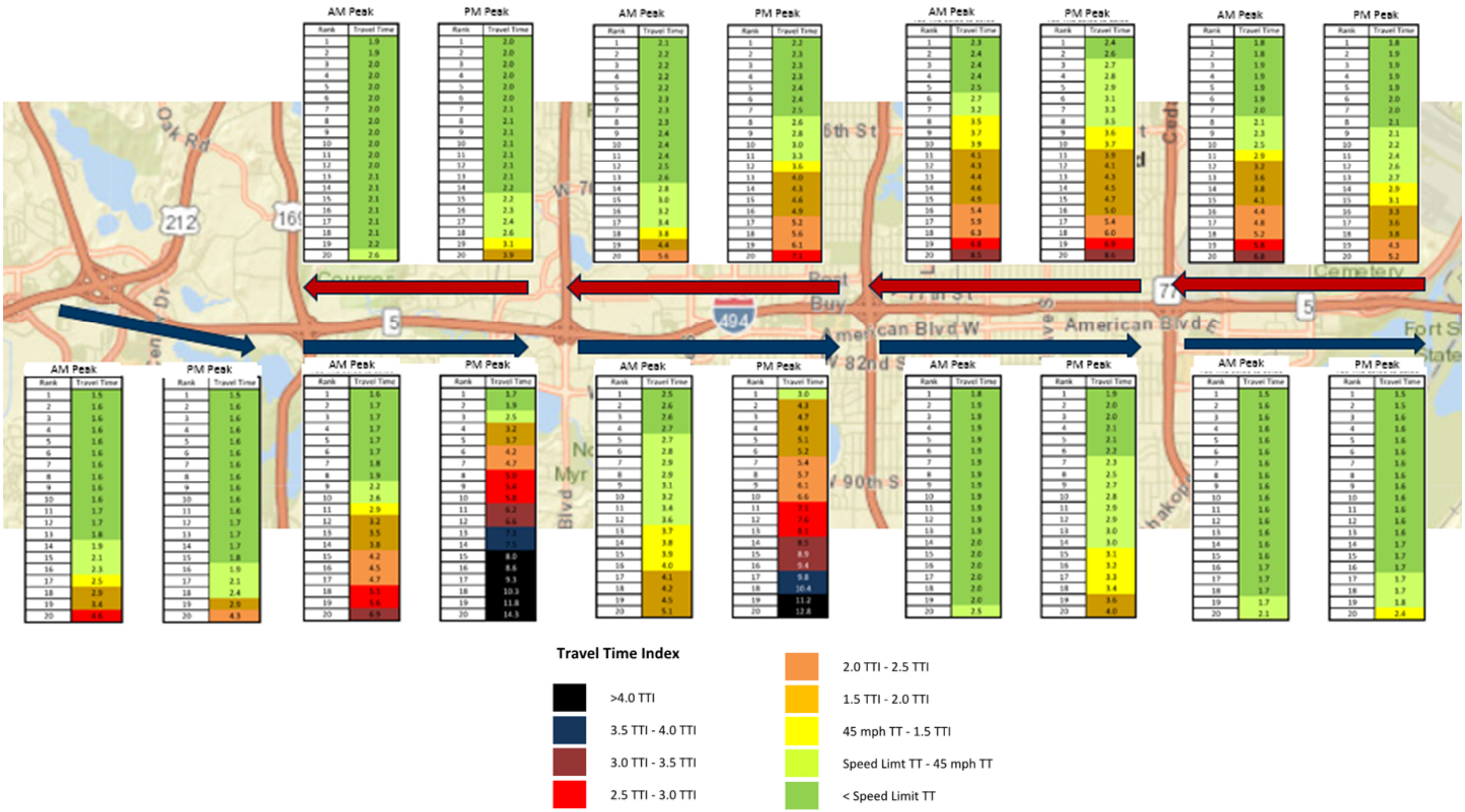


Figure 6. 2017 Travel Time Thermometers

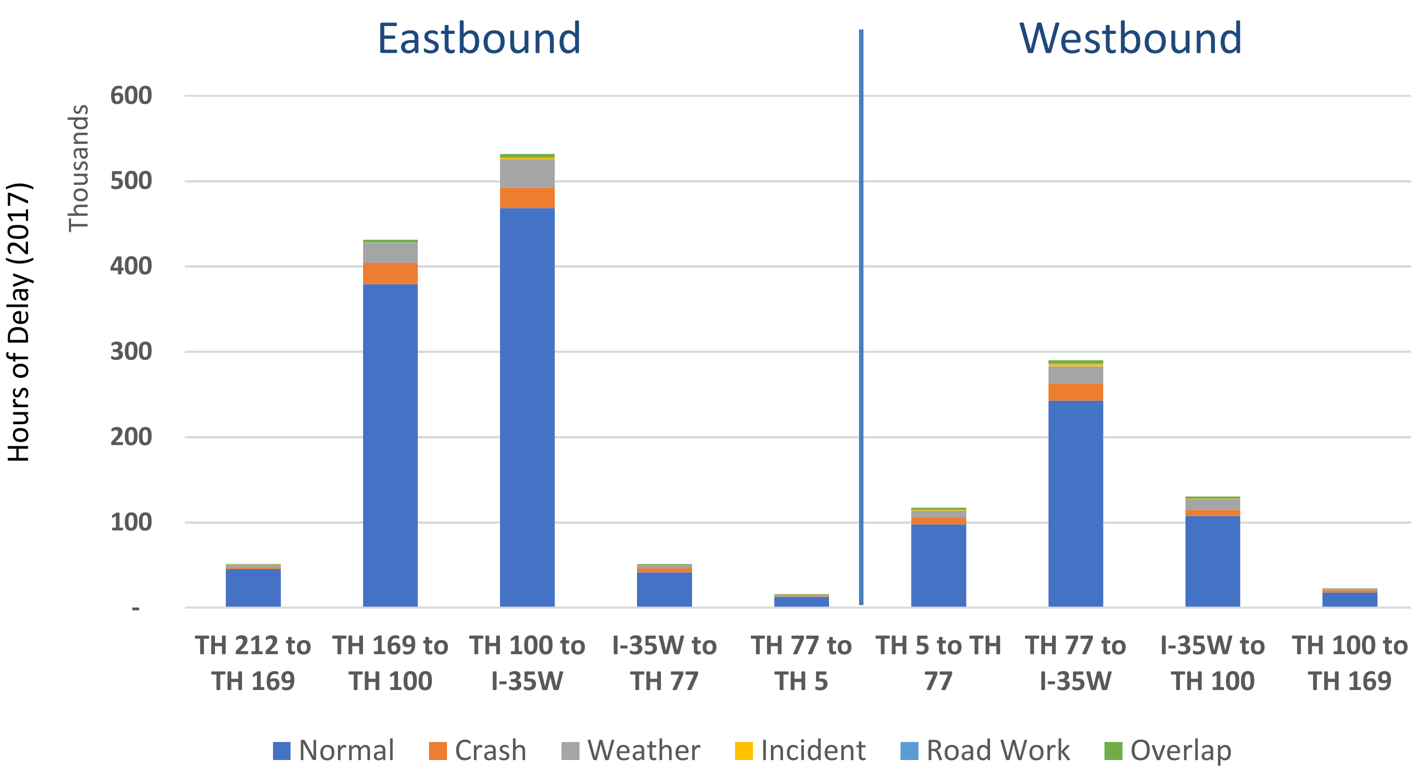


The travel time thermometers provide a more specific picture of travel times during the peak periods on each segment. For example, vehicles traveling eastbound between TH 100 and I-35W will only experience speeds greater than 45 mph once per month during the PM peak period. On half of the days, the TTI will be at least 2.5 with several days greater than 4.0 TTI. In contrast, some segments are free flow during the majority of commuting days but experience higher TTI values a few days each month.

Delay Type Distribution

The delay distribution stacked bar chart provides the distribution of travel time delay (hours) by categories of congestion for each segment. This includes normal recurring delay and delay caused by weather, crashes, incident, road work, and overlap.

Figure 7. 2017 Delay Distribution



Total annual delay is greatest eastbound between TH 169 and TH 100 and TH 100 and I-35W. Delay from these segments is greater than all other segments combined. In addition to having the most delay from recurring congestion, these two segments, along with westbound from TH 77 to I-35W, experience the greatest amounts of non-recurring congestion, primarily from crashes and weather events.

The following table compares the frequency of conditions with the amount of resulting delay. The frequency of each condition is determined by summing the amount of time where each condition is present throughout the year. The percentage of delay is calculated by adding the amount of delay from each time period where a condition is present on a given segment and dividing by the total annual delay on that segment. The table provides average values across all segments.

Table 4. Delay

	% of Time	% Delay
Normal	91.6%	86.1%
Crash	**1.2%**	**5.7%**
Weather	6.8%	6.4%
Incident	0.2%	0.4%
Road Work	0.0%	0.1%
Overlap	**0.2%**	**1.0%**

While crashes are present along the corridor 1.2% of the time, they account for 5.7% of all delay. Similarly, overlap (which is typically crashes and weather) occurs just 0.2% of the time, but results in 1.0% of the total delay. Weather events, on the other hand, which include snow and rain lead to a proportional amount of delay based on their frequency, or even occur more often than they contribute to delay. This is typically because weather events either occur during time periods of low volume and do not result in a reduction in speed, such as minor rain events which aren't severe enough to impair traffic.

Travel Time Reliability Metrics

The table below summarizes two reliability indices, reliability rating and planning time index, for each segment. The reliability rating looks at the percentage of reliable trips. Specifically, it's calculated as the percentage of trips in which the travel time is less than 1.25 times the free flow travel time. The planning time index provides an indication of how many times the free flow travel time one must plan to ensure arriving on time 95% of the time. The planning time index divides the 95% travel time by the free flow travel time. Both indices are calculated for all time periods and not just the peak periods.

Segment	Reliability Rating Percent of trips less than 1.25 of free flow travel time	Planning Time index 95% travel time divided by free flow travel time
EB TH 212 to TH 169	95.4%	1.21
EB TH 169 to TH 100	**78.0%**	**3.34**
EB TH 100 to I-35W	**69.4%**	**2.65**
EB I-35W to TH 77	94.4%	1.28
EB TH 77 to TH 5	98.9%	1.09
WB TH 5 to TH 77	90.7%	1.70
WB TH 77 to I-35W	**80.4%**	**1.98**
WB I-35W to TH 100	92.5%	1.56
WB TH 100 to TH 169	98.3%	1.06

Reliability Findings and Conclusions

The reliability results can be summarized in the following key findings:

- While the severity of AM and PM peak congestion in the westbound direction is fairly similar, the eastbound PM peak congestion is drastically greater than its AM congestion.

- Total delay is much greater eastbound than westbound, with the majority of delay occurring between TH 169 and I-35W. Improvements should aim to improve travel times through these segments.

- Three segments have reliability ratings for all time periods near or below 80%, meaning congestion isn't limited just to the peak periods.

- Effects of severe crashes and incidents are observed in multiple upstream segments, particularly when combined with a weather event and/or recurring peak period congestion. Some segments lack the capacity to adapt to the non-recurring events without causing severe slowdowns and queues which spill back far upstream.

- Crashes occur in 1.2% of time periods and account for 5.7% of annual delay. Most of the crash delay occurs in eastbound segments between Th 169 and I-35W and westbound segments between TH 77 and TH 100 as these are the most congested segments. Crash delay could potentially be reduced by adding crash investigation sites, additional shoulder width, or advanced traffic management (ATM) deployments.

APPENDIX

Reliability Heatmaps and Thermometers

Figure 1. **Eastbound TH 212 to TH 169**

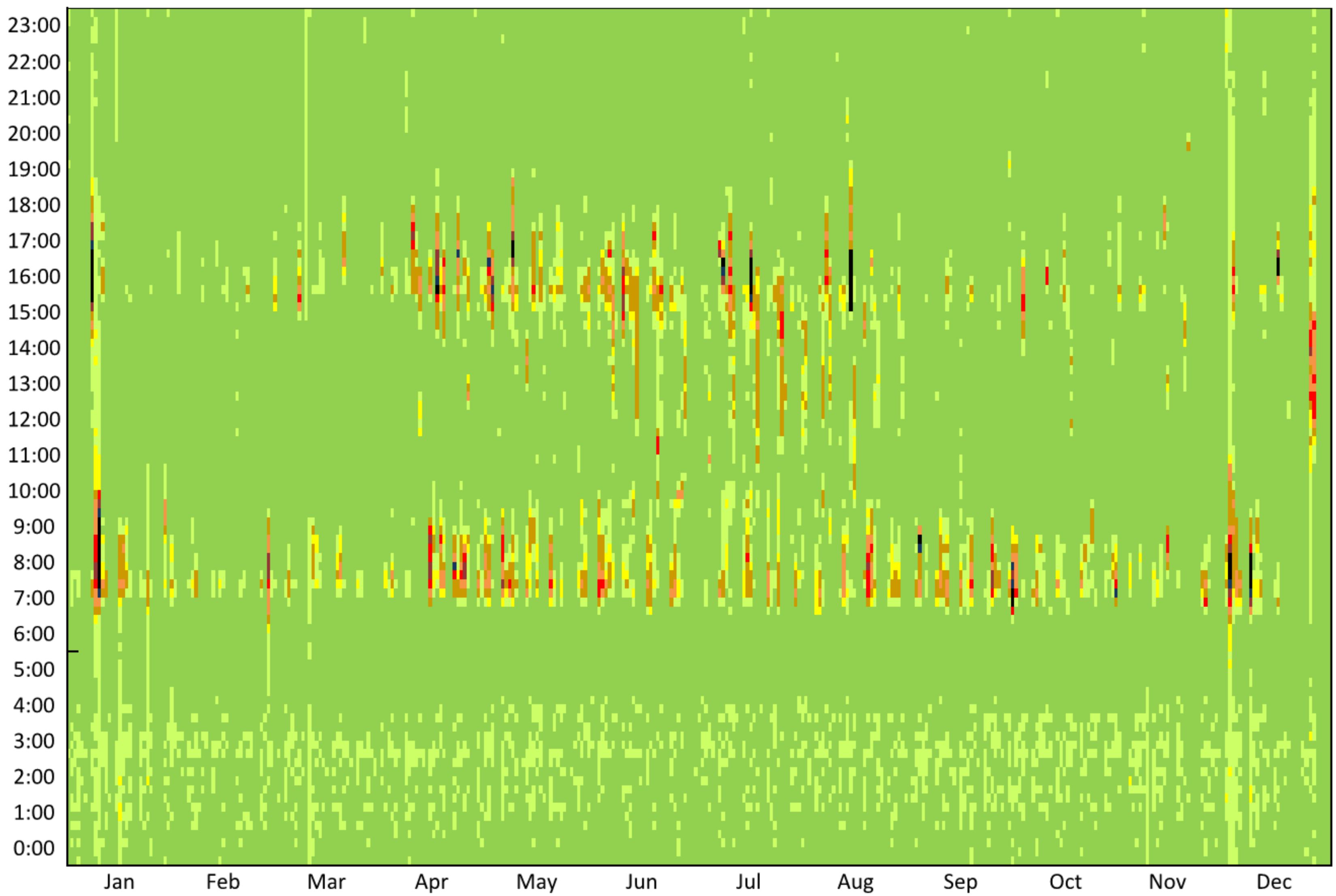


Figure 2. Eastbound TH 169 to TH 100

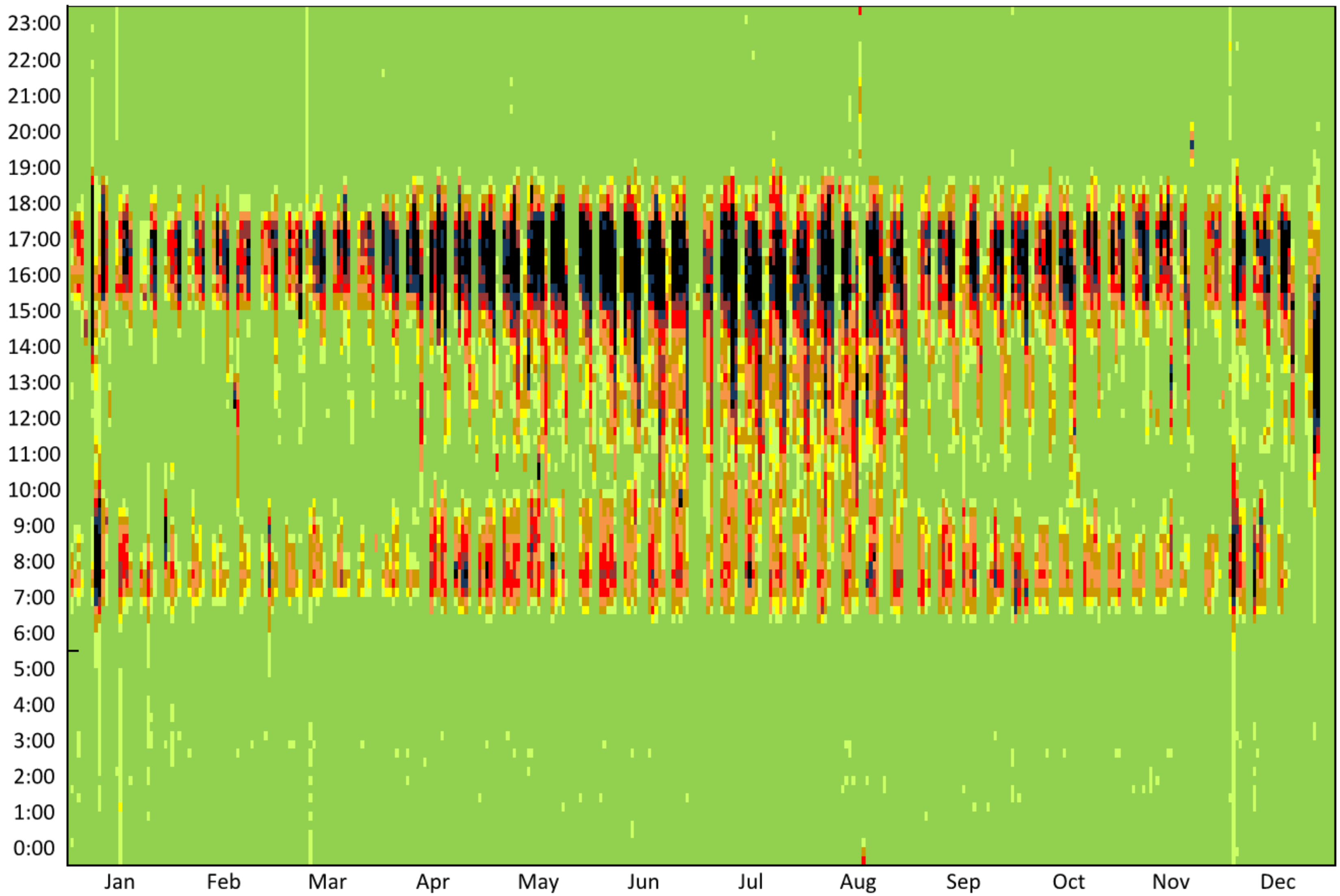


Figure 3. Eastbound TH 100 to I-35W

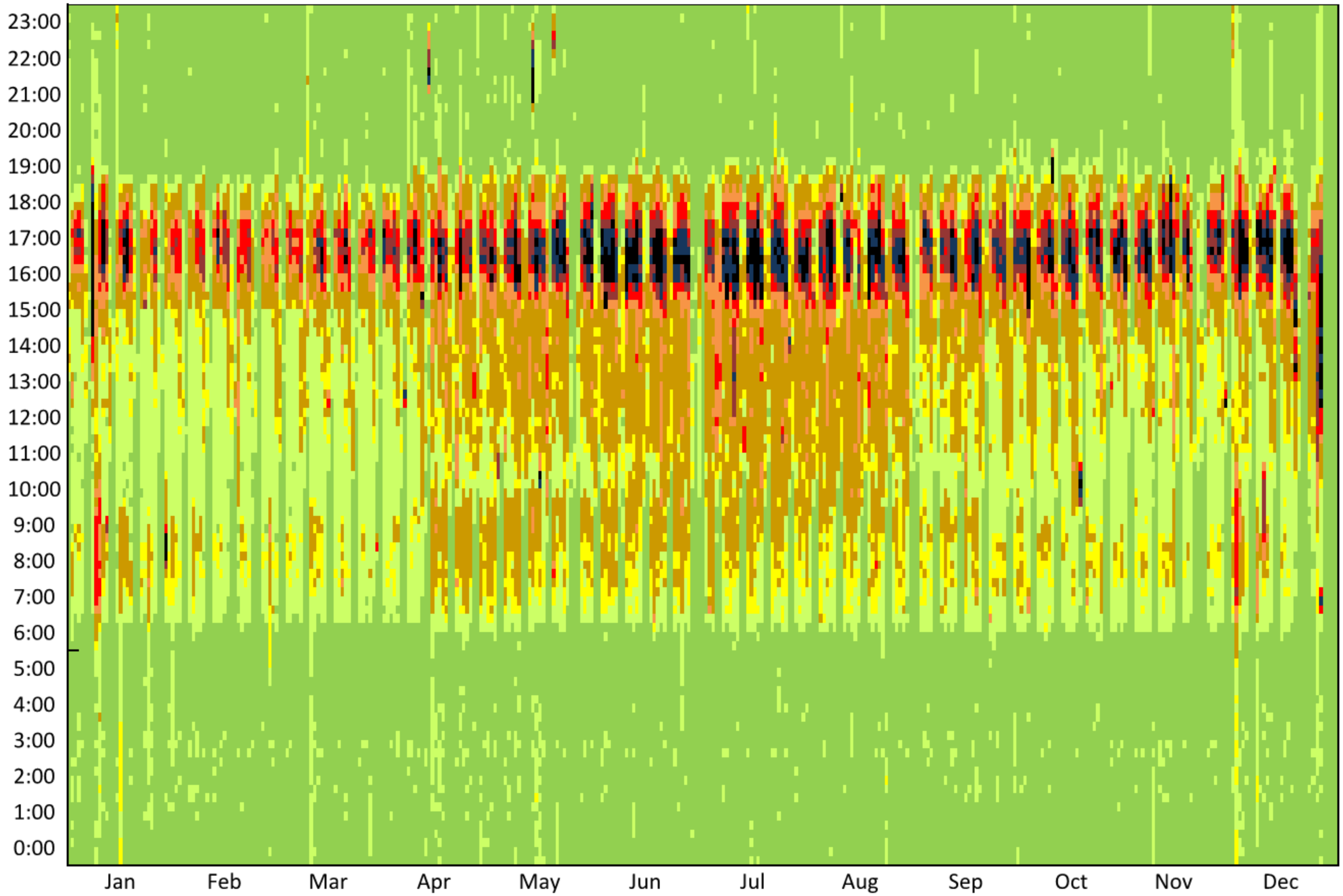


Figure 4. Eastbound I-35W to TH 77

Figure 5. Eastbound TH 77 to TH 5

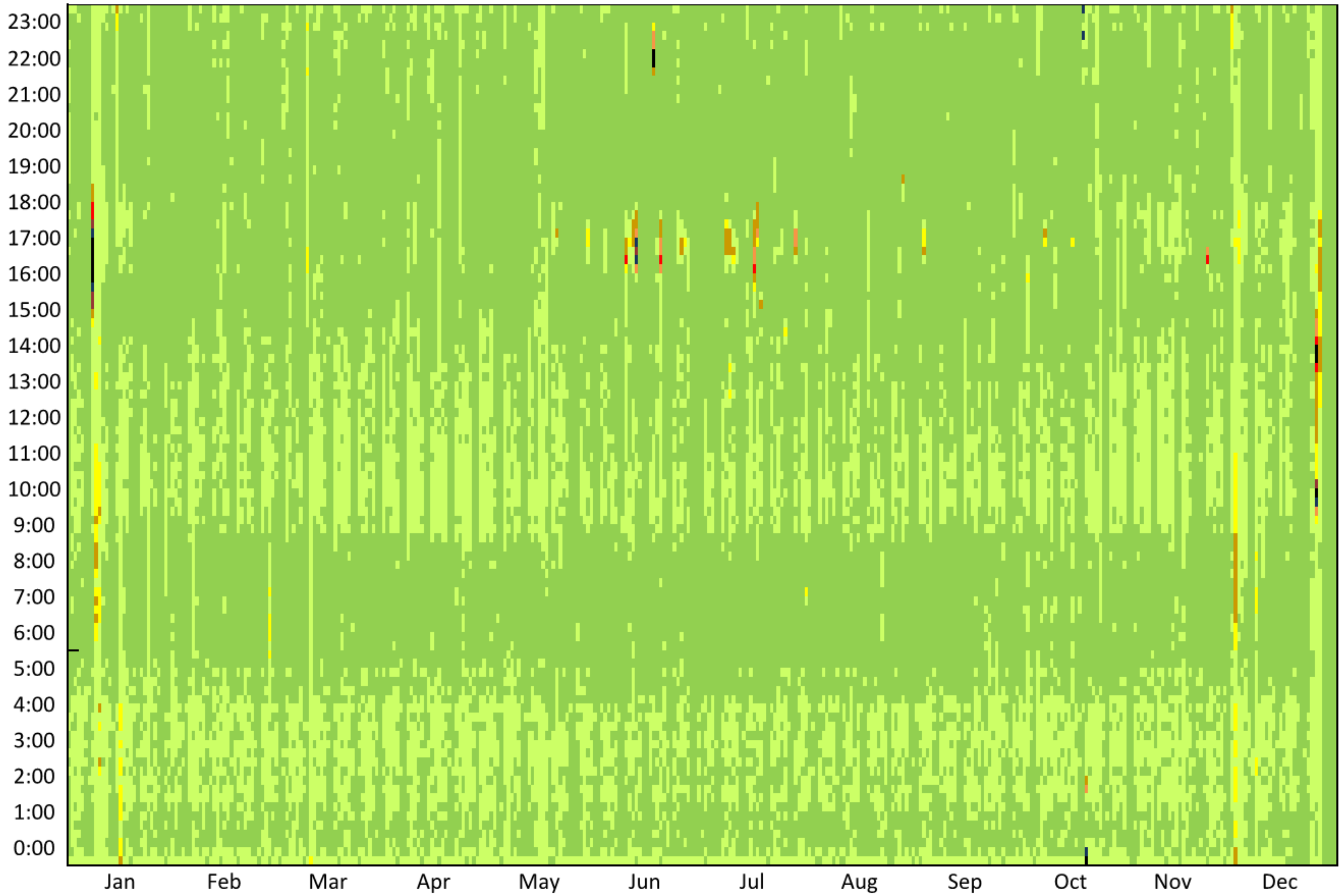


Figure 6. Westbound TH 5 to TH 77

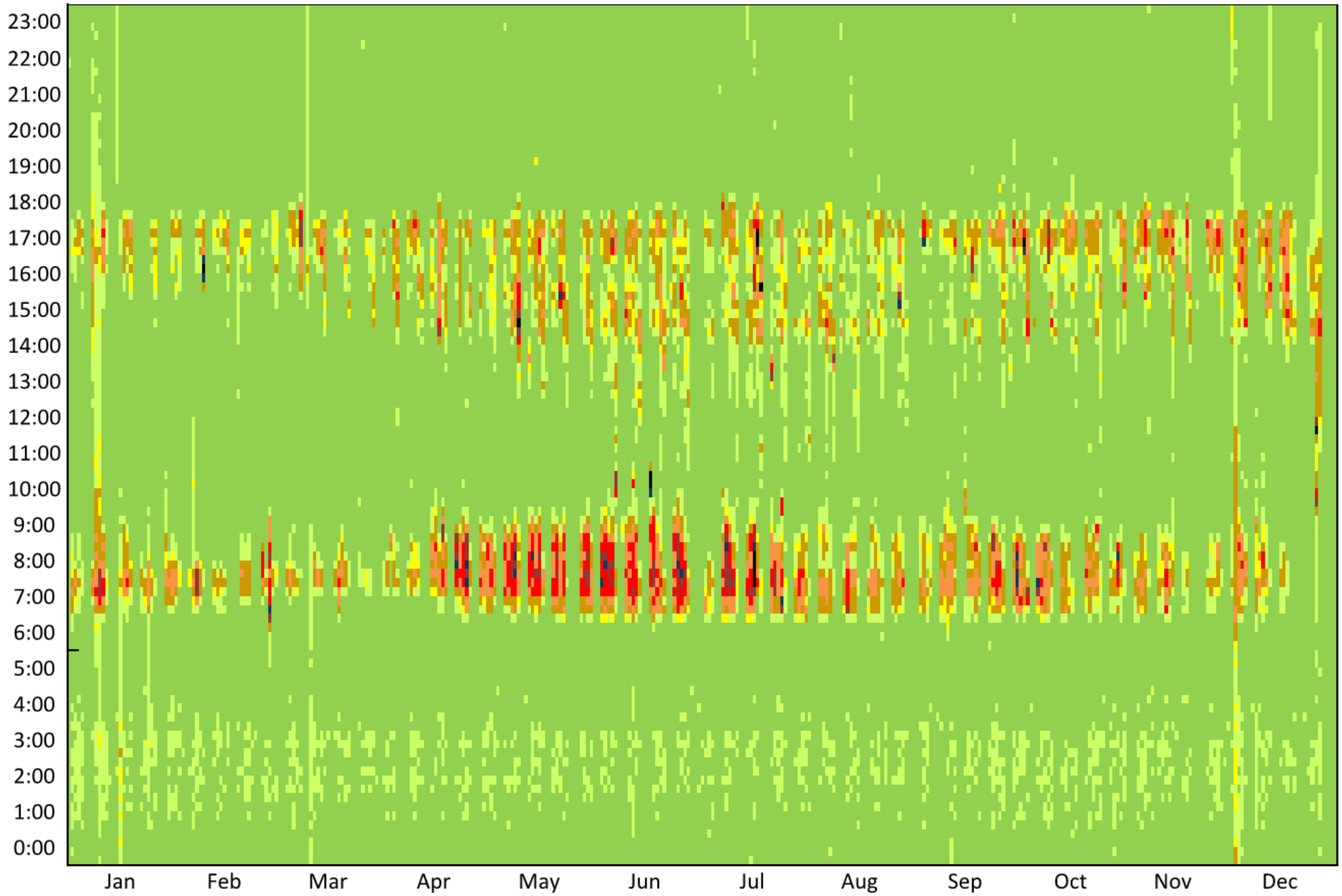


Figure 7. Westbound TH 77 to I-35W

Figure 8. Westbound I-35W to TH 100

Figure 9. Westbound TH 100 to TH 169

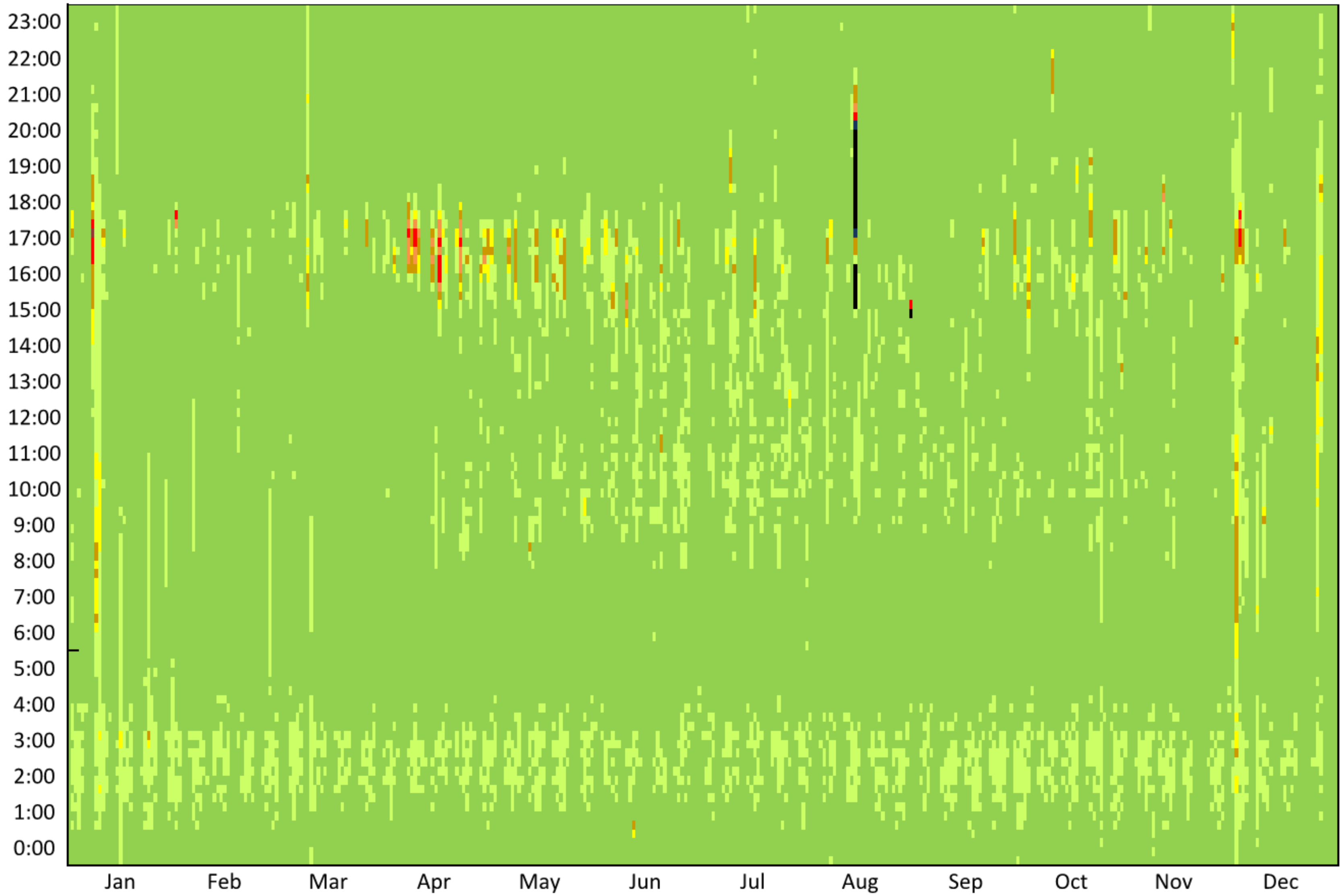


Figure 10. Eastbound TH 212 to TH 169

Tue-Thu 06:00 to 09:00

Rank	Travel Time
1	1.5
2	1.6
3	1.6
4	1.6
5	1.6
6	1.6
7	1.6
8	1.6
9	1.6
10	1.6
11	1.7
12	1.7
13	1.8
14	1.9
15	2.1
16	2.3
17	2.5
18	2.9
19	3.4
20	4.6

Tue-Thu 15:00 to 18:00

Rank	Travel Time
1	1.5
2	1.6
3	1.6
4	1.6
5	1.6
6	1.6
7	1.6
8	1.6
9	1.6
10	1.6
11	1.6
12	1.7
13	1.7
14	1.7
15	1.8
16	1.9
17	2.1
18	2.4
19	2.9
20	4.3

Figure 11. Eastbound TH 169 to Th 100

Tue-Thu 06:00 to 09:00

Rank	Travel Time
1	1.6
2	1.7
3	1.7
4	1.7
5	1.7
6	1.7
7	1.8
8	1.9
9	2.2
10	2.6
11	2.9
12	3.2
13	3.5
14	3.8
15	4.2
16	4.5
17	4.7
18	5.1
19	5.6
20	6.9

Tue-Thu 15:00 to 18:00

Rank	Travel Time
1	1.7
2	1.9
3	2.5
4	3.2
5	3.7
6	4.2
7	4.7
8	5.0
9	5.4
10	5.8
11	6.2
12	6.6
13	7.1
14	7.5
15	8.0
16	8.6
17	9.3
18	10.3
19	11.8
20	14.3

Figure 12. Eastbound TH 100 to I-35W

Tue-Thu 06:00 to 09:00

Rank	Travel Time
1	2.5
2	2.6
3	2.6
4	2.7
5	2.7
6	2.8
7	2.9
8	2.9
9	3.1
10	3.2
11	3.4
12	3.6
13	3.7
14	3.8
15	3.9
16	4.0
17	4.1
18	4.2
19	4.5
20	5.1

Tue-Thu 15:00 to 18:00

Rank	Travel Time
1	3.0
2	4.3
3	4.7
4	4.9
5	5.1
6	5.2
7	5.4
8	5.7
9	6.1
10	6.6
11	7.1
12	7.6
13	8.1
14	8.5
15	8.9
16	9.4
17	9.8
18	10.4
19	11.2
20	12.8

Figure 13. Eastbound I-35W to TH 77

Tue-Thu 06:00 to 09:00

Rank	Travel Time
1	1.8
2	1.9
3	1.9
4	1.9
5	1.9
6	1.9
7	1.9
8	1.9
9	1.9
10	1.9
11	1.9
12	1.9
13	1.9
14	2.0
15	2.0
16	2.0
17	2.0
18	2.0
19	2.0
20	2.5

Tue-Thu 15:00 to 18:00

Rank	Travel Time
1	1.9
2	2.0
3	2.0
4	2.1
5	2.1
6	2.2
7	2.3
8	2.5
9	2.7
10	2.8
11	2.9
12	2.9
13	3.0
14	3.0
15	3.1
16	3.2
17	3.3
18	3.4
19	3.6
20	4.0

Figure 14. Eastbound TH 77 to Th 5

Tue-Thu 06:00 to 09:00

Rank	Travel Time
1	1.5
2	1.6
3	1.6
4	1.6
5	1.6
6	1.6
7	1.6
8	1.6
9	1.6
10	1.6
11	1.6
12	1.6
13	1.6
14	1.6
15	1.6
16	1.7
17	1.7
18	1.7
19	1.7
20	2.1

Tue-Thu 15:00 to 18:00

Rank	Travel Time
1	1.5
2	1.5
3	1.6
4	1.6
5	1.6
6	1.6
7	1.6
8	1.6
9	1.6
10	1.6
11	1.6
12	1.6
13	1.6
14	1.7
15	1.7
16	1.7
17	1.7
18	1.7
19	1.8
20	2.4

Figure 15. Westbound TH 5 to TH 77

Tue-Thu 06:00 to 09:00

Rank	Travel Time
1	1.8
2	1.8
3	1.9
4	1.9
5	1.9
6	1.9
7	2.0
8	2.1
9	2.3
10	2.5
11	2.9
12	3.2
13	3.6
14	3.8
15	4.1
16	4.4
17	4.8
18	5.2
19	5.8
20	6.8

Tue-Thu 15:00 to 18:00

Rank	Travel Time
1	1.8
2	1.9
3	1.9
4	1.9
5	1.9
6	2.0
7	2.0
8	2.1
9	2.1
10	2.2
11	2.4
12	2.6
13	2.7
14	2.9
15	3.1
16	3.3
17	3.6
18	3.8
19	4.3
20	5.2

Figure 16. Westbound TH 77 to I-35W

Tue-Thu 06:00 to 09:00

Rank	Travel Time
1	2.3
2	2.4
3	2.4
4	2.4
5	2.5
6	2.7
7	3.2
8	3.5
9	3.7
10	3.9
11	4.1
12	4.3
13	4.4
14	4.6
15	4.9
16	5.4
17	5.9
18	6.3
19	6.8
20	8.5

Tue-Thu 15:00 to 18:00

Rank	Travel Time
1	2.4
2	2.6
3	2.7
4	2.8
5	2.9
6	3.1
7	3.3
8	3.5
9	3.6
10	3.7
11	3.9
12	4.1
13	4.3
14	4.5
15	4.7
16	5.0
17	5.4
18	6.0
19	6.9
20	8.6

Figure 17. Westbound I-35W to TH 100

Tue-Thu 06:00 to 09:00

Rank	Travel Time
1	2.1
2	2.2
3	2.2
4	2.2
5	2.2
6	2.3
7	2.3
8	2.3
9	2.4
10	2.4
11	2.4
12	2.5
13	2.6
14	2.8
15	3.0
16	3.2
17	3.4
18	3.8
19	4.4
20	5.6

Tue-Thu 15:00 to 18:00

Rank	Travel Time
1	2.2
2	2.3
3	2.3
4	2.3
5	2.4
6	2.4
7	2.5
8	2.6
9	2.8
10	3.0
11	3.3
12	3.6
13	4.0
14	4.3
15	4.6
16	4.9
17	5.2
18	5.6
19	6.1
20	7.1

Figure 18. Westbound TH 100 to TH 169

Tue-Thu 06:00 to 09:00

Rank	Travel Time
1	1.9
2	1.9
3	2.0
4	2.0
5	2.0
6	2.0
7	2.0
8	2.0
9	2.0
10	2.0
11	2.0
12	2.0
13	2.1
14	2.1
15	2.1
16	2.1
17	2.1
18	2.1
19	2.2
20	2.6

Tue-Thu 15:00 to 18:00

Rank	Travel Time
1	2.0
2	2.0
3	2.0
4	2.0
5	2.0
6	2.0
7	2.1
8	2.1
9	2.1
10	2.1
11	2.1
12	2.1
13	2.1
14	2.2
15	2.2
16	2.3
17	2.4
18	2.6
19	3.1
20	3.9