CAMBRIDGE SYSTEMATICS

C-470 Corridor, Kipling to I-25 Traffic Modeling

Level II Traffic and Revenue

draft

report

prepared for

Douglas County and C-470 Corridor Coalition

prepared by

Cambridge Systematics, Inc.

with contributions from

Parsons Brinckerhoff
Wilson & Company

January 15, 2014

www.camsys.com

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Table of Contents

1.0 Introduction 1-1
1.1 Study Purpose and Limitations 1-1
1.2 Existing Congestion 1-2
1.3 Alternatives Tested 1-3
1.4 EA Update Compatibility 1-5
1.5 Supporting Documents 1-5

2.0 Study Approach 2-1
2.1 Workflow 2-1
2.2 Modeling Methodology 2-1
2.3 Travel Demand 2-2
2.4 Microsimulation 2-5
2.5 Revenue 2-12

3.0 Traffic Demands 3-1
3.1 Base Year Traffic 3-1
3.2 Future traffic Demand 3-6

4.0 Design Concepts 4-1
4.1 Overview 4-1
4.2 Concept Design Process 4-2
4.3 Design Criteria 4-3
4.4 Initial Interim Concept 4-5
4.5 Ultimate Concept 4-8
4.6 RAMP Interim Concept/Project 4-10
4.7 I-25 to Westbound C-470 Direct Ramp Connections 4-12

5.0 Concept of Operations 5-1
5.1 Introduction 5-1
5.2 Tolling Zones 5-1

6.0 Revenue and Transactions 6-1
6.1 Introduction 6-1
6.2 Forecast Toll Rates 6-2

6.3 Transaction and Revenue Forecasts 6-7
6.4 Disclaimer 6-10

7.0 Traffic Operations 7-1
7.1 Overview 7-1
7.2 Interim Ramp Concept/Project 7-2
7.3 2035 Ultimate Configuration 7-6

8.0 HOV 3+ Exemption 8-1

9.0 Key Findings 9-1

List of Tables

Table 2.1 Temporal Limits of Simulation Models 2-6
Table 2.2 Revenue and Transaction Annualization Assumptions 2-12
Table 3.1 C-470 Base Year Comparison *Eastbound* 3-2
Table 3.2 C-470 Base Year Comparison *Westbound* 3-4
Table 3.3 Regional Travel Characteristics 3-6
Table 3.4 C-470 Peak Hour Volumes *Eastbound* 3-7
Table 3.5 C-470 Peak Hour Volumes *Westbound* 3-9
Table 4.1 Initial Alternative Ingress Egress Combinations 4-6
Table 4.2 Ultimate Concept Ingress Egress Combinations 4-8
Table 4.3 Ramp Interim Alternative Ingress Egress Combinations 4-10
Table 5.1 Concept of Operations Parameter Summary 5-1
Table 6.1 Percent of Modeled Revenue by Year 6-2
Table 6.2 Revenue and Transaction Forecast Summary *Revenue in 2013 Dollars* 6-8
Table 7.1 VMT and VHT Summary by Year 7-1

List of Figures

Figure 1.1 Study Location Map....1-2
Figure 1.2 Average Travel Speeds by Segment *May 2013*....1-3
Figure 1.3 Corridor Average Travel Speed *May 2013*....1-3
Figure 2.1 Overall Modeling Workflow....2-2
Figure 2.2 Simulation Modeling Workflow....2-5
Figure 2.3 Simulation Spatial Model Limits....2-6
Figure 2.4 Express Lane Traffic Assignment Illustration....2-8
Figure 2.5 Dynamic Toll Price Algorithm Illustrations....2-9
Figure 2.6 Fixed Pricing Illustration *Westbound C-470 Toll Prices*....2-10
Figure 2.7 Willingness to Pay Probabilities....2-11
Figure 4.1 Planning Process Flow Chart....4-2
Figure 4.2 Ultimate Configuration Typical Sections[a]....4-3
Figure 4.3 Ingress....4-4
Figure 4.4 Egress....4-4
Figure 4.5 Combined Ingress Egress....4-4
Figure 4.6 Lane Change Distance Requirements....4-5
Figure 4.7 Initial Interim Express Lane Concept Plan....4-7
Figure 4.8 Ultimate Express Lane Concept....4-9
Figure 4.9 RAMP Express Lane Concept....4-11
Figure 4.10 I-25 to Westbound C-470 Direct Connect *Ultimate Configuration*....4-13
Figure 5.1 Toll Zones Initial Interim and Ultimate Concepts....5-3
Figure 5.2 Toll Zones RAMP Interim Concepts....5-3
Figure 6.1 Forecast 2018 Toll Prices *Dynamic and Static Pricing Approaches, Interim RAMP Alternative*....6-4
Figure 6.2 Forecast 2025 Toll Prices *Dynamic and Static Pricing Approaches, Interim RAMP Alternative*....6-5
Figure 6.3 Forecast 2035 Toll Prices *Dynamic and Static Pricing Approaches, Interim RAMP Alternative*....6-6

Figure 6.4 Annual Gross Revenue Comparisons RAMP Interim Alternative....6-8

Figure 6.5 Annual Transaction Comparisons RAMP Alternative....6-9

Figure 6.6 Forecast 30-year Gross Revenue and Transactions *RAMP Interim Alternative*....6-9

Figure 6.7 Gross Revenue Stream *RAMP Interim Alternative Fixed-Price Scenario 1*....6-10

Figure 7.1 AM Peak Period VMT and VHT....7-2

Figure 7.2 PM Peak Period VMT and VHT....7-2

Figure 7.3 2035 AM Peak Eastbound C-470 Interim Ramp Project Speed Maps....7-4

Figure 7.4 2035 PM Peak Westbound C-470 Interim Ramp Project Speed Maps....7-5

List of Appendices

A. Base and Future Land Use Assumptions

B. Preliminary Financial Analysis of Segment 1 (I-25 to Kipling)

C-1. One Lane Interim Dynamic Pricing 2018AM

C-2. One Lane Interim Dynamic Pricing 2018PM

C-3. One Lane Interim Dynamic Pricing 2025AM

C-4. One Lane Interim Dynamic Pricing 2025PM

C-5. One Lane Interim Dynamic Pricing 2035AM

C-6. One Lane Interim Dynamic Pricing 2035PM

D-1. One Lane Interim Fixed Pricing I 2018AM

D-2. One Lane Interim Fixed Pricing I 2018PM

D-3. One Lane Interim Fixed Pricing I 2025AM

D-4. One Lane Interim Fixed Pricing I 2025PM

D-5. One Lane Interim Fixed Pricing I 2035AM

D-6. One Lane Interim Fixed Pricing I 2035PM

E-1. One Lane Interim Fixed Pricing II 2018AM

E-2. One Lane Interim Fixed Pricing II 2018PM

E-3. One Lane Interim Fixed Pricing II 2025AM

E-4. One Lane Interim Fixed Pricing II 2025PM

E-5. One Lane Interim Fixed Pricing II 2035AM

E-6. One Lane Interim Fixed Pricing II 2035PM

F-1. Two Lane Ultimate Dynamic Pricing 2035AM

F-2. Two Lane Ultimate Dynamic Pricing 2035AM

1.0 Introduction

1.1 STUDY PURPOSE AND LIMITATIONS

The purpose of this study is to evaluate traffic performance and develop revenue projections of a proposed express lane project on C-470 from I-25 to Kipling Avenue in Douglas County, Colorado. Figure 1.1 illustrates these project limits. This report documents:

- The modeling methodology and procedure;
- The process and criteria used to develop the concepts;
- The concept of operations assumed, as well as the toll setting policy; and
- The transaction and revenue forecasts based on modeling of the design and concept of operations.

The report also identifies issues and next steps needed to further analyze and refine the project

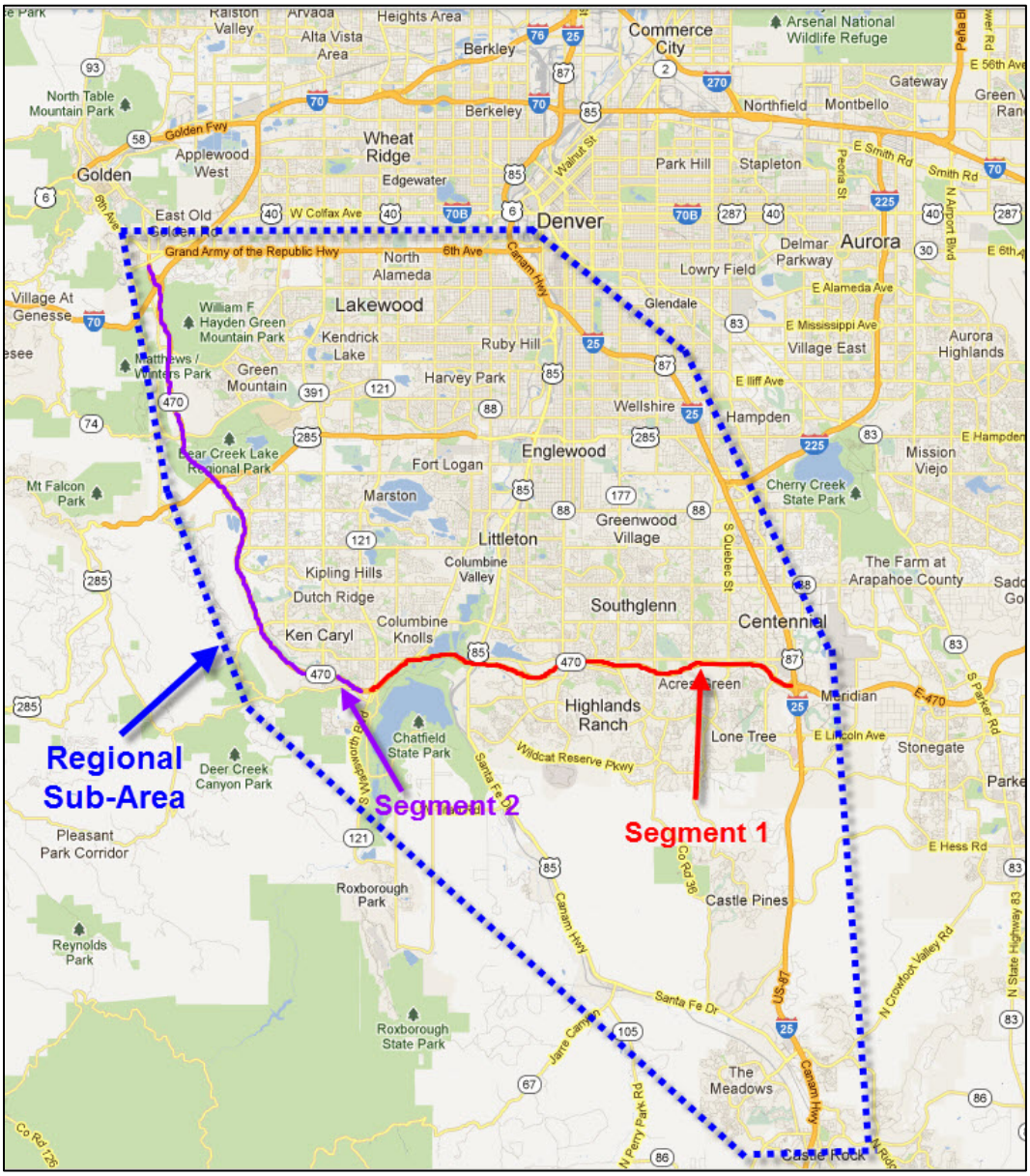
This report includes a Level II, planning-level traffic and revenue study. A Level II study uses existing travel demand models and socioeconomic forecasts, enhanced to allow the types of analysis needed to evaluate traffic and revenue, and should not be used to inform investor decisions. An investment grade study requires further independent verification of assumptions, as well as more extensive sensitivity testing or risk analysis.

The C-470 project that is analyzed in this report is in flux. The concept plans have been in a continual refinement process. Initial modeling results prepared by CS have been used to help inform the process. This document reflects the latest iteration. Given the time and resources invested into the design refinement process, the full extent of evaluating and testing a single concept under a variety of assumptions and conditions did not occur. The findings within this report will identify areas that will need to be refined or further analyzed.

Financial Analysis

This Study Report documents Gross Revenue in 2013 dollars. There is a separate report that has been prepared by Parson Brinkerhoff that uses the results of this study to conduct a Net Financial plan and an assessment of bonding capacity.

Figure 1.1 Study Location Map



1.2 EXISTING CONGESTION

The C-470 corridor experiences significant and increasing congestion today. Travel time runs were conducted in May 2013 at the same time that traffic data was collected. Figures 1.2 and 1.3 illustrate the average travel speeds by segment and by direction. The longest travel time observed in May 2013 was around 30 minutes. It has been observed that this travel time can be over 60 minutes for 13 miles.

Figure 1.2 Average Travel Speeds by Segment
May 2013

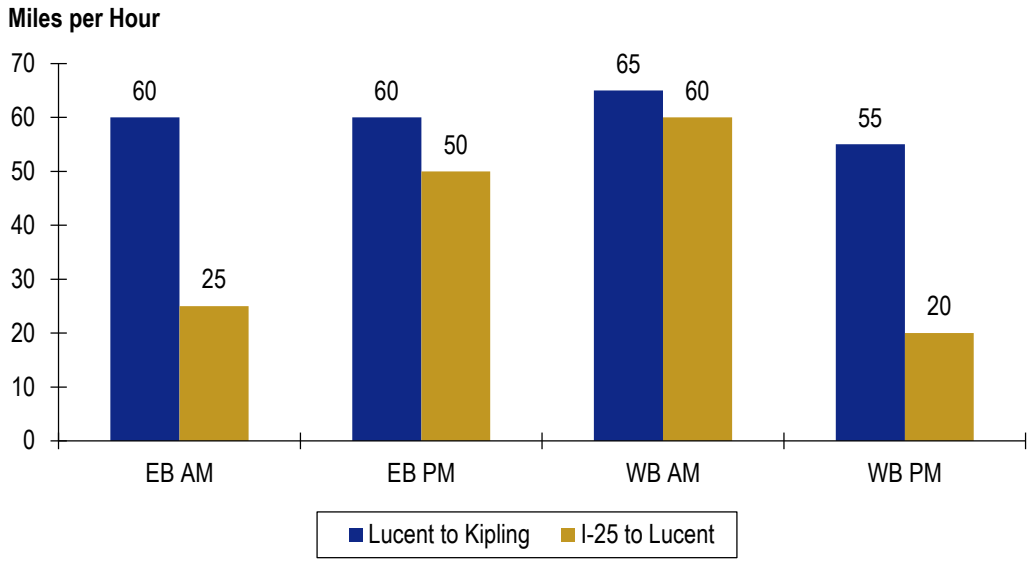
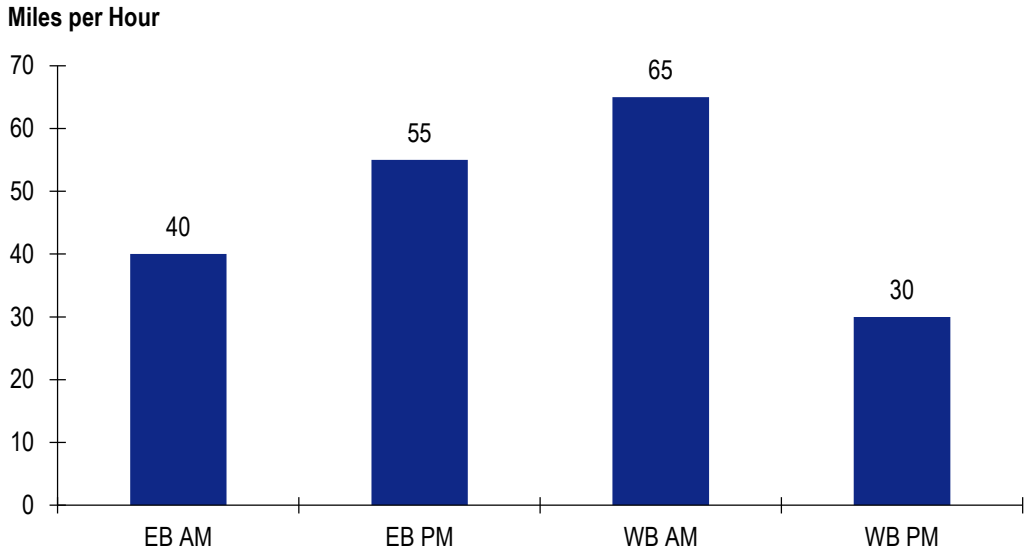


Figure 1.3 Corridor Average Travel Speed
May 2013



1.3 ALTERNATIVES TESTED

The C-470 Study has been an evolving process where a number of concepts have been developed and tested for refinement purposes. The concepts have include both an ultimate configuration and a interim (year opening configuration). Both of these configurations are part of the Environmental Assessment update that is

ongoing. The interim configuration was submitted to CDOT for a special funding program called RAMP (Responsible Acceleration of Maintenance and Partnerships). After the submission of the interim project to RAMP, CDOT made a program decision to scale back the interim project based on the funding availability. The scaled back project is the focus of this report. The alternatives tested in this study report included:

- RAMP Interim Alternative:
  - Westbound Direction – Single Express Toll Lane From Quebec to Wadsworth;
  - Eastbound Direction – Single Express Toll lane from Platte River to Quebec; and
  - Right-Hand Auxiliary Lanes East and Westbound:
    - » From Santa Fe Boulevard to University; and
    - » Quebec to I-25.
- RAMP Interim Alternative – Extended to Kipling (Limited test conducted to understand revenue potential):
  - Westbound Direction – Single Express Toll Lane From Quebec to Kipling;
  - Eastbound Direction – Single Express Toll lane from Kipling to Quebec; and
  - Right-Hand Auxiliary Lanes East and Westbound:
    - » From Santa Fe Blvd to University; and
    - » Quebec to I-25.
- 2035 Ultimate Alternative:
  - Westbound Direction – Single Express Toll Lane From Quebec to Wadsworth;
  - Eastbound Direction – Single Express Toll lane from Platte River to Quebec; and
  - Right-Hand Auxiliary Lanes East and Westbound:
    - » From Santa Fe Boulevard to University; and
    - » Quebec to I-25.

The analysis years modeled for this study included:

- 2018 (Year Opening);
- 2025 (Interim Year); and
- 2035 (Design Year).

The transponder ownership assumptions that have been made for this project by year are:

- Year Opening 2018 – 45%;
- 2025 Interim Year – 60%; and
- 2035 Design Year – 70%.

1.4 EA UPDATE COMPATIBILITY

The Level II traffic and revenue study documented within this report is a planning level study that is providing information on how to best design the study and to determine revenue potential. The traffic information is compatible with the EA update which is being prepared concurrently. The level of detail and traffic modeling methodologies necessary for the EA update are not the same level of micro-simulation being used in the Level II work. However, the source Travel Demand modeling information will be the same.

1.5 SUPPORTING DOCUMENTS

As the study progressed a number of white papers, presentations and documentation have been prepared. These supporting documents are available electronically on a Reading Room wiki page. The documents are as follows:

- Methods and Assumptions;
- Base Model Documentation [to be completed];
- Data Summary Report [to be completed];
- Ingress-Egress White Paper;
- Concept of Operations White Paper; and
- Numerous meetings.

The Reading Room is available at:

https://wiki.camsys.com/display/C470TRAFFIC

- Username: c470trafficuser
- Password: c470traffic

2.0 Study Approach

2.1 WORKFLOW

The C-470 I-25 to Kipling Improvement Study has been a highly interactive process between the Technical Working Group, the Policy Committee and the consultant team. The development and selection of alternatives to be modeled has been at the direction of the Coalition Technical Working Group. The CS modeling team has provided draft modeling information to help inform and guide the selection of the concepts to be carried forward into the Level II traffic and revenue Study and for the Environmental Assessment. The process has been adapted along the way to accommodate new information and changing funding priorities. The Methodology below focuses on the Level II traffic and Revenue Modeling. The information developed will be compatible with the future Environmental Assessment Update that is being developed concurrently with this study.

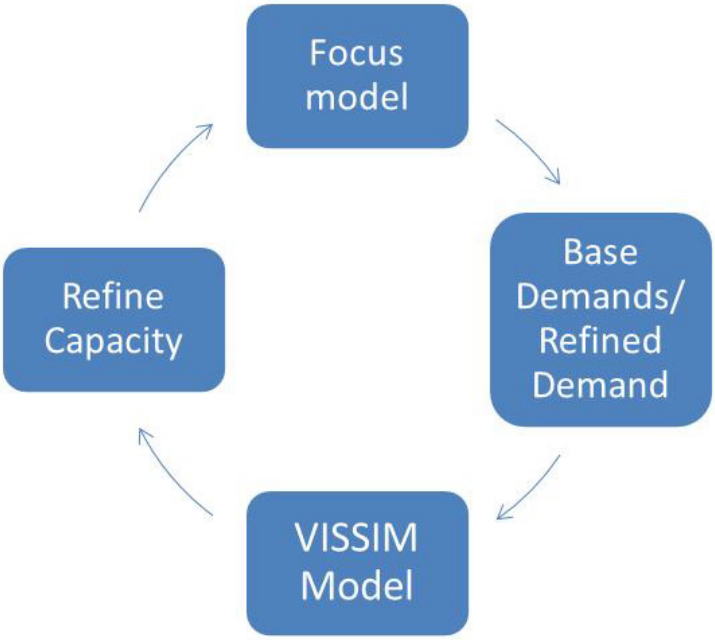
2.2 MODELING METHODOLOGY

There are generally two types of transportation models utilized in alternatives analysis – travel demand models and traffic operations models. DRCOG's FOCUS model is the region's state-of-the-art multimodal travel demand model and is utilized in regional and subregional analysis studies. The FOCUS traffic analysis zone (TAZ) system consists of over 2,800 zones and the highway network incorporates all roadways functionally classified as major arterials and above. While this level of detail is sufficient for regional analysis, evaluating corridor scenarios and especially corridors with a pricing component, such as the C-470 Corridor, requires additional roadway level detail and a model capable of analyzing the dynamic relationship between price and operations in order to accurately analyze different scenarios. Traffic operations models, in contrast with travel demand models, are specifically developed to assess the traffic operating conditions of congested environments and recently have been enhanced with fully integrated pricing components.

For this study these two types of models were fully integrated with one another. Figure 2.1 graphically depicts the concept of linking/integrating travel demand and microscopic models. The interaction between the two models was essentially a transfer of information. Origin-Destination (OD) trip tables, or demand, by vehicle classification were developed in the Focus model in a format compatible with the VISSIM model. The VISSIM model was run using the demands generated from FOCUS. The identification of bottlenecks and other operational issues was fed back to the DRCOG model for trip table refinement, and so on.

The following sections describe in more detail the two types of models.

Figure 2.1 Overall Modeling Workflow



2.3 TRAVEL DEMAND

The Focus travel model is an activity-based model for the Denver region developed by DRCOG. The model synthesizes individual regional households and persons, and forecasts their travel throughout a typical weekday based on personal and travel-related characteristics. A complete technical description of the model and all of its components can be found on DRCOG's web site at: http://www.drcog.org/index.cfm?page=FocusTechnicalResources.

Inputs and Assumptions

Networks – The 2010 and 2035 TransCAD Focus model datasets were provided to the project team by DRCOG. CS reviewed the base and future networks to ensure that the networks were consistent with the project study objectives. The review included, but was not limited to, connectivity, lane configurations, and link capacities.

Land Use – Future Year Land Use from DRCOG was reviewed and summarized to better understand growth in the region as well as within the study corridor. Particular attention was given to high-growth areas close to the corridor. Summaries of Base and Future Land Use Assumptions appear in Appendix A.

Base Year Travel Demand

Travel demand, in the form of origin-destination matrices (ODs) within the larger regional study area, which includes the smaller portion representing the C-470 Corridor, were based on the FOCUS model. To better match the observed traffic data, these ODs were calibrated to observed traffic counts. As shown in Figure 1.1, the regional study area includes the area within blue dashed line and the roadways that will be simulated are shown by the solid red line and is referred to as Segment 1.

The decision to calibrate the demands within the larger regional area, although only the trips within the simulated area are utilized for the revenue and operational analysis, was based on the need to be able to capture regional diversion dynamics associated with the proposed project. This is based on the idea that the design and operations of the C-470 facilities will impact regional travelers' decisions with regard to route choice. The inclusion of a regional network affords travelers that option.

In particular, the design of Segment 2, (denoted by the purple line in Figure ?), can influence the demand for travel in Segment 1, which in turn will impact the revenue estimates. Including all of Segment 2 in the study subarea allows the models to test different design options for Segment 2 to better qualify the estimated design alternatives.

A second level of demand refinement at the study corridor level was also performed to allow for more detailed calibration of the operational elements of the freeway. This step is required in order to calibrate the microsimulation models at the specific roadway level. The static assignments that are part of the FOCUS model are not sensitive to link level operational dynamics and may overestimate demand on specific interchanges.

The calibration of demands was an 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 simulation models. The procedures used to refine the demands is commonly referred to as Origin Destination Matrix Estimation (ODME) and is described in subsequent sections.

Trip matrices were calibrated for the entire regional subarea using the TransCAD ODME procedures, and traffic counts (both historical and new counts collected in 2013), for the following periods:

- AM Period (6:00 a.m. to 1:00 p.m.); and
- PM Period (1:00 p.m. to 8:00 p.m.).

The second level of trip table calibration and refinement at the corridor level (Segment 1) was performed at the hourly level for the full 14 hours, from 6:00 a.m. to 8:00 p.m., that were modeled.

A more complete description of this process is included in the Methods and Assumptions report.

Future Travel Demand

For each of the regional 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.

Modeling Express Lanes

The express lanes that were the focus of this study have a time-of-day pricing component that is based on the levels of congestion experienced within the express lanes at certain 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. Our 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. In terms of incorporating the cost of the proposed managed lanes, the pricing scheme, which is fixed for certain times of the day, matches the assignment time periods within the Focus model and so can be considered by the regional model.

En-Route Decisions

Similar to pre-trip decisions, since 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 and these time periods match those in the FOCUS model, it was 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 was no need to alter the current assignment methodology of the Focus model.

Future Year Growth Estimation

After all of the changes to the model inputs associated with the future year scenarios are 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 for each scenario. Incremental growth for every OD pair was added to the base year calibrated trips. The process is described in detail within the Methods and Assumptions Document.

2.4 MICROSIMULATION

A microsimulation model using VISSIM 5.4 software of C-470 Segment 1 was developed evaluate the Express Toll Lane concepts and to prepare Gross Revenue information. The detailed procedures are documented in the Methods and Assumptions Document. The following discussion is a summary of the microsimulation modeling methodology.

Simulation Workflow Overview

The VISSIM model was developed using the modeling steps outlined in Federal Highway Administration's *Traffic Analysis Tool Box Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*. Figure 2.2 highlights the key steps in the modeling process.

Figure 2.2 Simulation Modeling Workflow

Base Model

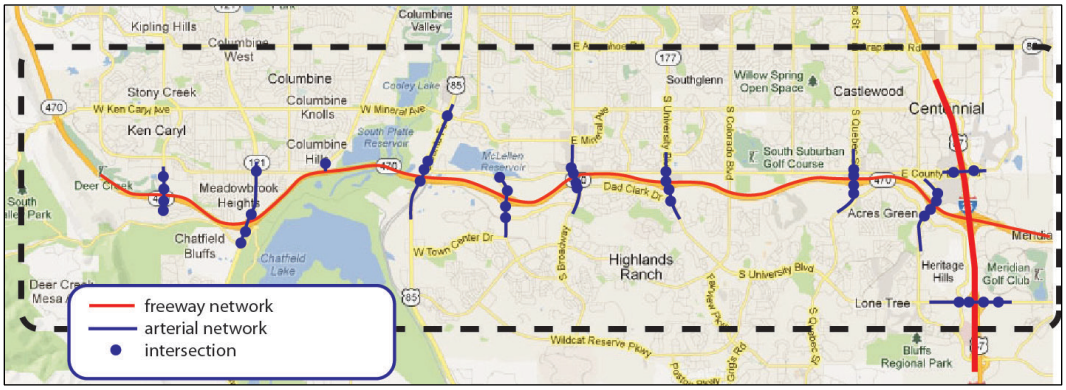
The base VISSIM model was developed following the procedures in the USER guide and the best practices based on industry and CS experience. The model inputs and guidance are documented in the Base Model Document.

Model Limits

VISSIM Model Spatial Limits: The spatial limits of the VISSIM model is illustrated in Figure 2.3. These limits include C-470 corridor from east of I-25 to

west of Kipling Avenue, I-25 from south of Lincoln Avenue to north of County Line Road. Figure 2.3 is an illustration showing the VISSIM model limits.

Figure 2.3 Simulation Spatial Model Limits



VISSIM Model Temporal Limits. The VISSIM models will be built to accommodate two seven-hour model peak periods. The longer periods will allow for more complete toll and revenue information from the simulation, leaving less to estimation. The base year models will only be calibrated to a stringent statistical criteria for the peak three hours within each of the two peak periods. The shoulder hours will be checked for reasonableness but will not receive the same level of scrutiny. The temporal limits are outlined in Table 2.1.

Table 2.1 Temporal Limits of Simulation Models

Time Period	Overall Model Duration
AM Peak Period	6:00 a.m. to 1:00 p.m.
PM Peak Period	1:00 p.m. to 8:00 p.m.

VISSIM Calibration

The VISSIM simulation model was calibrated based on existing conditions that were observed on May 15, 2013. in which the model is run and statistical analysis is conducted.

Model Alternatives

The future conditions will be analyzed using the VISSIM model. The process will include the coding of the geometry of the managed express toll lane concept, and the proposed the concept of operations. The VISSIM model will be coded to include the Managed Lane Module which incorporates toll price setting and willingness to pay. Within the VISSIM simulations, traffic will be dynamically assigned to the managed express toll lanes. The outcome of the traffic simulation will be traffic operations results in the general purpose lanes and the managed

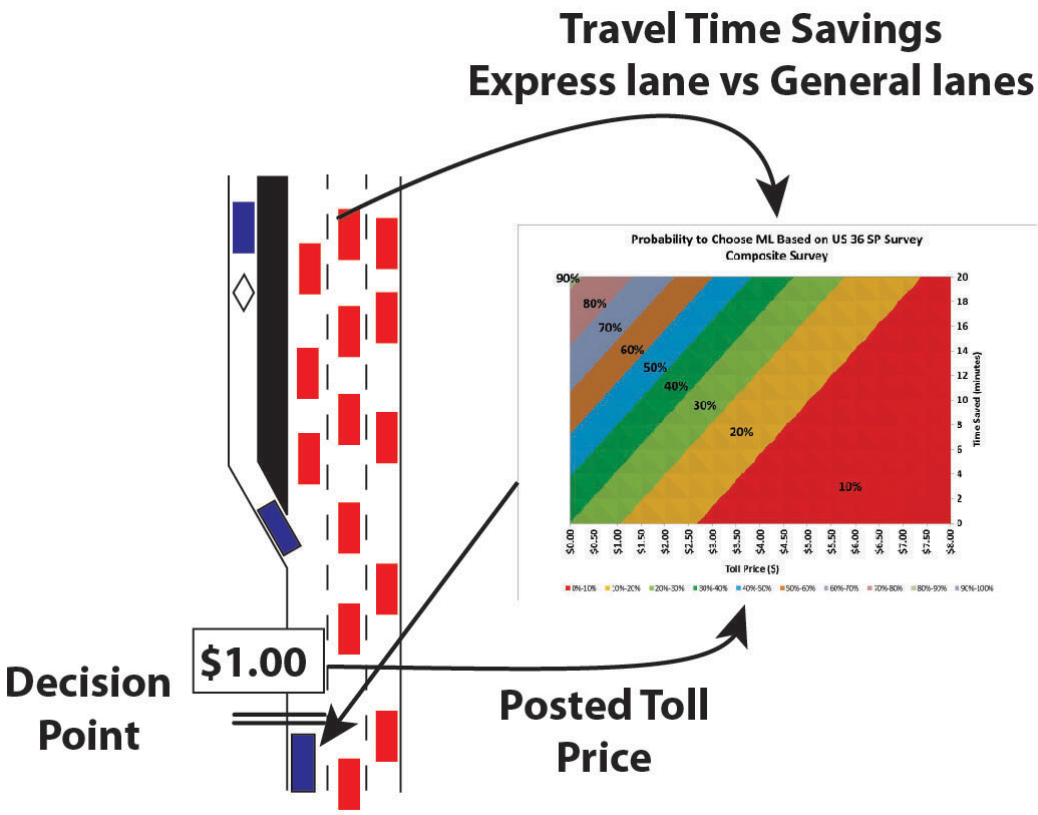
express toll lanes, gross revenue, and the number of toll transactions. The steps for analyzing the express lane alternatives will include the following:

1. Code express lanes and ingress/egress alternatives in the base VISSIM model;
2. Code VISSIM express lane operations including decisions points and tolling zones;
3. Develop and implement willingness to pay logit coefficients;
4. Code and model dynamic pricing to determine fixed variable rates;
5. Model scenarios with willingness to pay, fixed variable rates, and future demands; and
6. Perform sensitivity testing.

VISSIM Managed Lane Module

The VISSIM managed lane module was utilized to assign traffic within the simulation model to the managed express toll lane. 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 will be coded to reflect the ingress/egress of the design concept and the pricing zone structure. Figure 2.4 below illustrates how vehicles are assigned within VISSIM.

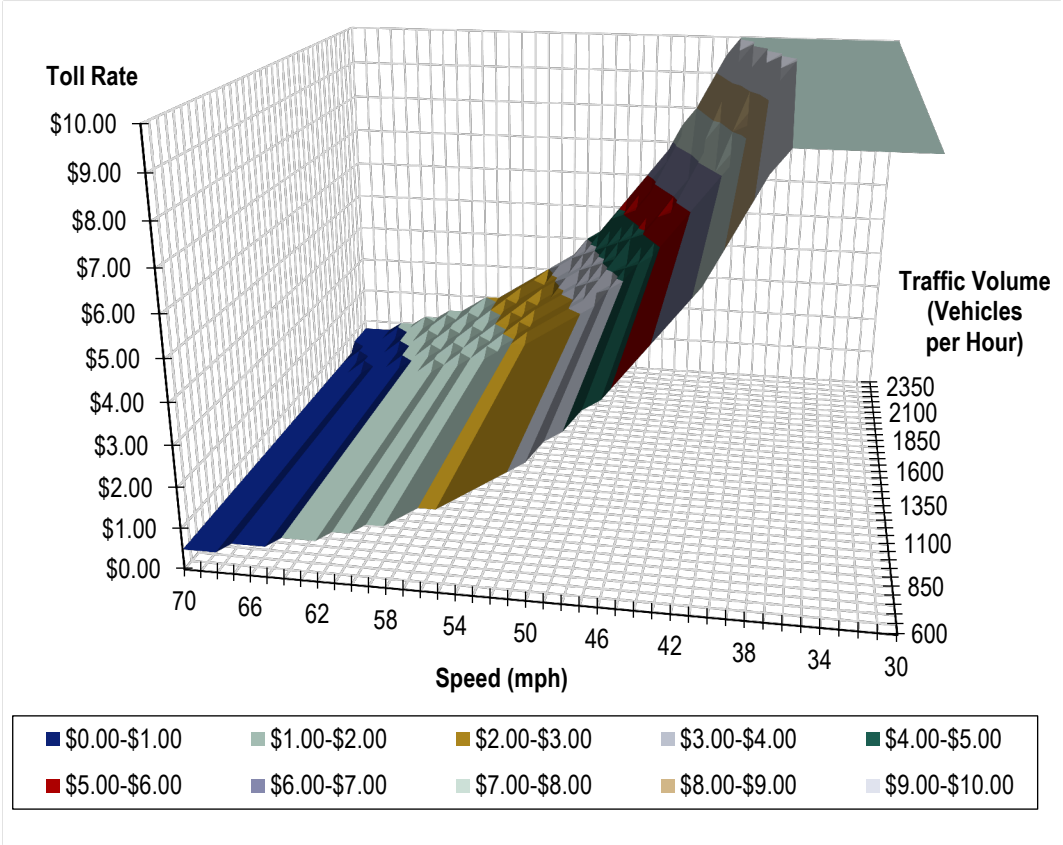
Figure 2.4 Express Lane Traffic Assignment Illustration



Toll Price Setting

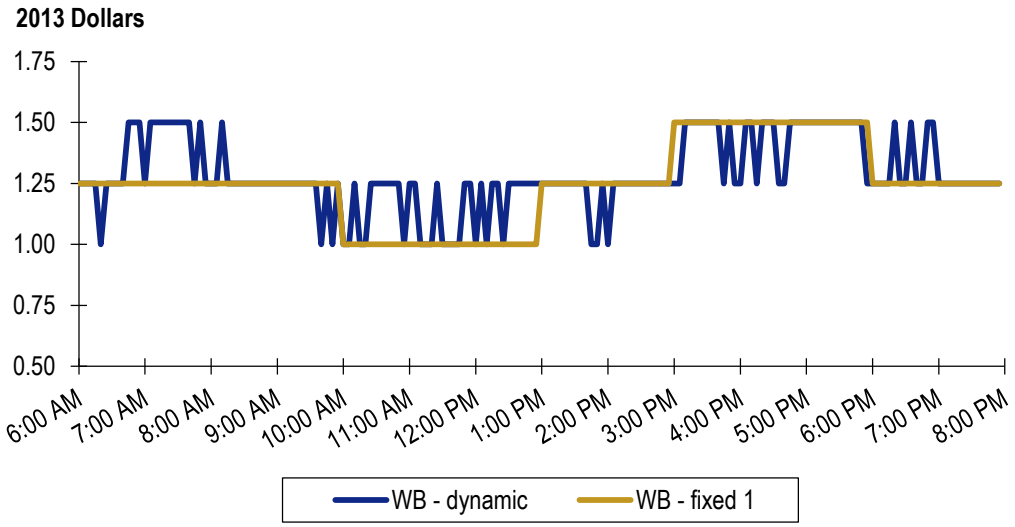
CDOT has established that the Toll Prices for the C-470 Express toll lane will be fixed time-of-day pricing. The idea being that it is simpler and the prices can be communicated in advance on a consistent schedule. In order to develop fixed pricing a Dynamic Pricing algorithm will be used within VISSIM. The algorithm was designed to meet the mobility objectives of the project. The pricing was set to change on 5-minute intervals. The pricing formula accounts for both speed and volumes in the Express Lane to come up with a price. Figure 2.5 is an illustration of the pricing formula used. This toll price is for the Express Pass user, the toll price for a license plate user is the base toll price plus a $0.75 surcharge for processing.

Figure 2.5 Dynamic Toll Price Algorithm Illustrations



After the dynamic pricing models were run the posted toll rates were evaluated and converted into fixed time-of-day pricing. The process was to examine the dynamic pricing results and simplify into time-of-day pricing rates. The schedule could vary by direction, however the consideration was for the driver. Too many discrete price changes would be confusing to communicate in web page or literature. Figure 2.6 illustrates conceptually how dynamic pricing results are converted into fixed time-of-day pricing.

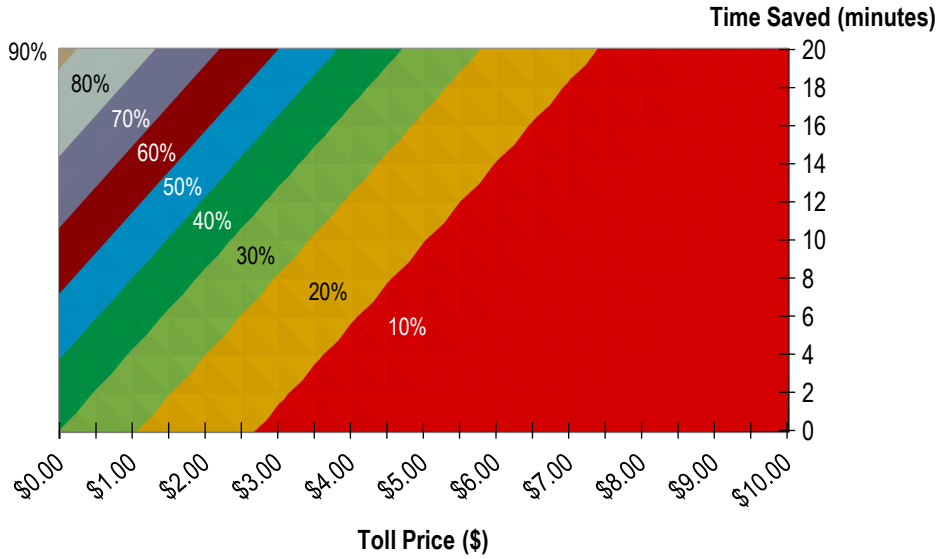
Figure 2.6 Fixed Pricing Illustration
Westbound C-470 Toll Prices



Willingness to Pay

Willingness to pay is represented in the VISSIM model with a logit model. The logit model for this project was based on the stated-preference survey that was Conducted for the U.S. 36 Investment Grade Study. The probability model is illustrated in Figure 2.5. Comparisons were made between the socioeconomic levels of the U.S. 36 survey versus the C-470 Corridor Area. The range of survey data was compatible with the C-470 area for the purposes of this planning study. However the investment grade study for C-470 would likely need a new Stated-preference Survey and the models should be run with different willingness to pay variables.

Figure 2.7 Willingness to Pay Probabilities



ExpressToll Pass User Percentage Assumptions

The state of Colorado uses a common electronic reader type transponder for all of the Tolled Facilities. ExpressToll Passes are stickers in the windshield that are connected to accounts. The C-470 Express Toll Lane project would use the same system for charging. The C-470 project will also allow for non ExpressPass Holders to access the system, these users would be billed based on a license plate capture and direct mailing of a toll bill plus surcharge for processing the bill.

The modeling implications on the percentage of ExpressToll Pass Users on Gross Revenue and Net Revenue is significant. Generally, the higher the percent of ExpressToll Pass users the more likely the Express lane will be used (more vehicles paying a lower toll) and the operating costs will be lower improving the financial bottom line. The agencies developing the C-470 project have every reason to believe that in this congested corridor that many people will have the ExpressToll Passes it is prudent to be conservative on what percentages are modeled.

For this study one set of ExpressToll Pass percentages were assumed which were varied by model year. The percentages were based on current ExpressToll Pass account information provided by the E-470 Toll Office. The E-470 office provided by zip code in Arapahoe, Douglass and Jefferson Counties the total number of ExpressToll Pass Accounts. CS compared the account data against the number of Households, the overall percentage of ExpressToll Pass Accounts by households in the 3 counties was 27%. CS also examined percentage ExpressToll Pass Accounts by users of C-470, the percentage of ExpressToll Pass accounts by household using C-470 was 43%. Based on this assessment of data the following assumptions were made for ExpressToll Pass percentages in the traffic models:

- Year Opening 2018 – 45%;
- 2025 Interim Year – 60%; and
- 2035 Design Year – 70%.

Further testing in the investment grade study should be conducted with ranges of these values to understand better the impact of differing ExpressToll Pass user percentages on Gross and Net revenues.

2.5 REVENUE

Methodology

The preparation of revenue and transaction annual and 30 year streams are based on factoring the results of the AM and PM peak period VISSIM models. The VISSIM models represent 14 hours of a typical weekday (2 seven hour models) which represents the majority of the revenue generated over the course of a year. The overnight revenue will be negligible and for the purposes of this study will not be included in the gross revenue estimates. The weekend and holiday weekday revenue will be estimated by applying a percentage to the typical weekday VISSIM model results. All revenue will be reported in ***2013 dollars***. Any inflation of the revenue will need to be applied to the revenue provided. Table 2.2 is a summary of the assumptions used in annualizing traffic model results.

Table 2.2 Revenue and Transaction Annualization Assumptions

Description	Assumption
Daily Assumptions	
AM Weekday Peak	6 a.m. to 1 p.m.
PM Weekday Peak	1 p.m. to 8 p.m.
Daily Weekday	AM Weekday peak plus PM Weekday peak
Weekday Off-peak	8 p.m. to 6 a.m. – negligible revenue not included
Daily Weekend	10% of Daily Weekday
Annual Assumptions	
Annual Weekday	252 times Daily Weekday
Annual Weekend	113 times Daily Weekend
Total Annual	Annual weekday plus Annual Weekend
Ramp up	
Year 1	50%
Year 2	50%
Year 3	75%

Description	Assumption
Year 4	75%
Year 5	100% (no ramp up % applied)
2035-2048 Assumptions	
Annual Growth Percentage	1% per year

Ramp Up

The modeled timeframes include 2018 (year opening), 2025 (interim forecast) and 2035 (design year). The revenue estimated by the models assume perfect knowledge of the system including pricing, ingress-egress and general operations. In reality the public will take time to learn the system and use it to its fullest extent. The condition of the public building this understanding is called "ramp up." Currently, there is not a lot of hard science or experience as to the extent of ramp up that will occur, it is just known that it does occur. In this study ramp up adjustments will be applied to the model results in the early years.

30 Year Revenue Streams

30 year revenue streams will be prepared by a straight line interpolation between the modeled years (with ramp up applied in the early years). The last modeled year is 2035 there is another 13 years of growth to get to the to get to the 2048 timeframe a nominal percentage growth will be applied to the 2035 model results.

3.0 Traffic Demands

3.1 BASE YEAR TRAFFIC

Comparison of Base Year Model and Counts

As described in the Methods and Assumptions Report, the base year trip tables were calibrated to match the ramp and mainline observed volumes. Tables 3.1 and 3.2 compare the estimated link volumes on all of the C-470 corridor ramps and mainline sections to the observed counts. In the eastbound direction, on average, the estimated volumes is within 70 vehicles of the observed volumes with a %RMSE of about 5%. In the westbound direction, estimated volumes are within 40 vehicles of the observed counts on average with a %RMSE of about 4%.

Table 3.1 C-470 Base Year Comparison
Eastbound

	AM Peak Hour			PM Peak Hour		
	Count	Volume	Difference	Count	Volume	Difference
C-470 EB	2,717	2,624	-3.4%	2,299	2,191	-4.7%
Kipling off-ramp	180	179	-0.6%	304	303	-0.3%
C-470 EB	2,537	2,445	-3.6%	1,995	1,887	-5.4%
Kipling on-ramp	763	658	-13.8%	804	792	-1.5%
C-470 EB	3,300	3,103	-6.0%	2,799	2,680	-4.3%
Wadsworth off-ramp	408	405	-0.7%	546	507	-7.1%
C-470 EB	2,892	2,697	-6.7%	2,253	2,172	-3.6%
Wadsworth on-ramp	354	559	57.9%	477	578	21.2%
C-470 EB	3,246	3,257	0.3%	2,730	2,751	0.8%
Santa Fe off-ramp	730	732	0.3%	800	788	-1.5%
C-470 EB	2,516	2,525	0.4%	1,930	1,963	1.7%
Santa Fe on-ramp	1,298	1,239	-4.5%	1,257	1,290	2.6%
C-470 EB	3,814	3,765	-1.3%	3,187	3,254	2.1%
Lucent off-ramp	989	895	-9.5%	932	938	0.6%
C-470 EB	2,825	2,869	1.6%	2,255	2,316	2.7%
Lucent on-ramp	567	550	-3.0%	611	579	-5.2%
C-470 EB	3,392	3,420	0.8%	2,866	2,895	1.0%
Broadway off-ramp	302	303	0.3%	407	406	-0.2%
C-470 EB	3,090	3,117	0.9%	2,459	2,489	1.2%
Broadway on-ramp	745	776	4.2%	807	824	2.1%

	AM Peak Hour			PM Peak Hour		
	Count	**Volume**	**Difference**	**Count**	**Volume**	**Difference**
C-470 EB	3,835	3,894	1.5%	3,266	3,313	1.4%
University off-ramp	346	376	8.7%	1,024	1,032	0.8%
C-470 EB	3,489	3,517	0.8%	2,242	2,281	1.7%
University on-ramp	845	899	6.4%	687	692	0.7%
C-470 EB	4,334	4,417	1.9%	2,929	2,974	1.5%
Quebec off-ramp	843	832	-1.3%	672	639	-4.9%
C-470 EB	3,491	3,584	2.7%	2,257	2,335	3.5%
Quebec on-ramp	2,006	1,920	-4.3%	956	1,047	9.5%
C-470 EB	5,497	5,504	0.1%	3,213	3,382	5.3%
Yosemite off-ramp	603	557	-7.6%	533	522	-2.1%
C-470 EB	4,894	4,947	1.1%	2,680	2,859	6.7%
I-25 NB off-ramp	4,023	3,824	-4.9%	2,425	2,164	-10.8%
C-470 EB	871	1,122	28.8%	871	695	-20.2%
Total Mainline	56,740	56,807	0.1%	42,231	42,437	0.5%
Total Ramps	15,002	14,704	-2.0%	13,242	13,101	-1.1%
Grand Total	**71,742**	**71,511**	**-0.3%**	**55,473**	**55,538**	**0.1%**

Table 3.2 C-470 Base Year Comparison
Westbound

	AM Peak Hour			PM Peak Hour		
	Count	Volume	Difference	Count	Volume	Difference
C-470 WB	721	985	36.6%	1,012	947	-6.4%
I-25 on-ramp	2,319	2,150	-7.3%	2,325	2,334	0.4%
C-470 WB	3,040	3,136	3.2%	3,337	3,281	-1.7%
Yosemite on-ramp	363	347	-4.4%	800	766	-4.3%
C-470 WB	3,403	3,484	2.4%	4,137	4,048	-2.2%
Quebec off-ramp	791	821	3.8%	1,700	1,693	-0.4%
C-470 WB	2,612	2,662	1.9%	2,437	2,354	-3.4%
Quebec on-ramp	714	662	-7.3%	785	885	12.7%
C-470 WB	3,326	3,325	0.0%	3,222	3,240	0.6%
University off-ramp	586	593	1.2%	581	607	4.5%
C-470 WB	2,740	2,731	-0.3%	2,641	2,633	-0.3%
University on-ramp	715	727	1.7%	615	622	1.1%
C-470 WB	3,455	3,458	0.1%	3,256	3,255	0.0%
Broadway off-ramp	979	991	1.2%	650	684	5.2%
C-470 WB	2,476	2,467	-0.4%	2,606	2,571	-1.3%
Broadway on-ramp	334	323	-3.3%	312	321	2.9%
C-470 WB	2,810	2,790	-0.7%	2,918	2,892	-0.9%
Lucent off-ramp	672	648	-3.6%	562	572	1.8%
C-470 WB	2,138	2,142	0.2%	2,356	2,320	-1.5%
Lucent on-ramp	695	687	-1.2%	716	734	2.5%
C-470 WB	2,833	2,829	-0.1%	3,072	3,054	-0.6%

	AM Peak Hour			PM Peak Hour		
	Count	**Volume**	**Difference**	**Count**	**Volume**	**Difference**
Santa Fe off-ramp	770	742	-3.6%	597	595	-0.3%
C-470 WB	2,063	2,087	1.2%	2,475	2,459	-0.6%
Santa Fe on-ramp	871	864	-0.8%	912	964	5.7%
C-470 WB	2,934	2,951	0.6%	3,387	3,423	1.1%
Chatfield off-ramp	264	256	-3.0%	518	583	12.5%
C-470 WB	2,670	2,695	0.9%	2,869	2,840	-1.0%
Chatfield on-ramp	164	172	4.9%	92	73	-20.7%
C-470 WB	2,834	2,867	1.2%	2,961	2,913	-1.6%
Wadsworth off-ramp	933	901	-3.4%	951	908	-4.5%
C-470 WB	1,901	1,966	3.4%	2,010	2,005	-0.2%
Wadsworth on-ramp	822	703	-14.5%	1,091	968	-11.3%
C-470 WB	2,723	2,669	-2.0%	3,101	2,973	-4.1%
Kipling off-ramp	729	712	-2.3%	953	922	-3.3%
C-470 WB	1,994	1,957	-1.9%	2,148	2,051	-4.5%
Kipling on-ramp	216	215	-0.5%	274	274	0.0%
C-470 WB	2,210	2,172	-1.7%	2,422	2,325	-4.0%
Total Mainline	48,883	49,373	1.0%	52,367	51,584	-1.5%
Total Ramps	12,937	12,514	-3.3%	14,434	14,505	0.5%
Grand Total	**61,820**	**61,887**	**0.1%**	**66,801**	**66,089**	**-1.1%**

3.2 FUTURE TRAFFIC DEMAND

Regional Growth Estimates

The FOCUS model forecasts form the basis for the future year travel demands for the C-470 corridor. The forecasted growth of trips from each origin-destination pair within the C-470 corridor are added to the calibrated base year trip table to form the future year trip tables. These adjusted trip tables become the inputs into the microsimulation models that are used to assess the operational characteristics and revenue potential of the design scenarios.

To better understand the demand, these same trip tables were assigned to the regional network as delimited in Figure 1.1 using the static assignment procedures consistent with the FOCUS model. Table 3.3 shows the estimated regional growth in VMT and VHT for the base year, year 2025 and year 2035. There is substantial growth estimated for the region. By year 2025, VMT is estimated to grow by about 28%. By year 2035, VMT is estimated to be about 43% higher. VHT is estimated to grow even faster, 38% and 60% respectively, as congestion increases. Increased congestion results in lower average calculated speeds throughout the region from about 35 mph to around 32 mph by 2035.

Table 3.3 Regional Travel Characteristics

		Existing	Year 2025	Year 2035
Total Pax	VMT	35,260,502	45,171,171	50,237,407
	VHT	994,266	1,373,954	1,593,783
	Average Speed	35.5	32.9	31.5
Total Com	VMT	3,846,126	5,113,483	5,495,259
	VHT	108,993	146,103	156,237
	Average Speed	35.3	35.0	35.2
Grand Total	VMT	39,106,628	50,284,654	55,732,666
	VHT	1,103,259	1,520,057	1,750,020
	Average Speed	35.4	33.1	31.8

Travel within the C-470 corridor is also estimated to grow significantly by Year 2035. Tables 3.4 and 3.5 show the peak hour and daily base year counts and forecasted demand volumes for each ramp and mainline segment within the study corridor. Mainline demand is estimated to increase on average by about 71% in the westbound direction in the PM Peak Hour and by about 50% on average in the eastbound direction in the AM Peak Hour.

Table 3.4 C-470 Peak Hour Volumes
Eastbound

	Existing			2018 – Concept 3			2025 – Concept 3			2035 – Concept 3			2035 – Ultimate		
	AM	PM	Daily	AM	PM	Daily	AM	PM	Daily	AM	PM	Daily	AM	PM	Daily
C-470 EB	2,717	2,299	26,993	2,982	2,535	30,481	3,326	2,935	34,824	3,550	3,264	37,800	3,621	3,284	38,147
Kipling off-ramp	180	304	2,934	244	344	3,696	310	416	4,595	359	518	5,155	359	513	5,157
C-470 EB	2,537	1,995	24,059	2,738	2,191	26,785	3,016	2,519	30,229	3,191	2,746	32,645	3,262	2,771	32,990
Kipling on-ramp	763	804	8,590	888	958	9,812	1,031	1,083	11,677	1,085	1,138	12,832	1,137	1,185	13,120
C-470 EB	3,300	2,799	32,649	3,626	3,149	36,597	4,047	3,602	41,906	4,276	3,884	45,477	4,399	3,956	46,110
Wadsworth off-ramp	408	546	5,146	445	513	5,304	494	571	6,110	535	784	6,930	527	758	6,805
C-470 EB	2,892	2,253	27,503	3,181	2,636	31,293	3,553	3,031	35,796	3,741	3,100	38,547	3,872	3,198	39,305
Wadsworth on-ramp	354	477	9,996	718	701	11,995	885	825	14,070	1,025	799	15,218	1,136	834	15,841
C-470 EB	3,246	2,730	37,499	3,899	3,337	43,288	4,438	3,856	49,866	4,766	3,899	53,765	5,008	4,032	55,146
Santa Fe off-ramp	730	800	8,929	922	1,109	11,596	1,076	1,266	14,049	1,101	1,185	14,745	1,157	1,240	15,122
C-470 EB	2,516	1,930	28,570	2,977	2,228	31,692	3,362	2,590	35,816	3,665	2,714	39,020	3,851	2,792	40,024
Santa Fe on-ramp	1,298	1,257	16,495	1,551	1,865	20,008	1,610	1,915	21,709	1,693	1,896	22,635	1,649	1,880	22,459
C-470 EB	3,814	3,187	45,065	4,528	4,093	51,700	4,972	4,505	57,526	5,358	4,610	61,655	5,500	4,672	62,483
Lucent off-ramp	989	932	10,329	976	1,163	9,754	1,055	1,295	10,424	1,285	1,371	11,174	1,328	1,400	11,222
C-470 EB	2,825	2,255	34,736	3,552	2,930	41,947	3,917	3,210	47,102	4,073	3,239	50,481	4,172	3,272	51,261
Lucent on-ramp	567	611	6,699	817	677	7,963	1,040	738	9,014	1,341	770	10,182	1,404	759	10,205
C-470 EB	3,392	2,866	41,435	4,369	3,607	49,909	4,957	3,948	56,116	5,414	4,009	60,663	5,576	4,031	61,466
Broadway off-ramp	302	407	4,677	379	462	6,060	812	457	6,646	1,046	469	6,918	1,126	473	7,032

	Existing			2018 – Concept 3			2025 – Concept 3			2035 – Concept 3			2035 – Ultimate		
	AM	**PM**	**Daily**	**AM**	**PM**	**Daily**	**AM**	**PM**	**Daily**	**AM**	**PM**	**Daily**	**AM**	**PM**	**Daily**
C-470 EB	3,090	2,459	36,758	3,990	3,145	43,850	4,145	3,491	49,470	4,368	3,540	53,745	4,450	3,558	54,434
Broadway on-ramp	745	807	11,991	858	855	13,602	1,297	949	14,808	1,471	949	15,583	1,560	946	15,802
C-470 EB	3,835	3,266	48,749	4,848	4,000	57,452	5,442	4,440	64,279	5,839	4,489	69,328	6,010	4,504	70,236
University off-ramp	346	1,024	9,062	923	1,096	10,721	1,216	1,028	11,127	1,336	1,011	11,406	1,416	1,027	11,576
C-470 EB	3,489	2,242	39,687	3,925	2,904	46,731	4,226	3,412	53,152	4,503	3,478	57,922	4,594	3,477	58,660
University on-ramp	845	687	8,637	1,377	712	10,805	1,735	728	11,690	1,841	830	12,208	1,927	868	12,547
C-470 EB	4,334	2,929	48,324	5,302	3,616	57,536	5,961	4,140	64,842	6,344	4,308	70,130	6,521	4,345	71,207
Quebec off-ramp	843	672	7,678	1,031	710	9,891	1,092	773	11,030	1,163	746	12,052	1,251	735	12,118
C-470 EB	3,491	2,257	40,646	4,271	2,906	47,646	4,869	3,367	53,812	5,181	3,562	58,078	5,270	3,610	59,089
Quebec on-ramp	2,006	956	15,751	2,086	1,314	18,653	2,278	1,497	20,977	2,580	1,746	22,464	2,658	1,765	22,476
C-470 EB	5,497	3,213	56,397	6,357	4,220	66,299	7,147	4,864	74,789	7,761	5,308	80,542	7,928	5,375	81,565
Yosemite off-ramp	603	533	8,795	839	658	10,834	1,066	638	12,136	1,163	582	12,419	1,203	580	12,799
C-470 EB	4,894	2,680	47,602	5,518	3,562	55,464	6,081	4,226	62,653	6,598	4,726	68,123	6,725	4,795	68,766
I-25 off-ramp	4,023	2,425	42,629	3,932	2,201	43,720	4,059	2,265	46,641	4,078	2,099	46,765	4,198	2,149	47,309
C-470 EB	871	871	4,973	1,586	1,361	11,744	2,022	1,961	16,012	2,520	2,627	21,358	2,527	2,646	21,457
I-25 on-ramp	795	1,739	12,336	890	1,659	11,531	1,013	1,680	12,588	1,195	2,268	16,164	1,190	2,246	16,066
C-470 EB	1,666	2,610	17,309	2,476	3,020	23,275	3,035	3,641	28,600	3,715	4,895	37,522	3,717	4,892	37,523
Mainline Totals	58,406	44,841	638,954	70,125	55,440	753,688	78,516	63,738	856,789	84,864	68,398	936,803	87,003	69,210	949,871
Ramp Totals	15,797	14,981	190,674	18,877	16,997	215,944	22,068	18,124	239,292	24,296	19,161	254,852	25,227	19,358	257,658
Grand Total	**74,203**	**59,822**	**829,628**	**89,001**	**72,437**	**969,632**	**100,585**	**81,862**	**1,096,081**	**109,159**	**87,559**	**1,191,655**	**112,229**	**88,568**	**1,207,529**

Table 3.5 C-470 Peak Hour Volumes
Westbound

	Existing			2018 – Concept 3			2025 – Concept 3			2035 – Concept 3			2035 – Ultimate		
	AM	PM	Daily	AM	PM	Daily	AM	PM	Daily	AM	PM	Daily	AM	PM	Daily
C-470 WB	2,431	1,985	23,109	3,136	2,783	27,477	3,561	3,625	33,532	4,448	4,412	40,406	4,404	4,409	40,335
I-25 off-ramp	1,710	973	13,038	1,485	1,267	13,229	1,306	1,544	14,660	1,628	1,700	16,901	1,523	1,645	16,625
C-470 WB	721	1,012	10,071	1,651	1,516	14,248	2,255	2,081	18,872	2,820	2,712	23,505	2,881	2,764	23,710
I-25 on-ramp	2,319	2,325	36,943	2,360	2,986	40,766	2,502	2,970	43,151	2,416	2,949	43,735	2,407	3,054	44,251
C-470 WB	3,040	3,337	47,014	4,011	4,502	55,013	4,757	5,051	62,023	5,236	5,661	67,240	5,288	5,818	67,961
Yosemite on-ramp	363	800	8,247	457	963	9,213	479	1,063	10,423	432	1,192	11,261	435	1,294	11,409
C-470 WB	3,403	4,137	55,261	4,468	5,465	64,226	5,236	6,114	72,446	5,668	6,853	78,501	5,723	7,112	79,370
Quebec off-ramp	791	1,700	15,018	942	2,010	16,605	1,266	2,174	19,083	1,601	2,396	21,049	1,597	2,449	21,115
C-470 WB	2,612	2,437	40,243	3,526	3,455	47,621	3,970	3,940	53,363	4,067	4,457	57,452	4,126	4,663	58,255
Quebec on-ramp	714	785	8,683	1,026	1,259	12,215	1,025	1,198	12,947	995	1,139	13,514	981	1,196	13,756
C-470 WB	3,326	3,222	48,926	4,552	4,714	59,836	4,995	5,138	66,311	5,062	5,596	70,966	5,107	5,859	72,011
University off-ramp	586	581	10,378	868	913	11,737	1,169	1,192	12,701	1,167	1,418	13,303	1,234	1,564	13,532
C-470 WB	2,740	2,641	38,548	3,684	3,801	48,099	3,826	3,946	53,609	3,895	4,178	57,663	3,873	4,295	58,479
University on-ramp	715	615	8,219	900	745	10,751	1,081	1,052	11,167	1,035	1,212	12,304	1,066	1,358	12,294
C-470 WB	3,455	3,256	46,767	4,584	4,546	58,850	4,907	4,998	64,777	4,930	5,390	69,968	4,939	5,653	70,774
Broadway off-ramp	979	650	11,074	1,134	786	14,400	1,230	1,058	15,429	1,250	1,215	15,873	1,258	1,388	16,082
C-470 WB	2,476	2,606	35,693	3,450	3,760	44,450	3,677	3,940	49,348	3,680	4,175	54,094	3,681	4,265	54,691
Broadway on-ramp	334	312	4,555	422	518	5,850	468	846	6,636	471	1,096	6,996	469	1,248	7,072
C-470 WB	2,810	2,918	40,248	3,872	4,278	50,300	4,145	4,786	55,984	4,151	5,271	61,090	4,150	5,513	61,763
Lucent off-ramp	672	562	8,081	746	777	8,542	767	964	9,748	738	1,278	10,751	733	1,408	10,760
C-470 WB	2,138	2,356	32,167	3,126	3,501	41,758	3,378	3,822	46,236	3,413	3,993	50,339	3,417	4,105	51,003
Lucent on-ramp	695	716	6,964	956	921	7,981	1,090	1,006	8,657	1,143	1,161	8,941	1,141	1,312	8,961

	Existing			2018 – Concept 3			2025 – Concept 3			2035 – Concept 3			2035 – Ultimate		
	AM	**PM**	**Daily**	**AM**	**PM**	**Daily**	**AM**	**PM**	**Daily**	**AM**	**PM**	**Daily**	**AM**	**PM**	**Daily**
C-470 WB	2,833	3,072	39,131	4,082	4,422	49,738	4,468	4,828	54,893	4,556	5,154	59,280	4,558	5,417	59,964
Santa Fe off-ramp	770	597	10,180	1,330	1,093	13,635	1,408	1,111	14,797	1,473	1,147	16,029	1,469	1,344	16,074
C-470 WB	2,063	2,475	28,951	2,752	3,329	36,104	3,060	3,717	40,097	3,083	4,007	43,251	3,089	4,073	43,890
Santa Fe on-ramp	871	912	9,382	1,028	1,064	11,711	1,213	1,186	14,007	1,378	1,243	15,819	1,389	1,451	16,004
C-470 WB	2,934	3,387	38,333	3,780	4,393	47,814	4,273	4,903	54,104	4,461	5,250	59,070	4,478	5,524	59,894
Chatfield off-ramp	264	518	5,081	536	805	8,848	635	836	9,946	649	920	10,346	656	912	10,365
C-470 WB	2,670	2,869	33,252	3,244	3,588	38,966	3,638	4,067	44,158	3,812	4,330	48,725	3,822	4,612	49,530
Chatfield on-ramp	164	92	1,308	248	167	2,348	298	258	2,917	330	340	3,679	334	347	3,665
C-470 WB	2,834	2,961	34,560	3,492	3,755	41,315	3,936	4,325	47,074	4,142	4,670	52,403	4,156	4,959	53,194
Wadsworth off-ramp	933	951	11,022	1,028	1,171	11,629	1,121	1,341	12,739	1,131	1,538	14,472	1,133	1,600	14,854
C-470 WB	1,901	2,010	23,538	2,464	2,584	29,686	2,815	2,984	34,335	3,011	3,132	37,932	3,023	3,359	38,341
Wadsworth on-ramp	822	1,091	4,744	777	1,005	6,257	876	1,083	7,477	1,078	1,128	8,393	1,076	1,083	8,313
C-470 WB	2,723	3,101	28,282	3,241	3,589	35,943	3,691	4,067	41,812	4,089	4,260	46,325	4,099	4,442	46,654
Kipling off-ramp	729	953	9,423	1,072	1,181	12,072	1,312	1,392	15,015	1,367	1,435	16,231	1,373	1,521	16,355
C-470 WB	1,994	2,148	18,859	2,169	2,408	23,871	2,379	2,675	26,797	2,722	2,825	30,093	2,726	2,921	30,298
Kipling on-ramp	216	274	3,209	253	301	3,455	296	347	3,988	369	372	4,561	366	368	4,543
C-470 WB	2,210	2,422	22,068	2,422	2,709	27,325	2,675	3,022	30,785	3,091	3,197	34,655	3,092	3,289	34,842
Mainline Totals	51,314	54,352	685,021	67,706	73,098	842,641	75,642	82,029	950,555	80,337	89,524	1,042,958	80,632	93,052	1,054,960
Ramp Totals	14,647	15,407	185,549	17,568	19,932	221,242	19,543	22,621	245,488	20,650	24,878	264,158	20,640	26,541	266,030
Grand Total	**65,961**	**69,759**	**870,570**	**85,274**	**93,030**	**1,063,883**	**95,184**	**104,650**	**1,196,043**	**100,988**	**114,401**	**1,307,117**	**101,272**	**119,594**	**1,320,990**

4.0 Design Concepts

4.1 OVERVIEW

The C-470 Corridor Coalition made a decision in February 2013 to move forward with advancing the Express Toll Lanes (ETL) on C-470 in order to improve mobility and reliability. The basic ETL concept is to provide from one to two Express Toll Lanes (ETL) in each direction on the left hand side from I-25 to Kipling Parkway (Kipling). The access to the ETLs will be with at-grade openings to the proposed buffer separated ETL facility. There is flexibility and many different strategies for locating at-grade access to ETLs. Concept Plans that were developed and analyzed for Traffic and Revenue in this report are developed based on the discussion in this chapter. As simulation models were run and the results reviewed, refinements were made.

The concept designs that were developed included access plans from I-25 to Kipling to the proposed ETL for both an interim concept as well as the 2035 ultimate concept. Both of these concepts were developed to provide one ETL in each direction from I-25 to Kipling. The length of the proposed express toll two-lane section was from I-25 west to Colorado Boulevard Overpass for Interim Concept and from I-25 to near Lucent for the 2035 Ultimate Concept.

RAMP Funding Implications

In 2012, the Colorado Department of Transportation (CDOT) developed the Responsible Acceleration of Maintenance and Partnership (RAMP) Program and the C-470 Corridor Coalition submitted an initial application to CDOT in April 2013 in order to pursue potential funding for the C-470 Corridor. In October 2013 the CDOT Transportation Commission conditionally selected the C-470 Corridor Coalition Managed Tolled Express Lanes Project to receive partial funding through the RAMP Program.

As a result of the limited funding allocated via the RAMP Program to the C-470 Corridor, the Interim Project needed to be scaled back to try to best fit the RAMP budget constraints. Therefore, the initial Interim Concept was reduced to a single lane ETL in each direction from I-25 to near Wadsworth in the westbound direction and from near the Platte River to I-25 in the eastbound direction; and the scaled back concept is referred to as the Interim RAMP Concept/Project.

This chapter will focus on the development of the initial interim and 2035 ultimate concepts that include the project for its entire length (from I-25 to Kipling). The Interim RAMP Concept/Project is documented in later chapters and became the primary model used to evaluate traffic and revenue as discussed later in this report.

4.2 CONCEPT DESIGN PROCESS

A sketch planning process was developed and implemented for the development of an interim and ultimate design concept. The process involved planning level traffic information, preliminary engineering by Wilson and Company, and input from the C-470 Corridor Coalition Technical Working Group (TWG) and Traffic Subcommittee of this technical working group. Figure 4.1 depicts a flow chart of the planning process.

Figure 4.1 Planning Process Flow Chart

The first step was to establish deign criteria. The criteria included developing design details for ingress, egress and combined ingress-egress access locations. The criteria was based in part on Caltrans design criteria for Managed Lane Access.

The second step involved locating ingress and egress openings. Locating ingress egress openings was based on minimum distances for changing lanes between interchanges on the right and ETLs on the left and on matching to optimal markets. The markets were considered based on traffic demands at interchanges and the length of travel between interchanges.

The third step involved reviewing a range of potential concept(s) and refining the most promising concept into a plan.

Finally, the concept(s) were evaluated using the Traffic Modeling methodology for Traffic and Revenue.

The process was highly iterative and involved a series of geometric, traffic and policy testing to develop the concept.

These results were presented to the C-470 TWG and C-470 Corridor Coalition Policy Committee (PC) and modifications/additions to ingress/egress locations were evaluated and incorporated when appropriate.

Concept Objectives

A key consideration for the concept design was the type and length of trip that the ETL should accommodate. The objective was to strike a balance between accommodating a reliable trip by minimizing weaving maneuvers and to providing access. The average trip length of C-470 users according to the FOCUS model is around 6 miles, since the project limits are roughly 13 miles in length there is a significant amount of traffic traveling longer distances. It was decided upon in the committee that the minimum length of trip that would be accommodated by this project would be 3 miles. In some cases the concepts

resulted in ingress egress trip lengths less than 3 miles. The shorter lengths were incidental as a result of trying to reach markets and geometric constraints.

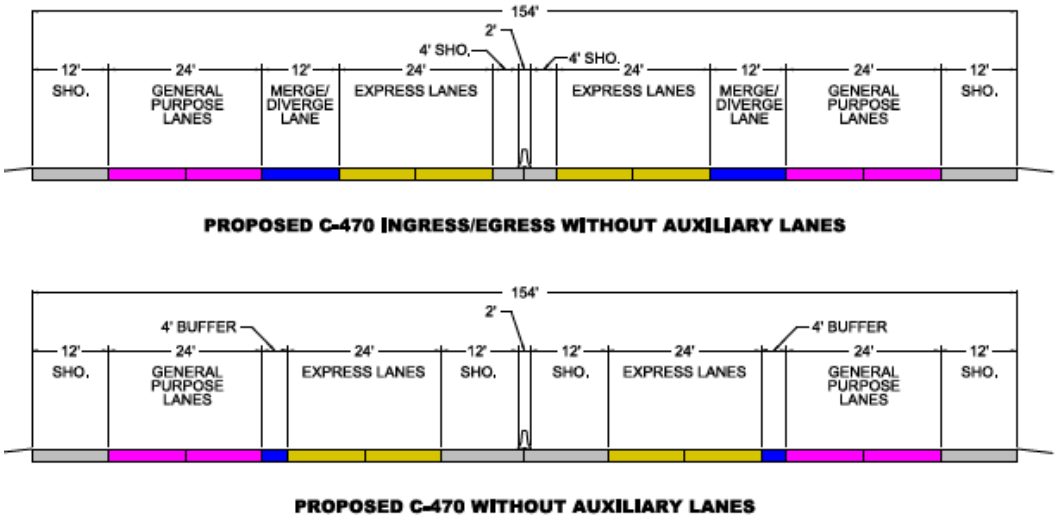
4.3 DESIGN CRITERIA

The design criteria included the development of a Typical Cross-Sections; stand alone ingress and egress; a combined ingress-egress type and; location criteria based on minimum distances for vehicles to change lanes.

Typical Sections

The typical sections for the Express Toll Lanes includes two types: one with a buffer separation and the other with a merge lane. Two typical sections are shown in Figure 4.2 both of the typical sections include two 12–foot (24 feet) general purpose and Express Lanes in each direction. This is the maximum typical section, the interim project includes only one lane in each direction, in this case the width would be reduced to 12 feet from 24 feet. The upper half of the exhibit shows the typical section at an ingress or egress location with a merge/diverge lane. the lower half of Figure 4.2 illustrates a 4-foot buffer between the Express Lanes and the General Purpose Lanes. This section would be located between ingress and egress locations, it will be illegal for vehicles to cross over the 4-foot buffer.

Figure 4.2 Ultimate Configuration Typical Sections[a]



[a] Typical Section Exhibit provided by Wilson and Company.

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 4.3 through 4.5. In all cases these designs include a weave lane, the design criteria is based in part on the April 2011 Policy Memo from Caltrans. This merge/diverge lane will provide a safer transition between the general purpose lanes and Express Lanes.

There was a different Ingress/Egress design type considered for this project. This type was a combined ingress egress opening with no additional weave lane. Based on the curvilinear alignment of C-470 and a desire to provide a reliable trip this basic concept was rejected.

Figure 4.3 Ingress[1]

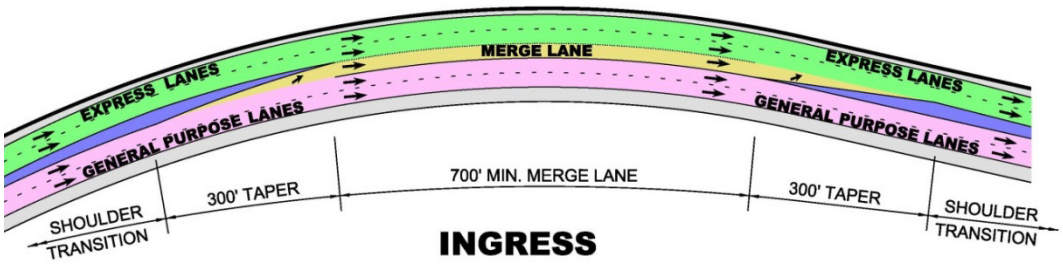


Figure 4.4 Egress

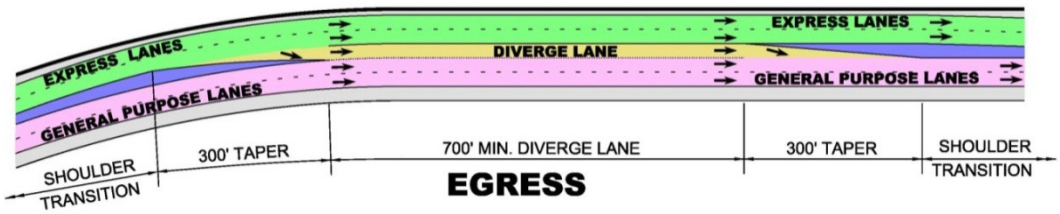
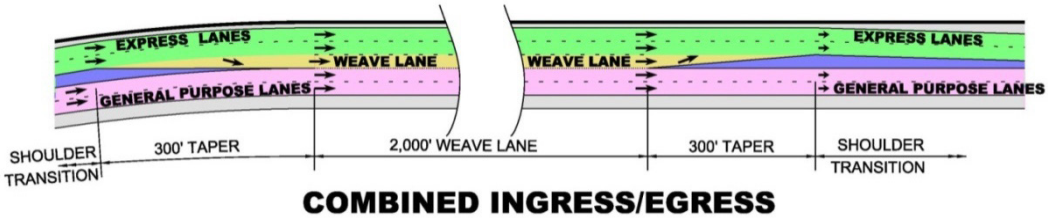


Figure 4.5 Combined Ingress Egress

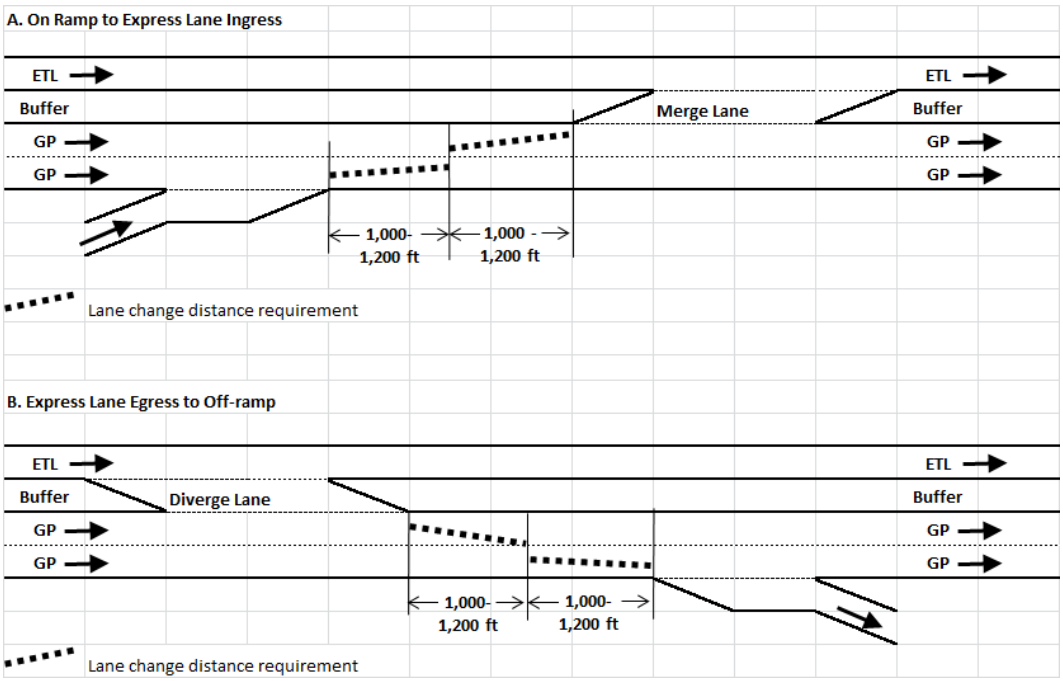


[1] Ingress-Egress Schematic's provided by Wilson and Company.

Ingress/Egress Location Criteria

The design criteria for locating ingress and egress must allow adequate lane-changing distance from the service interchange on-ramp to the Express Lane ingress, and from the Express Lane egress to the desired service interchange off-ramp. Beyond the provision of adequate weaving space, the design also must comply with state requirements for minimum signage distances. Figure 4.6 illustrates the lane changing distance requirements for locating ingress and egress.

Figure 4.6 Lane Change Distance Requirements



In addition to the lane changing distance requirement sight distance on curves is also important. It is possible that a location may meet the lane change requirement but due to inadequate sight distance on a curve the location would have to be relocated. The final plans tested in simulation reflect the correct geometric criteria for freeways eliminating the possibility that as a concept plan moves into final design a location would have to be eliminated due to geometric issues.

4.4 INITIAL INTERIM CONCEPT

The initial Interim Concept that emerged from the sketch planning process included 1-lane in each direction from I-25 to Kipling and 2 –lanes in each direction from around Quebec to around Colorado Boulevard The 2-lane section in each direction allowed for maintaining 2-lanes to and from E-470 all tolled facility, with egress provided in the westbound direction from the E-470 to the

C-470 general purpose lanes and Quebec interchange. Additional operational improvements were made by providing lane continuity and eliminating left lane drops / merges between I-25 and Quebec. In this initial Interim Concept, the 2-lane section ended around Colorado Boulevard as a way to contain costs for the initial construction. However, the RAMP funding allocated for this project may not be sufficient to construct the proposed initial two express toll lane section in each direction between I-25 and Colorado, and CDOT may need to scale back the limits of the 2 lane section. The initial Interim Concept is illustrated in schematic form in Figure 4.7.

There are 20 ingress egress combinations accommodated in the westbound direction with the longest trip length at 12.5 miles. There 16 ingress egress combinations accommodated in the eastbound direction with the longest trip length at 13.2 miles. Table 4.1 below summarizes all the combinations.

Table 4.1 Initial Alternative Ingress Egress Combinations

Westbound

Ingress		Egress		
No.	general location[1]	letter	general location[2]	length (miles)
1	E-470	A	University	3.6
		B	Broadway	4.7
		C	Santa Fe	7.3
		D	Wadsworth	11.1
		E	Kipling	12.5
2	Yosemite	A	University	1.8
		B	Broadway	3.0
		C	Santa Fe	5.6
		D	Wadsworth	9.3
		E	Kipling	10.8
3	Quebec	A	University	0.9
		B	Broadway	2.0
		C	Santa Fe	4.6
		D	Wadsworth	8.4
		E	Kipling	9.8
4	University	C	Santa Fe	1.1
		D	Wadsworth	4.9
		E	Kipling	6.3
5	Broadway	D	Wadsworth	3.4
		E	Kipling	4.9

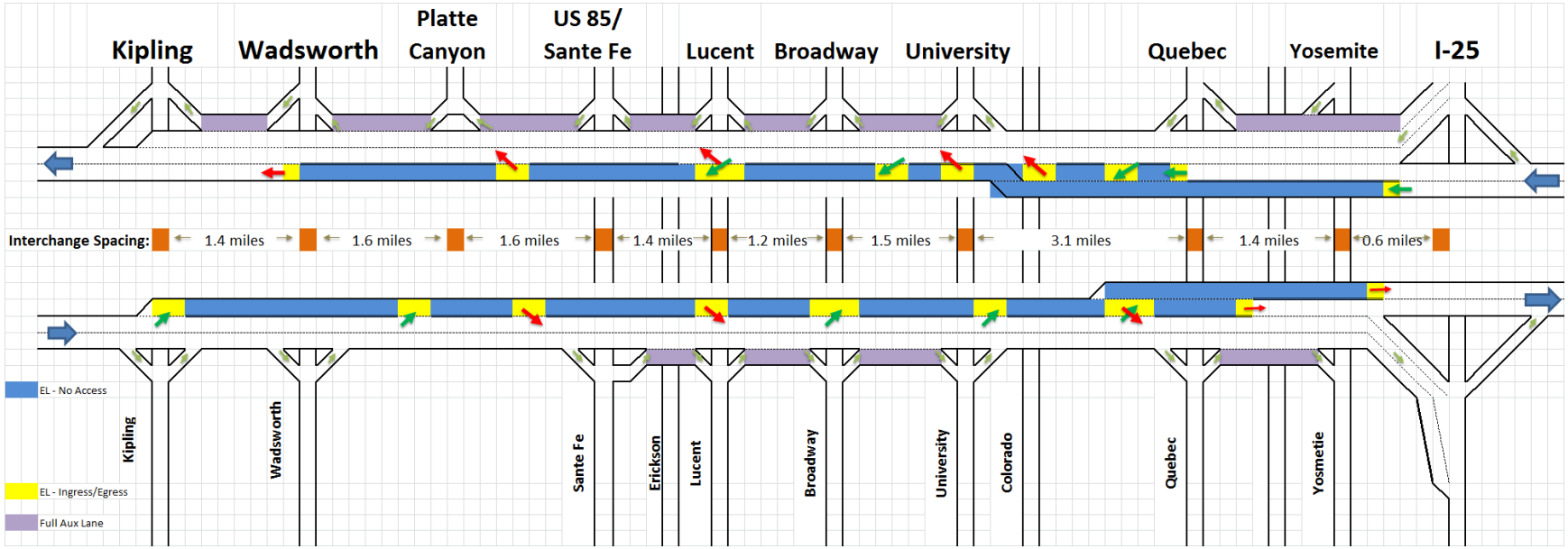
Eastbound

Ingress		Egress		
No.	general location[1]	letter	general location[2]	length (miles)
1	C-470	A	Santa Fe	3.1
		B	Broadway	5.5
		C	Quebec	10.1
		D	Yosemite	11.9
		E	E-470	13.2
2	Wadsworth	A	Santa Fe	1.2
		B	Broadway	3.6
		C	Quebec	8.3
		D	Yosemite	10.1
		E	E-470	11.4
3	Lucent	C	Quebec	3.1
		D	Yosemite	4.9
		E	E-470	6.2
4	Broadway	C	Quebec	1.9
		D	Yosemite	3.7
		E	E-470	5.0
5	University	D	Yosemite	1.1
		E	E-470	2.4

[1] General location description of Ingress is based on the closest interchange that can access the Express lane Ingress

[2] General location description of Egress is based on the closest interchange that the Express Lane Egress can get to

Figure 4.7 Initial Interim Express Lane Concept Plan



4.5 ULTIMATE CONCEPT

The 2035 Ultimate Concept includes 1-ETL in each direction from I-25 to Kipling and adds a second ETL (2 –ETL section) in each direction from around Quebec to around Lucent. The concept is illustrated in schematic form in Figure 4.8. The proposed 2-lane section to Lucent was decided upon after reviewing traffic demand information from the FOCUS model that indicated there was no need to have 2 express toll lanes in each direction west of Lucent.

There are 20 ingress egress combinations accommodated in the westbound direction with the longest trip length at 12.5 miles. There 16 ingress egress combinations accommodated in the eastbound direction with the longest trip length at 13.2 miles. Table 4.2 below summarizes all the combinations.

Table 4.2 Ultimate Concept Ingress Egress Combinations

Westbound

Ingress		Egress		
No.	general location[1]	letter	general location[2]	length (miles)
1	E-470	A	University	3.6
		B	Broadway	4.7
		C	Santa Fe	7.3
		D	Wadsworth	11.1
		E	Kipling	12.5
2	Yosemite	A	University	1.8
		B	Broadway	3.0
		C	Santa Fe	5.6
		D	Wadsworth	9.3
		E	Kipling	10.8
3	Quebec	A	University	0.9
		B	Broadway	2.0
		C	Santa Fe	4.6
		D	Wadsworth	8.4
		E	Kipling	9.8
4	University	C	Santa Fe	1.1
		D	Wadsworth	4.9
		E	Kipling	6.3
5	Broadway	D	Wadsworth	3.4
		E	Kipling	4.9

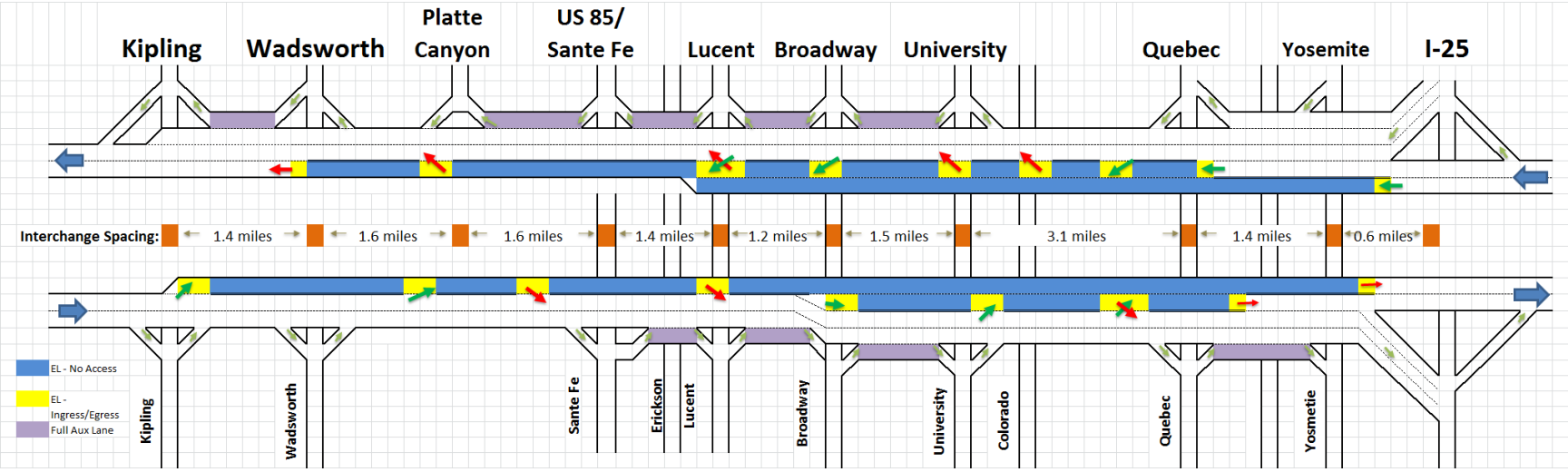
Eastbound

Ingress		Egress		
No.	general location[1]	letter	general location[2]	length (miles)
1	C-470	A	Santa Fe	3.1
		B	Broadway	5.5
		C	Quebec	10.1
		D	Yosemite	11.9
		E	E-470	13.2
2	Wadsworth	A	Santa Fe	1.2
		B	Broadway	3.6
		C	Quebec	8.3
		D	Yosemite	10.1
		E	E-470	11.4
3	Lucent	C	Quebec	3.1
		D	Yosemite	4.9
		E	E-470	6.2
4	Broadway	C	Quebec	1.9
		D	Yosemite	3.7
		E	E-470	5.0
5	University	D	Yosemite	1.1
		E	E-470	2.4

[1] General location description of Ingress is based on the closest interchange that can access the Express lane Ingress

[2] General location description of Egress is based on the closest interchange that the Express Lane Egress can get to

Figure 4.8 Ultimate Express Lane Concept



4.6 RAMP INTERIM CONCEPT/PROJECT

The Interim RAMP Concept was developed in response the limited RAMP funding available for the C-470 Corridor, which required scaling back the initial Interim Concept to try to best fit the initial project limits to match the available funding this the initial project. The elements that were reduced included:

- The proposed two 2) express toll lane section is reduced or removed;
- E-470 remains in its current configuration (reduced to 1-lane); and
- The project was shortened on the west end:
  - Westbound Direction Terminates prior To Wadsworth; and
  - Eastbound Direction Begins near the South Platte River.

Table 4.3 is a summary of the ingress and egress combinations that are included in the RAMP Interim Alternative. The Westbound Direction has 11 combinations with the longest length at 8.4 miles. The Eastbound Direction as 8 combinations with the longest trip at 8.4 miles.

Table 4.3 Ramp Interim Alternative Ingress Egress Combinations

Westbound

Ingress		Egress		
No.	general location[1]	letter	general location[2]	length (miles)
1	Yosemite	A	University	2.2
		B	Broadway	3.3
		C	Santa Fe	5.9
		D	Wadsworth	9.6
2	Quebec	A	University	0.9
		B	Broadway	2.0
		C	Santa Fe	4.6
		D	Wadsworth	8.3
3	University	C	Santa Fe	1.1
		D	Wadsworth	4.8
4	Broadway	D	Wadsworth	3.4

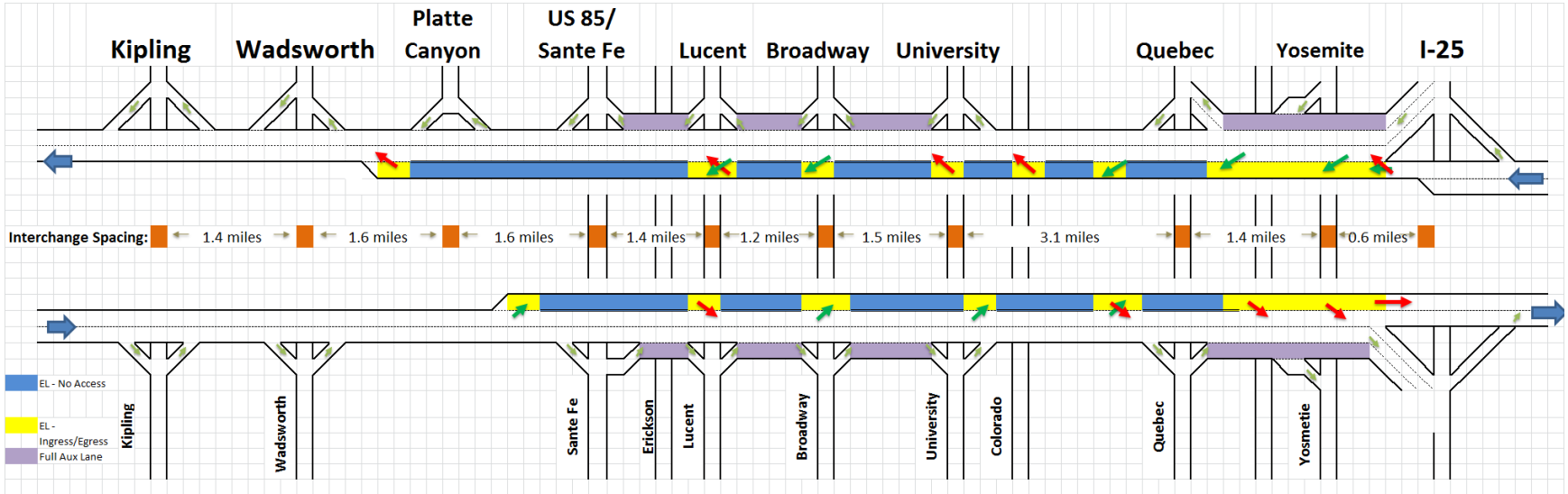
Eastbound

Ingress		Egress		
No.	general location[1]	letter	general location[2]	length (miles)
1	Wadsworth	A	Broadway	2.2
		B	Quebec	6.8
		C	Yosemite	8.4
2	Lucent	B	Quebec	3.3
		C	Yosemite	4.8
3	Broadway	B	Quebec	1.9
		C	Yosemite	3.5
4	University	C	Yosemite	0.9

[1] General location description of Ingress is based on the closest interchange that can access the Express lane Ingress

[2] General location description of Egress is based on the closest interchange that the Express Lane Egress can get to

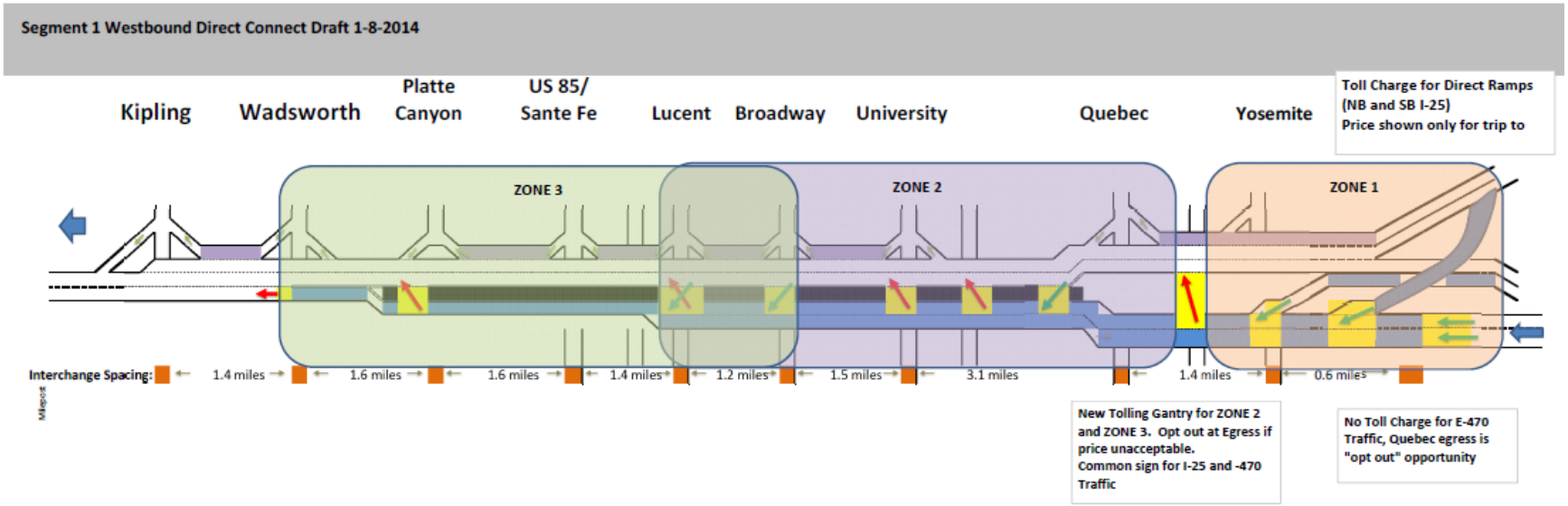
Figure 4.9 RAMP Express Lane Concept



4.7 I-25 TO WESTBOUND C-470 DIRECT RAMP CONNECTIONS

Section to be completed later. New analysis underway. The following Figure is a draft illustration of the type of concepts being considered.

Figure 4.10 I-25 to Westbound C-470 Direct Connect
Ultimate Configuration



5.0 Concept of Operations

5.1 INTRODUCTION

The Concept of Operations Plan contains the complete rules and procedures to operate and maintain a facility. Elements of the plan includes hours of operation toll price setting, maintenance, systems engineering and enforcement. For the purposes of this Traffic and Revenue Study the elements of the concept of operations that will be discussed are the parts necessary for testing traffic operations and preparing revenue estimates.

The parameters for the Concept of Operations were agreed upon by HPTE and CDOT staff. These parameters may be altered as the study results reveal issues. The Concept of Operations should be finalized for the Investment Grade Study. Table 5.1 represents is summary of the Concept of Operations Plan and the assumptions used in the modeling effort.

Table 5.1 Concept of Operations Parameter Summary

Item No.	Description	Setting
1	Toll Setting	Fixed Variable
2	Toll change interval	Hourly
3	Pricing Basis	Zone based
4	Minimum Toll	$0.50
5	Maximum Toll	TBD
6	License plate surcharge	$0.75
7	Accessibility	All SOVs No Heavy Trucks
8	Vehicle Exemption Policy	None
9	Heavy Trucks	Not allowed
10	Express Lane Operational Capacity	1,900 vphpl (max)
11	Performance Measure	Travel Speed
12	Performance Target	55 mph exceeded 90% of the time (LOS D)

5.2 TOLLING ZONES

The Structure for pricing trips in the Express Toll Lane will be by Zones. Zone will help keep the amount of information simplified with 1 or 2 prices for drivers to consider as opposed to have separate and unique pricing for every ingress

egress combination. The initial project limits from I-25 to Kipling divided the corridor into 2 tolling zones, illustrated in Figure 5.1. From traffic demand and an operations perspective there is a change in the characteristics around The Lucent Area. One pricing zone would be from I-25 to Lucent, the second from Lucent to Kipling.

The Tolling zone Structure in the Initial Ramp Concept/Project was changed to a single tolling zone for both directions. The primary reason is the short distance and the fewer ingress egress combinations does not lend itself to creating more pricing points. Introducing more pricing points for shorter trips may be more confusing. The eastbound direction is shorter distance and fewer ingress egress combinations than westbound, a single zone for eastbound is clear. It was debatable in the westbound direction whether or not that the last ingress egress combination could be priced as a second zone. The toll zoning of the interim RAMP project could be revisited.

Figure 5.1 Toll Zones Initial Interim and Ultimate Concepts

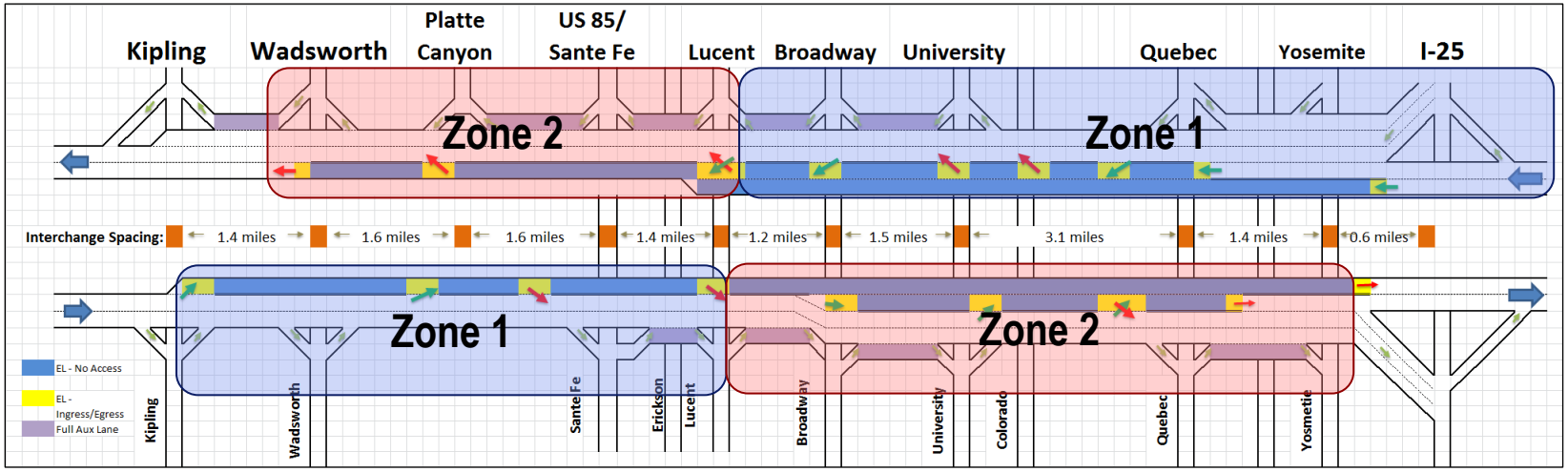
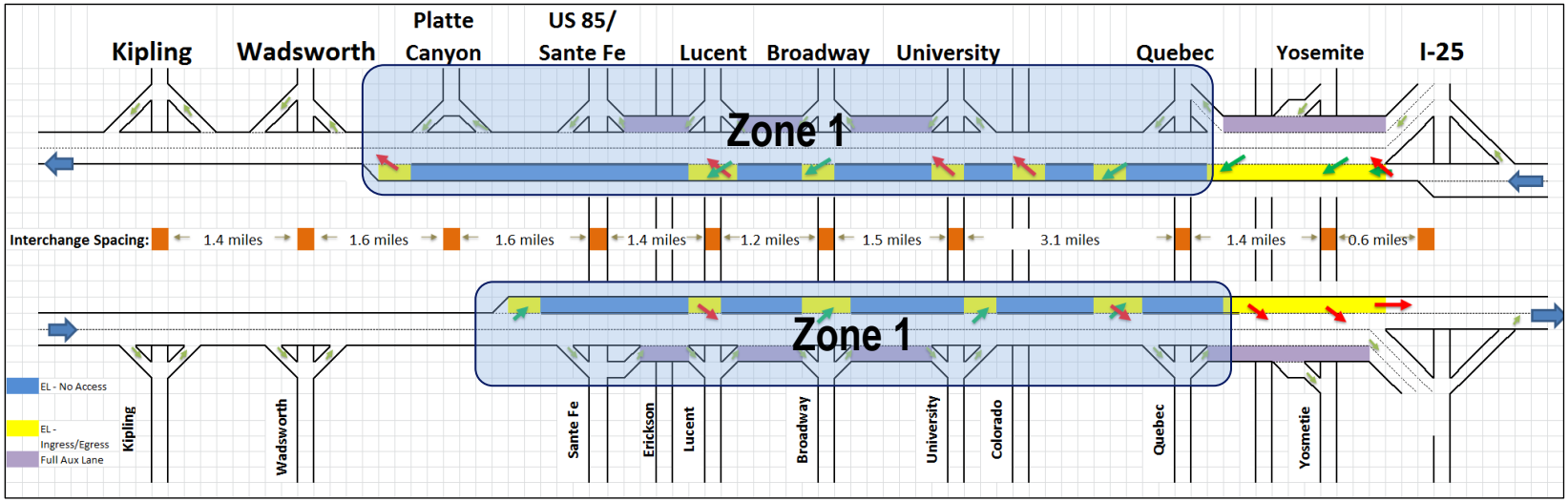


Figure 5.2 Toll Zones RAMP Interim Concepts



6.0 Revenue and Transactions

6.1 INTRODUCTION

This section presents forecasts of revenue and transactions for C-470 Express Toll Lane Concepts described in Sections 4 and 5. Revenue and transaction forecasts for express toll lanes can vary considerably from scenario to scenario since the viability of the concept depends so much on congestion in the general purpose lanes. Scenarios that improve congestion in the general purpose lanes will lead to lower transactions, lower tolls, and lower revenue.

Revenue and transaction forecasts for priced managed lanes are heavily dependent on assumptions such as values of time, traffic growth, transponder ownership, and toll setting criteria. It is prudent to test a range of assumptions, and use risk analysis techniques to consider the potential upsides and downsides of the revenue forecasts. Due to schedule and resource constraints, we did not do that on this project. Decision-makers should bear in mind that forecasts that represent a "central case," as presented in this Section, have a 50% chance of being lower than forecast. The revenue and transaction forecasts in this section are useful for comparing alternatives studied so far, and for comparison against other scenarios that are still being developed.

Note that all toll rates and revenues are expressed in 2013 dollars. This means that we assume that people's willingness to pay tolls will increase at the same rate as the overall rate of inflation, which is a conservative assumption given past history. Financial analysts should apply a range of inflation assumptions in their financial analysis, since inflation is potentially one of the most important risks, especially if bonds are used to finance the priced managed lanes.

Using the forecasting approach described in prior sections, we developed transaction and revenue forecasts for three horizon years: 2018, 2025, and 2035. We used these benchmark years to create annual toll revenue forecasts for the 30 year period from 2018-2047.

Ramp up

It is usual for potential customers to take some time to become familiar with transportation facilities, and the demand "ramps up" at a rapid rate over the first few years of operation. The impact of ramp up on Express Toll Lane utilization is difficult to predict and represents a significant revenue risk in the early years. This behavioral characteristic is not explicitly simulated in the traffic models, with the likely result that fewer people will pay to use the Express Toll Lanes in the early years than is initially forecast by our models. We adjusted for the

potential impact of ramp up by reducing the revenues in the early years of each project phase.

There is a high percentage (40%) of the population that use C-470 today that has Express Pass transponders for use on other tolled facilities in the Denver Region. Most notably E-470. Given the familiarity with tolling systems and with the pressing capacity deficiencies it is possible that the ramp up period could be short. Table 6.1 shows the adjustments to revenue that we applied in the early project years to reflect the impact of ramp up.

Table 6.1 Percent of Modeled Revenue by Year

Year	Ramp Up %
2018	50%
2019	50%
2020	75%
2021	75%
2022	100%

6.2 FORECAST TOLL RATES

There are two main ways to set variable tolls on priced managed lanes: dynamic and static. With dynamic pricing, sensors in the road provide real time travel information to the operator, who can then set the prices to achieve policy objectives, such as maintaining a particular speed in the managed lane or in a combination of the managed lane and the general purpose lane. Tolls can change every few minutes to achieve these objectives.

With static pricing, toll rates are set based on historical experience, with the aim of achieving policy objectives. The toll rates are published in advanced and typically are varied far less frequently (every few hours, for example). CDOT prefers static pricing, since it is consistent with other priced managed lanes projects already in operations.

In our forecasting, we can simulate dynamic pricing. We started with this approach, and then reviewed the range of toll rates and used our best judgment to estimate the tolls that would achieve CDOT's policy objectives using static pricing. There are numerous ways to accomplish this, and alternative approaches could yield significantly different outcomes.

Figure 6.1 shows the toll rates forecast for the RAMP interim Alternative that would be needed to achieve the CDOT policy goal of managing mobility as described in Section 5. It also shows two different approaches to static tolling (labeled "fixed") on the chart. The first approach attempted to closely match the Dynamic Pricing outcome. The second approach reduced the first approach by $0.25. In all three pricing scenarios the license plate users were charged the

posted toll plus $0.75. Figures 6.2 and 6.3 show the same information for 2025 and 2035.

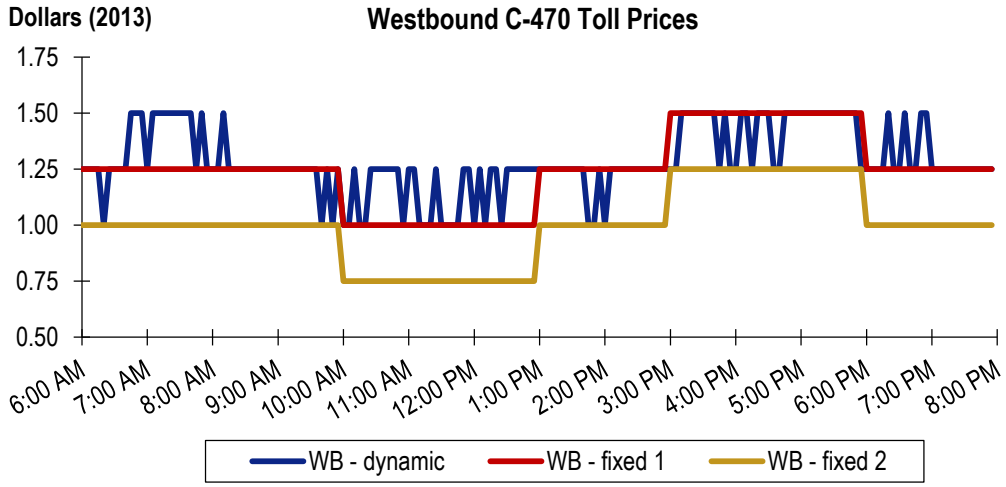
The charts and tables below illustrate the toll prices for the entire day (6:00 AM to 8:00 PM). The dynamic pricing algorithm examined setting new toll prices every 5 minutes. There were conditions set so that the prices would not oscillate and change in value too abruptly however, it will still show oscillating pricing. The development of the fixed pricing is not an exact science. The thought was to simplify the toll schedule as much as possible while trying to be sensitive to traffic performance.

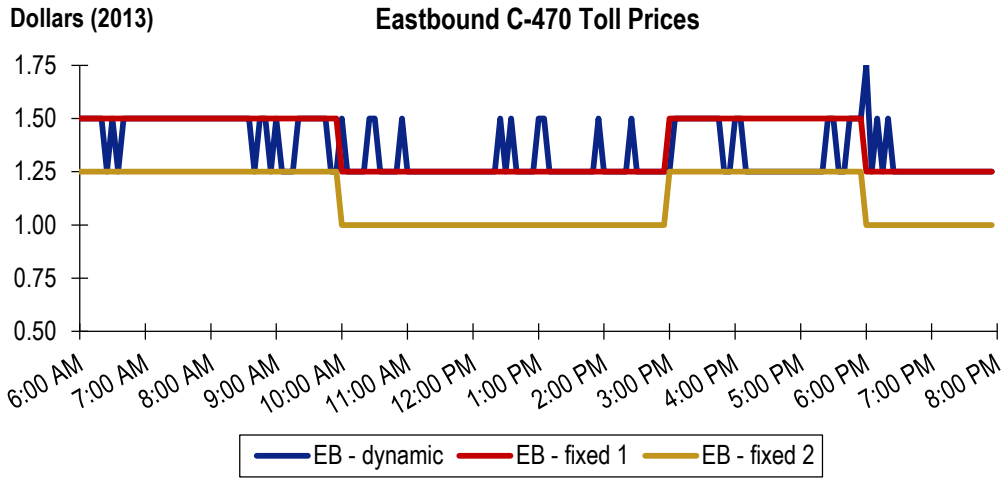
Eastbound Toll Setting Issues

The dynamic toll setting for the Eastbound direction in the later AM hours in 2025 and 2035 resulted in higher tolls than the other hours of the day. The reason for the high tolls was congestion on northbound I-25 mainline created congestion and spill backs onto C-470 Eastbound blocking the Express Toll Lane Egress. As traffic was blocked in the Express Toll Lane the pricing went up. One issue with Dynamic pricing is the unintended consequence of increasing the tolls when in fact it may be more desirable to maintain a lower price to spread the traffic in all lanes. In a dynamic pricing practice if this condition occurred an Traffic Management Operator would likely manually overwrite the price. Based on our observations of the dynamic priced model we felt it was too high and reduced the tolls to what is shown.

The Eastbound Congestion is related to a bottleneck outside of the project limits but within the model limits (northbound I-25). This condition will require more investigation.

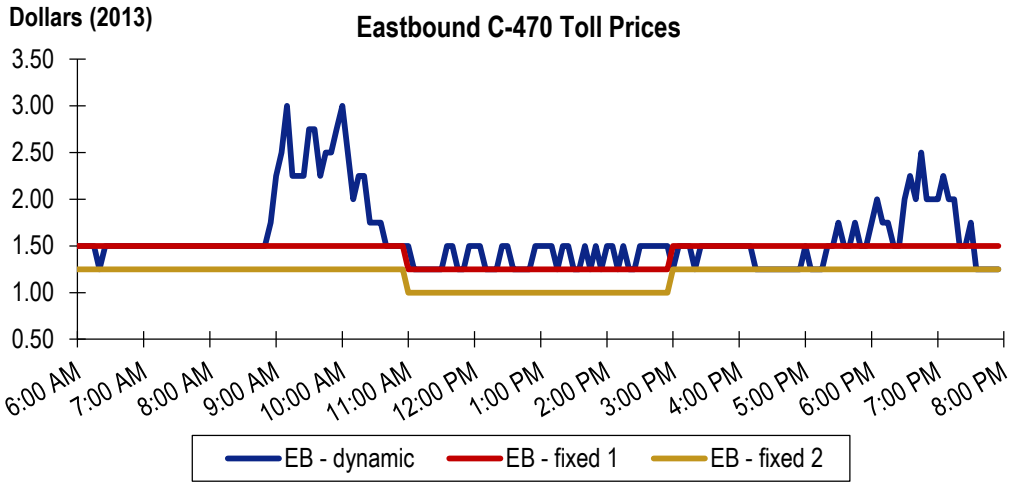
Figure 6.1 Forecast 2018 Toll Prices
Dynamic and Static Pricing Approaches, Interim RAMP Alternative

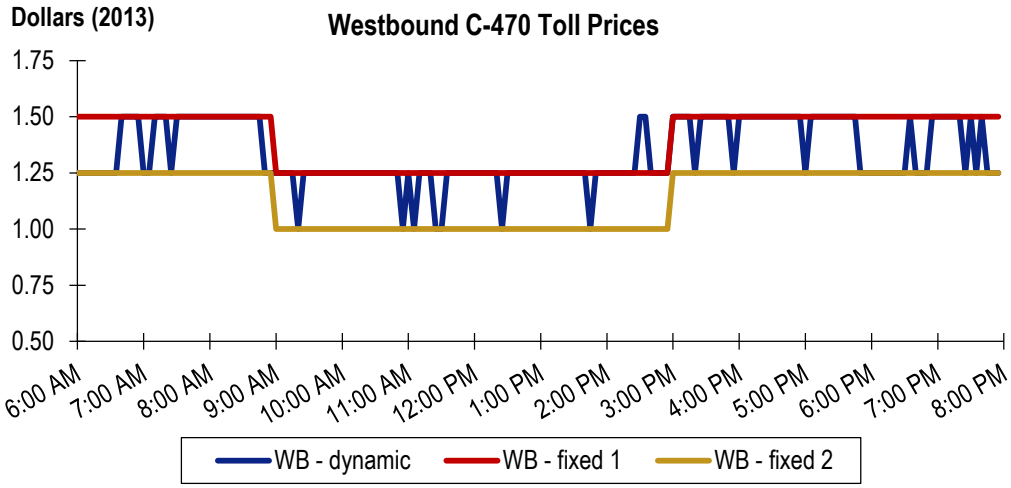




Fixed Time-of-Day Toll Schedule					
Time of Day		Fixed 1		Fixed 2	
From	To	EB	WB	EB	WB
6:00 AM	10:00 AM	$1.50	$1.25	$1.25	$1.00
10:00 AM	1:00 PM	$1.25	$1.00	$1.00	$0.75
1:00 PM	3:00 PM	$1.25	$1.25	$1.00	$1.00
3:00 PM	6:00 PM	$1.50	$1.50	$1.25	$1.25
6:00 PM	8:00 PM	$1.25	$1.25	$1.00	$1.00

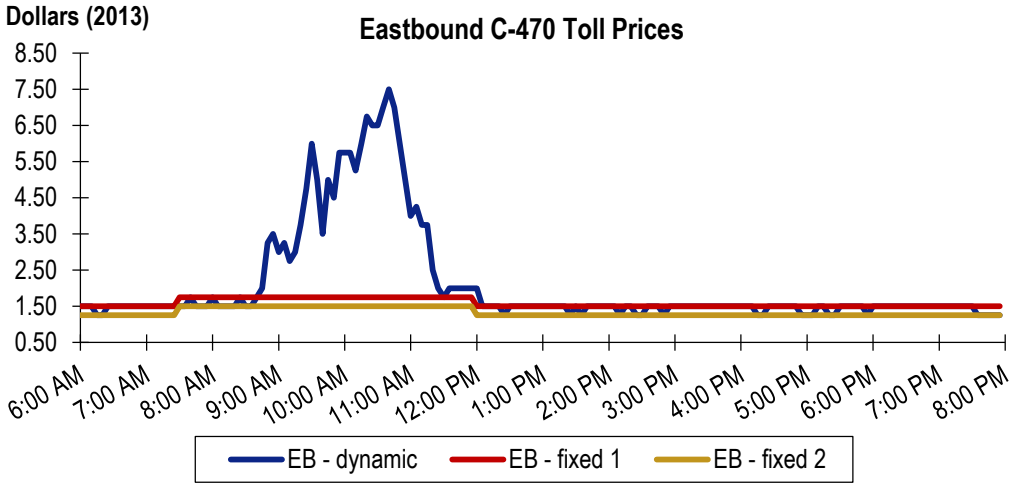
Figure 6.2 Forecast 2025 Toll Prices
Dynamic and Static Pricing Approaches, Interim RAMP Alternative

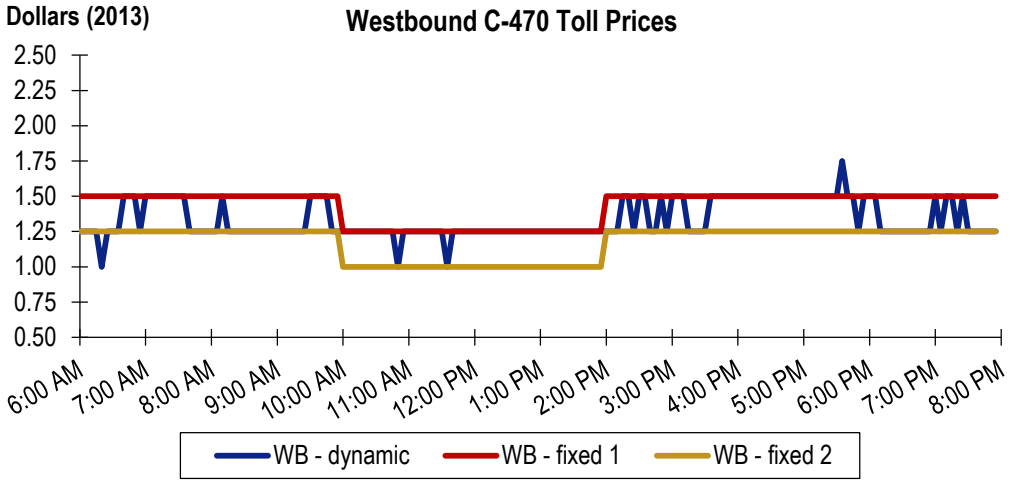




Fixed Time-of-Day Toll Schedule					
Time of Day		Fixed 1		Fixed 2	
From	To	EB	WB	EB	WB
6:00 AM	9:00 AM	$1.50	$1.50	$1.25	$1.25
9:00 AM	11:00 AM	$1.50	$1.25	$1.25	$1.00
11:00 AM	3:00 PM	$1.25	$1.25	$1.00	$1.00
3:00 PM	8:00 PM	$1.50	$1.50	$1.25	$1.25

Figure 6.3 Forecast 2035 Toll Prices
Dynamic and Static Pricing Approaches, Interim RAMP Alternative





Fixed Time-of-Day Toll Schedule					
Time of Day		Fixed 1		Fixed 2	
From	To	EB	WB	EB	WB
6:00 AM	7:30 AM	$1.50	$1.50	$1.25	$1.25
7:30 AM	10:00 AM	$1.75	$1.50	$1.50	$1.25
10:00 AM	12:00 PM	$1.75	$1.25	$1.50	$1.00
12:00 PM	2:00 PM	$1.50	$1.25	$1.25	$1.00
2:00 PM	8:00 PM	$1.50	$1.50	$1.25	$1.25

6.3 TRANSACTION AND REVENUE FORECASTS

Table 6.2 shows transaction and revenue forecasts for each of the design concepts and pricing scenarios for 2018, 2025, and 2035 as well as for the entire 30-year period. Figures 6.4 and 6.5 show the revenue and transaction forecasts for each of the benchmark years graphically, and Figure 6.6 compares the 30-year forecast totals.

For the RAMP Interim concept, the highest revenue can be achieved by the dynamic pricing concept, with a forecast of $353.5 million over 30 years. The static (fixed) price concept 1 is forecast to generate about 10 percent less, at $316.6 million, and static concept 2 another 2 percent lower, at $289.9 million. This demonstrates that the dynamic pricing approach is better able to optimize revenue. However, as noted in Section 7, the fixed price concepts are both forecast to achieve higher vehicle throughput. The primary reason for the difference is the Eastbound C-470 Revenue and Toll Pricing was escalated due to congestion on Northbound I-25. The I-25 congestion prevented Eastbound traffic from leaving C-470 blocking the Express Toll Egress driving the price up in the dynamic settings. When we reduced the prices in this time period more traffic found the ETL desirable at the lower price, allowing more traffic albeit at a lower price generating less revenue.

Extending the project to Kipling is forecast to achieve an additional 10 percent in revenue using the dynamic pricing concept, to $390.1 million. The Ultimate project, adding two Express Toll lanes in each direction and extending west to Kipling would generate $26.9 million in 2035, 80% more than the project that terminates at Kipling in 2035. We did not evaluate the ultimate project for the other years.

Table 6.2 Revenue and Transaction Forecast Summary
Revenue in 2013 Dollars

Concept	Pricing Scenario		Revenue and Transactions (Millions) 2018[a]	2025	2035	30-year
RAMP Interim	Dynamic	Revenue	$8.1	$9.7	$13.7	$353.5
		Transactions	4.9	5.8	6.8	186.0
	Fixed 1	Revenue	$8.1	$9.4	$11.8	$316.6
		Transactions	4.9	5.6	6.9	185.6
	Fixed 2	Revenue	$7.6	$8.8	$10.7	$289.9
		Transactions	5.4	6.2	7.3	199.5
RAMP Interim extended to Kipling[b]	Dynamic	Revenue	$10.4	$10.8	$14.9	$390.1
		Transactions	5.6	6.1	7.9	211.1
Ultimate	Dynamic	Revenue	N/A[c]	N/A	$26.9[d]	N/A
		Transactions	N/A	N/A	10.7	N/A

[a] 2018 revenue transaction and revenue forecasts in this table do not include ramp-up assumptions, but the 30-year revenue and transaction total does.

[b] Interim extended to Kipling is a draft result as the project was not pursued further and therefore was only modeled using a dynamic function.

[c] Modeling of the Ultimate was not done for the early years since the project would not be constructed until 2035.

[d] Annual revenue inflated due to congestion eastbound.

Source: Cambridge Systematics, Inc.

Figure 6.4 Annual Gross Revenue Comparisons RAMP Interim Alternative

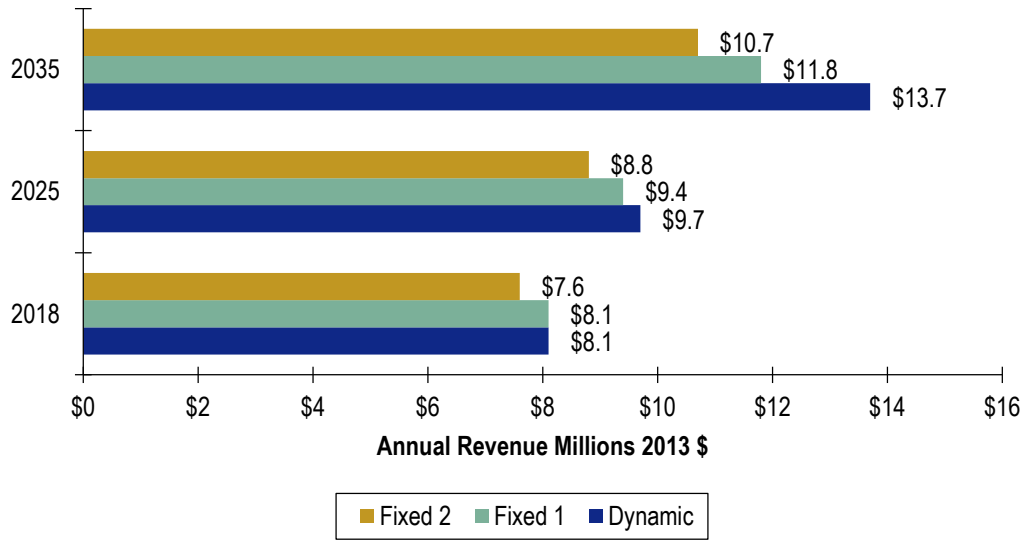


Figure 6.5 Annual Transaction Comparisons RAMP Alternative

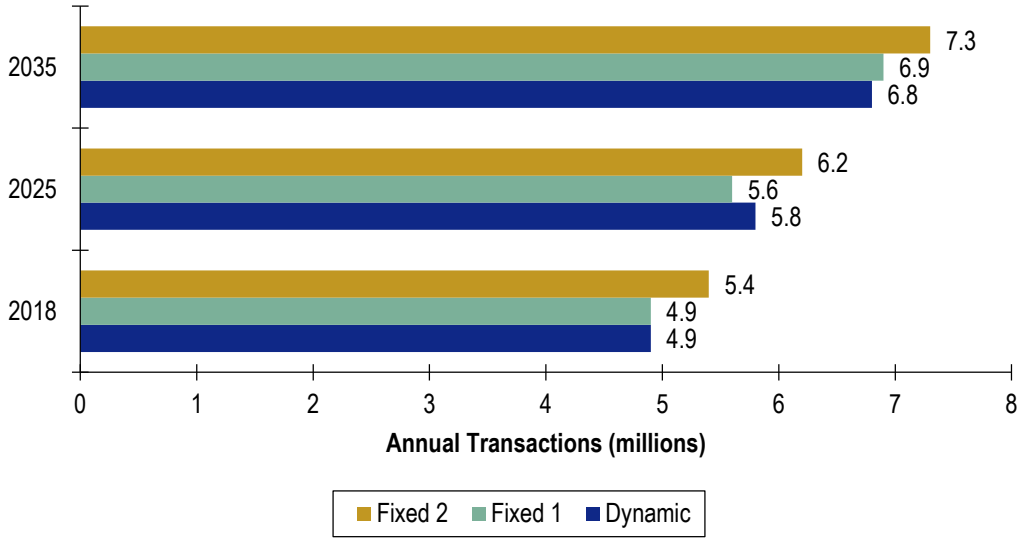
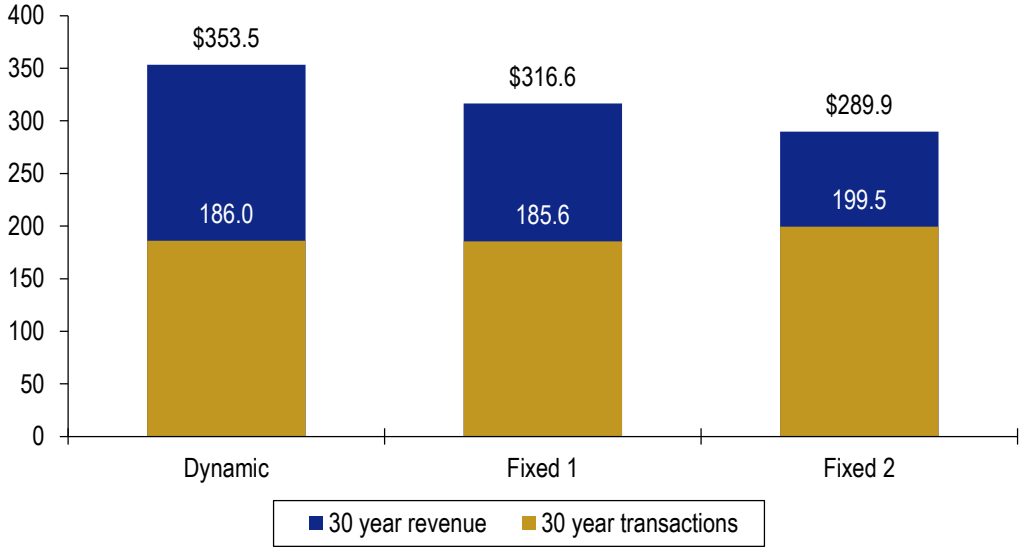


Figure 6.6 Forecast 30-year Gross Revenue and Transactions
RAMP Interim Alternative

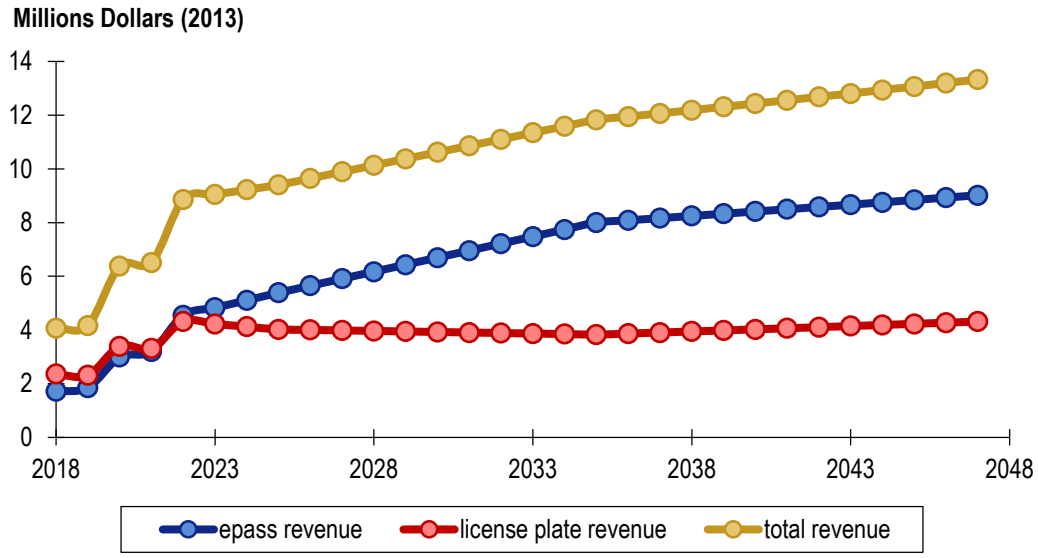


Revenue by ExpressToll Pass and License Plates

The study was conducted assuming a certain level of ExpressToll Pass Ownership Percentage that increased by analysis year. While a higher license plate usage could yield higher gross revenue, the net revenue would not increase due to the costs of billing a license plate user. Figure 6.7 below is traffic revenue stream for the Fixed Price 1 scenario. The relationship between license plate revenue and ExpressToll Pass Revenue was similar in all scenarios.

The revenue Stream also illustrates the ramp up assumptions in the first four years of the project being opened.

Figure 6.7 Gross Revenue Stream
RAMP Interim Alternative Fixed-Price Scenario 1



6.4 DISCLAIMER

This findings of this report were developed for use by Douglas County and the C-470 Corridor coalition to compare project alternatives. Additional work is still needed to refine the project concept and conduct studies that would be adequate to be used to inform financing.

The information and results presented in this report are estimates and projections that involve subjective judgments, and may differ materially from the actual future traffic and revenue. This report is not intended nor shall it be construed to constitute a guarantee, promise, or representation of any particular outcome(s) or result(s).

7.0 Traffic Operations

7.1 OVERVIEW

Traffic performance for the C-470 Express Toll Lane project is primarily being evaluated on travel speed/average travel Times, Throughput and bottlenecks. The VISSIM traffic models produce robust measures for 2 7-hour peak periods and by individual time slices as low as 5 minutes. Some of the measures are rolled up into 30 minute or hourly.

The interim concept was evaluated using three different pricing schemes, while the revenue varied, the traffic performance issues observed were very similar. The objective of the traffic operations chapter is to provide insights into overall performance and to identify areas of concern.

Appendices C through F include the detailed model summary tables and charts for each scenario run for this study report.

Network Summary Statistics

The network summary statistics are Vehicle Miles of Travel (VMT) and Vehicle Hours of Travel (VHT). Table 7.1 is a comparison of the Interim Project Fixed Price 1 scenario by year and the 2035 Ultimate Project. Figures 7.1 and 7.2 plot the same information. The VMT increases by year and for the 2035 Ultimate configuration. The VHT comparison between the interim and ultimate projects shows declining VHT in the PM peak and increasing in the AM peak. The AM Peak is worse mainly due to the affects of the northbound I-25 Bottleneck that in turn impacts eastbound C-470. Since C-470 in the ultimate condition has more lanes delivering traffic to the bottleneck at I-25, the traffic congestion builds faster and remains a problem longer.

Table 7.1 VMT and VHT Summary by Year

	VMT (Millions)		VHT (Thousands)	
Year	AM Peak	PM Peak	AM Peak	PM Peak
2018 Interim Fixed Price 1	1.42	1.47	30.1	46.7
2025 Interim Fixed Price 1	1.59	1.63	40.3	55.2
2035 Interim Fixed Price 1	1.70	1.76	58.0	60.1
2035 Ultimate Dynamic	1.71	1.80	61.8	59.4

Figure 7.1 AM Peak Period VMT and VHT

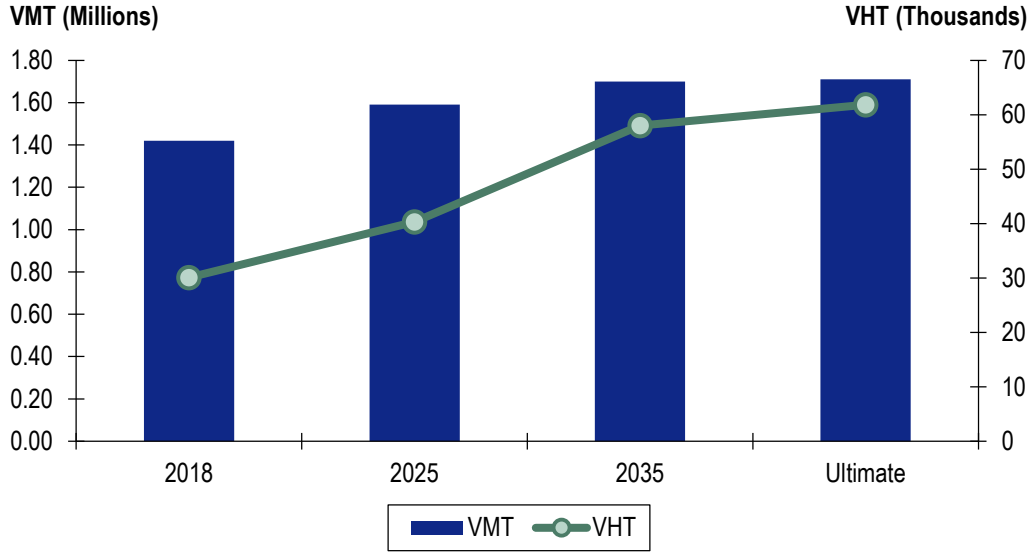
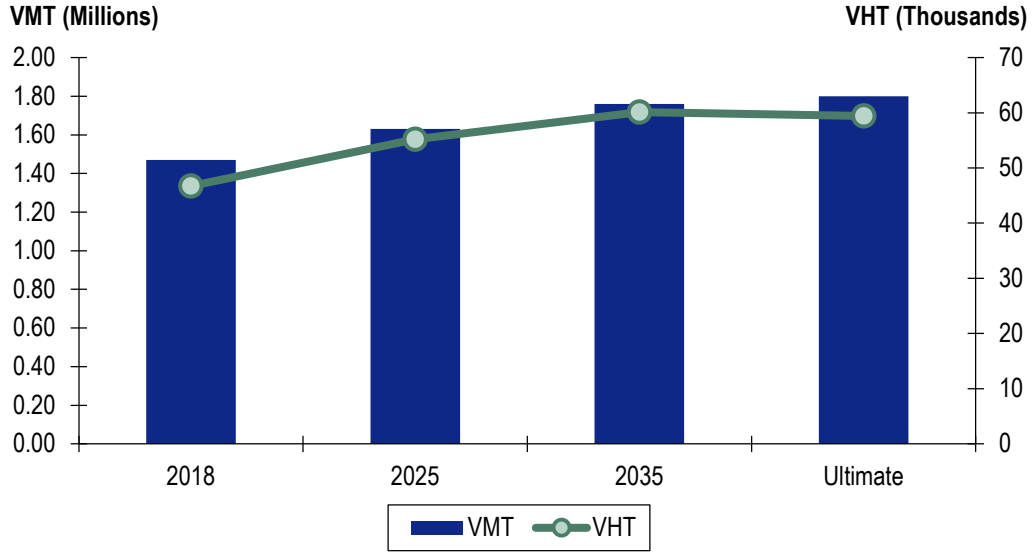


Figure 7.2 PM Peak Period VMT and VHT



7.2 INTERIM RAMP CONCEPT/PROJECT

Eastbound C-470

The AM peak period is the peak direction for Eastbound C-470. Figure 7.3 is a speed flow plot of the VISSIM model results for the mainline freeway in both the General Purpose Lanes and in the Express Toll Lanes. Each square in the diagram represents a location of a modeled detector (spaced every 2,000 feet) and

a 5 minute time interval. The diagram is color coded based on the speed, generally shades of green are high speeds 50 mph and above, and shades of yellow, orange and red are poor performing speeds. Red is the worst performance with speeds 20 mph or less. This type of diagram is often referred to as a "Heat Map," where the warm colors indicate congestion.

Figure 7.3 illustrates the 2035 AM peak condition for the Fixed pricing Scenario 1. The other scenarios and different years can be found in the appendix. However this scenario is illustrative of the operational issues observed in the Interim Cases. The congestion issues are as follows the numbers of the list correlate to the numbers on the exhibit.

1. **Eastbound C-470 Mainline around Wadsworth.** The traffic demand is more than the 2-lanes of traffic can handle prior to the start of the Express Toll Lanes. A queue of traffic builds up and backs towards Kipling and Beyond.
2. **Broadway Off Ramp**. Traffic at Broadway off ramp in the 6:30 a.m. to 8:00 a.m. is experience issues, this will require additional attention.
3. **University on-ramp.** Operational issues associate with the interchange University that will warrant further investigation.
4. **I-25 Congestion.** I-25 northbound is highly congested, this congestion affects traffic on eastbound C-470 attempting to get onto I-25 Resulting in a traffic spillback that extends back to Santa Fe.
5. **C-470 Express Toll Lanes.** The entire Express Toll Performance is a affected by the I-25 congestion discussed in Item 4.

Westbound C-470

Figure 7.4 is the speed map for 2035 Westbound C-470 Fixed Pricing Scenario 1 in the PM Peak period. There are two main issues associated with westbound operations. The numbers correlate to the numbers on the exhibit.

1. **Mainline bottleneck west of Quebec Interchange.** There is an extensive amount of traffic loadings from I-25 ramps, E-470, Yosemite and Quebec that neck down to 3 lanes (2 general purpose, 1 Express Toll Lane) west of Quebec. The reduction of lanes and the traffic combine to create a bottleneck that backs up C-470, the speeds in this area are less then 20 mph for a long period of time. This blockage is so sever that any issues from weaving to the Ingress of the Express Toll Lanes is masked.
2. **Wadsworth Egress From Express Toll Lane.** The Express Toll Lane terminates at the Wadsworth Egress, ideally this would not end until Kipling. As a result there is localized traffic as general purpose lane shifts and weaving from the Express Toll Lane Egress to Wadsworth Exit occurs.

Figure 7.3 2035 AM Peak Eastbound C-470 Interim Ramp Project Speed Maps

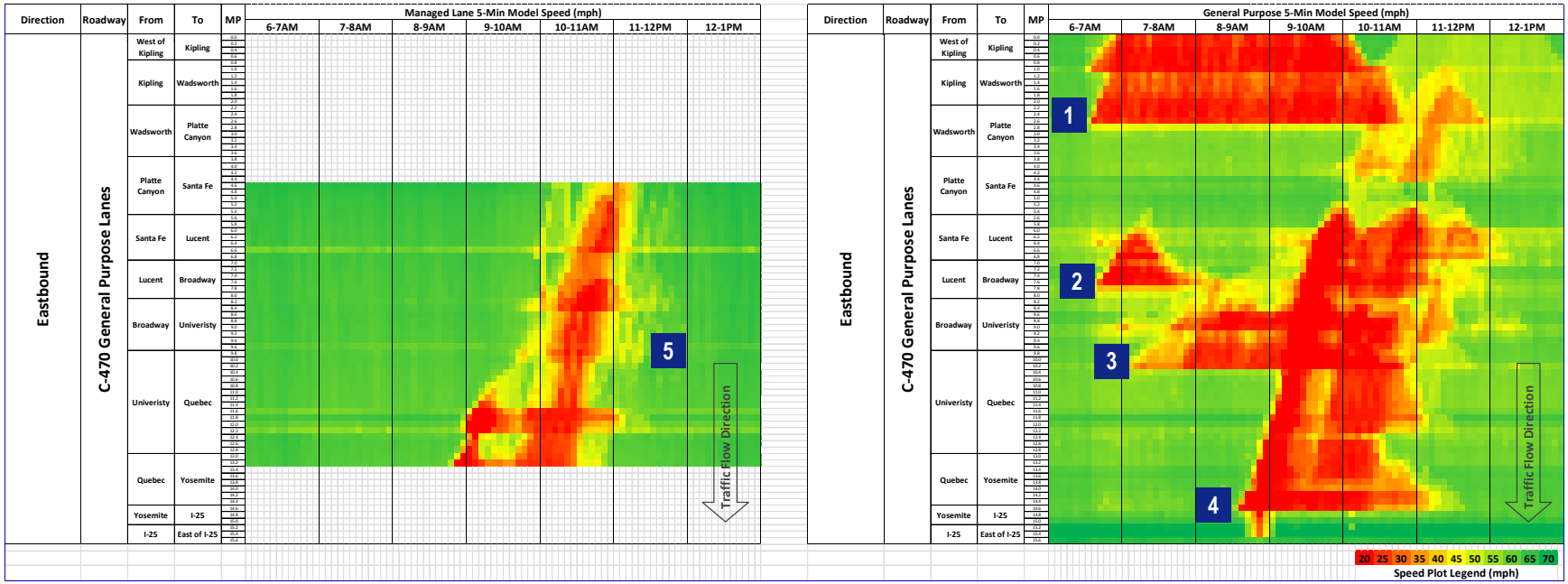
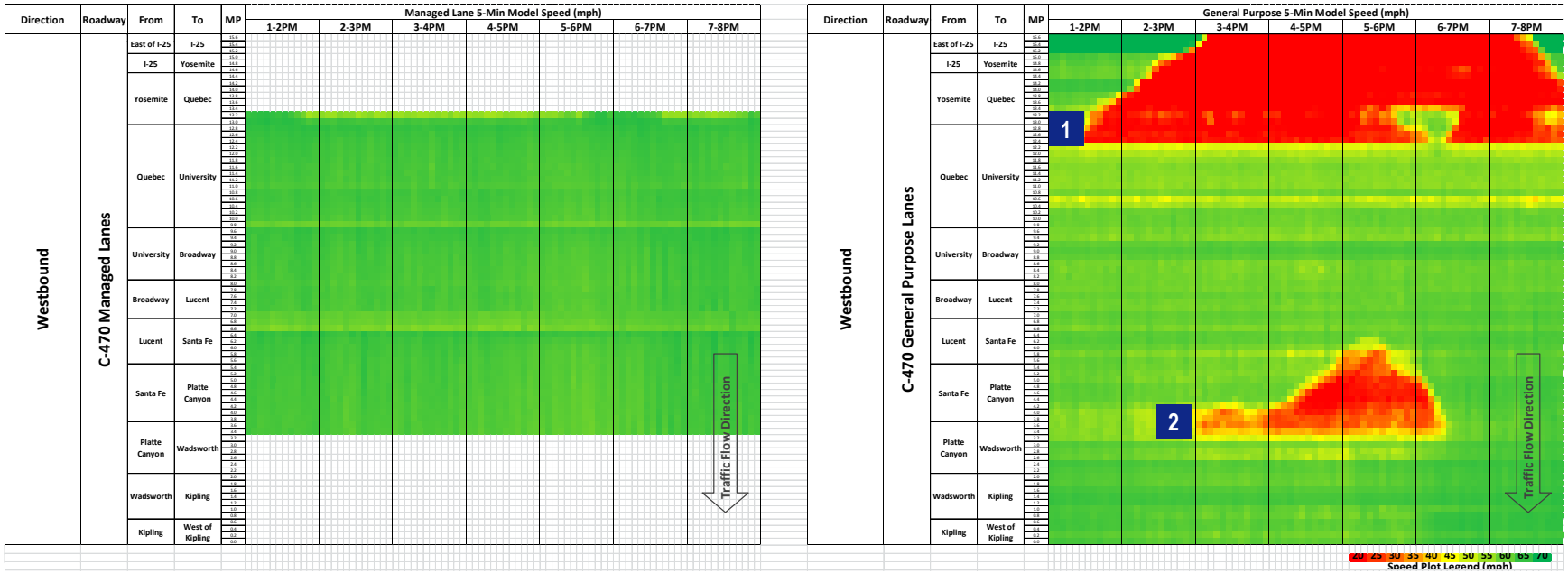


Figure 7.4 2035 PM Peak Westbound C-470 Interim Ramp Project Speed Maps



7.3 2035 ULTIMATE CONFIGURATION

To be completed.

8.0 HOV 3+ Exemption

TO BE COMPLETED LATER

9.0 Key Findings

- The Interim project will provides mobility relief to a very congested corridor.
- The effectiveness of the interim project begins to reduce by 2035, by then additional improvements will be needed:
  - Extend the project west to Kipling; and
  - Construct 2 lanes in each direction form I-25 to Lucent.
- Westbound operations between I-25 and Quebec are significantly congested due to the total lanes delivering traffic westbound (7 total lanes of traffic) are reduced to 3 lanes west of Quebec:
  - A secondary factor is the amount weaving that is occurring between I-25 and Quebec and the first Express Toll Lane Ingress. At this time it is difficult to say how significant the weaving issues are to operations with the bottleneck condition that is down stream.
- Eastbound C-470 operations are impacted by congestion on Northbound I-25:
  - The congestion on Northbound I-25 is caused by growth in traffic and is unrelated to the Express Toll Lane Project.

Appendix A

Land Use by County

2010					
County	Area	Population	Households	Employment	Enrollment
Adams	1,183	451,143	164,704	174,179	110,160
Arapahoe	807	556,375	227,635	287,344	141,355
Boulder	740	292,014	121,630	161,813	80,984
Broomfield	33	51,673	19,359	32,599	14,246
Clear Creek	397	10,036	4,456	3,056	1,076
Denver	155	584,659	265,531	445,062	191,419
Douglas	843	283,291	101,604	93,042	59,962
Gilpin	151	5,320	2,368	5,057	362
Jefferson	773	539,853	222,099	222,381	111,335
Park	580	56,818	19,170	10,242	10,636
Weld	589	32,715	11,823	9,040	3,288
Total	6,251	2,863,897	1,160,379	1,443,815	724,823

2035					
county	Area	Population	Households	Employment	Enrollment
Adams	1,183	723,290	276,367	281,630	152,509
Arapahoe	807	778,692	332,203	375,115	181,474
Boulder	740	361,262	152,827	169,160	102,496
Broomfield	33	87,665	34,062	67,675	21,000
Clear Creek	397	12,880	5,838	3,787	2,330
Denver	155	746,452	353,009	603,018	226,594
Douglas	843	481,681	178,871	173,940	84,199
Gilpin	151	7,091	3,223	5,613	829
Jefferson	773	680,690	290,084	290,590	126,275
Park	580	118,826	40,644	18,717	2,977
Weld	589	82,855	30,796	18,737	9,371
Total	6,251	4,081,384	1,697,924	2,007,982	910,054

Change (2035 - 2010)				
County	Population	Households	Employment	Enrollment
Adams	272,147	111,663	107,451	42,349
Arapahoe	222,317	104,568	87,771	40,119
Boulder	69,248	31,197	7,347	21,512
Broomfield	35,992	14,703	35,076	6,754
Clear Creek	2,844	1,382	731	1,254
Denver	161,793	87,478	157,956	35,175
Douglas	198,390	77,267	80,898	24,237
Gilpin	1,771	855	556	467
Jefferson	140,837	67,985	68,209	14,940
Park	62,008	21,474	8,475	(7,659)
Weld	50,140	18,973	9,697	6,083
Total	1,217,487	537,545	564,167	185,231

Percentage Change (2035 - 2010)				
County	Population	Households	Employment	Enrollment
Adams	60%	68%	62%	38%
Arapahoe	40%	46%	31%	28%
Boulder	24%	26%	5%	27%
Broomfield	70%	76%	108%	47%
Clear Creek	28%	31%	24%	117%
Denver	28%	33%	35%	18%
Douglas	70%	76%	87%	40%
Gilpin	33%	36%	11%	129%
Jefferson	26%	31%	31%	13%
Park	109%	112%	83%	-72%
Weld	153%	160%	107%	185%
Total	43%	46%	39%	26%

Appendix B

Preliminary Financial Analysis of Segment 1 (I-25 to Kipling)

PARSONS BRINCKERHOFF

C-470 Corridor Coalition

Preliminary Financial Analysis of Segment 1 (I-25 to Kipling)

January 10, 2014

TABLE OF CONTENTS

1. Executive Summary 3
2. Project Development and Background 4
3. Gross Toll Revenue 5
4. Operating and Maintenance Costs 7
5. Toll Revenue Bonding Capacity 7
6. Future Capacity Expansion of the Tolled Express Lanes (2035 Ultimate Project Configuration) 8
7. Variations to the Interim Project 9

1. EXECUTIVE SUMMARY

Since 2011, the C-470 Corridor Coalition Technical Working Group (TWG) has been investigating tolling options to pay for the expansion of capacity on C-470 for Segment I (between I-25 and Kipling (the Project)). During this conceptual analysis, the TWG concluded that the Project could be implemented in phases, and that the most critical need was for one additional lane in each direction. As such, the Project was split into Interim and Ultimate components in an attempt to improve the financial viability.

After several modeling iterations, the Interim Project component was sized to maximize operational improvements while maintaining financial feasibility. Toll revenues from the Interim Project will be matched with Responsible Acceleration of Maintenance and Partnerships (RAMP) and funding from other local, and potentially state, sources. When traffic levels warrant, the Ultimate Project components would be built using a cash reserve that accrues after several years of toll operations.

The Interim Project was established as one additional lane, both westbound and eastbound, from I-25 to Kipling Avenue. The Ultimate Project will add a second lane in each direction; westbound between I-25 and Lucent Boulevard and eastbound between Broadway and I-25.

The Interim Project capital cost is estimated at $205 million, and includes adding capacity with the tolled express lane and auxiliary lanes in certain areas and reconstructing certain parts of the existing roadway that demonstrate the need and can be accommodated within the funding envelope. The roadway construction elements of the Interim Project are somewhat flexible, providing latitude for meeting the capacity enhancement goals in an environment of shifting capital resources.

The gross toll revenue estimates resulting from the tolled express lane were developed by the TWG, as well as the operating and maintenance cost forecasts needed to render a projection of net revenues available for debt repayment. Table ES-1 summarizes the gross-to-net revenue calculations for certain years in the forecast. The forecasts were developed for the years 2017 through 2046, but used interpolation / extrapolation for revenue years other than 2018 and 2035.

Table ES-1
Summary Cash Flow - Select Years
Year of Expenditure ($1000s)

	2017	2020	2025	2030	2035
Gross Revenue	5,281	12,850	15,425	20,659	26,541
Roadway Maintenance	500	538	609	689	780
Toll Operations	1,706	3,225	3,543	4,226	5,019
Net Revenues	3,075	9,086	11,273	15,744	20,742

The bonding capacity of the toll revenues was estimated using the net revenue stream summarized above. Thirty (30) year debt was structured that includes a Transportation Infrastructure Finance and Innovation Act (TIFIA) loan. TIFIA is a USDOT program that provides financing assistance to infrastructure projects that meet certain innovative delivery criteria. It was included to take advantage of the lower borrowing rates and debt service coverage ratios required by TIFIA. The total bonding capacity (net bond proceeds) of the toll revenue stream amounts to approximately $95 million, which will be paired with the Project's RAMP allocation (P3 grouping), and other state and local funding in order to cover the total cost of the Interim Project. Table ES-2 illustrates the sources and uses of the Interim Project's funding package.

Table ES-2
Year of Expenditure ($1000s)

Sources:	
Toll Revenue Bonds	$ 95,000
RAMP P3 Allocation	$100,000
Local (Douglas County)	$ 10,000
Total Sources	$205,000
Uses:	
Design/Construction	$163,000
CDOT Mgmt./Oversight	$ 31,000
Right-of-Way	$ 6,000
Procurement / Level 3 T&R	$ 5,000
Total Uses	$205,000

The following sections detail the analysis and methodology that support the summary figures provided above. While the analysis reflects the most current information available, much of the analysis required to optimize the Interim Project definition, subsequent capacity improvements (limits and timing of various components), and associated toll revenue forecasting will continue into 2014. "Investment Grade" traffic and toll revenue analysis has not been performed, but is planned for 2014. The toll revenues currently in use by the TWG are considered a "level-2" effort and were developed after a number of iterations to test what size and scope of the tolled express lane facility was needed to insure sufficient mobility in the corridor.

The TWG's preliminary analysis suggests that the Ultimate Project improvements will be needed at some point between 2025 and 2035 at a cost of roughly $50 million in year of expenditure terms. These improvements would be initiated in 2033 such that they can be operational by 2035. The Interim Project funding plan accommodates these future capacity expansion costs, annual operating and maintenance costs, and periodic capital maintenance items, as detailed in the following sections.

2. Project Development and Background

The TWG began developing funding concepts for the Project in 2011. At that point there were three general approaches: Option A: managed lane, Option B: all tolled, and Option C: a free roadway expansion funded through a separate funding initiative. The separate funding initiatives under consideration for Option C were a privilege to work (head) tax, property tax, and a sales tax. These Project / funding concepts were analyzed and presented to the public to collect opinions. None of the Option C funding mechanisms were clear winners in the eye of the public or the Corridor Coalition Policy

Committee. Option B, tolling all traffic, was considered too restrictive. In 2012, the Policy Committee collectively moved to elect Option A, the managed lane concept, to be carried forward by the TWG.

More detailed traffic and revenue work was conducted by the TWG during 2013, evaluating a variety of roadway concepts that helped identify where pinch points in the traffic flow existed. Double and single lane phased concepts were developed, which showed promise, given that preliminary toll revenue may not be sufficient to cover all of the capital and operating costs. When the RAMP program was announced, the Project's financial prospects improved. The eventual award of the RAMP funding from CDOT provided a critical match to the toll revenue component of the preliminary financial plan.

The current Interim and Ultimate projects are the result of many iterations of modeling to balance operational aspects of the project with the financial resources available.

3. Gross Toll Revenue

CDOT projects average annual daily traffic (AADT) of 82,000 between Kipling Avenue and Lucent Boulevard and 113,000 between Lucent Boulevard and I-25 in 2020. The average projected AADT over the entire stretch of the Interim Project in 2020 is approximately 95,600.[1] The TWG's traffic modeling indicates that in 2020, the tolled express lane will capture an AADT of 15,600, or about 16% of total traffic. The average weekday traffic volume in the managed lane is expected to be just over 21,700 users in 2020, growing to over 30,100 users in 2035.

Gross toll revenue projections include revenues from transponder and photo tolling transactions, similar to operations on the E-470 toll road. Camera technology will be used both for enforcement and toll collection. With E-470 close by, transponder penetration is expected to be strong in the facility's opening year, and grow to 75% by 2035.

Gross toll revenues were reduced in the first three years of the forecast to account for "ramp-up." Ramp-up refers to the time period following the facility's opening for users to become accustomed to using the tolled express lane facility - understanding how to use it, where it goes, and becoming comfortable with paying for the time savings and reliability that the tolled express lane provides. The TWG adopted the ramp-up assumptions used in the US-36 managed lane investment grade traffic and revenue study.[2] Applying these factors reduced gross revenues by 55% in the first year of operation, 22% in the second year, and 4% in the third year. To achieve these ramp-up goals, it will be important for the facility to be marketed to users in advance of its opening to accelerate their understanding of the tolled express lanes and their benefits. This will likely include mailings, television commercials, on-line media, and opportunities for people to obtain transponders easily so that transponder penetration can be maximized as early as possible.

Based on experience at E-470 and other similar facilities, a reduction for leakage of 8% was applied to each year of the revenue forecast. This leakage mainly represents people who do not have an account

[1] http://dtdapps.coloradodot.info/Otis/TrafficData
[2] http://www.coloradodot.info/library/studies/us-36-managed-lanes-investment-grade-traffic-and-revenue-study/Final-20Report_080911.pdf/view

with the facility operator and do not pay the photo toll bill when received in the mail, either refusing to or because the driver cannot be identified such that a bill can be mailed to them.

The proposed system for the Interim Project assumes that each driver will pay the same toll regardless of the length of the trip. An open road tolling format is proposed, therefore there will be no option for tolled express lane users to stop and pay the toll with cash at a toll booth. Tolling points will be equipped with transponder readers to identify tolled express lane users who have an account and transponder. If the tolled express lane user does not have a transponder but has an account with the operator, the camera system will take a photograph of the user's license plate and deduct the toll (plus a photo transaction surcharge) from the account.

If the tolled express lane user does not have a transponder or an account with the authority, the camera system will take a photograph of the user's license plate and a bill will be sent to the registered owner of the vehicle based on Department of Motor Vehicles records and reciprocity agreements with other states. A $0.75 premium (charge in addition to the base toll rate) has been assumed for all photo transactions to cover the additional cost of processing. Additional charges to cover the cost of mailing and other collection costs may also be passed on to the customer but these costs are assumed to be revenue neutral.

The tolling points will be located at the tolled express lane exits, simplifying the toll collection system and reducing the cost of additional tolling equipment that would be required for distance base toll rates. The toll rate structure is proposed as "fixed – variable," meaning that time of day pricing will be used (i.e. different peak, shoulder, and off-peak rates) but the toll rates / structure will not change during the day in reaction to traffic volume or speed changes. Toll rates modeled in the current revenue projection range from $1.50 to $2.50.

Gross revenues and transactions net of ramp-up are provided in Table 1. The revenue projections use extrapolation and interpolation around the 2018 and 2035 modeled years. All revenues have been escalated to "year of collection" dollar terms, assuming a 2.5% inflation rate.

Table 1: Adjusted Gross Toll Revenue Projections
2017 to 2035 ($1000s)

	Transactions			Gross Revenues
	Transponder	Photo	Total	Total
2017	2,080	1,838	3,917	4,059
2018	2,217	1,783	3,999	7,515
2019	2,354	1,728	4,081	9,888
2020	2,491	1,673	4,163	11,021
2021	2,628	1,617	4,246	11,805
2022	2,765	1,562	4,328	12,657
2023	2,902	1,507	4,410	13,584
2024	3,039	1,452	4,492	14,592
2025	3,254	1,478	4,732	15,690
2026	3,468	1,504	4,972	16,887
2027	3,683	1,530	5,213	18,192
2028	3,897	1,556	5,453	19,617
2029	4,112	1,582	5,693	21,172
2030	4,326	1,607	5,934	22,872
2031	4,541	1,633	6,174	24,730
2032	4,755	1,659	6,414	26,762
2033	4,970	1,685	6,655	28,987
2034	5,184	1,711	6,895	31,423
2035	5,201	1,728	6,929	33,150
			Total	344,603

4. Operating and Maintenance Costs

The cost to operate a tolled express lane facility consists of all administrative and oversight functions within the organization, customer service, insurance, safety patrols, payment processing, marketing, and policing, among other things. For planning purposes, the majority of these costs can be expressed in a cost per transaction, which covers payment processing, customer service, and other "back office" administrative items. Payment processing for transponder transactions is highly automated relative to photo tolling transactions, and is therefore much less costly. Our analysis assumes $0.19 per transaction for transponders and $0.64 for photo tolls based on industry experience with similar toll facilities (2013 unit costs).

Additional operating costs deducted from Adjusted Gross Revenues are approximately $400,000 annually to fund HPTE in its oversight role and $135,000 annually for the Colorado State Highway Patrol to provide safety and enforcement on the facility (2013 unit costs). All operating costs are escalated annually at 2.5%.

Based on CDOT experience in the corridor and studies performed for US 36, a comprehensive roadway maintenance unit cost of $17,100 per lane mile (2013) was used to calculate the tolled express lane annual maintenance cost. This includes minor crack and pothole repair, sign and guardrail repair, mowing, snow removal, and other items. The Interim Project is approximately 26 lane miles long, requiring annual O&M funding of about $450,000 (2013). Table 2 provides the operating and maintenance costs for select years. All operating and maintenance costs have been escalated to year of expenditure terms using 2.5% inflation.

Table 2: Operating and Maintenance Costs, Select Years (YOE $1000s)

	2017	2020	2025	2030	2035
Facility (Roadway) O&M	500	538	609	689	780
Customer Service Center	1,127	2,602	2,838	3,429	4,117
HPTE Oversight	432	465	527	596	674
CSP Enforcement	147	158	179	202	229
Total Annual O&M Costs	2,206	3,763	4,152	4,916	5,799

5. Toll Revenue Bonding Capacity

The net revenues calculated by subtracting the operating and maintenance costs from the Adjusted Gross Revenues was used in a calculation of financial capacity of a "non-recourse" toll revenue bond transaction. Non-recourse refers to the assumption that only the toll revenues from the Project are dedicated to the bond's repayment (there is no state or local general liability, nor are other tax revenues from sales or property taxes available to repay debt if toll revenues do not meet expectations).

As noted above, all operations and maintenance costs will be paid for out of gross revenues before any debt service payments are made. This is a standard provision of toll road debt to insure the road is kept in a safe state of operation such that it can remain open for use. A 2.0X (times) debt service coverage

ratio was applied to the net toll revenues for all bonds, assumed to be issued by HPTE. The TIFIA loan assumes a lower debt service coverage ratio of 1.5X. The minimum combined average debt service coverage ratio is approximately 1.6X. Debt service coverage mitigates the risk that the roadway will not generate enough revenue to repay investors in the toll road debt. Put another way, the projections of revenue are 1.6 times greater than what is required to meet debt service payments.

Revenue set aside for debt service coverage, amounting to approximately $75 million between 2017 and 2035, will be used for capital maintenance (mill and overlay and toll system upgrades) and future expansion expected to be needed by 2035.[3] Tolling system hardware and software upgrades will be needed every ten years at a cost of approximately $5 million (2013 unit cost). One mill and overlay is expected to be needed 15 years after the facility opens at a cost of approximately $9.1 million (2013 unit cost).

Debt service coverage will accrue in an account over the life of the financing and these amounts will be deducted from that account as needed. We expect that after paying for the capital maintenance items noted above, the account balance will be approximately $53 million in 2033, which is adequate for building the required future capacity expansion needed by 2035. Expansion plans, estimated to cost $50 million in 2033 year of expenditure dollars, are described below in Section 6.

The revenue remaining after subtracting debt service coverage from net revenue was used in a bond structuring that combined senior current interest bonds, junior current interest bonds (TIFIA loan), and capital appreciation bonds. The interest rates for the various bond components ranged from 4.25% to 7.25% based on current experience with similar financings. Debt service reserve accounts (10% of gross bond proceeds), capitalized interest costs during the first five years of operations, and issuance costs were all subtracted from gross bond proceeds, leaving net proceeds of approximately $95 million available for constructing the Interim Project.

Other funding for the Interim Project is needed to make up the remainder to cover the $205 million capital cost, which includes $100 million in RAMP (under the P3 grouping) and $10 million identified, appropriated and / or expended by Douglas County and other local agencies.

6. Future Capacity Expansion of the Tolled Express Lanes (2035 Ultimate Project Configuration)

The traffic modeling under development by the TWG indicates that additional tolled express lane capacity will be needed sometime between 2025 and 2035 in order to keep traffic free flowing in the tolled express lanes. It is anticipated that the future capacity expansion program currently modeled will remedy any congestion issues that develop by 2035. The 2035 Ultimate Project configuration includes the following improvements:

1. Westbound: Construction of a second tolled express lane between I-25 and Lucent Boulevard.

[3] Assumes revenues in excess of debt service payments are deposited in an account having an investment rate of return averaging 1.5%.

2. Eastbound: Construction of a second tolled express lane between Broadway and I-25.

The cost of this expansion in current year dollar terms is approximately $30 million, including the tolled express lanes and associated soft costs. If built in 2033 (completion by 2035), these improvements would have a year of expenditure cost of approximately $50 million and could be accommodated with the funds deposited annually from debt service coverage, after capital maintenance items noted above are paid for and interest accrues on the balance of funds in the account each year.

If toll revenues from the tolled express lanes are less than expected, there will be fewer funds available in 2033 for the capacity improvements described above. However, if revenue is less than expected, traffic will also be lower than expected and the future capacity expansion improvements will not likely be needed by 2035, providing more time to accrue cash to pay for the eventual expansion associated with the 2035 Ultimate Project configuration. This flexible approach to addressing future expansion needs is highly efficient, because only what is needed is built when it is needed.

This program to build the Interim Project and subsequently phase capacity improvements over time is consistent with a P3 life-cycle budgeting approach to roadway asset management. After the capacity improvements noted above are completed in 2035, debt service coverage will continue to accrue during the life of the outstanding debt. Once the debt is repaid in 2046, or earlier if revenues are available, reserves can be made available for further expansion, rehabilitation, or other uses within the C-470 Corridor. We have not assumed any new debt will be issued before the debt to pay for the Interim Project is completely repaid, however, refinancing / refunding of debt is often done to take advantage of beneficial market conditions that can result in lower annual debt service payments.

7. Variations to the Interim Project

In late 2013, the TWC began to explore alternatives to connecting I-25 with the Interim Project using direct connector ramps. This concept showed potential to improve traffic operations and safety at the east end of the Project at additional cost. The potential cost of these concepts had not been developed as the ideas were very new and preliminary, however, additional funding from CDOT could be available for this part of the Project if it meets certain criteria related to traffic operations and safety. These potential changes to the Project and the implications for the financial plan were not taken into consideration in the analysis outlined herein.

At the time of this report's writing, the Project was begin transferred from the Corridor Coalition to CDOT for further analysis, development, and implementation.

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