Traffic Technical Report

For the C-470 Corridor
Revised Environmental Assessment

July 2015

Submitted to:
CDOT Region 1
2000 S. Holly Street
Denver, CO 80222

COLORADO
Department of Transportation

Submitted by:
Wilson & Company
1675 Broadway, Suite 200
Denver, CO 80202

Table of Contents

List of Figures

List of Tables

This page is intentionally blank

1.0 INTRODUCTION

This Traffic Technical Report examines potential traffic operations impacts that would result from proposed improvements to Colorado State Highway 470 (C-470) in the southwestern part of the Denver metropolitan area. The report documents the traffic operational analysis and crash analysis along the study corridor for current (2013) and future (2035) conditions.

C-470 is located about 13 miles south of downtown Denver. It passes through Arapahoe, Douglas, and Jefferson counties, as shown in **Figure 1**. In 2013, the Federal Highway Administration (FHWA) and Colorado Department of Transportation (CDOT) initiated a Revised Environmental Assessment (EA) for the 13.75-mile portion of C 470 between Kipling Parkway and Interstate 25 (I-25) to address congestion and delay, and to improve travel time reliability for C-470 users. The Proposed Action in the Revised EA differs slightly from the Express Lanes alternative identified in the previous EA that was approved by CDOT and FHWA in 2006.

Figure 1: C-470 Corridor and its Surrounding Vicinity

1.1 No-Action Alternative

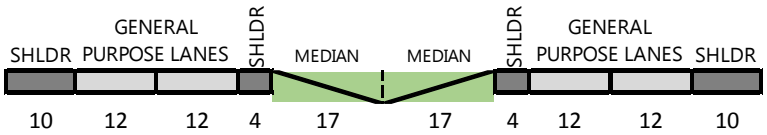
The existing C-470 freeway includes two general purpose lanes in each direction with a depressed median, resulting in a typical cross section approximately 110 feet wide. This width expands near grade-separated interchanges to include off-ramps, on-ramps, and in some cases, auxiliary lanes. In the No-Action Alternative, this configuration would remain unchanged, but would receive maintenance as needed to ensure the safety and functionality of the existing four-lane freeway.

1.2 Proposed Action

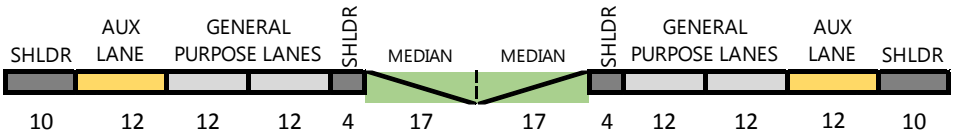
The Proposed Action would add two tolled express lanes in each direction, expanding the four-lane freeway to an eight-lane freeway. To aid motorists in merging onto or off of the highway, auxiliary lanes will be provided between closely spaced interchanges (e.g., one mile apart). The typical cross section will vary from 154 feet without auxiliary lanes to 174 feet in areas with auxiliary lanes. The Proposed Action does not include any new interchanges or any major interchange modifications. However, at the eastern end of the project area, the Proposed Action

also includes direct-connect ramps accommodating movements between I-25 and the C-470 Express Lanes. **Figure 2** shows the existing and proposed typical cross sections.

Figure 2: Existing and Proposed C-470 Typical Cross Sections

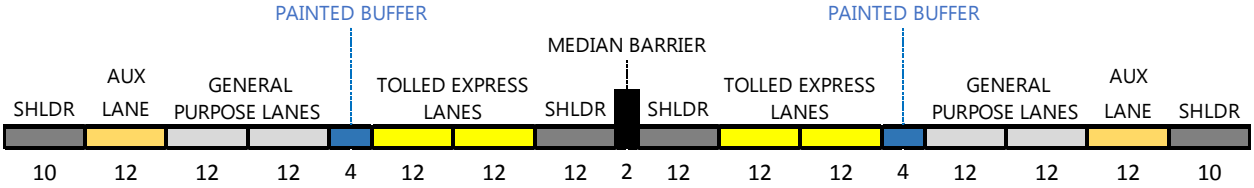


EXISTING TWO LANES EACH DIRECTION – KIPLING PKWY TO QUEBEC ST



EXISTING TWO LANES PLUS AUXILIARY EACH DIRECTION – QUEBEC ST TO I-25

PROPOSED C-470 WITHOUT AUXILIARY LANES

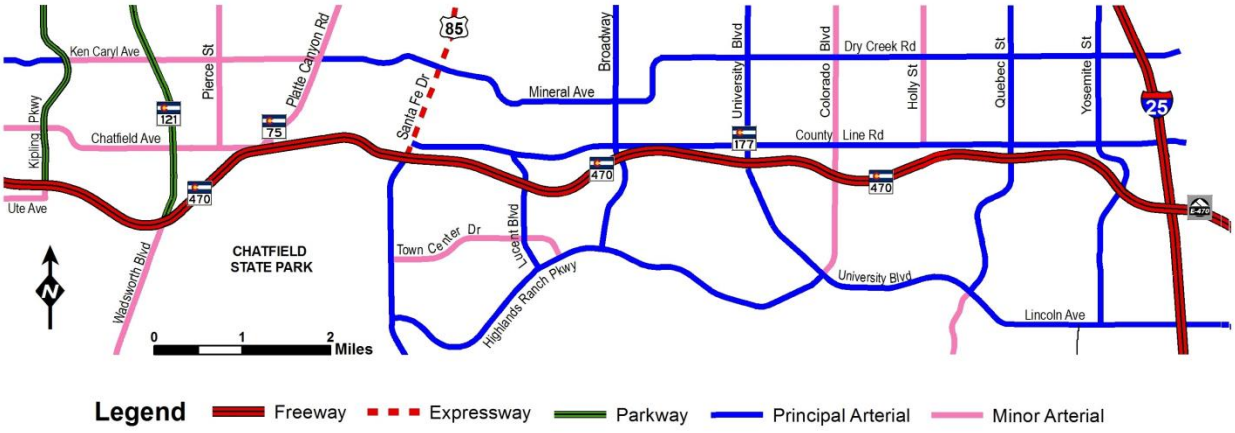


PROPOSED C-470 WITH AUXILIARY LANES

2.0 EXISTING ROADWAY CONDITIONS

Currently, C-470 has two through-lanes in each direction. From Quebec Street to I-25, the freeway also has auxiliary lanes that connect the on-ramp to the subsequent off-ramp, to provide maximum possible distance for merge and diverge movements to/from the through lanes. There is also a continuous auxiliary lane on eastbound C-470 between Santa Fe and Lucent Boulevard. The posted speed limit on all of C-470 is 65 miles per hour. **Figure 3** shows how C-470 fits in the context of the surrounding arterial roadway system**.**

Figure 3: C-470 and its Surrounding Roadway Network

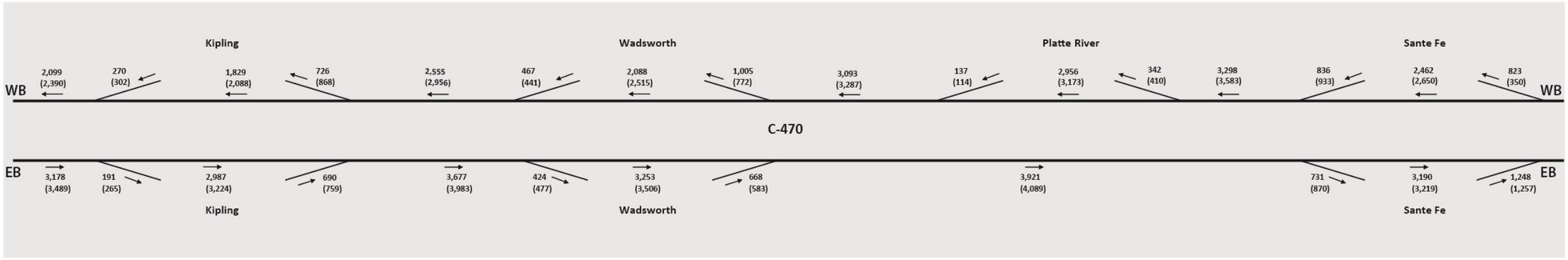


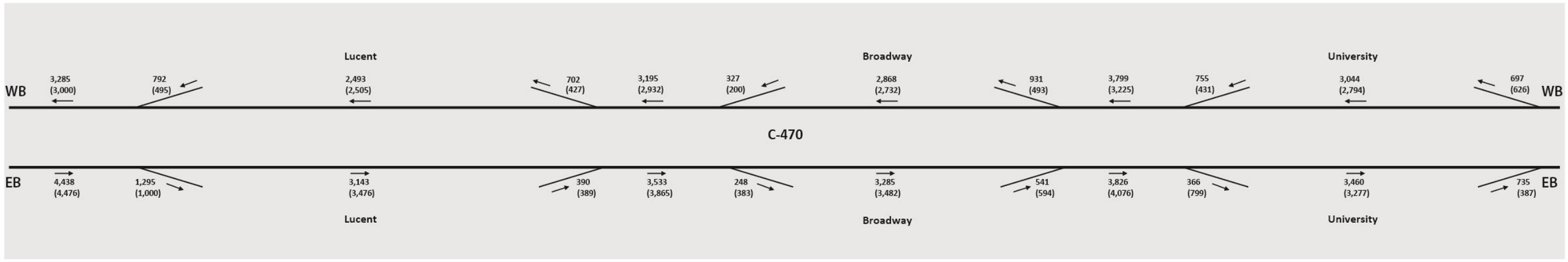
2.1 C-470 Corridor Peak Hour Traffic Volumes

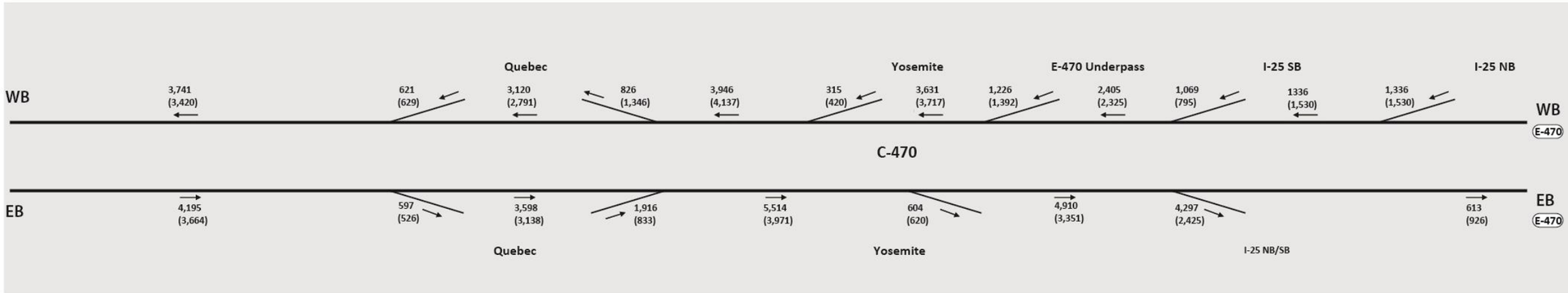
Current C-470 mainline peak hour traffic volumes were obtained from the Colorado Department of Transportation (CDOT). Corridor travel times, intersection turning movement counts and ramp traffic volumes were collected in May 2013. **Figures 4** through **Figure 6** depict the current peak hour traffic volumes along the C-470 corridor.

In general, during the peak hours, traffic on C-470 is balanced in each direction which is not well-suited for capacity improvement strategies that include reversible lanes.

Figure 4





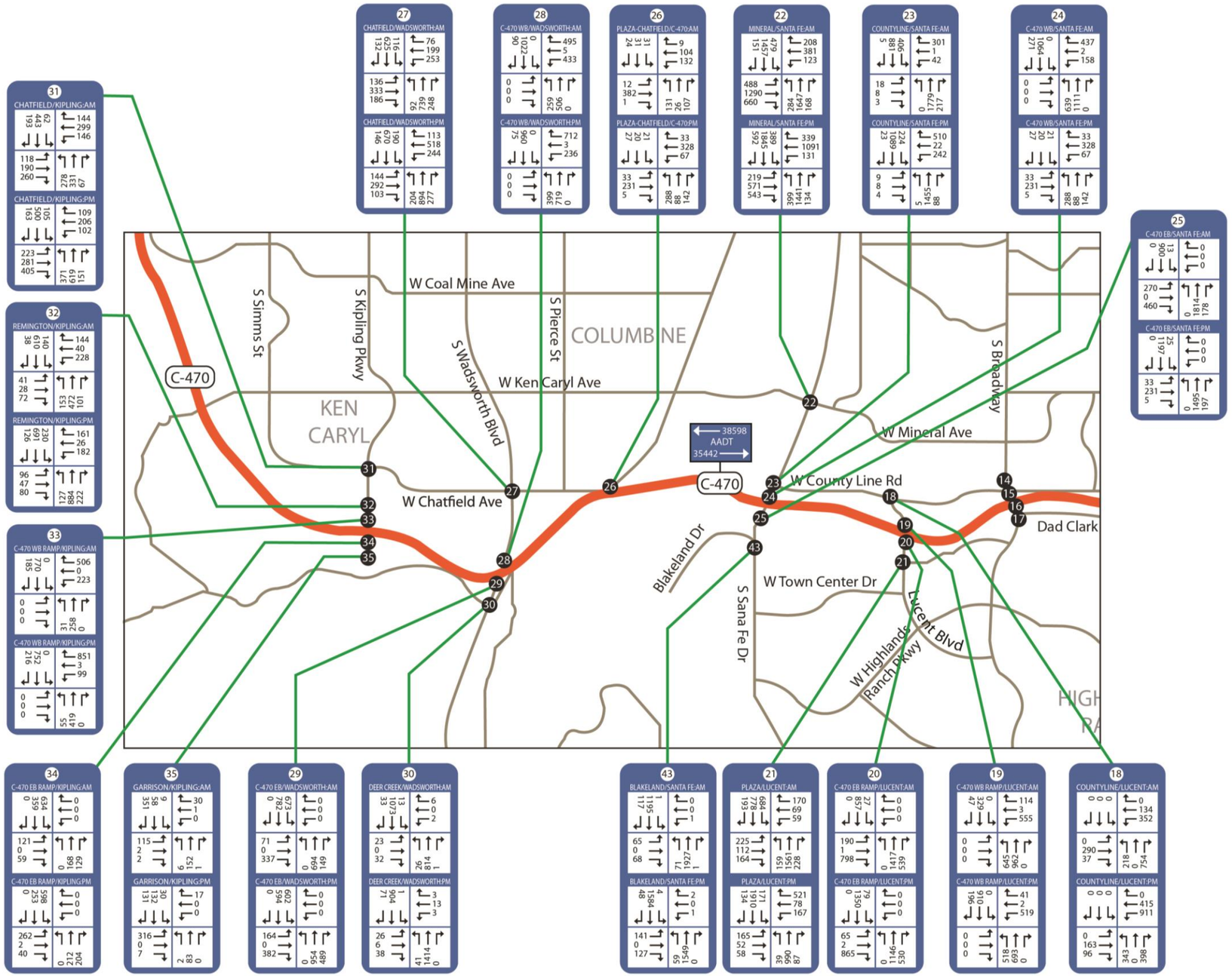


2014 Existing C-470 Freeway Traffic Volumes

Legend

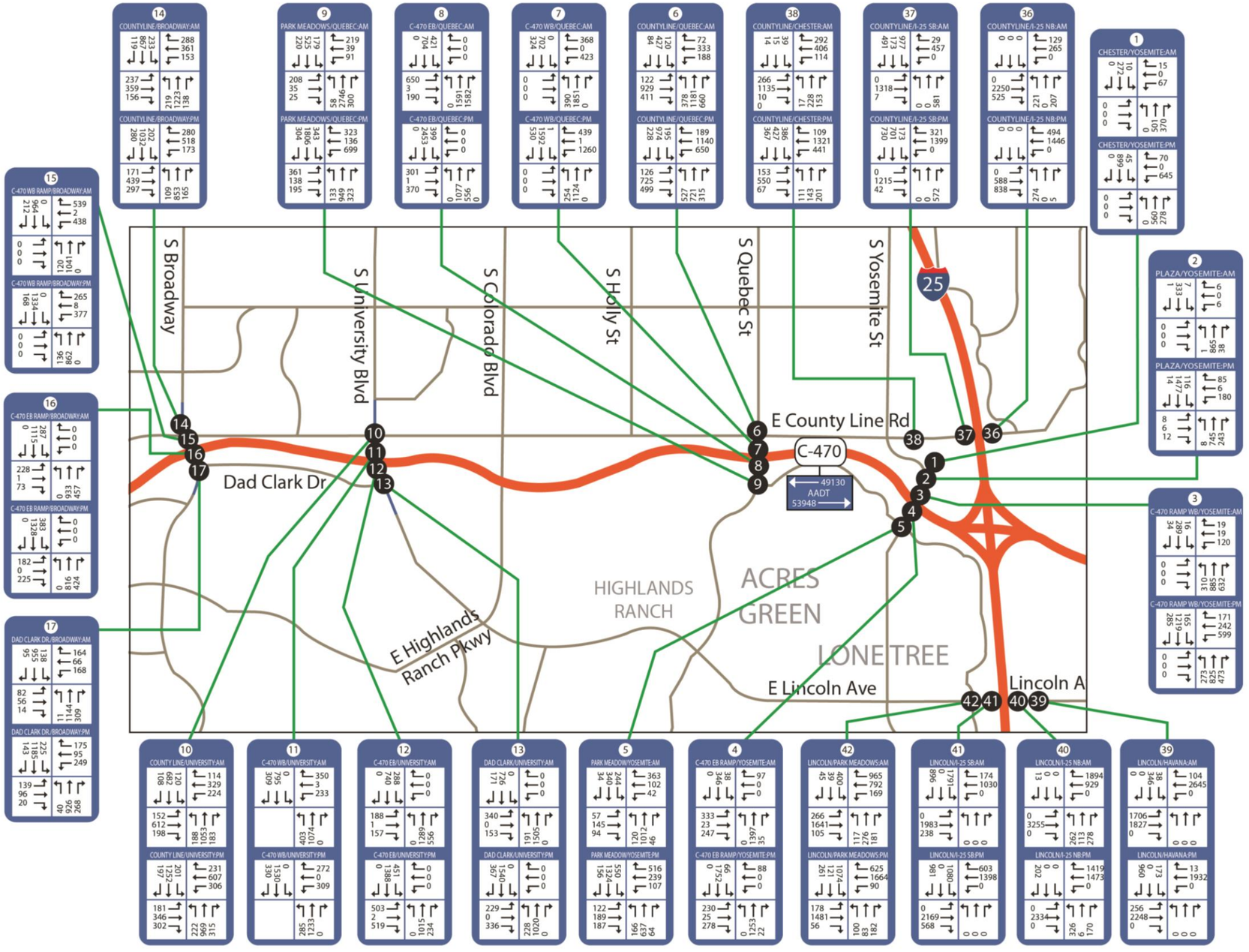
AM Peak Hour
(#) PM Peak Hour
General Purpose Lanes/Ramps
N

Figure 5



C-470 2013 Existing Traffic Volumes: West Segment

Figure 6



C-470 2013 Existing Traffic Volumes: East Segment

2.2 Level of Service Definition

Levels of Service (LOS) for the C-470 Corridor were computed for basic freeway segments, weave sections, and ramp junctions using Highway Capacity Software (HCS) 2010. The LOS thresholds for freeway facilities as taken from the Highway Capacity Manual (HCM) 2010 are summarized in **Table 1**. LOS is determined by vehicle density which is characterized by passenger car per mile per lane (pc/mi/ln).

LOS for the interchange ramp terminal intersections were determined applying the HCM 2010 Chapter 22, Interchange Ramp Terminals methodology. **Table 2** summarizes LOS thresholds for signalized intersections determined by control delay which is characterized by seconds per vehicle (sec/veh).

Table 1: LOS Thresholds for Freeway Facilities

Level of Service	Density (pc/mi/ln)		
	Basic Freeway Segments	Ramp Junctions	Weaving Segments
A	≤ 11	≤ 10	0-10
B	> 11-18	> 10-20	> 10-20
C	> 18-26	> 20-28	> 20-28
D	>26-35	> 28-35	> 28-35
E	>35-45	> 35	>35
F	>45 or v/c > 1.00	Demand exceeds capacity	

Table 2: LOS Thresholds for Signalized Intersections

Level of Service	Control Delay (sec/veh)
A	< 10
B	> 10 and < 20
C	> 20 and < 35
D	> 35 and <55
E	> 55 and < 80
F	> 80

It is important to understand the limitations of the HCM. The reported HCM results do not reflect upstream and downstream conditions. As a result operational and capacity problems downstream may have no impact on upstream analysis results, whereas in reality they would.

2.3 Freeway Operations

This section includes discussion of the following operational characteristics for current C-470 corridor conditions:

- Basic freeway segments
- Ramp junctions
- Weave segments

2.3.1 Basic Freeway Segments

The results of the C-470 basic freeway segments for current conditions are summarized in **Table 3**. The entire section of westbound C-470 between Kipling and I-25 has reported LOS D or better for the AM and PM peak hours. There are several deficiencies in the eastbound direction of C-470 during each of the peak hours that were reported primarily on the western end and middle sections of the C-470 Corridor.

Table 3: 2014 Existing Basic Freeway Segment Operations Summary

	Basic Freeway Segements		AM Peak		PM Peak	
	From	To	Density	LOS	Density	LOS
Westbound C-470	E of C-470	I-25 Off ramp	15.9	B	13.0	B
	E-470	I-25 N/S Ramp Split	17.3	B	10.0	A
	I-25 Off ramp	I-25 On ramp	10.1	A	11.4	B
	I-25 Ramps	C470	19.8	C	19.1	C
	I-25 On ramp	Yosemite On ramp	19.9	C	20.4	C
	Yosemite On ramp	Quebec Off ramp	21.6	C	22.7	C
	Quebec Off ramp	Quebec On ramp	26.1	D	23.0	C
	Quebec On ramp	University On ramp	33.3	D	29.3	D
	University Off ramp	University On ramp	25.3	C	23.0	C
	University On	Broadway Off	34.2	D	27.1	D
	Broadway Off ramp	Broadway On ramp	23.7	C	22.5	C
	Broadway On ramp	Lucent Off ramp	26.8	D	24.2	C
	Lucent Off ramp	Lucent On ramp	20.5	C	20.6	C
	Lucent On ramp	Santa Fe Off ramp	27.8	D	24.9	C
	Santa Fe Off ramp	Santa Fe On ramp	20.2	C	21.8	C
	Santa Fe On ramp	lane drop	27.9	D	31.2	D
	Lane drop	Platte Canyon Off ramp	18.1	C	19.6	C
	Platte Canyon Off ramp	Platte Canyon On ramp	24.5	C	26.6	D
	Platte Canyon On ramp	Wadworth Off ramp	25.8	C	27.8	D
	Wadworth Off ramp	Wadworth On ramp	17.2	B	20.7	C
	Wadworth On ramp	Kipling Off ramp	21.0	C	24.5	C
	Kipling Off ramp	Kipling On ramp	15.0	B	17.2	B
	Kipling On ramp	W of Kipling	17.2	B	19.6	C

Table 3: 2014 Existing Basic Freeway Segment Operations Summary – continued

	Basic Freeway Segements		AM Peak		PM Peak	
	From	To	Density	LOS	Density	LOS
Eastbound C-470	Kipling Off ramp	W of Kipling	26.6	D	30.1	D
	Kipling Off ramp	Kipling On ramp	24.8	C	27.1	D
	Kipling On ramp	Wadworth Off ramp	32.5	D	37.0	E
	Wadworth Off ramp	Wadworth On ramp	27.4	D	30.3	D
	Wadworth On ramp	Santa Fe Off ramp	36.0	E	38.8	E
	Santa Fe Off ramp	Santa Fe On ramp	26.8	D	27.1	D
	Lucent Off ramp	Lucent On ramp	26.3	D	29.9	D
	Lucent On ramp	Broadway Off ramp	30.6	D	35.2	E
	Broadway Off ramp	Broadway On ramp	27.8	D	30.0	D
	Broadway On ramp	University Off ramp	34.6	D	38.6	E
	University Off ramp	University On ramp	29.7	D	27.7	D
	University On ramp	Quebec Off ramp	40.8	E	32.3	D
	Quebec Off ramp	Quebec On ramp	31.4	D	26.2	D
	Quebec On ramp	Yosemite Off ramp	32.5	D	21.8	C
	Yosemite Off ramp	I-25 Off ramp	27.6	D	18.4	C
	I-25 Off ramp	I-25 On Ramp	5.0	A	7.6	A
	C470	I-25 N/S Ramp Split	41.0	E	18.5	C
	I-25 N/S On ramp Merge	E-470	5.2	A	13.3	B
	I-25 On ramp	E of C-470	7.1	A	14.6	B

2.3.2 Ramp Junctions

The results of the C-470 ramp junctions for current conditions are summarized in **Tables 4** and **5**. In the C-470 westbound direction all merge and diverge peak hour traffic operations were reported to be LOS D or better. In the C-470 eastbound direction there are reported congested ramp junction operations for nearly all the ramp junctions on C-470.

Table 4: 2014 Existing Freeway Merge Operations Summary

	On-ramp	AM Peak		PM Peak	
		Density	LOS	Density	LOS
Westbound C-470	Yosemite On	23.4	C	26.1	C
	Quebec On	27.1	C	24.4	C
	University On	33.5	D	28.6	D
	Broadway On	30.2	D	28.0	D
	Lucent On	31.4	D	28.9	D
	Santa Fe On	30.8	D	33.2	D
	Platte Canyon On	21.9	C	23.5	C
	Wadworth On	24.6	C	27.9	C
	Kipling On	20.4	C	22.8	C
Eastbound C-470	Kipling On	32.7	D	35.3	E
	Wadworth On	35.0	E	36.4	E
	Lucent On	32.0	D	34.8	D
	Broadway On	35.0	D	37.0	E
	University On	37.4	E	33.1	D
	Quebec On	41.3	F	28.9	D

Table 5: 2014 Existing Freeway Diverge Operations Summary

	Off- Ramp	AM Peak		PM Peak	
		Density	LOS	Density	LOS
Westbound C-470	I-25 Off	*17.0*	*B*	*13.8*	*B*
	Quebec Off	16.0	B	18.2	B
	University Off	25.1	C	22.2	C
	Broadway Off	25.7	C	20.4	C
	Lucent Off	20.1	C	17.7	B
	Santa Fe Off	20.9	C	18.3	B
	Platte Canyon Off	12.0	B	13.9	B
	Wadworth Off	19.2	B	21.0	C
	Kipling Off	14.2	B	17.9	B
Eastbound C-470	Kipling Off	19.9	B	22.8	C
	Wadworth Off	33.5	D	36.3	E
	Santa Fe Off	26.8	C	28.3	D
	Broadway Off	23.2	C	26.3	C
	University Off	25.9	C	28.2	D
	Quebec Off	29.3	D	24.4	C
	Yosemite Off	22.6	C	15.6	B
	I-25 Off	*28.6*	*D*	*19.5*	*B*
	I-25 N/S Ramp Split	42.8	E	25.6	C

2.3.3 Weave Segments

The results of the C-470 weave segment analysis for current conditions are summarized in **Table 6**. Presently there is one weave section in each direction of C-470, Santa Fe to Lucent in the eastbound direction and Yosemite to Quebec in the westbound direction. The C-470 eastbound weave section was reported to operate at LOS F during both the AM and PM peak hours. The C-470 westbound weave was reported to operate at LOS D or better during the peak hours.

Table 6: 2014 Existing Freeway Weave Operations Summary

	Weave Segment		AM Peak		PM Peak	
	From	To	Density	LOS	Density	LOS
WB C-470	Yosemite On	Quebec Off	26.3	C	28.1	D
EB C-470	Santa Fe On	Lucent Off	*	F	*	F

2.4 Interchange Operations

Each of the interchange signalized intersections were analyzed using the HCM 2010 Chapter 22, Interchange Ramp Terminals methodology, as noted previously and the results are summarized in **Table 7**. Out of the 16 total intersections evaluated, 2 intersections exhibited capacity deficiencies; Quebec/C-470 EB ramp and Quebec/C-470 WB ramp intersections. The intersections with reported deficient operations are highlighted in the table.

Table 7: 2014 Existing Interchange Intersection Operations Summary

	Existing 2014			
	AM		PM	
Intersection	Delay	LOS	Delay	LOS
Kipling & C-470 EB	9.6	A	34.8	C
Kipling & C-470 WB	18.0	B	28.3	C
Wadworth & C-470 EB	12.7	B	12.5	B
Wadworth & C-470 WB	20.9	C	17.8	B
Santa Fe & C-470 EB	14.1	B	15.3	B
Santa Fe & C-470 WB	21.0	C	28.5	C
Lucent & C-470 EB	26.1	C	12.8	B
Lucent & C-470 WB	36.4	D	36.1	D
Broadway & C-470 EB	9.1	A	9.9	A
Broadway & C-470 WB	18.4	B	23.2	C
University & C-470 EB	12.5	B	30.8	C
University & C-470 WB	11.9	B	14.4	B
Quebec & C-470 EB	115.7	F	14.5	B
Quebec & C-470 WB	15.1	B	>120	F
Yosemite & C-470 EB	23.1	C	12.7	B
Yosemite & C-470 WB	7.7	A	30.3	C

2.5 Existing Safety Conditions

The *Roadway Safety Technical Report, November 2013* was completed for the C-470 Corridor Revised EA. The report was a safety analysis conducted for the C-470 Corridor that included a query of CDOT's database identifying all reported accidents for the five years from 2008 to 2012, inclusive, on the C-470 mainline, its ramps, and selected cross-street intersections. The safety report analyzed 1,465 C-470 accidents over the five-year period and the following summarizes the key information contained in the safety technical report. See the full report for additional information.

The predominant category of C-470 mainline accidents was multi-vehicle collisions, which accounted for 62.2% of the total. This category is dominated by rear-end collisions, averaging 142 per year, which comprised nearly half (48%) of all accidents on mainline C-470.

The prevalence of rear-end collisions in 2008-2012 is the same percentage that was found in the 2005 C-470 safety study. The 2005 study stated that "most of these accidents are the direct result of one or more of the involved vehicles either unexpectedly slowing or actually stopping, due to congestion, on a high-speed roadway." With continued growth and development in this portion of the metro area, C-470 traffic volumes and congestion have continued to increase since then.

The second type of accident included in the multi-vehicle collisions category is sideswipe collisions, averaging 40 per year on a corridor-wide basis. This is also the second most prevalent accident type overall on mainline C-470. Sideswipe accidents can occur when motorists attempt a lane change, inadvertently drift from their lane, or attempt to merge without adequate clearance.

Collisions with a fixed object were the second leading accident category, at 26.3%, which is less than half the multi-vehicle collision share. Collisions with cable rail (e.g., in the roadway median, dividing the two directions of traffic), guard rail (preventing drivers from entering areas with no opportunity to recover vehicle control), and other fixed objects all accounted for relatively similar shares of total accidents. CDOT minimizes the inclusion of fixed objects in the vicinity of the roadway in an attempt to avoid crashes of this nature. CDOT has strict criteria for installing cable rail, guard rail, and other structures to ensure that their benefits outweigh their risks. Much of the cable rail installation is fairly recent, preventing a vehicle from veering across the median to hit other vehicles in a more catastrophic head-on collision.

Collisions with a non-fixed object (other than a moving vehicle) accounted for 6.1% of the five-year accident total on C-470. These include collisions with debris (8 accidents per year), wild animals (6 accidents per year) and other unspecified objects (4 accidents per year) which typically cannot be predicted or controlled. Several accidents listed in this category involved crashing with a motor vehicle that was parked along the roadway. Animal crossing warning signs exist in locations near the South Platte River and other areas where crashes with animals have been recorded.

The remainder (5.4%) of the five-year accident total consists of non-collision accidents, including an average of 12 rollover accidents per year, 2 cases of driving off of embankments (i.e., without hitting guardrail), and 2 other miscellaneous cases. Rollover accidents typically

indicate traveling at high speed. C-470 has posted speed limits of 65 miles per hour, which obviously some motorists exceed, sometimes even under unfavorable driving conditions.

2.5.1 Mainline Accidents by Location

Traffic volumes on C-470 are highest at the eastern (I-25) end, and gradually diminish for successive segments to the west. This explains why there appear to be fewer accidents per mile in the westernmost parts of the study area.

The average number of yearly accidents for the full-mile segments of the C-470 mainline was approximately 20 and ranged from a low of 8 in mile 13 (Wadsworth Boulevard) to a high of 34 in mile 24 (Quebec Street), as shown in Figure 3. The vicinity of Quebec Street also had the highest number of accidents reported in the 2005 CDOT safety study, based on the data available at that time. The 2008 to 2012 data for mile 24 includes 106 rear-end accidents out of a total of 172, accounting for approximately 62% of the total. This exceeds the 48% average for the corridor overall, and is likely due in large part to traffic congestion.

The locations with the highest average annual accidents during 2008 to 2012 were:

- mile 24 (includes the Quebec interchange) - 34 accidents per year
- mile 19 (includes the Broadway interchange) – 31 accidents per year
- mile 17 (includes the Santa Fe interchange) - 28 accidents per year
- mile 21 (includes the University interchange) - 27 accidents per year
- mile 25 (includes the Yosemite interchange) - 27 accidents per year

2.5.2 Mainline Accidents by Severity

Of the 1,465 C-470 mainline accidents reported during 2008 through 2012, almost 92% resulted in property damage only, almost 8% resulted in one or more injuries, and one half of one percent (8 accidents) resulted in fatalities. Mile-by-mile comparison of injury accidents does not reveal any dense clusters of injury accident locations, and the same is true for the eight accidents that resulted in fatalities.

3.0 FUTURE 2035 ROADWAY CONDITIONS

3.1 No-Action Alternative

The 2035 No-Action Alternative assumed no improvements to the existing C-470 freeway corridor other than performing basic maintenance and/or safety improvements to maintain roadway operations. Improvements to the I-25 and E-470 freeway facilities and other surface street facilities in the vicinity of the C-470 corridor that are included in the Denver Regional Council of Governments *2040 Fiscally Constrained Regional Transportation Plan* and included in the CDOT STIP were included as part of the No-Action Alternative.

3.2 Proposed Action

The development of the Proposed Action was the result of an extensive study and design process that started in late 2012 and was concluded in 2014. The design concept evolved as new information and insights about operations and maximizing the use of the proposed express toll lanes in the corridor were obtained. The Proposed Action (Build Condition) of the 2015 Revised EA for C-470 would add one tolled express lane in each direction between Kipling Parkway and I-25, and a second tolled express lane as follows:

- Westbound, I-25 to Lucent Boulevard
- Eastbound, Broadway to I-25

The tolled express lanes would be open in both directions at all times. Only drivers who choose to use the tolled express lanes would pay a toll. The tolled express lanes would provide users with more choices about how to travel, taking travel time and costs into consideration. The benefits of the tolled express lane are:

- **Travel Time Reliability**

  As travel demand on C-470 continues to grow, congestion, long travel times and uncertain travel time reliability will increase. Congestion, which in 2013 is confined primarily to week day peak periods, will grow over time and extend beyond the weekday peak periods as well. A managed lane provides a mechanism for CDOT to assure a reliable and efficient travel time for 2035 and beyond as travel time reliability degrades in the general purpose lanes. Studies have shown that travelers are willing to pay a toll for travel time reliability.

- **Tolled Express Lanes Provide Options**

  Tolled express lanes that are added in the same corridor as existing general purpose lanes provide options for travelers. Travelers are not required to use the facility, and many will only use them periodically, but travelers are provided the option for a faster, more reliable trip.

- **Tolled Express Lanes are More Consistent with a User Pay Philosophy**

  Nationwide, highway funding and environmental groups have been advocating funding of highway capacity that ties highway travel more closely to a user pay philosophy. Tolled express lanes that clearly match an increasing cost with higher demand is more likely to encourage alterations in travel behavior.

Environmental groups nationwide support this approach because it more clearly passes on transportation costs to the user and serves to encourage transit use or carpooling, which increase person throughput rather than vehicle throughput.

- **Tolled Express Lanes are a More Efficient Use of a Highway**

There is a substantial premium in adding highway capacity in most highway corridors. Providing the long-term ability to maintain a lane of free-flow travel will greatly enhance the capacity of the corridor.

- **Tolled Express Lanes Improve Emergency Response Reliability**

Emergency vehicles will be allowed to use the lanes without paying a toll as long as they have been dispatched to run with lights and sirens for emergency purposes. The tolled express lanes will provide a less congested alternative for emergency vehicles, increasing their reliability and response time.

- **Tolled Express Lanes Improve Economic Viability**

In contrast to congestion gridlock, tolled express lanes provide an option for those willing to pay to travel through the corridor with a reliable travel time. This will improve conditions for commuter travelers as well as other providers of goods and services along the C-470 corridor. This enhances the economic competitiveness of all users of C-470 as well as those communities adjacent to C-470.

These new tolled express lanes, plus new auxiliary lanes where warranted, would supplement the existing (non-tolled) general purpose lanes. In the modeling of the Proposed Action, it was assumed that there would be no designated lanes or toll exemptions for buses or carpools. New direct-connect ramps would be provided to serve some movements at the I-25/C-470/E-470 interchange. The Proposed Action would eliminate the existing two left lane drops on westbound C-470 between E-470 and Yosemite, a design that will operate in a safer manner, also noting that eliminating these left lane drops. This improvement was a key improvement requested by local corridor stakeholders. Improvements to the I-25 and E-470 freeway facilities and other surface street facilities in the vicinity of the C-470 corridor that are included in the *Denver Regional Council of Governments 2040 Fiscally Constrained Regional Transportation Plan* and included in the CDOT STIP were included as part of the Proposed Action. It was recognized early on that the tolled express lane ingress/egress would be a key component of the Proposed Action impacting traffic safety and operations as well as toll revenue. The tolled express lane ingress/egress design and location are discussed below.

3.2.1 Tolled Express Lane Ingress/Egress Design and Location

Ingress/Egress Design Types

The design detail of the different types of ingress and egress for C 470 Express Toll lanes are illustrated in **Figure 7**. In all the pictured cases, these designs include a weave lane for vehicles to enter and exit the express lanes. This merge/diverge/weave lane will provide refuge for transitioning vehicles which will be a safer transition than having vehicles cross directly between the general purpose lanes and express lanes.

The design criteria are based in part on the April 2011 Policy Memo from Caltrans. The design criteria in the Caltrans Policy Memo was based on current Caltrans design criteria and on the

evaluation of safety and mobility performance issues, over the last several years, associated with HOT lane access points that resulted in substantial changes to access opening location, spacing and geometry. Some of the findings of the evaluation included:

- General collision studies in California support increasing the weaving length at and between access openings beyond the current practices found in the HOV Guidelines.
- Nationally recognized research findings and products recommend longer openings and longer distances for the weaving along and between successive access openings. Prior and current national practice allows for a 1,000 foot minimum access opening, and (two-sided) weaving lengths that are based on providing 500-800 ft per lane change.

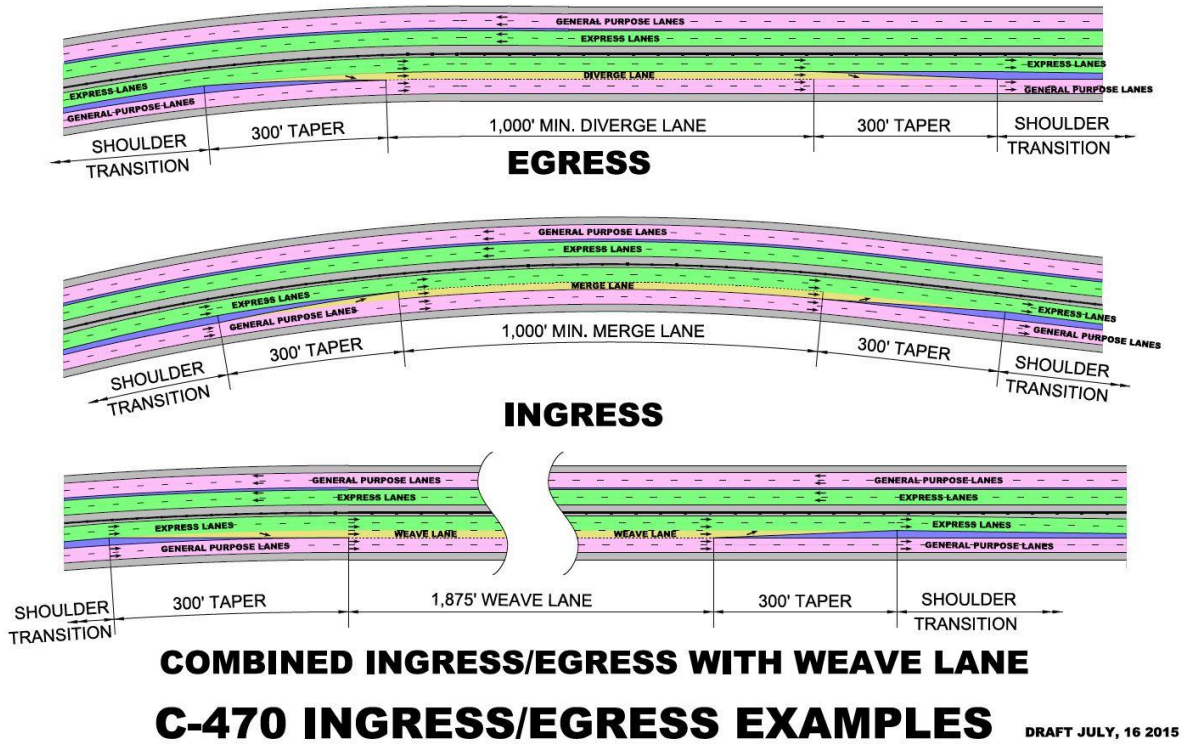
Based on the above research findings, and years of experience managing location-specific operational and safety problems, the Department's freeway operations and traffic safely engineering practitioners recommend the following changes to their standard practices:

  - Increase the minimum access opening length from 1,300 ft to 2,000 ft, and
  - Increase the per-lane change- distance from 650 ft to 800 ft in order to avoid pushing drivers to make consecutive lane change maneuvers across the entire freeway

The design criteria outlined in the April 2011 Policy Memo from Caltrans was discussed in detail with the C-470 Coalition Technical Working and approved and incorporated into the design of the C-470 tolled express lanes.

The design team also considered a different ingress/egress design. This type was a combined ingress/egress opening with **no additional** weave lane. Based on the curvilinear alignment of C-470, the ability for weaving vehicles to safely navigate and a desire to provide a reliable trip this basic concept was rejected. The recommended ingress/egress design also addresses safety concerns by some reviewers that provided public comment on the original C-470 EA in 2006.

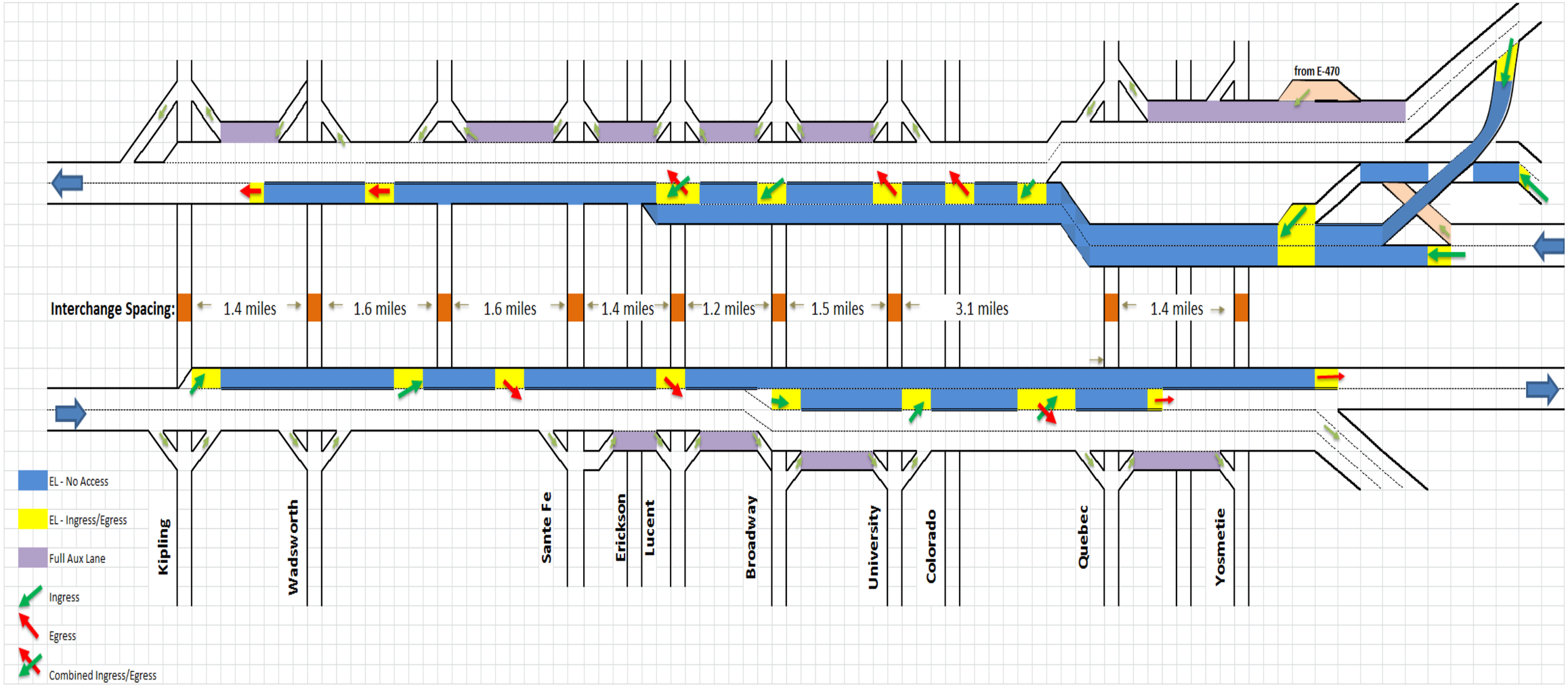
Figure 7: Typical Design for Ingress, Egress and Combined Ingress/Egress



Ingress/Egress Locations

Defining the tolled express lane ingress/egress locations of the Proposed Action was part of the design process that started in late 2012 and also included iterative public process as the Proposed Action was being developed. It is understood that the tolled express lane ingress/egress will create additional turbulence in the C-470 general purpose lanes especially since they would occur on the left hand side of these lanes. The locations of the tolled express lane ingress/egress are shown in **Figure 8**.

Figure 8: Tolled Express Lane Ingress/Egress Locations



4.0 TRAFFIC FORECASTING AND OPERATIONS

4.1 Future Year Peak Hour Traffic Volumes

Forecasting of the 2035 traffic volumes for the C-470 corridor was conducted by Cambridge Systematics and is documented in the *C-470 Express Toll Lanes Traffic Operations Analysis Report*, *May 15, 2015.* The following is taken from that report.

Future patterns and projected increases in volume is an important step within the traffic analysis, and the Denver Regional Council of Governments 2035 Focus model was used to update the regional patterns for the 2035 No Action and Proposed Action scenarios. The Focus model was updated to reflect all of the changes associated with the future alternatives and applied utilizing the entire model process. This included any changes associated with Highway and Transit network projects, as well as any changes to the demographic data.

After all of the changes to the model inputs associated with the future year scenarios were incorporated into the regional model dataset, the regional model was used to forecast future year traffic flows in a manner consistent with the base year traffic forecasting. Incremental growth for every OD pair was added to the base year calibrated trips. The process is described below:

1. Perform standard Focus model forecast to produce estimates of traffic demands;

2. Extract future year subarea OD demands for the regional study area corridor;

3. Adjust future year demands based on the base year validation. The final scenario-specific future year matrices were calculated using the following formula for each vehicle type/class:

Adj. Future Year Matrix = (Raw Future Year Matrix –

Raw Base Year Matrix) +

Calibrated Base Year Matrix

4. Extract C-470 Corridor-level ODs used as input into the simulation models. Multiple iterations of regional travel demand model and simulation model runs were completed to generate reliable future forecasts.

In addition to the major considerations of the future traffic forecast, the Focus model also had to take in to consideration the use of dynamic tolling models in the managed lanes in order to properly assign traffic and determine the correct impact of the addition of the express lanes. The remainder of the section discusses how the express lanes were modeled in the Focus model.

Modeling Express Lanes in the Focus Model

The C-470 Express Lanes that are the focus of this study use a dynamic pricing component that is based on the levels of congestion experienced within the express lanes at very small time

increments. It is expected that the express lanes will have some minimum toll at all times they are in operation. Also, some travelers may be averse to paying a toll regardless of the time savings. Therefore, including express lanes without some consideration of the additional cost might result in an over-prediction of demand.

The behavioral response to the pricing component can be divided into pre-trip decisions and en-route decisions. Pre-trip decisions include the activity location, mode, travel time, and toll receptivity. En-route, the traveler is choosing a path and deciding if the time savings in the express lanes justify the cost. The CS team's approach to capture these sensitivities is described below.

Pre-Trip Decisions

Regional travel demand models assume that decision-makers are aware of the equilibrium level of service and cost for each trip. Models also assume that travelers make pre-trip decisions regarding activity location and mode based on the average price for the time period of travel in addition to transportation network level of service (LOS). Some regional travel models address this issue with the inclusion of toll acceptance models that sort travelers into groups of those that will pay a toll and those that will not. Although there is no explicit toll acceptance choice model within the Focus model system, all of the activity-based model elements are sensitive to roadway pricing and have been calibrated and validated across the region with existing toll facilities. To introduce a new element at this time would be inconsistent and would require the models to be recalibrated. Therefore, the current regional model was not modified for this study.

In terms of incorporating the cost of the proposed managed lanes, a pricing scheme such as "fixed variable" that matches the assignment time periods would require no changes to the Focus model. To test dynamic pricing, an average price for each time period was estimated. This was done by applying the micro-simulation model with dynamic pricing to determine an "average" price for each time period that matches the Focus model.

En-Route Decisions

Similar to pre-trip decisions, if the pricing scheme for the express lanes is "fixed variable" where the price is constant for a set period of time but changes based on a predetermined schedule, it is possible to incorporate the effects of price on route choice into the existing Focus model assignment procedure. For instance, if the toll for using the express lane is a fixed amount from 7:00 a.m. to 8:00 a.m., the current generalized cost assignment methodology could be used with the corresponding hourly AM trip table by setting a fixed price for the express lane use for that hourly assignment. The price could then be changed for the next time increment as planned, etc. There would be no need to alter the current assignment methodology of the Focus model.

In the case where the pricing level is dynamic at time periods less than the Focus model and is related to congestion levels, the decision to use the express lanes would be made depending on the actual dynamic price level. As mentioned above, the Focus model utilizes a static assignment procedure to assign demands to the highway network. Static assignment cannot represent moment-to-moment fluctuations in volume; instead the average volume over the time

period is calculated. Static assignment, however, can be used to find the equilibrium between the delay on the mainline and the toll on the express lanes. The dynamic price is determined by traffic volume so an iterative process is necessary to determine the price demand equilibrium.

Two different potential approaches were examined to estimate the average dynamic price for a time period. The static assignment of volume between the two facilities was used to estimate the average toll rate for each time segment with some modification to the current Focus model volume delay functions. Alternatively, the average toll rate from the micro-simulation model, which represented the short-term decisions, was fed back into the Focus model network. The implementation of the two approaches is described below.

Develop a Volume Delay Function (VDF) that contains a cost or pricing component that is sensitive to the level of congestion; or

1) Utilize the existing VDF (BPR curve) within the Focus model in a more manual, iterative fashion as follows:

    a) First estimate maximum demand for the express lanes in the static assignment subarea model by allowing all eligible vehicles to use the express lanes at the minimum toll rate;

    b) Run these demands through the micro-simulation model that has a variable pricing component to determine an average cost per time slice;

    c) Re-estimate the demands with the static assignment subarea model using the average price information from the micro-simulation model above; and

    d) Continue this process until equilibrium is reached.

VISSIM Managed Lane Module

The VISSIM managed lane module was utilized to assign traffic within the simulation model to the managed express toll lane(s). The module consists of physical paths in parallel between the general purpose (GP) lanes and the managed express toll lanes, a decision model, and a pricing model. The paths were coded to reflect the ingress/egress of the design concept (design of facilities is discussed in more detail in Chapter 4.0) and the pricing zone structure. The toll pricing and willingness to pay are discussed in more detail below.

Toll Price Setting

The pricing strategy deployed in the VISSIM model is a combination of the logic used in the VISSIM Managed Lane Module and custom scripts written and implemented by the CS Team. The current pricing schemes in the Denver region is time-of-day pricing. In order to develop toll pricing rates for C-470, the CS team ran VISSIM with dynamic pricing and deployed a dynamic congestion pricing algorithm to help determine the time-of-day pricing rates and schedule. Tolls were charged by either a transponder or, if there is not a transponder, through license plate recognition. There is a surcharge on the tolls for vehicles using the express lane with only vehicle recognition, and this will need to be reflected in the pricing.

The parameters and objectives of the toll price setting have been established by High-Performance Transportation Enterprise (HPTE) staff and the TWG. The parameters and objectives are as follows:

- Facility Length – ~13 miles;
- Pricing Basis – Zone based. Three zones westbound; one or two zones eastbound (Interim/Ultimate);
- Minimum Toll – $0.50;
- Maximum Toll – Determined by VISSIM dynamic conditions;
- Toll change time interval – 60 minutes;
- License plate charge – $0.75;
- Operational Capacity – 1,900 vphpl;
- Performance measure – Travel Speed; and,
- Performance target – 55 mph exceeded 90 percent of the time (LOS D).

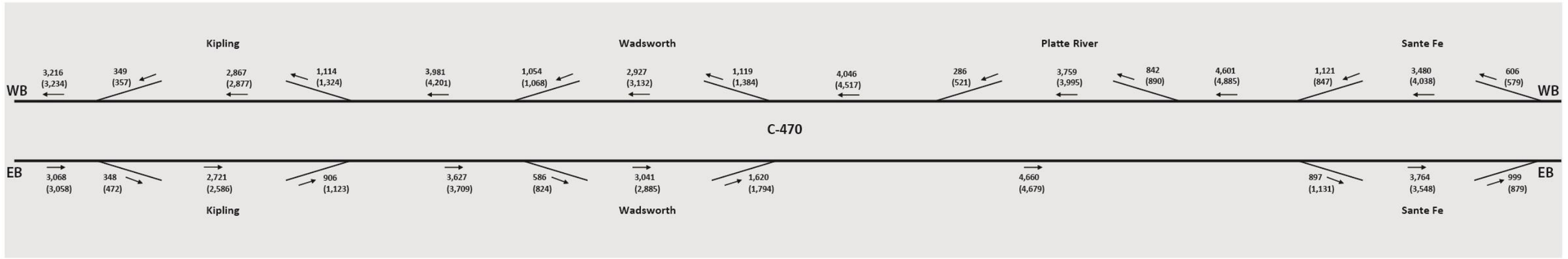
During the scenario analyses, it was determined to provide a slight change in the toll price structure for Zone 1 Westbound traffic entering from E-470. Instead of paying the established rate for the managed lanes as is done by traffic entering from I-25, a smaller minimal toll ($0.50) is charged for vehicles continuing from the E-470 toll facility onto the managed lane facilities. This was to better mitigate congestion along the C-470 corridor and to better balance traffic between the managed lanes and the general purpose lanes.

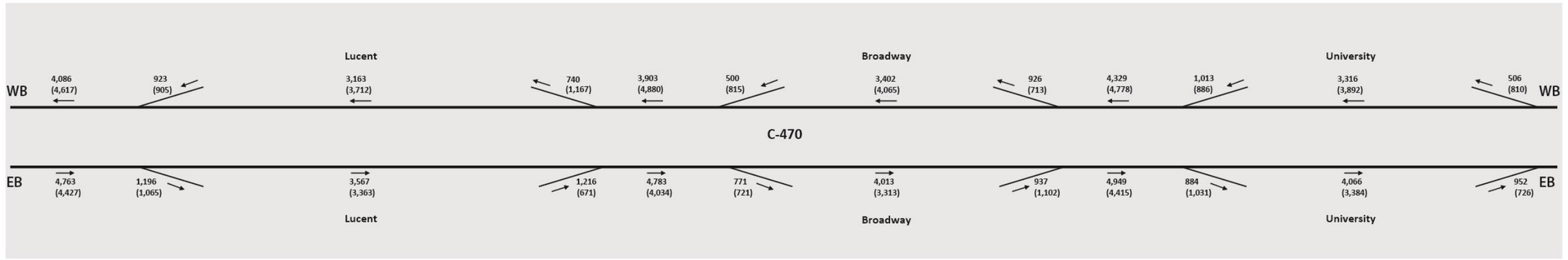
Willingness to Pay

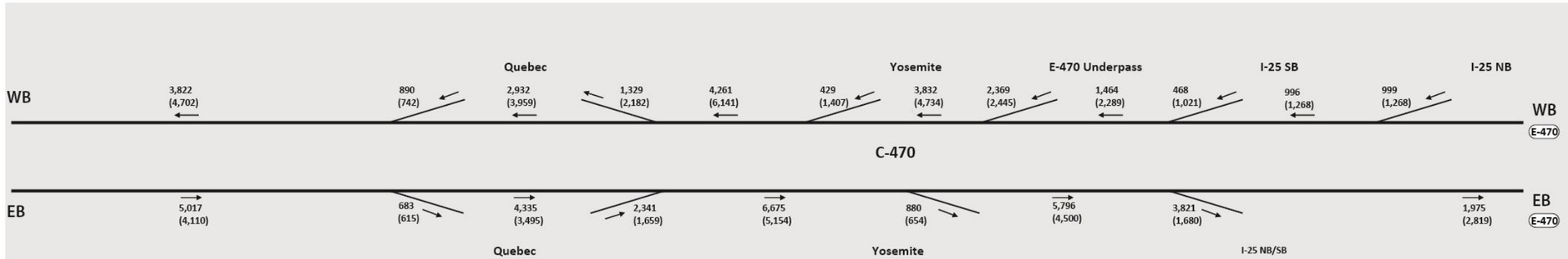
Willingness to pay is represented in the VISSIM model with a logit model. The logit model has coefficients that are developed based on stated-preference surveys. CS utilized the recent U.S. 36 stated-preference survey that was conducted for the proposed managed lanes between Denver and Boulder in order to set these model coefficients in the model. The survey was adjusted according to prevailing socioeconomic differences between the U.S. 36 corridor and the C-470 Corridor.

The above iterative process that involved refining the demands in the static equilibrium assignment procedure within the FOCUS model and then testing the operations of these demands within the VISSIM simulation models resulted in the 2035 No-Action Alternative and Proposed Action AM and PM peak hour volumes along the C-470 corridor that are shown in **Figure 9** through **Figure 14**.

Figure 9







2035 No Action C-470 Freeway Traffic Volumes

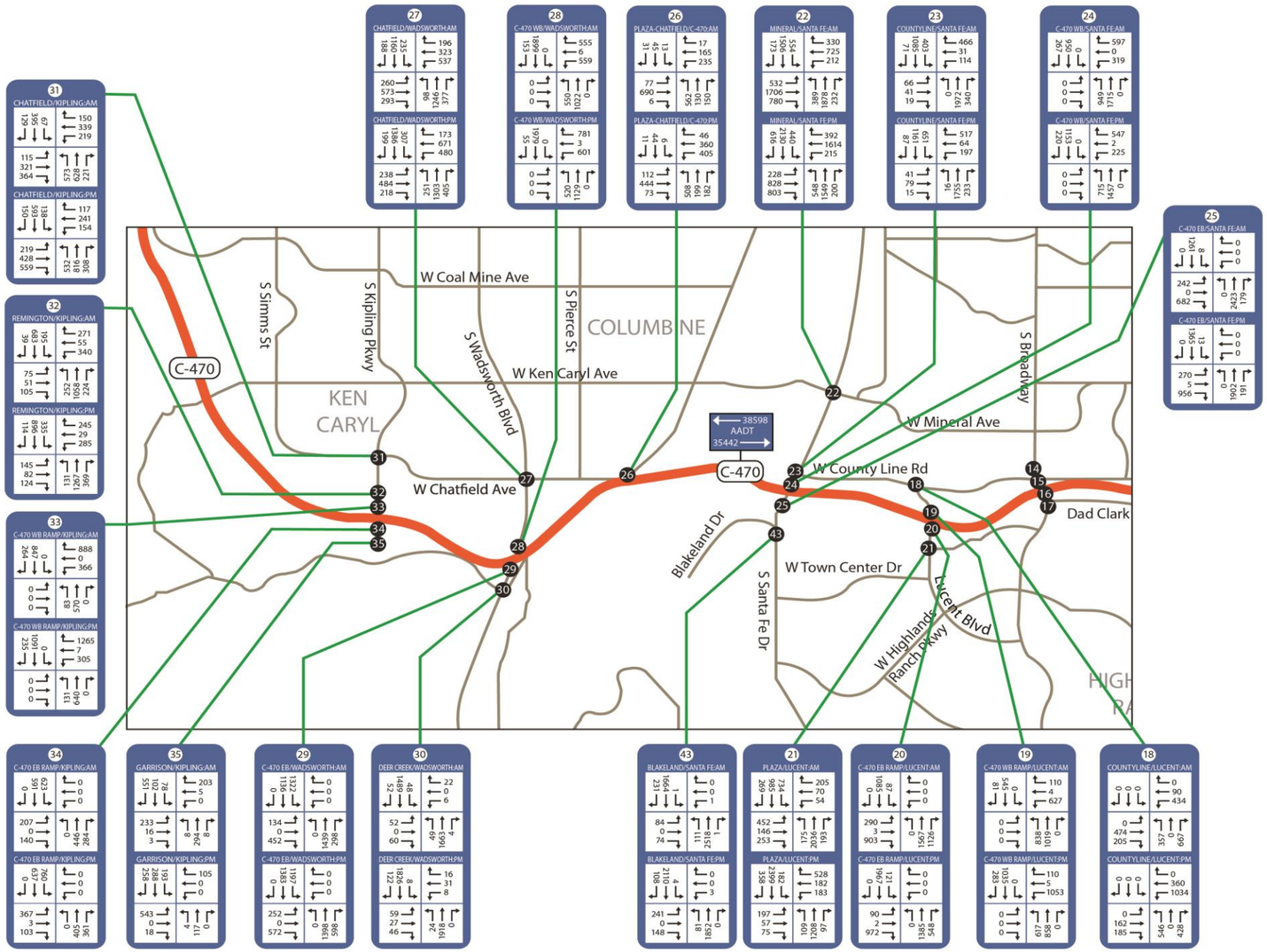
Legend

AM Peak Hour
(#) PM Peak Hour

General Purpose Lanes/Ramps

N

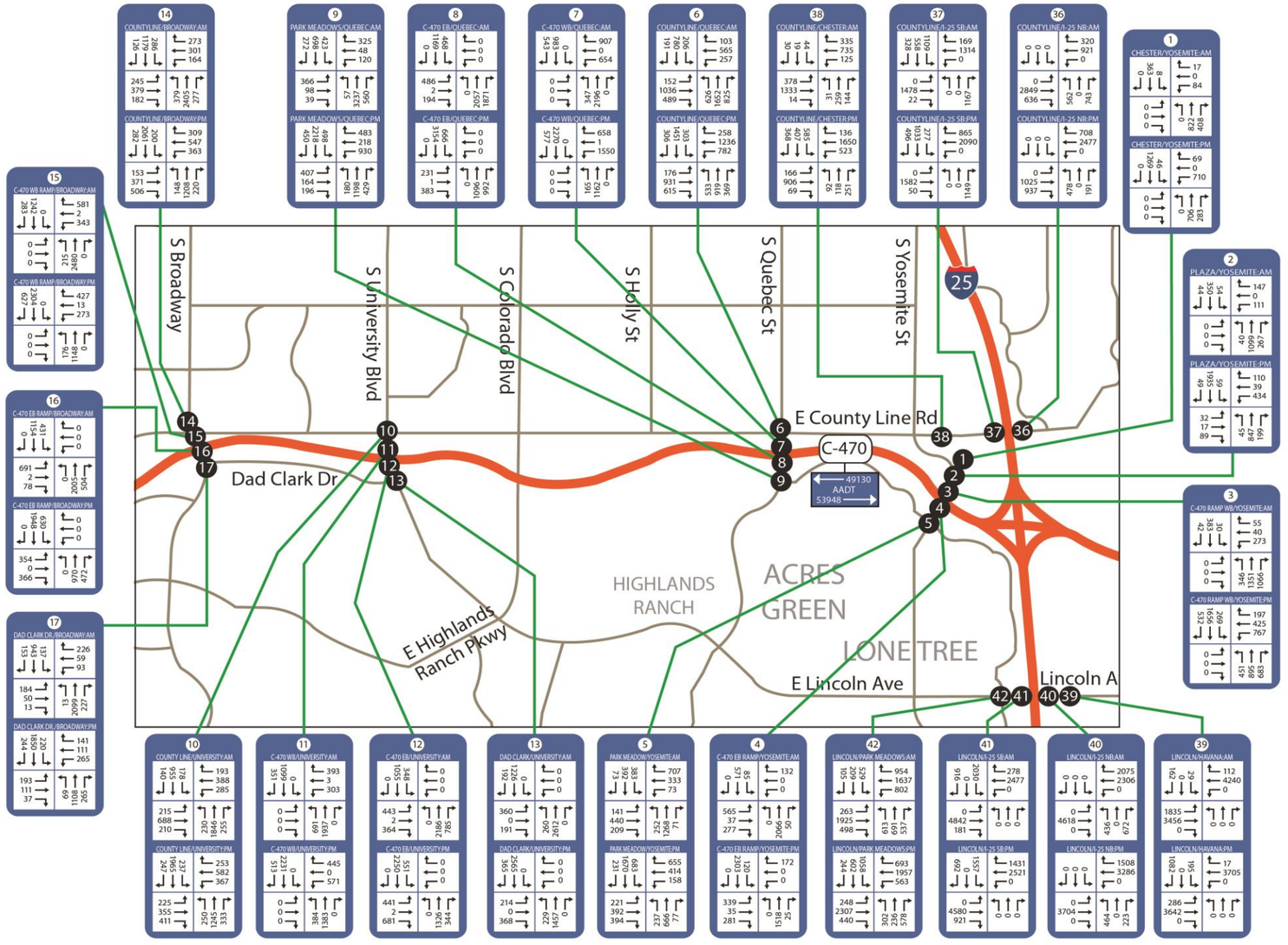
Figure 10



C-470 2035 No-Action Traffic Volumes: West Segment

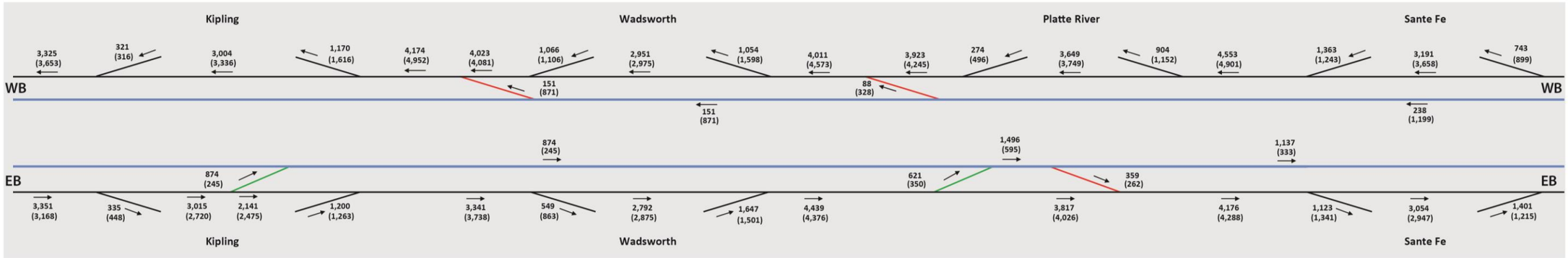
N

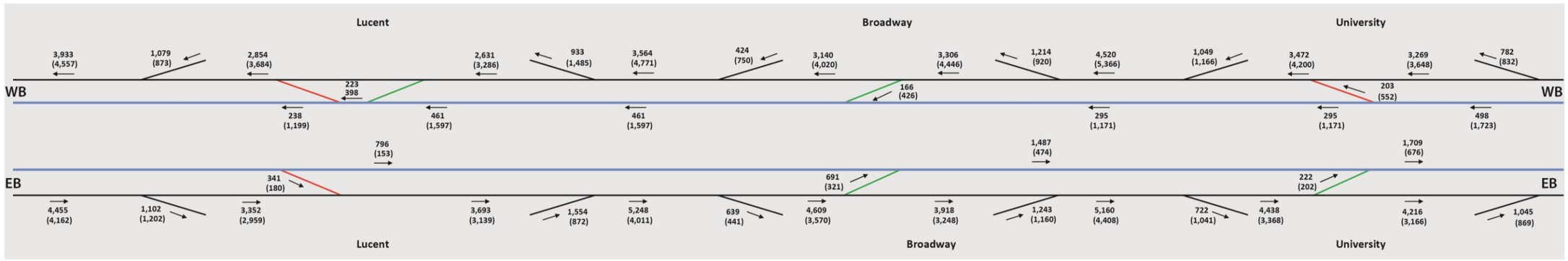
Figure 11

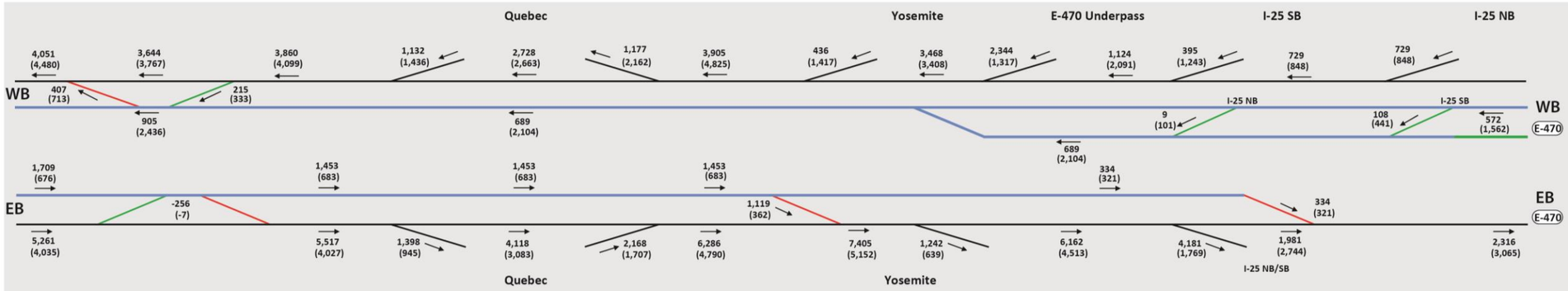


C-470 2035 No-Action Traffic Volumes: East Segment

Figure 12





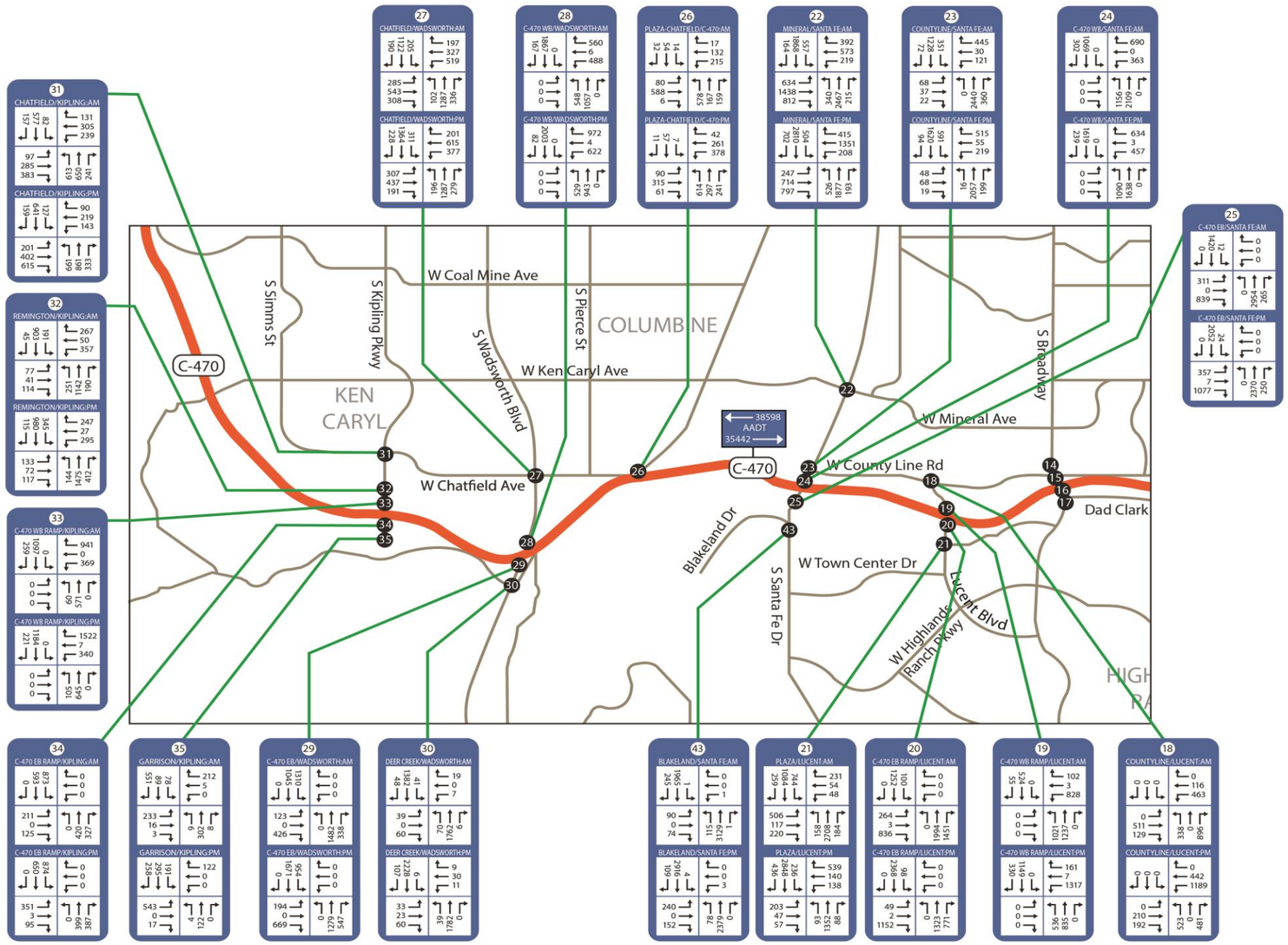


C-470 Proposed Action Freeway Traffic Volumes

Legend

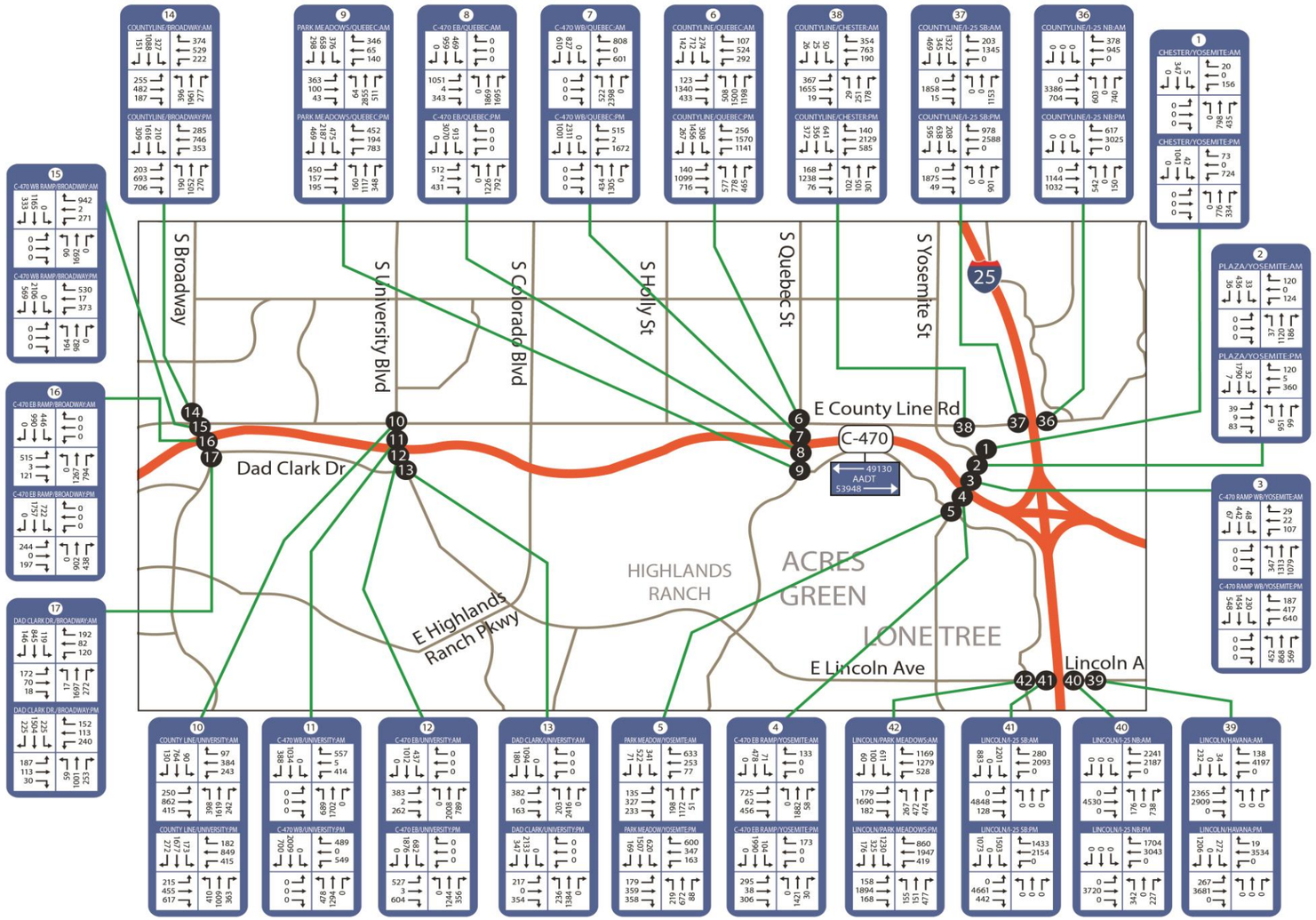
AM Peak Hour
(#) PM Peak Hour
General Purpose Lanes/Ramps
Toll Managed Lanes
Tolled Managed Lane Egress
Tolled Manged Lane Ingress
N

Figure 13



C-470 2035 Proposed Action Traffic Volumes: West Segment

Figure 14



C-470 2035 Proposed Action Traffic Volumes: East Segment

4.2 Future Year Truck Percentages for Operations Analysis

In order to establish the current level of truck activity in the C-470 Corridor, additional classification counts were collected along C-470 in July 2014, east of Quebec and east of Broadway to assess the existing heavy truck percentages on the C-470 Corridor. The average current observed truck percentages are summarized in the following **Table 8** for each of the peak hours. These truck percentages were used to conduct the 2035 traffic operation analyses.

Table 8: Current/Future Year Truck Percentages

AM Peak	PM Peak
2.3%	1.9%

Source: Average of observed classification counts conducted in the C-470 corridor in July 2014

4.3 Future Year Freeway Operations

Future No-Build and Build traffic analyses were performed the same way as described in the existing traffic conditions. Level of Service (LOS) for C-470 were computed for basic freeway segments, weave sections, ramp junctions and signalized intersections using Highway Capacity Software (HCS) 2010. It should be noted that the LOS in the tolled express lanes is measured the same way as the general purpose lanes but there is not an explicit standard or currently defined HCM methodology. However it is recognized that CDOT intend to manage these lanes such that traffic flows freely and to keep the express toll lanes flowing at 45 MPH or faster along the C-470 corridor. To accomplish these goals CDOT will continuously monitor traffic volumes along the corridor in both the general purpose and tolled express lanes and adjust the time of day toll rates, increasing or decreasing depending on the levels of congestion to meet the operational goals. LOS C can be considered a reasonable maximum LOS for the tolled express lanes.

As noted for existing conditions LOS for the interchange ramp terminal intersections were determined applying the HCM 2010 Chapter 22, Interchange Ramp Terminals methodology.

4.3.1 Basic Freeway Segments

The results of the C-470 basic freeway segments for the 2035 No Action and the 2035 Proposed Action are summarized in **Table 9**. The results indicate that for the No-Action Alternative nearly all freeway sections in each direction, between interchanges, are projected to operate at a deficient LOS E or F during one or both peak hours, as shown in yellow. Under the Proposed Action basic freeway LOS and/or freeway density is expected to improve relative to the No-Action Alternative for nearly all C-470 segments.

Table 9: 2035 Basic Freeway Segment Operations Summary

	Basic Freeway Segements		No Action				Proposed Action			
			AM Peak		PM Peak		AM Peak		PM Peak	
	From	To	Density	LOS	Density	LOS	Density	LOS	Density	LOS
Westbound C-470	E-470	I-25 Off ramp	23.4	C	24.7	C	23.2	C	25.0	C
	I-25 Off ramp	I-25 N/S Off ramp Split	19.4	C	20.9	C	11.7	B	14.6	B
	I-25 Off ramp	I-25 On ramp	19.5	C	20.1	C	24.1	C	23.8	C
	I-25 Ramps	C470	12.0	B	18.8	C				
	I-25 SB On Ramp	I-25 N/S On ramp Merge					3.5	A	11.1	B
	I-25 N/S Ramp Merge	C470					10.0	A	18.6	C
	I-25 On ramp	Yosemite On ramp	21.0	C	26.4	D	19.0	C	18.7	C
	Yosemite On ramp	Quebec Off ramp	23.4	C	38.9	E	21.4	C	27.0	D
	Quebec Off ramp	Quebec On ramp	24.2	C	36.6	E	22.4	C	21.9	C
	Quebec On ramp	University On ramp	34.5	D	52.9	F				
	Quebec On ramp	ML ingress					35.1	E	39.0	E
	ML ingress	ML egress					32.0	D	33.7	D
	ML egress	University Off ramp					38.2	E	46.9	F
	University Off ramp	University On ramp	28.1	D	35.6	E				
	University Off ramp	ML egress					27.6	D	32.1	D
	ML egress	University On ramp					29.9	D	40.9	E
	University On	Broadway Off	43.5	E	55.3	F				
	Broadway Off ramp	Broadway On ramp	29.1	D	38.4	E				
	Broadway Off ramp	ML ingress					28.0	D	46.1	F
	ML ingress	Broadway On ramp					26.2	D	37.6	E
	Broadway On ramp	Lucent Off ramp	35.7	E	58.8	F				
	Lucent Off ramp	Lucent On ramp	26.5	D	33.0	D				
	Lucent Off ramp	ML combo					21.6	C	27.8	D
	ML combo	Lucent On ramp					11.7	B	15.1	B
	Lucent On ramp	Santa Fe Off ramp	38.8	E	50.4	F	21.6	C	25.2	C
	Santa Fe Off ramp	Santa Fe On ramp	30.0	D	37.9	E	26.8	D	32.2	D
	Santa Fe On ramp	lane drop	50.0	F	59.0	F				
	Lane drop	Platte Canyon Off ramp	25.5	C	27.5	D				
	Platte Canyon Off ramp	Platte Canyon On ramp	33.6	D	37.2	E	32.1	D	33.5	D
	Platte Canyon On ramp	Wadworth Off ramp	38.1	E	47.8	F				
	Platte Canyon Off ramp	ML egress					36.1	E	41.8	E
	ML egress	Wadworth Off ramp					22.0	C	25.4	C
	Wadworth Off ramp	Wadworth On ramp	24.2	C	26.2	D	24.5	C	24.6	C
	Wadworth On ramp	ML egress					22.1	C	22.4	C
	Wadworth On ramp	Kipling Off ramp	37.0	E	40.9	E				
	Kipling Off ramp	Kipling On ramp	23.7	C	23.7	C	24.9	C	28.3	D
	Kipling On ramp	W of C-470	27.0	D	27.2	D	28.2	D	32.1	D

Table 9: 2035 Basic Freeway Segment Operations Summary, continued

	Basic Freeway Segements		No Action				Proposed Action			
			AM Peak		PM Peak		AM Peak		PM Peak	
	From	To	Density	LOS	Density	LOS	Density	LOS	Density	LOS
Eastbound C-470	Kipling Off ramp	W of C-470	25.5	C	25.4	C	28.5	D	26.5	D
	Kipling Off ramp	Kipling On ramp	22.4	C	21.2	C				
	Kipling Off ramp	ML ingress					25.0	C	22.4	C
	ML ingress	Kipling on Ramp					11.7	B	13.6	B
	Kipling On ramp	Wadworth Off ramp	31.8	D	32.9	D				
	Wadworth Off ramp	Wadworth On ramp	25.3	C	23.8	C	23.0	C	23.7	C
	Wadworth On ramp	Santa Fe Off ramp	51.7	F	52.3	F				
	Wadworth On ramp	ML ingress					45.9	F	44.5	E
	ML ingress	ML egress					34.4	D	37.7	E
	ML egress	Santa Fe Off ramp					40.4	E	42.6	E
	Santa Fe Off ramp	Santa Fe On ramp	33.7	D	30.8	D	25.4	C	24.4	C
	Lucent Off ramp	Lucent On ramp	31.1	D	28.6	D				
	Lucent Off ramp	ML egress					28.5	D	24.5	C
	ML egress	Lucent On ramp					32.7	D	26.2	D
	Lucent On ramp	Broadway Off ramp	55.4	F	37.9	E				
	Broadway Off ramp	Broadway On ramp	37.5	E	28.1	D				
	Broadway Off ramp	ML ingress					50.2	F	31.1	D
	ML ingress	Broadway On ramp					36.0	E	27.4	D
	Broadway On ramp	University Off ramp	61.4	F	45.4	F				
	University Off ramp	University On ramp	38.4	E	28.9	D				
	University Off ramp	ML ingress					45.9	F	28.7	D
	ML ingress	University On ramp					41.2	E	26.5	D
	University On ramp	Quebec Off ramp	64.2	F	39.2	E				
	University On ramp	ML Combo					76.3	F	37.9	E
	ML Combo	Quebec Off ramp					32.5	D	22.1	C
	Quebec Off ramp	Quebec On ramp	43.6	E	30.2	D	39.3	E	25.7	C
	Quebec On ramp	Yosemite Off ramp	46.2	F	29.5	D				
	Quebec On ramp	ML egress					40.7	E	26.8	D
	Yosemite Off ramp	I-25 Off ramp	35.1	E	24.9	C	39.2	E	25.0	C
	C470	I-25 N/S Split					22.9	C	9.7	A
	I-25 Off ramp	I-25 On Ramp	16.2	B	23.2	C				
	ML egress	I-25 On ramp					19.0	C	25.5	C
	C470	I-25 N/S Ramp Split	33.0	D	12.8	B				
	I-25 N/S Ramp Merge	I-25 On ramp					10.4	A	18.5	C
	I-25 N/S On ramp Merge	E-470	9.3	A	17.0	B				
	I-25 On ramp	E of I-25	17.5	B	28.7	D	19.0	C	29.3	D

4.3.2 Freeway Merge

The results of the C-470 freeway merge analysis for the 2035 No-Action Alternative and the 2035 Proposed Action are summarized in **Table 10.** The Proposed Action includes a continuous auxiliary lane on C-470 in each direction between many of the interchanges along the corridor. Locations with auxiliary lanes were analyzed as weave sections instead of separate merge and diverge conditions, as appropriate. As shown, nearly all merge operations for the No-Action Alternative were predicted to operate at congested levels LOSE/F during one or both peak hours. Under the Proposed Action interchange merge conditions were reported to improve compared to the No-Action Alternative with the exception in the Kipling westbound on ramp where degradation in LOS was reported. Under the Proposed Action, additional traffic is being served by this ramp creating the congested merge operations. As noted previously, the tolled express lane egress creates turbulence in the general purpose lanes as reported in the westbound direction of C-470 during the PM peak hour.

Table 10: 2035 Freeway Merge Operations Summary

	On-ramp	No Action				Proposed Action			
		AM Peak		PM Peak		AM Peak		PM Peak	
		Density	LOS	Density	LOS	Density	LOS	Density	LOS
Westbound C-470	I-25 On from C-470					27.6	C	26.4	C
	I-25 On from I-25 NB					4.3	A	12.9	B
	Yosemite On	26.8	C	42.9	F	22.0	C	31.6	D
	Quebec On	27.7	C	35.1	F	29.1	D	31.0	D
	Que - Colo ML egress					32.2	D	35.6	F
	Univ - Broad ML egress					31.2	D	37.1	E
	University On	38.0	F	41.7	F				
	Broadway On	36.0	E	44.0	F				
	Lucent On	38.1	E	42.6	F				
	Santa Fe On	41.7	F	44.0	F	25.8	C	27.2	C
	Platte Canyon On	29.8	D	33.6	F	35.0	D	37.6	E
	Wadworth On	36.6	E	38.4	F				
	Kipling On	29.7	D	29.8	D	40.3	F	46.8	F
Eastbound C-470	Kipling On	32.3	D	33.0	D				
	Wadworth On	40.8	F	40.9	F	34.6	F	34.1	D
	Wads - SF ML egress					30.7	D	31.7	D
	Luc - Broad ML egress					34.8	D	30.3	D
	Lucent On	42.4	F	36.2	E				
	Broadway On	44.3	F	39.8	F				
	University On	44.2	F	36.7	E	41.5	F	31.3	D
	Quebec On	50.8	F	38.4	F	47.6	F	35.3	F
	ML egress					15.2	B	21.5	C

4.3.3 Freeway Diverge

The results of the C-470 freeway diverge analysis for the 2035 No-Action Alternative and the 2035 Proposed Action are summarized in **Table 11**. As discussed in the Merge Analysis, the Proposed Action includes a continuous auxiliary lane on C-470 in each direction between many of the interchanges along the corridor. Locations with auxiliary lanes were analyzed as weave sections instead of separate merge and diverge conditions, as appropriate. As shown, the majority of diverge operations for the No-Action Alternative were predicted to operate at congested levels LOSE/F during at least one of the peak hours. Under the Proposed Action, interchange diverge conditions were reported to be consistent and or improved compared to the No-Action Alternative. As noted previously, the tolled express lane ingress creates turbulence in the general purpose lanes at some of the ingress locations.

Table 11: 2035 Freeway Diverge Operations Summary

	Off- Ramp	No Action				Proposed Action			
		AM Peak		PM Peak		AM Peak		PM Peak	
		Density	LOS	Density	LOS	Density	LOS	Density	LOS
Westbound C-470	I-25 Off	*24.8*	*C*	*26.1*	*C*	*24.7*	*C*	*26.3*	*C*
	Quebec Off	*24.9*	*C*	*35.8*	*F*	*22.8*	*C*	*4.0*	*A*
	ML ingress					37.2	E	39.3	E
	University Off	25.9	C	34.0	F	28.0	C	31.9	F
	Broadway Off	30.5	D	34.7	F				
	ML ingress					32.5	D	42.9	F
	Lucent Off	26.6	C	35.6	F				
	Santa Fe Off	28.3	D	33.2	F				
	Platte Canyon Off	20.8	C	21.2	C	19.5	B	24.5	C
	Wadworth Off	27.9	C	32.2	F	23.4	C	26.7	C
	Kipling Off	27.3	C	29.3	D				
Eastbound C-470	Kipling Off	19.0	B	18.8	B	21.5	C	19.9	B
	ML ingress					18.5	B	15.7	B
	Wadworth Off	33.0	D	33.7	D				
	ML ingress					33.8	E	33.2	D
	Santa Fe Off	33.6	F	33.7	F	11.1	B	12.1	B
	Broadway Off	34.7	F	27.8	C				
	ML ingress					44.1	F	34.6	D
	University Off	36.2	F	31.3	F				
	ML ingress					42.8	F	32.9	D
	Quebec Off	36.9	F	28.5	D	23.4	F	9.8	A
	Yosemite Off	34.1	F	21.2	C				
	I-25 Off	*33.8*	*D*	*26.2*	*C*				
	E-470 Off (left exit)					42.6	E	38.4	F
	I-25 N/S Ramp Split	38.5	E	18.8	B	*24.4*	*C*	*10.3*	*B*

4.3.4 Freeway Weave

The results of the C-470 freeway weave analysis for the 2035 No-Action Alternative and the 2035 Proposed Action are summarized in **Table 12**. As shown, there are only two weave sections, one in each direction, along C-470 and the reported weave LOS indicate congested operations during one or both peak hours. Under the Proposed Action, the current weave operations were reported to be better under this alternative compared to the No Action alternative. However as noted previously the tolled express lane ingress/egress create additional turbulence on C-470 creating congested weave operations at several of these locations. These locations are highlighted in the table and summarized below including the weave lengths:

Westbound C-470

- Quebec on ramp to ML ingress – 4,260'
- ML egress to University off ramp – 4,500'

Eastbound C-470

- Wadsworth on ramp to ML ingress – 2,000'
- ML egress to Santa Fe off ramp – 4,200'
- ML egress to Yosemite off ramp – 2,800'

Nearly all weave sections are over ¾ mile long with the exception of C-470 eastbound ML egress to Yosemite off ramp weave that has a weave length over ½ mile and the C-470 eastbound Wadsworth to ML egress weave that has a weave length over one third mile. These weave locations are along sections of C-470 that do not have any auxiliary lanes. Therefore, traffic volumes in the general purpose lanes are concentrated in only two lanes contributing to the reported congested weave traffic operations.

Table 12: 2035 Freeway Weave Operations Summary

	Weave Segment		No Action				Proposed Action			
			AM Peak		PM Peak		AM Peak		PM Peak	
	From	To	Density	LOS	Density	LOS	Density	LOS	Density	LOS
WB C-470	Yosemite On	Quebec Off	29.1	D	*	F	26.5	C	*	F
	Quebec On	ML ingress					37.7	E	40.6	E
	ML egress	University Off					40.4	E	44.3	F
	University On	Broadway Off					28.7	D	34.6	D
	Broadway On	Lucent Off					22.5	C	30.9	D
	Lucent combo						10.7	B	17.5	B
	ML egress	Wadworth Off					24.9	C	29.0	D
	ML egress	Kipling Off					18.9	B	22.8	C
EB C-470	Kipling On	Wadworth Off					23.3	C	26.3	C
	Wadworth On	ML ingress					41.7	E	41.0	E
	ML egress	Santa Fe Off					41.9	E	42.4	E
	Santa Fe On	Lucent Off	*	F	35.3	E	28.4	D	26.4	C
	Lucent On	Broadway Off					33.7	D	25.1	C
	Broadway On	University Off					32.9	D	27.6	C
	Combo						26.0	C	16.8	B
	ML egress	Yosemite Off					35.7	E	23.6	C

*V/C > 1

4.4 Interchange Operations

As for existing conditions each of the interchange signalized intersections were analyzed using the HCM 2010 Chapter 22, Interchange Ramp Terminals methodology and the results are summarized in **Table 13**. Even with additional traffic being drawn to the C-470 Corridor due to the increased capacity of the Proposed Action alternative LOS at the interchange intersections were reported to be relatively consistent between the No-Action Alternative and the Proposed Action.

Table 13: 2035 Interchange Operations Summary

	No Action				Proposed Action			
	AM		PM		AM		PM	
Intersection	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
Kipling & C-470 EB	13.3	B	19.5	B	15.0	B	21.7	C
Kipling & C-470 WB	28.1	C	81.1	F	25.7	C	110.2	F
Wadworth & C-470 EB	73.8	E	74.5	E	79.6	E	42.0	D
Wadworth & C-470 WB	33.8	C	42.0	D	27.0	C	53.3	D
Santa Fe & C-470 EB	52.7	D	>120	F	95.7	F	72.3	E
Santa Fe & C-470 WB	23.5	C	22.8	C	30.6	C	63.2	E
Lucent & C-470 EB	24.0	C	26.0	C	31.7	C	39.1	D
Lucent & C-470 WB	36.7	D	108.2	F	62.1	E	>120	F
Broadway & C-470 EB	51.5	D	15.6	B	>120	F	11.6	B
Broadway & C-470 WB	16.0	B	20.4	C	23.9	C	25.8	C
University & C-470 EB	43.4	D	28.5	C	49.0	D	51.7	D
University & C-470 WB	29.0	C	68.5	E	39.3	D	64.3	E
Quebec & C-470 EB	79.9	E	14.1	B	>120	F	35.1	D
Quebec & C-470 WB	26.2	C	>120	F	26.3	C	>120	F
Yosemite & C-470 EB	39.1	D	14.6	B	54.1	D	12.9	B
Yosemite & C-470 WB	14.7	B	47.4	D	7.0	A	38.2	D

4.4 2035 C-470 Corridor System Analysis

The corridor system evaluation consists of corridor travel times/travel reliability, vehicles miles traveled (VMT) and vehicle hours traveled (VHT). Peak hour corridor travel times were estimated from a macro-level evaluation using reported HCS travel speeds from the basic freeway segment, merge/diverge weave analyses and current corridor travel times. Peak period corridor travel times were determined from a micro-level traffic analysis using traffic simulation model results prepared as part of the *C-470 Express Toll Lanes Traffic Operations Analysis Report*, June 2015, by Cambridge Systematics for Douglas County. Reported VMT and VHT results from the traffic micro-simulation model are presented in this report also.

4.4.1 Peak Hour Corridor Travel Time/Travel Reliability – Macro-level

C-470 corridor peak hour, peak direction travel times from I-25 to Kipling were estimated for the No-Action Alternatives and the Proposed Action for the AM and PM peak hours. During the morning the peak direction of travel is in the eastbound direction and during the evening the westbound direction is the peak travel direction. Travel times for the general purpose lanes and tolled express lanes associated with each alternative were estimated. For the general purpose

lanes the peak hour, peak direction travel times were estimated based on current C-470 peak hour, peak direction corridor travel times and travel speed results reported from the HCS analyses for each of the alternatives. As discussed previously, CDOT will manage the tolled express lanes such that traffic flows freely. LOS C can be considered a reasonable maximum LOS for the tolled express lanes which would reflect a corridor travel speed of approximately 55 MPH. The estimated C-470 peak hour, peak direction corridor travel times are summarized in **Table 14**.

Table 14: 2035 Peak Hour Peak Direction C-470 Travel Times (minutes)

Alt.	Lanes	Time Period	Eastbound	Westbound
No-Action	Existing	AM Peak Hour	23-25	
		PM Peak Hour		32-33
Proposed Action	GP lanes	AM Peak Hour	22-24	
		PM Peak Hour		29-30
	Express Lanes	AM Peak Hour	14-15	
		PM Peak Hour		14-15

As shown, travel time in the express lanes for the C-470 section from Kipling Parkway to I-25 would be approximately 14-15 minutes during of each of the peak hours. Peak direction travel times in the general purpose lanes of the Proposed Action would be 1 to 3 minutes shorter than for the No-Action Alternative.

The reliability of travel with the No-Action Alternative would continue to worsen, resulting in substantial effects to corridor mobility, affecting economic viability of businesses in the corridor area and quality of life for corridor residents.

The Proposed Action would provide reliable travel times in the tolled express lanes while maintaining consistent and/or better travel times in the general purpose lanes compared to the No-Action Alternative.

4.4.2 Vehicle Miles of Travel /Vehicle Hours Traveled

The following is contained in the *C-470 Express Toll Lanes Traffic Operations Analysis Report*, June 2015 prepared by Cambridge Systematics for Douglas County.

The two major MOEs for understanding the overall changes in network-wide performance that were used are the Vehicle Miles Traveled (VMT) and the Vehicle Hours Traveled (VHT). The VMT can show increases in vehicle throughput or be used to analyze changes in routing, where the VHT can be used as an overall statistic to show increases or decreases in congestion and/or delay along the roadway. The future VMT and VHT for both the AM and PM peak periods can be seen below in **Table 15**.

Table 15: 2035 Forecast WMT and VHT

6:00 am to 1:00 pm and 1:00 pm to 8:00 pm

	VMT (Millions)		VHT (Thousands)	
	AM	**PM**	**AM**	**PM**
No Action	1.67	1.62	53.4	69.1
Proposed Action	1.77	1.90	49.1	52.3
Percent Change	6%	17%	-8%	-24%

Source: Cambridge Systematics, Inc.

It can be seen above in **Table 15** that the Proposed Action design has an impact on the entire corridor. In the 2035 design year, a slight reduction (8%) in VHT can be seen in the AM peak period, but a more significant impact is seen in the PM peak period, with a 24% reduction in VHT for all vehicles in the network. Another interesting impact that can be seen in the network-wide statistics is that an increase in VMT is achieved with the Proposed Action. This VMT is the result of increase of vehicle throughput along the C-470 mainline as a result of the reduction of congestion and addition of toll lanes to avoid the congestion. Given that the total VMT increased and the total VHT is still decreased is clear indication that the Proposed Action is improving the operational conditions of the entire network, which includes the general purpose lanes, auxiliary lanes, express lanes, ramps, and the arterials up to the nearest adjacent intersections.

4.4.3 Peak Period Corridor Travel Time/Travel Reliability – Micro-level

The average travel times from one end of the study area corridor to the other along C-470 is a good measure of the impact of the express lanes. This helps to show the expected travel time savings that the average user can expect if they choose to pay to use the express lanes. The average travel times in the AM peak period (6AM-1PM) eastbound direction and PM peak period (1PM-8PM) westbound direction of travel on C-470 are shown below in **Table 16**.

Table 16: 2035 Peak Period Peak Direction C-470 Travel Times (minutes)

Alt.	Lanes	Time Period	Eastbound	Westbound
No-Action	Existing	AM Peak Hour	37-38	
		PM Peak Hour		48-49
Proposed Action	GP lanes	AM Peak Hour	32-33	
		PM Peak Hour		42-43
	Express Lanes	AM Peak Hour	15-16	
		PM Peak Hour		19-20

Source: Cambridge Systematics, Inc.

It should be noted that the C-470 Corridor limits for the reported peak period travel times are eastbound C-470 (Kipling to I-25) and westbound C-470, an average of travel times that end at Kipling and start at the following locations:

- E-470 WB approximately ¼ mile east of I-25
- I-25 NB approximately ¼ mile south of Lincoln Avenue
- I-25 SB approximately ¼ mile north of County Line Road

These starting westbound travel time limits were selected in order to capture all the delays on I-25 and E-470 associated with delays and queuing of traffic from westbound C-470 that spillback onto these facilities and associated ramps, especially under the No-Action Alternative. For the Proposed Action, the reported travel times also begin at the locations noted above, and the 19-20 minute travel time for the tolled express lanes include time spent on E-470 or I-25 before the vehicles physically enter the tolled express lanes (the average speeds in the tolled express lanes exceed 45 miles per hour).

It is acknowledged that the reported corridor peak period travel times from the micro-simulation model are greater than the peak hour travel times which were determined at a macro-level that were estimated based on current corridor travel times and HCS reported travel speeds. The HCM methodologies have limitations with regard to upstream and downstream congested conditions as well as the accounting for the interaction of vehicles traveling along the corridor. The micro-simulation model better captures traffic operating conditions affecting the corridor. Each of the corridor travel time evaluations, macro-level and micro-level, confirm that the Proposed Action alternative would provide reliable travel times in the tolled express lanes in addition to maintaining and or improving travel times in the general purpose lanes, relative to the No Action alternative.

4.5 Future Safety Conditions

Capacity improvements and/or some type of demand management, on the C-470 corridor is needed to accommodate the additional travel demand, and address congestion and delay both now and in the future years. If the existing conditions were perpetuated, maintaining the existing freeway would expose motorists to increased traffic congestion above what currently exists. Because the No-Action Alternative would keep the facility "as is" no substantial improvements to safety would occur to reduce the crash rates. Because the rate at which the crashes occur remains the same as existing, but the amount of traffic using the facility increases, the total number of crashes would be expected to increase over time for the No-Action Alternative.

The Proposed Action would improve safety conditions along the C-470 corridor by providing additional capacity on C-470 with the tolled express lanes, eliminating the two left lane drops on westbound C-470 between E-470 and Yosemite, a design that will operate in a safer manner. Eliminating these left lane drops was identified as an important improvement for local corridor stakeholders. In addition corridor safety and traffic flow also would benefit from the continuous auxiliary lanes between many of the interchanges along the corridor. All C-470 corridor improvements would meet current design standards. The combination of increased capacity, the elimination of left lane drops and applying current design standards along the C-470 corridor would improve highway operations and provide higher levels of safety. CDOT studies of multi-lane roadways show that additional lanes result in lower crash rate for a given volume. It is

recognized that the tolled express lane ingress/egress will create additional turbulence in the C-470 general purpose lanes especially since they would occur on the left hand side of these lanes which may offset some of the Proposed Action safety and operational benefits.

5.0 TRANSPORTATION IMPACTS AND IMPROVEMENTS

Intersection delay was used to measure transportation impacts of adding capacity to C-470 associated with the Proposed Action. The following methodology was used to determine if the Proposed Action would create an impact at an intersection:

1. Overall intersection peak hour delay was calculated for the No Action
2. Overall intersection peak hour delay was calculated for the Proposed Action
3. If the overall intersection peak hour delay increased 20 seconds or more as a result of the Proposed Action over the No Action then opportunities to improve overall peak intersection delay were identified.

The focus of the evaluation was on the immediately adjacent major intersections along the C-470 corridor. **Table 17** summarizes the 2035 overall intersection peak hour delay evaluation. As shown seven intersections were identified where the Proposed Action overall peak hour intersection delay increased by 20 seconds or more over the No Action.

Table 17: 2035 Overall Intersection Peak Period Hour Delay Summary

Intersection	Intersection Delay (seconds)			
	AM Peak Hour		PM Peak Hour	
	No Action	Proposed Action	No Action	Proposed Action
Yosemite St & Chester St	2.8	3.2	13.5	12.7
Yosemite & Plaza Dr	10.6	10.5	29.8	17.7
Yosemite & C 470 WB on ramp	17.6	14.3	31.2	28.6
Yosemite & C 470 EB Off ramp	18.3	20.5	13.2	13.6
Yosemite & Park Meadows	62.3	48.1	48.7	44.2
Chester & County Line	27.1	28.6	28.9	32
County Line & Quebec	55.7	125.7	130.3	192.2
Quebec & C 470 WB on ramp	26.8	36.1	113.7	146.5
Quebec & C 470 EB on ramp	134.8	151.5	31	50.7
Quebec & Park Meadows Dr	222.1	171.7	59.7	44.1
University & County Line	48.8	41.2	98.4	133.9
University & C 470 WB on ramp	33.3	45.9	52.6	54.6
University & C 470 EB on ramp	45.6	44.9	55.3	54.9
University & Dad Clark	22.2	20.5	26.2	16.6
Broadway & County Line	65.2	67.6	68.2	82.9
Broadway & C 470 WB on ramp	21.6	23.2	27	40.1
Broadway & C 470 EB on ramp	31.8	23	22.4	19.5
Broadway & Dad Clark	23.9	21.2	21.9	22.4
Lucent & County Line	42.2	73.8	110.5	139.4
Lucent & C 470 WB on ramp	25.7	28.7	52.9	72
Lucent & C 470 EB on ramp	25.6	50.1	37.2	76.5
Lucent & Plaza	166.3	254	95.9	129.9
Santa Fe & County Line	310.9	459.4	104.8	118.2
Santa Fe & C 470 WB on ramp	18.1	19.4	19.2	36.2
Santa Fe & C 470 EB on ramp	9.4	11.1	8.1	15.5
Santa Fe & Blakeland Dr	14	46.3	17.1	63.7
Wadsworth & Chatfield Ave.	69.3	66.4	67.4	56.1
Wadsworth & C 470 WB on ramp	16.2	14.7	16.6	19.2
Wadsworth & C 470 EB on ramp	129.4	124.2	97.8	83.3
Wadsworth & Deer Creek Canyon	4.3	3.9	6.1	6
Kipling/Kipling Pkwy & Chatfield Ave.	28.1	29	28.3	28.7
Kipling & Remington	27.2	26.7	26.4	25.4
Kipling & C 470 WB on ramp	8.6	8.7	9.3	22.4
Kipling & C 470 EB on ramp	22.5	22.3	27.9	29

Improvements to the identified intersections were examined to reduce overall peak hour intersection delay associated with the Proposed Action. A sensitivity evaluation was conducted to determine at what year improvements to these intersections would be needed. **Table 18** summarizes the intersection improvements and probable year that these improvements would be required.

The off-system intersections are not impacts and mitigation. The off-system intersections are requirements of the 2035 ultimate configuration.

Table 18: Potential Local Intersection Improvements Summary

Intersection	Year			Intersection Improvement
	2018	2025	2035	
Quebec and County Line	X			Provide three southbound thru lanes, one southbound right-turn lane, and eastbound right-turn overlap phasing
Lucent and County Line	X			Add westbound dual left-turn lanes and change eastbound to shared thru/right-turn lane.
Lucent and Plaza	X			Change eastbound/westbound phasing from split phase to protected left. Add westbound right-turn overlap phasing
Santa Fe and County Line	X			Change westbound to separate single left and through lanes. Change phasing to protected eastbound/westbound left turns.
Quebec and C-470 WB on-ramp		X		Change westbound to dual left-turn lanes and shared through/right-turn lane
University and County Line		X		Add eastbound right-turn overlap phasing
Santa Fe and Blakeland			X	Major improvements TBD by Santa Fe Planning and Environmental Linkages Study

These improvements would fit within the existing ROW of the intersection and would not result in substantial reconstruction. Therefore, minimal impacts to the surrounding area would result.