Appendix A1

TRANSPORTATION OPERATIONS ANALYSES

TECHNICAL MEMORANDA

FOR THE

I-25 (US 36 to 104th Avenue) Environmental Assessment

Prepared for:

Colorado Department of Transportation
Region 1
2829 W. Howard Place
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July 2018

MEMORANDUM

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DATE: July 30, 2018

SUBJECT: I-25 North, US 36 to SH 7 – Microsimulation Traffic Operations Evaluation
CDOT Project No. NHPP 0253-250 (21180)
FHU Reference No. 115388-01

1. BACKGROUND & PURPOSE

This technical memorandum documents the TransModeler microsimulation model evaluation of the proposed improvements on Interstate 25 (I-25) between US Highway 36 (US 36) and 104th Avenue. This section of I-25 is one of the most congested corridors in the Denver metro area and carries approximately 180,000 vehicles per day just north of the US 36/I-270 interchange.

In December 2014, the Colorado Department of Transportation (CDOT) completed the *North I-25 Planning and Environmental Linkages (PEL) Study,* which identified projects necessary to improve operational and safety conditions within the corridor. The recommended improvements include the addition of an auxiliary lane (acceleration/deceleration lane between interchange ramps) between the 84th Avenue and Thornton Parkway interchanges in each direction; a general-purpose (GP) lane between the 84th Avenue and Thornton Parkway interchanges in the southbound direction; and a GP lane between the 84th Avenue and 104th Avenue interchanges in the northbound direction.

The TransModeler microsimulation modeling exercise was used to evaluate and refine the proposed I-25 improvements under a 20-year (2040) time horizon.

This memorandum builds on three previous memoranda that documented the methods and assumptions, data collection, and calibration used to develop the microsimulation models:

- *I-25 North, US 36 to SH 7 – Methods and Assumptions Technical Memorandum (Methods and Assumptions Memo)* dated June 8, 2017. This technical memorandum describes the process used in the technical analysis of the proposed improvements.
- *I-25 North, US 36 to SH 7 – Data Collection Technical Memorandum (Data Collection Memo)* dated June 8, 2017. This technical memorandum documents the TransModeler data collection efforts to support the development and calibration of the TransModeler model used to evaluate the proposed improvements.
- *I-25 North, US 36 to SH 7 – TransModeler Calibration Technical Memorandum (Calibration Memo)* dated September 25, 2017. This technical memorandum summarizes the TransModeler microsimulation model development and calibration process.

2. EXISTING CONDITIONS

The *Methods and Assumptions Memo* describes the selection of the model area, consistent with the Federal Highway Administration (FHWA) *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software* simulation guidelines.

Figure 1 represents the TransModeler study area.

2.1 2017 Roadway Network

The 2017 TransModeler roadway network reflects the existing roadway network as of May 2017. The *Data Collection Memo* summarizes field observations and traffic volume data collection efforts. The TransModeler network was constructed as shown on **Figure 2** and **Figure 3**. **Figure 2** illustrates the east/west arterial roadway network and node system, and **Figure 3** highlights the interchange network and node system. The number of lanes, location of lane additions and drops, and roadway geometry were coded based on aerial imagery and confirmed by field observations. The model includes added details such as posted speed limits, ramp meters, and traffic control devices to better reflect field conditions.

The freeway, ramp, and intersection recorded traffic counts have been adjusted to produce an internally consistent set of volumes for every link and node in the model. **Figure 4** through **Figure 7** show existing traffic counts.

The *Calibration Memo* summarizes the traffic count validation and post-processing adjustment process used to (1) reconcile data collection variations among multiple data sources; (2) provide a balanced network with an internally consistent set of volumes for each link and node; and (3) understand the interactions between the I-25 GP and tolled express lanes (TEL).

The COGNOS recorded traffic volumes were used to determine the existing typical-day TEL volumes. These recorded volumes were compared to the *2014 CDMSmith Tech Memo* opening day (2015) forecasted volumes. The existing TEL recorded segment volumes were validated using field observations of ingress/egress patterns, and CDMSmith Scenario X1 2015 ingress/egress patterns to develop a consistent set of existing typical day TEL volumes and interactions with GP lanes.

The model includes a few intermediate intersections/nodes that are not included on **Figure 4** through **Figure 7** but are represented on **Figure 2** and **Figure 3**. These nodes represent sinks and sources within the network and account for intermediate commercial driveways and accesses on the arterial network.

Figure 1. Project Study Area

Figure 2. TransModeler Arterial Road Network and Node System

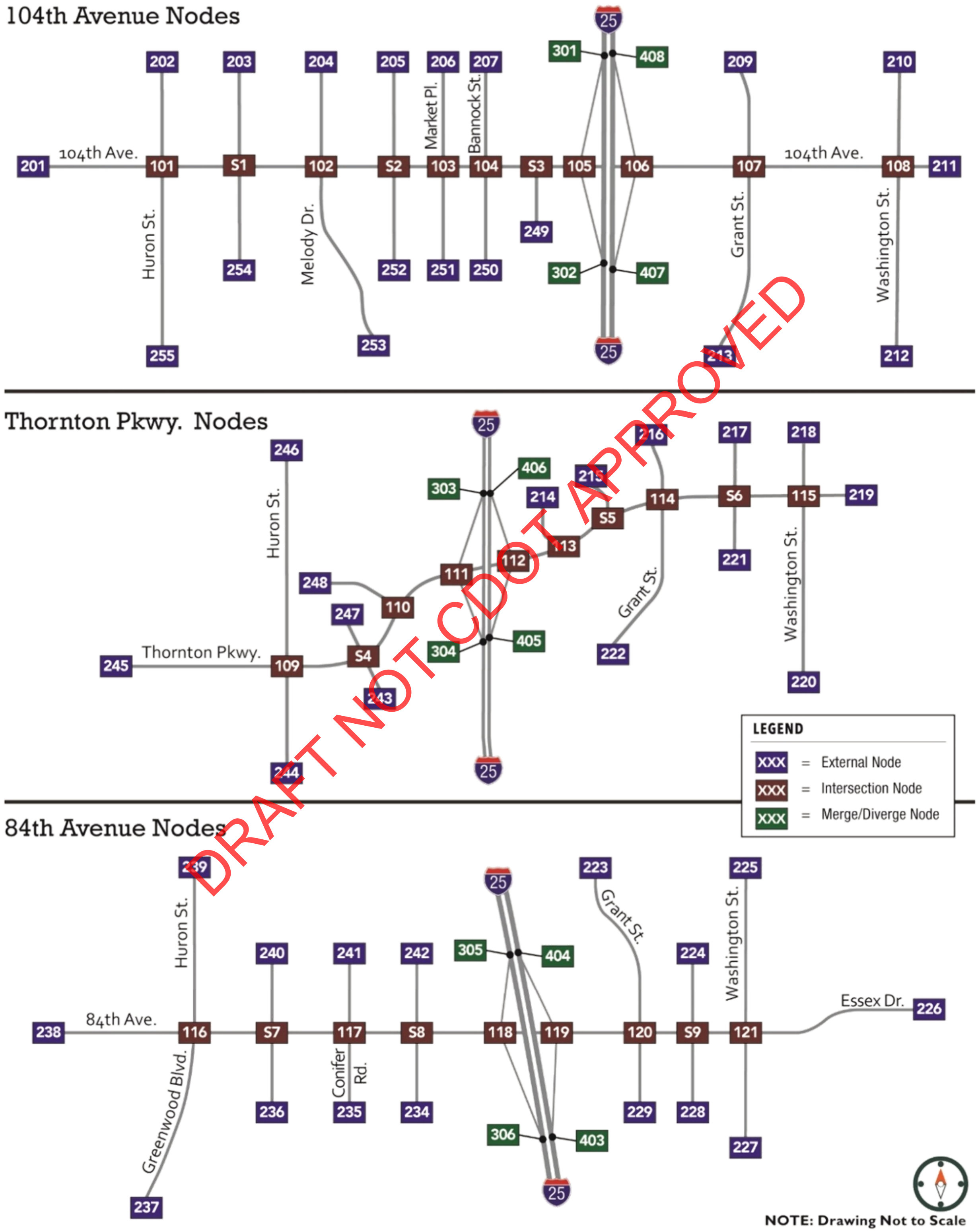


Figure 3. TransModeler Interstate Road Network and Node System

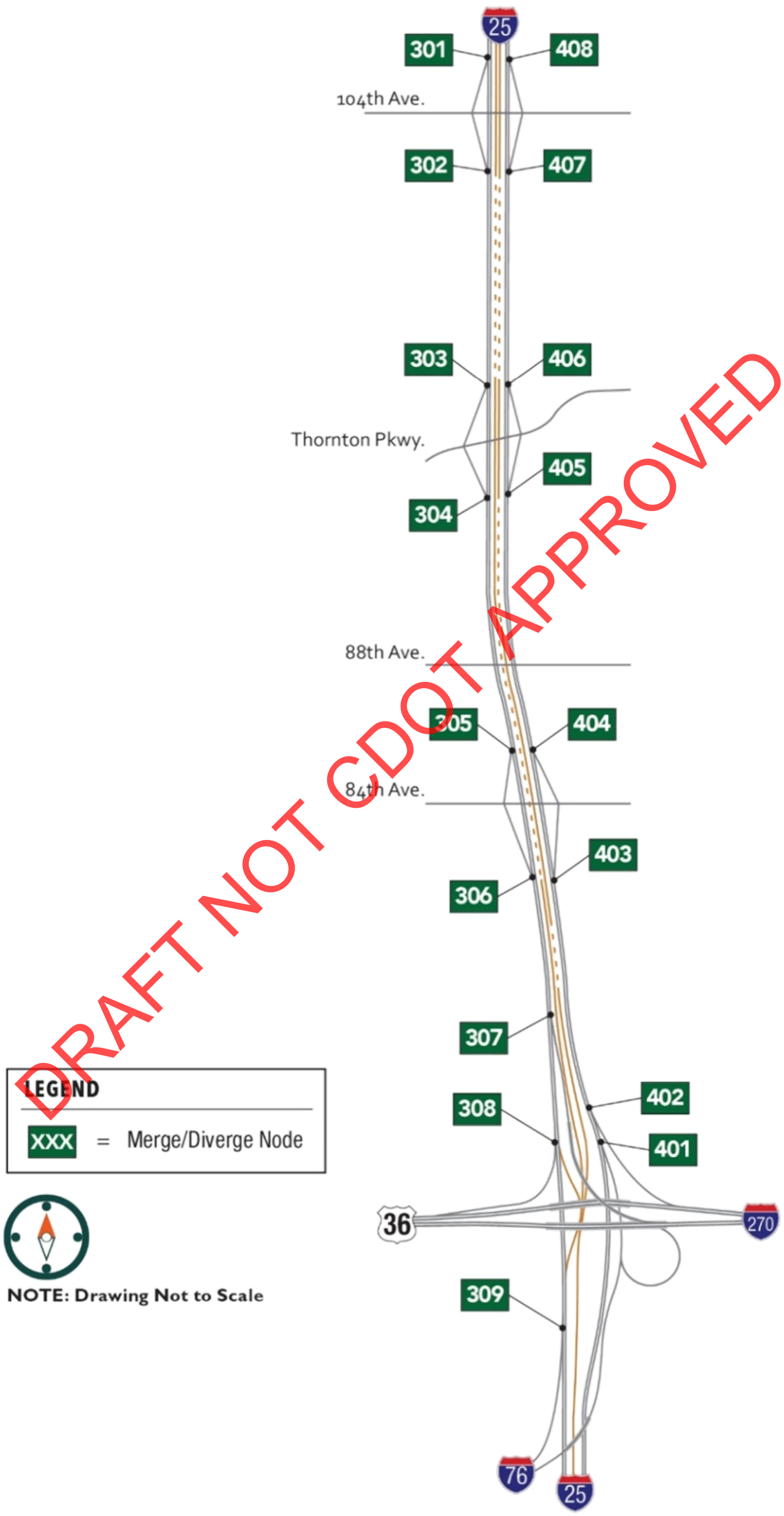


Figure 4. Existing (2017) AM and PM Traffic Volumes – 104th Avenue

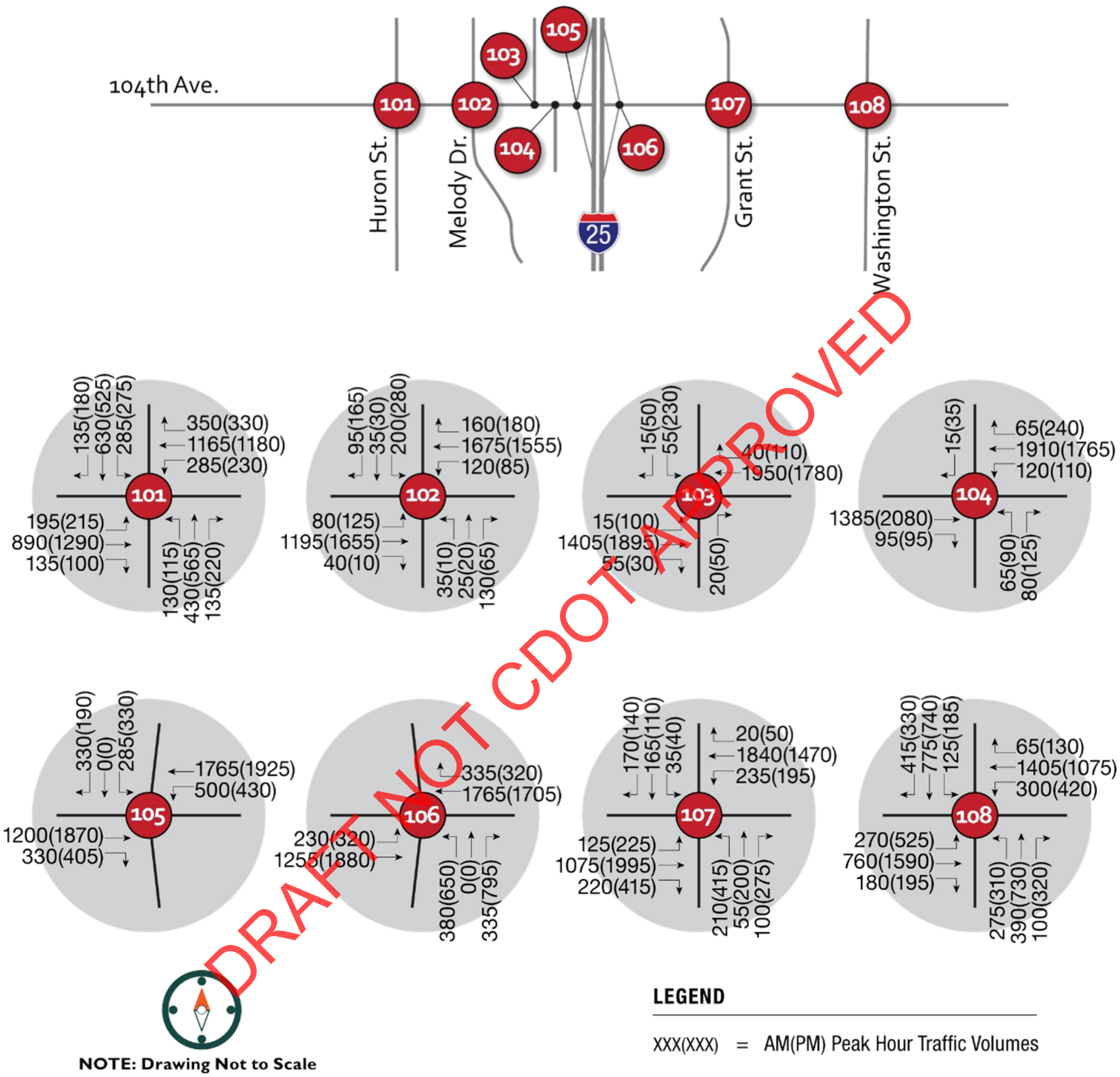


Figure 5. Existing (2017) AM and PM Traffic Volumes – Thornton Parkway

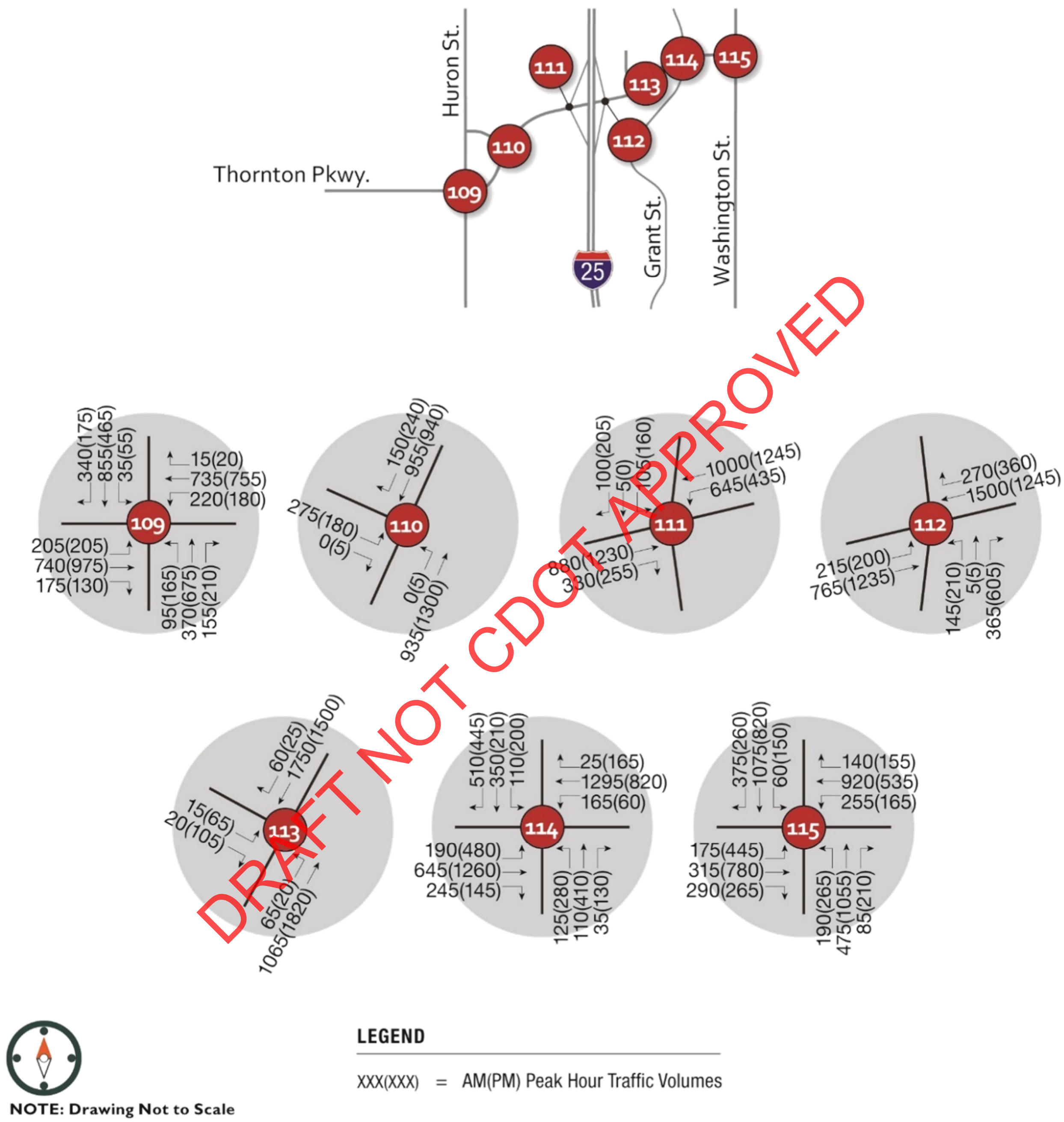


Figure 6. Existing (2017) AM and PM Traffic Volumes – 84th Avenue

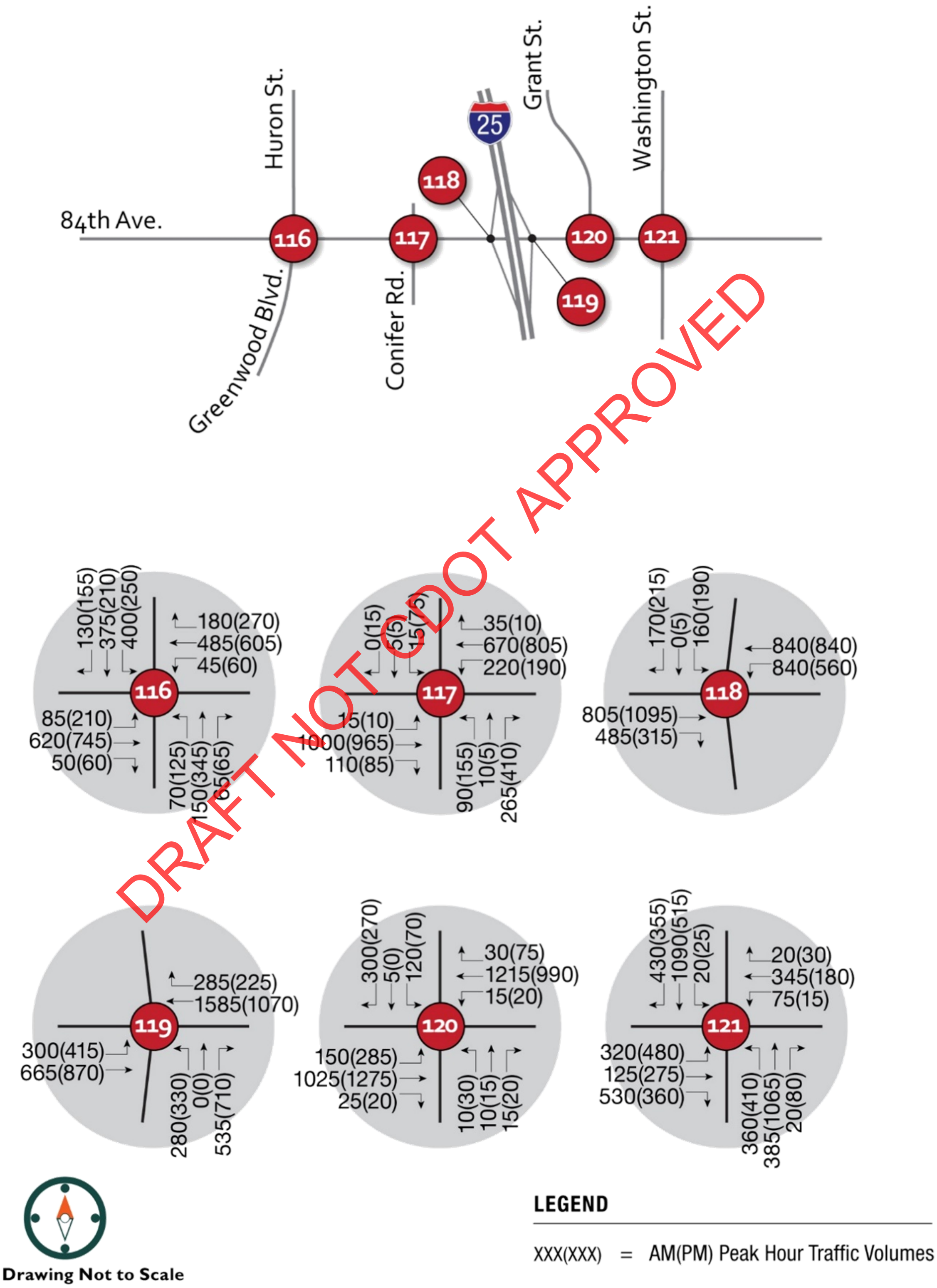
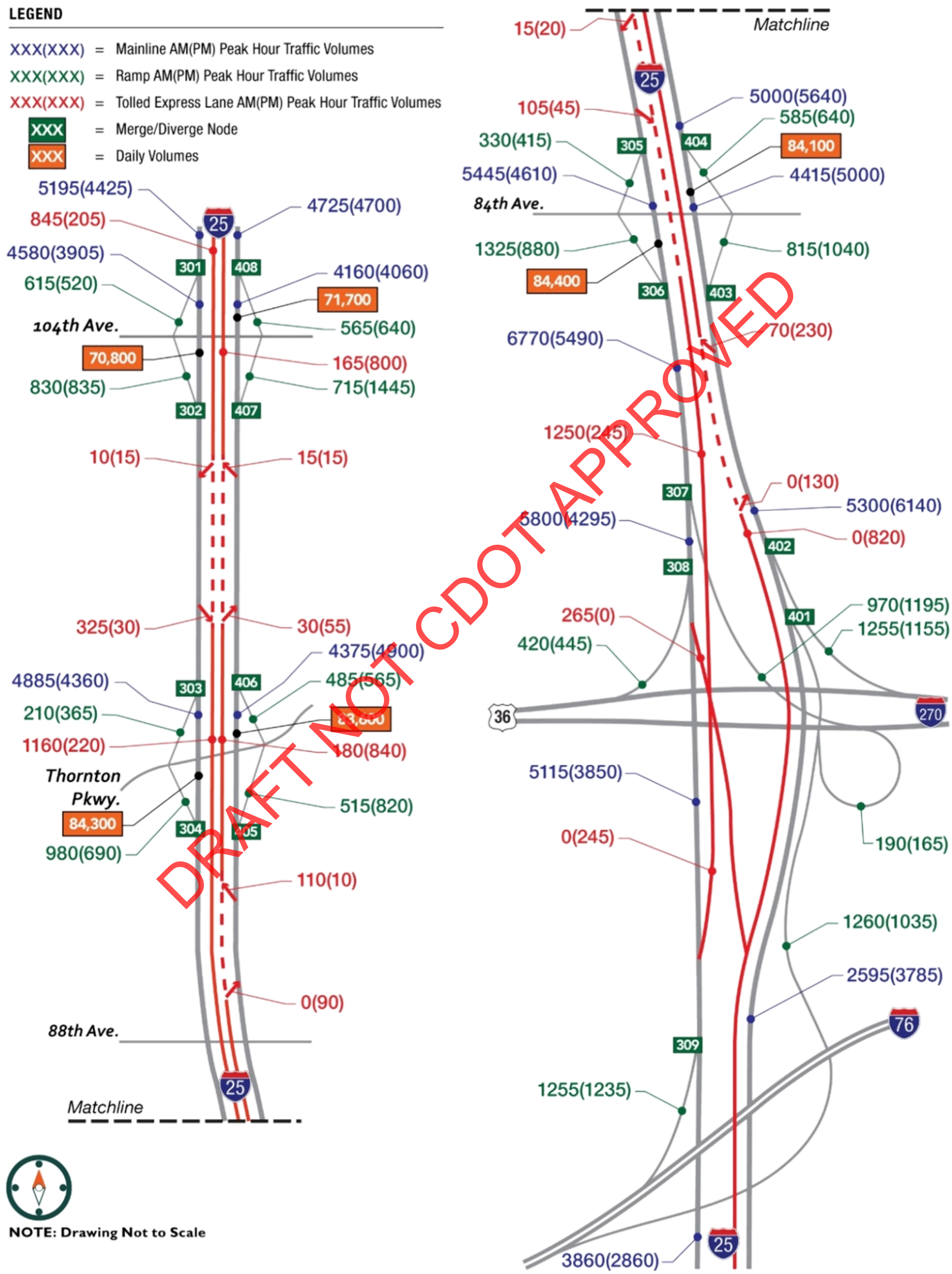


Figure 7. Existing (2017) AM and PM Traffic Volumes – Ramps, Mainline GP, and TEL



2.2 Base Model Validation & Calibration

The *Calibration Memo* previously documented the calibration process. The base model has been calibrated in accordance with the FHWA *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*. The following provides a brief overview of the calibration goals and criteria.

2.2.1 Calibration Goals

The calibration goals for this project included:

- Goal 1: Identification of locations of persistent queuing and recurring bottlenecks
- Goal 2: Model link vs. observed flows to meet the following criteria:
    - Within 100 vehicles per hour (vph)for volumes less than 700 vph
    - Within 15 percent for volumes between 700 and 2700 vph
    - Within 400 vph for volumes greater than 2700 vph
    - Sum of all link flows to be within 5 percent
    - GEH[1] Statistic should be < 5 for individual link flows in more than 85 percent of cases
    - GEH Statistic should be < 4 for the sum of all link counts
- Goal 3: Model Link vs. Observed Travel Time meets the following criterion
    - Travel times to be within 15 percent (or one minute, if higher) for greater than 85 percent of cases for the selected segments

As shown in **Table 1**, the AM and PM peak hour TransModeler models have been calibrated to the established calibration acceptance targets for freeway, ramp and intersection volumes, travel times, and observed travel speeds and queues.

Table 1. Link Volume Calibration Validation Criteria and Results

Criteria	Criteria Threshold	% Met Target	AM Peak Hour		PM Peak Hour	
			% Met	Pass/Fail	% Met	Pass/Fail
Individual Link Volumes						
< 700 vph	100 vph	> 85%	100%	Pass	100%	Pass
Between 700 and 2,700 vph	15 %	> 85%	100%	Pass	100%	Pass
> 2,700 vph	400 vph	> 85%	100%	Pass	100%	Pass
GEH Statistic	5	> 85%	100%	Pass	100%	Pass
Sum of Link Volumes						
Sum of All Links	5%	-	-	Pass	-	Pass
GEH Statistic	< 4	-	-	Pass	-	Pass

[1] The GEH Statistic is a formula developed by Geoffry E. Havers that is used to compare two sets of traffic volumes.

3. TRAFFIC GROWTH FORECASTS, LAND USE, AND TRAVEL DEMAND ASSUMPTIONS

The DRCOG Focus travel demand model was used to develop future daily vehicle forecasts for roadways within the study area. The process began with the verification of the existing laneage and roadway configuration in the base year model (2015). Due to recent highway construction in the study area, the model network was revised to match existing conditions as recorded and observed during the data collection efforts (performed in spring 2017). Then, the 2040 model was reviewed for consistency with the DRCOG Fiscally Constrained Regional Transportation Plan and made to represent the No-Build configuration.

The model outputs from the base and 2040 regional models were used to prepare daily traffic forecasts for the study area. The forecasting process relied on methodologies described in the *Transportation Research Board's (TRB) National Cooperative Highway Research Program (NCHRP) Report 765*. This process recognizes that travel demand models cannot precisely match existing traffic volumes due to the complexity of real-world travel behavior. As a result, future daily forecasts are prepared by comparing existing traffic counts to the base year model, and the difference is transferred to the output from the future travel demand model. This process has been applied to all study area forecasts to develop the 2040 No-Build daily traffic volumes.

3.1 Household and Employment Growth

For transportation planning purposes, DRCOG divides the Denver metropolitan area into transportation analysis zones (TAZs). Population, number of households, number of jobs, and income projections are estimated for each TAZ. DRCOG incorporates several variables into the projections, including, but not limited to, overall regional growth and current and long-range development plans. Traffic volume forecasts were developed using existing and future land uses in the study area. The 2040 model includes the most recently approved population and employment projections for the area. **Figure 8** shows the study area TAZ system.

Figure 9 shows projected household growth between 2015 and 2040 by TAZ; the darker the color, the greater the number of additional households forecasted. Most of the household growth is occurring outside the TransModeler model area. **Figure 10** shows projected employment growth between 2015 and 2040 in each TAZ. As with the projected household growth, the darker the color, the greater the number of additional jobs forecast. The areas with the greatest expected employment growth are located near the northern end of the study area.

Between 2015 and 2040, DRCOG forecasts an additional 3,399 households and 5,341 jobs in the study area.

Table 2 shows the projections for household and employment growth in the study area relative to the growth projections for the DRCOG region as a whole.

Table 2. Household and Employment Growth, 2015–2040

	2015	2040	Growth 2015–2040	% Growth 2015–2040	Annual Growth Rate
Household					
Study Area	25,863	29,262	3,399	13%	0.49%
DRCOG Region	1,285,300	1,832,941	547,641	43%	1.42%
Employment					
Study Area	28,196	33,537	5,341	19%	0.69%
DRCOG Region	1,708,001	2,391,994	683,993	40%	1.35%

Figure 8. Study Area Transportation Analysis Zones

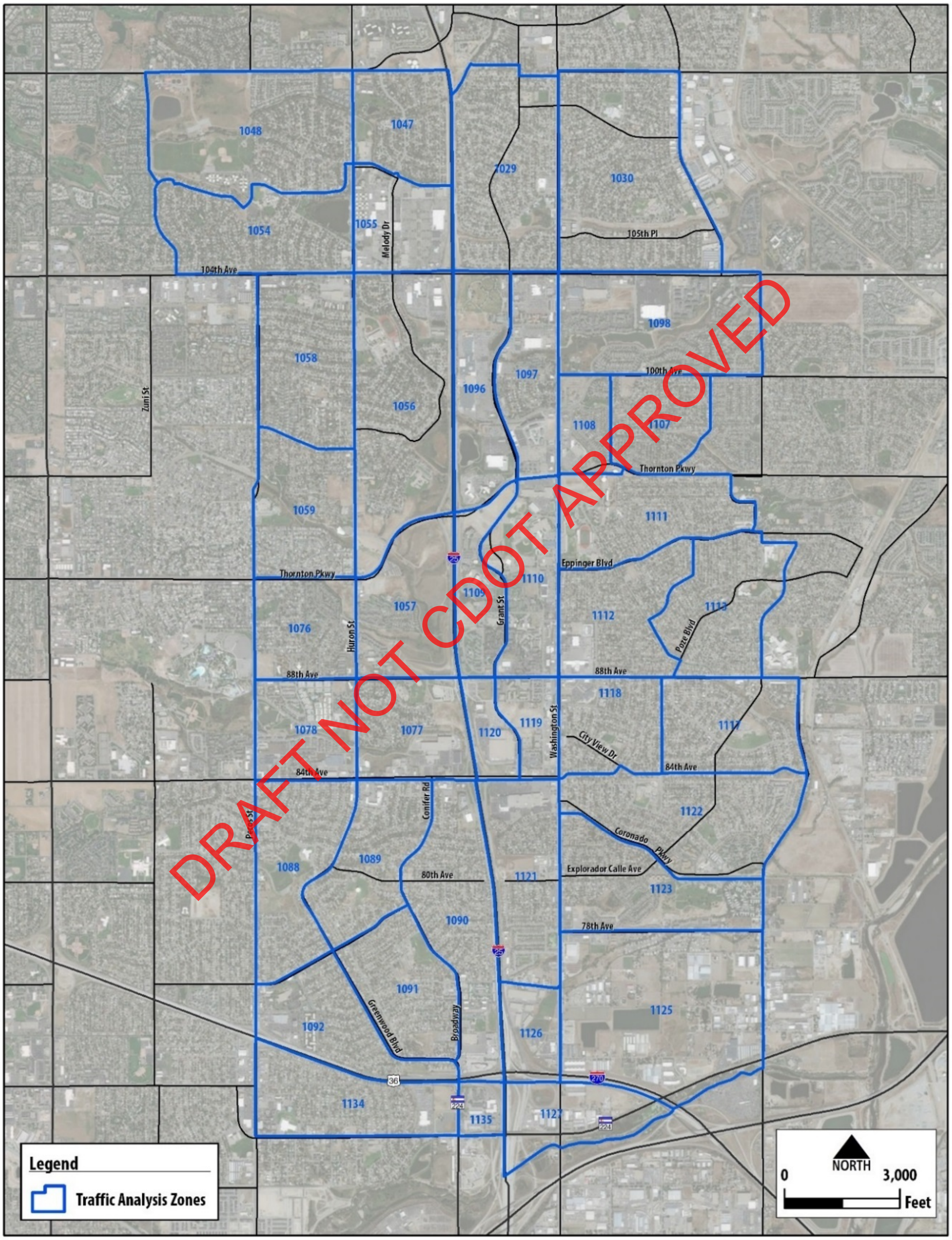


Figure 9. Household Growth (2015 – 2040)

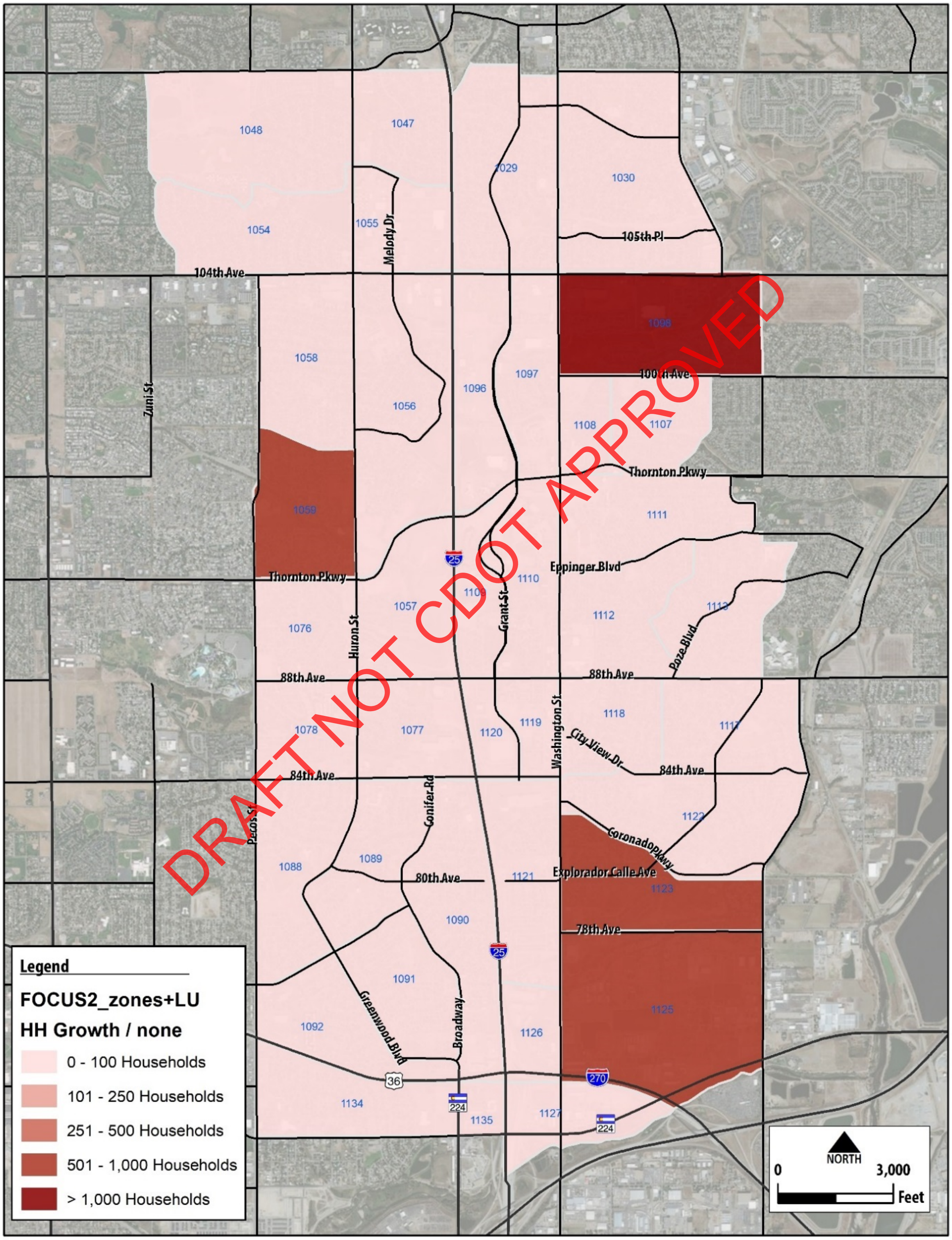
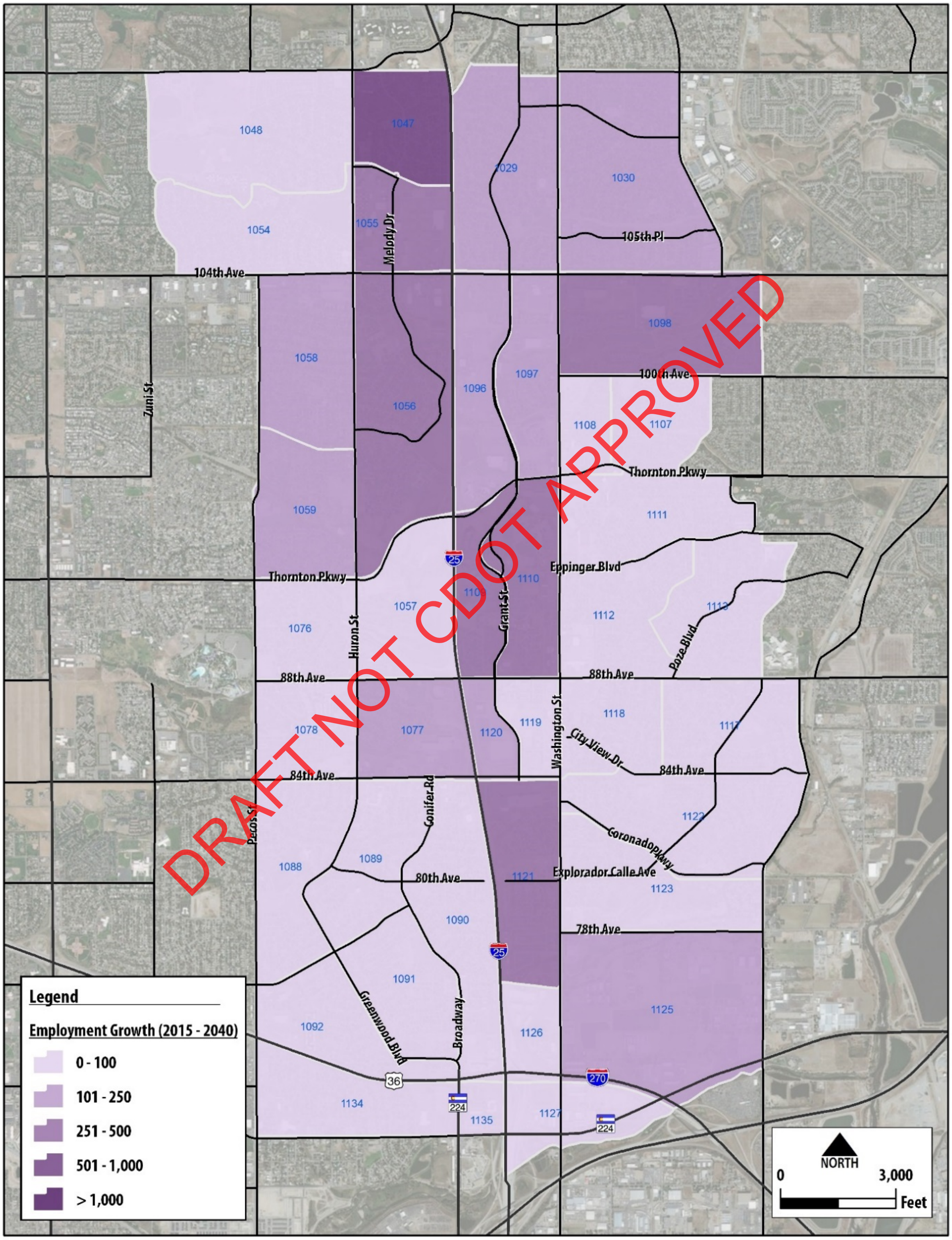


Figure 10. Employment Growth (2015 – 2040)



4. 2040 NO-BUILD TRAFFIC VOLUMES

The latest version of the travel demand model, Focus 2.0 (Cycle RTP-2016), was used for the No-Build Scenario for this project. The model reflects the planned network of the 2040 Fiscally-Constrained Regional Transportation Plan (RTP). Because the Fiscally-Constrained RTP includes no study area roadway improvements, the roadway network is identical in the 2015 and 2040 travel demand models.

Within the study area, daily traffic volumes along mainline I-25 are projected to grow between 0.8 percent and 1.8 percent annually from 2017 to future year 2040 under the No-Build Scenario.

4.1 2040 No-Build Arterial Volumes

NCHRP 765 similarly provides a methodology for approximating future intersection peak hour turning movements using existing daily and peak hour traffic counts and adjusted future daily traffic volumes. The NCHRP 765 modeling adjustment process uses model growth estimates and observed counts to arrive at forecasted 2040 AM and PM peak hour traffic volumes.

The travel demand model forecasts do not include local roads or access roads that are included more detailed TransModeler microsimulation models. The 84th Avenue, Thornton Parkway, and 104th Avenue arterial volumes were initially projected using the NCHRP 765 methodology. Resulting turning movements were subsequently adjusted to ensure reasonable turning volumes and balanced volumes for all intersections along the corridor and included in the microsimulation model. **Figure 11** through **Figure 13** show the projected 2040 No-Build arterial traffic volumes**.**

4.2 2040 No-Build I-25 General Purpose & Tolled Express Lane Volumes

The NCHRP 765 methodology was also used to forecast arterial intersection volumes and at the ramp terminal intersections. The resulting AM and PM peak hour ramp volumes were referenced to calculate the entering/exiting volumes as a percent of adjusted daily forecasts. The projected I-25 segment volumes were adjusted to arrive at a set of balanced total projected (GP + TEL) AM and PM peak hour volumes.

The 2040 TEL volumes were forecast using (1) the existing TEL volumes and ingress/egress interactions, (2) the April 2014 and July 2016 Technical Memoranda completed by CDM Smith updating the I-25 TEL forecasts, and (3) the total projected volumes (GP + TEL) on I-25 from the 2040 Travel Demand Model. **Appendix B** includes the CDM Smith April 2014 and July 2016 Technical Memoranda.

The April 2014 Technical Memorandum provided the most up-to-date TEL opening day forecasts available during the calibration of existing conditions. The July 2016 Technical Memorandum includes updated 2035 TEL forecast information and was referenced for the development of the 2040 No-Build TEL forecasts. The GP/TEL volume splits for the AM and PM peak hours were forecast using the followed parameters:

- The *CDM Smith Technical Memoranda* assumed a maximum service volume of 1,500 to 1,800 vph per lane; for the purposes of this modeling effort, TEL volumes were restricted to 1650 vph or less on all segments
- The ingress/egress patterns as reflected in the *July 2016 CDM Smith Technical Memorandum* 2035 TEL forecasts.

Figure 14 shows the 2040 No-Build Scenario peak hour mainline GP, TEL, and ramp volumes**.**

Figure 11. No-Build Scenario – 2040 AM and PM Traffic Volumes – 104th Avenue

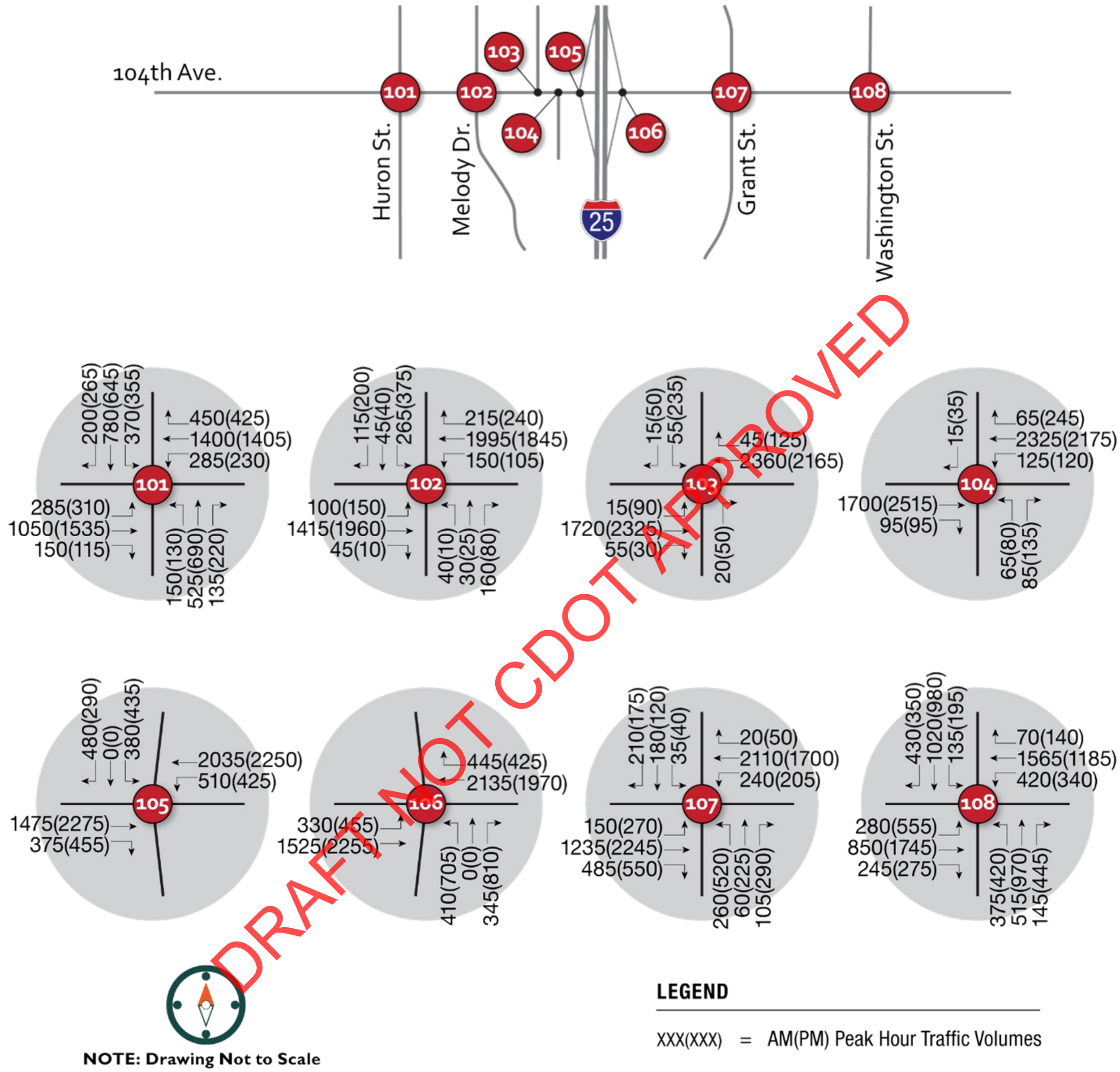


Figure 12. No-Build Scenario – 2040 AM and PM Traffic Volumes – Thornton Parkway

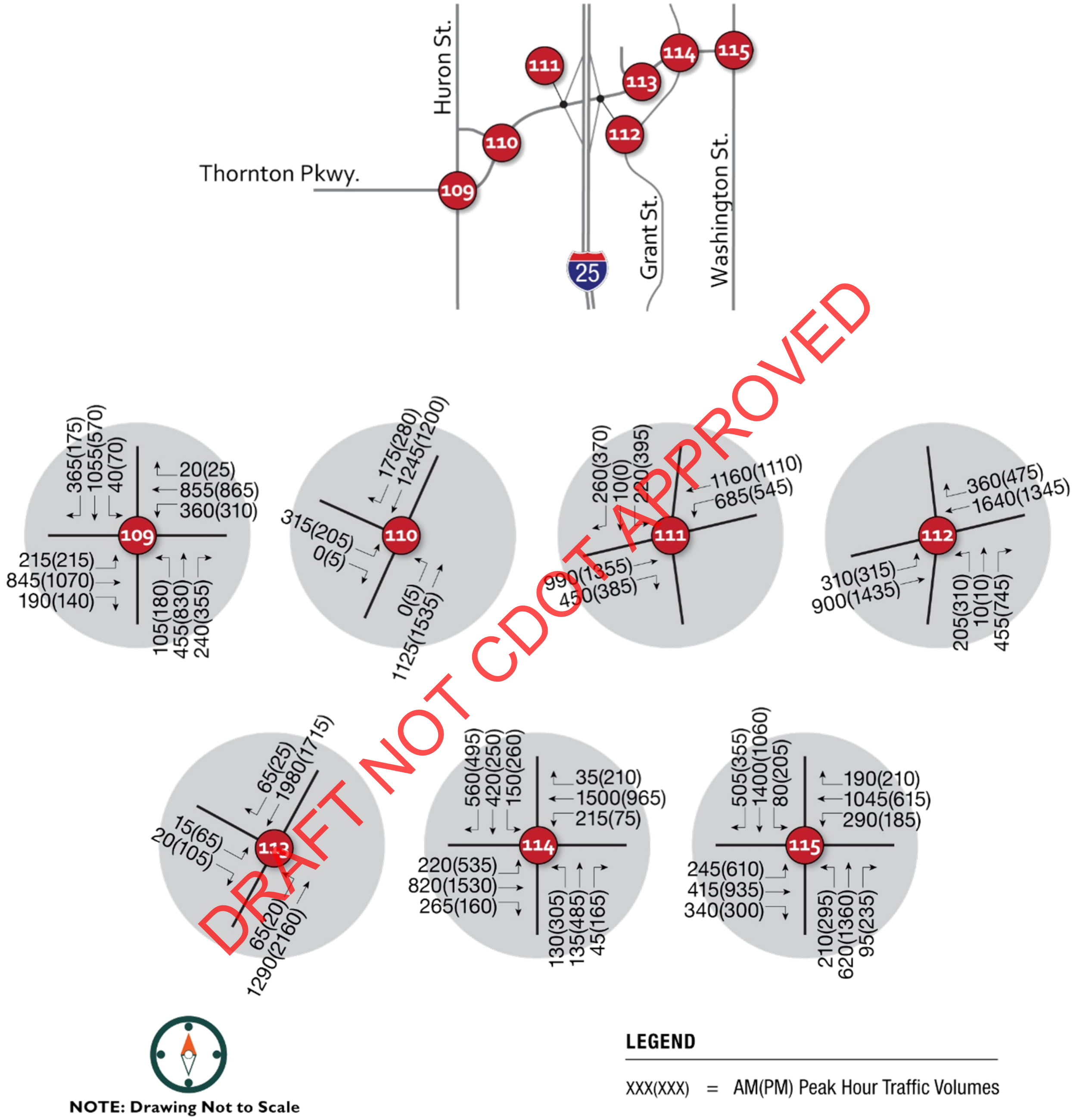


Figure 13. No-Build Scenario – 2040 AM and PM Traffic Volumes – 84th Avenue

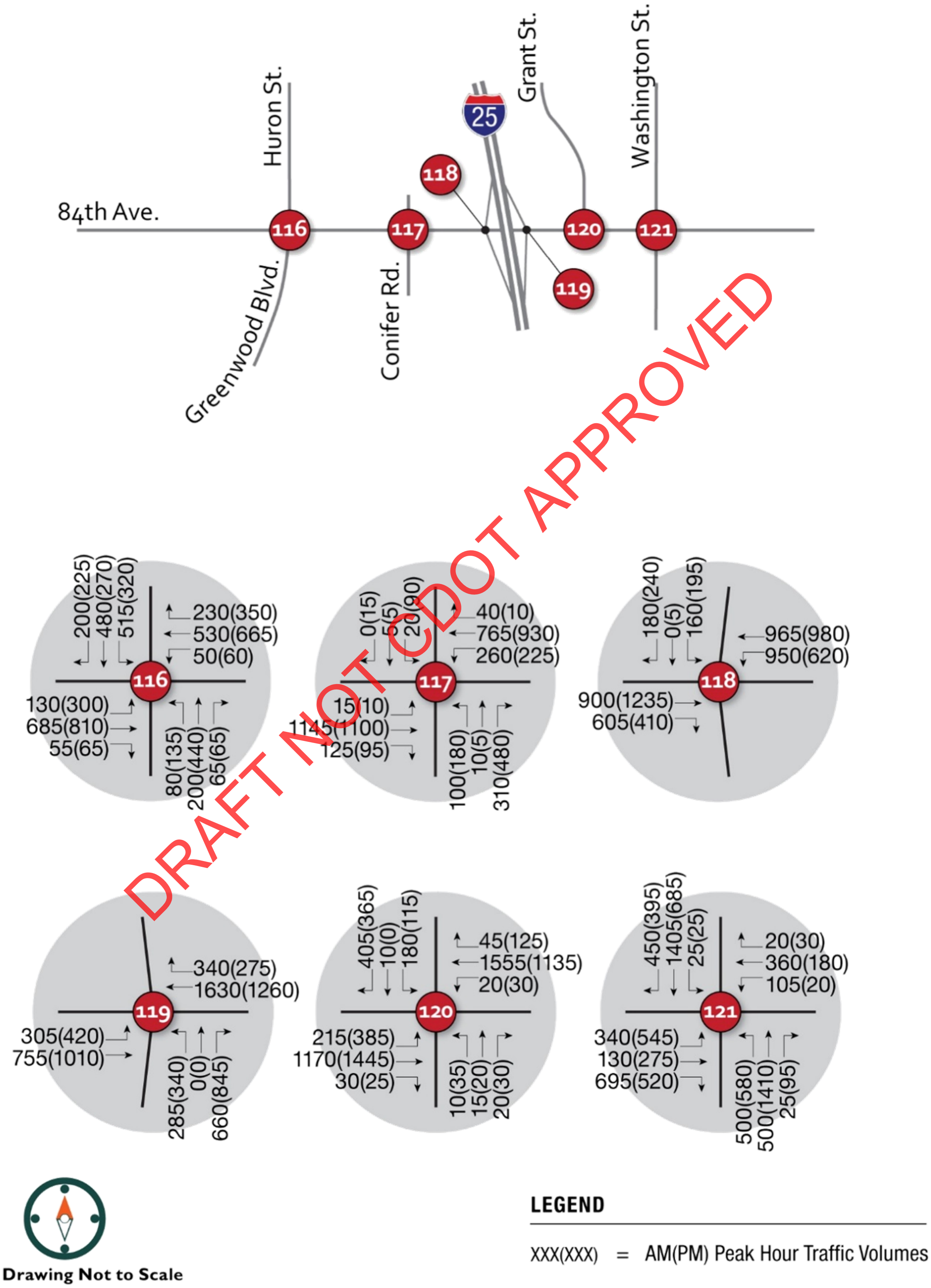
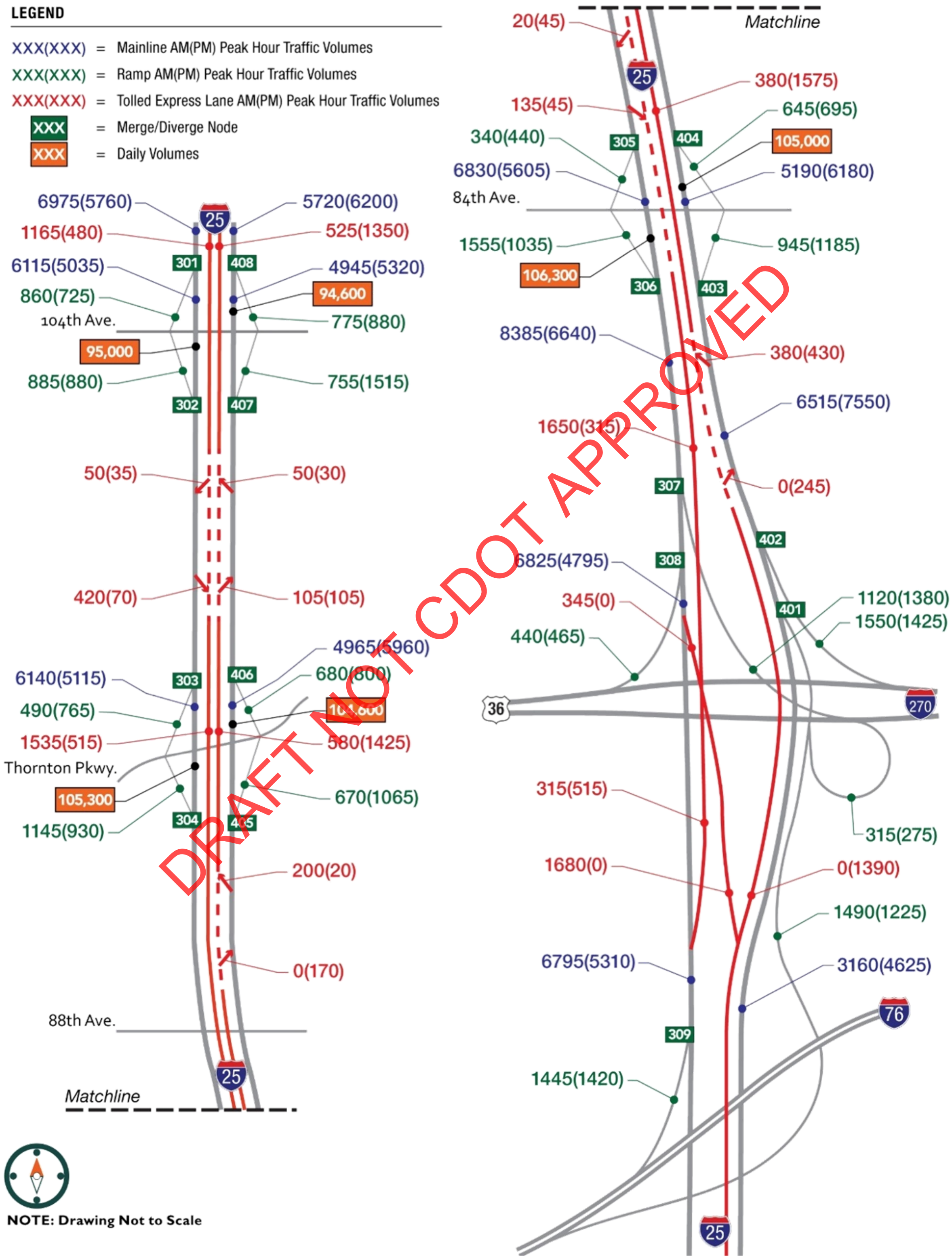


Figure 14. No-Build Scenario – 2040 AM and PM Traffic Volumes – Ramps, Mainline GP, and TEL

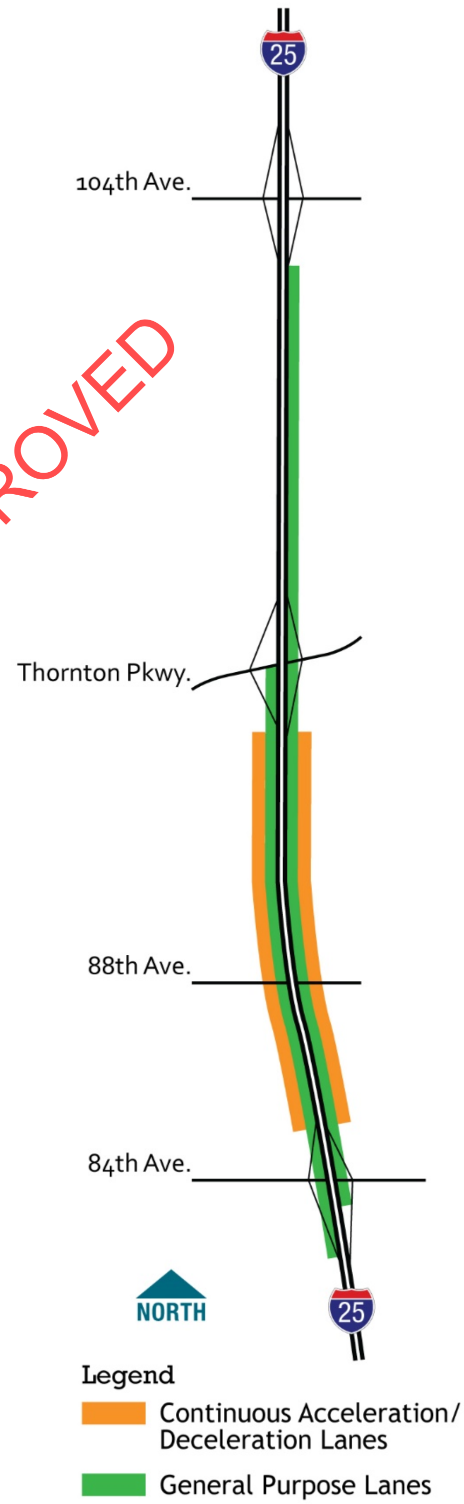


5. 2040 BUILD CONDITIONS

5.1 2040 Build – Southbound I-25 Roadway Configuration

In the southbound direction, the Preferred Alternative includes:

- Adding one GP lane in the southbound direction between the Thornton Parkway and 84th Avenue interchanges
- Adding one continuous acceleration/deceleration auxiliary lane between the Thornton Parkway and 84th Avenue interchanges



The fourth GP lane has been added between the Thornton Parkway southbound off- and on-ramps, under the Thornton Parkway bridge. To accommodate both the fourth GP lane and the continuous acceleration/deceleration lane, the southbound Thornton Parkway on-ramp merges from two lanes to one lane beyond the ramp meter, before merging onto I-25 southbound in the Build configuration.

The 84th Avenue interchange was identified as the southern terminus of the project improvements. Under the existing and No-Build roadway configuration, additional capacity is available south of the 84th Avenue interchange where the 84th on-ramp forms a continuous lane to the I-70 off-ramp. The fourth GP ties into the 84th Avenue on-ramp continuous lane to I-76 and the 84th Avenue on-ramp is converted to a merge condition with a 1,620 ft acceleration lane (measured from the stop bar at the ramp meter to the start of the 300 ft taper).

5.2 2040 Build – Northbound I-25 Roadway Configuration

In the northbound direction, the Preferred Alternative includes:

- Adding one GP lane in the northbound direction between the 84th Avenue and 104th Avenue interchanges
- Adding one continuous acceleration/deceleration auxiliary lane between the 84th Avenue and Thornton Parkway interchanges

6. 2040 BUILD TRAFFIC VOLUMES

The 2040 DRCOG travel demand model was modified to reflect the Preferred Alternative roadway improvements. Like the 2040 No-Build volumes, the model forecasts underwent the NCHRP 765 post-processing adjustment process, and the NCHRP 765 methodology was used to develop AM and PM peak hour intersection turning movements traffic volumes. All resulting turning movements were subsequently adjusted to ensure reasonable turning volumes and balanced volumes along the corridor.

Under the 2040 Build Scenario, daily traffic volumes are projected to grow at a slightly higher rate of between 0.9 percent and 1.9 percent annually.

6.1 2040 Build Arterial Volumes

As with the 2040 No-Build volumes, NCHRP 765 was used to forecast future intersection peak hour turning movements. There were no changes to the land use assumptions (see *Section 3, Traffic Growth Forecasts, Land Use, and Travel Demand* Assumptions) between the 2040 No-Build and Build scenarios. As such, arterial volumes to/from the various commercial accesses remained similar.

Figure 15 through **Figure 18** show the projected 2040 traffic volumes for the No-Build Scenario.

6.2 2040 Build Tolled Express Lane Volumes

Like the 2040 No-Build I-25 mainline volumes, the 2040 Build volumes (GP + TEL) were forecast using the NCHRP methodologies, as discussed in *Section 6, 2040 Build Traffic Volumes*.

Acknowledging that the Build Scenario adds GP capacity, the GP/TEL volume splits were forecast using the followed guidance:

- TEL volumes were restricted to 1,650 vph or less on all segments
- GP volume per lane was generally held constant on segments not affected by the proposed roadway improvements

Building on these general assumptions, the TEL volumes and ingress/egress interactions were estimated as follows:

- Calculate the No-Build GP per lane volume on the segments not affected by the proposed Build improvements
- Subtract the GP volumes from the total forecasted volumes to estimate TEL volumes
- Calculate the Existing and No-Build GP per lane volume on segments affected by the proposed Build improvements
- In the peak direction, assume the Build GP per lane volume to be less than the 2040 No-Build but greater than the Existing GP per lane volume.
- Adjust the TEL ingress and egress volumes to achieve the forecasted TEL segment volumes and reflect existing and 2040 No-Build ingress/egress patterns
- Generally, hold GP/TEL ratios constant on segments not affected by the proposed roadway improvements

Figure 19 shows the 2040 Build Scenario peak hour mainline GP, TEL, and ramp volumes.

Figure 15. Build Scenario – 2040 AM and PM Traffic Volumes – 104th Avenue

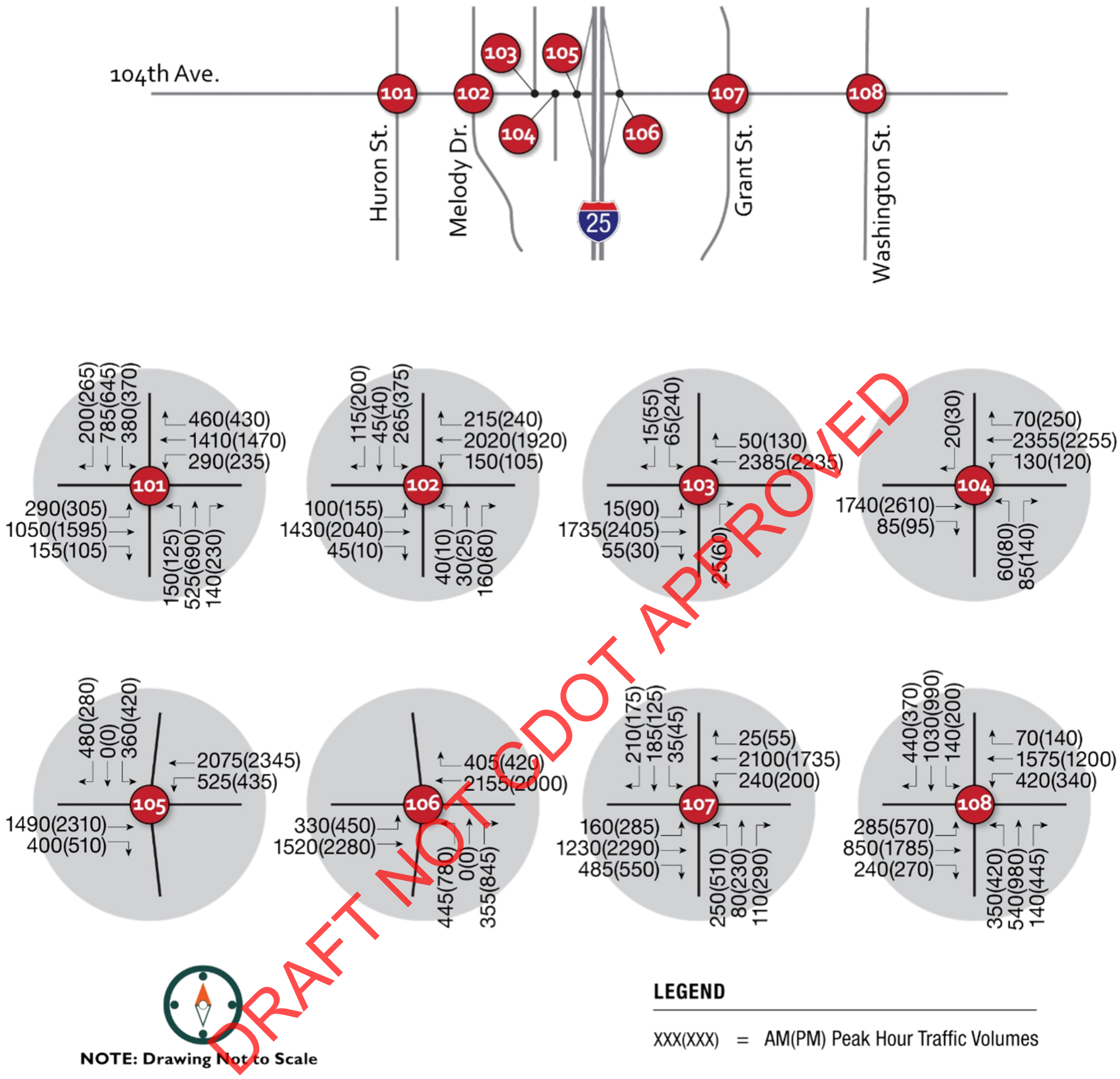

104th Ave.
101
102
103
104
105
106
107
108
Huron St.
Melody Dr.
25
Grant St.
Washington St.
200(265)
785(645)
380(370)
460(430)
1410(1470)
290(235)
290(305)
1050(1595)
155(105)
150(125)
525(690)
140(230)
115(200)
45(40)
265(375)
215(240)
2020(1920)
150(105)
100(155)
1430(2040)
45(10)
40(10)
30(25)
160(80)
15(55)
65(240)
50(130)
2385(2235)
15(90)
1735(2405)
55(30)
25(60)
20(30)
70(250)
2355(2255)
130(120)
1740(2610)
85(95)
60(80)
85(140)
480(280)
0(0)
360(420)
2075(2345)
525(435)
1490(2310)
400(510)
405(420)
2155(2000)
330(450)
1520(2280)
445(780)
0(0)
355(845)
210(175)
185(125)
35(45)
25(55)
2100(1735)
240(200)
160(285)
1230(2290)
485(550)
250(510)
80(230)
110(290)
440(370)
1030(990)
140(200)
70(140)
1575(1200)
420(340)
285(570)
850(1785)
240(270)
350(420)
540(980)
140(445)
NOTE: Drawing Not to Scale
LEGEND
XXX(XXX) = AM(PM) Peak Hour Traffic Volumes

Figure 16. Build Scenario – 2040 AM and PM Traffic Volumes – Thornton Parkway

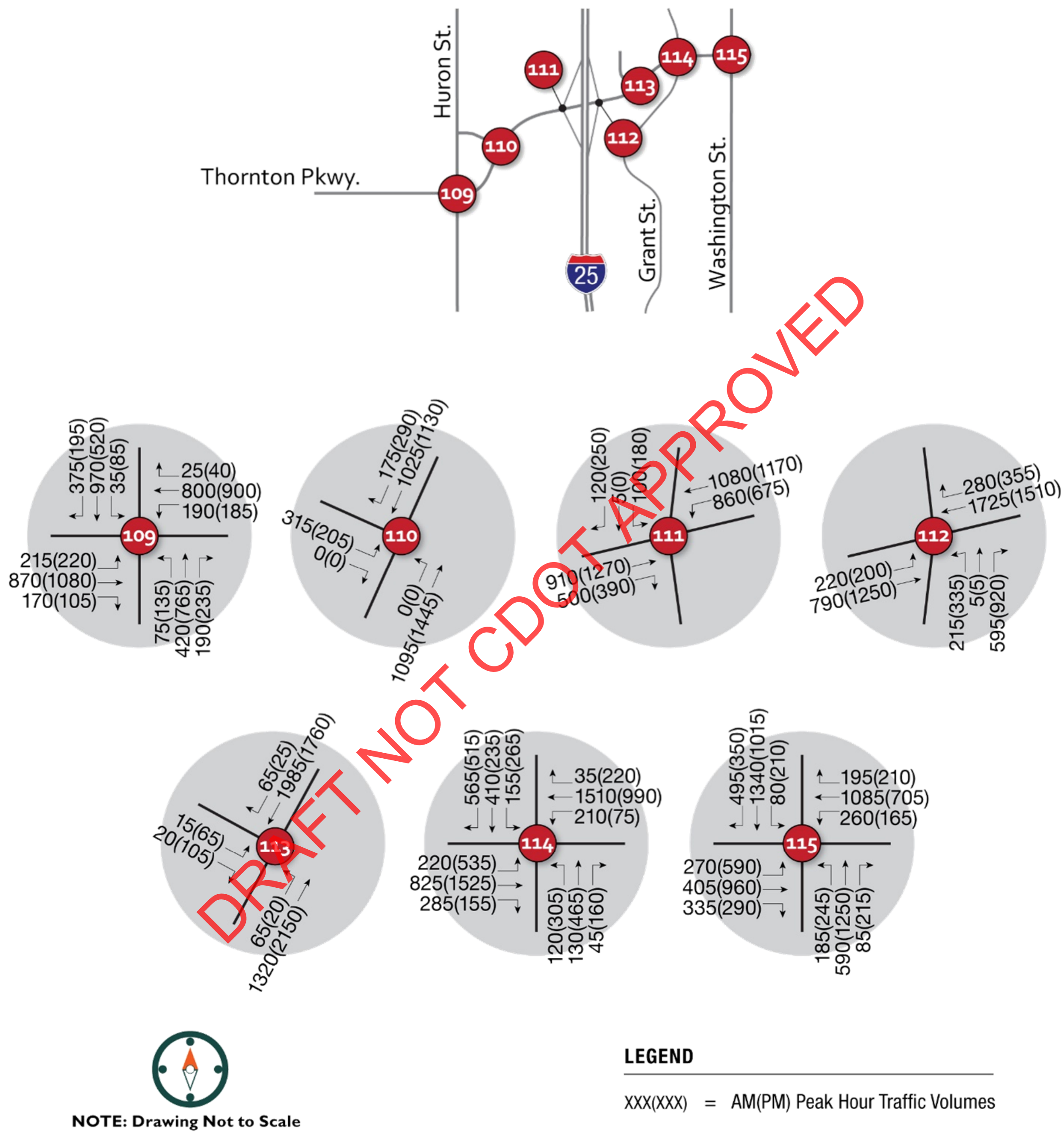
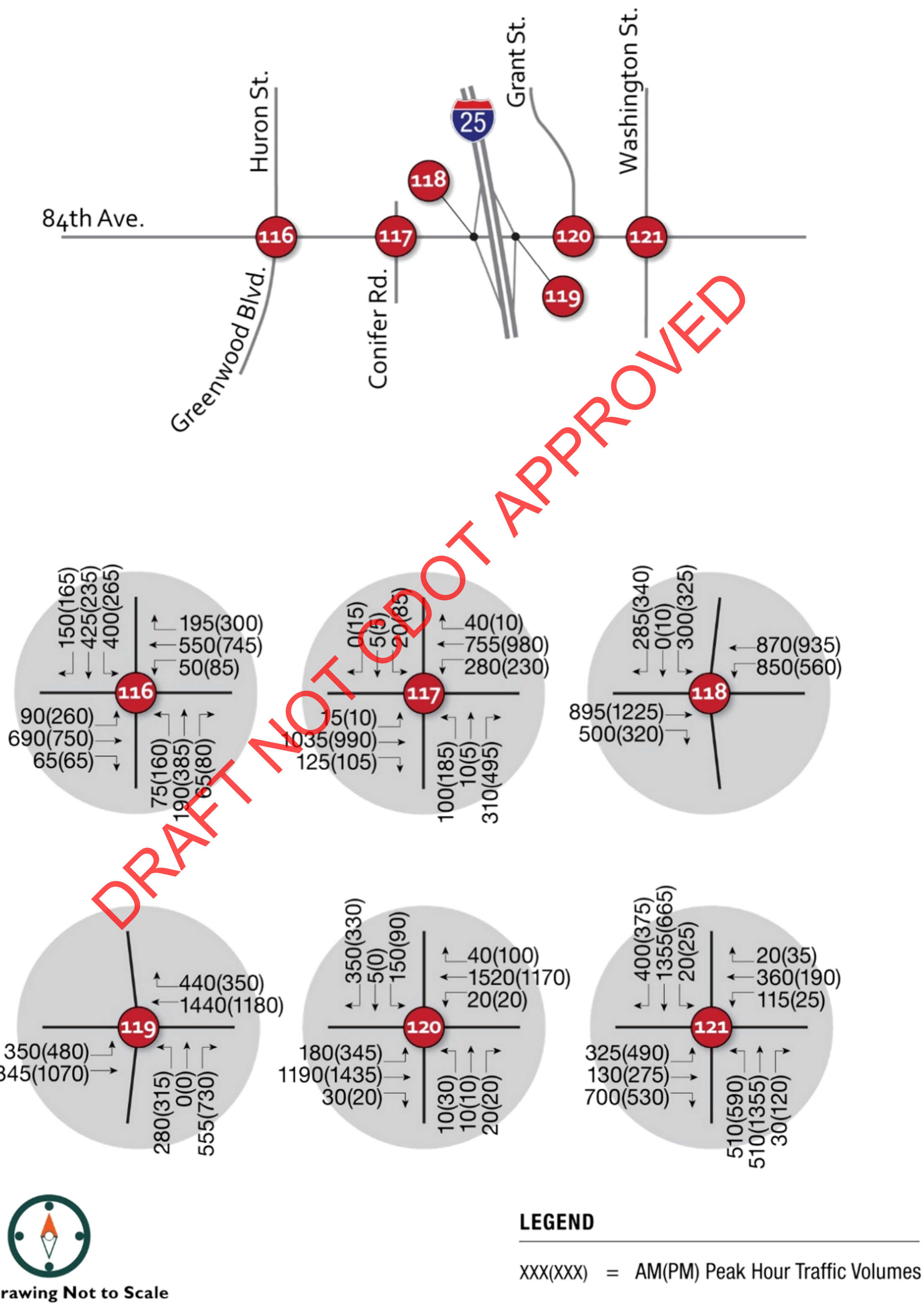


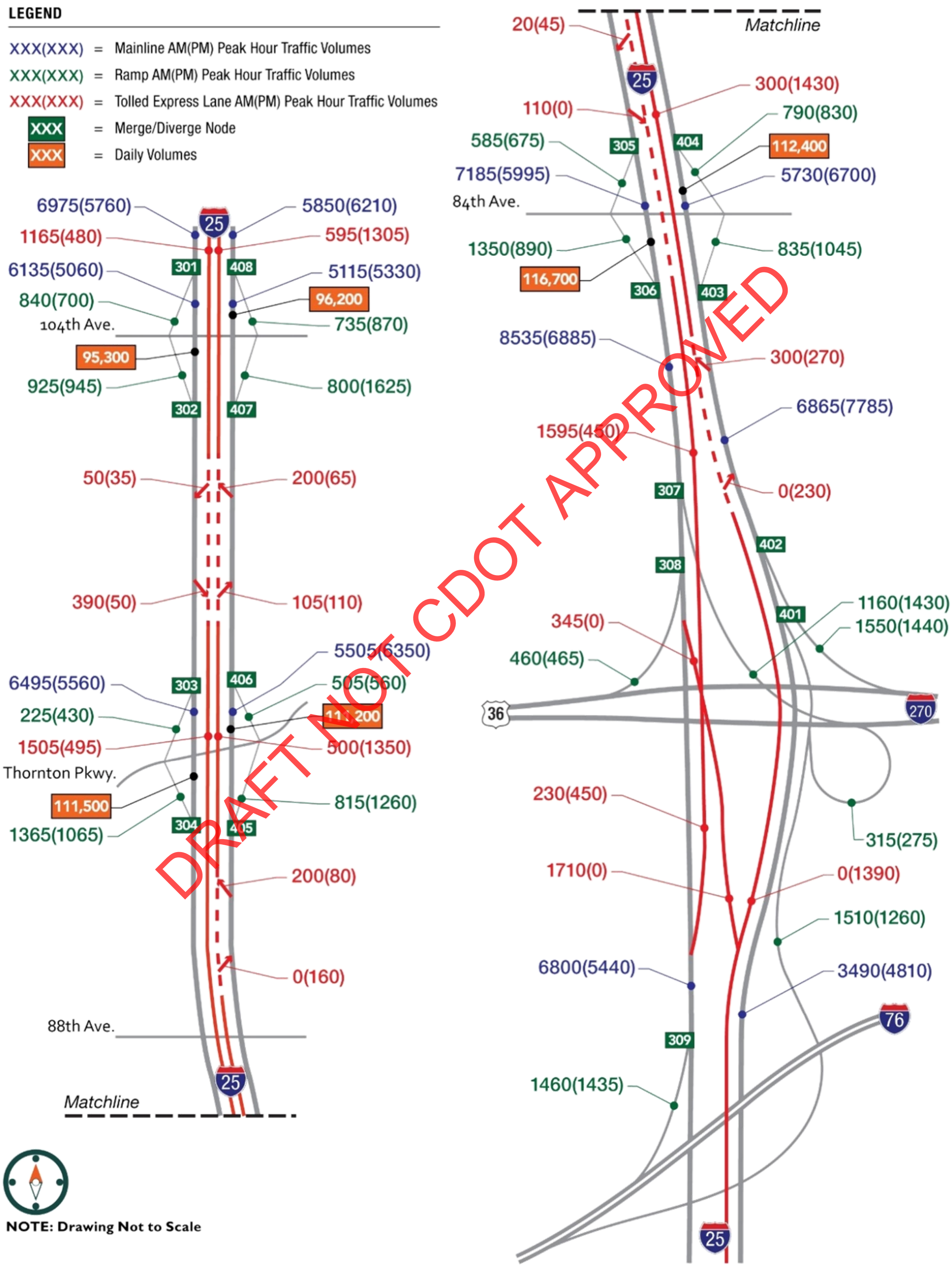
Figure 17. Build Scenario – 2040 AM and PM Traffic Volumes – 84th Avenue



LEGEND

XXX(XXX) = AM(PM) Peak Hour Traffic Volumes

Figure 18. Build Scenario – 2040 AM and PM Traffic Volumes – Ramps, Mainline GP and TEL



7. MEASURES OF EFFECTIVENESS

Measures of Effectiveness (MOEs) are the system performance statistics that quantify the degree to which a proposed improvement meets the project objectives.

It is important to note that there are inherent limitations for MOEs to evaluate extremely congested conditions. Speed, density, stops, and travel-time variance are invariant under "parking lot" conditions where vehicles are not moving (speed equals zero, density equals jam density). For these extreme congestion conditions, it is better to rely on travel time and delay (which continue to increase over the length of the analysis period) to understand the extent of the congestion.

Furthermore, the various model and software outputs summarized in this memorandum represent conditions without roadway incidents that can occur from time to time on I-25 or any study area roadways and would be expected to affect operations.

7.1 System Performance

The following network-wide performance metrics were used to evaluate each TransModeler model:

- **Average Speed:** Travel speed averaged all vehicles that completed their trips in the analysis period.
- **Total Delay:** Total difference between experienced travel time and free-flow travel time, summed over all vehicles that completed their trips in the analysis period.
- **VHT:** Vehicle hours traveled; the sum total travel time experienced by all vehicles that completed their trips in the analysis period.
- **VMT:** Vehicle miles traveled; the sum total distance traveled by all vehicles that completed their trips in the analysis period.

Table 3 compares the following network performance metrics for the 2040 AM and PM peak hour No-Build and Build scenarios.

Table 3. 2040 No-Build and Build Network Performance Metrics

	AM Peak Hour		PM Peak Hour	
	2040 No-Build Scenario	2040 Build Scenario	2040 No-Build Scenario	2040 Build Scenario
Average Speed (mph)	26.8	28.0	25.3	29.1
Total Delay (hrs)	2,055	2,030	2,325	2,065
VHT (hrs)	3,565	3,660	3,830	3,835
VMT (veh-mi)	95,625	102,630	98,375	111,475

During the AM peak hour, the 2040 Build Scenario is projected to process a higher VMT, with a modest reduction to the total delay (in hours) and a small increase to network-wide average speed.

The 2040 Build Scenario PM peak hour is projected to experience a 4 mph increase in average network speed compared to the No-Build Scenario. This increase in average speed is also reflected in a 260-hour reduction in total delay and an increase in total VMT.

Subsequent sections summarize the operational differences between the No-Build and Build scenarios.

7.2 Vehicle Throughput and Percent Incomplete Trips

Measuring vehicle throughput (vehicles/hour) can be one indicator of the productivity of a facility or a network by reflecting the number of vehicles processed by the system for the analysis period. Generally, higher throughputs and lower percentages of incomplete trips reflect higher productivity of the transportation network being evaluated.

Incomplete trips reflect the total number of trips unable to reach their destination in the modeled period. The peak hour demand estimations reflect trips that were completed from 7 to 8 AM and from 5 to 6 PM.

As previously noted, study area 2040 Build traffic volumes along mainline I-25 are projected to be higher than those under the No-Build Scenario. Increased vehicle throughput is reflected in the increase in peak hour VMT between the No-Build and Build scenarios.

Table 4 compares the percent of incomplete trips for the entire TransModeler study network and the corresponding VMT as an indicator of change in vehicle throughput.

Table 4. Percent of Incomplete Trips

	AM Peak Hour		PM Peak Hour	
	2040 No-Build Scenario	2040 Build Scenario	2040 No-Build Scenario	2040 Build Scenario
% of Incomplete Trips	5.4 %	5.2 %	5.3 %	2.5 %
VMT (veh-mi)	95,625	102,630	98,375	111,475

7.3 Travel Time Index

The Travel Time Index (TTI) is the ratio of peak period travel time to the free-flow travel time. TTI is used to determine if facility operation during peak periods is unacceptably worse than during off-peak periods.

The FHWA *Traffic Analysis Toolbox Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools and Measures of Effectiveness* provides the following interpretation of the TTI:

- For more focused systems of mixed freeway and arterial facilities (no local streets), a TTI of under 2.5 roughly indicates generally uncongested conditions and good signal coordination.
- For a system of solely unsignalized facilities (freeways, highways, 2-lane rural roads), a TTI of over 1.4 indicates a facility that is over-capacity for the entire length of the analysis period.
- A qualifier of "Good" for TTIs <= 1.5, "Potentially Acceptable" for TTIs between 1.5 and 2.5, and "Less Desirable" for TTIs > 2.5.

The TTIs for the No-Build and Build scenarios have been evaluated on the "Good," "Potentially Acceptable," and "Less Desirable" levels outlined in the FHWA Toolbox. **Table 5** compares the calculated TTIs of the Existing, 2040 No-Build, and Build scenarios.

Table 5. Travel Time Indices

	AM Peak Hour		PM Peak Hour	
	TTI	Interpretation	TTI	Interpretation
Existing (2017)	1.66	Potentially Acceptable	1.78	Potentially Acceptable
2040 No-Build	2.36	Potentially Acceptable	2.56	Less Desirable
2040 Build	2.24	Potentially Acceptable	2.17	Potentially Acceptable

Under the 2040 No-Build Scenario, the PM peak hour TTI for the network exceeds 2.5 and falls under the "Less Desirable" range. However, under the Build Scenario, the proposed improvements decrease the variability between the projected off-peak and PM peak hour travel time variability and the TTI returns to the "Potentially Acceptable" range.

7.4 Mainline I-25 Operations

Microsimulation is especially useful in analyzing freeways because of its sophisticated driver behavior algorithms that can more accurately reflect lane changing and car follow maneuvers.

Several mainline I-25 MOEs have been considered to better understand the operational differences between the 2040 No-Build and Build scenarios.

7.4.1 Freeway Operational Analysis – Level of Service

Density generally determines Level of Service (LOS) on freeway facilities (basic freeway segments, merge segments, weaving segments, and diverge segments).

Table 6 summarizes the relationship between density and LOS for merging, diverging, and basic freeway segments.

Table 6. Freeway Level of Service Thresholds

Level of Service (LOS)	Merging and Diverging Segment Density (pc/mi/ln)	Basic Freeway Segment Density (pc/mi/ln)
A	0 – 10	0 – 11
B	> 10 – 20	> 11 – 18
C	> 20 – 28	> 18 – 26
D	> 28 – 35	> 26 – 35
E	> 35	> 35 – 45
F	Demand exceeds capacity	> 45

Existing (2017) Freeway Operations

During the AM peak hour, southbound vehicles heading into downtown experience congestion and delay near the Thornton Parkway interchange. Queuing extends upstream from the Thornton Parkway merge point, through the interchange. Southbound volumes between the Thornton Parkway interchange and the 84th Avenue interchange are roughly at capacity. Further south, AM southbound demand heading into downtown Denver creates queuing and congestion beginning near the I-76 on-ramp to southbound I-25, extending north to approximately the I-25/US 36/I-270 interchange.

During the PM peak hour, northbound congestion similarly occurs between the 84th Avenue and Thornton Parkway interchanges, where existing volumes are nearing/exceeding capacity. Existing turbulence created vehicles merging onto I-25 from the US 36, I-76, and I-270 on-ramps and heavy exiting volumes at 84th Avenue result in delay and congestion. Once through this area, northbound vehicles encounter some congestion relief near the Thornton Parkway interchange as demand decreases heading north; at 104th Avenue, the existing demand is below capacity. **Table 7** summarizes the existing AM and PM peak hour freeway LOS for mainline I-25.

Table 7. Existing (2017) Peak Hour Freeway Level of Service

	Facility Type	AM Peak Hour		PM Peak Hour	
		Density (pc/mi/ln)	LOS	Density (pc/mi/ln)	LOS
Southbound I-25					
North of 104th Avenue Interchange	Basic	28.4	D	21.4	C
104th Avenue Off-Ramp	Diverge	28.0	D	23.7	C
Between 104th Avenue Ramps	Basic	29.3	D	22.0	C
104th Avenue On-Ramp	Merge	32.0	D	26.5	C
Between Thornton Parkway and 104th Avenue	Basic	34.6	D	27.1	D
Thornton Parkway Off-Ramp	Diverge	32.0	D	28.2	D
Between Thornton Parkway Ramps	Basic	37.2	E	25.1	C
Thornton Parkway On-Ramp	Merge	34.0	D	24.0	C
Between 84th Avenue and Thornton Parkway	Basic	41.8	E	31.0	D
84th Avenue Off-Ramp	Diverge	32.9	D	22.8	C
Between 84th Avenue Ramps	Basic	38.5	E	27.2	D
84th Avenue On-Ramp	Basic	35.2	E	24.3	C
Between I-270 and 84th Avenue	Basic	35.2	E	24.3	C
I-270 Off-Ramp	Basic	35.2	E	24.3	C
US 36 Off-Ramp	Diverge	37.4	E	29.5	D
Between US 36 and I-76 Ramps	Basic	28.0	D	21.6	C
I-76 Off Ramp	Basic	28.0	D	31.6	D
South of I-76 Off-Ramp	Basic	42.4	E	19.0	C
Northbound I-25					
North of 104th Avenue Interchange	Basic	62.5	C	24.7	C
104th Avenue On-Ramp	Merge	55.6	C	19.7	B
Between 104th Avenue Ramps	Basic	54.1	C	25.3	C
104th Avenue Off-Ramp	Diverge	51.9	C	35.1	E
Between Thornton Parkway and 104th Avenue	Basic	50.1	D	36.4	E
Thornton Parkway On-Ramp	Merge	46.5	C	37.2	E
Between Thornton Parkway Ramps	Basic	49.9	C	33.4	D
Thornton Parkway Off-Ramp	Diverge	28.1	D	36.5	E
Between 84th Avenue and Thornton Parkway	Basic	30.0	D	39.7	E
84th Avenue On-Ramp	Merge	29.5	D	38.8	E
Between 84th Avenue Ramps	Basic	25.9	C	35.0	E
84th Avenue Off-Ramp	Basic	22.8	C	30.2	D
Between I-270 and 84th Avenue	Basic	22.8	C	30.2	D
I-270 On-Ramp	Basic	28.0	D	31.4	D
US 36/I-76 On-Ramp	Basic	23.9	C	29.9	D
South of US 36/I-76 On-Ramp	Basic	17.5	B	25.6	C

2040 No-Build Freeway Operations

Table 8 summarizes the 2040 No-Build Scenario AM and PM peak hour freeway LOS for mainline I-25.

Key findings for the 2040 No-Build freeway operations include:

- Southbound AM peak hour queuing and congestion at Thornton Parkway are projected to extend north of the 104th Avenue interchange.
- The southbound AM peak hour merge and diverge interactions at the I-76/US 36/I-270 interchange are projected to experience increased demand resulting in increased delays and queuing.
- The northbound AM peak hour merge from I-270, between the 84th Avenue and Thornton Parkway interchanges, and between the Thornton Parkway and 104th Avenue interchanges are projected to be at LOS E; the rest of the corridor is projected to operate at LOS D or better.
- The northbound PM peak hour increased demand is projected to result in increased delays and queuing, and reduced speeds from the southern terminus of the corridor to the 104th Avenue off-ramp; operating at LOS F for most of the corridor with a few LOS E segments.
- The northbound PM peak hour merge onto I-25 near the I-76/US 36/I-270 interchange complex experiences significant queuing and congestion.
- The southbound PM peak hour operates at LOS F/E between the 104th Avenue and 84th Avenue interchanges and the 84th Avenue Off-Ramp operates at LOS D.

2040 Build Freeway Operations

Table 9 summarizes the 2040 Build Scenario AM and PM peak hour freeway LOS for mainline I-25.

Key findings for the 2040 Build freeway operations include:

- The southbound AM peak hour freeway LOS between the Thornton Parkway and 84th Avenue interchanges improves from LOS E/F to LOS D/E.
- The southbound AM peak hour merge and diverge interactions at the I-76/US 36/I-270 interchange are projected to experience increased demand resulting in increased delays and queuing; there are no improvements to this segment of I-25 in the Build Scenario.
- The northbound AM peak hour is projected to experience improved operations with all segments operating at LOS D or better, except the I-270 on-ramp segment, which is projected to remain at LOS E.
- The northbound PM peak hour is projected to improve to LOS D/E between the 84th Avenue and 104th Avenue interchanges.
- The northbound PM peak hour merge onto I-25 near the I-76/US 36/I-270 interchange complex is not affected by the Build improvements and continues to operate at LOS F.
- The southbound PM peak hour improves to LOS C/D between the Thornton Parkway and 84th Avenue interchanges.

Table 8. 2040 No-Build Peak Hour Freeway Level of Service

	Facility Type	AM Peak Hour		PM Peak Hour	
		Density (pc/mi/ln)	LOS	Density (pc/mi/ln)	LOS
Southbound I-25					
North of 104th Avenue Interchange	Basic	64.5	F	31.1	D
104th Avenue Off-Ramp	Diverge	72.0	F	33.3	D
Between 104th Avenue Ramps	Basic	85.9	F	34.4	D
104th Avenue On-Ramp	Merge	84.9	F	53.7	F
Between Thornton Parkway and 104th Avenue	Basic	74.0	F	49.2	F
Thornton Parkway Off-Ramp	Diverge	82.7	F	55.9	F
Between Thornton Parkway Ramps	Basic	81.0	F	35.4	E
Thornton Parkway On-Ramp	Merge	53.2	F	36.2	E
Between 84th Avenue and Thornton Parkway	Basic	44.3	E	39.4	E
84th Avenue Off-Ramp	Diverge	51.2	F	34.8	D
Between 84th Avenue Ramps	Basic	44.5	E	36.2	E
84th Avenue On-Ramp	Basic	41.0	E	30.5	D
Between I-270 and 84th Avenue	Basic	41.0	E	30.5	D
I-270 Off-Ramp	Basic	41.0	E	30.5	D
US 36 Off-Ramp	Diverge	44.7	E	38.1	E
Between US 36 and I-76 Ramps	Basic	82.4	F	26.1	D
I-76 Off Ramp	Basic	82.4	F	26.1	D
South of I-76 Off-Ramp	Basic	58.7	F	25.7	C
Northbound I-25					
North of 104th Avenue Interchange	Basic	29.0	D	30.7	D
104th Avenue On-Ramp	Merge	31.0	D	25.8	C
Between 104th Avenue Ramps	Basic	29.9	D	30.6	D
104th Avenue Off-Ramp	Diverge	36.8	E	40.8	E
Between Thornton Parkway and 104th Avenue	Basic	36.3	E	40	E
Thornton Parkway On-Ramp	Merge	37.8	E	46.6	F
Between Thornton Parkway Ramps	Basic	35.0	D	44.5	E
Thornton Parkway Off-Ramp	Diverge	37.0	E	60.1	F
Between 84th Avenue and Thornton Parkway	Basic	38.7	E	58.4	F
84th Avenue On-Ramp	Merge	39.4	E	65.6	F
Between 84th Avenue Ramps	Basic	33.9	D	77.9	F
84th Avenue Off-Ramp	Basic	31.3	D	104.4	F
Between I-270 and 84th Avenue	Basic	31.3	D	104.4	F
I-270 On-Ramp	Basic	35.1	E	152.0	F
US 36/I-76 On-Ramp	Basic	30.0	D	134.2	F
South of US 36/I-76 On-Ramp	Basic	22.0	C	78.8	F

Table 9. 2040 Build Peak Hour Freeway Level of Service

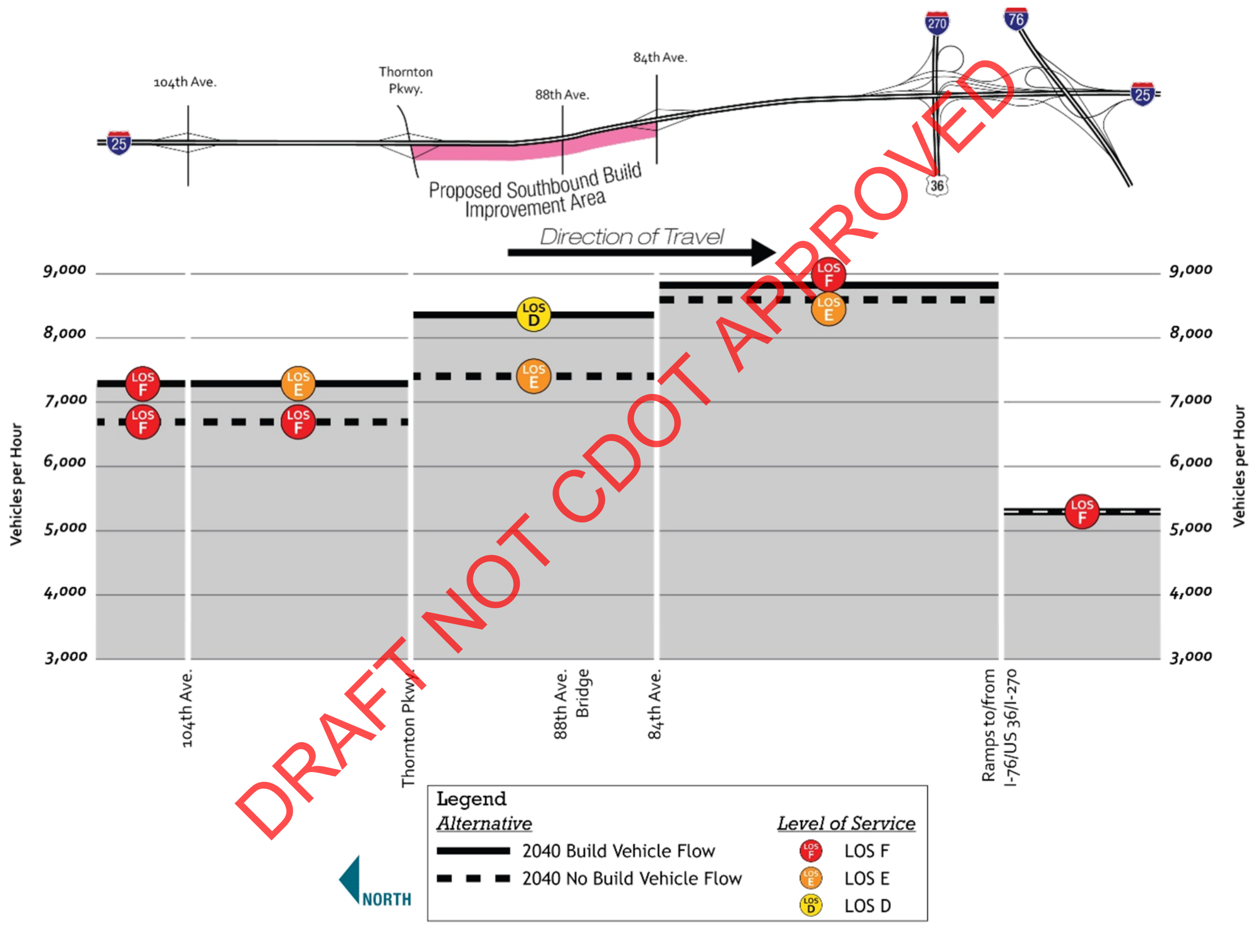
	Facility Type	AM Peak Hour		PM Peak Hour	
		Density (pc/mi/ln)	LOS	Density (pc/mi/ln)	LOS
Southbound I-25					
North of 104th Avenue Interchange	Basic	55.0	F	30.8	D
104th Avenue Off-Ramp	Diverge	58.7	F	34.7	D
Between 104th Avenue Ramps	Basic	78.3	F	36.9	E
104th Avenue On-Ramp	Merge	62.4	F	54.7	F
Between Thornton Parkway and 104th Avenue	Basic	41.9	E	49.3	F
Thornton Parkway Off-Ramp	Diverge	55.1	F	56.8	F
Between Thornton Parkway Ramps	Basic	36.6	E	27.8	D
Thornton Parkway On-Ramp	Merge	34.4	D	23.4	C
Between 84th Avenue and Thornton Parkway	Basic	34.4	D	23.4	C
84th Avenue Off-Ramp	Diverge	34.4	D	23.4	C
Between 84th Avenue Ramps	Basic	61.9	F	26.0	D
84th Avenue On-Ramp	Basic	77.0	F	26.4	C
Between I-270 and 84th Avenue	Basic	60.9	F	29.5	D
I-270 Off-Ramp	Basic	60.9	F	29.5	D
US 36 Off-Ramp	Diverge	94.4	F	38.8	E
Between US 36 and I-76 Ramps	Basic	112.6	F	27.0	D
I-76 Off Ramp	Basic	112.6	F	27.0	D
South of I-76 Off-Ramp	Basic	52.1	F	25.6	C
Northbound I-25					
North of 104th Avenue Interchange	Basic	29.8	D	34.4	D
104th Avenue On-Ramp	Merge	34.8	D	33.1	D
Between 104th Avenue Ramps	Basic	31.5	D	35.2	E
104th Avenue Off-Ramp	Diverge	26.5	C	32.6	D
Between Thornton Parkway and 104th Avenue	Basic	29.1	D	36.3	E
Thornton Parkway On-Ramp	Merge	27.5	C	34.6	D
Between Thornton Parkway Ramps	Basic	27.2	D	31.8	D
Thornton Parkway Off-Ramp	Diverge	21.9	C	36.5	E
Between 84th Avenue and Thornton Parkway	Basic	23.5	C	31.5	D
84th Avenue On-Ramp	Merge	23.5	C	31.5	D
Between 84th Avenue Ramps	Basic	27.9	D	34.9	D
84th Avenue Off-Ramp	Basic	32.4	D	77.9	F
Between I-270 and 84th Avenue	Basic	32.4	D	77.9	F
I-270 On-Ramp	Basic	37.0	E	126.6	F
US 36/I-76 On-Ramp	Basic	32.1	D	101.4	F
South of US 36/I-76 On-Ramp	Basic	24.2	C	36.4	E

7.4.2 Vehicle Throughput and Percent Incomplete Trips

Vehicle throughput has been measured as processed flows for the peak hour direction of travel on mainline I-25.

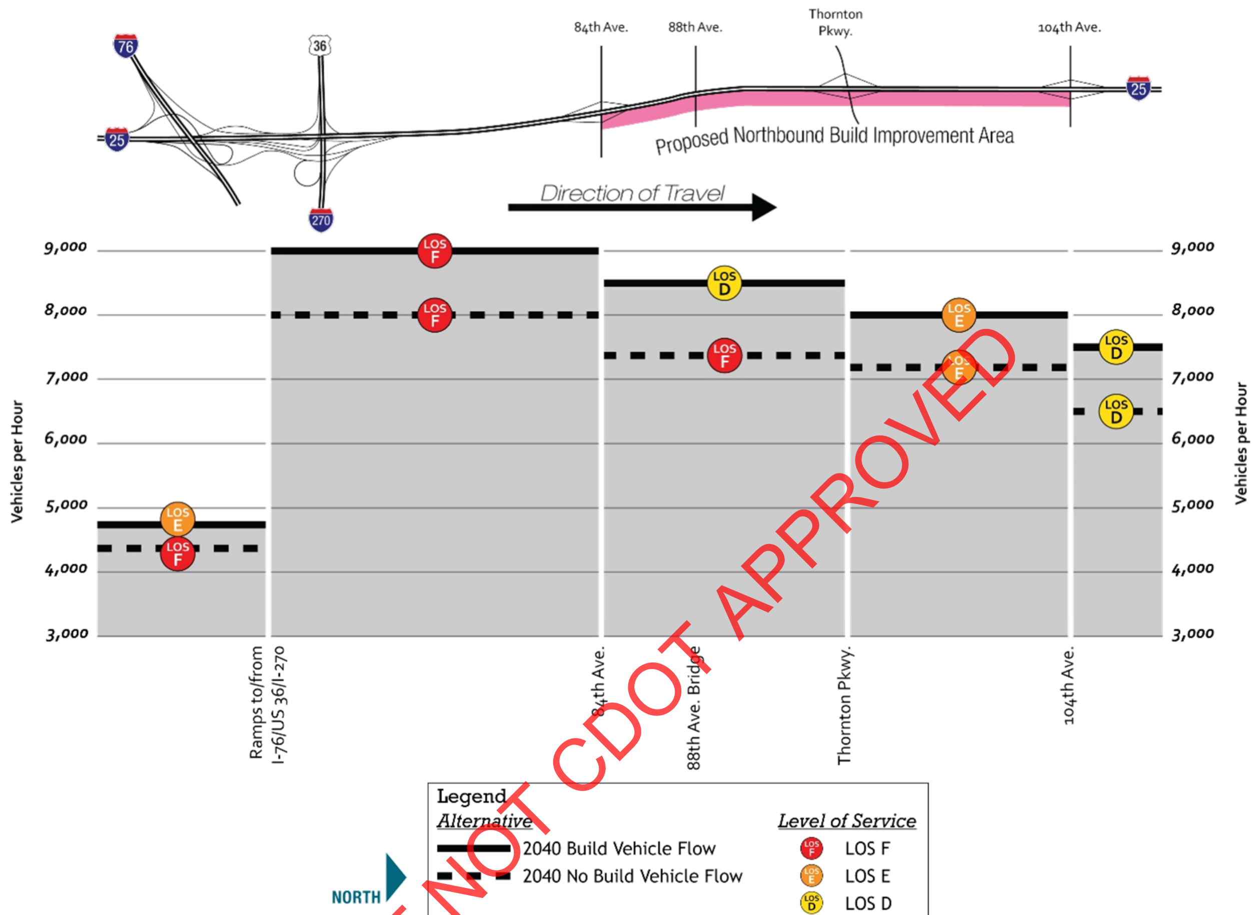
Figure 19 and **Figure 20** show the AM and PM peak hour recorded 2040 No-Build and Build flows for study area I-25 segments, respectively. **Figure 19** and **Figure 20** also indicate the corresponding segment LOS (as previously discussed in *Section 7.4.1, Freeway Operational Analysis – Level of Service*).

Figure 19. 2040 AM Peak Hour No-Build and Build Flow and Level of Service



The AM peak hour 0.2 percent decrease in the percent of network-wide incomplete trips from the No-Build to the Build Scenario is reflected in LOS and vehicle throughput. The proposed improvement adds capacity at the Thornton Parkway that increases vehicle throughput north of the improvement. South of the improvement, there are fewer gains in vehicle throughput between the 84th Avenue interchange and the I-76/US 36/I-270 interchange complex where I-25 is projected to continue to be capacity constrained; however, the increased vehicle throughput increases density and pushes the segment just over the threshold between LOS E and LOS F.

Figure 20. 2040 PM Peak Hour No-Build and Build Flow and Level of Service



The PM peak hour is projected to see nearly a 2.8 percent decrease in network-wide incomplete trips. The proposed northbound capacity improvements result in increased vehicle throughput on all I-25 northbound segments. LOS improvements from LOS F to LOS D are projected for the segment between the 84th Avenue and Thornton Parkway interchanges.

7.4.3 Travel Times

Travel times can help identify and quantify traveler benefits associated with alternative improvements. TransModeler can be programmed to record travel time between selected points in the model network. The average travel time for these selected segments is calculated from the recorded travel times for all vehicles that pass both the start point and the destination point during the evaluation period. Vehicles that have not reached the destination point or have been denied entry are not included in the travel time results.

Table 10 compares the Existing, 2040 No-Build, and 2040 Build AM and PM peak hour travel times along I-25. The southbound travel time route was recorded between the 104th Avenue and 84th Avenue interchange. The northbound travel time route was recorded from the I-76 bridge to the 104th Avenue interchange.

Table 10. Corridor Long Travel Times

	AM Peak Hour			PM Peak Hour		
	Existing	2040 No-Build Scenario	2040 Build Scenario	Existing	2040 No-Build Scenario	2040 Build Scenario
SB: 104th Avenue to 84th Avenue	2–4 minutes	4–6 minutes	2–4 minutes	2–3 minutes	3–4 minutes	2–3 minutes
NB: I-76 Bridge to 104th Avenue	5–6 minutes	6–7 minutes	5–7 minutes	6–8 minutes	10–12 minutes	7–9 minutes

AM peak hour southbound travel times between the 104th Avenue and 84th Avenue interchanges are projected nearly double from 2–4 minutes (2017) to 4–6 minutes under the 2040 No-Build Scenario. The 2040 Build Scenario is projected to return travel times through the proposed improvement area to existing travel times, 2–4 minutes.

PM corridor long travel times from I-76 to 104th Avenue are also projected to nearly double from 6–8 minutes (2017) to 10–12 minutes under the 2040 No-Build Scenario. Under the 2040 Build Scenario, northbound travel times are projected to decrease relative to the No-Build Scenario to 7–9 minutes.

It is also important to note that the Build configuration was also found to result in travel time improvements for vehicles traveling in the off-peak direction. As shown in **Table 10**, corridor long off-peak direction travel times approximately return to existing ranges under the Build configuration.

7.4.4 Travel Time Index

To better understand the impacts of the proposed Build configuration, GP lane TTIs were calculated on southbound I-25 for the AM peak hour and northbound I-25 for the PM peak hour for the GP lanes only.

The HCM provides a TTI threshold specific to freeway facilities; a TTI between 1.25 and 1.31 would reflect that I-25 is operating at capacity. **Table 11** summarizes the peak hour, peak direction travel time indices for I-25.

Table 11. I-25 Peak Travel Direction Travel Time Indices

	AM Peak Hour (SB)		PM Peak Hour (NB)	
	TTI	Interpretation	TTI	Interpretation
2040 No-Build	2.90	Less Desirable	2.39	Potentially Acceptable
2040 Build	2.69	Less Desirable	1.68	Potentially Acceptable

Both the 2040 No-Build and Build peak hour demand volumes are projected to continue to exceed available capacity. However, as a ratio of the projected peak hour VHT to the theoretical free-flow speed for the same VMT, the AM peak hour TTI is approaching the higher, less desirable levels.

The AM peak hour TTI has been evaluated as “Less Desirable” in both the No-Build and Build scenarios. The TTI index is decreasing reflected reduced variability and equates to 15–20 hours of reduced delay and 5 to 10-hour reduction VHT.

Similarly, the PM peak hour TTI remained in the “Potentially Acceptable” range, and the reduction in the TTI between the No-Build and Build scenarios reflects a 90–95 hour decrease in delay and a 60 to 65-hour reduction in VHT.

The peak hour, peak direction TTIs reflect that the travel time improvements (see *Section 7.4.3, Travel Times)* associated with the Build Scenario result in decreased variation between peak and off-peak travel times.

7.5 I-25 Ramp Terminal Intersections

As a microscopic simulation software, TransModeler results are compiled from each individually simulated vehicle and the interaction between vehicles. The HCM methodology has been used to assess the intersection control delay and LOS for the ramp terminal interchange intersections for each scenario.

7.5.1 Intersection Level of Service

Table 12 summarizes LOS thresholds used in the signalized/unsignalized intersection operations analyses.

Table 12. Intersection Level of Service Thresholds

Level of Service (LOS)	Control Delay (seconds per vehicle)	
	Signalized Intersection	Unsignalized Intersection
A	≤ 10	≤ 10
B	> 10 – 20	> 10 – 15
C	> 20 – 35	> 15 – 25
D	> 35 – 55	> 25 – 35
E	> 55 – 80	> 35 – 50
F	> 80	> 50

LOS is a qualitative measure of traffic operational conditions based on roadway capacity and vehicle delay. LOS is described by a letter designation ranging from A to F, with LOS A representing almost free-flow travel, while LOS F represents congested conditions. For signalized intersections, LOS is reported as an average for the entire intersection. In urbanized areas, LOS D is typically considered to be acceptable for peak hour traffic operations.

The existing ramp terminal intersections have been evaluated under the existing traffic signal timing plans, as shown in **Table 13**.

Table 13. Existing (2017) Conditions – Ramp Terminal Intersection Operations

Intersection	#	AM Peak Hour		PM Peak Hour	
		Average Control Delay (sec/veh)	LOS	Average Control Delay (sec/veh)	LOS
104th Avenue & I-25 SB Ramps	105	14.2	B	14.1	B
104th Avenue & I-25 NB Ramps	106	10.0	A	18.1	B
Thornton Parkway & I-25 SB Ramps	111	12.8	B	12.0	B
Thornton Parkway & I-25 NB Ramps	112	9.6	A	14.6	B
84th Avenue & I-25 SB Ramps	118	18.9	B	16.0	B
84th Avenue & I-25 NB Ramps	119	14.8	B	15.6	B

Traffic signal timings have been optimized under the 2040 No-Build and Build scenarios. The ramp terminal intersections are projected to operate at LOS D or better, acceptable conditions. **Table 14** and **Table 15** show the 2040 No-Build and 2040 Build ramp terminal intersection LOS results**,** respectively.

Table 14. 2040 No-Build Conditions – Ramp Terminal Intersection Operations

Intersection	#	AM Peak Hour		PM Peak Hour	
		Average Control Delay (sec/veh)	LOS	Average Control Delay (sec/veh)	LOS
104th Avenue & I-25 SB Ramps	105	13.2	B	20.8	C
104th Avenue & I-25 NB Ramps	106	9.3	A	16.5	B
Thornton Parkway & I-25 SB Ramps	111	13.2	B	19.7	B
Thornton Parkway & I-25 NB Ramps	112	17.4	B	41.8	D
84th Avenue & I-25 SB Ramps	118	22.0	C	16.5	B
84th Avenue & I-25 NB Ramps	119	14.1	B	16.2	B

Table 15. 2040 Build Conditions – Ramp Terminal Intersection Operations

Intersection	#	AM Peak Hour		PM Peak Hour	
		Average Control Delay (sec/veh)	LOS	Average Control Delay (sec/veh)	LOS
104th Avenue & I-25 SB Ramps	105	15.0	B	19.5	B
104th Avenue & I-25 NB Ramps	106	16.0	B	15.1	B
Thornton Parkway & I-25 SB Ramps	111	17.8	B	10.6	B
Thornton Parkway & I-25 NB Ramps	112	45.8	D	19.7	B
84th Avenue & I-25 SB Ramps	118	21.2	C	21.3	C
84th Avenue & I-25 NB Ramps	119	14.3	B	29.2	C

7.5.2 Queuing

The HCM defines a queue as: "A line of vehicles, bicycles or persons waiting to be served by the system in which the flow rate from the front of the queue determines the average speed within the queue. Slowly moving vehicles or people joining the rear of the queue are usually considered part of the queue."

Queues can be used as indicators of operational problem spots within the roadway network where capacity inefficiencies may exist due to intersection blockages or turn bay overflows.

Queue length outputs are provided in terms of length and include the following outputs:

- 95^{th} Percentile queue length (ft)
- Average queue length (ft)

Queue lengths have been evaluated at all study area ramp terminal intersections. Queuing at ramp terminal intersections has the potential to affect mainline freeway operations and safety if queues extend from the ramps back onto the mainline freeway or are found to affect mainline operations.

Typically. left-turn movements at the ramp terminal intersections were observed to occasionally include five or more vehicles per lane. Most right-turn movements at ramp terminal intersections are yield or free movements, often with acceleration lanes and were rarely observed to have queues of five or more vehicles. Therefore, the queuing evaluation focused on the lanes including left-turn movements. Simulated average and 95^{th} percentile queues were compared to the existing striped storage (2040 No-Build) and the proposed striped storage (2040 Build) lengths. It is important to note that at many of the intersections, there is available storage beyond the striped storage and on the ramps before the queue would be expected to affect mainline flows or operations.

Figure 21 shows that there are no projected queuing concerns at northbound ramp terminal intersections.

Figure 21. 2040 Projected Northbound Off-Ramp Left-Turn

For the southbound ramp terminal intersections (**Figure 22**), a few locations have potential queuing problems.

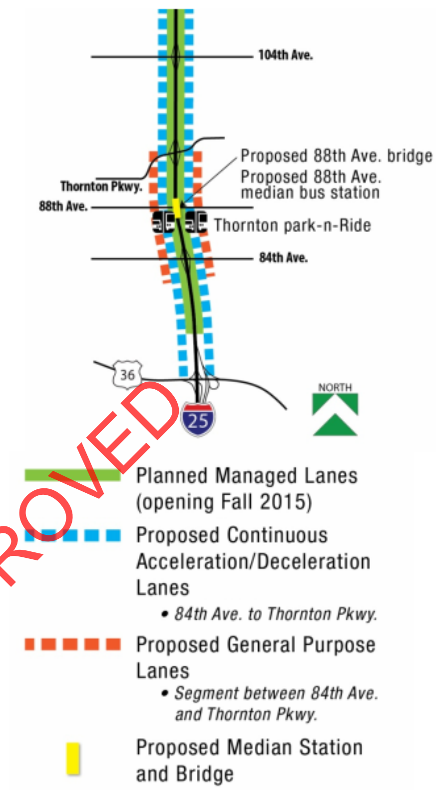
Figure 22. 2040 Projected Southbound Off-Ramp Left-Turn

According to the *AASHTO Greenbook*, the required stop condition deceleration length for a freeway facility with a 70-mph design speed is 615 feet. From the gore point to the stop bar, the 84th Avenue ramp is approximately 1035 feet long (deceleration + storage), indicating a total storage length of 420 feet; 90 feet of two-lane storage and 330 feet of single lane storage.

As previously noted, **Figure 22** reflects the available two-lane striped storage. Under the 2040 No-Build Scenario, the AM and PM peak hour 95th percentile queues at the 84th Avenue southbound ramp terminal intersection are projected to exceed the available striped storage length but not the total storage; the average queue is not projected to exceed the available two-lane striped storage. The 95th percentile queues are not projected to affect mainline operations.

APPENDIX A. 2040 BUILD – DESIGN REFINEMENTS

TransModeler was used to evaluate and inform the design of the 2040 Build condition. The evaluation of the Build condition began with the recommendations from the North I-25, US 36 to State Highway 7 Planning and Environmental Linkages Study for the portion of I-25 between the 84th Avenue and Thornton Parkway interchanges.



The improvements initially evaluated included:

- Continuous acceleration/deceleration lanes between the 84th Avenue and Thornton Parkway interchanges, in both directions
- One additional general purpose (GP) lane between the 84th Avenue and Thornton Parkway interchanges, in both directions

The TransModeler microsimulation models were used to evaluate:

- The best location to add the fourth northbound GP lane
- The best location to drop the fourth northbound GP lane

Preliminary PM peak hour TransModeler models were used to identify the best location to add and drop the fourth northbound GP lane between 84th Avenue and 104th Avenue. The PM peak hour was selected for this analysis due to the greater northbound demand during the PM peak hour related to prevailing commuting patterns. Models were visually inspected for locations of persistent queuing and evaluated using density to calculate freeway level of service (LOS) to compare operational effectiveness of various geometric configurations (see *Section 7* for additional information on density and flow as Measures of Effectiveness).

Adding the Northbound General Purpose Lane

Two options for adding the fourth GP lane were evaluated using TransModeler. **Figure A-1** illustrates the existing northbound off-ramp configuration and the two configurations for adding the fourth GP lane.

Option A converts the existing mandatory exit lane at 84th Avenue to optional exit, adding the fourth GP lane as an extension of the existing continuous lane from the US 36/I-76 on-ramp. A merge occurs from I-270 between the US 36/I-76 on-ramp and the 84th Avenue interchange and the I-25 PEL ultimately recommends a continuous acceleration/deceleration lane from I-270 to 84th Avenue.

Option B maintains the existing lane configuration approaching the interchange and adds the fourth GP lane after the 84th Avenue off-ramp.

Figure A-1. Options for Adding the Fourth General Purpose Lane at the 84th Avenue Intersection

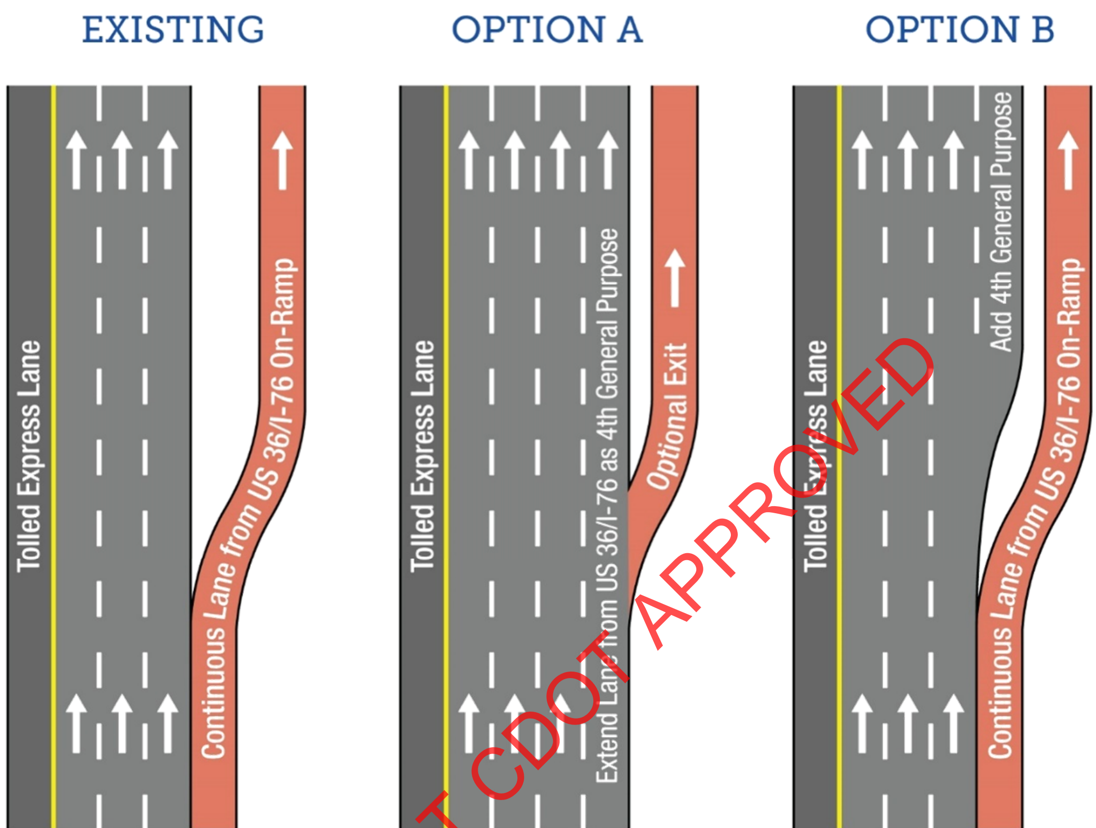


Table A-1 illustrates the PM peak hour LOS between the I-270 on-ramp and the Thornton Parkway interchange for Option A and Option B.

Table A-1. 2040 Option A vs. Option B – Freeway Level of Service

	Facility Type	No-Build		Option A		Option B	
		Density (pc/mi/ln)	LOS	Density (pc/mi/ln)	LOS	Density (pc/mi/ln)	LOS
Northbound I-25							
Between 84th Avenue and Thornton Parkway	Basic	58.4	F	69.3	F	31.1	D
84th Avenue On-Ramp	Merge	65.6	F	69.3	F	31.1	D
Between 84th Avenue Ramps	Basic	77.9	F	54.8	F	35.8	E
84th Avenue Off-Ramp	Basic	104.4	F	54.9	F	79.6	F
Between I-270 and 84th Avenue	Basic	104.4	F	59.1	F	79.6	F
I-270 On-Ramp	Basic	152.0	F	41.1	E	119.0	F

As **Table A-1** indicates, the No-Build Scenario and Option A would be expected to operate at LOS F between the I-270 on-ramp and the Thornton Parkway interchange. Option A indicated the potential for incremental operational improvements through this segment of I-25 due to the added capacity. Visual inspections of the TransModeler model indicated that the Option A conversion of the existing mandatory exit lane at 84th Avenue to optional exit resulted in higher volumes of traffic using the optional exit lane (vehicles exiting at 84th Avenue in addition to vehicles remaining on northbound I-25); vehicles slowing to exit at 84th Avenue, consequently, affected travel speeds for vehicles continuing on I-25.

Option B, adding the fourth GP lane north of the 84th Avenue off-ramp, reflected greater potential for operational improvements. Like Option A, all segments were projected to see improvement relative to the No-Build Scenario. However, freeway segments north of the fourth GP lane improved from LOS F in the No-Build Scenario to LOS D/E in the Option B Build Scenario.

Option B demonstrated the best operational improvement, and the 2040 Build Scenario has been evaluated with this configuration.

Dropping the Northbound General Purpose Lane

Additionally, the fourth GP lane was originally programmed to extend between the 84th Avenue and Thornton Parkway interchanges. Updated 2040 volume forecasts indicated a substantial No-Build increase in northbound demand through the Thornton Parkway interchange. The TransModeler software was used to model the fourth GP lane lane-drop at two locations: Option C – at Thornton Parkway and Option D – at 104th Avenue interchanges. The 104th Avenue interchange lane drop demonstrated the best operational improvement.

Table A-2 illustrates the PM peak hour LOS between the I-270 on-ramp and the Thornton Parkway interchange for Option A and Option B.

Table A-2. 2040 Option C vs. Option D – Freeway Level of Service

	Facility Type	No-Build		Option C		Option D	
		Density (pc/mi/ln)	LOS	Density (pc/mi/ln)	LOS	Density (pc/mi/ln)	LOS
Northbound I-25							
Between 104th Avenue Ramps	Basic	30.6	D	33.2	D	35.6	E
104th Avenue Off-Ramp	Diverge	40.8	E	45.0	F	32.4	D
Between Thornton Parkway and 104th Avenue	Basic	40	E	43.6	E	36.5	E
Thornton Parkway On-Ramp	Merge	46.6	F	50.9	F	33.5	D
Between Thornton Parkway Ramps	Basic	44.5	E	77.1	F	32.8	D
Thornton Parkway Off-Ramp	Diverge	60.1	F	32.4	D	25.6	C
Between 84th Avenue and Thornton Parkway	Basic	58.4	F	31.1	D	29.9	D

Option C indicated improved freeway operations between the 84th Avenue and Thornton Parkway interchanges. However, dropping the fourth GP at the Thornton Parkway interchange was observed to create a bottleneck where vehicles continuing northbound through the Thornton Parkway interchange needed to merge from four GP lanes into three GP lanes. This merge resulted in a decrease from LOS E in the No-Build Scenario to LOS F in the Option C Build Scenario at the location of the merge.

Option D, extending the fourth GP lane through the Thornton Parkway interchange and transitioning the lane to the mandatory exit at 104th Avenue, improved operations at the Thornton Parkway Interchange from LOS E/F in the No-Build Scenario to LOS C/D in the Option D Build Scenario. Option D also improved operations at the 104th Avenue off-ramp from LOS E in the No-Build Scenario to LOS D in the Option D Build Scenario.

Option D demonstrated the best operational improvement by adding capacity to the LOS E/F segments in the No-Build Scenario. The 2040 Build Scenario has been evaluated with the Option D configuration.

APPENDIX B. TECHNICAL MEMORANDA

FELSBURG HOLT & ULLEVIG
connecting and enhancing communities

June 8, 2017

MEMORANDUM

TO: Stephanie Alanis, PE
Andy Stratton, PE

FROM: Jeanne Sharps, PE
Holly Buck, PE, PTP
Steven Marfitano, PE
Rachel Ackermann, EI

SUBJECT: I-25 North, US 36 to SH 7 – Methods and Assumptions
CDOT Project No. NHPP 0253-250 (21180)
FHU Reference No. 115-388-01

This methods and assumptions document describes the process for the technical analysis of improvements to Interstate 25 (I-25) between US Highway 36 (US 36) and State Highway 7 (SH 7). This section of I-25 is one of the most congested corridors in the Denver Metro Area and carries 115,000 vehicles per day near SH 7, with volumes building to 258,000 vehicles per day near US 36. In December 2014, CDOT completed the North I-25 Planning Environmental Linkage (PEL) Study that identified projects necessary to improve operational and safety conditions within the corridor.

The PEL study evaluated the existing (2010) and future (2035) operating conditions of the interstate to identify geometric improvements needed for the corridor to minimize congestion and increase safety. Based on this analysis, a selection of improvements was determined to be the Recommended Alternative for the corridor.

This environmental clearance and design project is focused on further evaluation of the Recommended Alternative from the North I-25 PEL. The environmental review and design processes have been divided into two segments:

- **Segment 1**: US 36 to Thornton Pkwy – The improvements include the addition of a general-purpose lane and an auxiliary lane (acceleration/deceleration lane between interchange ramps) in each direction.
- **Segment 2**: Thornton Pkwy to SH 7 – The improvements include the addition of an outside auxiliary lane (acceleration/deceleration lane between interchange ramps) in each direction.

A Template EA will be completed for the additional capacity improvements identified in Segment 1. Categorical Exclusions (CatExs) are anticipated for the acceleration/deceleration lanes planned on the northern end of the corridor, Segment 2.

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The analysis methodologies and tools discussed in this memorandum have been specifically selected to inform the design process in a few critical ways:

- Verification/fine-tuning of prior alternative recommendations
- Support for the environmental process/documentation
- Update the analysis forecast year from 2035 to 2040

Discussions with FHWA indicated that the traffic analyses should be focused on determining the ramp terminal intersection operations, queuing and stacking conditions on all ramps, and evaluating the weaving and merging/diverging conditions along the corridor.

The objective of the traffic analysis is to confirm that no adverse impacts are expected to result from the Recommended Alternative improvements; understanding that the improvements cannot achieve elimination of congestion on the corridor and are expected to provide a reduction in length of the congested period along the corridor.

The history of technical analysis along this corridor is extensive. Throughout the various study efforts, a variety of analysis tools and software have been used. The methods and assumptions differ for the operational analysis for Segment 1 and Segment 2 and will be addressed separately in this memorandum.

SEGMENT 1: US 36 TO THORNTON PARKWAY

STEP 1: Selection of the TransModeler Modeling Tool

Due to the existing and anticipated high levels of congestion on Segment 1 during the peak period, microsimulation is recommended for Segment 1. The project team identified microsimulation for Segment 1 for the following reasons:

- Microsimulation tools are effective in evaluating the dynamic evolution of traffic congestion problems on transportation systems (over time and space)
- Microsimulation can evaluate the interference that occurs when congestion occurs at one location and impacts capacity at another location (i.e., bottlenecks and signal delay)
- Microsimulation can provide a visual simulation to assist with comparing outputs
- The microsimulation network can analyze the complex operational interactions between the managed lane, general purpose lane, and interstate to interstate interactions

The North I-25 PEL used a DynusT model to evaluate alternative packages and select the Recommended Alternative. A significant calibration/validation effort was coordinated with FHWA during the process. The analyses focused on vehicle operations during the southbound morning peak period and northbound evening peak period to aid alternatives screening and selection. DynusT provided mesoscopic analysis but is no longer supported. Therefore, the I-25 PEL model cannot be updated to reflect 2040.

The North I-25 PEL also used a microscopic VISSIM model to analyze the operations and interactions between the future managed lanes and general purpose lanes along I-25 between US 36 and 120th Avenue (originally developed to evaluate the design of the managed lanes). VISSIM was used as a complementary analytic tool to test alternatives performance. The project team considered the viability of using this VISSIM model and determined there was limited benefit as it was built in a previous version of VISSIM, was not fully calibrated, and did not include ramp terminals.

It was determined that it would be more efficient to build a new microsimulation model and that VISSIM or Transmodeler could be used. VISSIM has been used in the past successfully and CDOT is currently using TransModeler on several projects. TransModeler was determined to provide a more streamlined process to replace the DynusT mesoscopic model due to efficiency in how information is pulled from the regional travel model.

The project team identified the TransModeler microsimulation modeling tool as an appropriate tool for the following reasons. TransModeler can:

- efficiently integrate with the TransCAD travel demand model,
- more accurately model over-capacity conditions than other tools,
- provide a visual simulation to assist when comparing outputs, and
- analyze the interaction between freeway facilities (general purpose and managed lanes) and the interchanges

STEP 2: Identify Study Area

The model area was chosen consistent with FHWA's simulation guidelines. FHWA's "Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software" indicates that the model network should extend up to 2.4 kilometers (1.5 miles) from both termini of the interchange improvement being evaluated and up to 1.6 kilometers (1 mile) on either side of the interstate route.

Therefore, the study area has been selected to include the interchange to the north (104th Avenue) and south (relevant movements to/from the US 36/I-25 and I-76 interchanges) and to extend along 104th Avenue, Thornton Parkway and 84th Avenue to the east and west to the nearest major arterials. See **Figure 1**.

Figure 1. TransModeler Model Study Area

STEP 3: Identify Analysis Time Periods

The extensive data collection summarized in the *Data Collection Memorandum* will be used to identify the AM and PM peak hours for the study area. Analysis of historic COGNOS data indicates that the anticipated peak hours are:

- 7:00 AM to 8:00 AM
- 5:00 PM to 6:00 PM

It is understood that the temporal and spatial limits of the congested peak periods extend beyond the peak hour. The analysis of the peak hour will provide an operational analysis of the freeway operations under the most congested period. To successfully model the peak hour, identification of an appropriate simulation initialization period is essential.

The estimation of the simulation initialization period will be conducted in a manner consistent with Appendix C of FHWA's "Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software." Because simulation model runs begin empty with zero vehicles on the network, the simulation model starts with the warmup period that preloads the network to achieve typical conditions leading into the analysis period. The warmup period is then excluded from system performance evaluation and the desired analysis period is reported.

The toolbox identifies that at a minimum the "analyst should choose a warmup period that is equal to at least twice the estimated travel time at free-flow conditions to traverse the length of the network" and that "initialization is achieved when the number of vehicles entering the system is approximately equal to the number leaving the system."

The determination of the length of the warmup period will be fully documented in the calibration technical memorandum.

STEP 4: Identify Modeling Scenarios

The analysis will begin with a base year analysis to replicate current conditions and to evaluate the performance of the new managed lane. A future year model will be used for the verification/fine-tuning of the North I-25 PEL Recommended Alternative.

<u>Current Conditions</u>

The 2015 model will be developed to replicate existing conditions, and this model will be calibrated using traffic counts and speeds recorded in the spring of 2017.

<u>2040 No Action</u>

The No Action condition incorporates programmed roadway improvements. For Segment 1, there are no programmed interstate improvements. All off-system improvements in the fiscally constrained plan will be included in the 2040 No Action scenario.

<u>2040 Build Scenario</u>

The Segment 1 2040 Build Scenario includes:

- Adding one GENERAL PURPOSE lane in each direction between the 84th Avenue and Thornton Parkway interchanges in each direction
- Adding one continuous acceleration/deceleration auxiliary lane between the 84th Avenue and Thornton Parkway interchanges in each direction

STEP 5: Develop & Calibrate the TransModeler Current Conditions Model

The microsimulation process will begin with the development of a calibrated and validated TransModeler model representing existing conditions.

The TransModeler model will be calibrated using methodology consistent with FHWA's simulation guidelines found in the "Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software." The calibration process will be fully documented in the subsequent calibration technical memorandum.

STEP 6: Develop 2040 Forecasts

As previously noted, a major component of this analysis is to update the analysis forecast year from 2035 to 2040. This process will update the daily vehicular forecasts with the current planning horizon prepared by the Denver Regional Council of Governments (DRCOG). Additionally, since the PEL, significant changes to the DRCOG regional travel demand model have transitioned the tool from a four-step model to an activity-based model, this new tool called FOCUS 2 will be used to understand future vehicular growth expectations along the corridor.

The travel demand modeling process involves a geometric review of the model network and a confirmation of future improvement assumptions in the model network. Two separate project specific 2040 models will be developed to provide vehicular forecasts along the corridor in the No Build (without improvements related to this study) and Build (with improvements identified in the PEL Recommended Alternative).

As is typical, the travel modeling process involves the development of a base year model that is used to adjust existing vehicular volumes according to procedures described in the *National Cooperative Highway Research Program Report 765*. This adjustment process takes into account inaccuracies in the travel demand model structure by comparing existing count data collected as part of this study against the base year model, and translates those differences as adjustments in the future forecasts. The result of these processes will be 2040 No Build and 2040 Build traffic forecasts to be used in the No Action and Build operational analysis of the corridor.

STEP 7: Evaluate the 2040 No Action and Build Scenarios

The future year analysis will utilize the existing year model parameters for the development of 2040 No Build and 2040 Recommended Alternative models to confirm the purpose and need and anticipated benefits of the proposed design. This analysis will include verification of interstate merge, diverge, and weave segments (including the relationship between the exit ramps and the managed lanes) along with intersection operations at ramp terminals connecting the interstate to local facilities.

Measures of Effectiveness (MOEs) are the system performance statistics that best characterize the degree to which the proposed improvements meet the project objectives. For this analysis, the following MOEs have been selected to evaluate the No Action and Build network scenarios:

- Travel time
- Density/Level of Service (LOS)
- Average Speed
- Queuing Analysis
- Delay

TransModeler provides other metrics for evaluating the operations of the roadway network that are not included in the list of MOEs identified in FHWA's "Traffic Analysis Toolbox Volume III: Definition, Interpretation, and Calculation of Traffic Analysis Tools and Measures of Effectiveness." These other metrics are helpful in providing a comparative analysis for the No Action and Build scenarios and include:

- Incomplete trips (i.e., trips that were en route but had not arrived by the end of the reporting period)
- Queued trips (i.e., trips waiting to enter the network when the run ended; also referred to as vehicles denied entry)
- Loaded trips (i.e., trips that were in the network at the start of the reporting period and may include trips loaded from the initial state)

These statistics can provide additional insight into the level of unmet demand in the system and the efficiency of the scenarios to process demand. These statistics will also be included in the final evaluation.

SEGMENT 2: THORNTON PARKWAY TO STATE HIGHWAY 7

STEP 1: Selection of the Highway Capacity Software & Synchro Tools

The procedures and methodologies outlined in the Highway Capacity Manual (HCM) are used for analyzing the performance of isolated facilities with relatively moderate congestion problems. Segment 2 does not currently experience the same levels of congestion as Segment 1, a trend expected to continue into the 2040 horizon. Interstate operations for Segment 2 will be based on the HCM freeway facilities methodology. This analysis will include verification of interstate merge, diverge, and weave segments (focusing on the interactions between vehicles entering and exiting the freeway).

Freeway operational analyses will be conducted in a manner consistent with the methodology outlined in *Chapter 10: Freeway Facilities Core Methodology* found in the *Highway Capacity Manual, 6th Edition (2016)*; the updated freeway facilities methodology analyzes the operational performance of freeway facilities with one or more managed lanes, as well as the interactions between managed lane facilities and adjacent general purpose lanes. Freeway operational analyses will be conducted using facilities module from the FREEVAL computational engine.

Trafficware Synchro 9 software will be used to analyze existing and future signalized and intersection levels of service according to the methodologies found in the HCM along east-west corridors and at ramp terminal locations. This process will provide a comparison of the intersection operations and an understanding of the potential impacts resulting from the improvements in the Recommended Alternative.

STEP 2: Identify Study Area

Segment 2 extends from Thornton Parkway to SH 7. The HCM facilities analysis methodology evaluates basic, weaving, merge, and diverge segments. The study area includes I-25 mainline and all ramp terminals in the application of the freeway facility methodology; beginning and ending the facility with a basic freeway segment. Intersection operational analyses will be conducted using Synchro at all ramp terminals and the intersections immediately adjacent to the ramp terminals. The Segment 2 study area for all operational analysis is shown on **Figure 2**.

Figure 2. Segment 2 Study Area

STEP 3: Identify Analysis Time Periods

The FREEVAL model will use the HCM facilities analysis methodology. The methodology analyzes a set of connected segments over a set of sequential 15-minute periods. The HCM specifies that when deciding which segments and time periods to analyze, two principles should be observed:

1. The first and last segments of the defined facility should not operate at LOS F.
2. The first and last time periods of the analysis should not include any segments that operate at LOS F.

Daily mainline traffic volume counts and turning movement counts at all study area ramp terminals will be recorded in 15-minute intervals for input into the FREEVAL computational engine. For the current conditions model, the project team has observed that congestion in the study area typically builds and dissipates within the following time periods:

- 6:00 AM to 9:00 AM
- 3:30 PM to 6:30 PM

The Current Conditions FREEVAL model will evaluate these time periods.

It is anticipated that the growth associated with the future 2040 No Action and Build Scenario volumes will extend these currently congested periods. To capture these currently congested hours and allow for analysis of potential longer congested periods in the future, the FREEVAL model is anticipated to span the following time periods:

- 5:00 AM to 11:00 AM
- 2:00 PM to 9:00 PM

Synchro intersection analysis will evaluate the identified existing and future AM and PM peak hour traffic volumes.

STEP 4: Identify Modeling Scenarios

Current Conditions

The 2015 model is being developed to replicate existing conditions, and this model will be calibrated using traffic counts and speeds recorded in the spring of 2017.

2040 No Action

The No Action condition incorporates programmed roadway improvements. The Segment 2 2040 No Action model will include:

- Managed lanes on I-25 between 104th Avenue and E-470
- A continuous acceleration/deceleration auxiliary lane between the 136th Avenue and 144th Avenue interchanges in the northbound direction

Additionally, all off-system improvements in the fiscally constrained plan will be included in the 2040 No Action scenario.

<u>2040 Build Scenario</u>

The Segment 2 2040 Build Scenario includes:

- Adding one continuous acceleration/deceleration auxiliary lane between the Thornton Parkway and 104th Avenue interchanges in each direction
- Adding one continuous acceleration/deceleration auxiliary lane between the 104th Avenue and 120th Avenue interchanges in each direction
- Adding one continuous acceleration/deceleration auxiliary lane between the 120th Avenue and 136th interchanges in each direction
- Adding one continuous acceleration/deceleration auxiliary lane between the 136th Avenue and 144th Avenue interchanges in the southbound direction
- Adding one continuous acceleration/deceleration auxiliary lane between the 144th Avenue and E-470 interchanges in each direction

STEP 5: Develop & Calibrate the FREEVAL Current Conditions Model

Segment capacities can be affected by many conditions that may not be accounted for in the segment methodologies. Calibration adjusts demands, capacities, and free-flow speeds to reflect observed conditions. The demand adjustment factor DAF_{cal}, capacity adjustment factor CAF_{cal}, and speed adjustment factor SAF_{cal} can be modified for each segment and each time period. The adjustment factors are used as multipliers for the base demand, capacity, and free-flow speeds input into the methodology.

The base run will not include any adjustments, with the three adjustment factors above being used as calibration tools in one or more subsequent iterations with the intent of matching field data. The FREEVAL model will reference the COGNOS speed and travel time data for calibration.

STEP 6: Develop 2040 Forecasts

The development of the 2040 traffic forecasts for the Segment 2 FREEVAL model will follow the same methodology outlined above for Segment 1.

2040 No Build and 2040 Build traffic forecasts which will be used in the performance analysis of the corridor with and without the study improvements. As previously discussed, the FREEVAL computational engine requires sequential 15-minute volume intervals. Traffic count data will be collected in 15-mintue intervals and will be used to inform the development of the 2040 15-minute traffic volume intervals.

While the methodology may be used to evaluate HOV lanes, HOT lanes or express toll lanes, the methodology does not include demand estimation, specifically demand dynamics because of pricing on the managed lane facility; demand is a time-dependent input to the method. The demand projections for the managed lanes will come from the previously completed managed lane traffic and revenue forecasts and will be updated to be consistent with the updated TransCAD travel demand model traffic forecasts.

Projected volumes will be aggregated for Synchro intersection analysis to evaluate the identified existing and future AM and PM peak hour traffic volumes.

STEP 7: Evaluate the 2040 No Action and Build Scenarios

The evaluation of the No Action and Build scenarios will include a comparison of the following performance measures:

- Demand-to-capacity and volume-to-capacity ratios
- Travel time (min/veh)
- LOS
- Space mean speed
- Vehicle miles traveled (VMT, demand and volume served)

NEXT STEPS

Upon approval of these methods and assumptions, the project team will proceed with modeling efforts and will continue to coordinate with CDOT and FHWA staff as needed to address questions or provide information from the modeling effort.

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June 8, 2017

MEMORANDUM

TO: Stephanie Alanis, PE
Andy Stratton, PE

FROM: Jeanne Sharps, PE
Holly Buck, PE, PTP
Steven Marfitano, PE
Rachel Ackermann, EI

SUBJECT: I-25 North, US 36 to SH 7 – Data Collection Technical Memorandum
CDOT Project No. NHPP 0253-250 (21180)
FHU Reference No. 115-388-01

BACKGROUND & PURPOSE

This technical memorandum documents the TransModeler data collection efforts to support development and calibration of the TransModeler model for the evaluation of proposed improvements on Interstate 25 (I-25) between US 36 and Thornton Parkway.

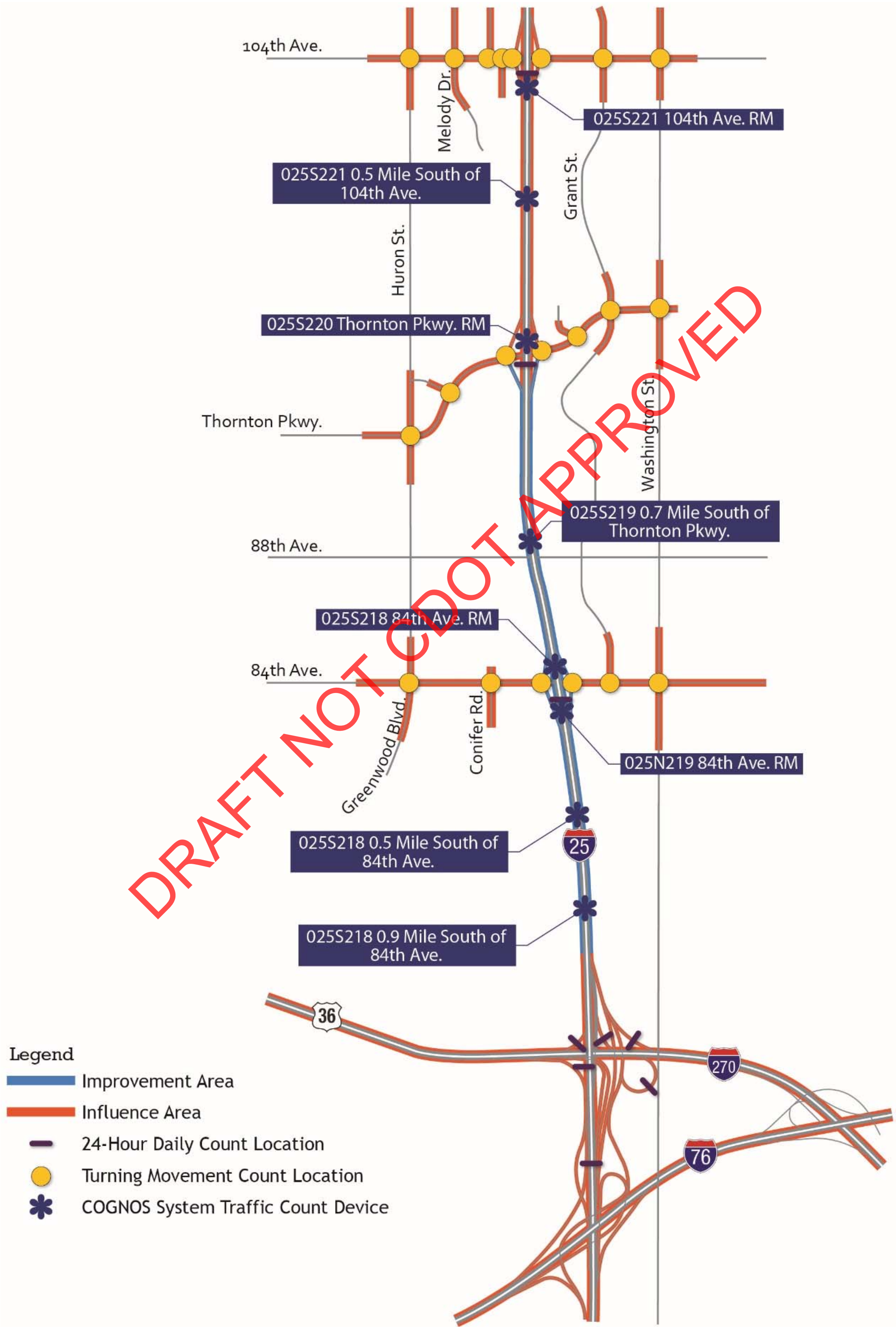
The data collection effort summarized in this memorandum will be used to calibrate the existing conditions TransModeler model and the calibrated existing conditions model will subsequently be used to evaluate the 2040 No Action and 2040 Build conditions. An extensive data collection effort was conducted to help the project team understand the existing issues along the I-25 corridor and to ultimately ensure that the TransModeler simulation models are calibrated to reflect real-world conditions in the project analysis study area.

The goal of this analysis is to understand the future operations of the interstate with the proposed improvements. The analysis will include the interactions between the on- and off-ramps, mainline general purpose lanes, and managed lanes.

The FHWA *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software* has been used as a reference for data collection efforts in support of the calibration of the TransModeler model.

Figure 1 depicts the project study area; the blue highlighted area represents the proposed improvement area. The FHWA *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software* indicates that “the model network should extend up to 2.4 km (1.5 mi) from both termini of the interchange improvement being evaluated and up to 1.6 km (1 mi) on either side of the interstate route.” Therefore, the study area has been selected to include the interchange to the north (W 104th Avenue) and south (relevant movements to/from the I-76 interchange) and to extend along W 104th Avenue, Thornton Parkway, and W 84th Avenue to the east and west approximately 1 mile.

Figure 1. Study Area & Traffic Count Locations



OBSERVATION HOURS & DAYS

CDOT Traffic Operations staff suggested conducting three days of data collection. The following summarizes four days of observations.

To obtain data representative of a typical weekday, data collection and field observations are often collected on a Tuesday, Wednesday, or Thursday of a non-holiday week. Avoiding data collection on Mondays and Fridays prevents capturing atypical traffic pattern resulting from weekend travel beginning early on Fridays and extending into Mondays.

Peak period and peak hours for observations were determined using available COGNOS count data from Tuesdays, Wednesdays, and Thursdays in April 2017. Through this research, the AM and PM peak periods were identified as 6:00-9:00 AM and 4:00-7:00 PM, respectively. The anticipated AM and PM peak hours are estimated to be 7:00-8:00 AM and 5:00-6:00 PM, respectively. COGNOS data indicated that the PM peak period had the potential to build and dissipate outside the identified peak period; field observations began prior to the start of the identified PM peak period to observe building congestion and continued until congestion had dissipated.

The data collection efforts for this project began on Tuesday, April 25, 2017. By selecting a Tuesday, there was flexibility to contact the traffic count vendor to leave the data collection equipment set up to collect data on the following day should an incident result in atypical data not representative of an average weekday.

The findings from each day of data collection are summarized in greater detail in subsequent sections. For this data collection effort, traffic counts and field observations were completed during the AM and PM peak periods on:

- Tuesday, April 25th
- Wednesday, April 26th
- Wednesday, May 3rd
- Thursday, May 4th

TRAFFIC COUNT PROGRAM

Peak period turning movement counts were recorded at the following intersections (peak period turning movement locations can also be seen on **Figure 1**):

- 104th Avenue/Huron Street
- 104th Avenue/Melody Drive
- 104th Avenue/Market Place
- 104th Avenue/Bannock Street
- 104th Avenue/I-25 SB Ramp
- 104th Avenue/I-25 NB Ramp
- 104th Avenue/Grant St
- 104th Avenue/Washington St
- Thornton Pkwy/Huron Street
- Thornton Pkwy/Conifer Rd
- Thornton Pkwy/I-25 SB Ramp
- Thornton Pkwy/I-25 NB Ramp
- Thornton Pkwy/Grant St
- Thornton Pkwy/Washington St
- 84th Avenue/Huron Street
- 84th Avenue/Conifer Rd
- 84th Avenue/I-25 SB Ramp
- 84th Avenue/I-25 NB Ramp
- 84th Avenue/Grant St
- 84th Avenue/Washington St

The 24-hour traffic volume counts were recorded at the following locations (count locations can also be seen on **Figure 1**):

- I-25 NB/SB at 104th Avenue Interchange
- I-25 NB/SB at Thornton Parkway Interchange – including vehicle classification
- I-25 NB/SB at 84th Avenue Interchange
- I-25 NB/SB at US 36/I-270 Interchange
- I-25 on-/off-ramps 24-hr counts at the US 36/I-270 interchange
- SB I-25 off-ramp to US 36
- SB I-25 off-ramp to I-270
- I-76/US 36 on-ramp to NB I-25
- SB I-25 off-ramp to I-76

FHU engaged All Traffic Data (ATD) to execute the count program outlined above.

VALIDATION OF COGNOS DATA

Correspondence with staff from CDOT Traffic Operations indicated a need to verify/validate the COGNOS data with the independent efforts being conducted as part of this data collection effort.

Figure 2 through **Figure 5** provide a comparison of the COGNOS and daily traffic volumes recorded independently at the 84th Avenue Interchange. This location was selected for a multi-day comparison (May 3, 2017 and May 4, 2017) of the COGNOS and ATD data prior to the selection of a design day for complete processing of the ATD data. While field observations and traffic counts were recorded on each of the above-mentioned field observation days, only one day of traffic counts has been completely processed to inform the development of the calibrated existing conditions model.

There are limitations to the accuracy and validity of all traffic counting devices and discrepancies between devices are expected. The variations between the two data sources can be attributed to several factors. Microwave sensors, such as the Remote Traffic Microwave Sensor (RTMS) devices on the COGNOS system, and video recording devices such as those used by ATD have noted inconsistencies in sensing vehicles in the "shadow" of a larger vehicle. Furthermore, if the two devices are calibrated to different clocks reporting different time-periods as the same period, there is potential for significant variation in the 15-minute volumes. The May 3, 2017 COGNOS and ATD counts indicate this type of discrepancy for the reported traffic volumes.

On average the variation between the COGNOS and ATD data at 84th Avenue for the southbound 15-minute traffic counts was 5 to 10 percent, with a total variation for the day of approximately 5 to 7 percent. In the northbound direction, the 15-minute traffic count variation was less than 1 percent, and the total variation for the day was approximately 1 to 2 percent.

Variations in the collected data can also stem from the locations of the counting devices; COGNOS and ATD traffic counting devices were set up to count roughly the same locations. However, the locations were not identical, which also contributed to slight variations in counted traffic volumes.

In conclusion, the variation between the COGNOS and ATD data has been determined to be within the anticipated levels and valid for use in the development and calibration of the TransModeler model. **Figure 6** and **Figure 7** provide additional comparison of the COGNOS and ATD data at Thornton Parkway.

Figure 2. **SB I-25 @ 84th Avenue Interchange – May 3, 2017**

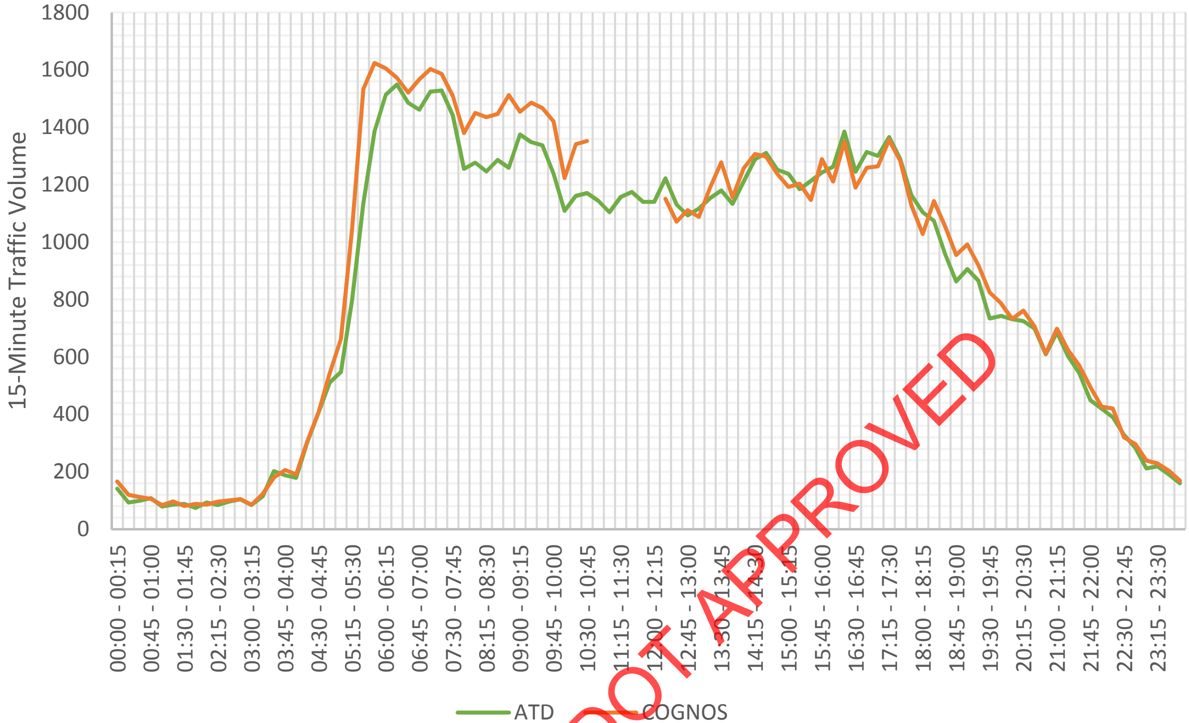
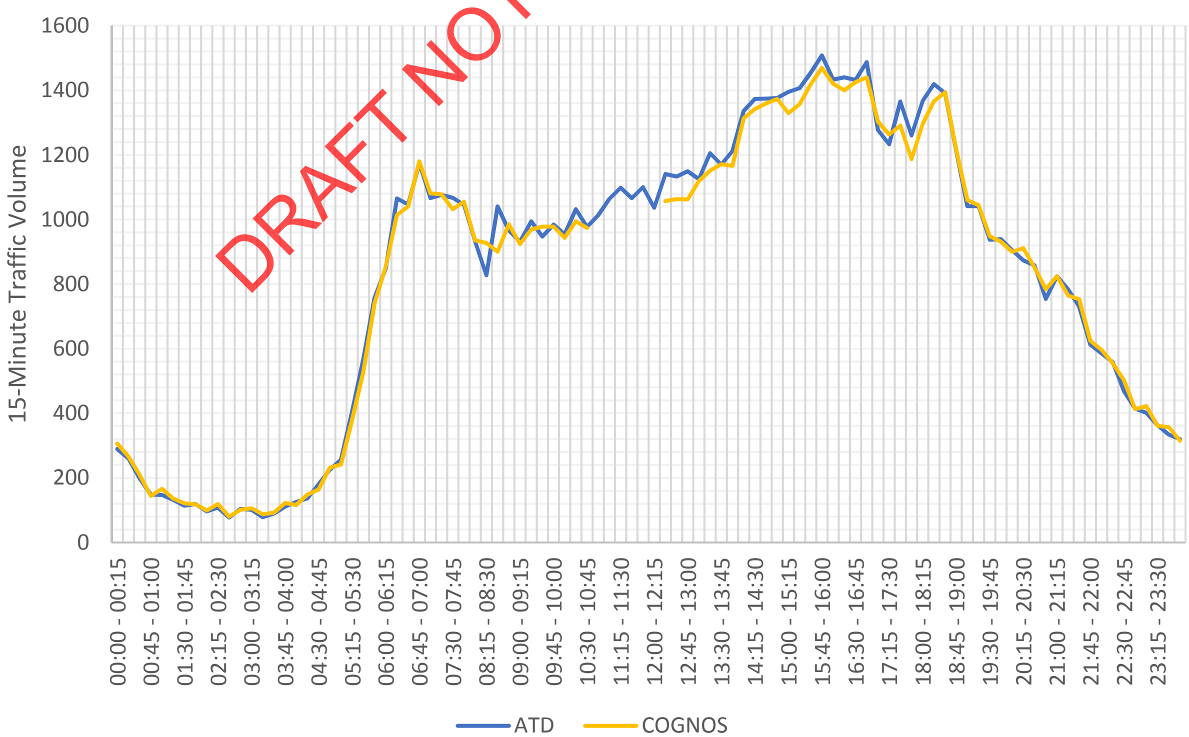


Figure 3. **NB I-25 @ 84th Avenue Interchange – May 3, 2017**



Note: COGNOS data was not available for May 3rd from 11:00 AM to 12:00 PM

Figure 4. SB I-25 @ 84th Avenue Interchange – May 4, 2017

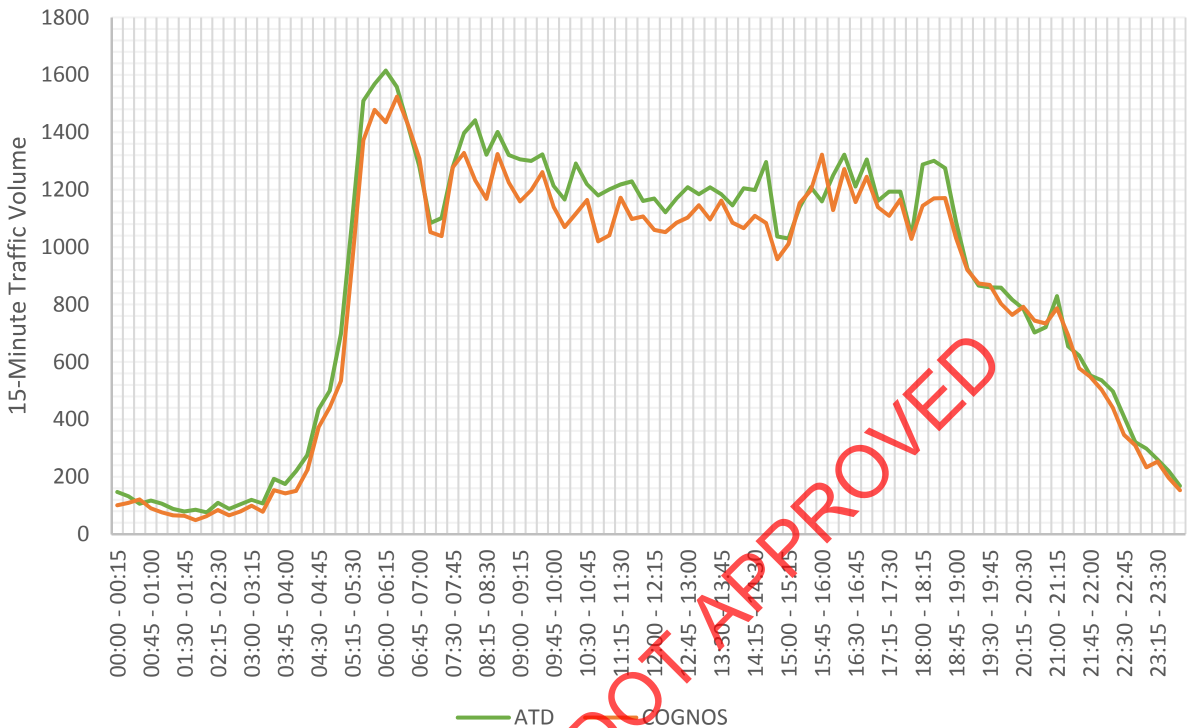


Figure 5. NB I-25 @ 84th Avenue Interchange – May 4, 2017

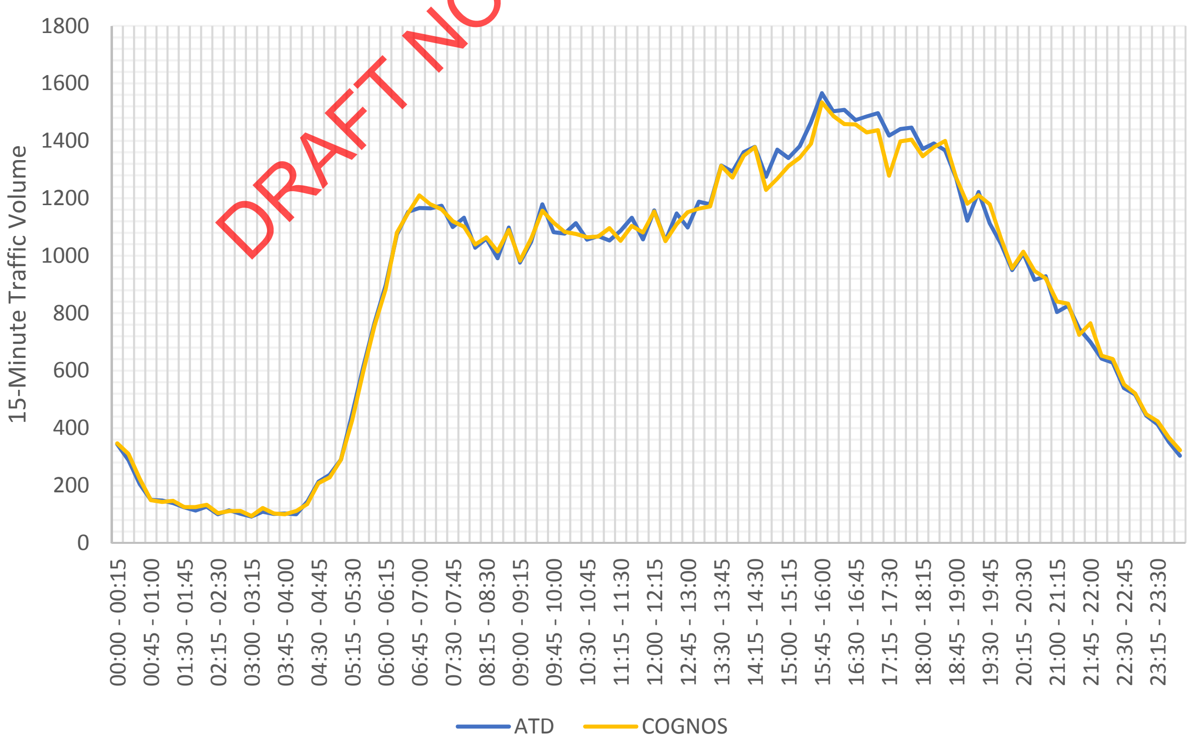


Figure 6. SB I-25 @ 104th Avenue Interchange – May 4, 2017

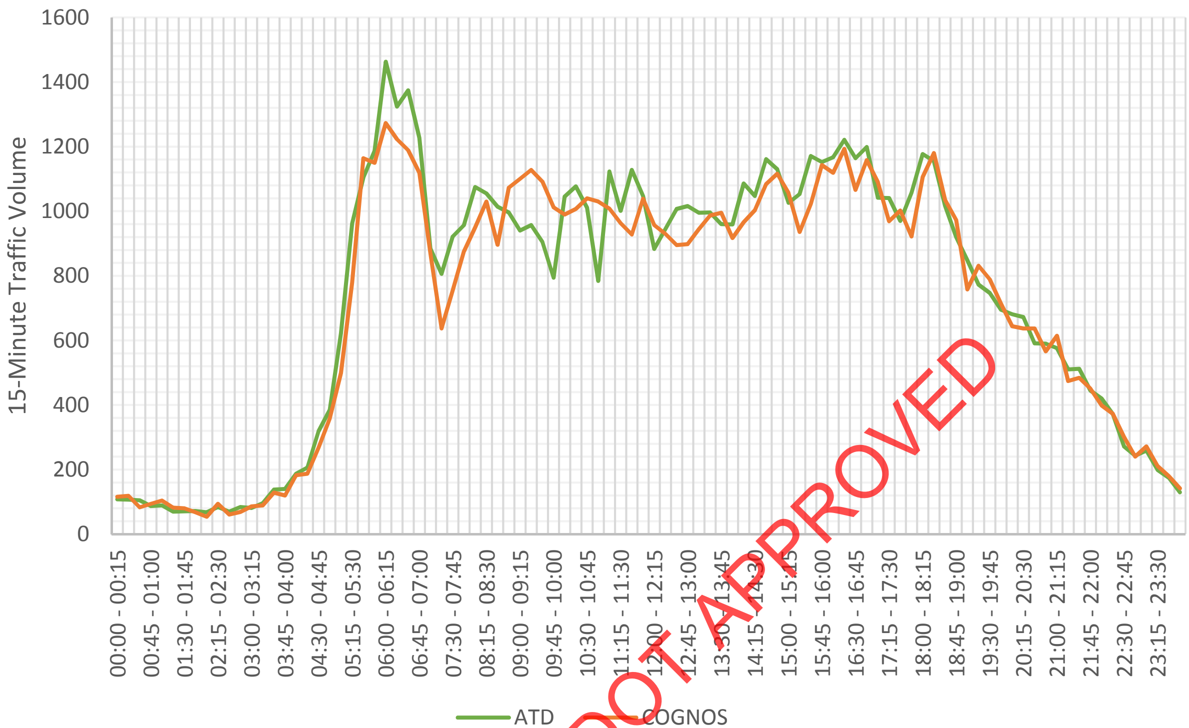
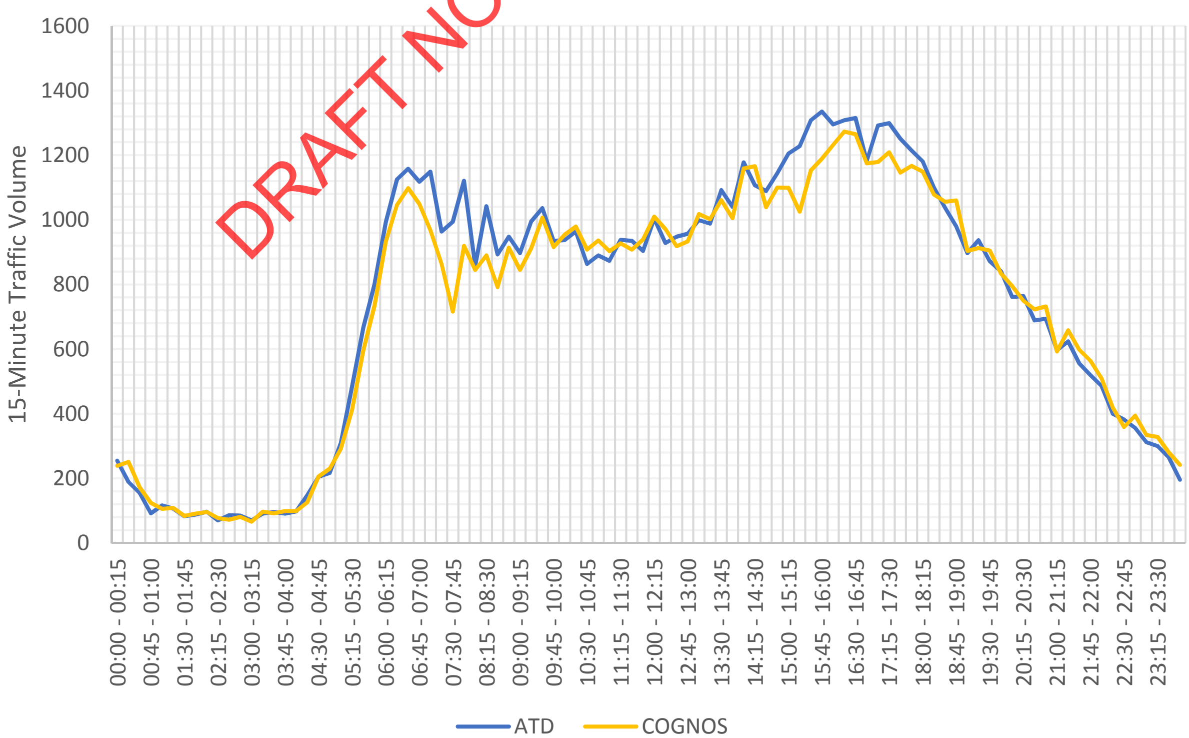


Figure 7. NB I-25 @ 104th Avenue Interchange – May 4, 2017



COGNOS DATA

CDOT provided the project team with access to the COGNOS database that contains a wealth of information from the various ITS devices on CDOT facilities. These devices can provide information on traffic volumes, speeds, incident reports, weather conditions, etc.

The traffic count and speed monitoring devices provide data with a higher level of granularity than the data collected as part of the independent traffic count program. The CDOT RTMS and Ramp Meter (RM) devices provide speed, volume, and occupancy readings by lane. Preliminary review of the per lane volumes suggests that the data collection devices used to gather these data have limitations. These per lane speeds and volumes from COGNOS will be used to better understand the volumes and speeds traveling in the managed lanes as well as to develop lane utilization factors for the calibration of the TransModeler model. The final model input volumes will reflect a combination of the project specific traffic counts and the COGNOS data.

PROJECTING A TYPICAL DAY

Upon completion of the four-day data collection effort, the team reviewed field notes and the available COGNOS data to identify a day that would be most indicative of a “typical day.” It is important to remember that traffic varies from day to day and there will always be some variation between model simulations and typical traffic conditions.

To aid in the identification of the data collection day most indicative of a typical day, directional daily mainline volumes were queried from the COGNOS database for all Tuesdays, Wednesdays, and Thursdays in April and through May 11th, at the following stations (also identified on **Figure 1**):

- 025S221 0.5 MI S OF 104TH AVE
- 025S220 THORNTON PKWY
- 025S219 0.70 MI S OF THORNTON PKWY
- 025N219 84TH AVE RM
- 025S218 0.5 MI S OF 84TH AVE
- 025S218 0.9 MI S OF 84TH AVE

The data were reviewed in 15-minute intervals, and days with incomplete collection during one or more peak period or atypical traffic patterns likely resulting from incidents were removed from the dataset. The remaining weekdays were evaluated to better understand the expected variation in traffic volumes. **Figure 8** through **Figure 19** plot the calculated average traffic volumes. The graphs also show the expected variation volumes as +/- one sample standard deviation.

Figure 8. Typical Day – 0.5 MI S of 104th Ave – Southbound (025S221)

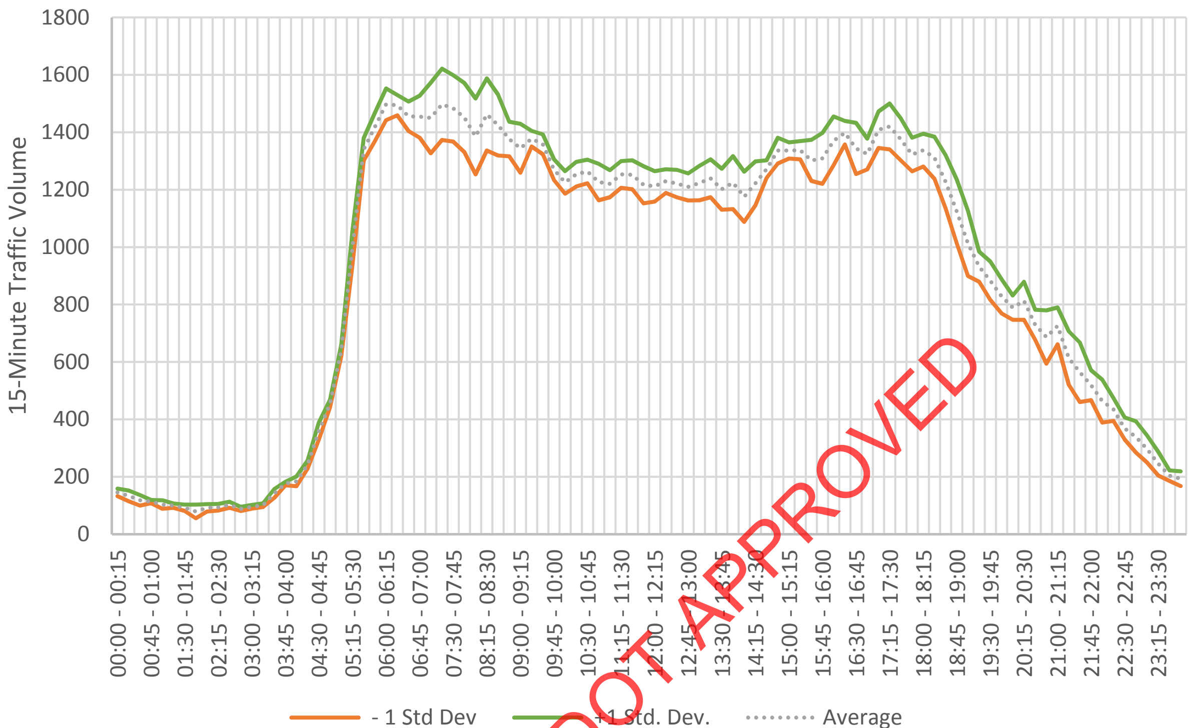


Figure 9. Typical Day – 0.5 MI S of 104th Ave – Northbound (025S221)

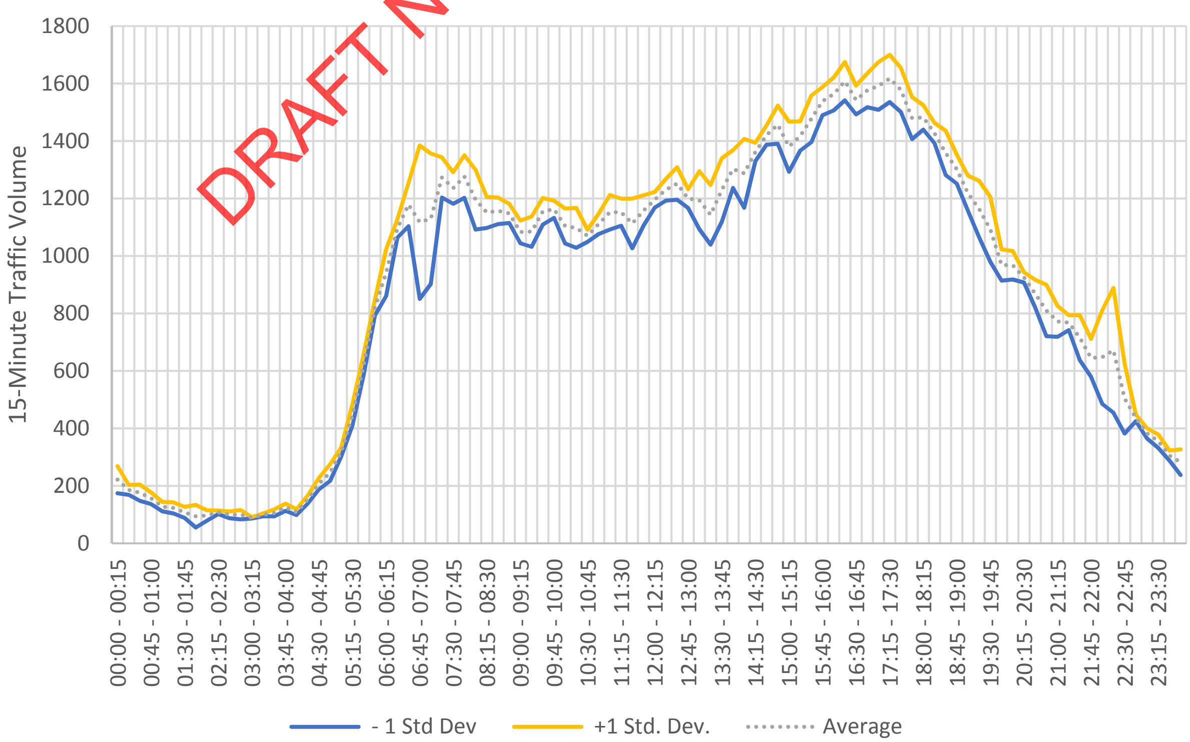


Figure 10. Typical Day – Thornton Parkway – Southbound (025S220)

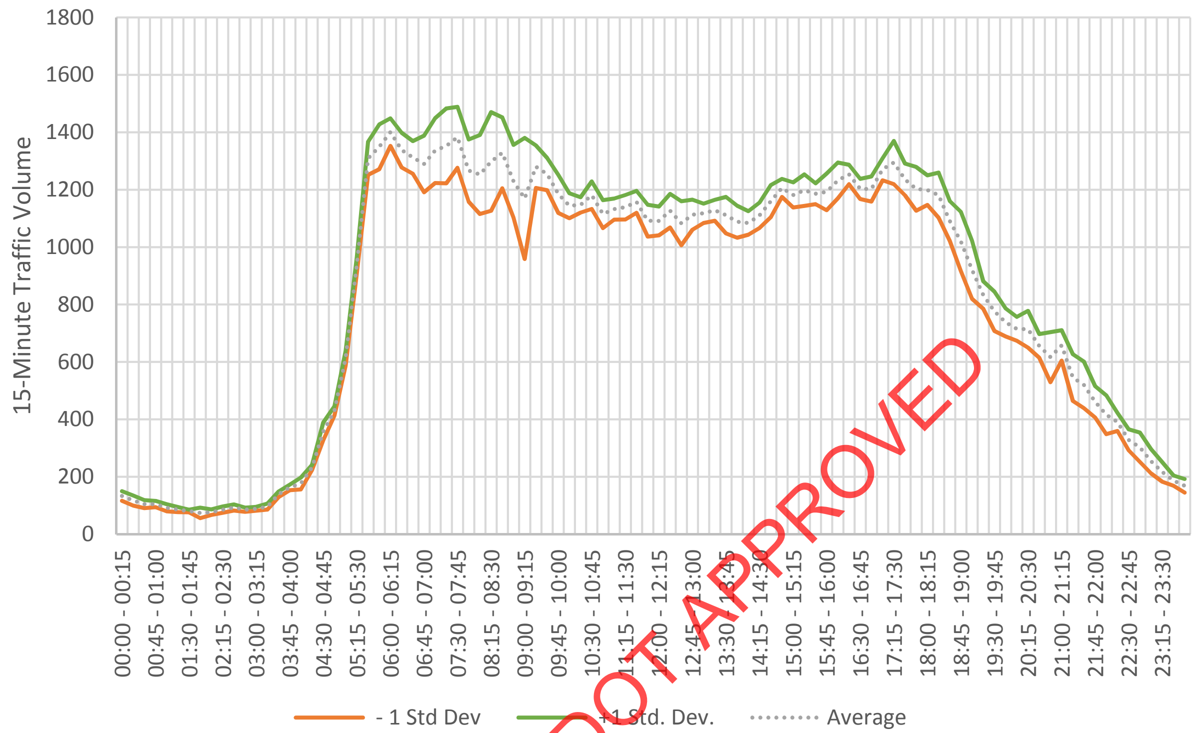


Figure 11. Typical Day – Thornton Parkway – Northbound (025S220)

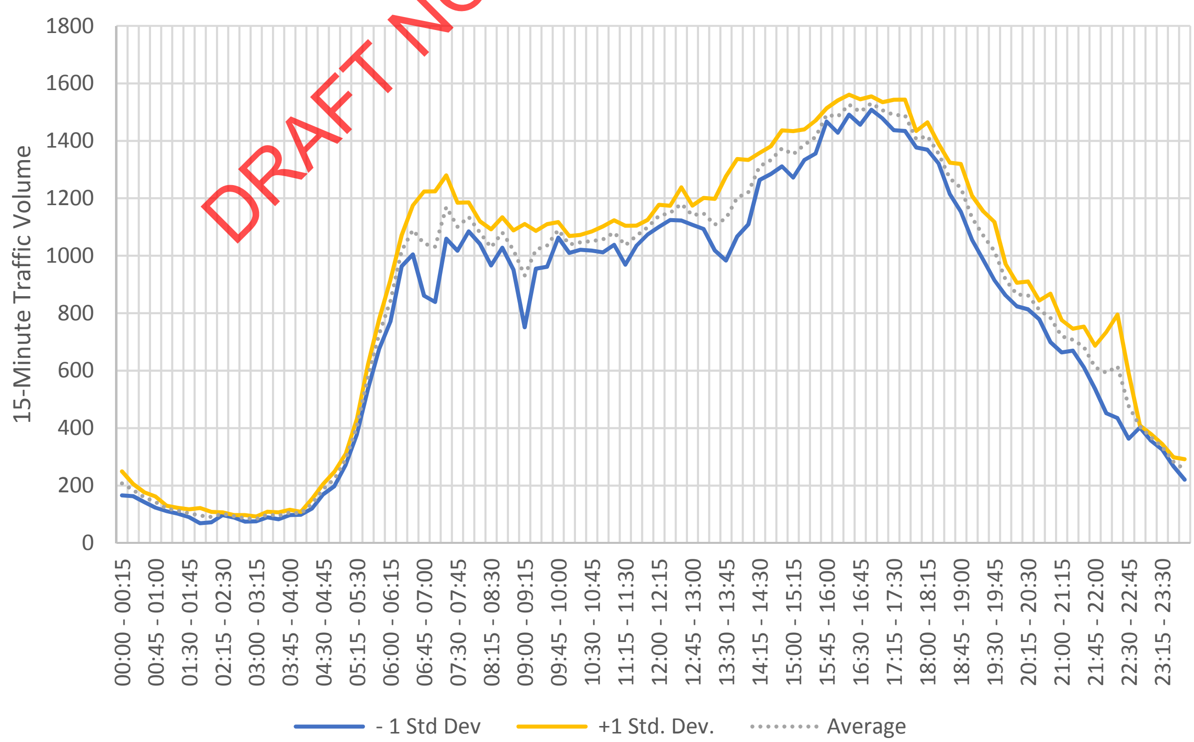


Figure 12. Typical Day – 0.7 MI S of Thornton Parkway – Southbound (025S219)

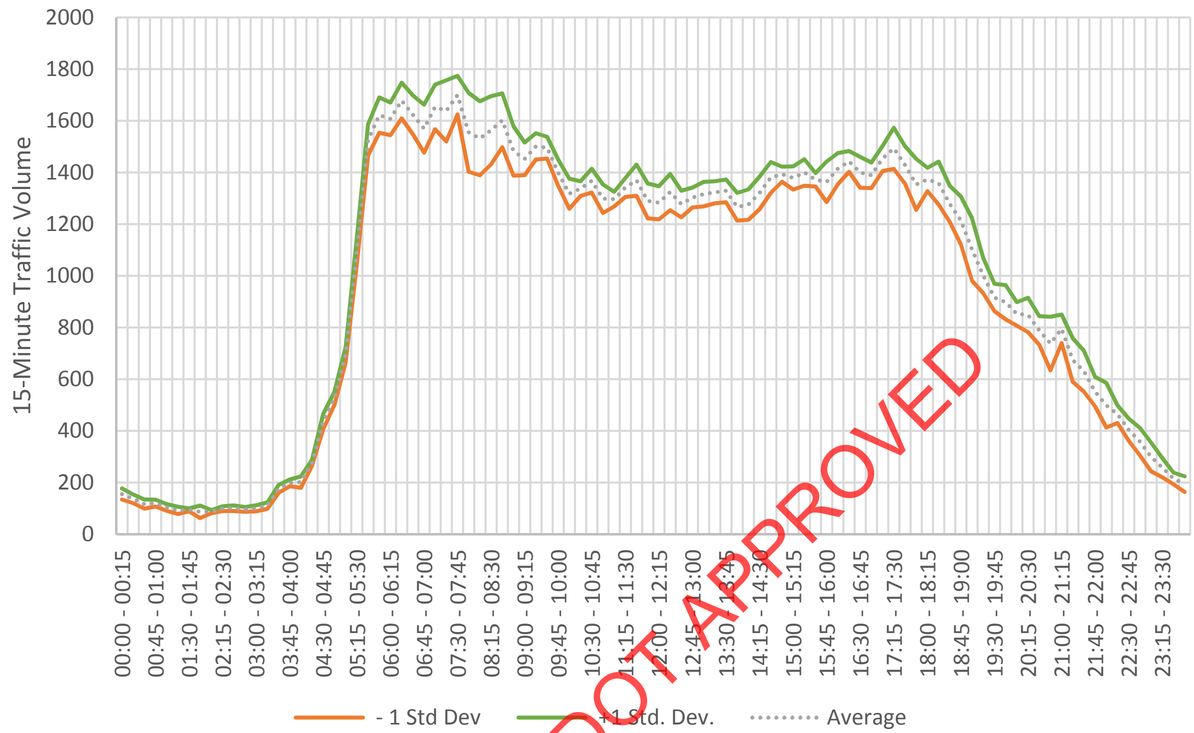


Figure 13. Typical Day – 0.7 MI S of Thornton Parkway – Northbound (025S219)

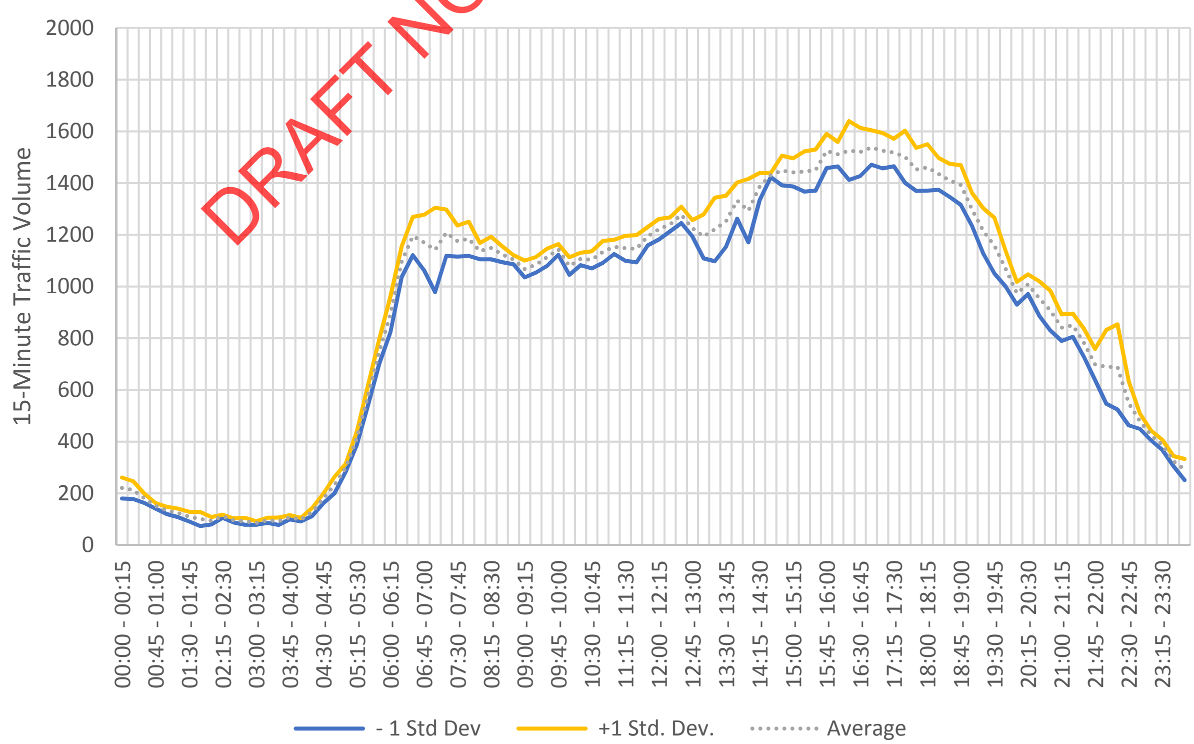


Figure 14. Typical Day – 84th Avenue – Southbound (025S219)

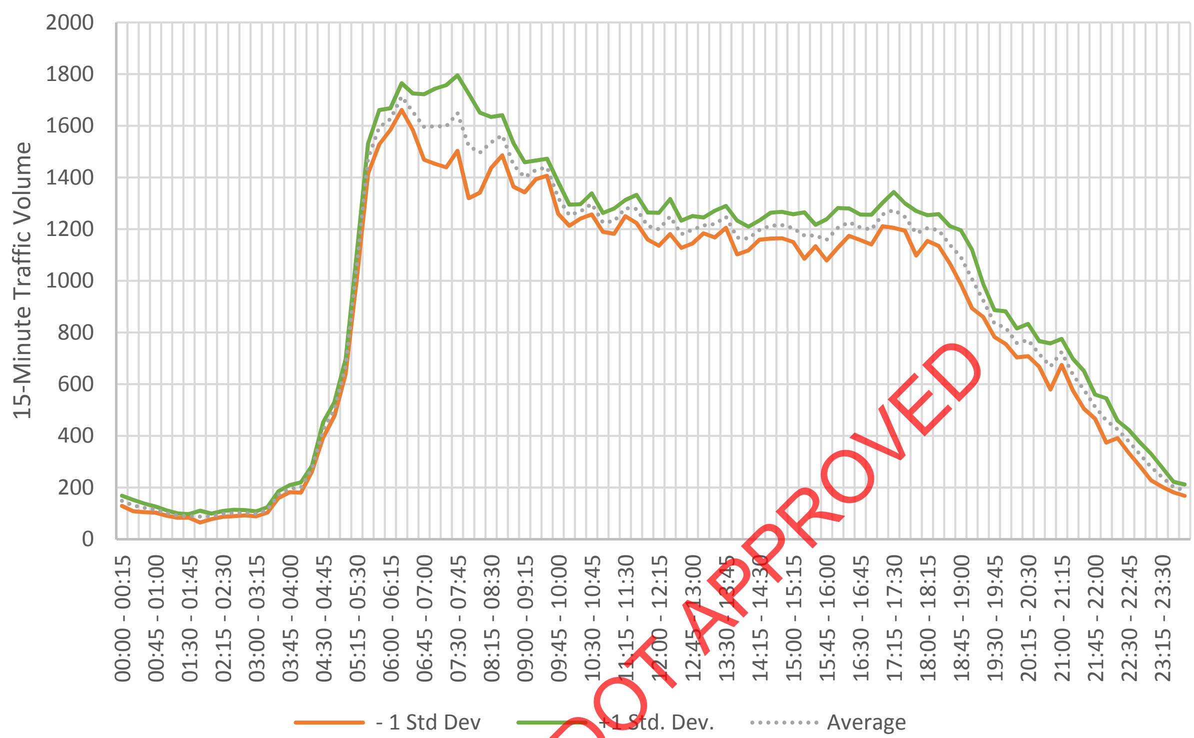


Figure 15. Typical Day – 84th Avenue – Northbound (025S219)

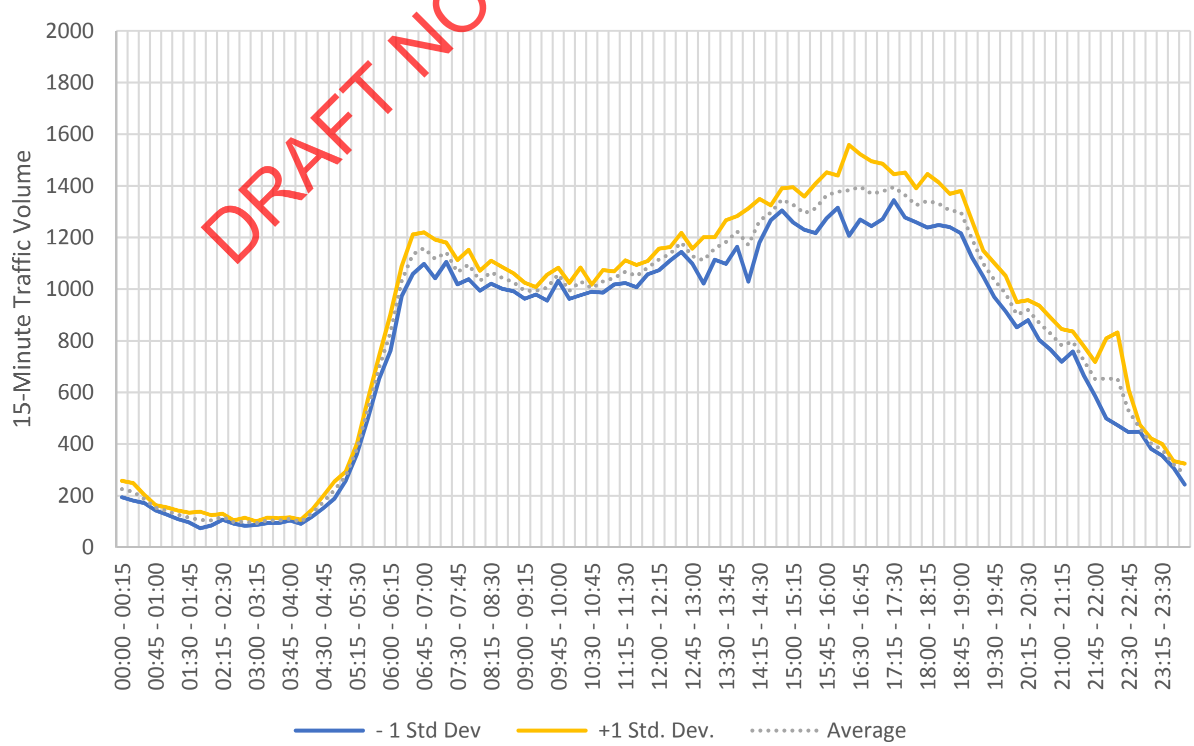


Figure 16. Typical Day – 0.5 MI S of 84th Avenue – Southbound (025S218)

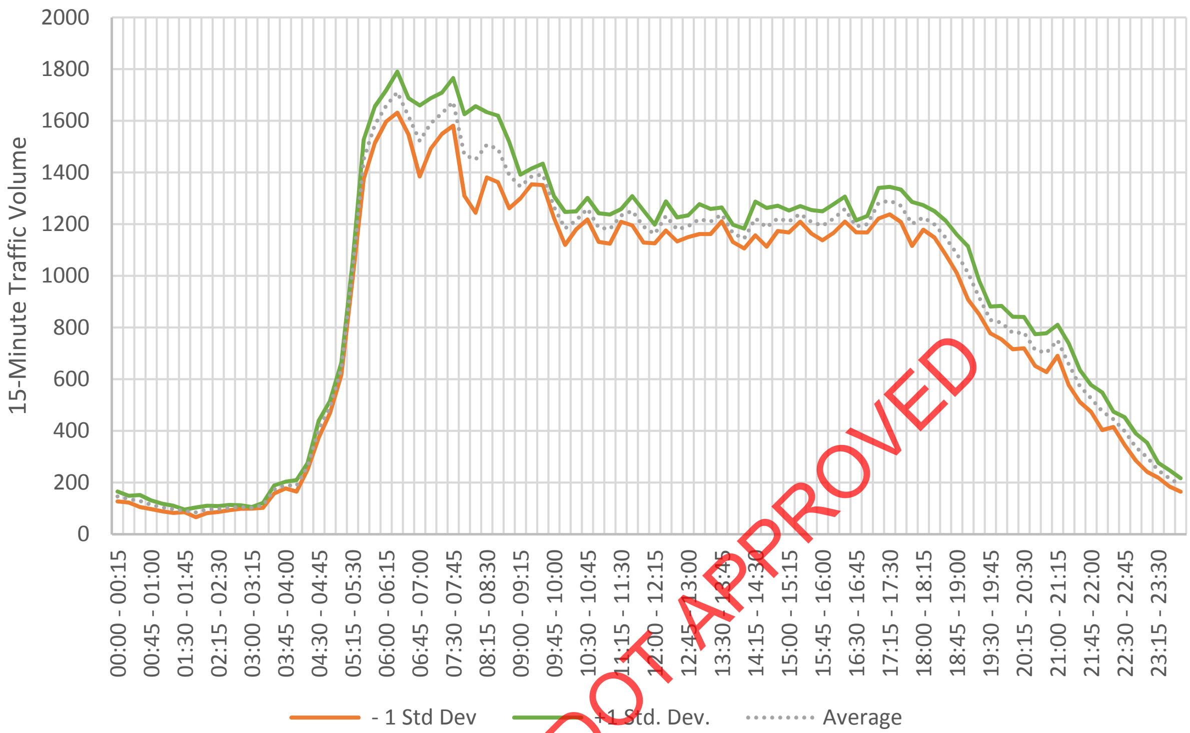


Figure 17. Typical Day – 0.5 MI S of 84th Avenue – Northbound (025S218)

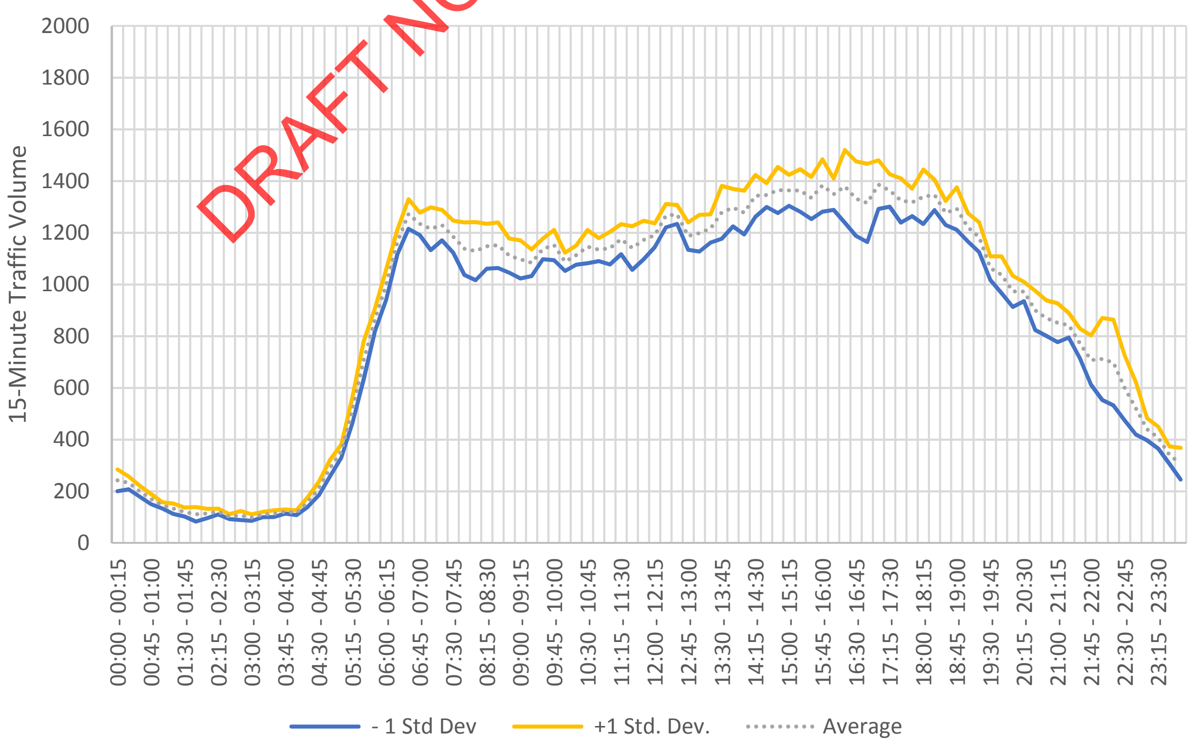


Figure 18. Typical Day – 0.9 MI S of 84th Avenue – Southbound (025S218)

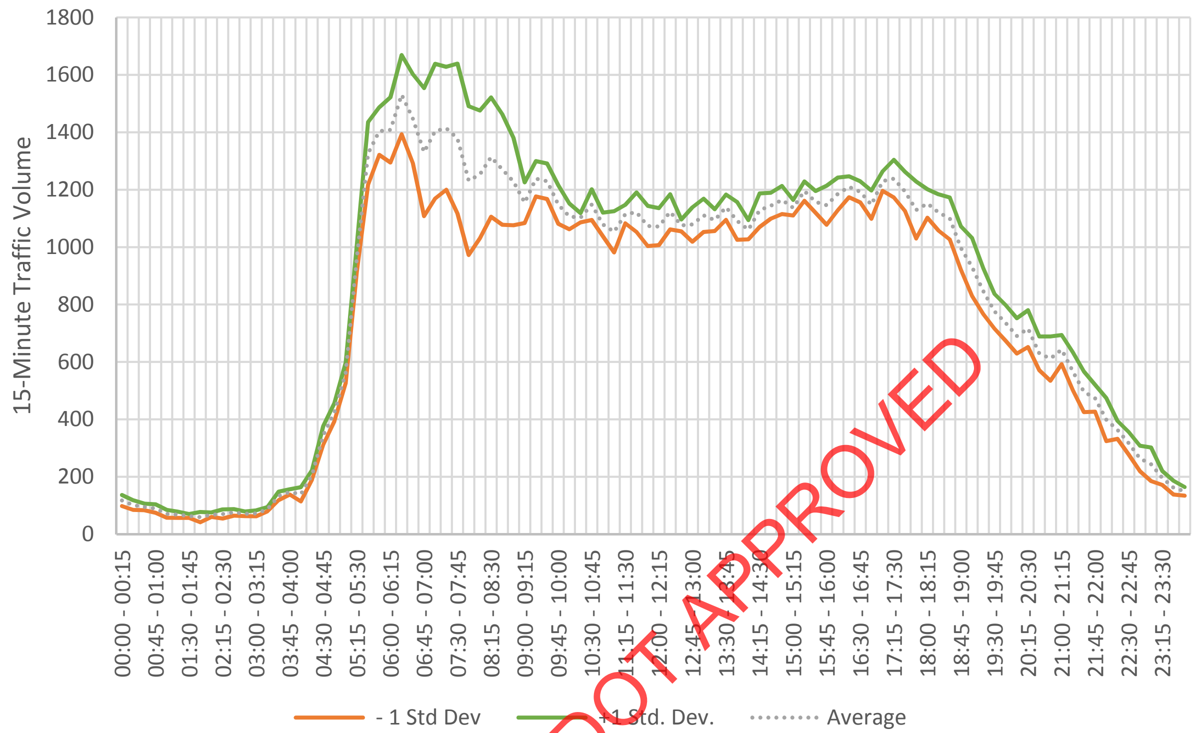
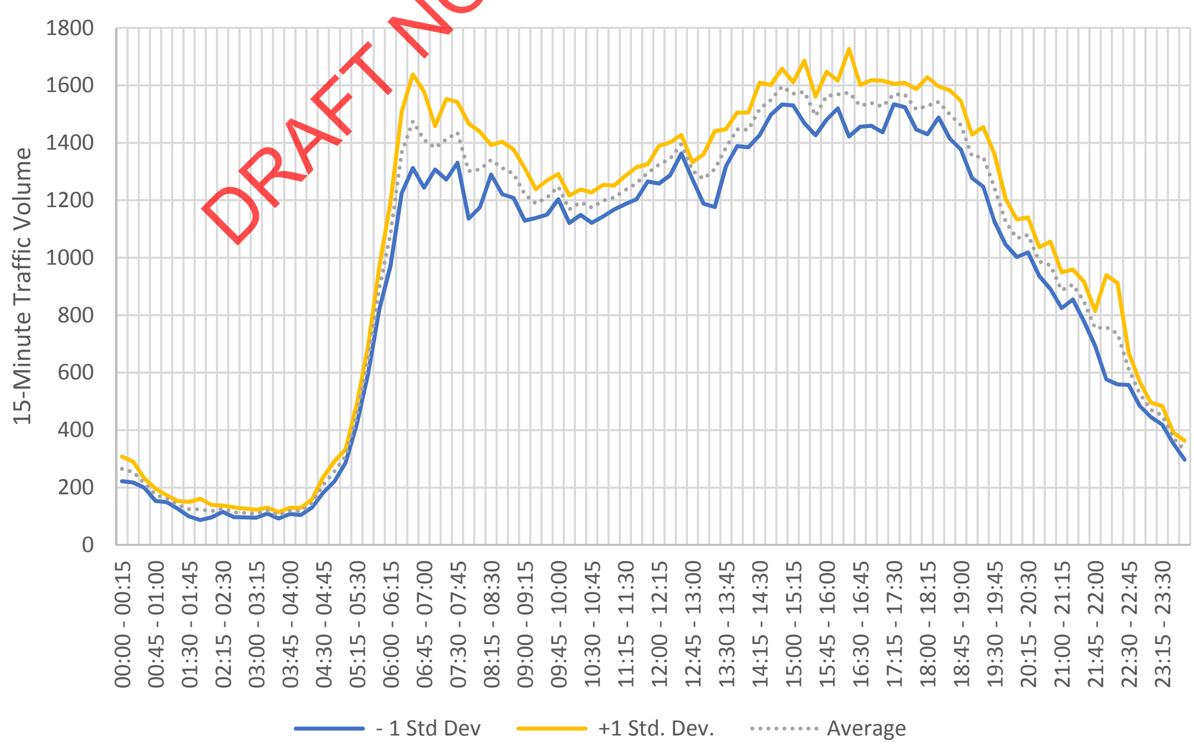


Figure 19. Typical Day – 0.9 MI S of 84th Avenue – Northbound (025S218)



IDENTIFYING A TYPICAL DAY

The data collection day most representative of a typical day was identified using the projections of expected traffic volumes and patterns depicted above. The following summarizes the incidents observed on each data collection day and the corresponding impacts to traffic volumes and operations.

April 25, 2017

On April 25th, the data collection team observed several incidents within and just outside the study area during the AM peak period that resulted in atypical data. A few of the observed and reported incidents included:

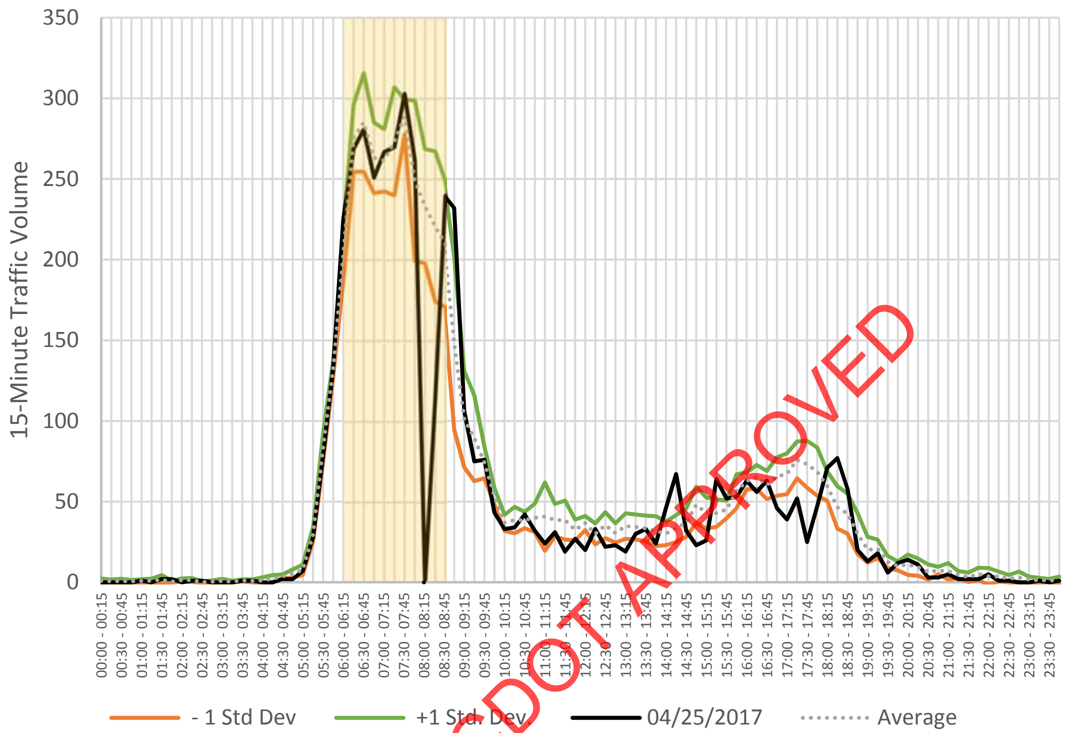
- A crash on SB I-25 between US 36 and I-76 that occurred a little before 8 AM
- A crash on SB I-25, south of 104th Avenue that blocked two travel lanes, including the express toll lane, occurred before 8 AM. The crash impacted traffic flows until approximately 8:45 AM, emergency vehicles were observed on the scene at 8 AM. See **Figure 20**.

Figure 20. Crash on SB I-25, South of 104th Avenue – April 25, 2017

- A smoking semi on NB I-25, north of Thornton Parkway, was pulled off on the shoulder, but a slow-down was observed in both directions.
- A crash on EB Thornton Parkway approaching the I-25 interchange complex that closed a lane and resulted in EB queuing backing up to Conifer Road.

The major incident during the AM peak period on SB I-25 (the AM peak direction) was observed to limit the traffic volumes able to pass the incident and volumes on SB I-25, south of the incident, were observed to result in lower than the projected typical day. Furthermore, the incident also closed the managed lane in the southbound direction, as shown on **Figure 21**.

Figure 21. April 25, 2017 – 0.5 MI S of 104th Avenue – Southbound Managed Lane (025S221)



Since one of the objectives of the analysis is to understand interactions between the mainline general purpose lanes, managed lanes and ramps, this day of data collection was determined to reflect atypical traffic conditions and was not selected as a typical day.

April 26, 2017

The data collection team returned to the study area on Wednesday, April 26th in hopes of observing and collecting traffic counts and field observations that were incident free and more representative of a typical day. There were no observed or reported crashes in the study area during the AM peak period. During the PM peak period, there was a crash between the on-ramp from I-270 WB and 84th Avenue that occurred around 4:45 PM. The crash was cleared at approximately 5:30 PM. During this period, increased speeds on NB I-25, north of the crash were observed during field work and reported by the COGNOS system.

Unfortunately, due to technical difficulties with the traffic count devices, this day of data collection is not available to use as the typical day. However, travel time and average speed field observations are still valid.

May 3, 2017

The data collection team returned to the field the following Wednesday, May 3rd to collect additional data. The team noted the following factors affecting data collection on May 3rd:

- Rain and fog reduced visibility in the area and reduced speeds were observed throughout the AM peak period; see **Figure 22**.

Figure 22. Rain during AM Peak Period – May 3, 2017

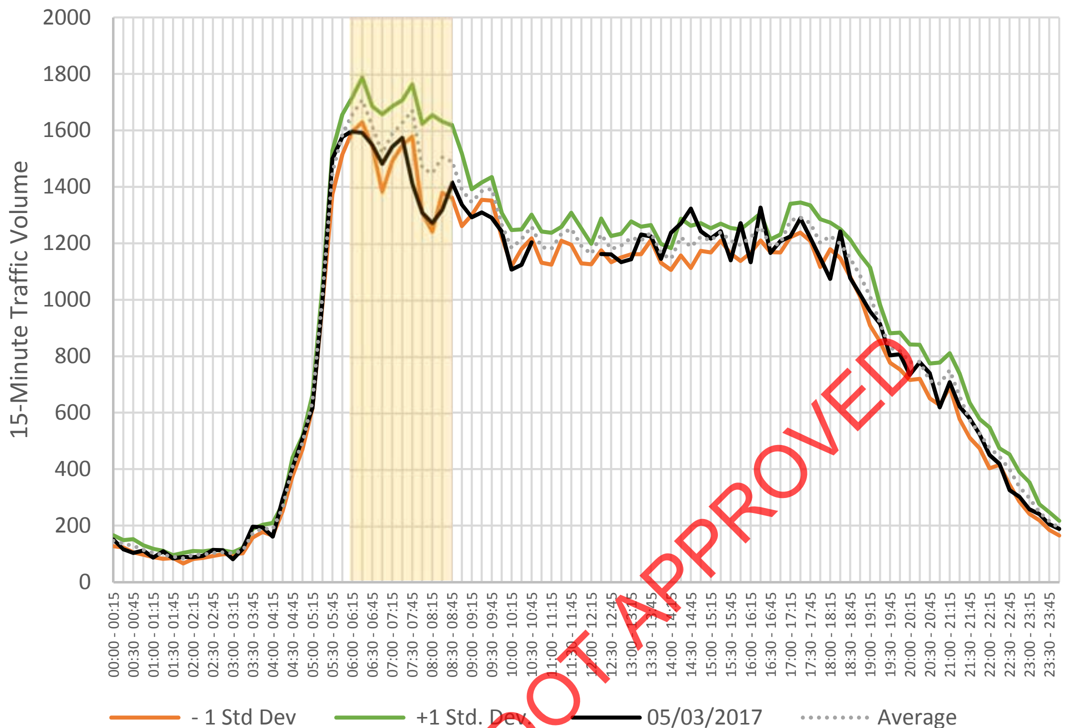
- A minor crash was also observed on SB I-25, just north of the US-36 off-ramp around 7:45 AM but was cleared by 8:00 AM; no significant impacts to through traffic were observed.
- A stalled vehicle on NB I-25, located in the leftmost general purpose lane and at the merge point for traffic from WB US 36 caused significant delays beginning around 5:00 PM; see **Figure 23**. The incident was observed to impact traffic until 5:45; CDOT tweeted that the vehicle was moved to the shoulder and all lanes were opened at 5:40 PM.

Figure 23. Stalled Vehicle on NB I-25 during the PM Peak Period – May 3, 2017

- A crash was reported on NB I-25 between I-76 and US 36 around 5:30 but was quickly cleared by 5:45.

During the AM peak period, observed weather conditions resulted in reduced travel speeds and lower than expected volumes. The COGNOS data confirmed that the AM peak period volumes were below the average expected volumes and at the lower limit of the expected daily volume variation, as shown on **Figure 24**.

Figure 24. May 3, 2017 – 0.5 MI S of 84th Avenue – Southbound (025S218)

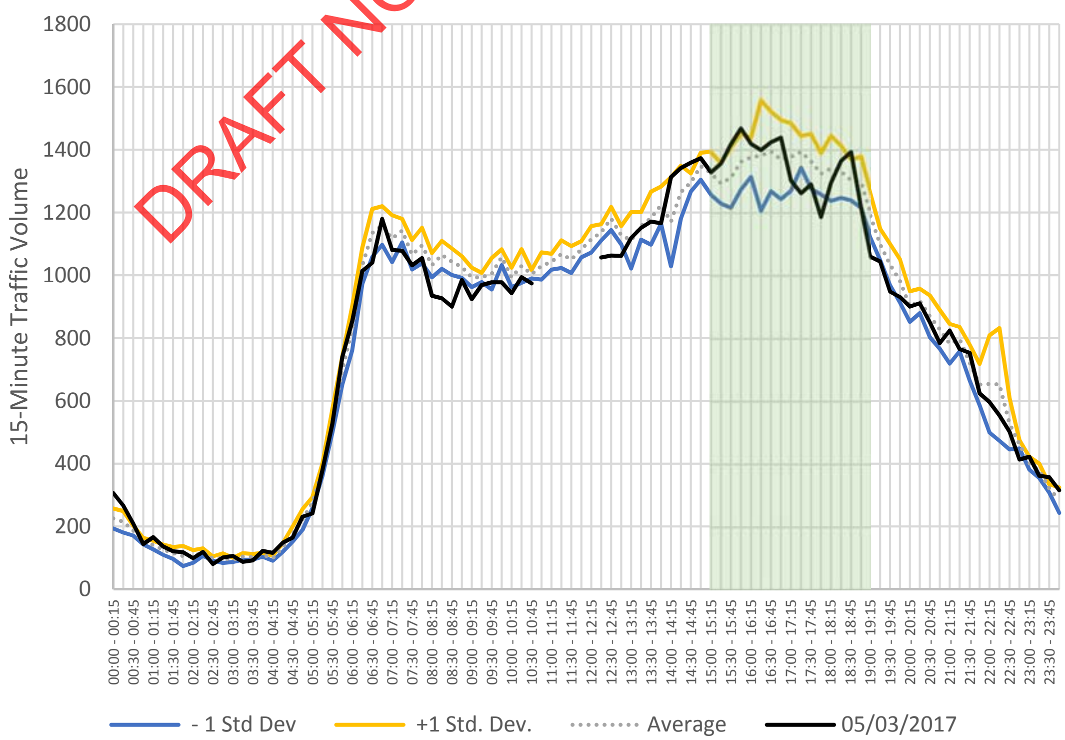


During the PM peak period, the stalled vehicle on NB I-25 was located in the leftmost general purpose lane and at the merge point for traffic from WB US 36. North of the crash, free flow travel speeds were observed and speeds greater than 40 MPH were reported for all RTMS stations north of 84th Avenue for the entire PM peak period, as shown on **Figure 25. Figure 26** illustrates the corresponding impacts to volumes on northbound I-25 because of the incident. Due to the lower than expected volumes during the AM peak hour and higher than expected speeds in the PM peak hour, this day was not selected as a typical day.

Figure 25. May 3, 2017 Incident – Northbound I-25 Speeds (COGNOS)

	16:45 - 17:00	17:00 - 17:15	17:15 - 17:30	17:30 - 17:45	17:45 - 18:00
	63.46	62.94	63.97	64.70	63.91
	63.46	62.94	63.97	64.70	63.91
104th	63.46	62.94	63.97	64.70	63.91
	63.46	62.94	63.97	64.70	63.91
	63.46	62.94	63.97	64.70	63.91
	62.40	61.60	63.49	63.61	62.21
	62.40	61.60	63.49	63.61	62.21
	62.40	61.60	63.49	63.61	62.21
	62.40	61.60	63.49	63.61	62.21
	62.40	61.60	63.49	63.61	62.21
	62.40	61.60	63.49	63.61	62.21
	55.49	58.18	58.38	59.12	56.00
	55.49	58.18	58.38	59.12	56.00
	55.49	58.18	58.38	59.12	56.00
Thornton	55.49	58.18	58.38	59.12	56.00
	55.49	58.18	58.38	59.12	56.00
	55.49	58.18	58.38	59.12	56.00
	55.49	58.18	58.38	59.12	56.00
	56.94	59.34	64.06	61.18	58.71
	56.94	59.34	64.06	61.18	58.71
	56.94	59.34	64.06	61.18	58.71
	56.94	59.34	64.06	61.18	58.71
	56.94	59.34	64.06	61.18	58.71
	56.94	59.34	64.06	61.18	58.71
	56.94	59.34	64.06	61.18	58.71
	33.38	45.00	59.34	49.22	24.89
	33.38	45.00	59.34	49.22	24.89
	33.38	45.00	59.34	49.22	24.89
84th	33.38	45.00	59.34	49.22	24.89
	33.38	45.00	59.34	49.22	24.89
	33.38	45.00	59.34	49.22	24.89
	27.61	51.52	56.17	47.93	26.07
	27.61	51.52	56.17	47.93	26.07
	27.61	51.52	56.17	47.93	26.07
	27.61	51.52	56.17	47.93	26.07
	27.61	51.52	56.17	47.93	26.07
	25.13	35.00	35.38	31.29	24.23
	25.13	35.00	35.38	31.29	24.23
	25.13	35.00	35.38	31.29	24.23
	25.13	35.00	35.38	31.29	24.23
	25.13	35.00	35.38	31.29	24.23

Figure 26. May 3, 2017 – 84th Avenue – Northbound (025S219)



May 4, 2017

Due to the potential impacts from the weather during the AM peak period and the stalled vehicle severely impacting traffic volumes and operations during the PM peak period on May 3rd, the team returned on May 4th to collect additional field observations and record traffic counts. The data collection team noted the following factors with the potential to impact data collection results on May 4th:

- A minor crash was observed near the SB I-25 on-ramp from 84th Avenue at 7:15 AM. However, the data collection team noted that the accident was pulled off on the shoulder and did not appear to impact traffic flows from the 84th Avenue on-ramp. At 7:30 AM, police and tow trucks were observed in the area; at 7:20 AM CDOT tweeted that one lane was closed on the ramp from 84th Avenue to SB I-25 while the crash was removed. CDOT tweeted that the lane was officially re-opened at 7:50 AM.
- A crash was reported on the SB on-ramp from US 36 EB at 8:20 AM. The data collection team observed the crash pulled off on the side of the ramp. No lane closures were observed and traffic could easily pass the crash; likely due to the low speeds and high volumes on the ramp during the AM peak period; see **Figure 27**.

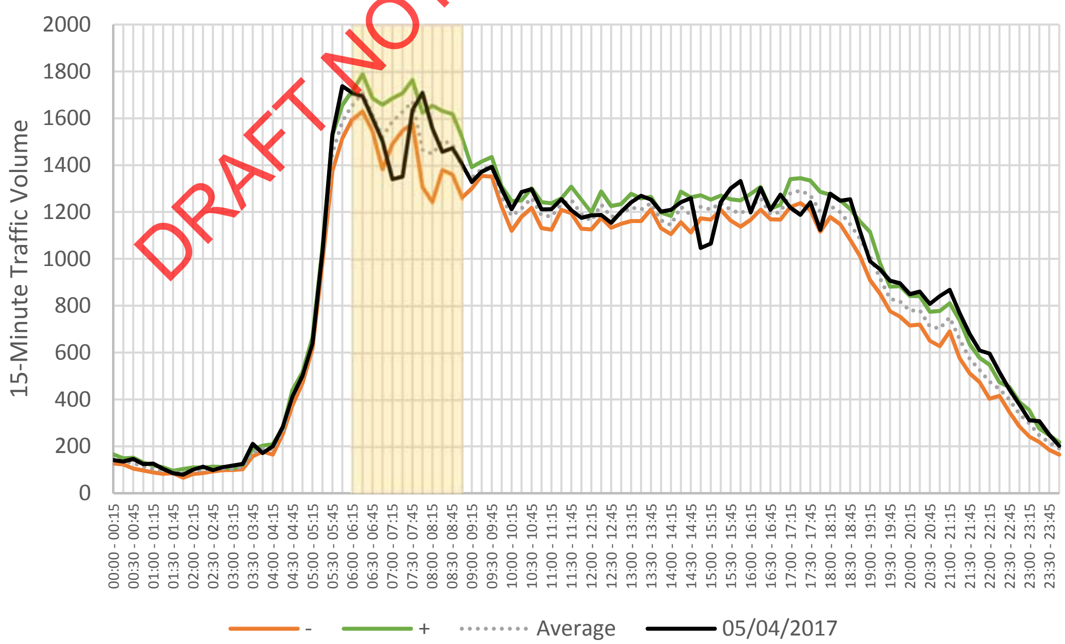
Figure 27. Crash on SB on-ramp from US 36 – May 4, 2017

- A crash was reported on NB I-25 just south of 104th Avenue at 8:30 AM and was cleared by 8:45 AM.
- A crash was observed on SB I-25 at 4:10 PM and was cleared by 4:30 PM. The vehicles involved in the crash were pulled off on the shoulder and no lane closures resulted; see **Figure 28**.

Figure 28. Crash on SB I-25 during PM Peak Period – May 4, 2017

As previously noted, a minor incident was observed during the AM peak period on SB I-25, just south of the southbound on-ramp from 84th Avenue. **Figure 29** illustrates the corresponding decrease in traffic on southbound I-25, south of the incident. For a 30-minute period, the southbound traffic volumes were slightly below the expected volumes.

Figure 29. May 4, 2017 – 0.5 MI S of 84th Avenue – Southbound (025S218)



Conclusion

Field observations and data collection did not yield a single 24-hour incident free period. Therefore, it was necessary to select a day that provided the data deemed most representative of a typical, incident-free day. May 4, 2017 was selected as the data collection day most representative of typical, incident-free conditions.

The following graphs (**Figure 30** through **Figure 34**) show the AM and PM peak periods at each interchange station. Generally speaking, the observed traffic volumes on May 4th fall within the projected range for typical peak period volumes at all count locations. The AM peak period and peak hour will require adjustments to arrive at a set of volumes more representative of a typical day.

Due to the abundance of data available through the COGNOS system and given the relatively consistent traffic volumes reported from the COGNOS system and the ATD sample selection, the team is confident that the necessary data are available to interpolate traffic volumes and average travel speeds to effectively remove the impacts of the AM peak period incident. This process will be discussed in greater detail in the *Traffic Volume Adjustment* section of this memorandum.

Figure 30. May 4, 2017 – 0.5 MI S of 84th Avenue – Northbound (025S218)

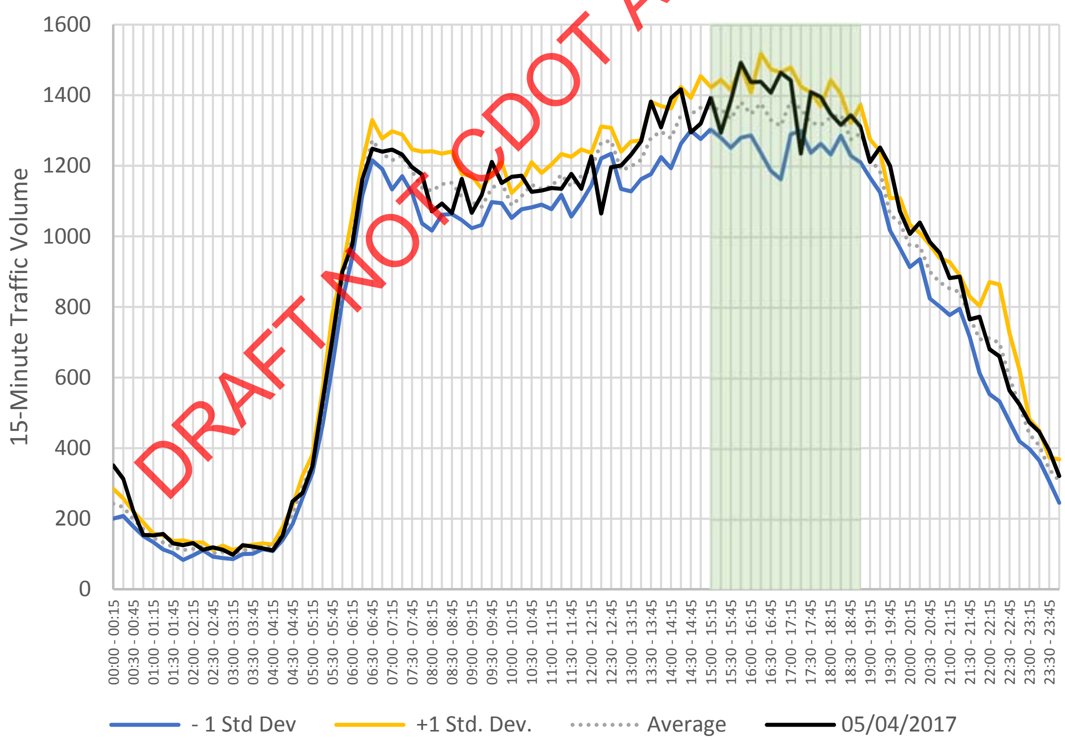


Figure 31. May 4, 2017 – Thornton Parkway – Southbound (025S220)

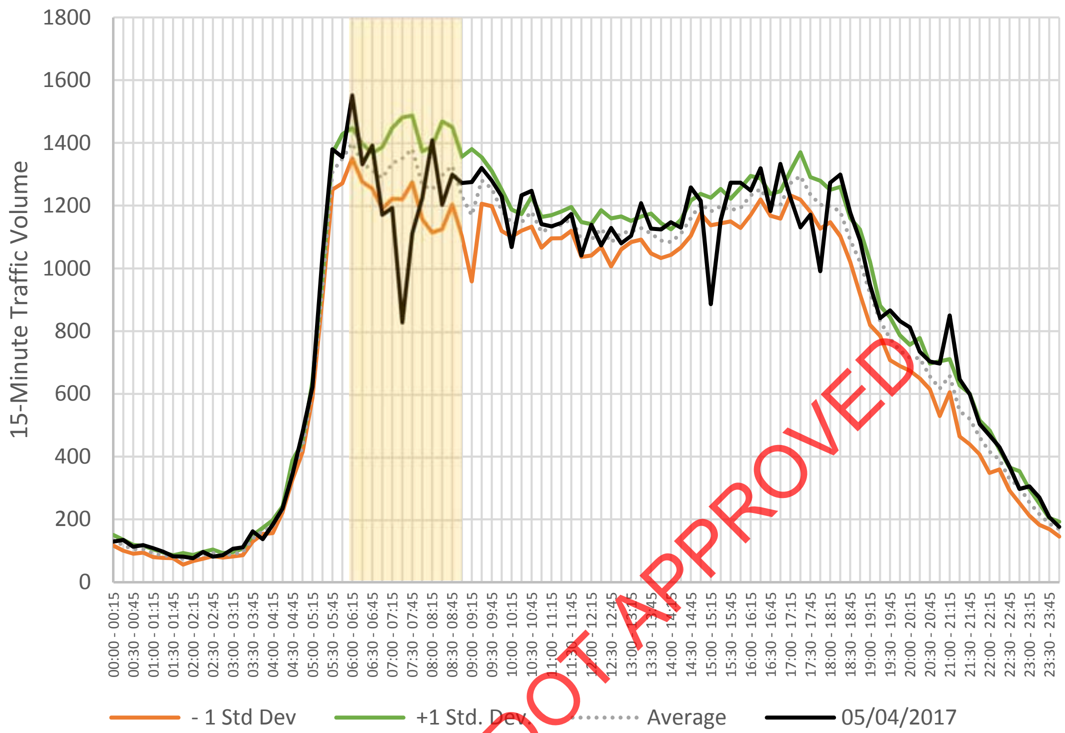


Figure 32. May 4, 2017 – Thornton Parkway – Northbound (025S220)

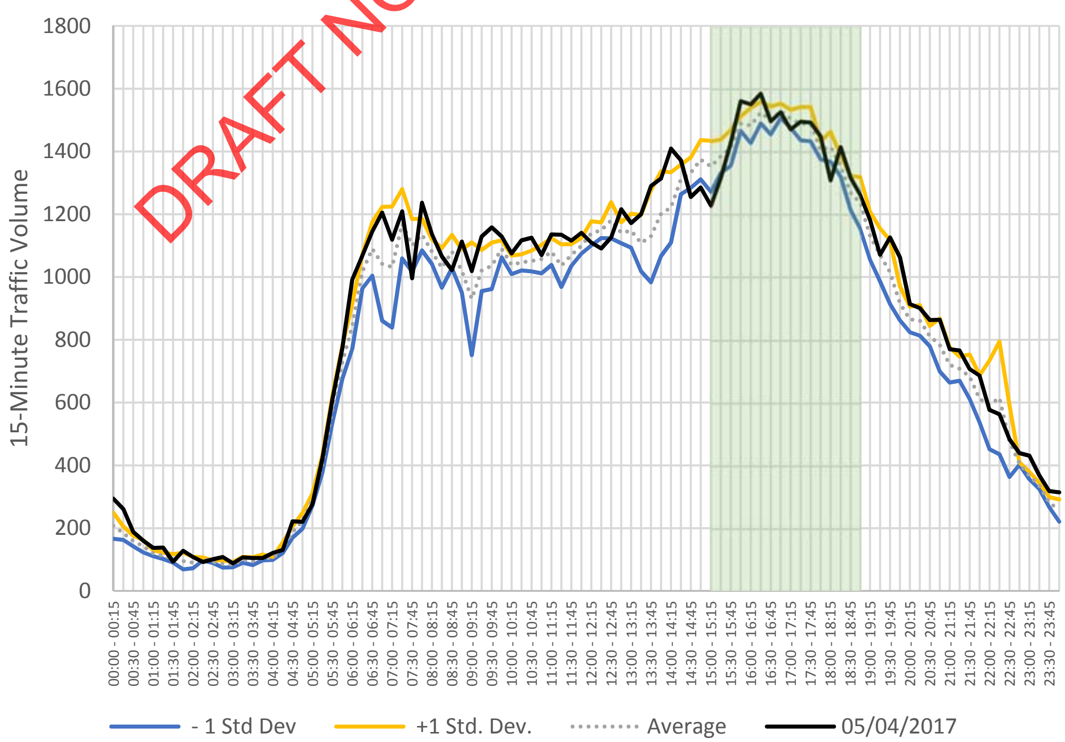


Figure 33. May 4, 2017 – 0.5 MI S of 104th Avenue – Southbound (025S221)

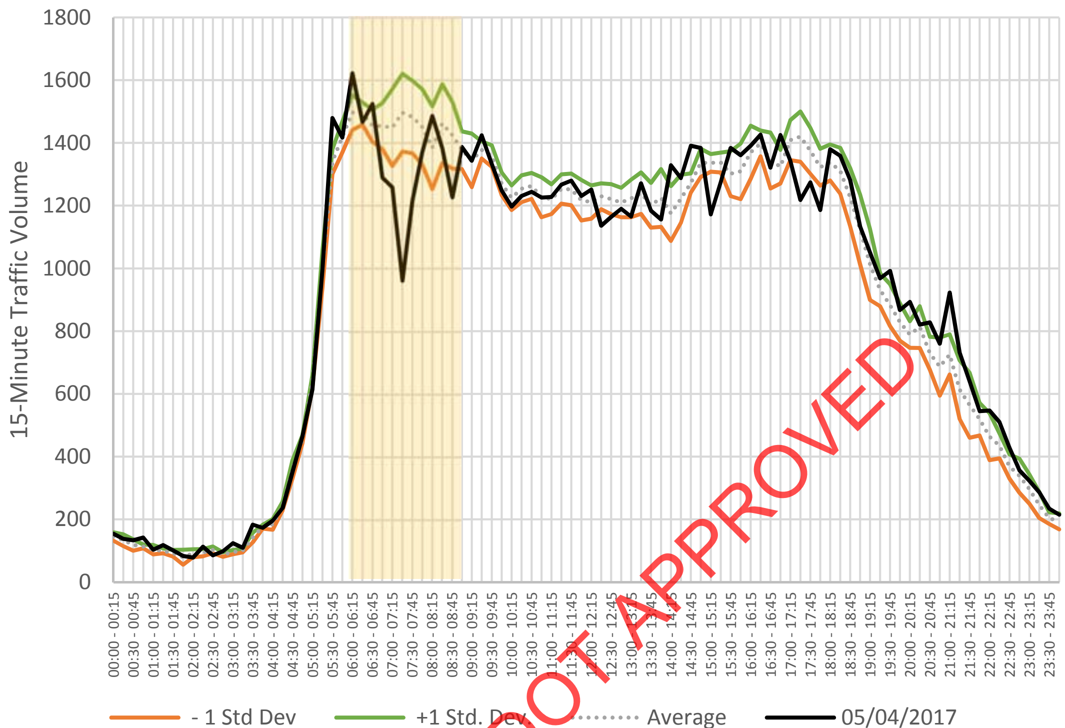
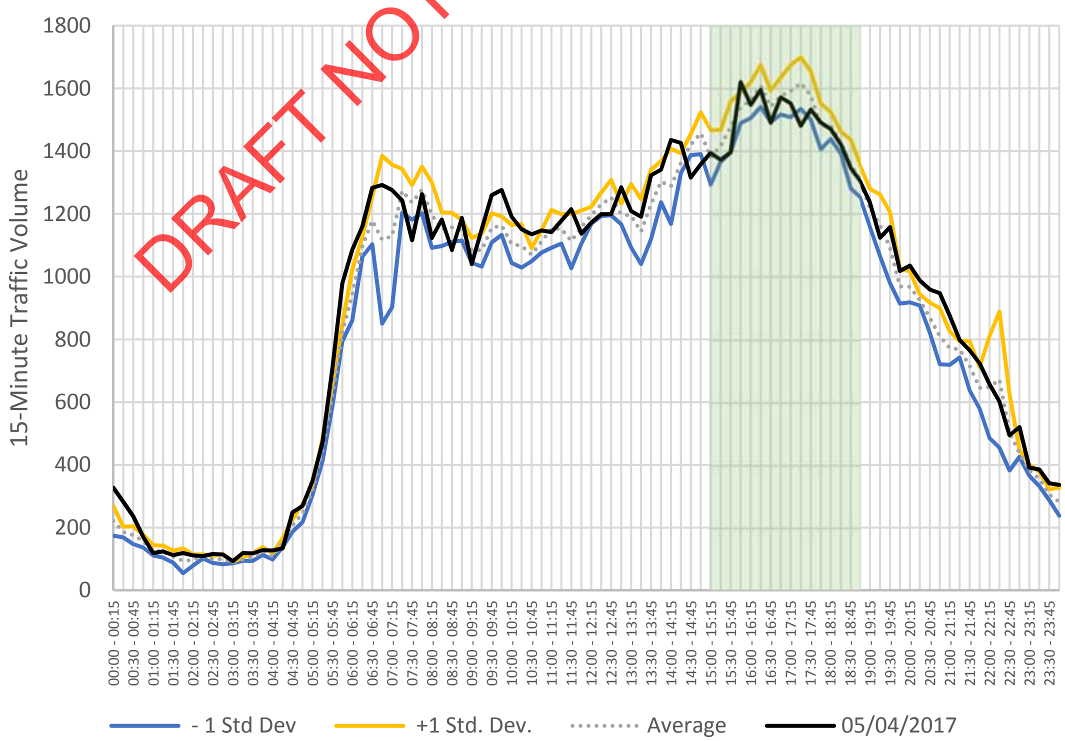


Figure 34. May 4, 2017 – 0.5 MI S of 104th Avenue – Northbound (025S221)



QUEUING: DEMAND VS. SERVICE VOLUMES

Queues were observed at the I-25 interchange ramp terminal intersections with spot checks at other major movements during the peak hour to better understand the vehicle demand and compared to the number of vehicles processed at each intersection. Interchange to interchange ramps demand and queuing has been estimated using observations where possible and speed information from Google Maps and COGNOS. Observation locations of interest were:

- SB I-25 on-ramp at 104th Avenue (AM)
- SB I-25 on-ramp at Thornton Parkway (AM)
- SB I-25 on-ramp from EB US 36 (AM)
- SB I-25 on-ramp from WB I-76 (AM)
- NB I-25 on-ramp at Thornton Parkway (PM)
- NB I-25 on-ramp at 84th Avenue (PM)
- NB I-25 on-ramp from WB I-270 (PM)
- NB I-25 on-ramp from EB I-76 (PM)

The observed queue field observations have been used to identify locations of persistent queuing and recurring bottlenecks at the following locations during the AM peak period:

- WB I-76 to SB I-25: Queue extends to approximately Washington Street.
- EB US 36 to SB I-25: Queue extends to mainline US 36 and was observed to extend onto mainline US 36 during the peak hour.
- SB I-25 north of on-ramps from I-76 and US 36: Queue/slow moving traffic extends north to approximately 75th Avenue; speeds and congestion were observed to continue south of the I-76 bridge.
- SB I-25 on-ramp at Thornton Parkway: Queues at the ramp meter were observed to extend approximately 8 to 10 cars in each lane's merge point until the 58th Avenue exit.
- SB I-25 on-ramp at 104th Avenue: queuing was observed to occasionally fill the ramp; however, it is important to note that construction in the area resulted in temporary changes to the ramp.
- Thornton Parkway Interchange: Traffic on SB I-25 was observed to slow near the Thornton Parkway interchange to accommodate vehicles merging onto SB I-25 from Thornton Parkway.

During the PM peak period, persistent queuing and recurring bottlenecks were observed at the following locations:

- EB I-76 to NB I-25: Queue was observed to extend west, back near the Broadway bridge structure.
- WB I-270 to NB I-25: Queue extends to mainline I-270.
- NB I-25 south of the I-76/I-270 NB on-ramp: Congestion and queuing were observed to build consistently around the start of the bend of I-25, near 70th Avenue.
- NB I-25 on-ramp at 84th Avenue: Queue was occasionally observed to fill the ramp; however, only twice was unmet demand of one vehicle observed to remain in the queue on 84th Avenue.
- 84th Avenue Interchange: between the merge point from I-76/I-270 and the diverge point for the 84th Avenue northbound off-ramp, vehicular speeds were observed to increase slightly before reaching another bottleneck location created by the northbound I-25 on-ramp merge from 84th Avenue.

TRAVEL TIME RUNS & AVERAGE SPEEDS

Point-to-point travel time data were collected using "floating car runs" and GPS monitoring. The GPS data recorded average travel speeds for comparison to segment travel speeds reported in the CDOT COGNOS system. Mainline travel time speed data collected have been compared to COGNOS travel time data for comparative purposes and to ensure consistency.

The COGNOS Device Speed Reports for RTMS provide speed, volume, and occupancy readings. To ensure continuity and consistency between volume and speed data for the COGNOS data, the speed and volume data reported has been pulled from the COGNOS Device Speed Reports.

Travel times and speeds in the off-peak direction focused on mainline I-25 to better understand the actual travel speeds (above the posted speed limit) and will be compared to the COGNOS calculated speed data. In the peak direction, travel time runs were targeted at movements that are congested and that may result in the greatest measurable benefit from the proposed improvements.

Travel time run routes were selected in a manner that the team thought would best inform the calibration of the TransModeler model and provide the best understanding of the potential impacts of the proposed improvements. Full study area travel time runs were conducted to better understand how the general purpose lanes are currently operating, and to understand how the proposed improvements impact through volumes. The ramp to mainline travel time runs were conducted to better understand the operations of the existing merge and diverge segments, as well as provide data to better evaluate the proposed auxiliary lane improvements.

AM travel time segments include:

- NB I-25 (approximately MM 216 to MM 223)
- SB I-25 to WB Thornton Pkwy
- EB Thornton Pkwy to SB I-25
- SB I-25 to WB 84th Avenue
- EB 84th Avenue to SB I-25

PM travel time segments include:

- SB I-25 (approximately MM 223 to MM 216)
- NB I-25 to EB 84th Avenue
- WB 84th Avenue to SB I-25
- NB I-25 to EB Thornton Pkwy
- WB Thornton Pkwy to NB I-25

The field collected travel speeds have been compared to the COGNOS travel speeds reported in the Device Speed Report. Travel time runs conducted during periods where incidents were observed to impact speeds/flows on I-25 have been removed from the dataset. The following tables compare the GPS tracked mainline travel time run average speeds to the COGNOS average speeds. Average recorded travel times are shown in **Table 1** and a comparison of average recorded speeds for travel time runs to COGNOS reported speeds are shown in **Table 2**. Comparisons are only provided for mainline travel times.

Table 1. Recorded Travel Times

	Average Travel Time (mm:ss)	
	AM Peak	PM Peak
	Observed	Observed
NB I-25: I-76 to 104th	05:07	07:33
NB I-25: 84th to Thornton	01:21	01:47
NB I-25: I-76 to 84th	02:19	04:18
NB I-25 to 84th/Grant		04:59
84th to NB I-25		02:37
NB I-25 to Thornton		01:40
Thornton to NB I-25		01:52
NB I-25 to 104th		01:58
SB I-25: Bonita Pl to I-76 Bridge	13:01	05:34
SB I-25: 104th to 84th	05:32	02:19
104th to SB I-25	03:55	
SB I-25 to Thornton	01:35	
Thornton to SB I-25	03:25	
SB I-25 to 84th	01:44	
84th/Huron to SB I-25 (I-76 Bridge)	06:49	

Table 2. Comparison of Recorded Speeds

	Average Speed (mph)			
	AM Peak		PM Peak	
	Observed	COGNOS	Observed	COGNOS
NB I-25: I-76 to 104th	61.84	60.45	43.25	46.06
NB I-25: 84th to Thornton	63.37	61.86	44.63	53.42
NB I-25: I-76 to 84th	65.01	60.96	38.37	31.44
NB I-25 to 84th/Grant			35.15	
84th to NB I-25			20.72	
NB I-25 to Thornton			44.61	
Thornton to NB I-25			35.66	
NB I-25 to 104th			33.80	
SB I-25: Bonita Pl to I-76 Bridge	27.54	37.44	60.38	62.77
SB I-25: 104th to 84th	32.75	39.04	61.69	59.60
104th to SB I-25	23.69			
SB I-25 to Thornton	41.97			
Thornton to SB I-25	24.56			
SB I-25 to 84th	36.40			
84th/Huron to SB I-25 (I-76 Bridge)	27.66			

Traffic volume adjustments and continual evaluation of the field collected data to the COGNOS collected speed data will ultimately inform the development of the travel time and average speed calibration targets.

TRAFFIC VOLUME ADJUSTMENTS

Reconciliation of Traffic Counts

All count programs result in unbalanced totals for traffic counts at two or more nearby adjacent locations; and as a result, manual balancing of vehicular volumes along corridors is necessary for input into TransModeler. Unbalanced corridors can be a result of counting errors, unsynchronized counting devices, major traffic sources (or sinks) between the two locations, or queuing between the two locations. In the case of the freeway volumes, the discrepancy between the total traffic volumes entering the freeway and the total exiting vehicles may also be caused by storage or discharge of some of the vehicles in growing or shrinking queues on the freeway.

Differences in entering and exiting counts that are caused by queuing in between the two count locations have been addressed by ensuring that the count period includes the build-up and dissipation of congestions so that all demand is included in both counts.

The freeway, ramp, and intersection counts have been adjusted to produce an internally consistent set of volumes for every link and node in the model. The model includes a few intermediate intersections/nodes that are not included in **Figure 35** through **Figure 37** (which only reflects locations with traffic count data).

Traffic Volume Adjustments – Accounting for the AM Peak Period Incident

A comparison of the total volumes processed during the AM peak period (6:00 AM to 9:00 AM) indicated that typically 13,850 to 18,500 vehicles are processed through this section of I-25; on average 16,200 vehicles are processed during the AM peak period. On May 4, 2017, approximately 15,350 vehicles were processed through this section. The extensive data from COGNOS will be used to adjust the count volumes recorded on May 4, 2017 to correct the data set impacted by the minor incident on the southbound on-ramp at 84th Avenue.

Figure 35. Raw AM and PM Peak Hour Traffic Counts – 104th Avenue

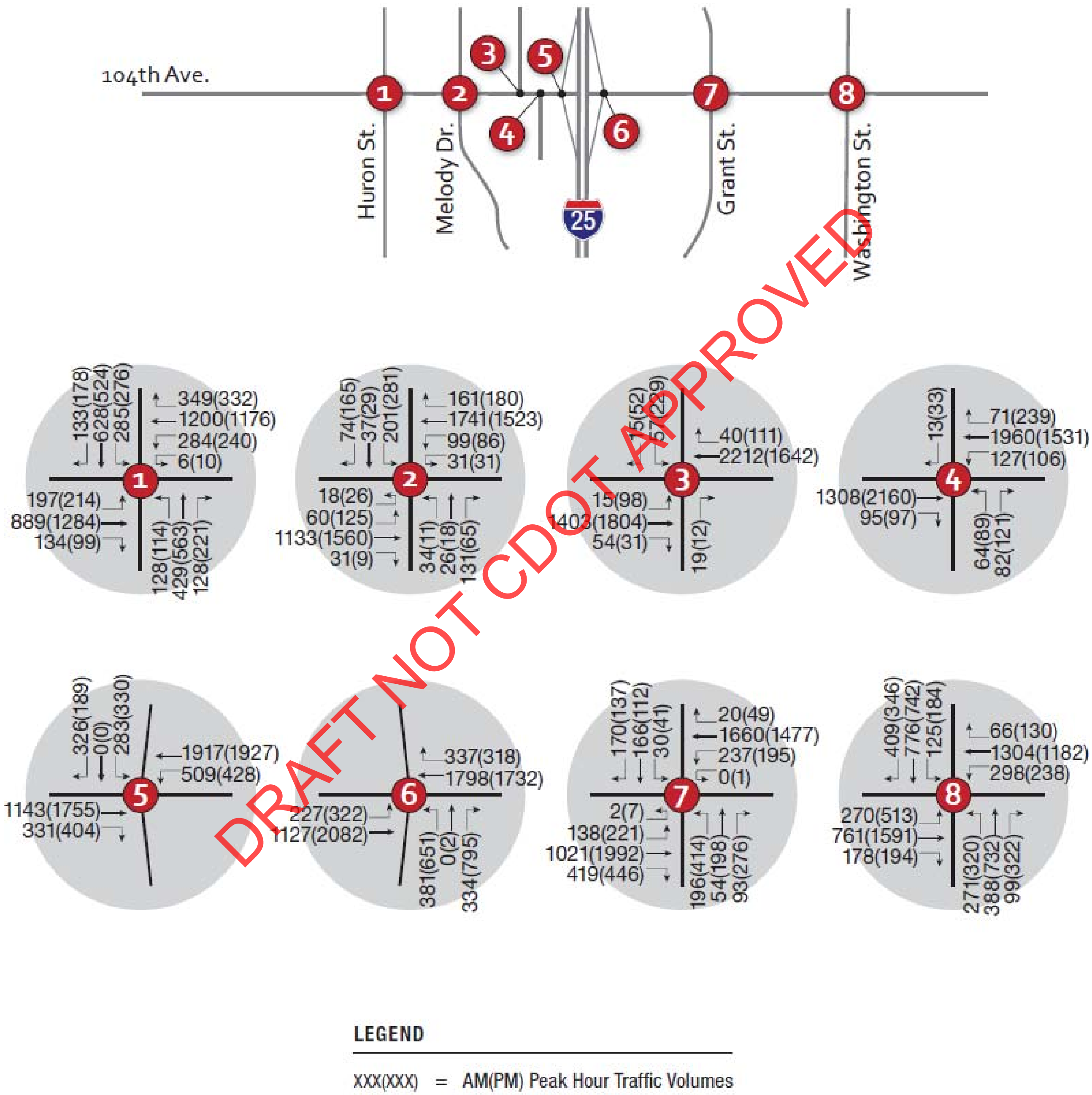


Figure 36. Raw AM and PM Peak Hour Traffic Counts – Thornton Parkway / 84th Avenue

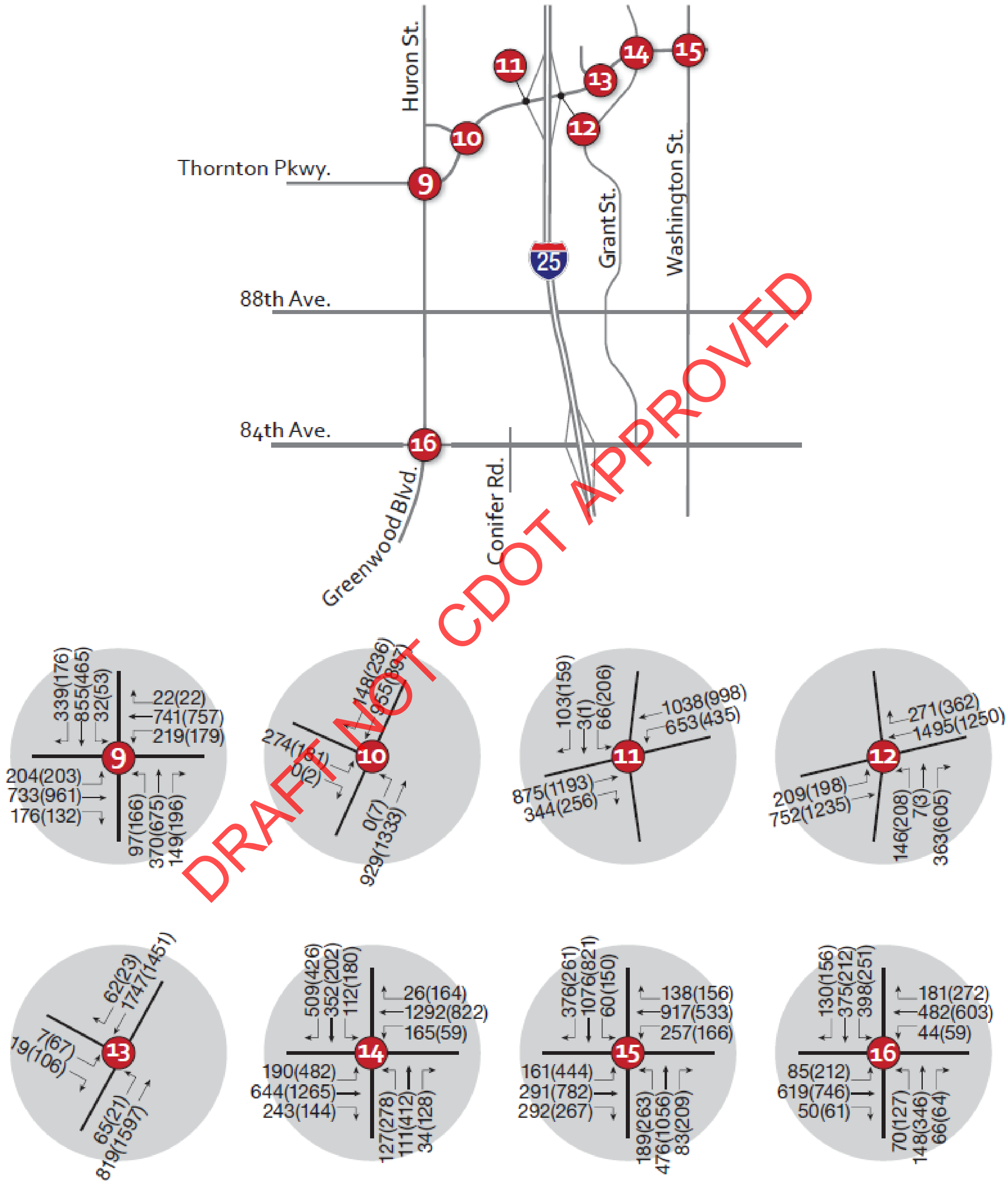
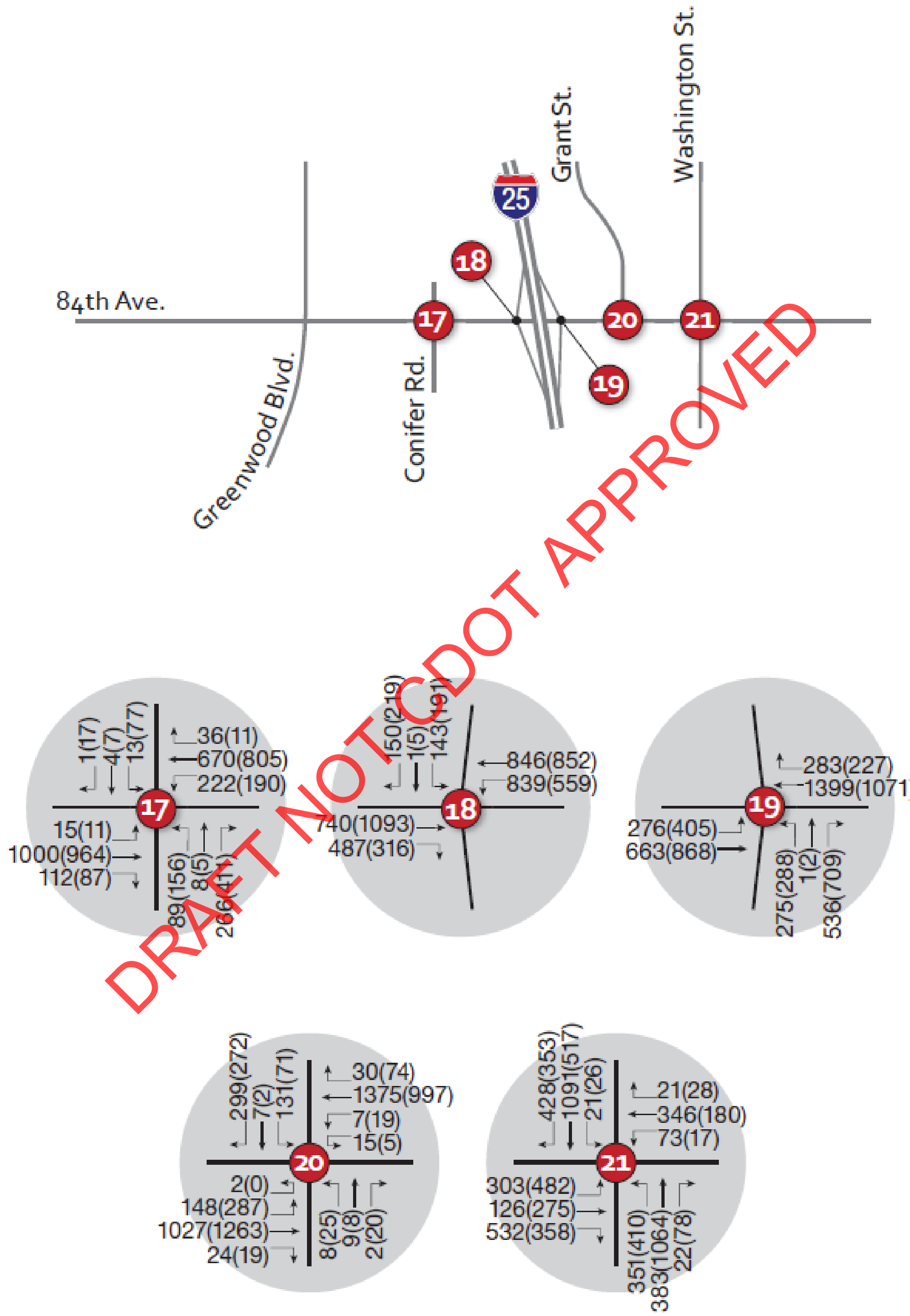


Figure 37. Raw AM and PM Peak Hour Traffic Counts – 84th Avenue



FELSBURG HOLT & ULLEVIG

connecting and enhancing communities

September 25, 2017

MEMORANDUM

To: Stephanie Alanis, PE
Andy Stratton, PE

From: Jeanne Sharps, PE
Steven Marfitano, PE
Rachel Ackermann, EI

Re: I-25 North, US 36 to SH 7 – TransModeler Calibration Memo
CDOT Project No. NHPP 0253-250 (21180)
FHU Reference No. 115-388-01

DRAFT NOT CDOT APPROVED

BACKGROUND & PURPOSE

This technical memorandum documents the TransModeler microsimulation model development and calibration process to evaluate proposed improvements on Interstate 25 (I-25) between US 36 and Thornton Parkway (Segment 1). The memorandum builds upon two prior companion memorandums:

- *I-25 North, US 36 to SH 7 – Methods and Assumptions Technical Memorandum (Methods and Assumptions Memo)* dated June 8, 2017. This methods and assumptions document describes the process for the technical analysis of improvements to Interstate 25 (I-25) between US Highway 36 (US 36) and State Highway 7 (SH 7).
- *I-25 North, US 36 to SH 7 – Data Collection Technical Memorandum (Data Collection Memo)* dated June 8, 2017: This technical memorandum documents the TransModeler data collection efforts to support development and calibration of the TransModeler model for the evaluation of proposed improvements.

The *FHWA Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software (FHWA Toolbox)* has been used as a reference for development and calibration of the TransModeler models.

AM and PM peak hour microsimulation models have been developed and calibrated to reflect existing traffic conditions and travel patterns indicative of a typical, incident-free weekday.

The goal of this calibration effort is to demonstrate that the existing AM and PM peak hour models reasonably and accurately reproduce local traffic conditions. The calibrated existing conditions models will subsequently be used to develop and evaluate the 2040 No Action and 2040 build conditions for use in the environmental clearance and engineering design processes.

TRAFFIC COUNT POST-PROCESSING ADJUSTMENTS & VALIDATION

As summarized in the *Data Collection Memo,* field observations and data collection did not yield a single 24-hour incident free period. Thursday, May 4, 2017, was selected as the data collection day most representative of typical, incident-free conditions. However, there was a minor incident observed on southbound I-25 during the AM peak period.

The raw data provided from the All Traffic Data (ATD) short duration traffic counting devices and the continuous count data available through CDOT's COGNOS system provided an abundance of data requiring reconciliation and validation.

The objectives for the traffic count post-processing adjustments were:

1. **Reconcile variation between multiple data sources.** There are limitations to the accuracy and validity of all traffic counting devices and discrepancies between devices are expected. The variations between data sources can be attributed to several factors. Microwave sensors (such as the Remote Traffic Microwave Sensor [RTMS] devices on the COGNOS system) and video recording devices (such as those used by ATD) have noted inconsistencies in sensing vehicles in the "shadow" of a larger vehicle. Furthermore, if the two devices are calibrated to different clocks reporting different time-periods as the same period, there is potential for variation in the 15-minute volumes.
2. **Provide a balanced network with an internally consistent set of volumes for every link and node.** All count programs resulted in unbalanced totals for traffic counts at two or more nearby adjacent locations. Unbalanced corridors can be a result of counting errors, unsynchronized counting devices, major traffic sources (or sinks) between the two locations, or queuing between the two locations. In the case of the freeway volumes, the discrepancy between the total traffic volumes entering the freeway and the total exiting vehicles may also be caused by storage or discharge of some of the vehicles in growing or shrinking queues on the freeway.
3. **Identify a traffic volume data set representative of typical weekday, incident free conditions.**

This section describes the steps followed to complete the traffic count post-processing adjustments and validation.

Step 1: East-West Arterial Balancing

ATD provided intersection turning movement counts. No continuous count data on the east-west arterials were available for comparison. The field observation and data collection team observed no incidents during the peak periods on the study area east-west arterial system. Therefore, it was assumed that the turning-movement count data are representative of a typical incident-free weekday.

The intersection counts have been adjusted to produce an internally consistent set of volumes for every link and node in the model. Because the count program did not include unsignalized intersections or accesses between signalized intersections, source/sink nodes have been added between signalized intersections where necessary to achieve a balanced network.

Where both data sources were available, ATD turning movement count data were compared to COGNOS ramp meter data for validation of peak hour volumes at ramp meter terminals.

Step 2: Reconciliation of I-25 Mainline Traffic Counts Data Sources

As previously mentioned, variation between ATD and COGNOS data collection devices at similar locations was anticipated.

As described in the *Data Collection Memo*, the COGNOS data were used to evaluate the expected variation in traffic volumes on a typical day. The raw traffic counts collected on the selected design day (May 4, 2017) were compared to the typical day graphs produced in the *Data Collection Memo* to validate mainline I-25 traffic volumes.

Step 3: Traffic Volume Adjustments – Accounting for the AM Peak Period Incident

A comparison of the total volumes processed during the AM peak period (6:00 AM to 9:00 AM) indicated that typically 13,850 to 18,500 vehicles are processed through this section of I-25; on average, 16,200 vehicles are processed during the AM peak period. On May 4, 2017, approximately 15,350 vehicles were processed through this section with a noticeable delay to when arriving peak volumes traveled through the study area as a result of the peak hour incident.

The extensive data from COGNOS were used to adjust the count volumes recorded on May 4, 2017, to account for the impacts to traffic volumes from the minor incident on the southbound on-ramp at 84th Avenue. As discussed in the *Data Collection Memo*, the COGNOS data were used to calculate the average traffic volumes observed on incident-free days and the expected variation in typical day 15-minute traffic volumes ± standard deviation). The AM mainline volumes were adjusted and balanced to more closely reflect the typical day volume graphs produced in the *Data Collection Memo.*

Step 4: Understanding the interactions between I-25 General Purpose Lanes and Tolled Express Lanes

The ATD mainline traffic counts did not distinguish between those vehicles traveling in the general purpose (GP) lanes and those travelling in the tolled express (TE) lanes. However, the COGNOS Wavetronix devices do provide lane-by-lane traffic counts and specifically count the number of vehicles traveling in the TE lanes.

Follow-up clarification with CDOT ITS staff indicated that two of the COGNOS Wavetronix devices were not recording all lanes at their location. Extensive review of historical COGNOS data indicated that the devices were recording the TE lane, but were missing a GP lane. Therefore, the TE lane volumes were used in the development of the GP/TE volume splits.

Step 5: Verification of an Internally Consistent Set of Volumes

The efforts of Steps 1 through 4 were compiled and reviewed to produce an internally consistent set of typical day, incident-free volumes for every link and node in the model. The resulting AM and PM peak hour traffic counts are shown on **Figures 1** through **3**. As previously addressed in Step 1, the model includes intermediate intersections/nodes as sinks and sources that are not shown on **Figures 1** through **3**. **Figure 4** illustrates the ramp volumes as well as the mainline GP and TE volumes.

Figure 1. Existing AM and PM Traffic Volumes – 104th Avenue

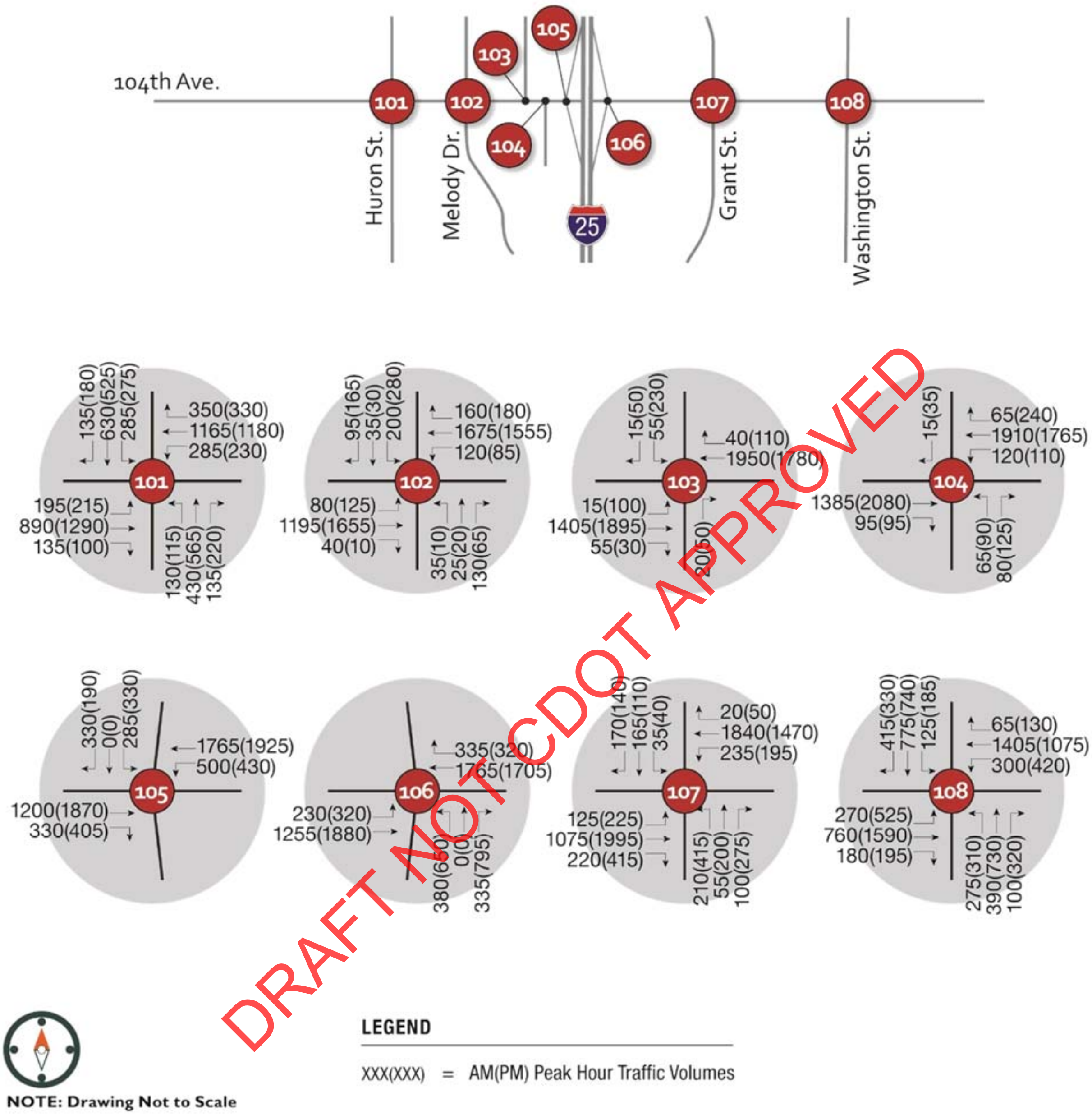


Figure 2. Existing AM and PM Traffic Volumes – Thornton Parkway

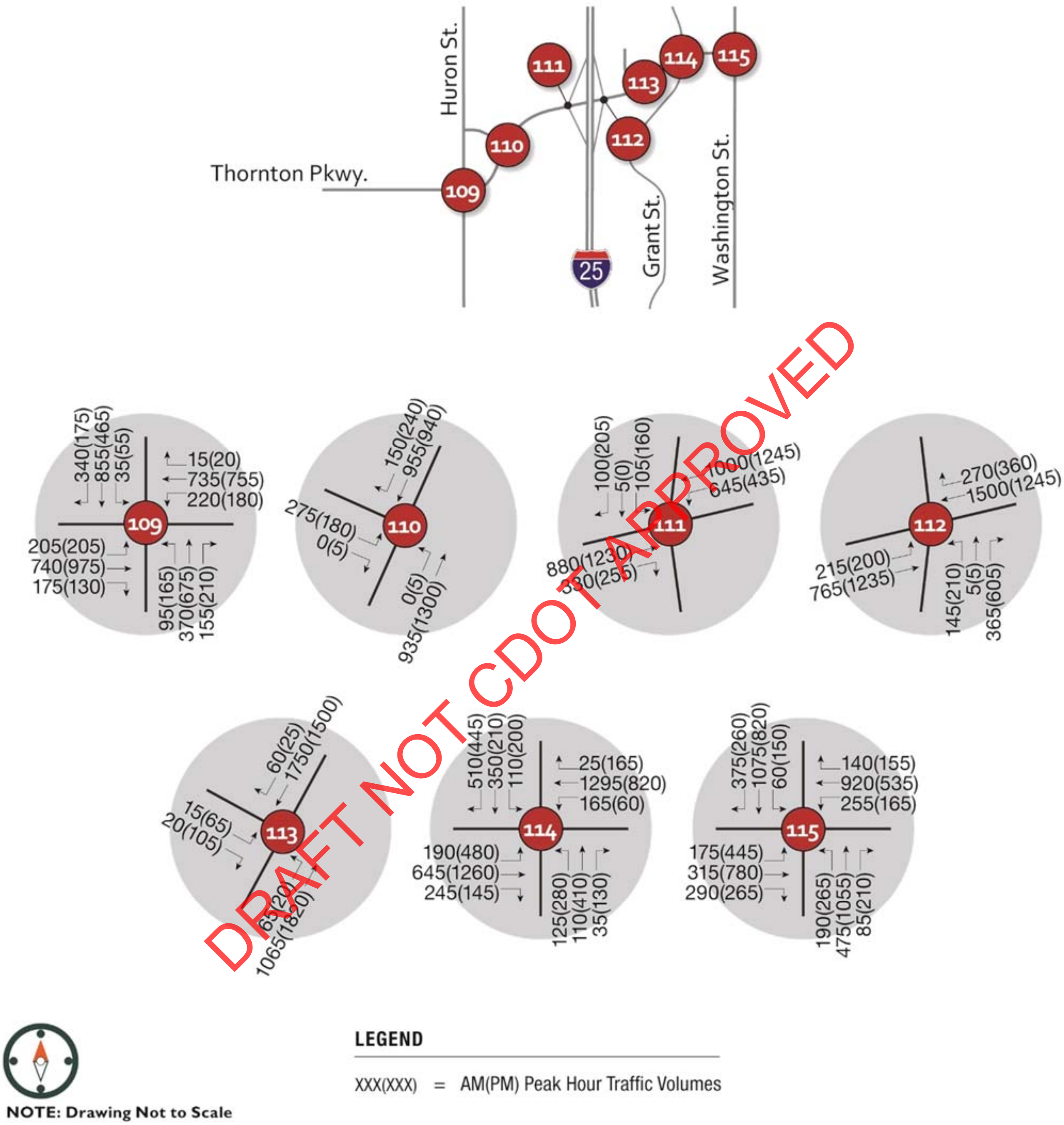


Figure 3. Existing AM and PM Traffic Volumes – 84th Avenue

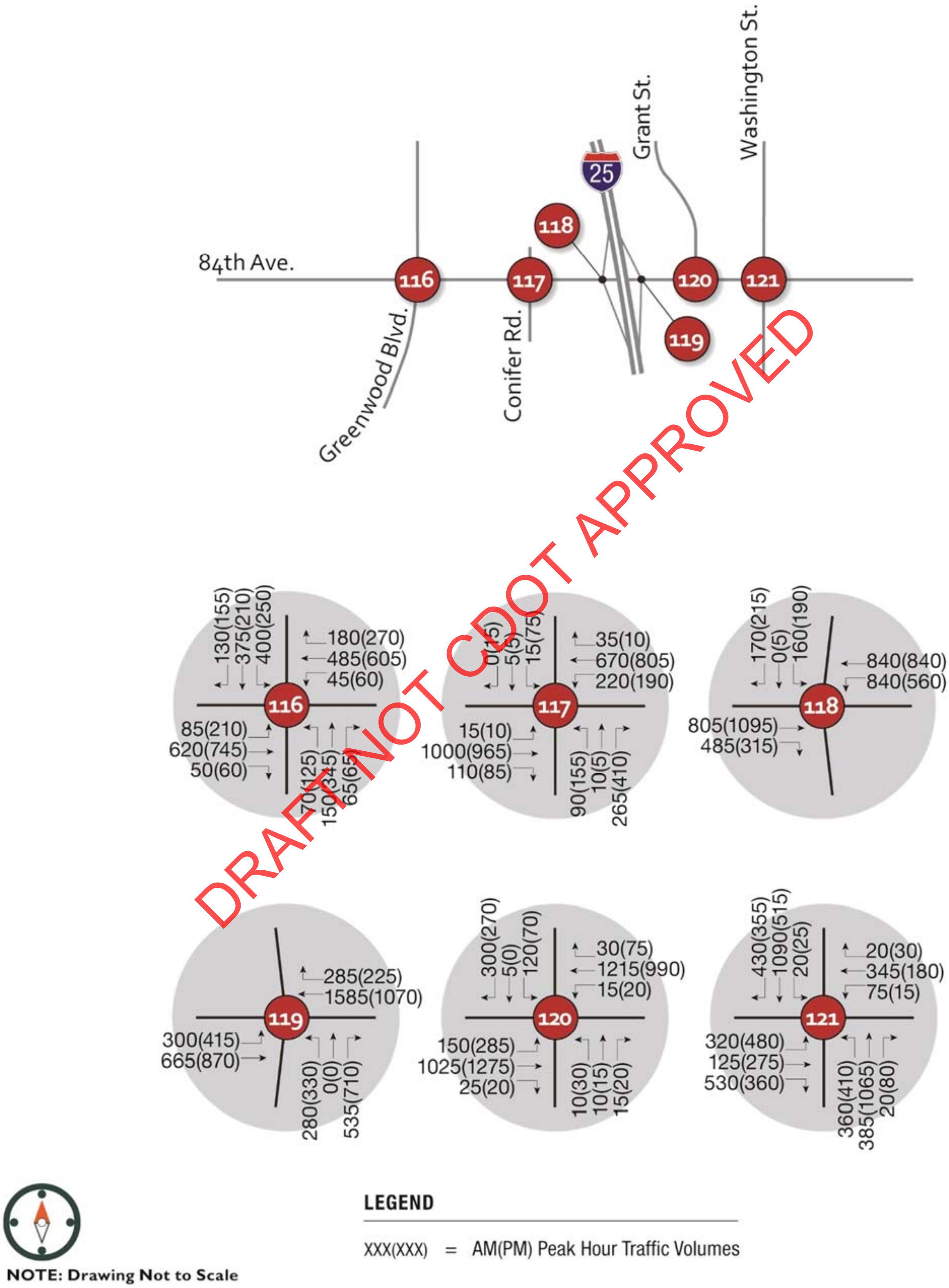
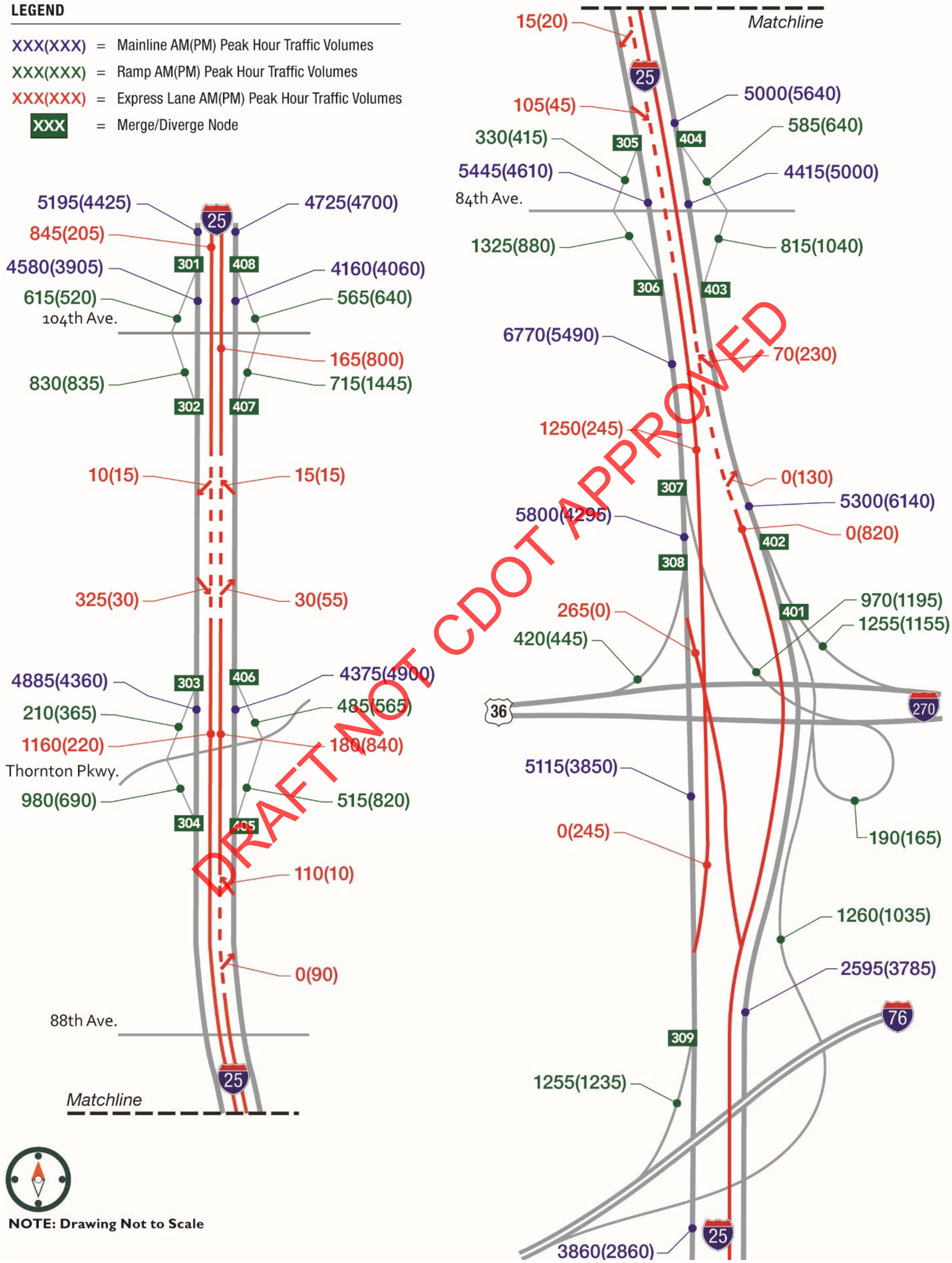


Figure 4. Existing AM and PM Traffic Volumes – Ramps, Mainline GP and TE



MODEL DEVELOPMENT

The *Methods & Assumptions Memo* describes the selection of the model area, consistent with FHWA's simulation guidelines. The study area includes the interchange to the north (104th Avenue) and south (US 36/I-25 and I-76 interchanges; ramps to/from the north) and extends east/west along 104th Avenue, Thornton Parkway and 84th Avenue to the nearest major arterials. **Figure 5** presents the study area.

The TransModeler network was constructed as shown on **Figures 6** and **7**. **Figure 6** illustrates the east/west arterial roadway network and node system and **Figure 7** highlights the interchange network and node system. The number of lanes, location of lane additions and drops, and roadway geometry were coded based on aerial imagery and confirmed by field observations. The model includes additional details such as posted speed limits, ramp meters, and traffic control devices to better reflect field conditions. Existing signal timing information was provided by CDOT, City of Westminster, City of Northglenn, and City of Thornton.

I-25 / US 36 / I-270 / I-76 Interchange Complex

The interchange complex ramps to/from the south were not included in the data collection program and were not included in the model.

An AM peak period bottleneck was identified on southbound I-25, extending north of the I-76 and US 36 southbound on-ramps. Queuing and congested southbound traffic was observed to extend from outside the improvement area (and the study area) north into the study area (as far north as 75th Avenue).

To replicate the congestion occurring at the southern end of the study area, most prominently during the AM peak period, the I-25 southbound roadway geometry has been reduced by one through lane south of the I-25 southbound off-ramp to I-76 in both the AM and PM peak hour model networks to effectively replicate the impacts of the bottleneck and queuing that occurs at this location.

This microsimulation evaluation was designed to validate that operational and safety improvements are anticipated for the acceleration/deceleration lane and additional through lane components of the *North I-25 PEL* Recommended Alternative shown on **Figure 5**. While the proposed improvements are not intended to relieve the congestion at this location, this model modification to replicate this existing bottleneck condition will inform the evaluation of the operational changes that can be associated with the recommended improvements.

Grade & Elevation

TransModeler includes algorithms to model driver behavior and vehicle operations on segments with up- and down-grades. Within the study area, significant grade change occurs along I-25 between US 36 and the 88th Avenue bridge and impacts vehicular acceleration and deceleration. The elevation of the roadways, ramps, and bridge structures were input into the model using the survey data collected in August 2017 by Farnsworth.

Figure 5. Study Area

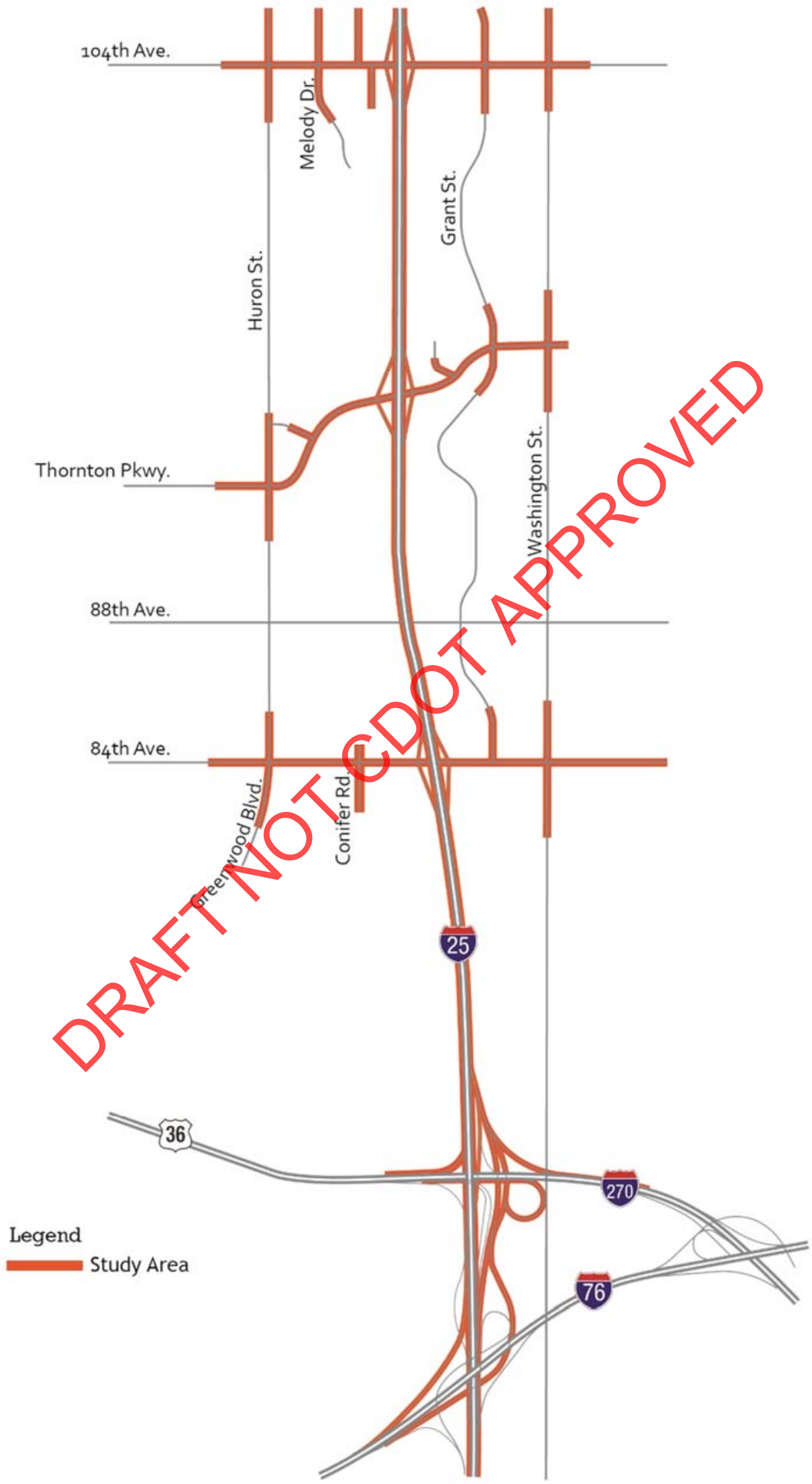


Figure 6. TransModeler Arterial Road Network and Node System

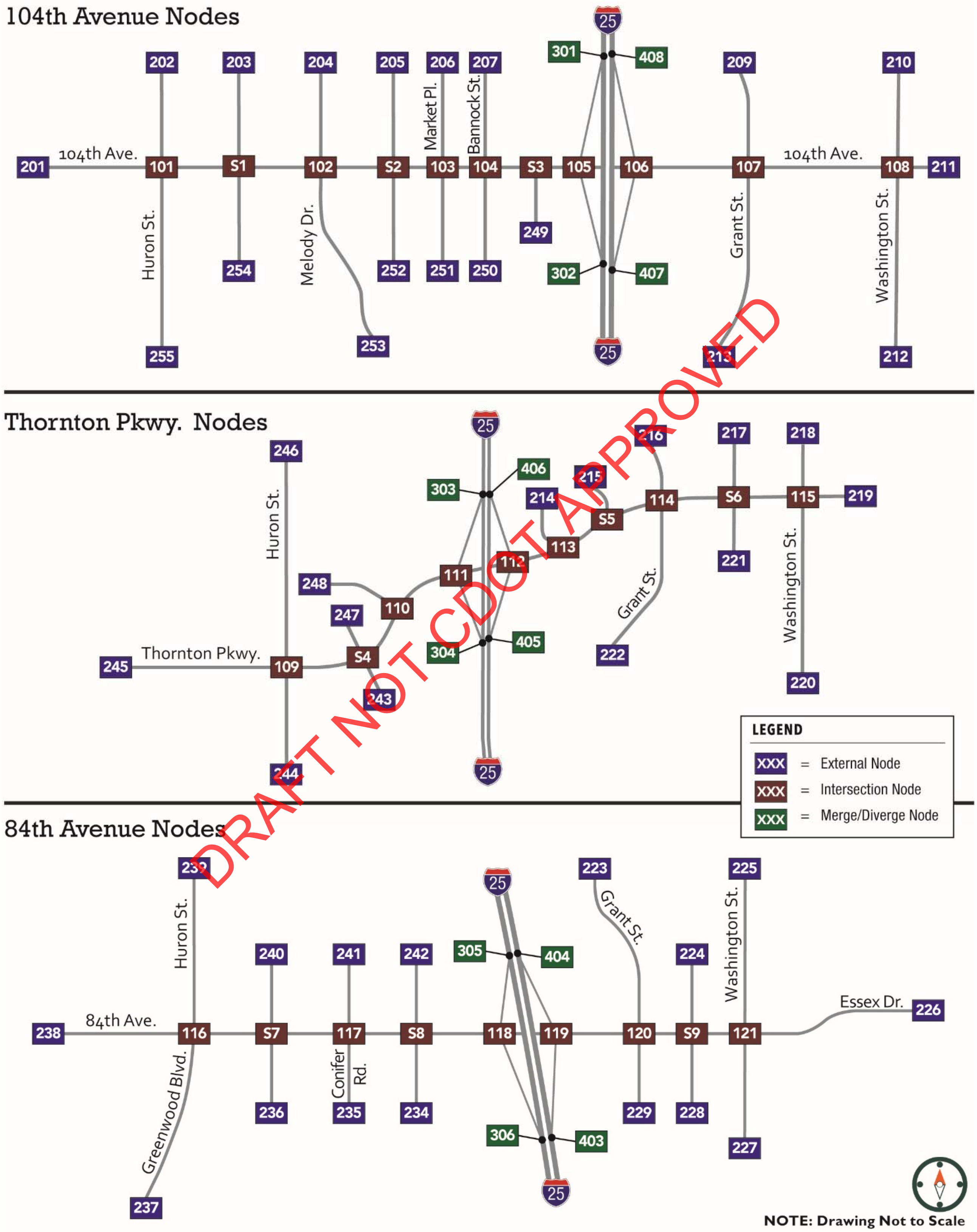
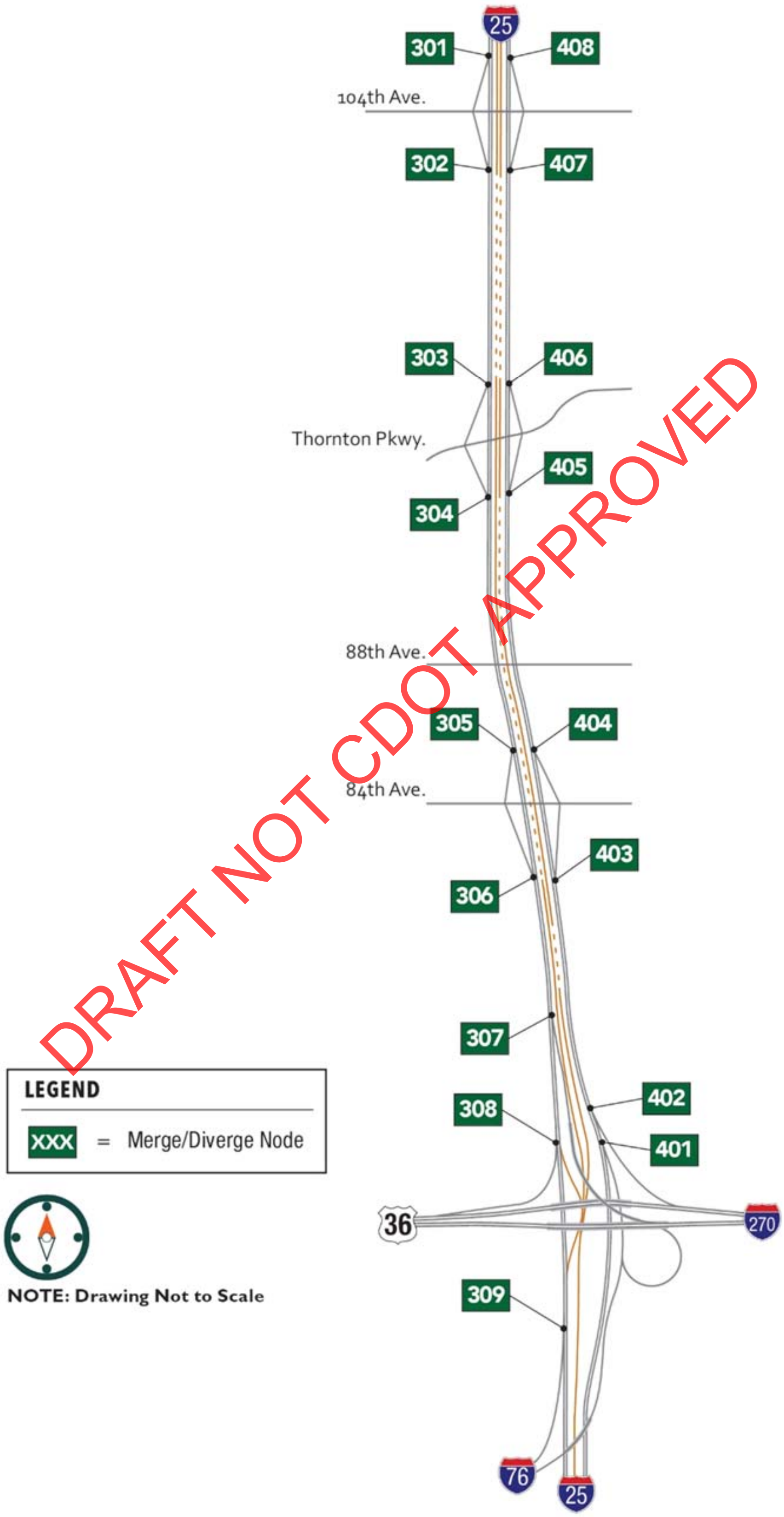


Figure 7. TransModeler Interstate Road Network and Node System



Traffic Coding

Vehicle composition defines the mix of each vehicle type as a relative flow percentage and is another adjustable parameter in TransModeler. As part of the data collection process, a vehicle classification count was recorded in both directions on mainline I-25 at Thornton Parkway.

In TransModeler, default vehicle types can be used to define traffic composition in the network. The default vehicle types include high performance passenger cars, middle performance passenger cars, low performance passenger cars, pickup trucks or utility vehicles, single-unit trucks, and trailer trucks. Adjustments were made to the default vehicle classification tables based on the recorded vehicular splits described below.

The vehicle classification grouped vehicles into the following FHWA vehicle classification types:

- Small: motorcycle; passenger car; and two-axle, 4-tire unit
- Medium: buses; two-axle, 6-tire units; three-axle, single unit; and four or more axle units
- Large: three- or four-axle trailer; five-axle single trailer; six or more axles, single trailer; five or less axles, multi-trailer; seven or more axles, multi-trailer; and six axles, multi-trailer

In the TransModeler model, the vehicles were coded as:

- Small: high-performance passenger cars, middle performance passenger cars, low performance passenger cars, pickup trucks, or utility vehicles.
- Medium: single-unit trucks
- Large: trailer trucks

Table 1 summarizes the vehicle classification count percentages for the AM and PM peak hours.

Table 1. Vehicle Classification on I-25 at Thornton Parkway

	Small	Medium	Large
AM Peak Hour	89.2%	5.7%	5.1%
PM Peak Hour	96.1%	2.1&	1.8%

Driver Behavior

Driver behavior models inform the more detailed actions that a driver takes in response to local conditions, including traffic conditions, traffic signals, signs, and incidents. These models simulate acceleration, lane changing, gap acceptance, merge, and yielding driver behavior.

The default driver behavior parameters included in TransModeler were retained following visual inspection of acceptable driving behavior and confirmed reasonable model performance.

Ramp Meters

In the TransModeler model, ramp meters can be programmed with the following control options:

- Fixed cycle, pretimed
- Fixed cycle, actuated
- Local feedback, closed loop

For this project, the ramp meters were programmed using local feedback, closed-loop control with simultaneous platoon release to simulate the “one vehicle per green” condition. Measurement detectors were programmed to monitor the occupancy on I-25, check-in detectors were added to indicate the presence of vehicles waiting at the ramp meter, and queue detectors were placed upstream of the entrance ramp to monitor queue length on the ramp.

While the ramp meters operating within the study area operate with slightly different parameters, the following ramp meter parameters are considered global parameters in TransModeler:

- Minimum green time
- Minimum red time
- Maximum red time
- Queue occupancy
- Minimum release metering rate
- Maximum metering rate

Each individual ramp meter in TransModeler can be programmed with the following parameters:

- Target Occupancy
- Regulator
- Cycle Length

Discussions with Caliper, the TransModeler software developer, indicated that the limitations of the current ramp metering parameters will be addressed in later versions of the software.

Ramp meter global parameters were adjusted to achieve the highest possible level of calibration for travel time routes impacted by the ramp meters.

Traffic Assignment & Routing

Estimating origin-destination (O-D) trip matrices is often the most difficult step of any traffic simulation project. The TransModeler O-D Matrix Estimation (ODME) tool was used to produce an O-D matrix consistent with observed traffic counts by matching link volumes and turning movement volumes.

In addition to the traffic count information, the ODME process also requires a base O-D matrix, which serves two purposes: (1) to set the dimensions for the output matrix and (2) to provide initial values for the estimated trip table. The base O-D matrix was developed using the external nodes (shown on **Figures 6** and **7**) as the origins and destinations. Per guidance from the Caliper TransModeler manual, the base O-D matrix was constructed with a small positive value (e.g., 0.1 or 0.01) for every O-D pair expected to have a positive flow in the estimated matrix.

The ODME procedure in TransModeler uses an independently developed procedure that is consistent with the procedure for TransCAD 2.1. The ODME process was run using the User Equilibrium traffic assignment. User Equilibrium uses an iterative process to achieve a convergent solution, in which no travelers can improve their travel times by shifting routes. In each iteration, TransModeler computes network link flows to match turning movement counts at nodes and link counts while also incorporating link capacity restraint effects and flow dependent travel times.

The DRCOG travel demand model uses a user equilibrium (UE) traffic assignment technique to compute network link flows and path choice. The UE traffic assignment determines path cost as a function of travel time and incorporates tolls where present. The process is said to converge when no traveler can improve their travel times by shifting routes.

While TransModeler also includes a UE dynamic traffic assignment route choice model, the TransCAD regional travel demand model provides regional context for route choice, whereas the TransModeler model is limited to the study area extents.

The TransCAD model was used to provide a larger view of the regional travel patterns with consideration to parallel travel routes and the entire regional network. Future ODs will also be identified using the 2040 regional TransCAD model. As a result, the dynamic assignment tool included in the TransModeler software was not used for this calibration nor will be used for future evaluation and parallel routes have been excluded from the TransModeler model.

Therefore, the selected study area network includes one reasonable route for each O-D pair; O-D pairs identified during the ODME process, and refined using existing traffic counts were used to determine traffic assignment and routing.

Future turning movement projections will be identified using the 2040 regional TransCAD model and will inform projected. As a result, the dynamic assignment tool included in the TransModeler will not be needed for this calibration nor future evaluation.

CALIBRATION STRATEGY

Calibration Objective: To obtain the best match possible between model performance estimates and field measurements of performance.

It should be noted that there are no universally accepted procedures for conducting calibration and validation for complex transportation networks. Calibration targets are developed based on the minimum performance requirements for the microsimulation model, taking into consideration the available resources. The *FHWA Toolbox* provides guidance for system performance calibration.

RANDOM SEED VARIATIONS & MODEL INITIALIZATION

The first step in the calibration process was to conduct a visual inspection of the animation of the simulated environment to ensure that all traffic components were operating properly. Model parameters were adjusted to produce realistic network operations.

Microsimulation models assign driver-vehicle characteristics from statistical distributions; changing the random number seed produces a different sequence of random numbers to assign these characteristics. The random seed affects the realization of the stochastic quantities in TransModeler, such as inlet flows and vehicle capabilities. Once a visually calibrated model was established, the calibrated parameter set was run with at least five different random seeds to provide a reasonable level of statistical accuracy and validity. For congested corridors, at least five different seeded runs are generally recommended.

The results presented herein were based on an average of five different random seed simulations. The simulation was programmed to execute a preload simulation to achieve an acceptable initial condition in the simulation network. The initial state acceptance criteria include two pairs of thresholds: (1) the percent difference in number of vehicles and (2) the absolute number of vehicles in the network. The following default parameters were used:

- 1-Interval Threshold: less than 8 percent (relative) or less than 5 vehicles (absolute)
- 2-Interval Threshold: less than 12 percent (relative) or less than 10 vehicles (absolute)

The preload evaluation interval was set to the default 60 seconds; TransModeler compares the number of vehicles in the network at the time of the evaluation with the number in the network 60 seconds earlier and 120 seconds earlier. The preloaded runs until a steady state is reached; at which time TransModeler saves the state of the network as an initial state file, stops the preload simulation, and begins the recorded simulation from the saved initial state.

MODEL CALIBRATION

To calibrate the existing conditions model, model outputs were compared against AM and PM peak hour system performance measures, such as link volumes, travel time, speed and queues, as observed and recorded as part of the data collection effort.

Calibration Goals

The calibration goals for this project included:

- Goal 1: Qualitative match of locations of persistent queuing and recurring bottlenecks
- Goal 2: Model link vs. observed flows to meet the following criteria:
    - Within 100 vehicles per hour (vph) for volumes less than 700 vph
    - Within 15 percent for volumes between 700 and 2700 vph
    - Within 400 vph for volumes greater than 2700 vph
    - Sum of all link flows to be within 5 percent
    - GEH[1] Statistic should be < 5 for individual link flows in more than 85 percent of cases
    - GEH Statistic should be < 4 for the sum of all link counts
- Goal 3: Model Link vs. Observed Travel Time meets the following criteria:
    - Travel times to be within 15 percent (or one minute, if higher) for greater than 85 percent of cases for the selected segments

CALIBRATION RESULTS

GOAL 1: Persistent Queuing and Recurring Bottlenecks

Per *FHWA Traffic Analysis Toolbox* guidance, ramp terminal intersections with approach legs that have queues of at least 10 vehicles have been identified:

- Southbound 104th Avenue on-ramp (AM)
- Southbound Thornton Parkway on-ramp (AM)
- Northbound 84th Avenue on-ramp (PM)

Bottlenecks were also noted during field observations. Locations of persistent bottlenecks were identified at the following locations:

- Southbound between the ramp terminals at Thornton Parkway (AM)
- Southbound near the US 36 Interchange (AM)
- Northbound near the I-270 and US 36/I-76 on-ramps (PM)

---

[1] The GEH Statistic is a formula that was developed by Geoffry E. Havers and is used to compare two sets of traffic volumes.

Queuing observed at the on-ramps during the AM and PM peak periods is the result of the ramp metering in place at the 84th Avenue, Thornton Parkway and 104th Avenue on-ramps. CDOT provided the ramp metering plans. During the data collection period, the 84th Avenue southbound on-ramp meter was not in service during the AM peak period.

Ramp metering has been implemented in the model with the ramp metering parameters provided for:

- 104th Avenue SB on-ramp (AM/PM)
- Thornton Parkway SB on-ramp (AM/PM)
- 84th Avenue SB on-ramp (PM only)
- Thornton Parkway NB on-ramp (AM/PM)
- 84th Avenue NB on-ramp (AM/PM)

Global ramp meter parameters were adjusted to reflect field observations at as many ramp meter locations as possible. As a result, model queues were observed to be shorter or longer at some locations than field observations indicated. Once the travel time runs from the arterial roadways to I-25 were found to be within the acceptable calibration range, the global ramp meter parameters to the model network were deemed calibrated to existing conditions.

All identified queue and bottleneck locations were visually inspected by comparing field observations to simulated conditions. Model queues were observed to reasonably reflect field observations.

GOAL 2: Model Link vs. Observed Flows

The *FHWA Traffic Analysis Toolbox* provides calibration targets for individual link flows (model versus observed) that are based on calibration targets developed by Wisconsin DOT. According to these criteria, individual link flows, modeled versus observed, should have a calibration acceptance target of more than 85 percent of cases and meet the following criteria:

- Within 100 vph for volumes less than 700 vph
- Within 15 percent for volumes between 700 and 2700 vph
- Within 400 vph for volumes greater than 2700 vph
- Sum of all link flows should be within 5 percent

The TransModeler batch simulation outputs include recorded turning movement volumes. The average recorded turning movement counts were compared to the existing typical day turning movement counts, shown on **Figures 1** through **4,** to determine link volumes concurrence.

The GEH Statistic is a formula that was developed by Geoffry E. Havers and is used to compare two sets of traffic volumes. While mathematically similar to the Chi-Squared statistical test, the GEH formula is not a true statistical test. For traffic modeling work, a GEH of less than 5.0 is considered a good match between modeled and observed hourly volumes. If the GEH is greater than 19, there is a high probability that there is a problem either with the travel demand model or the input data.

The GEH statistic is calculated using the following equation: $GEH = \sqrt{(E-V)^2 / (E+V)/2}$

where *E* represents the model estimated volume and *V* represents the field recorded volume. The calibration targets for the GEH statistic are as follows:

- GEH Statistic should be < 5 for individual link flows in more than 85 percent of cases
- GEH Statistic should be < 4 for the sum of all link counts

Table 2 summarizes volume thresholds and turning movement model results and provides a comparison of modeled and observed volumes using the GEH statistic, a modified Chi-Squared statistic.

Table 2. Link Volume Calibration Validation Criteria and Results

Criteria	Criteria Threshold	% Met Target	AM Peak Hour		PM Peak Hour	
			% Met	Pass/Fail	% Met	Pass/Fail
Individual Link Volumes						
< 700 vph	100 vph	> 85%	100%	Pass	100%	Pass
Between 700 and 2,700 vph	15 %	> 85%	100%	Pass	100%	Pass
> 2,700 vph	400 vph	> 85%	100%	Pass	100%	Pass
GEH Statistic	5	> 85%	100%	Pass	100%	Pass
Sum of Link Volumes						
Sum of All Links	5%	-	-	Pass	-	Pass
GEH Statistic	< 4	-	-	Pass	-	Pass

Figure 8 through **Figure 13** graphically illustrate the modeled versus observed link volumes for the various volume calibration thresholds.

Figure 8. Calibration Targets for Link Volumes < 700 VPH – AM Peak Period

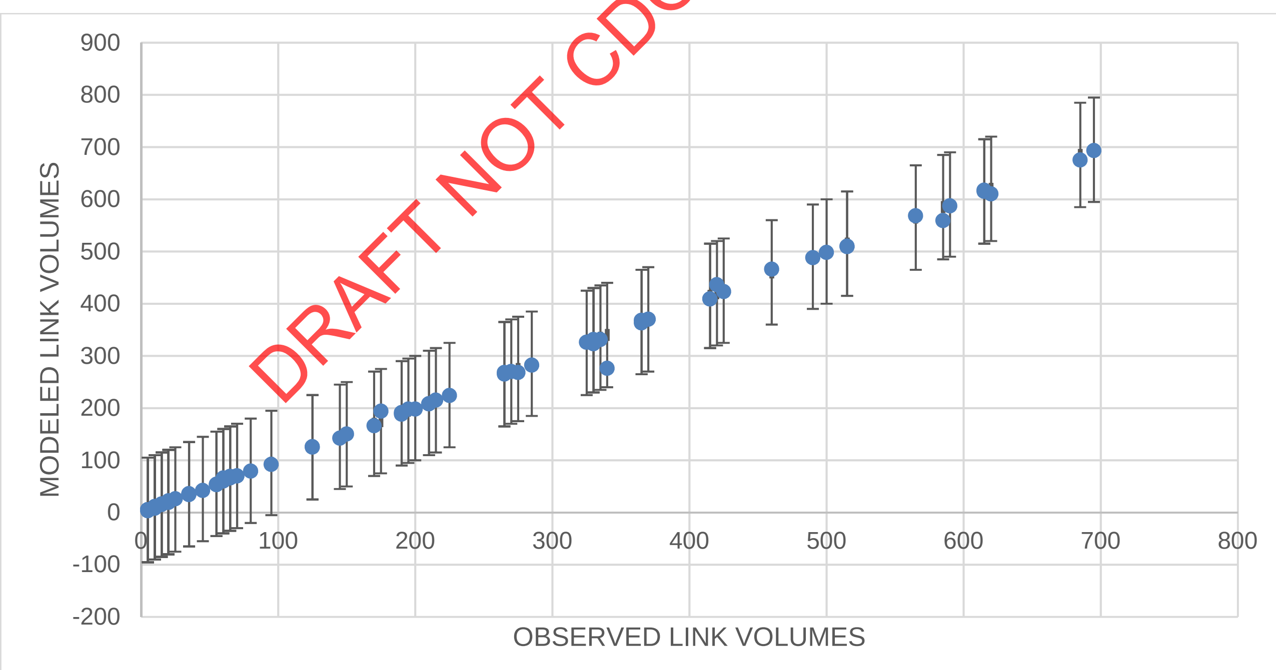


Figure 9. Calibration Targets for Link Volumes between 700 and 2700 VPH – AM Peak Period

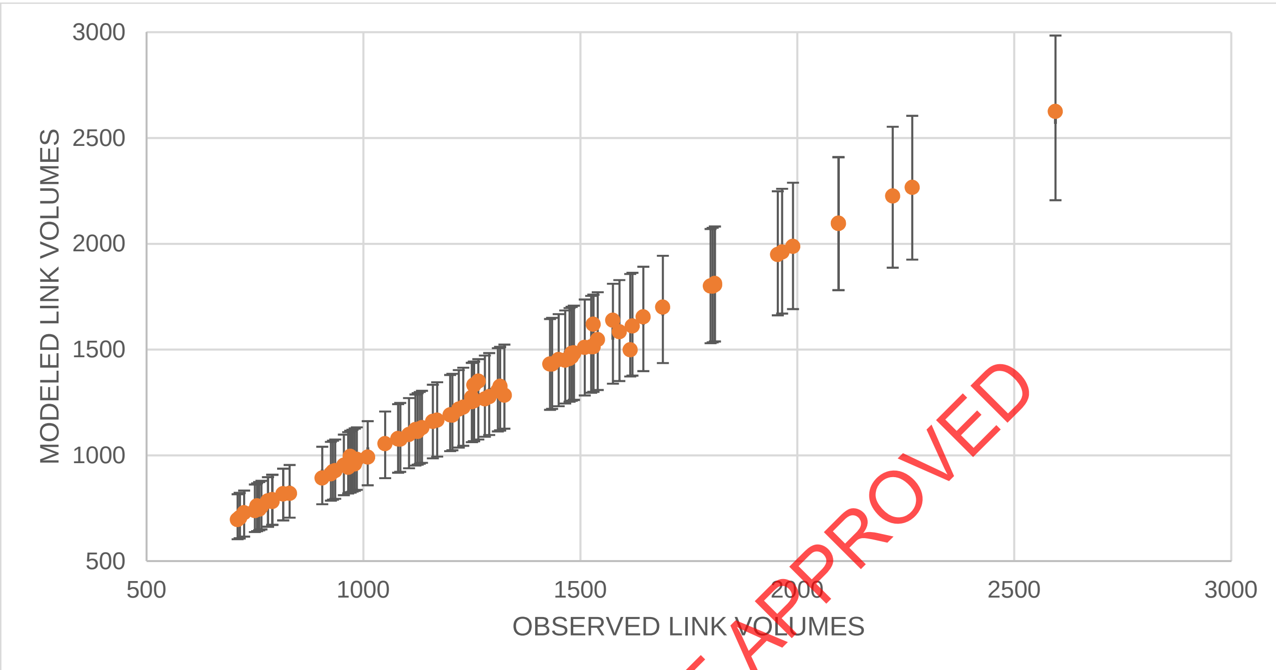


Figure 10. Calibration Targets for Link Volumes > 2700 VPH – AM Peak Period

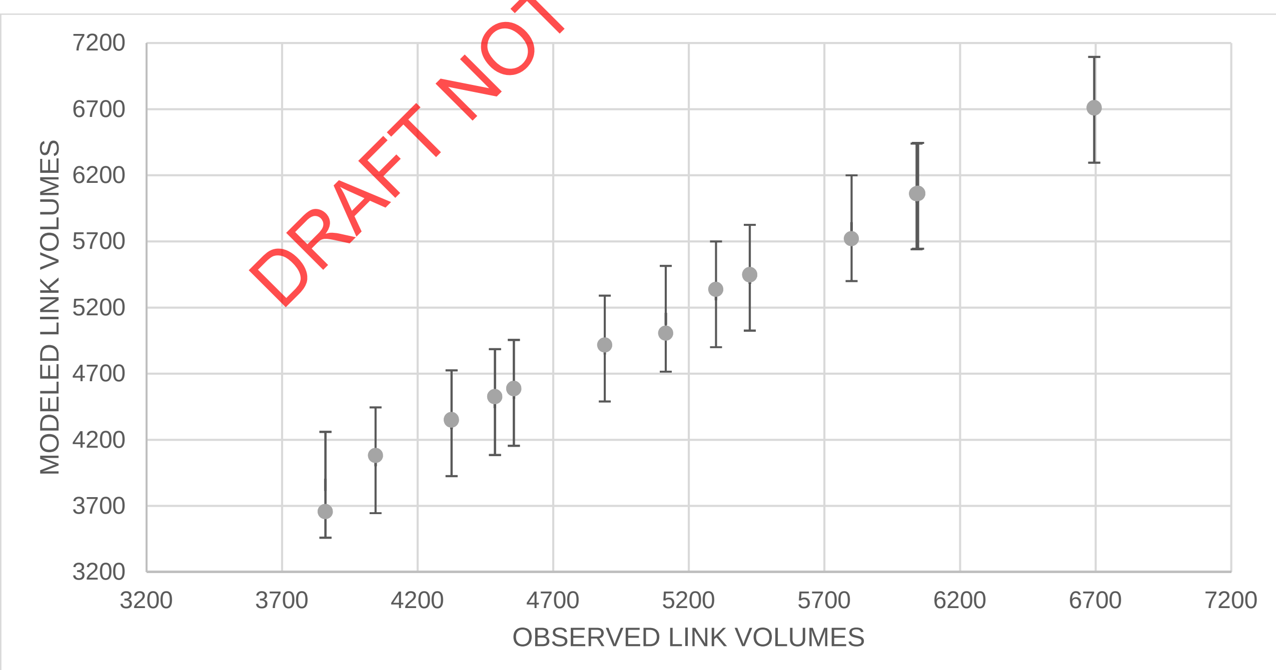


Figure 11. Calibration Targets for Link Volumes < 700 VPH – PM Peak Period

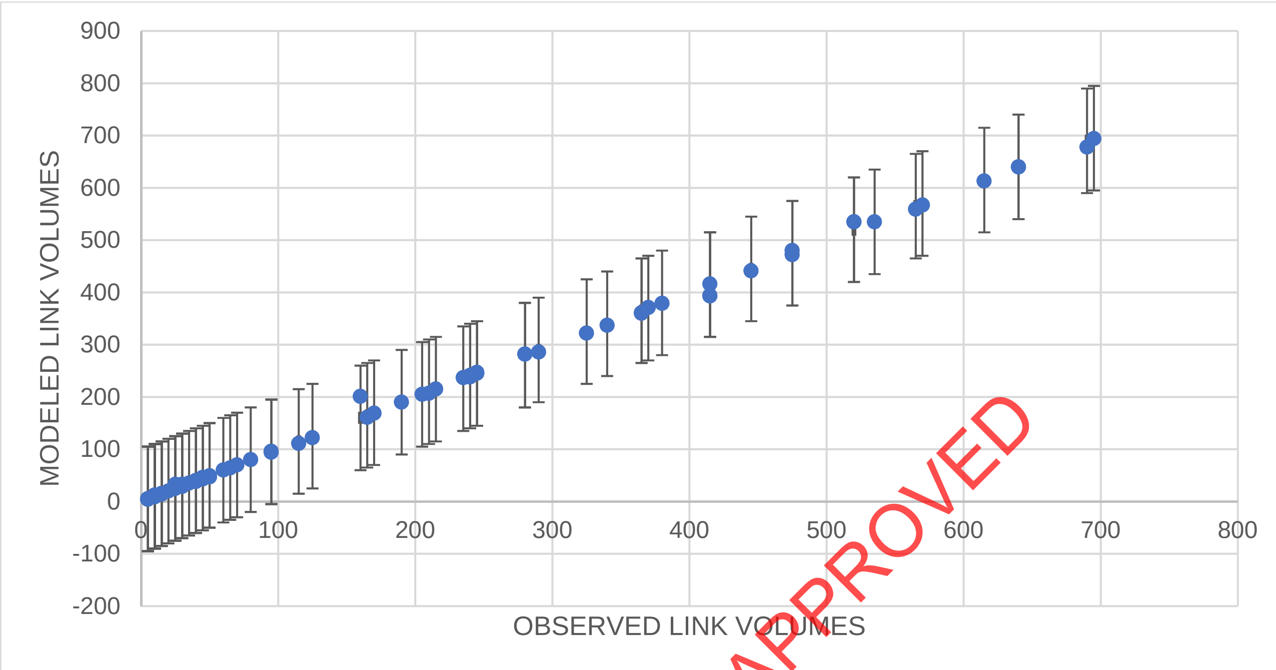


Figure 12. Calibration Targets for Link Volumes between 700 and 2700 VPH – PM Peak Period

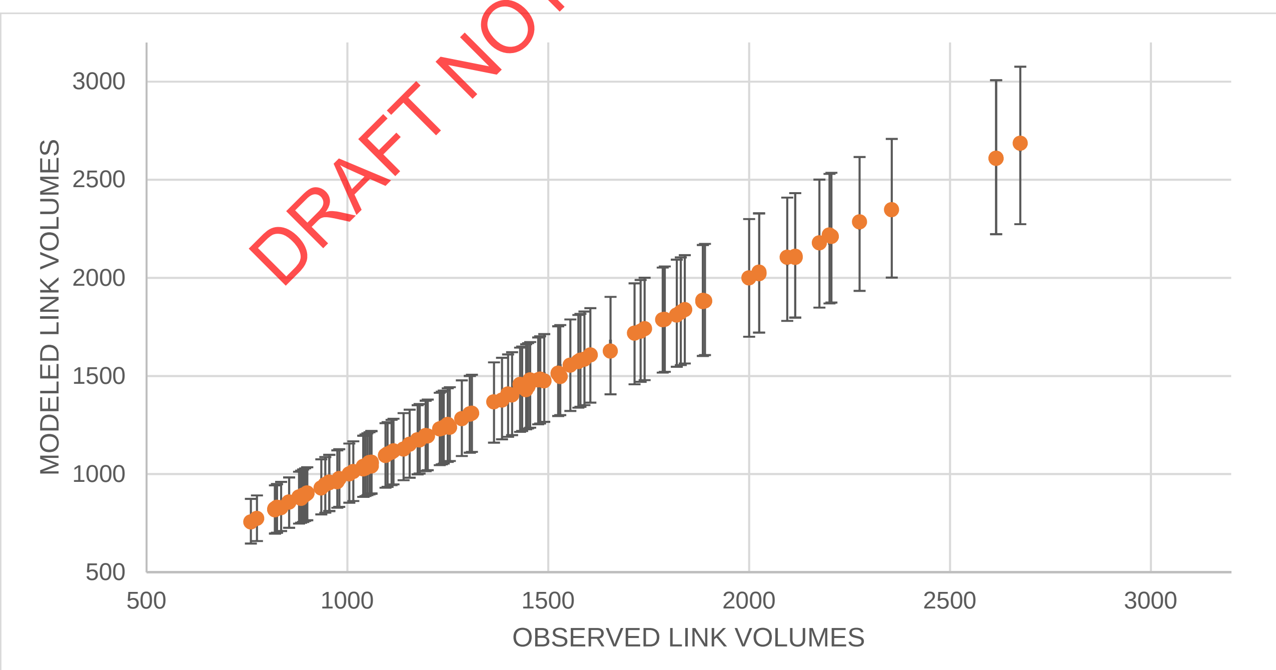
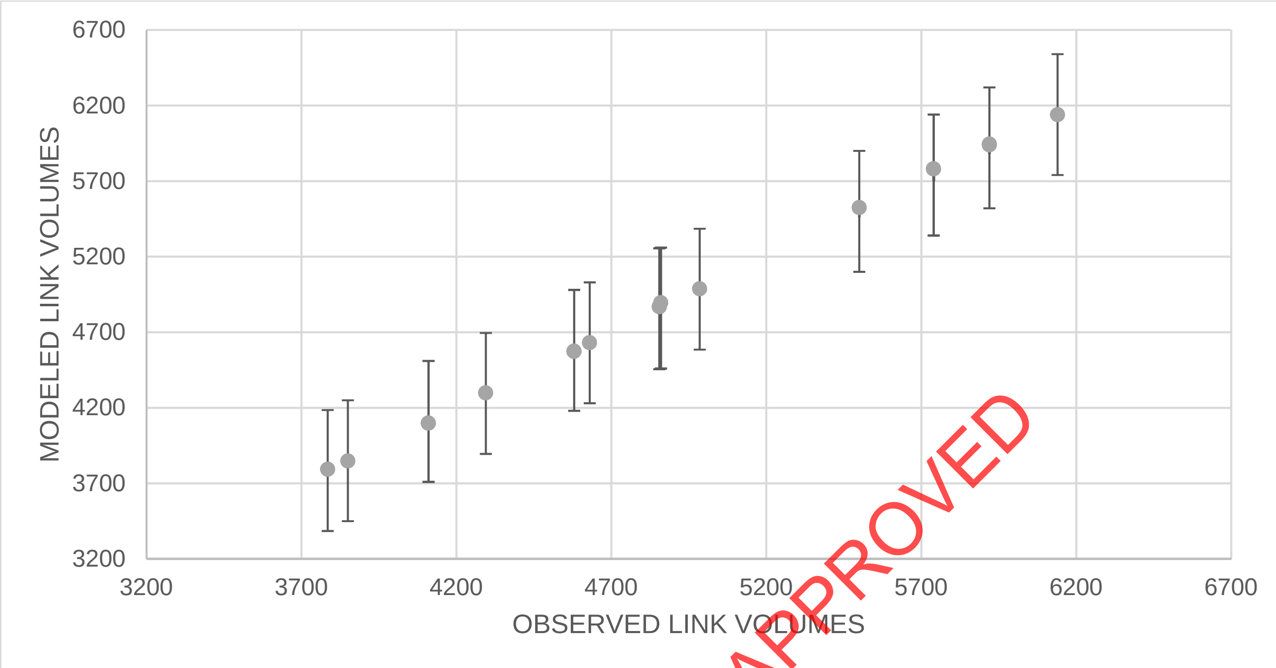


Figure 13. Calibration Targets for Link Volumes > 2700 VPH – PM Peak Period



As shown, the AM and PM peak hour TransModeler models have been calibrated to the established calibration acceptance targets for all link volumes.

GOAL 3: Travel Times

Travel times and speeds were recorded using GPS monitoring during the floating car travel time runs. Travel times from floating car runs conducted during the data collection process were used to calculate average travel times within the study area. AM and PM peak period floating car travel time runs were recorded for different routes to better understand the predominant freeway movements for the peak period.

The *Data Collection Memo* summarizes the results of all floating travel time runs recorded between the identified AM and PM peak periods; only incident-free travel time runs were reported.

The minimum number of floating car runs required to determine the mean travel time within a desired 95-percent confidence interval depends on the acceptable width of the interval. For this calibration effort, travel time data were initially evaluated with a confidence interval of ± 10 percent of the mean travel time. Free-flow conditions, such as those frequently observed in the off-peak direction, may require as few as three runs to establish a reliable mean travel time for calibration. During congested conditions and peak direction travel, routes were found to require significantly more runs. The variation in the recorded travel times were calculated to require up to 100 runs to achieve the desired statistical significance. The data collection process for this project occurred over 4 days and included multiple floating car runs. If the sample set for a given travel time route were determined to lack the minimum number of travel time runs to meet the ± 10 percent confidence interval, the route was subsequently evaluated using ± 15 percent and ± 20 percent confidence intervals.

The following AM travel time routes met the minimum run requirements and have been used in the calibration of the existing AM TransModeler model:

- Northbound I-25 between the I-76 bridge and the 84th Avenue interchange (± 10 percent confidence interval)
- Northbound I-25 between the I-76 bridge and the 104th Avenue interchange (± 10 percent confidence interval)
- Northbound I-25 between the 84th Avenue and Thornton Parkway interchanges (± 10 percent confidence interval)
- Eastbound 104th Avenue to southbound I-25 (± 20 percent confidence interval)
- Southbound I-25 to westbound Thornton Parkway (± 10 percent confidence interval)
- Southbound I-25 to westbound 84th Avenue (± 10 percent confidence interval)
- Eastbound 84th Avenue to southbound I-25 (± 15 percent confidence interval)

The following PM travel time routes met the minimum run requirements and have been used in the calibration of the existing PM TransModeler model:

- Northbound I-25 to eastbound 84th Avenue (± 15 percent confidence interval)
- Northbound I-25 to eastbound Thornton Parkway (± 10 percent confidence interval)
- Westbound Thornton Parkway to northbound I-25 (± 10 percent confidence interval)
- Northbound I-25 between the 84th Avenue and Thornton Parkway interchanges (± 20 percent confidence interval)
- Southbound I-25 from Bonita Place to the I-76 Bridge (± 10 percent confidence interval)
- Southbound I-25 between the 104th Avenue and 84th Avenue interchanges

The *FHWA Traffic Analysis Toolbox* provides the calibration target for travel times, model versus observed. Travel times should be within 15 percent (or one minute, if higher) for greater than 85 percent of cases for the selected segments. Modeled versus observed travel times are compared on **Table 3**.

Table 3. Travel Time Comparison – Model vs. Observed

Route	Travel Time (min)							
	AM Peak Hour				PM Peak Hour			
	Model	Obs.	Δ	Pass/Fail	Model	Obs.	Δ	Pass/Fail
NB I-25 I-76 to 84th Ave	2.74	2.32	0.42	Pass				
NB I-25 I-76 to 104th Ave	4.24	5.20	(0.96)	Pass				
NB I-25 84th Ave to Thornton Pkwy	1.52	1.35	0.17	Pass	1.59	1.63	(0.04)	Pass
EB 104th Ave to SB I-25	2.91	4.19	(1.28)	Fail				
SB I-25 to WB Thornton Pkwy	1.49	1.86	(0.37)	Pass				
SB I-25 to WB 84th Ave	1.48	1.65	(0.17)	Pass				
EB 84th Ave to SB I-25	5.32	6.05	(0.73)	Pass				
NB I-25 to EB 84th Ave					3.43	4.41	(0.98)	Pass
NB I-25 to EB Thornton Pkwy					1.81	1.67	0.14	Pass
WB Thornton Pkwy to NB I-25					1.89	1.87	0.02	Pass
SB I-25 Bonita Pl to I-76					6.47	5.57	0.90	Pass
SB I-25 104th Ave to 84th Ave					2.74	2.16	0.58	Pass

While the recorded travel times for the eastbound 104th Avenue to southbound I-25 were statistically valid for the ± 20 percent confidence interval, the inability of ramp meter parameters to be adequately replicated in the TransModeler model may be reflected in the failure of the travel time route to meet calibration parameters. In addition, because the extents of the travel time run fall outside the proposed improvement area the project team decided that global ramp parameters had been adequately adjusted to maximize the number of calibrated travel time runs impacted by the ramp meters.

CONCLUSION & NEXT STEPS

Table 4 provides a comparison of the validation criteria and calibration results.

Table 4. Validation Criteria and Calibration Results

Criteria	Criteria Threshold	% Met Target	AM Peak Hour		PM Peak Hour	
			% Met	Pass/Fail	% Met	Pass/Fail
Individual Link Volumes						
< 700 vph	100 vph	> 85%	100%	Pass	100%	Pass
Between 700 and 2700 vph	15 %	> 85%	100%	Pass	100%	Pass
> 2700 vph	400 vph	> 85%	100%	Pass	100%	Pass
GEH Statistic	5	> 85%	100%	Pass	100%	Pass
Sum of Link Volumes						
Sum of All Links	5%	-	-	Pass	-	Pass
GEH Statistic	< 4	-	-	Pass	-	Pass
Travel Time						
Journey/Travel Times, Network	15%	> 85%	86%	Pass	100%	Pass
Visual Inspection						
Travel Speeds	Match Observations		-	Pass	-	Pass
Queuing	Match Observations		-	Pass	-	Pass

Based on the calibration targets and visual inspections, the base AM and PM peak hour models have been adequately calibrated and meet all calibration acceptance targets.

It is recommended that the AM and PM calibrated existing conditions models should be used as the base model for evaluating/validating the operational and safety improvements for the acceleration/deceleration lane and additional through lane components.

REFERENCES

Federal Highway Administration. “Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software.” U.S. Department of Transportation, July 2004.

Felsburg Holt & Ullevig (FHU). June 8, 2017. *I-25 North, US 36 to SH 7 – Methods and Assumptions Technical Memorandum.*

FHU. June 8, 2017. *I-25 North, US 36 to SH 7 – Data Collection Technical Memorandum.*