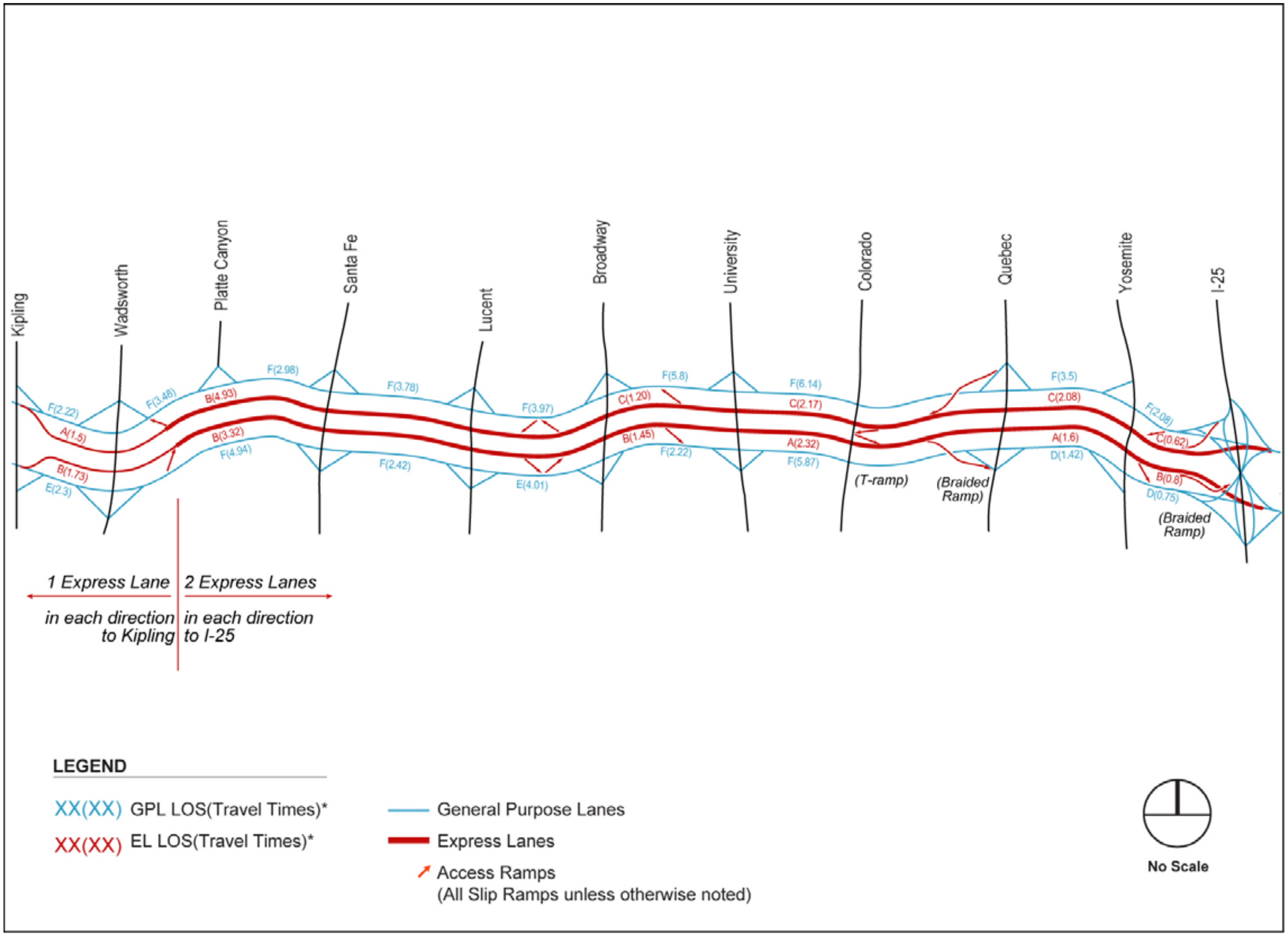
Figure 6.3
PM Peak Hour Travel Times



* Travel Time in minutes

Table 6.1
AM/PM Peak Hour Intersection Delay and Levels of Service

Intersection	AM Average Delay (seconds)	AM LOS	PM Average Delay (seconds)	PM LOS
Ken Caryl Avenue/West Ramps	17.13	B	17.79	B
Ken Caryl Avenue/East Ramps	6.47	A	15.51	B
Ken Caryl Avenue/Simms Street	26.90	C	36.11	D
Ken Caryl Avenue/Simms Street	41.90	D	35.63	D
Chatfield Avenue/Kipling Parkway	37.56	D	46.81	D
Kipling Parkway/North Ramps	17.07	B	13.96	B
Kipling Parkway/South Ramps	32.74	C	36.48	D
Ken Caryl Avenue/Wadsworth Boulevard	30.79	C	45.04	D
Chatfield Avenue/Wadsworth Boulevard	37.39	D	50.89	D
Wadsworth Boulevard/North Ramps	16.35	B	20.49	C
Wadsworth Boulevard/South Ramps	39.53	D	47.15	D
Ken Caryl Avenue/Pierce Street	34.41	C	38.82	D
Chatfield Avenue/Pierce Street	9.53	A	12.87	B
Ken Caryl Avenue/Platte Canyon Drive	51.77	D	27.23	C
Chatfield Avenue/Platte Canyon Drive	49.37	D	>100.00	F
Santa Fe Drive/Mineral Avenue	52.79	D	62.57	E
Santa Fe Drive/County Line Road	41.86	D	24.80	C
Santa Fe Drive/North Ramps	32.44	C	36.72	D
Santa Fe Drive/South Ramps	45.45	D	32.35	C
Santa Fe Drive/Blakeland Drive	27.11	C	32.97	C
Santa Fe Drive/Town Center Drive	22.74	C	12.77	B
Santa Fe Drive/Highlands Ranch Parkway	55.79	E	64.77	E
Lucent Boulevard/County Line Road	14.55	B	34.53	C
Lucent Boulevard/North Ramps	23.34	C	33.02	C
Lucent Boulevard/South Ramps	6.77	A	16.98	B
Lucent Boulevard/Plaza Drive	30.32	C	34.02	C
Lucent Boulevard/Town Center Drive	19.46	B	12.12	B
Lucent Boulevard/Highlands Ranch Parkway	34.78	C	35.77	D
Broadway/Dry Creek Road	25.99	C	27.38	C

Intersection	AM	AM	PM	PM
	Average Delay (seconds)	LOS	Average Delay (seconds)	LOS
Broadway/Mineral Avenue	47.38	D	75.73	E
Broadway/County Line Road	84.63	F	91.72	F
Broadway/North Ramps	33.19	C	30.34	C
Broadway/South Ramps	22.95	C	21.37	C
Broadway/Dad Clark Drive	52.49	D	51.21	D
Broadway/Plaza Drive	48.62	D	31.89	C
Broadway/Highlands Ranch Parkway	>100.00	F	67.90	E
Mineral Avenue/Dry Creek Road	11.76	B	24.42	C
University Boulevard/Dry Creek Road	50.54	D	66.24	E
University Boulevard/County Line Road	85.69	F	>100.00	F
University Boulevard/North Ramps	28.33	C	10.76	B
University Boulevard/South Ramps	19.59	B	10.94	B
University Boulevard/Dad Clark Drive	26.71	C	25.78	C
University Boulevard/Highlands Ranch Parkway	42.89	D	85.04	F
Colorado Boulevard/T-Ramps	50.08	D	20.10	C
Colorado Boulevard/Dry Creek Road	35.59	D	54.00	D
Colorado Boulevard/County Line Road	66.75	E	69.13	E
Holly Street/Dry Creek Road	70.66	E	>100.00	F
Holly Street/County Line Road	25.91	C	30.28	C
Quebec Street/Dry Creek Road	77.58	E	>100.00	F
Quebec Street/County Line Road	70.27	E	>100.00	F
Quebec Street/North Ramps	18.01	B	20.42	C
Quebec Street/South Ramps	34.93	C	26.55	C
Quebec Street/Park Meadows Drive	>100.00	F	71.89	E
Quebec Street/University Boulevard	54.55	D	57.89	E
Yosemite Street/Dry Creek Road	49.23	D	>100.00	F
Yosemite Street/County Line Road	53.56	D	>100.00	F
Yosemite Street/South Ramps	15.73	B	29.77	C
Yosemite Street/North Ramps	20.46	C	59.14	E
Yosemite Street/Park Meadows Drive	20.07	C	77.17	E
Yosemite Street/Lincoln Avenue	34.06	C	42.65	D

Table 6.2
AM Peak Hour Freeway Levels of Service/Density

Express Lanes - Eastbound

From	To	Density	LOS
Kipling	Wadsworth	19.18	C
Wadsworth	Lucent	19.37	C
Lucent	Broadway	17.05	B
Broadway	Colorado	16.10	B
Colorado	Quebec	33.67	D
Quebec	Yosemite	26.55	D
Yosemite	I-25	25.10	C

General Purpose Lanes - Eastbound

From	To	Density	LOS
Ken Caryl Ramps		23.00	C
Ken Caryl	Kipling	39.66	E
Kipling Ramps		32.79	D
Kipling	Wadsworth	39.51	E
Wadsworth Ramps		105.51	F
Wadsworth	Santa Fe	52.55	F
Santa Fe Ramps		23.03	C
Santa Fe	Lucent	94.55	F
Lucent Ramps		52.91	F
Lucent	Broadway	69.25	F
Broadway Ramps		84.37	F
Broadway	University	67.79	F
University Ramps		36.79	E
University	Quebec	41.58	E
Quebec Ramps		24.42	C
Quebec	Yosemite	33.83	D
Yosemite	I-25	55.29	F

Express Lanes - Westbound

From	To	Density	LOS
I-25	Yosemite	9.74	A
Yosemite	Quebec	11.03	B
Quebec	Colorado	23.15	C
Colorado	Broadway	12.93	B
Broadway	Lucent	8.58	A
Lucent	Wadsworth	4.76	A
Wadsworth	Kipling	4.50	A

General Purpose Lanes - Westbound

From	To	Density	LOS
I-25	Yosemite	9.74	A
Yosemite Ramps		0.00	-
Yosemite	Quebec	23.46	C
Quebec Ramps		53.55	F
Quebec	University	44.79	E
University Ramps		62.24	F
University	Broadway	73.23	F
Broadway Ramps		99.14	F
Broadway	Lucent	61.64	F
Lucent Ramps		44.40	E
Lucent	Santa Fe	64.23	F
Santa Fe Ramps		18.09	C
Santa Fe	Platte Canyon	0.00	A
Platte Canyon Ramps		0.00	-
Platte Canyon	Wadsworth	26.02	D
Wadsworth Ramps		16.08	B
Wadsworth	Kipling	27.49	D
Kipling Ramps		13.54	B
Kipling	Ken Caryl	19.18	C
Ken Caryl Ramps		12.94	B

Table 6.3
PM Peak Hour Freeway Levels of Service/Density

Express Lanes - Eastbound			
From	To	Density	LOS
Kipling	Wadsworth	17.31	B
Wadsworth	Lucent	8.62	A
Lucent	Broadway	9.72	A
Broadway	Colorado	7.26	A
Colorado	Quebec	13.84	B
Quebec	Yosemite	9.50	A
Yosemite	I-25	11.15	B
General Purpose Lanes - Eastbound			
From	To	Density	LOS
Ken Caryl Ramps		26.13	D
Ken Caryl	Kipling	48.60	F
Kipling Ramps		70.58	F
Kipling	Wadsworth	97.20	F
Wadsworth Ramps		98.73	F
Wadsworth	Santa Fe	53.71	F
Santa Fe Ramps		19.89	C
Santa Fe	Lucent	31.51	D
Lucent Ramps		59.10	F
Lucent	Broadway	58.53	F
Broadway Ramps		50.18	F
Broadway	University	70.63	F
University Ramps		20.35	C
University	Quebec	39.32	E
Quebec Ramps		20.66	C
Quebec	Yosemite	27.42	D
Yosemite	I-25	25.80	C

Express Lanes - Westbound			
From	To	density	LOS
I-25	Yosemite	20.01	C
Yosemite	Quebec	27.85	D
Quebec	Colorado	32.56	D
Colorado	Broadway	20.47	C
Broadway	Lucent	18.86	C
Lucent	Wadsworth	14.09	B
Wadsworth	Kipling	28.82	D
General Purpose Lanes - Westbound			
From	To	Density	LOS
I-25	Yosemite	20.01	C
Yosemite Ramps		0.00	-
Yosemite	Quebec	50.19	F
Quebec Ramps		52.79	F
Quebec	University	73.02	F
University Ramps		76.25	F
University	Broadway	73.26	F
Broadway Ramps		112.46	F
Broadway	Lucent	67.07	F
Lucent Ramps		56.55	F
Lucent	Santa Fe	55.12	F
Santa Fe Ramps		21.12	C
Santa Fe	Platte Canyon	68.87	F
Platte Canyon Ramps		0.00	-
Platte Canyon	Wadsworth	29.41	D
Wadsworth Ramps		25.12	C
Wadsworth	Kipling	66.54	F
Kipling Ramps		85.23	F
Kipling	Ken Caryl	37.94	E
Ken Caryl Ramps		50.40	F

6.2 TRAFFIC MODELING

Two traffic modeling software programs were used in the analysis of the express toll lanes. The TP+ model, an extension of the DRCOG MINUTP, was used initially due to its ability to model toll lane demand within a macroscopic model. By using the TP+ model initially, the number of access points that needed to be modeled later in the AIMSUN model was reduced. The AIMSUN micro-simulation model was primarily used for the majority of the express lane analysis. It was used to estimate the traffic diversion into the express lanes, and to analyze the traffic operations in the express lanes.

6.2.1 Initial Toll Diversion Forecasts Using Travel Demand Model

The TP+ model is an extension of the macroscopic travel demand model that allows for the assignment of trips to toll roads based on a given toll rate in order to predict volume at potential express lane access locations. Before using the AIMSUN micro-simulation model, a cursory analysis of access locations was performed to reduce the number of alternatives and the amount of calibration that needed to be performed to the AIMSUN model. The TP+ model also allowed for the modeling of the potential extension of C-470 to the northwest corridor to determine the amount of demand that was created through the extension. Using the origin and destination matrices in the travel demand model, the connection between C-470 and the northwest corridor showed little demand for trips between the two corridors. The majority of trips along C-470 are contained within the southwest quadrant of the metro area, with little demand to travel outside the area except to connect to I-70 or I-25. It is anticipated as the entire beltway system reaches full build out, and development exists along its entire length, trips between beltway segments will increase.

6.2.2 Forecasts and Traffic Operations Using Micro-simulation Model

Origin and destination matrices from the regional travel demand model were used as volume input into the simulation model, which was calibrated to mirror traffic operations for existing conditions along C-470. Various parameters including queue lengths, delays, and existing turning movement counts were used to compare and calibrate the dynamic assignment model in AIMSUN to produce results similar to existing conditions. Express lanes were introduced in the simulation model after calibrating the model for existing conditions.

The proportion of travelers using each section of the express lanes was calculated using the dynamic traffic assignment model in the AIMSUN micro-simulation program. The program uses dynamic traffic assignment algorithms to estimate the probability of travelers using a given route from a set of available routes between each origin and destination. The calculated probability is a function of a "utility" that is calculated for each route. The AIMSUN route choice model used is a discrete path choice model, referred to as the C-logit model, and is a variation of the multinomial logit model. The model calculates the choice probability for a given route using the value of the utility of that path as compared to utilities of all other alternative paths.

The utility or the "cost function" can be defined by the user to include a combination of path variables. In this study, the cost function is defined as a combination of travel time and monetary costs as follows:

$$\textit{utility} = \textit{travel time} + a * \textit{monetary cost} \qquad (1)$$

The coefficient "a" in the above equation is used to convert the monetary cost in dollars to travel time in minutes. This value can be estimated based on how much commuters value their travel times; that is, how much they are willing to pay in dollars to save in their travel times.

The value of the coefficient "a" was estimated based on a model developed from results from the stated preference survey completed as part of the ELFS. The model was developed to estimate the monetary cost that the commuters are willing to pay to use the express lanes under different travel time conditions on the C-470 corridor. The model has the following format:

$$\textit{time saved per mile} = \textit{coefficient} * \textit{cost per mile} \qquad (2)$$

The statistical analysis performed in the survey indicated that the following model produced the best fit for the data:

$$\textit{time saved per mile (minutes)} = 10.019 * \textit{cost per mile (dollars)} \qquad (3)$$

Thus, the utility equation to decide on the route choice probability (Equation 1) was coded in the simulation model as follows:

$$\textit{utility} = \textit{travel time} + 10.019 * \textit{monetary cost} \qquad (4)$$

Also, in the simulation model, monetary costs were assigned to express lane sections as follows:

$$\textit{express lane section monetary cost} = \textit{express lane section length} * \textit{cost per mile} \qquad (5)$$

For all other segments, the monetary costs were set to zero so that the utility values for these segments were equal to the travel time on the segments.

The dynamic traffic assignment model assigned the number of trips to the express lanes based on the congestion levels in the general purpose lanes and how much these travelers were willing to pay to avoid these congestion levels, according to Equation 4. During the calibration process, the number of express lane users projected by the simulation model was compared to the number of users derived from the responses in the stated preference survey. If necessary, the model parameters were refined to have the model more accurately reflect the survey results.

To determine the revenue generated from a given express lane cost per mile charge, the following equation was used:

revenue (dollars) = toll charged per vehicle per mile * EL VMT (6)

EL VMT in the above equation is the express lane vehicle mile traveled. Separate simulation runs were performed with different toll rates on the express lanes to determine the toll that produced the best traffic operations combined with the most users.

6.2.3 Calibration of AIMSUN Model

Various parameters including queue lengths, delays, and existing turning movement counts were used to compare and calibrate the dynamic assignment model in AIMSUN to produce results similar to existing conditions. All intersections in the study area were initially analyzed for the existing AM and PM peak volumes and for the existing laneage using the HCM methodologies to identify oversaturated movements and intersections.

Queue data were later collected for these pre-identified, oversaturated movements to measure queues and discharge volumes in the AM and PM peak period. Queue and discharge data were collected every 20 seconds for a minimum of 20 minutes, or 10 signal cycles, to obtain the queue build-up pattern, discharge rate for a specific movement, and queue length. These data, in conjunction with signal timing and phasing patterns were then used not only to verify existing counts but also to calibrate the model. Travel time data and spot traffic volume counts on C-470 were collected to calibrate the micro-simulation model and validate the data collected.

The micro-simulation model was developed using existing laneage, volume, speed, and signal timing information. The micro-simulation model was then calibrated by adjusting vehicle performance, link saturation flow rates, decision distances, and maximum allowable speeds for various turning movements such that the queue build-up patterns, travel speeds, discharge rates, and queue lengths observed in the micro-simulation model were similar to those observed in the field.

Express lanes were introduced into the micro-simulation model after the existing conditions model had been calibrated, validated, and verified against existing operational (field) conditions. The express lanes were introduced with an initially assumed toll rate and the pre-determined value of time to assess validity of traffic diverting into the express lanes. The express lane traffic volumes were then examined for reasonableness by using the pre-determined value of time and the delay or travel time savings (along C-470) that was being predicted by the micro-simulation model.

The micro-simulation model was further refined until equilibrium was achieved between the declared value of time, toll price, and projected travel time savings. This calibrated model was used as a basis for coding and analyzing the proposed future configurations.

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