CAMBRIDGE SYSTEMATICS

C-470 Corridor, Kipling to I-25 Express Toll Lanes

Level II Traffic and Revenue

Final

Report

prepared for

Douglas County and C-470 Corridor Coalition

prepared by

Cambridge Systematics, Inc.

with contributions from

Parsons Brinckerhoff
Wilson & Company

September 4, 2014

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1.0 Key Findings

The key findings from this analysis are as follows:

- The Interim RAMP Concept will provide mobility relief to a congested corridor.
- The direct ramp connections from I-25 to westbound C-470 express toll lanes provide substantial relief and revenue potential to the project.
- The effectiveness of the interim project begins to lessen by 2035, by then additional improvements will be needed:
  - Extend the project west to Kipling; and
  - Construct two lanes in each direction from I-25 to Lucent.
- Westbound Operations:
  - Based on the results of this study, additional improvements to the Wadsworth interchange area (see Section 8.0) need to be explored in order to increase trip reality for the Interim RAMP Concept; and
  - The general purpose lanes between I-25 and Quebec are expected to be very congested and other improvements beyond the scope of this ETL project should be explored.
- 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 C-470 express toll lanes project.
  - Within the corridor limits (between Kipling and Quebec) travel reliability will be improved with an ETL.
  - Long-term planning should include mitigation of I-25 and connections between the C-470 ETL and I-25, and perhaps long-term improvements can be implemented similar to improvements that are recommended be made from I-25 to westbound C-470.

Toll setting needs to be explored further. This Level II Analysis included testing four different pricing scenarios. In the westbound direction in particular the pricing elasticity should be further explored. Developing the optimal tolls for this direction will take additional effort.

2.0 Introduction

2.1 STUDY PURPOSE AND LIMITATIONS

The purpose of this study is to evaluate traffic performance and develop revenue projections for a proposed express toll lane on C-470 from I-25 to Kipling Avenue in Douglas County, Colorado. Figure 2.1 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 express toll lane concept plans have been refined over the two years that CS has been involved in the project. Initial modeling results prepared by CS were used to help inform the process. This document reflects the latest iteration. Given the time and resources invested in the design refinement process, time, and funding limitations did not permit CS to conduct extensive sensitivity testing or risk analysis – such testing should be performed in future work. Throughout this report, we identify areas that should be refined or further analyzed.

C-470 Project Management Team

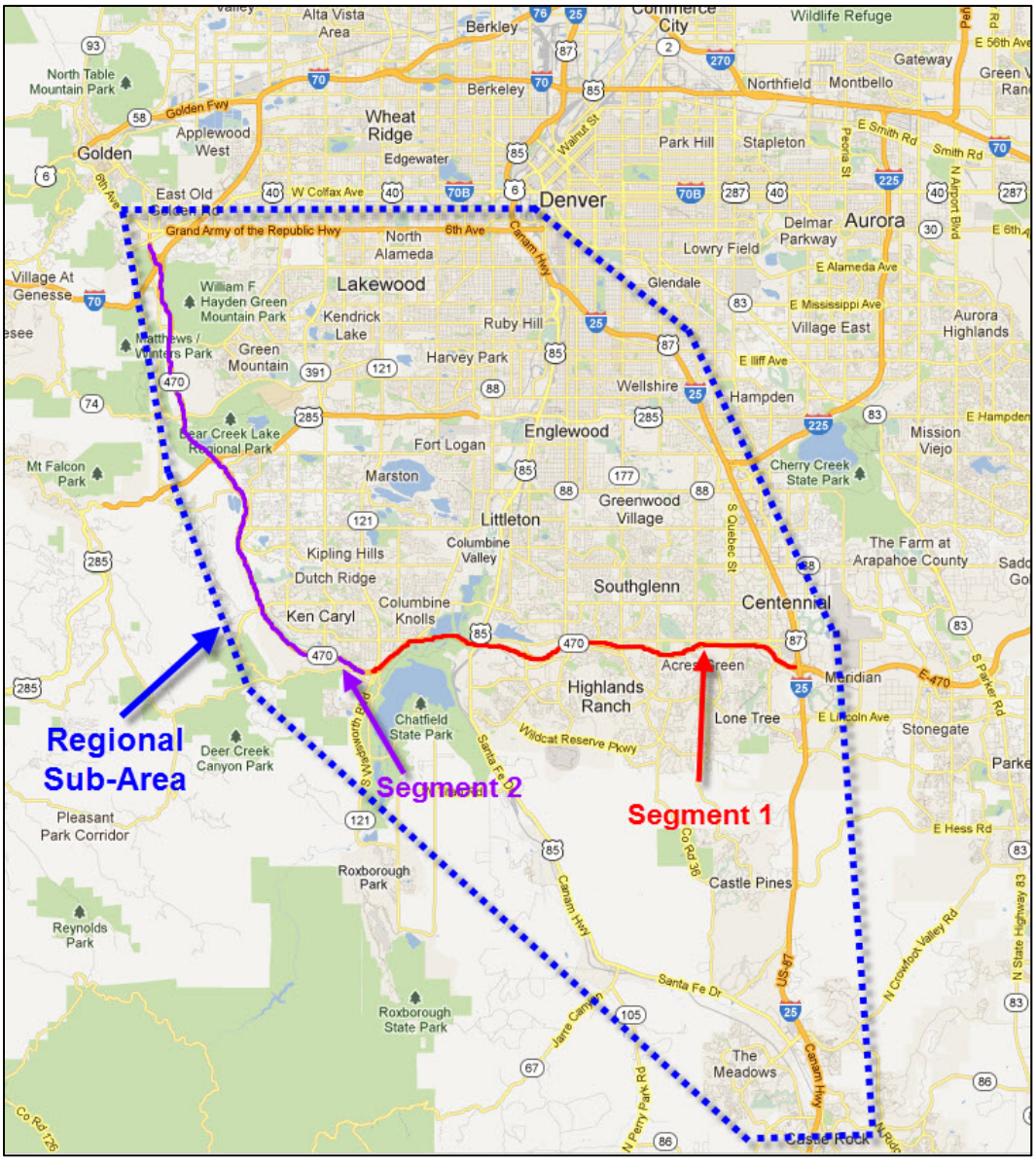
The C-470 Project Management Team consisted of technical staff from agencies that are part of the C-470 Corridor Coalition. The following Internet link is the charter document of the coalition.

http://www.douglas.co.us/engineering/documents/adopted-charter-c-470-corridor-coalition.pdf.

Financial Analysis

We prepared gross revenue forecasts in 2013 dollars. A separate report prepared by Parson Brinkerhoff uses the results of this study along with other information to present a financial plan.

Figure 2.1 Study Location Map

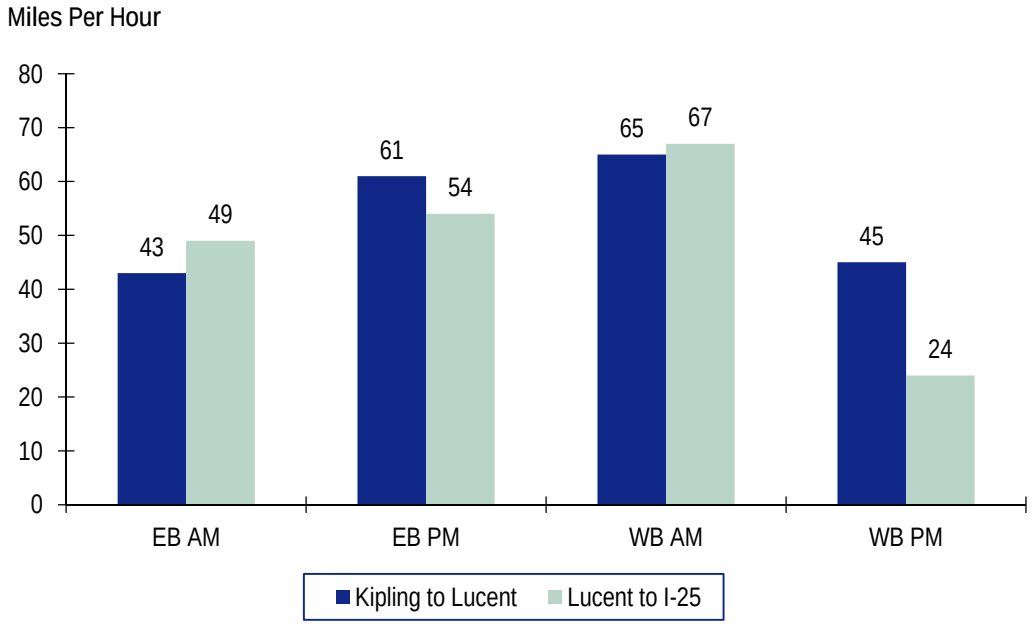


Source: Cambridge Systematics, Inc.

2.2 EXISTING CONDITIONS

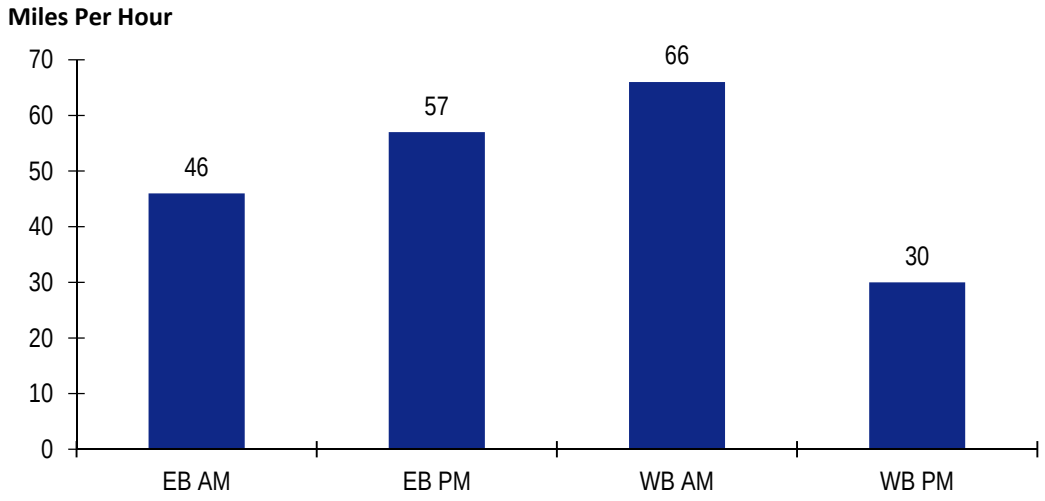
The C-470 corridor experiences significant and increasing congestion today. CS contracted to have travel-time runs and traffic counts conducted in May 2013. Figures 2.2 and 2.3 illustrate the average travel speeds by segment and by direction. We observed the lowest speeds in the westbound direction in the p.m. peak period, and in particular in the I-25 to Lucent section. The longest travel time we observed in May 2013, was around 30 minutes. CS conducted spot travel-time runs in the p.m. peak in July and August of 2013, it was observed that it can take over 60 minutes for the 13-mile westbound trip from I-25 to past Wadsworth.

Figure 2.2 Average Travel Speeds by Segment
May 2013



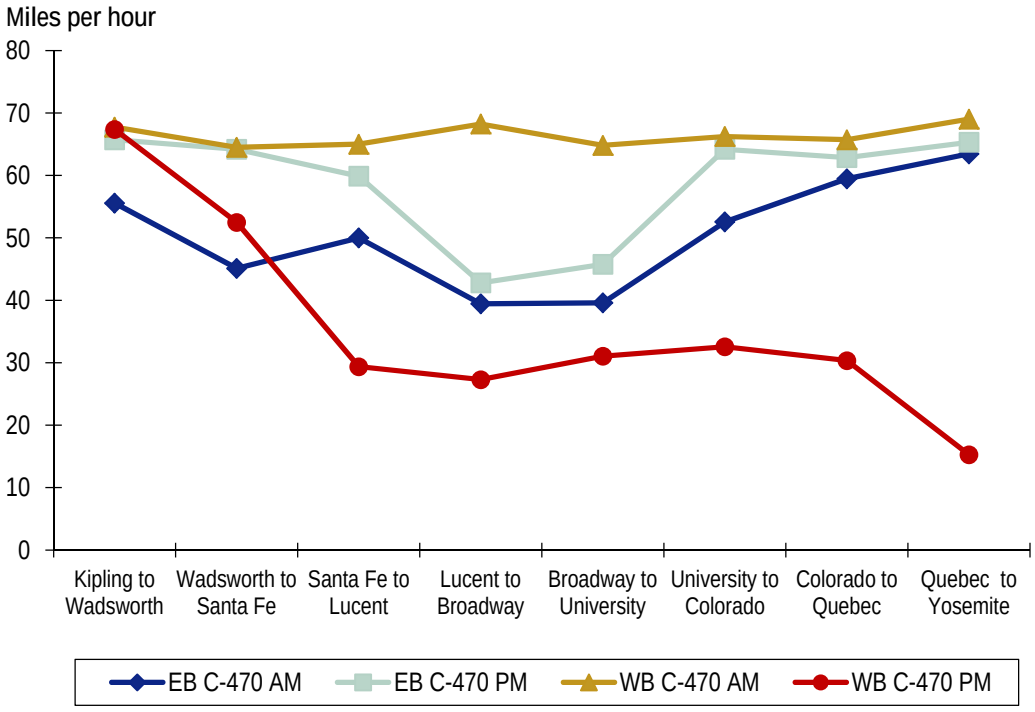
Source: Cambridge Systematics, Inc.

Figure 2.3 Corridor Average Travel Speed
May 2013



Source: Cambridge Systematics, Inc.

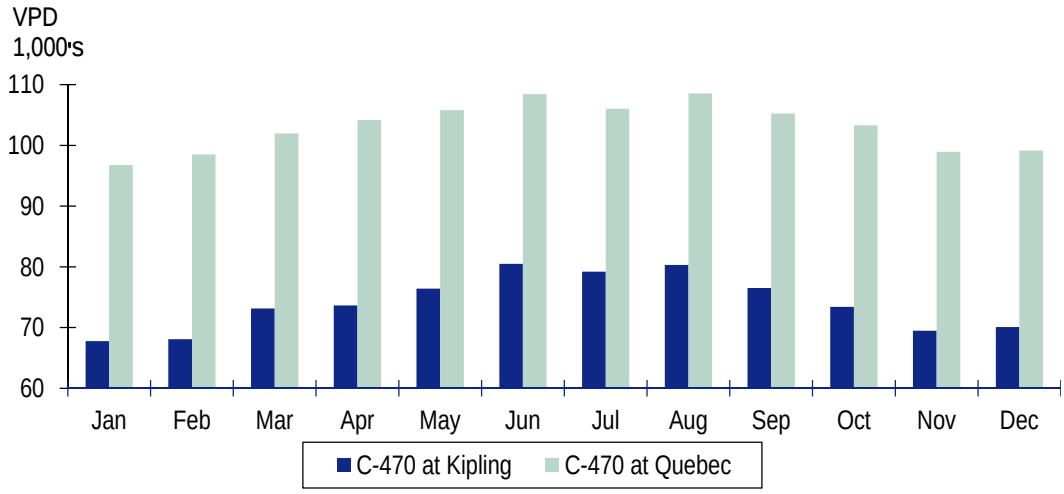
Figure 2.4 Average Speed Profiles by Data Collection Segments



Source: Cambridge Systematics, Inc.

Daily traffic volumes along C-470 vary by month and by location along the corridor. The Colorado Department of Transportation (CDOT) has two permanent count stations, one at Kipling and one at Quebec. Figure 2.5 is a chart that shows the two-way average daily traffic volumes by month at these two locations. The charts show that the peak months for traffic are from May to September. The data collection that was conducted for the traffic modeling effort was done in May 2013, which falls within the peak volume pattern.

Figure 2.5 2013 Daily Traffic Volumes



Source: Colorado Department of Transportation.

2.3 ALTERNATIVES TESTED

Throughout this project, we worked with Douglas County and CDOT to develop, test, and refine alternative concepts. The concepts included both an ultimate (2035) configuration and an opening-year configuration, both of which are part of the ongoing Environmental Assessment update. The initial interim configuration was submitted to CDOT in April 2013 for a special funding program opportunity called RAMP (Responsible Acceleration of Maintenance and Partnerships). This submittal occurred prior to CS preparing this report; and revenue projections were taken from the 2006 Environmental Assessment (EA), with some modifications. In October 2013, this project was successful in being conditionally selected to receive $100 million in RAMP funding, and the project management team made a decision to scale back the length of the interim project limits in order to take advantage of the RAMP funding opportunity; and revenue predictions were updated accordingly. Refining the Interim RAMP Alternative was a priority and it is a primary focus of this report. The design alternatives tested in this study report (the alternatives are discussed in detail and illustrated Section 5.0) included:

- RAMP Interim Alternative:
  - Westbound Direction – Single express toll lane from Quebec to Wadsworth.
  - Eastbound Direction – Single express toll lane from near the South Platte River to Quebec.
  - Right-Hand Auxiliary Lanes for Eastbound and Westbound:
    - » From Santa Fe Boulevard to University; and
    - » Quebec to I-25.
- RAMP Interim Alternative – with additional Westbound ETL improvements (limited modeling tests were performed to identify increased revenue potential and operational performance improvements) which include:
  - Extend the two-lane ETL WB from east of University to Lucent.
  - Extend the single express toll lane WB from Wadsworth to Kipling.
- 2035 Ultimate Alternative:
  - Westbound Direction – Single express toll lane from Quebec to Wadsworth.
  - Eastbound Direction –Single express toll lane from near the South Platte River to Quebec.
  - Right-Hand Auxiliary Lanes for Eastbound and Westbound:
    - » From Santa Fe Boulevard to University.
    - » Quebec to I-25.

CS evaluated traffic conditions for these benchmark years, and interpolated the revenue forecasts for other years:

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

2.4 EA UPDATE COMPATIBILITY

The Level II traffic and revenue study contained in this report is intended to provide information to inform the best design to estimate revenue potential. The traffic information is compatible with the EA update that currently also is being prepared. The EA update traffic analysis and the Level II modeling work are being conducted using the same background travel demand volumes and concept designs for the C-470 express toll lane project. One difference between the two studies is that the EA traffic analysis will focus on single-peak design hour set of volumes for the a.m. and p.m. peak period, while the Level II traffic study used 14-hour trip tables.

2.5 SUPPORTING DOCUMENTS

We prepared the following white papers, presentations, and documents – over the course of the study:

- 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.

These documents are available for review at a reading room Wiki page at: https://wiki.camsys.com/display/C470TRAFFIC.

- Username: c470trafficuser
- Password: c470traffic

3.0 Study Approach

3.1 CONTEXT

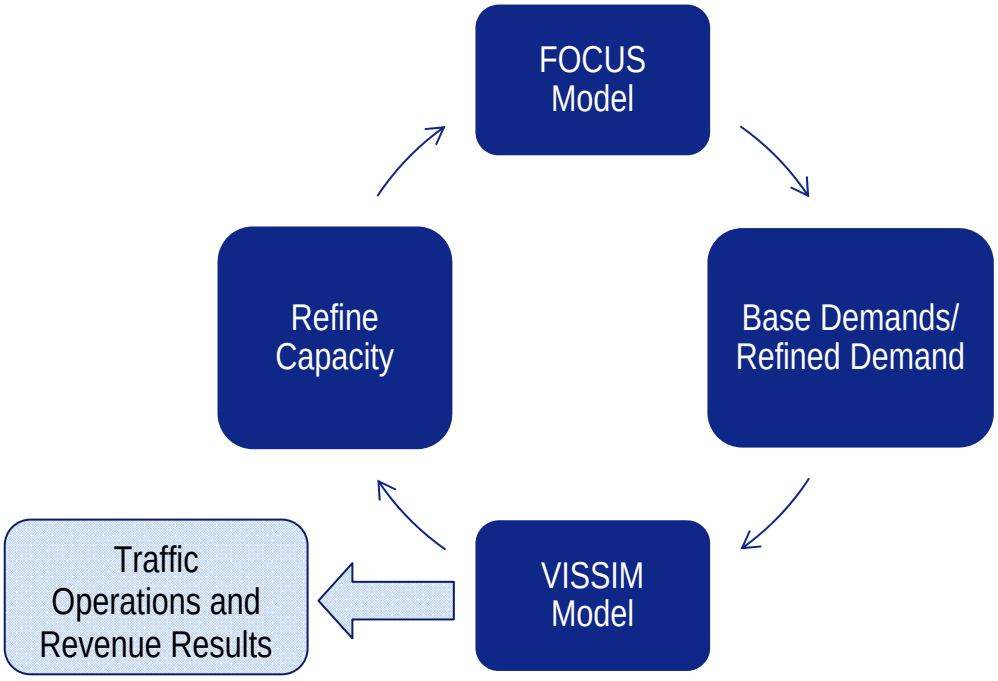
The C-470 (I-25 to Kipling) Improvement Study has been a highly interactive process between the C-470 Corridor Coalition Technical Working Group (TWG), the Policy Committee, and the consultant team. The TWG directed the development and selection of alternatives to be modeled. The CS modeling team provided draft forecasts to 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 was adapted along the way to accommodate new information and changing funding priorities. The modeling methodology is the same for both the Level II and the EA update. The EA traffic analysis will focus on the peak-hour analysis while the Level II study includes modeling of traffic for two seven-hour peak periods.

3.2 MODELING METHODOLOGY

We used two types of transportation models in the alternatives. DRCOG's FOCUS model is the region's state-of-the-art multimodal travel demand model used for regional and subregional studies. The FOCUS model has of over 2,800 traffic analysis zones (TAZ) 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 express toll lanes requires additional detail and the capability to analyze the dynamic relationship between price and operations. Traffic operations models, in contrast with travel demand models, can assess the traffic operating conditions of congested environments and recently have been enhanced to integrate dynamic and time-of-day pricing.

Figure 3.1 depicts how we integrated the regional FOCUS travel demand model with a corridor microscopic simulation model. Estimates of trip origins and destinations 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 3.1 Overall Modeling Workflow



Source: Cambridge Systematics, Inc.

Travel Demand

The FOCUS travel model is an activity-based model for the Denver region developed by DRCOG on the TransCAD software platform. 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 is on DRCOG's web site at: http://www.drcog.org/index.cfm?page=FocusTechnicalResources.

Inputs and Assumptions

Networks – The 2010 and 2035 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 – CS reviewed the future-year land use forecasts from DRCOG to better understand growth in the region as well as within the study corridor. CS paid particular attention to high-growth areas close to the corridor. Summaries of base and future land use assumptions appear in Appendix A.

Base-Year Travel Demand

CS used the FOCUS model to estimate the origins and destinations of travel regionally, and then extracted the origins and destinations relevant to the C-470 corridor. This is the "regional subarea" shown in Figure 2.1. The roadways that were simulated – Segment 1 – are shown by the solid red line. We calibrated the origin destination patterns in the entire Denver region to match the observed traffic data in the C-470 study area.

We then calibrated the demand matrices at the study corridor level 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), as described below.

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:

- A.M. Period (6:00 a.m. to 1:00 p.m.); and
- P.M. 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. 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, we updated the FOCUS model 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 Toll Lanes in the FOCUS Model

The proposed express toll lanes would have a time-of-day pricing component that is based on the levels of congestion in the express toll lanes. Therefore, toll rates could vary considerably over the course of a typical day, but there would likely be a minimum toll at all times they are in operation. 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 pretrip decisions and enroute decisions. Pretrip decisions include the activity location, mode, travel time, and toll receptivity. Enroute, 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.

Pretrip 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 pretrip 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.

Enroute Decisions. Similar to pretrip decisions, 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 was used with the corresponding hourly a.m. trip table by setting a fixed price for the express-lane use for that hourly assignment. The price was then 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 were incorporated into the regional model dataset, the regional model was used to forecast future-year traffic flows in a manner consistent with the base year for each scenario. Incremental growth for every origin-destination pair was added to the base-year calibrated trips. The process is described in detail within the Methods and Assumptions Document. The growth has not been assigned by each pair it is the result, since there are thousands of origin-destination pairs it is not practical to identify the growth individually. Table 3.1 summarizes the subarea growth in vehicle miles of travel by year.

Table 3.1 Daily VMT Growth in The Study Area

	No-build		Interim		Ultimate	
Year	VMT[a]	Percent change over existing	VMT[a]	Percent change over existing	VMT[a]	Percent change over existing
2013	4.78		4.78		4.78	
2018	5.72	20%	5.75	20%	N/A	
2025	6.65	39%	6.71	40%	N/A	
2035	7.27	52%	7.36	54%	7.38	54%

Source: DRCOG FOCUS Model.

[a] VMT (Vehicle Miles of Travel) Millions.

3.3 MICROSIMULATION

A microsimulation model of C-470 Segment 1 was developed using VISSIM 5.4 software to evaluate the express toll lane concepts and to prepare gross revenue forecasts. The following discussion is a summary of the microsimulation modeling methodology, with detailed procedures documented in the Methods and Assumptions Document.

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 3.2 highlights the key steps, which are further described below.

Figure 3.2 Simulation Modeling Workflow

Source: Cambridge Systematics, Inc.

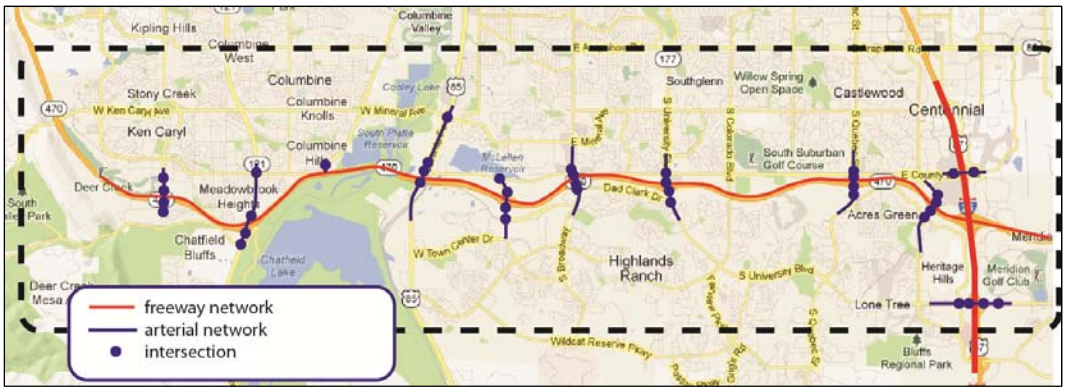
Base Model

The base VISSIM model was developed following the procedures in the VISSIM 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 include the 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 (see Figure 3.3).

Figure 3.3 Simulation Spatial Model Limits



Source: Cambridge Systematics, Inc.

VISSIM Model Temporal Limits. The VISSIM models were built to accommodate two seven-hour peak periods (Table 3.2). The base-year models were calibrated to a stringent statistical criteria for the peak three hours within each of the two peak periods. The shoulder hours were checked for reasonableness but will not receive the same level of scrutiny.

Table 3.2 Temporal Limits of Simulation Models

Time Period	Overall Model Duration
A.M. Peak Period	6:00 a.m. to 1:00 p.m.
P.M. 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. The data collected during that week included traffic counts at all on and off ramps, arterial tube counts and intersection turning movement counts. The count data was synthesized into a set of origin-destinations that coincided where the VISSIM model started and ended. There also were speed studies conducted on C-470, the speed information was used to help identify bottleneck locations and to provide information to compare model results.

Evaluate Alternatives

The future conditions were analyzed using the VISSIM model. CS coded the geometry and concept of operations of the express toll lane concept, and used the VISSIM Managed-Lane Module which incorporates toll price setting and willingness to pay. The VISSIM simulations dynamically assign traffic to the express toll lanes and report forecast traffic operations in the general purpose lanes and the express toll lanes, gross revenue, and the number of toll transactions. The steps for analyzing the express-lane alternatives included 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.

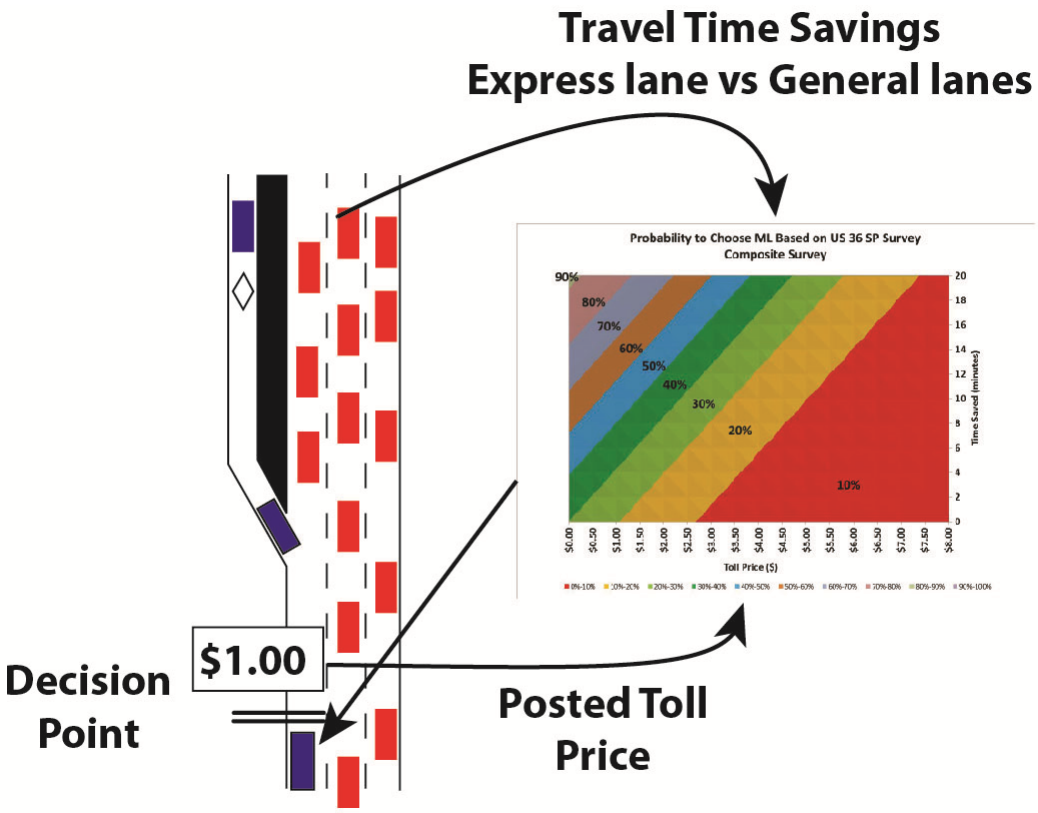
Key elements of this process are described below.

VISSIM Managed Lane Module

We used the VISSIM managed-lane module to assign traffic between the express toll lanes and the general purpose lanes. The module consists of physical paths in parallel between the general purpose (GP) lanes and the express toll lanes, a decision model, and a pricing model. The paths reflected the ingress/egress of the design concept and the pricing zone structure. Figure 3.4 illustrates how vehicles are assigned within VISSIM. The modeling process follows these steps:

1. The toll price is set, in the case of C-470 the toll price will be variable and established and published in advance. The illustration below is a $1.00 toll.
2. Travel-time savings between the general purpose lanes and the express toll lanes are calculated in the VISSIM model run.
3. Travel-time savings, and Toll Price are entered into a logit probability model (represented by graph in illustration below and in Figure 3.7)
4. Based on logit model express toll lane eligible vehicle will choose the express lane or not.

Figure 3.4 Express Lane Traffic Assignment Illustration



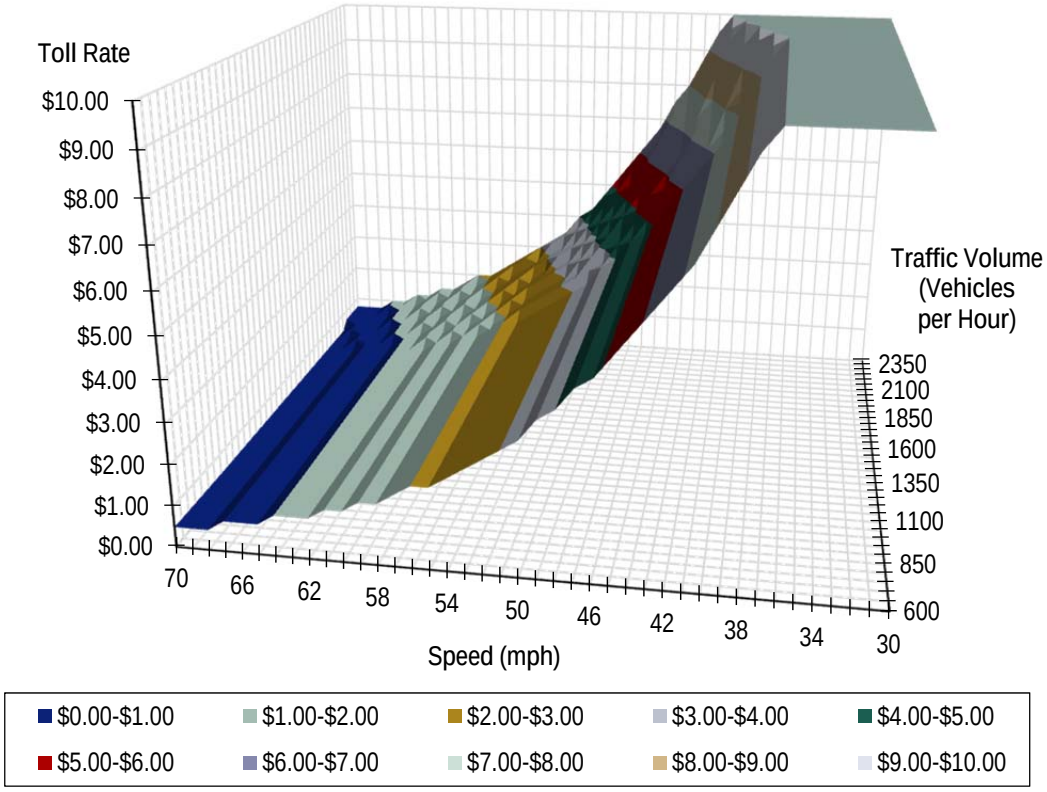
Source: Cambridge Systematics, Inc.

Toll Setting

CDOT established that the toll for the C-470 Express toll lane will vary by time of day on a prearranged schedule rather than dynamically based on real-time traffic conditions. The rationale is that time-of-day pricing is easier to communicate to drivers. Time-of-day pricing also is being used on the I-25 express toll lane project as well as on the U.S. 36 project that is under construction.

CS developed a proposed fixed price schedule for use in this study by first using the VISSIM model (with managed-lane module) to find the rates that would maintain free-flowing traffic in the express toll lanes using a dynamic pricing system. The pricing formula accounts for both speed and volumes in the express toll lane to come up with a new toll every five minutes. Figure 3.5 is an illustration of the pricing formula used.

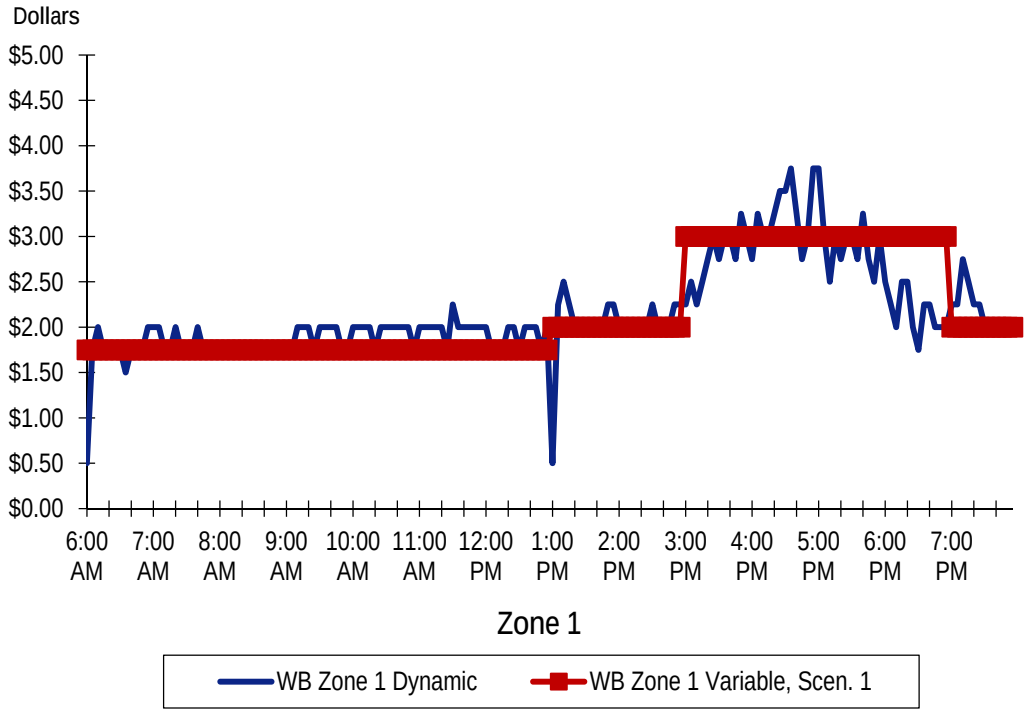
Figure 3.5 Dynamic Toll Price Algorithm Illustrations



Source: Cambridge Systematics, Inc.

We used the outcome of the dynamic pricing evaluation to develop a simpler time-of-day system with only a few toll rates per day, recognizing that too many discrete price changes would be confusing to communicate. Figure 3.6 illustrates conceptually how dynamic pricing results were converted into fixed time-of-day pricing. The dynamic pricing algorithm is designed to maintain reliable operations in the ETL. The first fixed variable pricing scenario was developed to approximate the dynamic pricing, then the pricing was simplified so a toll schedule could be communicated in schedule. The other fixed pricing scenarios developed were higher and lower than the first scenario.

Figure 3.6 Fixed Pricing Illustration
Westbound C-470 Toll Prices



Source: Cambridge Systematics, Inc.

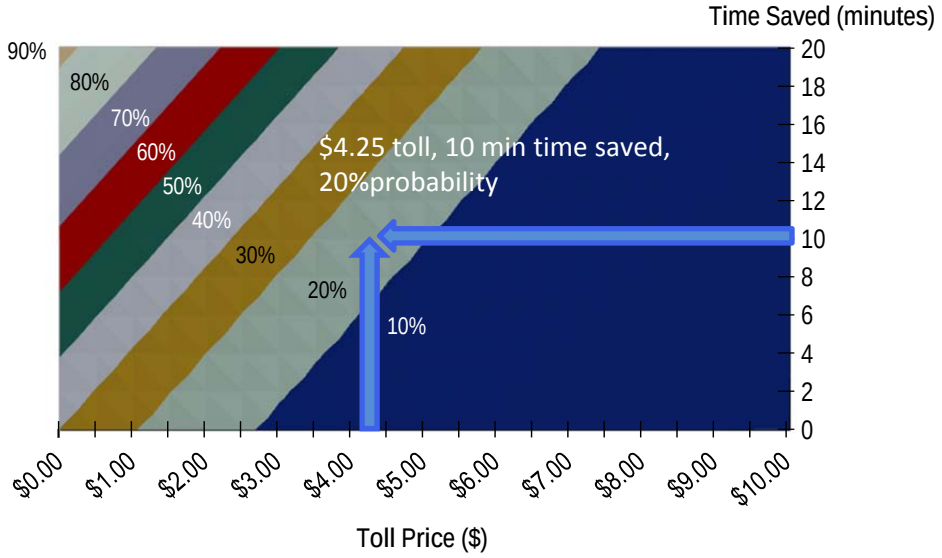
Willingness to Pay

Willingness to pay is represented in the VISSIM model with a logit model that was based on the stated-preference survey conducted for the U.S. 36 Investment-Grade Study.[1] The logit model estimates the probability that drivers will choose the express toll lane or the general purpose lane given certain travel conditions. The probability model is illustrated in Figure 3.7. In the illustration there is toll prices (x-axis), time saved (y-axis) and probability color bands. The percentage probability of using the express toll lane may change depending on the combination of toll price and the amount of time saved. For example, in Figure 3.7 a posted toll of $4.25 and time saved of 10 minutes is shown with arrows, these 2 arrows intercept at the 20 percent probability band. This means that there is a 20 percent chance that a toll eligible vehicle will use the express lane, and or that 20 percent of the express toll lane eligible population would use the ETL under this condition.

[1] Denver Boulder Stated-preference Survey Report Prepared For Wilbur Smith December 2010 (Appendix 1: Investment Grade Traffic and Revenue Study U.S. 36 Managed Lanes Study).

It is important to note that willingness to pay varies considerably from person to person, and even from day to day. It is a significant uncertainty in any toll project, and in express toll lane projects in particular. Additional research (by others) regarding the willingness to pay should be conducted for the C-470 corridor as part of an investment-grade study, as should additional sensitivity tests or risk analysis that may vary this value.

Figure 3.7 Willingness to Pay Probabilities



Source: Cambridge Systematics, Inc.

Express Toll Pass User Percentage Assumptions

Colorado uses ExpressToll Passes – a windshield sticker transponder that is connected to customer accounts – for all of toll facilities in the State. The C-470 Express toll lane project would use the same system, and also will allow for non Express Pass Holders to access the system. Non Express Toll users would be billed based on a license plate capture and direct mailing of a bill plus surcharge for processing the bill.

The implications on the percentage of Express Toll Pass Users on Gross Revenue is significant. Generally, the higher the percent of Express Toll Pass users the more likely the Express lane will be used (more vehicles paying a lower toll). The agencies developing the C-470 project have every reason to believe that in this congested, commuter-oriented corridor that many people will have the Express Toll Passes.

We assumed one set of Express Toll Pass percentages that varied by model year. The percentages were based on current Express Toll Pass account information provided by the E-470 Toll Office. The E-470 office provided the total number of

Express Toll accounts by zip code in Arapahoe, Douglass, and Jefferson Counties. CS found that:

- 27 percent of Express Toll accounts in the three counties had transponders.
- 43 percent of the households that use C-470 have Express Toll Pass accounts.

The following assumptions regarding the percent of Express Toll accounts, took into consideration information provided by the E-470 office, in projecting the percent of ExpressToll accounts for this project. The following assumptions regarding percent ExpressToll accounts took into consideration information from the E-470 office related to the current number of express toll accounts in the region. A percentages shown below are subjective and based in current account:

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

It is recommended that additional testing be performed as part of an investment-grade study (completed by others), as the Project Management Team decided not to include those elements in this report. The additional testing should be conducted for the ranges stated above as well as others to better understand the impact of differing ExpressToll Account percentages may have on projected revenues.

3.4 REVENUE

Methodology

CS factored the results of the a.m. and p.m. peak-period VISSIM models to create annual toll revenue forecasts. The VISSIM models represent 14 hours of a typical weekday (two, 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 was not included. The weekend and holiday revenue was estimated by applying a percentage to the typical weekday VISSIM model results. All revenue was estimated in ***2013 dollars***, with any assumed inflation of toll rates applied in the financial model prepared by Parsons Brinckerhoff. The underlying assumption is that toll rates will rise to track inflation, so that the relationship of people's value of time to the toll remains constant over time. This is a reasonable assumption for an express toll lane project where the purpose is to manage traffic flow in the express lane to maintain free-flowing conditions. Table 3.3 is a summary of the assumptions used in annualizing traffic model results.

Table 3.3 Revenue and Transaction Annualization Assumptions

Description	Assumption
Daily Assumptions	
A.M. weekday peak	6 a.m. to 1 p.m.
P.M. weekday peak	1 p.m. to 8 p.m.
Daily weekday	A.M. weekday peak plus p.m. weekday peak
Weekday off-peak	8 p.m. to 6 a.m. – negligible revenue not included
Daily weekend	10 percent 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 percent
Year 2	50 percent
Year 3	75 percent
Year 4	75 percent
Year 5	100 percent (no ramp up percent applied)
2035 to 2048 Assumptions	
Annual Growth Percentage	1 percent per year

Ramp Up

The modeled timeframes include 2018 (year opening), 2025 (interim forecast), and 2035 (design year). The revenue estimated by the models assumed perfect knowledge of the system, including pricing, ingress/egress and general operations. In reality, the public will take time to learn the system, and may not use it in the early months, even though it might be in their best interest to do so. It takes a while for demand to "ramp up" to forecast levels. Ramp up is difficult to predict, but we have made some reasonable assumptions in this planning study These assumptions are:

- Year 1: 50 percent;
- Year 2: 50 percent;
- Year 3: 75 percent;
- Year 4: 75 percent; and
- Year 5: 100 percent (no ramp up assumptions).

30-Year Revenue Streams

We prepared 30-year revenue streams using straight line interpolation between the modeled years (with ramp up applied in the early years). The last modeled year is 2035, so there is another 13 years of growth to get to 2048. We applied a nominal percentage growth (approximately one percent) to the 2035 forecasts.

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. The concept plans in this section formed the basis for the traffic and revenue forecasts. The plans were developed in an iterative process with the design team, using interim runs of the simulation models as a tool to identify modifications.

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 Colorado State Transportation Commission conditionally selected the C-470 Corridor Coalition Managed Tolled Express Lanes Project to receive partial funding through the RAMP Program.

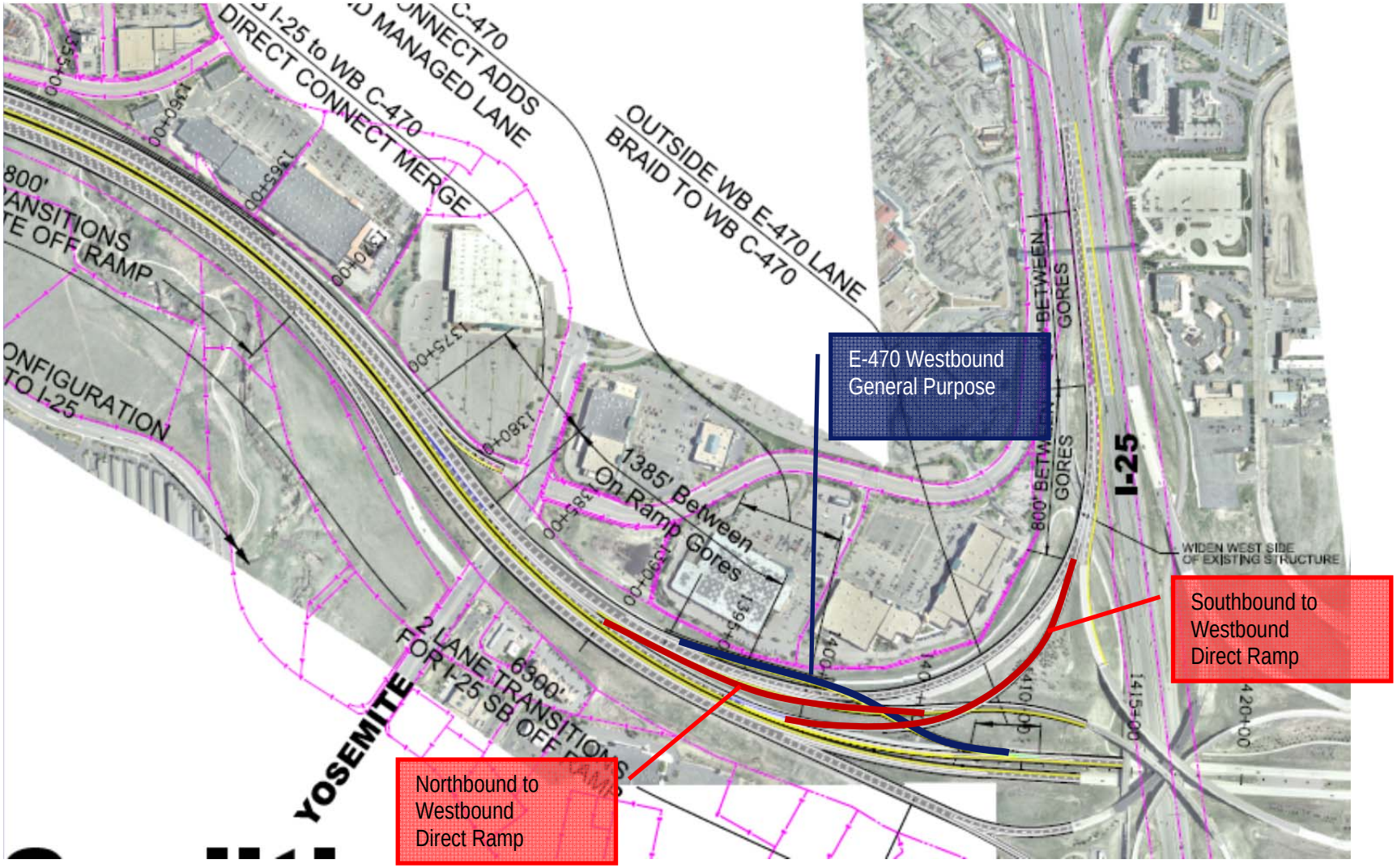
As a result of the funding allocation, the Interim RAMP Project was scaled back to best fit the RAMP funding opportunity. Therefore, the initial Interim RAMP Concept was refined and reduced to a single-lane ETL in each direction from I-25 to near Wadsworth in the westbound direction and from near the South Platte River to I-25 in the eastbound direction. The scaled back concept is referred to as the Interim RAMP Concept/Project.

The analysis of the Interim RAMP Concept revealed that traffic operations in the westbound direction between I-25 and Quebec was expected to be unacceptable. The congestion in this area was expected to affect both express toll lane traffic and general purpose-lane traffic. ETL traffic was forecast to be stuck in a bottleneck unable to get to the ETL ingress at Quebec. After the Quebec ingress, the travel times in the GP lanes and the ET Lanes were similar with only a slight advantage to ETLs, which resulted in lower forecast toll and revenues. As result, a new design solution for the westbound direction was explored by the design team, and the solution included direct ramps from the I-25 to C-470 Ramps to the express toll lane system. Figure 4.1 is a layout of the interchange area, the new ramp connections are highlighted.

Section Purpose

This section describes the design process, the design criteria, and the design concepts for the interim and ultimate configurations.

Figure 4.1 I-25 to Westbound C-470 Direct Ramp Connections



Source: Wilson and Company.

4.2 CONCEPT DESIGN PROCESS

The Project Management Team utilized a sketch planning process in order to develop and refine the interim and ultimate design concepts. The process involved planning-level traffic information, preliminary engineering by Wilson and Company, with additional input from the C-470 Corridor Coalition Technical Working Group (TWG) and the C-470 Coalition's Traffic Subcommittee and the C-470 Finance Subcommittee (see Figure 4.2).

Figure 4.2 Planning Process Flow Chart

Source: Cambridge Systematics, Inc.

The first step was to establish design criteria. The criteria included developing design details for ingress, egress, and combined ingress/egress access locations. The criteria were based in part on Caltrans[2] design criteria for managed-lane access.

The second step involved locating ingress and egress openings 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 identified 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. The concept(s) were evaluated were then fully evaluated with the simulation models.

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 smooth traffic operations that would result from minimizing weaving maneuvers and providing frequent access. The average trip length of C-470 users according to the FOCUS model is around six miles, since the project limits are roughly 13 miles in length there is a significant amount of traffic traveling

[2] Caltrans design criteria as found in the Priced Managed Lane Guide FHWA-HOP-13-007.

longer distances. Based on input from the various Coalition subcommittee's, the Project Management Team decided that the minimum length of a trip that would be accommodated by the ETL should be approximately three miles. In some cases the concepts resulted in ingress/egress trip lengths less than three miles. The shorter trip lengths were incidental as a result of trying to address markets and geometric constraints.

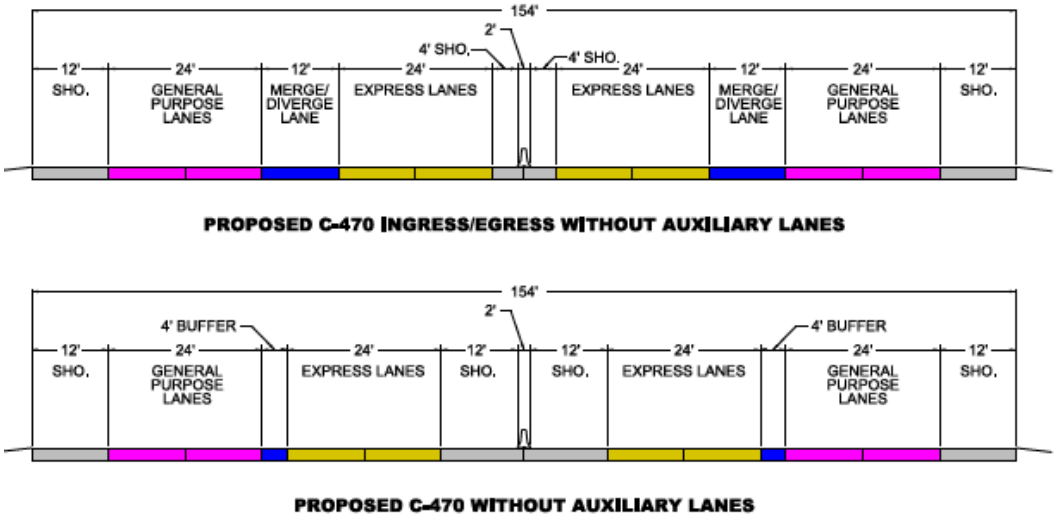
4.3 DESIGN CRITERIA

The design criteria included the development of a typical cross sections; stand-alone ingress and egress points; a combined ingress/egress point; and minimum distances for vehicles to change lanes.

Typical Sections

The Project Management Team developed two types of typical sections: one with a buffer separation and the other with a merge lane (see Figure 4.3). Both of the typical sections include two 12-foot general purpose and express lanes in each direction (total of 24 feet for each). The interim project includes only one lane in each direction, so the width would be reduced to 12 feet from 24 feet. The upper half of Figure 4.3 shows the typical section at an ingress or egress location with a merge/diverge lane, while the lower half illustrates a four-foot buffer between the Express Lanes and the general purpose lanes where it will be illegal for vehicles to cross.

Figure 4.3 Ultimate Configuration Typical Sections



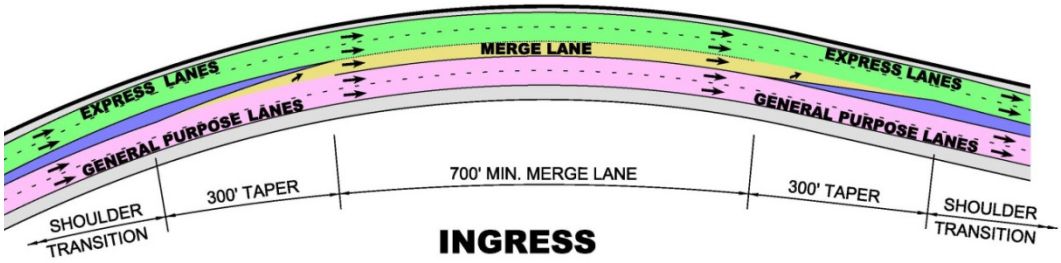
Source: Wilson and Company.

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 4.4 through 4.6. In all cases these designs include a weave lane. The design criteria are based in part on the April 2011 Policy Memo from Caltrans. This merge/diverge lane will provide refuge for transitioning vehicles which will be a safer transition than having vehicles cross directly between the general purpose lanes and express lanes.

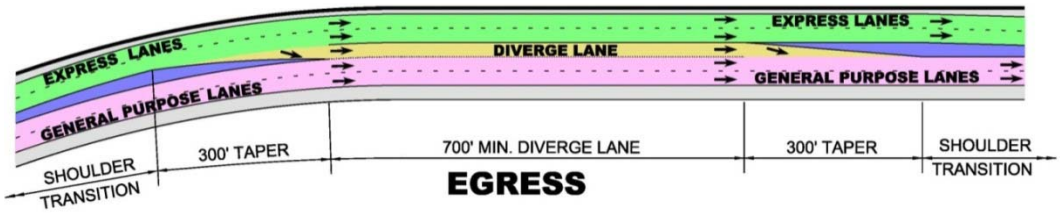
The design team also considered a different ingress/egress design. This type was a combined ingress/egress opening with no additional weave lane. Based on the curvilinear alignment of C-470 the ability for weaving vehicles to safely navigate and a desire to provide a reliable trip this basic concept was rejected.

Figure 4.4 Typical Ingress Design



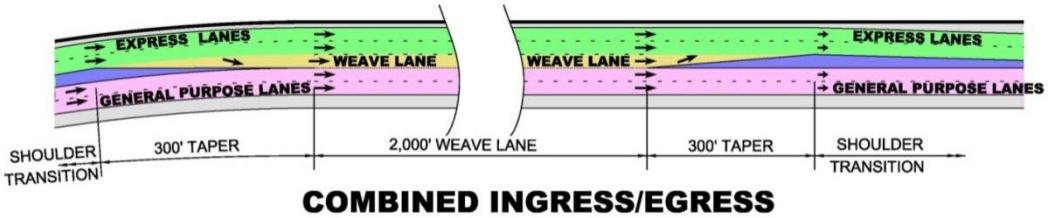
Source: Wilson and Company.

Figure 4.5 Typical Egress Design



Source: Wilson and Company.

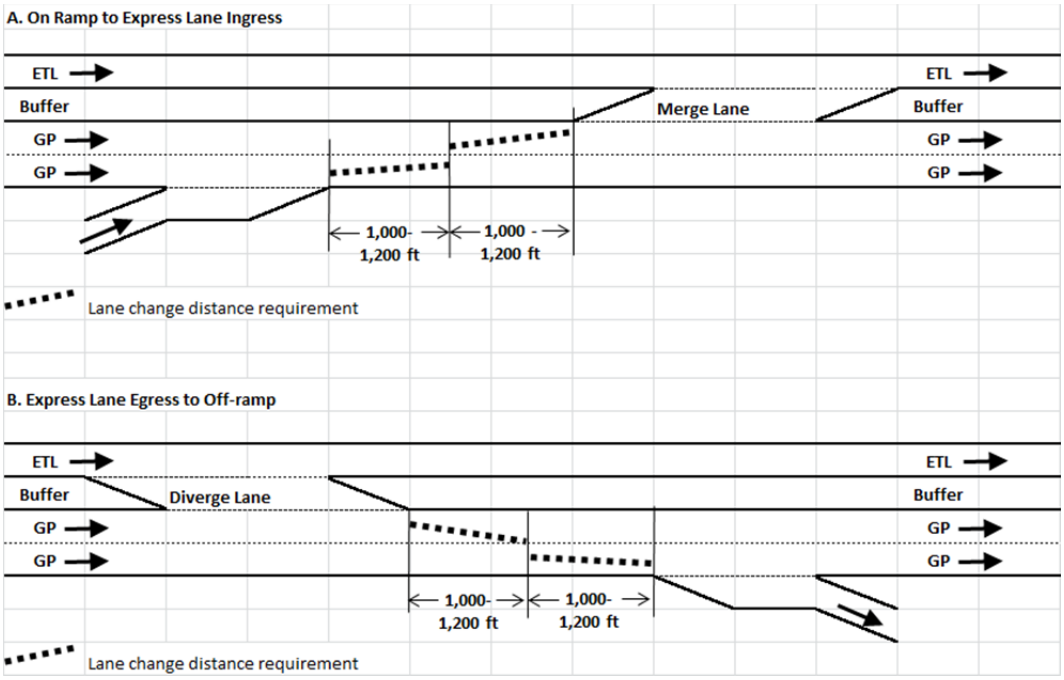
Figure 4.6 Typical Combined Ingress Egress



Source: Wilson and Company.

Ingress and egress must allow adequate lane-changing distance from a local access interchange (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 4.7 illustrates the lane changing distance requirements for locating ingress and egress.

Figure 4.7 Lane Change Distance Requirements



Source: Cambridge Systematics, Inc. Drawing based on CDOT desired lane change distances.

Sight distance on curves also is 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 REFINED INTERIM CONCEPT

The initial Interim RAMP Concept that emerged from the sketch planning process included one lane in each direction from I-25 to Kipling and two lanes in each direction from around Quebec to around Colorado Boulevard. The two-lane section in each direction allowed for maintaining two lanes to and from the E-470 toll road, with egress provided in the westbound direction from E-470 to the C-470 general purpose lanes and to the Quebec Street interchange. Additional

operational improvements were made by providing lane continuity and eliminating left-lane drops/merges between I-25 and Quebec.

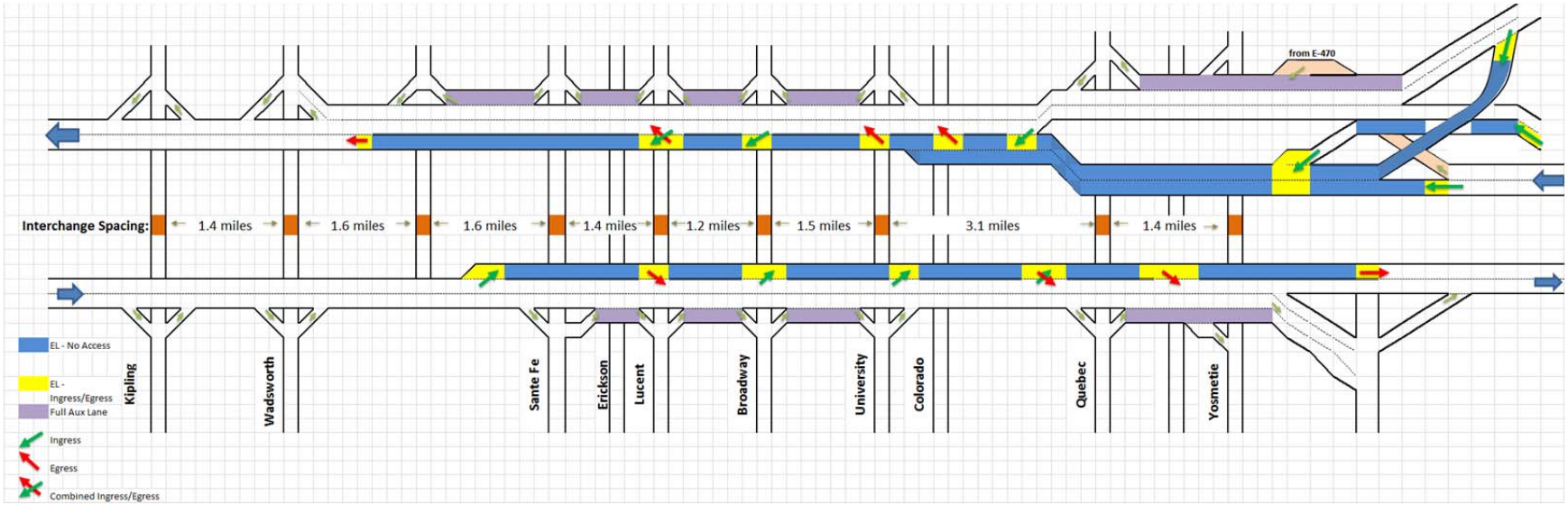
In the Refined Interim RAMP Concept, the two-lane section ended around Colorado Boulevard as a way to contain initial construction cost associated with the Interim RAMP Project. However, the initial funding, presently identified for this project, may not be sufficient to construct the proposed initial two express toll lane section in ***each*** direction between I-25 and Colorado Boulevard. Therefore, the Project Management Team may determine it is necessary to further scale back the limits of the two-lane section or reduce other project elements. In order to meet current projected funding levels, this could be achieved by delaying building the two-lane section in the eastbound direction between Colorado Boulevard and I-25 and/or reducing how far reconstructing the existing pavement extends to the west. At the time this report was finalized, the current Refined Interim Concept is illustrated in schematic form in Figure 4.8.

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

Table 4.1 Ingress/Egress Combinations
Interim RAMP Concept

Westbound C-470						**Eastbound C-470**				
Ingress		Egress				Ingress		Egress		
No	General Location	Letter	General Location	Length (miles)		No	General Location	Letter	General Location	Length (miles)
1	SB I-25 Direct Ramp	A	University	3.9		1	Wadsworth	A	Broadway	2.1
		B	Broadway	5.1				B	Quebec	6.8
		C	Santa Fe	7.7				C	Yosemite	8.3
		D	Wadsworth	11.3		2	Lucent	A	Quebec	3.3
2	NB I-25 Direct Ramp	A	University	3.7				B	Yosemite	4.8
		B	Broadway	4.9		3	Broadway	A	Quebec	1.9
		C	Santa Fe	7.5				B	Yosemite	3.4
		D	Wadsworth	11.1		4	University	A	Yosemite	0.8
3	E-470	A	University	3.8						
		B	Broadway	5.0						
		C	Santa Fe	7.6						
		D	Wadsworth	11.2						
4	Quebec	A	University	0.8						
		B	Broadway	2.0						
		C	Santa Fe	4.6						
		D	Wadsworth	8.2						
5	Univeristy	A	Santa Fe	1.1						
		B	Wadsworth	4.7						
6	Broadway	A	Wadsworth	3.3						
General Locations: Nearest Interchange that can be acccessed by C-470 Express Toll Lane System										

Figure 4.8 Initial Interim Express-Lane Concept Plan



Source: Cambridge Systematics, Inc.

4.5 ULTIMATE CONCEPT

The 2035 Ultimate Concept includes one ETL in each direction from I-25 to Kipling and adds a second ETL in each direction from around Quebec to the vicinity of Lucent (see Figure 4.9). The design team decided on a proposed two-lane section to Lucent after reviewing traffic demand forecasts from the FOCUS model that indicated there was no need to have two express toll lanes in each direction west of Lucent. Notwithstanding the above, the C-470 Corridor improvements are being developed such they can readily accommodate extending the second ETL between Lucent and Wadsworth.

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

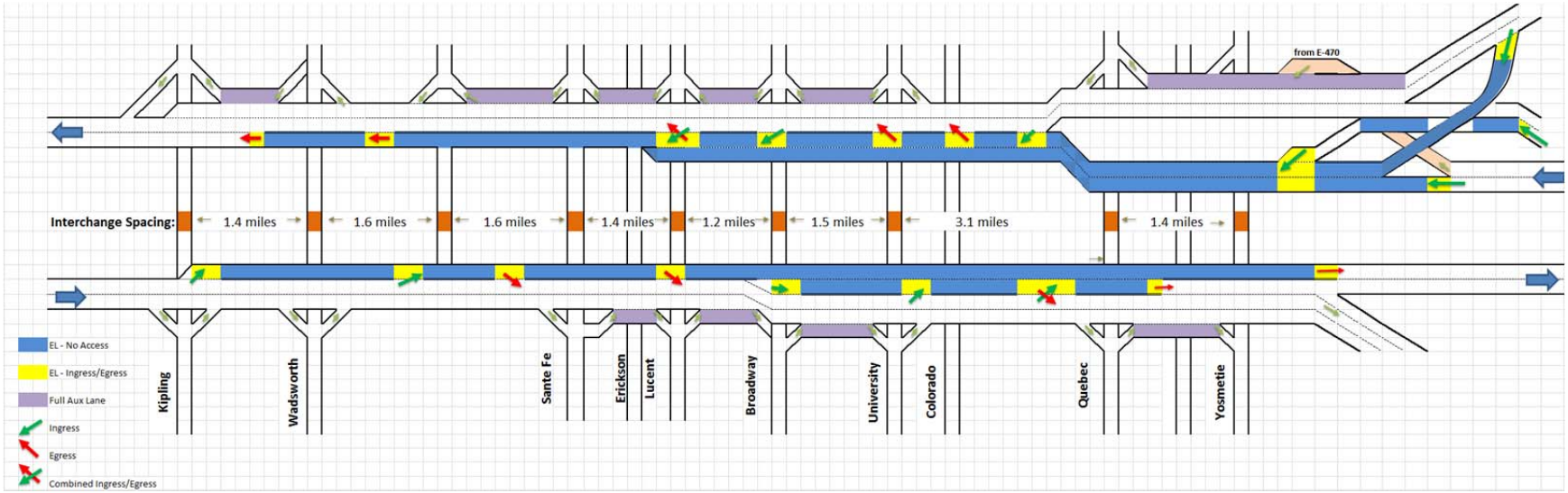
Table 4.2 Ultimate Concept Ingress/Egress Combinations

Westbound C-470				
Ingress		Egress		
No	General Location	Letter	General Location	Length (miles)
1	SB I-25 Direct Ramp	A	University	3.9
		B	Broadway	5.1
		C	Santa Fe	7.7
		D	Wadsworth	11.3
		E	Kipling	12.9
2	NB I-25 Direct Ramp	A	University	3.7
		B	Broadway	4.9
		C	Santa Fe	7.5
		D	Wadsworth	11.1
		E	Kipling	12.7
3	E-470	A	University	3.8
		B	Broadway	5.0
		C	Santa Fe	7.6
		D	Wadsworth	11.2
		E	Kipling	12.8
4	Quebec	A	University	0.8
		B	Broadway	2.0
		C	Santa Fe	4.6
		D	Wadsworth	8.2
		E	Kipling	9.8
5	Univeristy	A	Santa Fe	1.1
		B	Wadsworth	4.7
		C	Kipling	6.3
6	Broadway	A	Wadsworth	3.3
		B	Kipling	4.9

Eastbound c-470				
Ingress		Egress		
No	General Location	Letter	General Location	Length (miles)
1	C-470	A	Santa Fe	3.1
		B	Broadway	4.0
		C	Quebec	8.7
		D	Yosemite	10.2
		E	E-470	13.3
2	Wadsworth	A	Santa Fe	1.2
		B	Broadway	2.1
		C	Quebec	6.8
		D	Yosemite	8.3
		E	E-470	11.4
3	Lucent	A	Quebec	3.3
		B	Yosemite	4.8
		C	E-470	7.9
4	Broadway	A	Quebec	1.9
		B	Yosemite	3.4
		C	E-470	6.5
5	University	A	Yosemite	0.8
		B	E-470	3.9

General Locations: Nearest Interchange that can be acccessed by C-470 Express Toll Lane System

Figure 4.9 Ultimate Express-Lane Concept



Source: Cambridge Systematics, Inc.

5.0 Traffic Demands

5.1 BASE-YEAR TRAFFIC

Comparison of Base-Year Model and Counts

CS calibrated the base-year trip tables to match the ramp and mainline observed volumes.[3] Tables 5.1 and 5.2 compare the estimated link volumes on all of the C-470 corridor ramps and mainline sections to the May 2013 observed counts. In the eastbound direction, on average, the estimated volumes are within one percent of the observed volumes with a percent root mean squared error (%RMSE) between four and five percent in both peak hours. In the westbound direction, estimated volumes also are within 1 percent of the observed counts on average with a %RMSE between three and four percent in both the a.m. and p.m. peak hours.

5.2 FUTURE TRAFFIC DEMAND

Regional Growth Estimates

CS used the FOCUS model as the basis for future travel demand forecasts for the C-470 corridor. We added the forecasted growth of trips from each origin-destination pair within the C-470 corridor to the calibrated base-year trip table to form the future-year trip tables. These adjusted trip tables become the inputs to the microsimulation models.

To better understand the demand, we assigned these same trip tables to the regional network shown in Figure 2.1 using the static assignment procedures consistent with the FOCUS model. Table 5.3 shows the estimated regional growth in vehicle miles of travel (VMT) and vehicle hours of travel (VHT) for the base year, year 2025, and year 2035. The FOCUS model predicts substantial growth estimated for the region – 29 percent growth in VMT by 2025 and 43 percent growth by 2035. VHT is estimated to grow even faster, 38 percent by 2025 and 60 percent by 2035, as congestion increases. Increased congestion is expected to result in lower average speeds throughout the region from about 35 mph to around 32 mph by 2035.

[3] Details are provided in the Methods and Assumptions report.

Table 5.1 C-470 Base-Year Traffic Volume Comparison
Eastbound, from West to East

	A.M. Peak Hour			P.M. 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%
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 5.2 C-470 Base-Year Traffic Volume Comparison
Westbound, from East to West

	A.M. Peak Hour			P.M. 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%
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%

Table 5.3 Forecast Regional Vehicle Miles and Vehicle Hours
2013 through 2035

		Existing	Year 2025	Percentage Change over Existing	Year 2035	Percentage Change over Existing
Grand Total	VMT	39,106,628	50,284,654	29%	55,732,666	43%
	VHT	1,103,259	1,520,057	38%	1,750,020	60%
	Average Speed (mph)	35.4	33.1	-6%	31.8	-10%

Source: DRCOG FOCUS model.

The FOCUS model also predicts that travel within the C-470 corridor will grow significantly by Year 2035. Tables 5.4 and 5.5 show the peak hour and daily base year counts and forecasted demand volumes for each ramp and mainline segment in the study corridor. Mainline demand is estimated to increase on average by about 46 percent in the eastbound direction on a daily basis and by about 51 percent on average in the westbound direction on a daily basis.

Table 5.4 Existing and Forecast C-470 Traffic Volumes
Eastbound, from West to East

	Existing			2018 – Interim			2025 – Interim			2035 – Interim			2035 – Ultimate		
	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	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

Table 5.4 Existing and Forecast C-470 Traffic Volumes
Eastbound, from West to East (continued)

	Existing			2018 – Interim			2025 – Interim			2035 – Interim			2035 – Ultimate		
	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily
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
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

Table 5.4 Existing and Forecast C-470 Traffic Volumes
Eastbound, from West to East (continued)

	Existing			2018 – Interim			2025 – Interim			2035 – Interim			2035 – Ultimate		
	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily
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
Percentage Change over Existing				20%	21%	17%	36%	37%	32%	47%	46%	44%	51%	48%	46%

Table 5.5 Existing and Forecast C-470 Traffic Volumes
Westbound, from East to West

	Existing			2018 – Interim			2025 – Interim			2035 – Interim			2035 – Ultimate		
	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	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

Table 5.5 Existing and Forecast C-470 Traffic Volumes
Westbound, from East to West (continued)

	Existing			2018 – Interim			2025 – Interim			2035 – Interim			2035 – Ultimate		
	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily
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
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

Table 5.5 Existing and Forecast C-470 Traffic Volumes
Westbound, from East to West (continued)

	Existing			2018 – Interim			2025 – Interim			2035 – Interim			2035 – Ultimate		
	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily	A.M.	P.M.	Daily
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
Percentage Change over Existing					29%	22%	44%	50%	37%	53%	64%	50%	54%	71%	52%

6.0 Operational Assumptions

6.1 INTRODUCTION

The Concept of Operations is a systems engineering document that contains the complete rules and procedures to operate and maintain a facility, including hours of operation, toll setting, maintenance, systems engineering, and enforcement. For the purposes of this Traffic and Revenue Study, we worked with the Coalition, FHWA, CDOT, and HPTE staff to develop enough elements of a Concept of Operations to make reasonable assumptions. These parameters are likely to be altered prior to implementation, and a more substantial Concept of Operations should be finalized prior to the implementation based on the worked performed in the Investment-Grade Study (to be completed by others). Table 6.1 provides a summary of the Concept of Operations assumptions used in the modeling effort. The final and complete Concept of Operations Document will be prepared by others.

Table 6.1 Summary of Operational Assumptions for Modeling

Item No.	Description	Setting
1	Toll rates	Variable, on a published schedule
2	Toll change interval	Hourly
3	Pricing Basis	Zone based Three Zones Westbound One or Two Zones Eastbound (Interim/Ultimate)
4	Minimum Toll	$0.50
5	Maximum Toll	None for the purposes of the Study
6	License plate surcharge	$0.75
7	Accessibility	All passenger vehicles and light trucks such as pick ups No heavy trucks (multi axel and larger delivery type trucks)
8	Vehicle Exemption Policy	High-Occupancy Vehicles not exempt
9	Transit	Currently no transit on corridor
10	Express-Lane Target Capacity	1,900 vphpl (max)
11	Performance Measure	Travel Speed
12	Performance Target	*55 mph* exceeded 90 percent of the time (LOS D)

License Plate Surcharge

The State of Colorado uses open road tolling technologies and allows for transponder owner and non transponder owners to use tolled facilities. On E-470 for example, the toll booth stations have been removed. If a vehicle that passes through a toll gantry area does not have a transponder a photo is taken of the vehicle's license plate and the owner is sent a bill. The C-470 express toll lane facility will use a similar system. There is an added cost to processing license plate transactions, therefore a surcharge is added to the toll rate. The license plate user surcharge assumed for this study is $0.75.

6.2 TOLLING ZONES

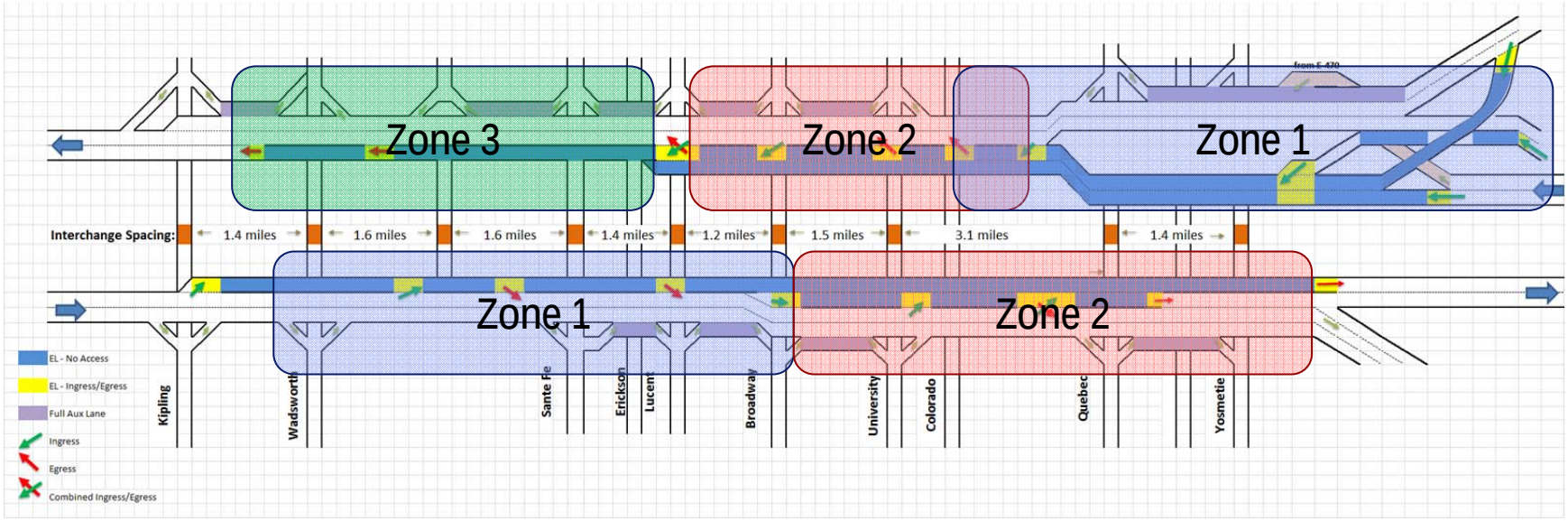
The length of the express toll lane facility will be close to 13 miles when the ultimate concept is constructed, and 8 miles eastbound and 11 miles westbound in the Interim RAMP concept. We developed a toll system that reflected tradeoffs among several objectives:

- Optimize traffic flow;
- Generate toll revenue;
- Simplicity;
- Ability to communicate to drivers; and
- Reflect travel patterns – the average trip length in the corridor is about six miles.

We worked with the Technical Committee and devised a three-zone system for the westbound direction. In the eastbound direction, the Interim RAMP concept is much shorter, so only one zone is needed. For the ultimate concept, we added a second zone.

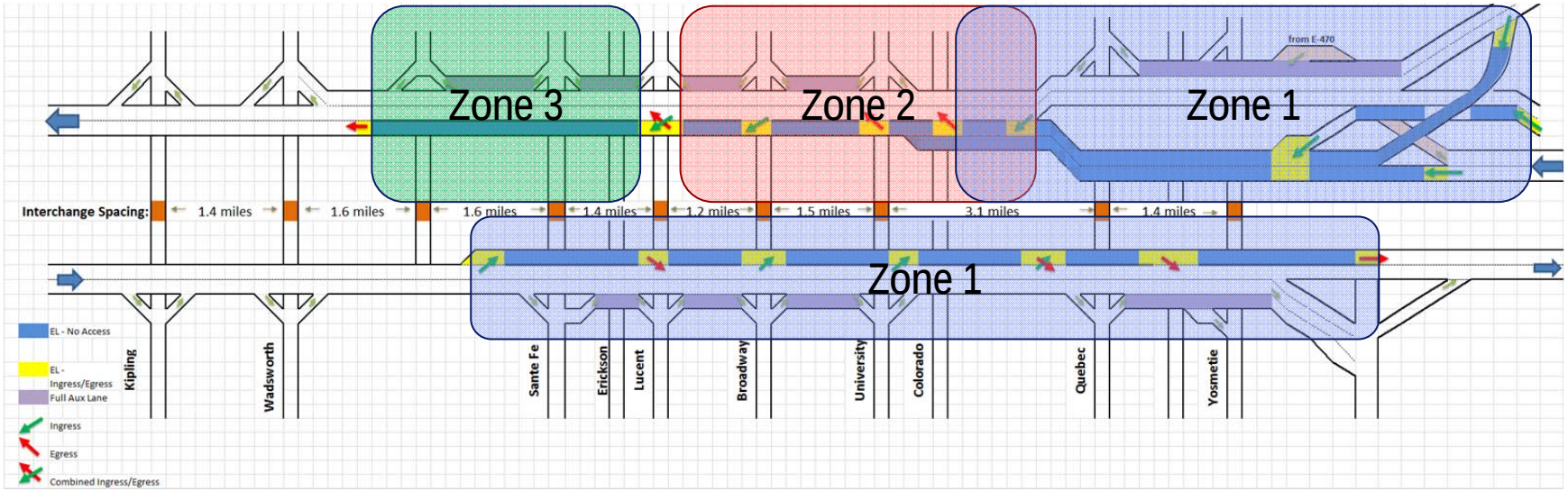
An overlay of the Tolling zones are shown for the Ultimate and Interim RAMP configurations In Figures 6.1 and 6.2.

Figure 6.1 Toll Zones Ultimate Concept



Source: Cambridge Systematics, Inc.

Figure 6.2 Toll Zones RAMP Interim Concept



Source: Cambridge Systematics, Inc.

7.0 Revenue and Transactions

7.1 INTRODUCTION

This section presents forecasts of revenue and transactions for C-470 express toll lane concepts described in Sections 5.0 and 6.0. 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. This means that scenarios that improve congestion in the general purpose lanes may make the express toll lane less attractive to drivers, resulting in lower tolls and lower revenue.

Revenue and transaction forecasts for priced managed lanes depend 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 percent 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 we have expressed all toll rates and revenues 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. Financial analysts should apply a range of inflation assumptions in their financial analysis, since inflation is one of the most important risks to revenue.

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 to 2047.

Traffic and Revenue During the Ramp Up Period

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. We do not explicitly simulate this behavioral characteristic in the traffic models, so were reduced the revenue forecasts in the early years of each project phase.

A high percentage (40 percent) of the population that drive C-470 today already have Express Toll transponders for use on other tolled facilities in the Denver

Region. Given the familiarity with tolling systems it is possible that the ramp up period could be short. Table 7.1 shows the adjustments to revenue that we applied in the early project years to reflect the impact of ramp up.

Table 7.1 Revenue Adjustments to Account for Ramp Up

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

7.2 FORECAST TOLL RATES

There are two ways to set variable tolls on express toll lanes: dynamic and static. With dynamic pricing, road sensors provide real-time travel information that allow the toll-lane operator (usually through system software) 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 hour, or few hours, for example). CDOT prefers static pricing, since it is consistent with other priced managed lanes projects already in operation in Colorado.

In our forecasting, we first simulated dynamic pricing, reviewed the resulting range of toll rates by period, and then 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, with alternative approaches yielding significantly different outcomes – therefore, we developed several plausible options.

Figure 7.1 shows the forecast toll rates (in 2013$) for the RAMP interim alternative in 2018 for each of the three zones in the westbound direction that would be needed to achieve the CDOT policy goal of managing mobility as described in Section 6.0. Dynamic tolling was used to help develop three different approaches to static variable tolling (labeled "variable") on the chart:

- Scenario 1: Closely match the Dynamic Pricing outcome.
- Scenario 2: Reduce the Scenario 1 approach generally by $0.50.
- Scenario 3: Increase the Scenario 1 approach generally by $0.50.

In all three pricing scenarios the license plate users would be charged the posted toll plus $0.75.

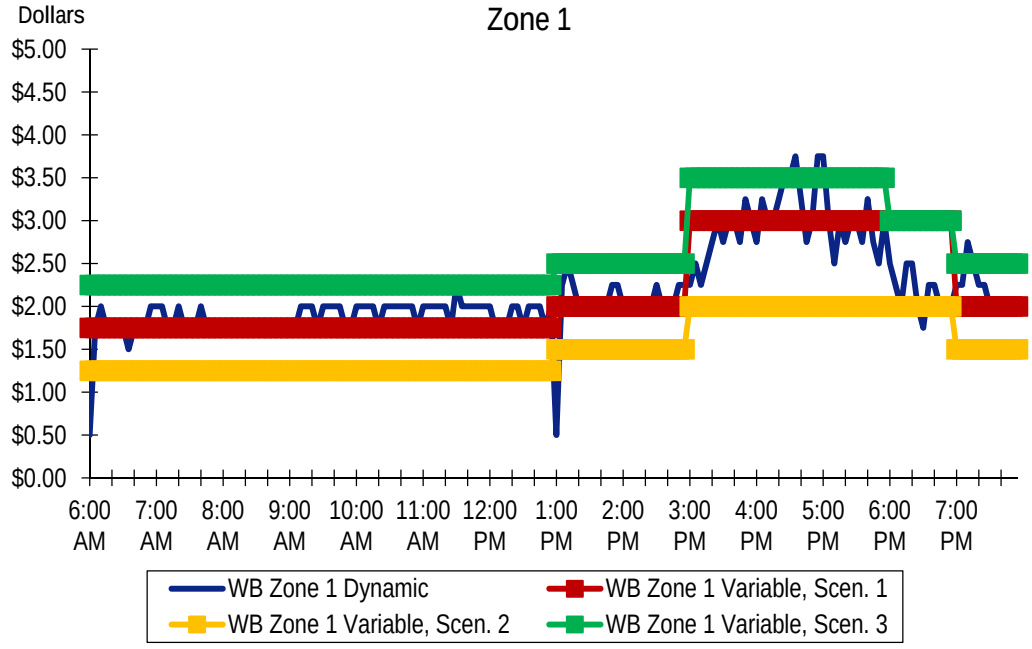
Under Scenario 1, which matches the dynamic pricing forecast most closely, the lowest toll rates are expected to be $1.75 from 6:00 a.m. until 1:00 p.m., after which the rate would gradually rise to $3.00 in Zone 1 and 2, and $2.50 in Zone 3 by 3:00 to 4:00 p.m.[4] The total toll to traverse all three zones is forecast to be $5.50 in the less congested periods, rising to $8.50 during peak times (see Figure 7.2).

In the eastbound direction, we forecast considerably less congestion, so the toll rates are expected to be $1.25 for any length trip in the single eastbound zone during the less congested periods (10:00 a.m. to 8:00 p.m.). In the morning peak (6:00 a.m. to 10:00 a.m.) toll rates are expected to be slightly higher, at $1.50 (see Figure 7.3).

Forecast toll rates by zone in 2025 are forecast to be similar to those for 2018 (in 2013$), as shown in Figure 7.4. Figure 7.5 shows the full-length toll rates. Figure 7.6 shows forecast toll rates in the eastbound direction for 2025, which are expected to be about $1.00 more expensive than in 2018 in the peak of the morning peak.

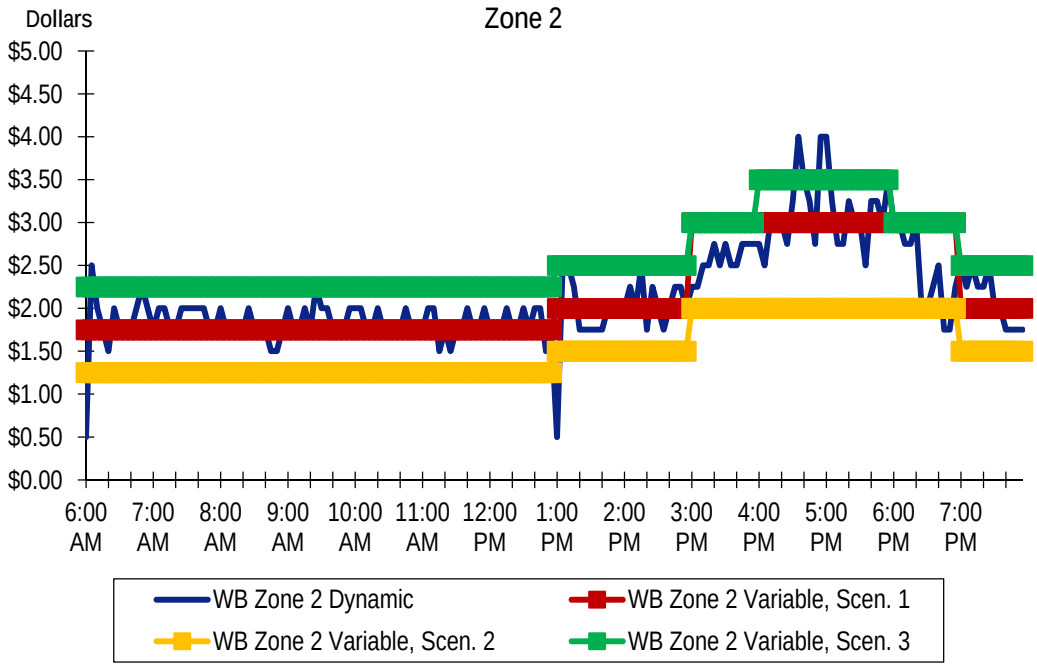
By 2035, forecast toll rates are considerably more expensive throughout (Figures 7.7 through 7.9.)

Figure 7.1 Forecast Average Weekday Toll Rates by Zone
Scenarios 1, 2, and 3 and Dynamic Westbound, 2018

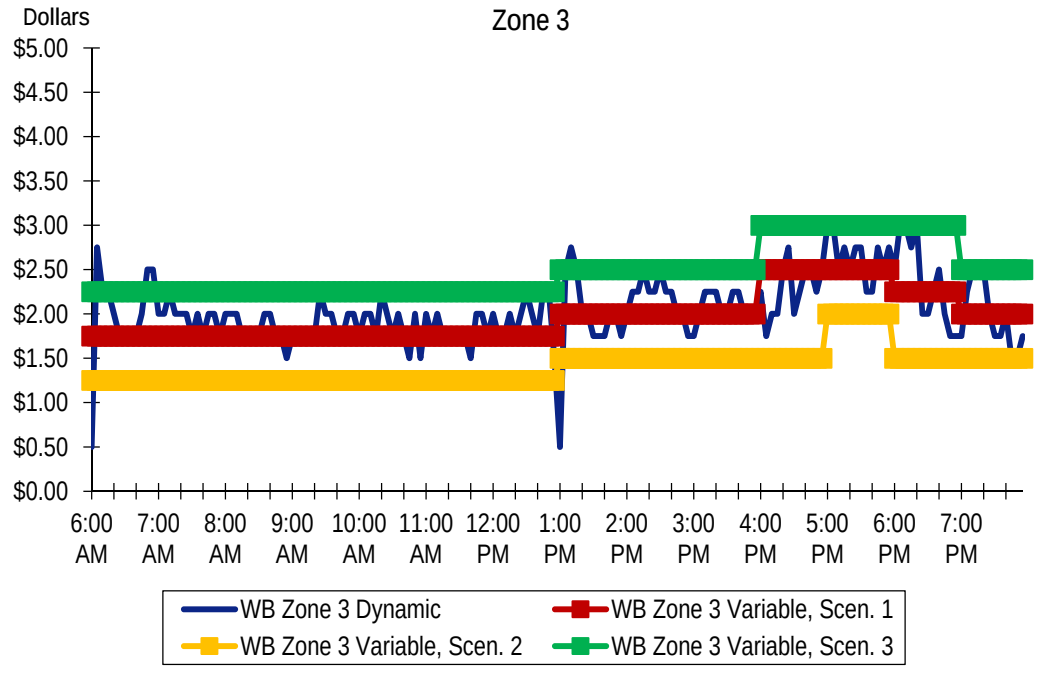


Source: Cambridge Systematics, Inc.

[4] We only describe Scenario 1 toll rates, to simplify this discussion, throughout.

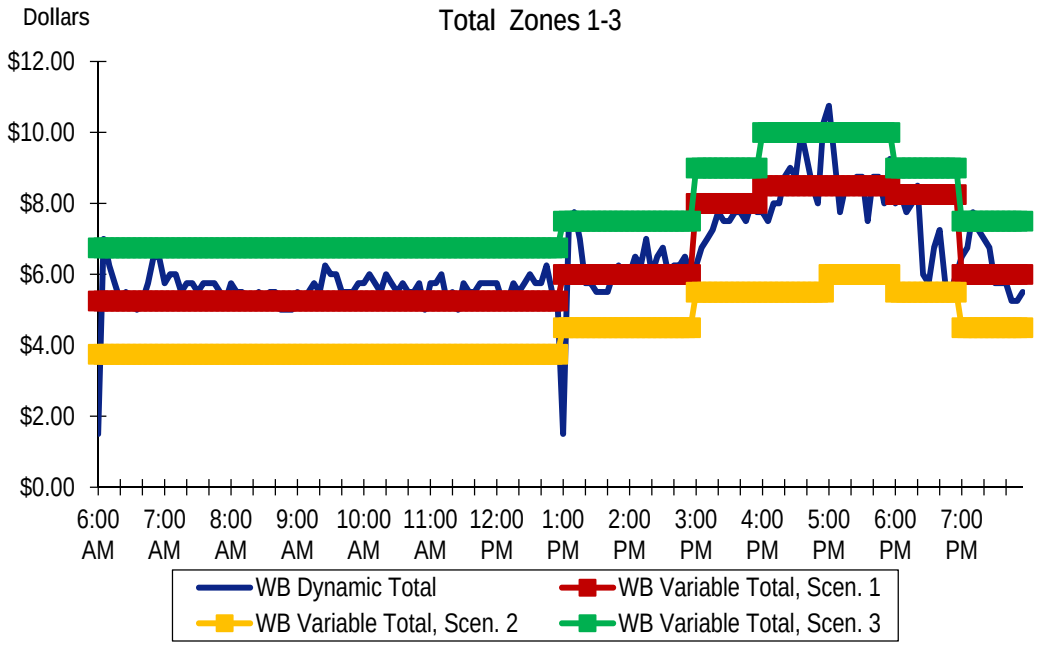


Source: Cambridge Systematics, Inc.



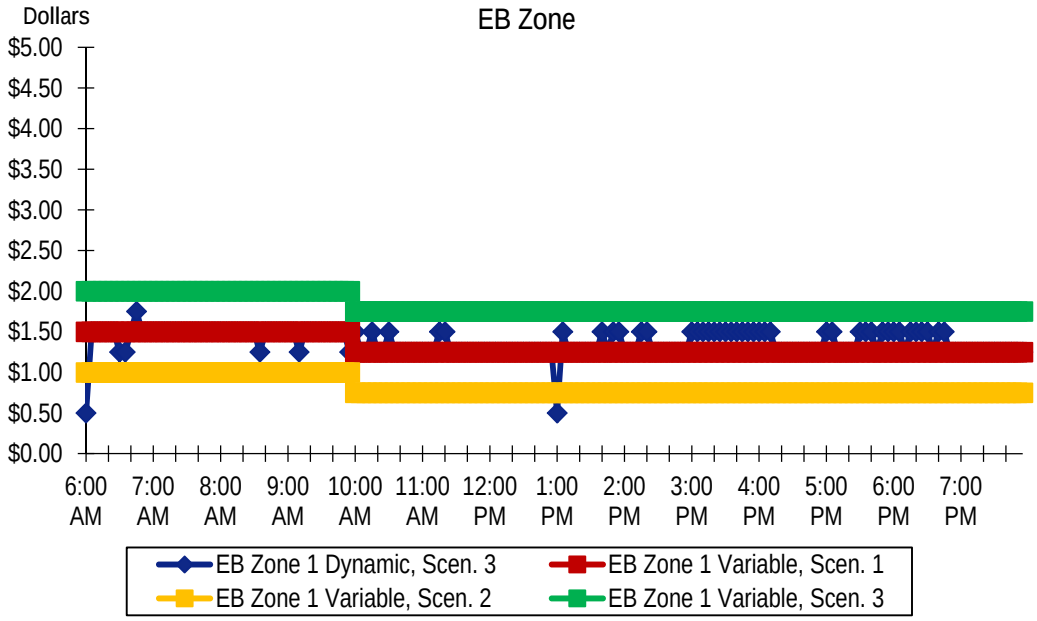
Source: Cambridge Systematics, Inc.

Figure 7.2 Forecast Average Weekday Toll Rates by Zone Full Length Trip
Scenarios 1, 2, and 3 and Dynamic Westbound, 2018



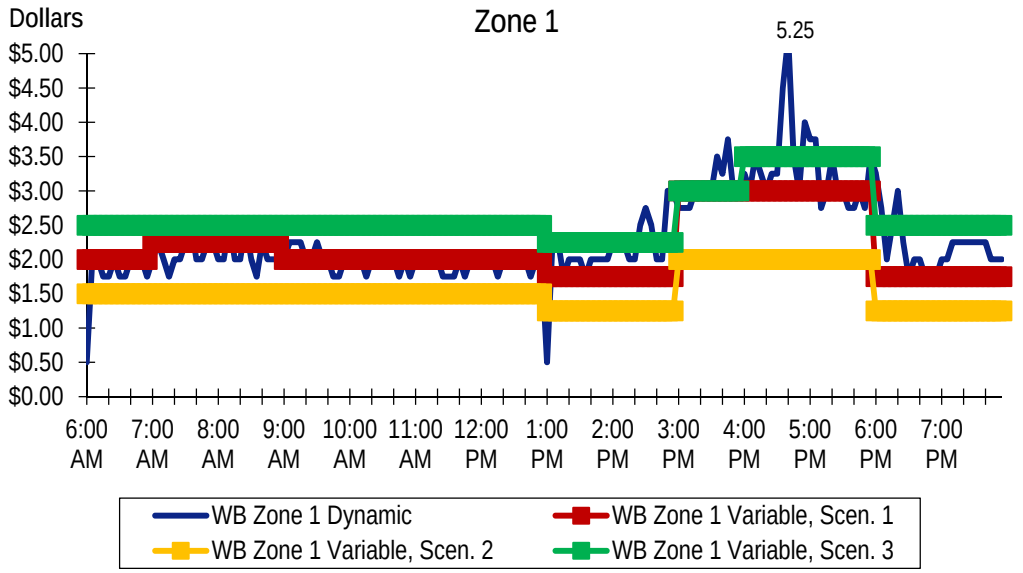
Source: Cambridge Systematics, Inc.

Figure 7.3 Forecast Average Weekday Toll Rates by Zone Full Length Trip
Scenarios 1, 2, and 3 and Dynamic Eastbound, 2018



Source: Cambridge Systematics, Inc.

Figure 7.4 Forecast Average Weekday Toll Rates by Zone
Scenarios 1, 2, and 3 and Dynamic Westbound, 2025



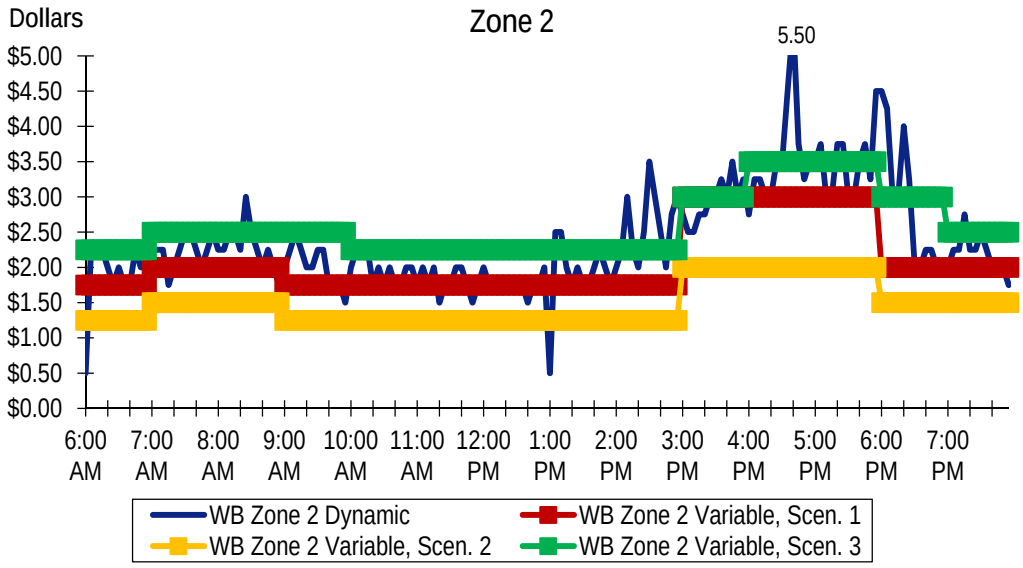
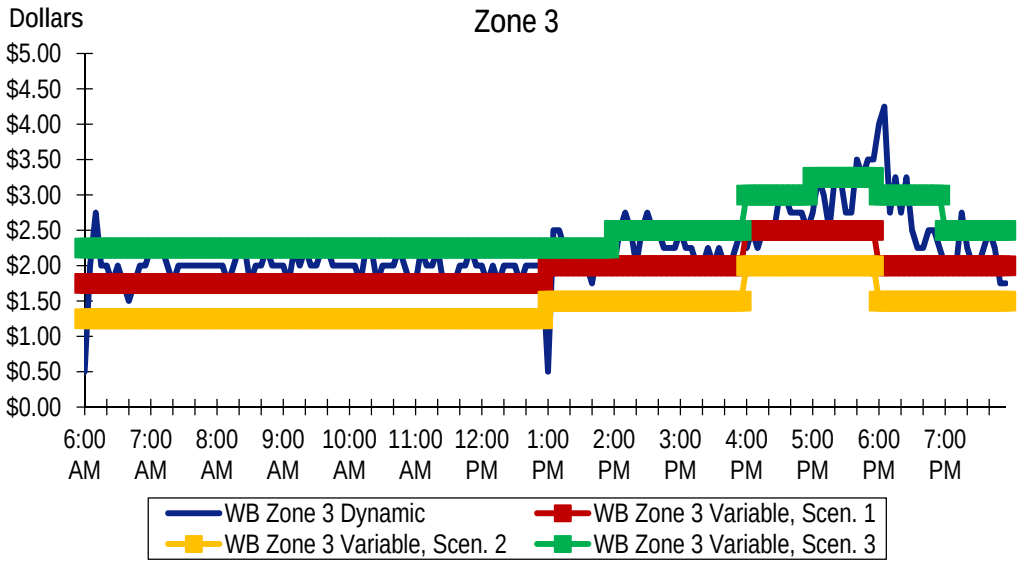
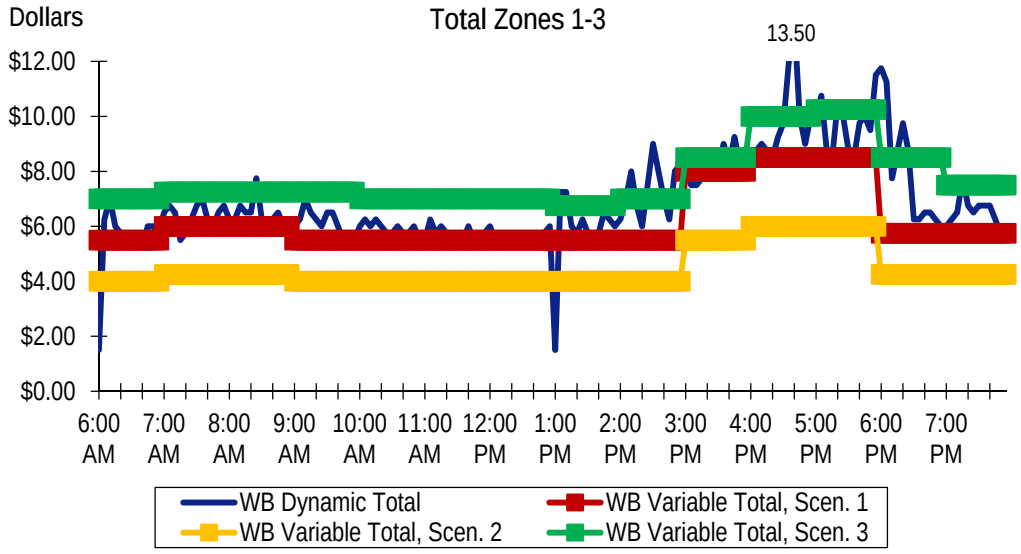


Figure 7.4 Forecast Average Weekday Toll Rates by Zone
Scenarios 1, 2, and 3 and Dynamic Westbound, 2025 (continued)



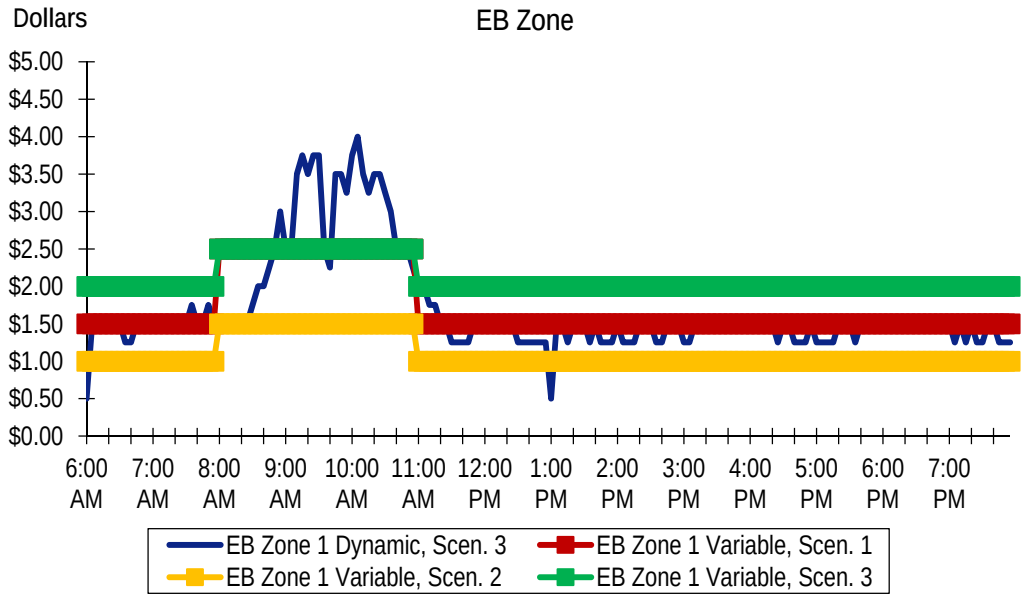
Source: Cambridge Systematics, Inc.

Figure 7.5 Forecast Average Weekday Toll Rates by Zone Full Length Trip
Scenarios 1, 2, and 3 and Dynamic Westbound, 2025



Source: Cambridge Systematics, Inc.

Figure 7.6 Forecast Average Weekday Toll Rates by Zone Full Length Trip
Scenarios 1, 2, and 3 and Dynamic Eastbound, 2025



Source: Cambridge Systematics, Inc.

Figure 7.7 Forecast Average Weekday Toll Rates by Zone
Scenarios 1, 2, and 3 and Dynamic Westbound, 2035

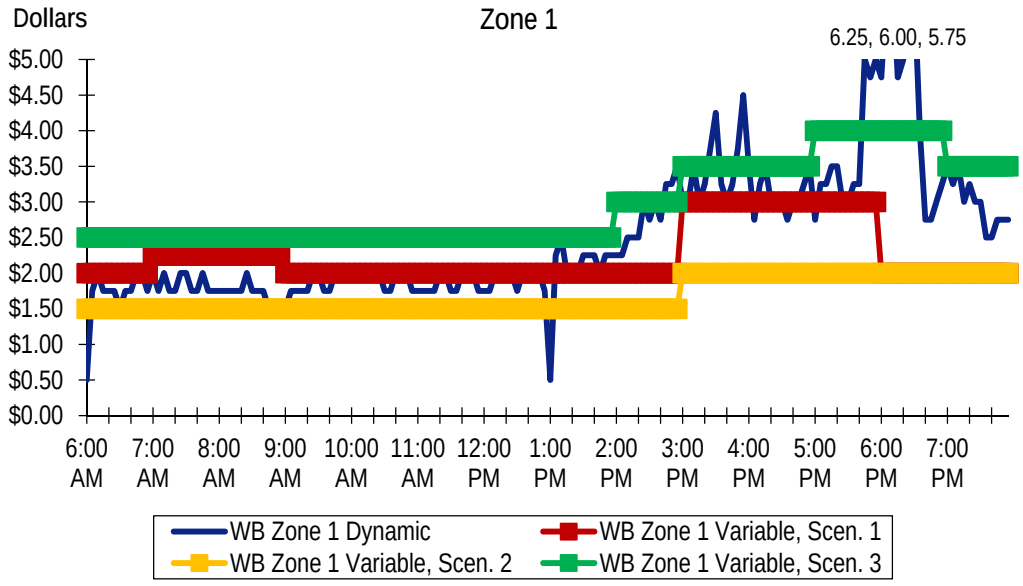
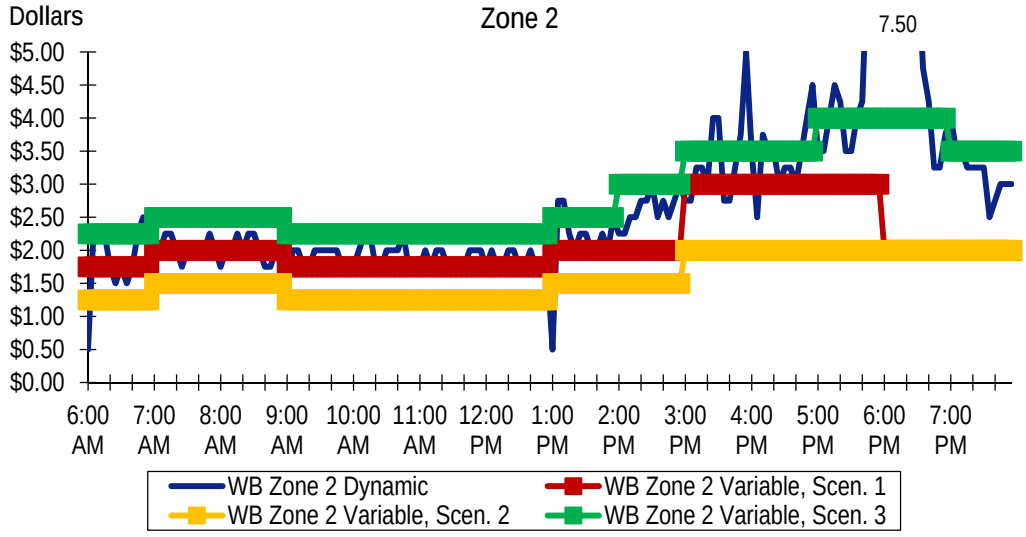
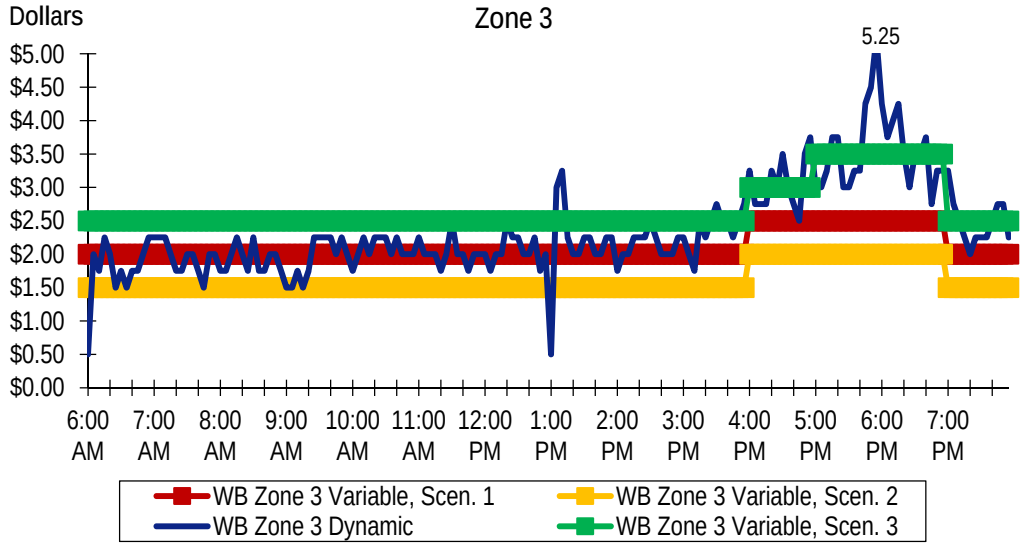


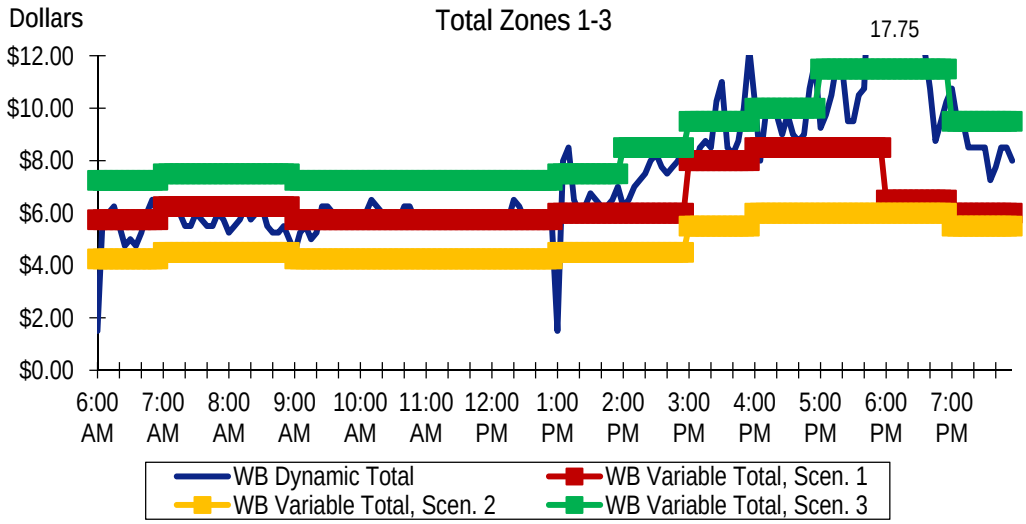
Figure 7.7 Forecast Average Weekday Toll Rates by Zone
Scenarios 1, 2, and 3 and Dynamic Westbound, 2035 (continued)





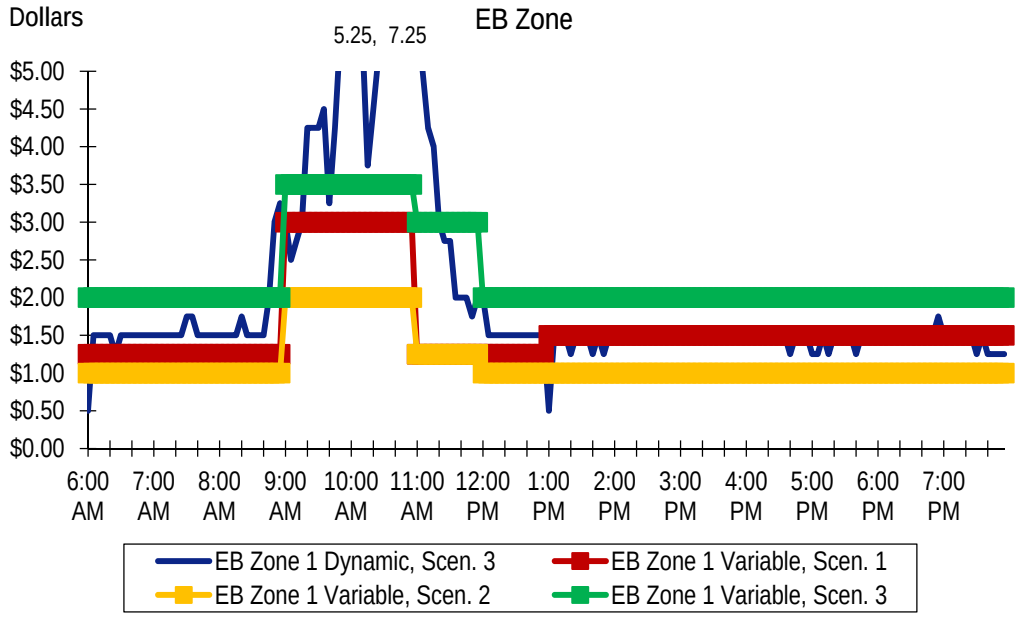
Source: Cambridge Systematics, Inc.

Figure 7.8 Forecast Average Weekday Toll Rates by Zone Full Length Trip
Scenarios 1, 2, and 3 and Dynamic Westbound, 2035



Source: Cambridge Systematics, Inc.

Figure 7.9 Forecast Average Weekday Toll Rates by Zone Full Length Trip
Scenarios 1, 2, and 3 and Dynamic Eastbound, 2035



Source: Cambridge Systematics, Inc.

7.3 TRANSACTION AND REVENUE FORECASTS

Transaction and revenue forecasts were developed based on interpolation and expansion of the VISSIM traffic model results. The model variables that drive the results have been discussed in Section 3.0. The other key input is the toll prices that were described in section 7.2. The following section of the report summarize the toll price ranges, and transaction and revenue streams.

Toll Ranges

Table 7.2 and Table 7.3 summarizes the ranges in toll prices for end to end trips for the RAMP Interim Concept by Fixed pricing scenarios. Fixed Pricing II option is the most likely tolls that would be implemented. The westbound tolls range from $3.75 to $6.00 in 2018 for an end to end westbound trip. The eastbound end to end trip ranged from $0.75 to $1.00.

Table 7.2 Westbound Toll Ranges for end to end trip

	2018		2025		2035	
Toll Scenario	Low Toll	High Toll	Low Toll	High Toll	Low Toll	High Toll
Fixed I	$5.25	$8.50	$5.5	$8.5	$5.75	$8.5
Fixed II	$3.75	$6.00	$4.0	$6.00	$4.25	6.00
Fixed III	$6.75	$10.00	$6.75	$10.25	$7.25	11.50

Source: Cambridge Systematics Inc.

Table 7.3 Eastbound Toll Ranges for end to end trip

	2018		2025		2035	
Toll Scenario	Low Toll	High Toll	Low Toll	High Toll	Low Toll	High Toll
Fixed I	$1.25	$1.50	$1.50	$2.50	$1.25	$3.00
Fixed II	$0.75	$1.00	$1.00	$1.50	$1.00	$2.00
Fixed II	$1.75	$2.00	$2.00	$2.50	$2.00	$3.50

Source: Cambridge Systematics Inc.

Transaction and Revenue Forecasts

Table 7.4 shows transaction and revenue forecasts for each of the pricing scenarios for 2018, 2025, and 2035 as well as for the entire 30-year period. Figures 7.10 and 7.11 show the revenue and transaction forecasts for each of the benchmark years graphically, and Figure 7.12 compares the 30-year forecast totals.

The highest total revenue is forecast for the Fixed III concept, which would charge 50 cents more than the dynamic concept, with a forecast of $747.6 million over 30 years. The dynamic price concept 1 is forecast to generate about three percent less, at $728.9 million. The lowest revenue is forecast for the Fixed II concept (50 cents less than dynamic) at $563.2 million, or 25 percent less than the Fixed III concept.

This analysis is useful to illustrate that small changes in toll policy can create fairly significant changes in traffic and revenue outcomes. In reality, toll setting will need to be adjusted once the lanes are open, and then revisited frequently to make sure that the desired policies are being achieved.

Figure 7.13 illustrates the forecast annual toll revenue streams from 2018 through 2047 for each of the pricing strategies.

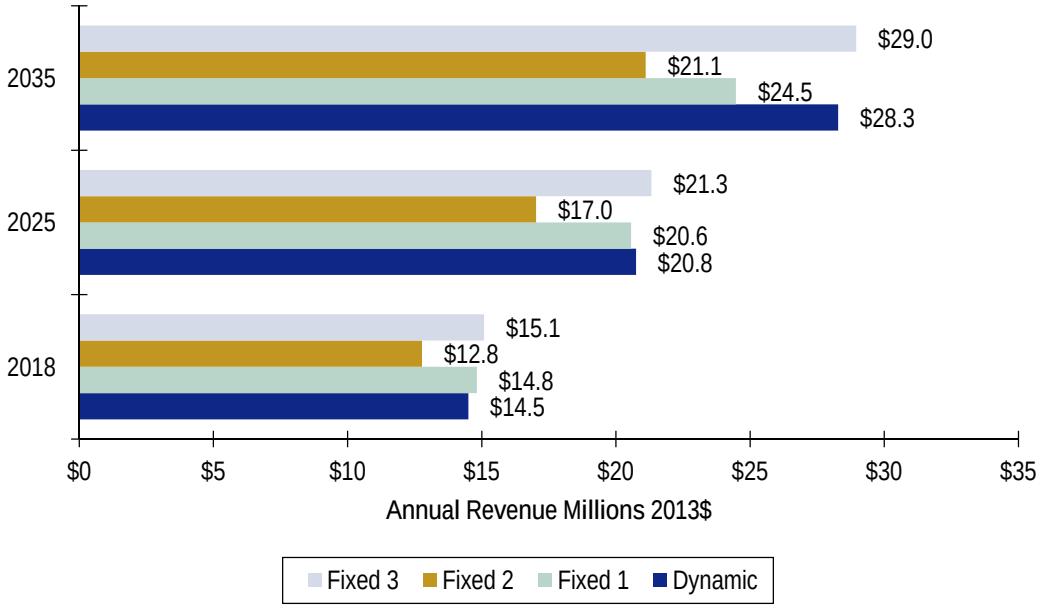
Table 7.4 Revenue and Transaction Forecast Summary
RAMP Interim Scenarios

Pricing Scenario	2018	2025	2035	30 year
Revenue (millions of 2013$)				
Dynamic	$14.5	$20.8	$28.3	$728.9
Fixed I: closest to dynamic	$14.8	$20.6	$24.5	$658.5
Fixed II (Fixed I - $0.50)	$12.8	$17.0	$21.1	$562.1
Fixed III (Fixed I + $0.50)	$15.1	$21.3	$29.0	$747.6
Annual Transactions (millions)				
Dynamic	5.4	6.9	8.1	220.0
Fixed I: closest to dynamic	5.4	7.1	8.1	226.5
Fixed II (Fixed I - $0.50)	6.3	8.1	9.5	258.3
Fixed III (Fixed I + $0.50)	4.6	6.3	7.5	203.3

Source: Cambridge Systematics, Inc.

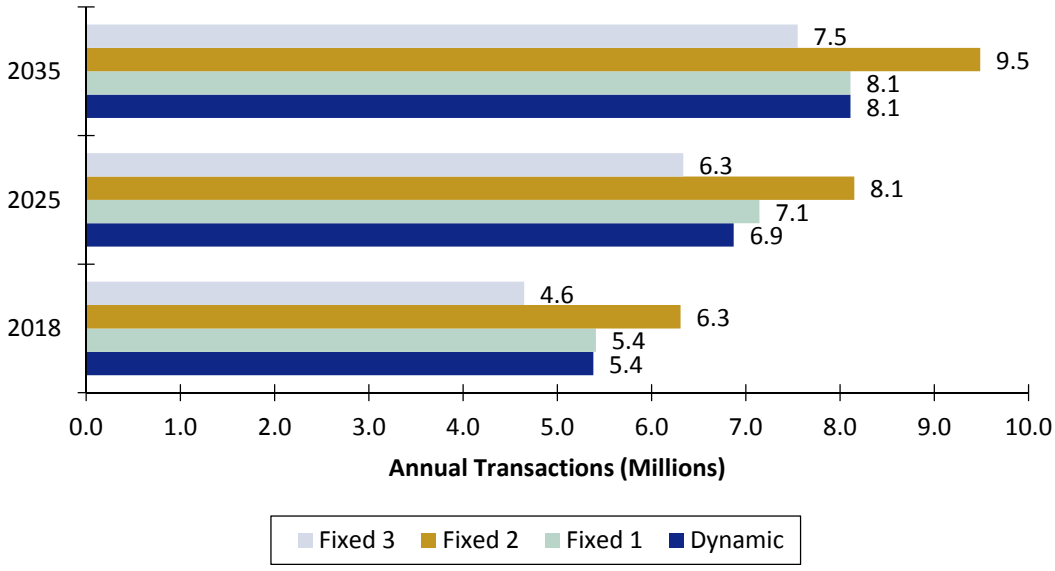
Note: 2018 revenue transaction and revenue forecasts in this table do not include ramp-up assumptions, but the 30-year revenue and transaction total does.

Figure 7.10 Annual Gross Revenue Comparisons
RAMP Interim Scenario, Millions of 2013$



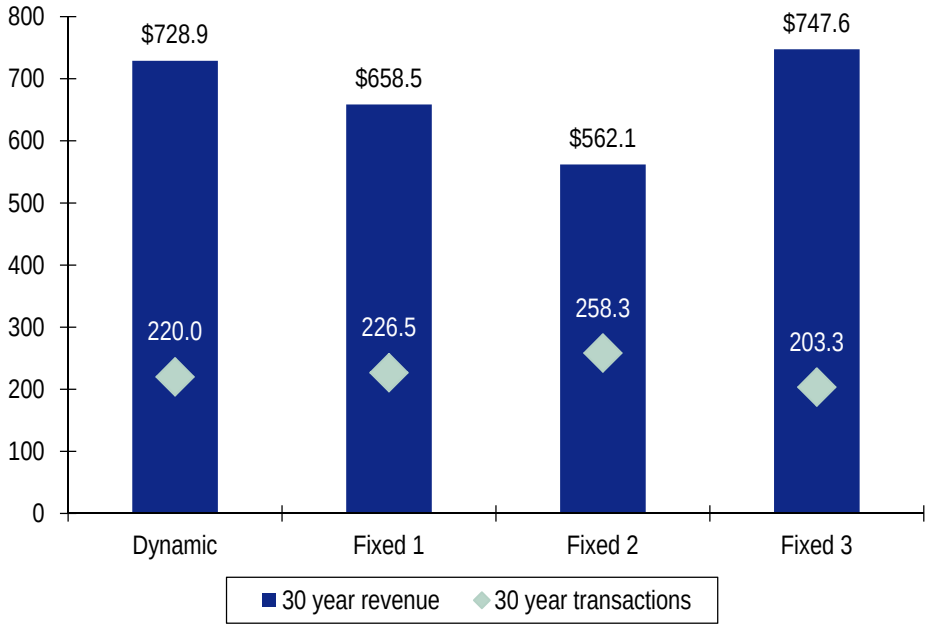
Source: Cambridge Systematics, Inc.

Figure 7.11 Annual Transaction Comparisons
RAMP Interim Scenario, Millions



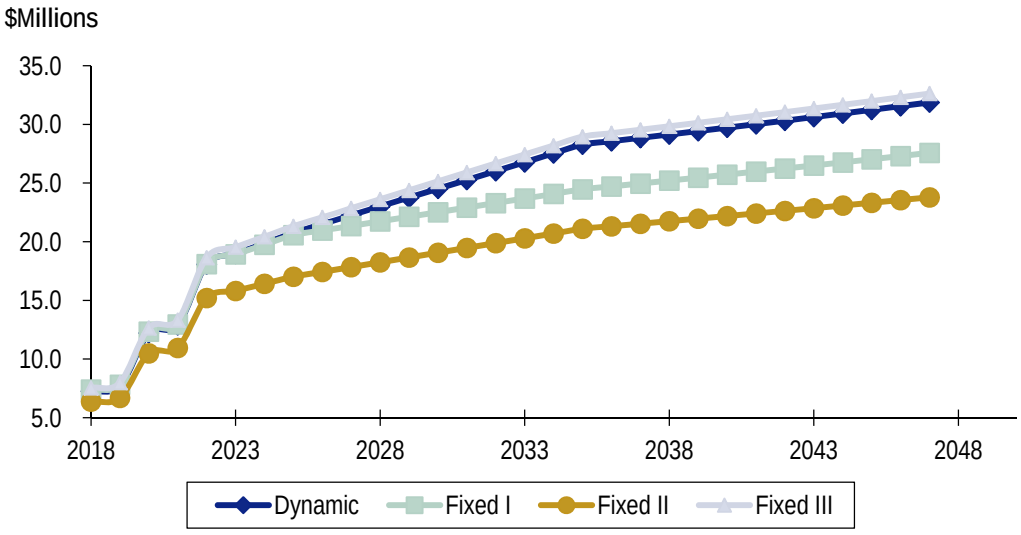
Source: Cambridge Systematics, Inc.

Figure 7.12 Forecast 30-Year Gross Revenue (millions of 2013$) and Transactions (millions):
RAMP Interim Scenario



Source: Cambridge Systematics, Inc.

Figure 7.13 Gross Revenue Stream
RAMP Interim Alternative Fixed-Price Scenario I



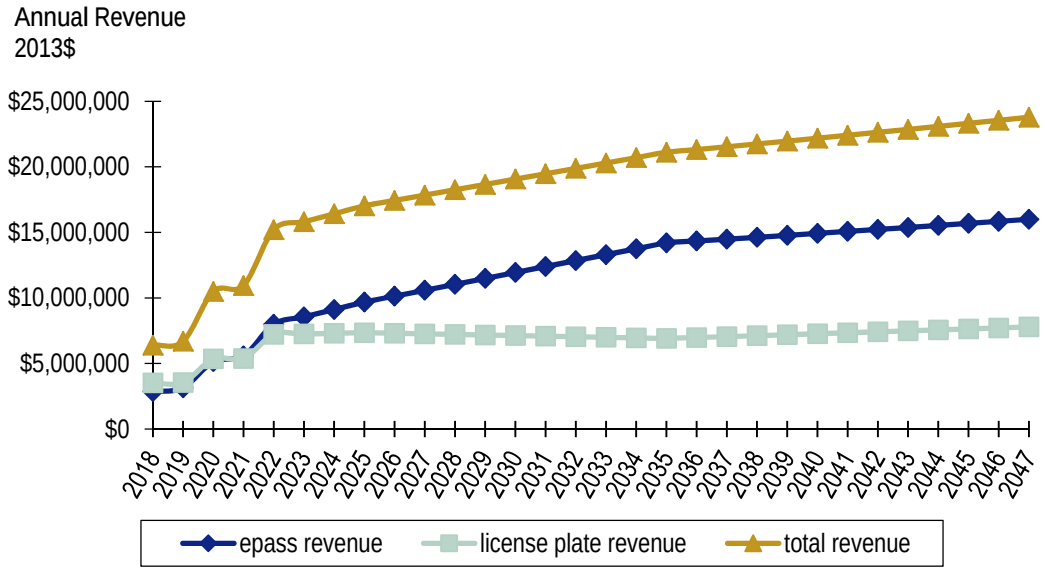
Source: Cambridge Systematics, Inc.

Revenue by ExpressToll Pass and License Plates

The study was conducted assuming a certain level of Express Toll 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 7.14 below is traffic revenue stream for the Fixed Price Scenario II. The relationship between license plate revenue and Express Toll 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 7.14 Revenue Streams by Transponder and License Plate User Fixed Pricing Scenario II
2013$



Source: Cambridge Systematics, Inc.

7.4 DISCLAIMER

The findings of this report were developed for use by Douglas County and the C-470 Corridor Coalition to compare project alternatives. Additional work is 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).

8.0 Traffic Operations

8.1 OVERVIEW

CS evaluated expected traffic performance for the C-470 express toll lane project considering speed, average travel times, throughput and bottlenecks. The VISSIM traffic models produce these measurements of forecast traffic for two seven-hour peak periods. The performance measures are aggregated by five-minute periods, which were rolled up into larger-time periods as needed. The objective of the traffic operations section is to provide insights into overall performance and to identify areas of concern.

We tested the design concepts using a variety pricing schemes, each of which resulted in different revenue outcomes. Although there were differences in traffic performance between different pricing schemes, there are many similarities as well. The ultimate concept in 2035 demonstrates an improvement in the p.m. peak period for westbound C-470, and marginal improvement in the a.m. peak for the eastbound direction.

Appendices C through K provide details of the operations analysis for each scenario.

The two Design Concepts (Interim RAMP Concept and the Ultimate Concept) are described in Section 4.0.

8.2 NETWORK SUMMARY STATISTICS

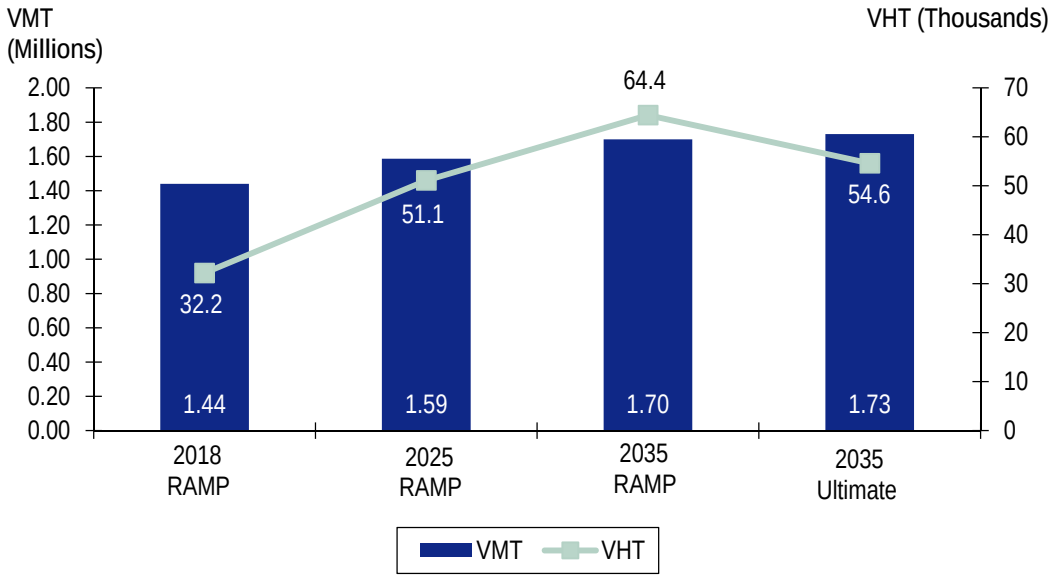
We used Vehicle Miles of Travel (VMT) and Vehicle Hours of Travel (VHT) as key indicators of system performance (see Table 8.1 and Figures 8.1 and 8.2) We expect that the Ultimate concept would deliver more traffic in 2035 than the Interim RAMP concept, but with less travel time, as indicated by higher forecast VMT coupled with lower VHT. The VHT and VMT summaries include both directions of C-470.

Table 8.1 Forecast VMT and VHT Outcomes by Scenario and Year

	VMT (Millions)		VHT (Thousands)	
	A.M.	P.M.	A.M.	P.M.
2018				
2018 Interim Fixed Price I	1.44	1.52	32.0	39.5
2018 Interim Fixed Price II	1.44	1.53	31.8	37.8
2018 Interim Fixed Price III	1.44	1.51	32.8	41.5
2025				
2025 Interim Fixed Price I	1.58	1.69	53.0	48.5
2025 Interim Fixed Price II	1.59	1.71	49.7	45.0
2025 Interim Fixed Price III	1.59	1.68	50.6	50.9
2035				
2035 Interim Fixed Price I	1.71	1.82	60.8	58.1
2035 Interim Fixed Price II	1.69	1.84	67.1	56.4
2035 Interim Fixed Price III	1.70	1.79	65.4	62.3
2035 Ultimate Fixed Price	1.73	1.84	54.6	58.2

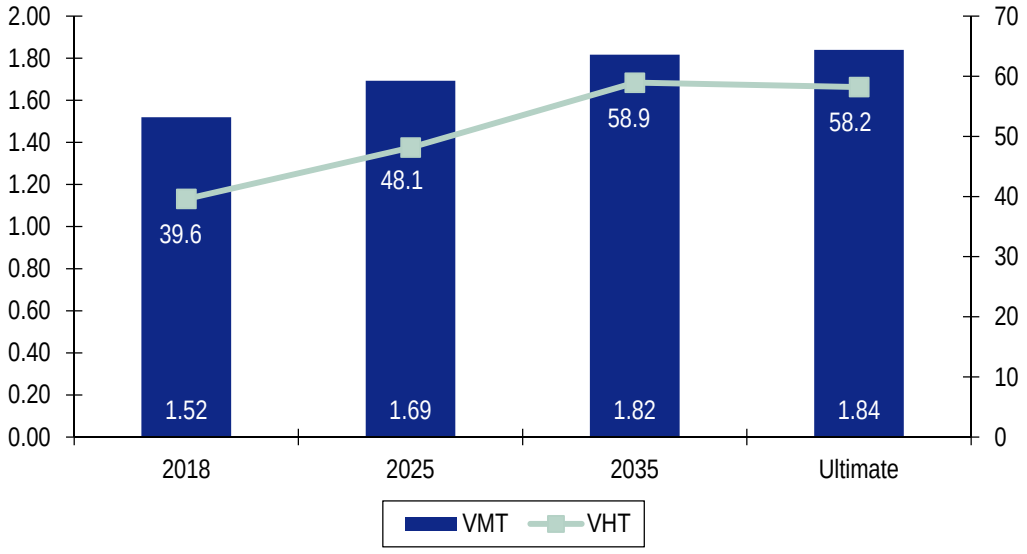
Source: Cambridge Systematics, Inc.

Figure 8.1 A.M. Peak-Period VMT and VHT



Source: Cambridge Systematics, Inc.

Figure 8.2 P.M. Peak-Period VMT and VHT



Source: Cambridge Systematics, Inc.

8.3 EASTBOUND C-470

Eastbound C-470 traffic operations and capacity will be constrained by the operations and accessibility to I-25. At the eastern end of the project limits the majority of eastbound traffic is destined to either northbound or southbound I-25, with the least amount of traffic continuing on to E-470. The I-25 interchange and I-25 northbound operations are a constraint to C-470 Eastbound traffic. The constraints at I-25 limits the capacity and the overall traffic that can be served eastbound and as a result the traffic volumes delivered were similar from 2025 and 2035.

Eastbound Traffic Volumes

Table 8.2 summarize seven-hour a.m. peak-period traffic volumes along C-470 at locations after an ETL ingress or egress point. In 2018 the percentage of total traffic using the ETL is expected to range from 7 percent to 15 percent, in 2025 the percentage is expected to grow from 14 percent to 23 percent, and in 2035 the range is from 14 to 29 percent. The ultimate configuration shows up to as much as 35 percent, attributed to the additional express toll lane that is part of the Ultimate concept from Lucent to Yosemite.

Eastbound Travel-Time Savings

Travel-time savings were computed by comparing the travel times in the general purpose and express toll lanes that were computed in the VISSIM model. Table 8.3 summarizes the peak half hour of 7:00 to 7:30 a.m. travel time by tolling zone as a representative example. For the Interim RAMP concept there is only

one tolling zone so the travel-time represents the end to end trip, roughly 10 miles in a single express toll lane. The 2035 Ultimate Concept is broken up into two tolling zones – the first zone is from just before Wadsworth to Lucent and the second zone is from Lucent to I-25 for a total trip length of over 13 miles.

Table 8.2 Forecast Eastbound C-470 Screenline Volumes by Year
Fixed I Pricing Scenario Seven-Hour A.M. Peak Period

Segment		2018 Interim			2025 Interim			2035 Interim			2035 Ultimate		
No.	Description	ETL	GP	Percentage ETL	ETL	GP	Percentage ETL	ETL	GP	Percentage ETL	ETL	GP	Percentage ETL
1	Kipling to Platte										5,840	15,492	27%
2	Platte to Santa Fe										9,084	16,653	35%
3	Santa Fe to Lucent	2,316	18,717	11%	4,335	18,038	19%	4,921	18,717	21%	8,959	16,643	35%
4	Lucent to Broadway	1,799	23,221	7%	3,616	22,890	14%	4,089	24,163	14%	7,389	18,204	29%
5	Broadway to University	2,874	25,282	10%	5,361	24,346	18%	5,918	25,760	19%	7,388	21,387	26%
6	University to Quebec	3,602	25,032	13%	6,358	23,812	21%	7,167	24,654	23%	5,621	24,178	19%
7	Quebec to Yosemite	3,459	19,916	15%	5,701	18,862	23%	6,345	19,544	25%	8,252	18,921	30%
8	Yosemite to I-25										1,851	34,977	5%

Source: Cambridge Systematics, Inc.

Table 8.3 Eastbound C-470: Interim Fixed II Models (lowest toll $) – Weighted Travel-Time Comparison ETL verse GP Lanes
6:00 a.m. to 1:00 p.m.

		Travel Times (Minutes)			
		Interim			
		2018 RAMP	2025 RAMP	2035 RAMP	2035 Ultimate
Zone 1	GP	11.0	29.1	37.4	32.5
	ETL	9.7	17.2	32.5	9.5
	Time Saving	1.3	11.8	5.0	23.0
Zone 2	GP				13.7
	ETL	NA	NA	NA	6.0
	Time Saving				7.7
Total	GP	11.0	29.1	37.4	46.2
	ETL	9.7	17.2	32.5	15.5
	Time Saving	1.3	11.8	5.0	30.7

Source: Cambridge Systematics, Inc.

Eastbound Speed Contours

The a.m. peak period is the peak direction for Eastbound C-470. Figures 8.3 through 7.5 are speed/flow plots of the VISSIM model results for the eastbound direction for the mainline 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 five-minute-time interval. The diagram is color coded based on the speed, with shades of green representing 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 and hot colors indicate congestion. In Appendices C through K contain "heat maps" of all the model scenarios.

2018 Interim

Figure 8.3 illustrates the speed contours for the 2018 a.m. peak-period condition and shows:

1. Location 1 highlights the congestion that is expected to build up before the start of the express toll lane.
2. Location 2 indicates minor congestion expected to occur around the Lucent Broadway interchanges.
3. The traffic operations in the express toll lane is forecast to be very good, with speeds typically over 50 mph throughout the morning peak.

2035 Interim

Figure 8.4 illustrates the eastbound C-470 2035 a.m. peak condition for the fixed pricing Scenario I. While there are subtle variations between the operations of the other pricing scenarios, fixed pricing I this scenario is illustrative of the operational issues observed in the Interim Cases. The congestion issues are as follows, with the numbers on the list correlated to the numbers on the exhibit.

1. **Eastbound C-470 Mainline around Wadsworth.** The forecast traffic demand is more than the two lanes of traffic can handle prior to the start of the express toll lanes. A queue of traffic is expected to build up and back towards Kipling and beyond.
2. **Broadway Off-Ramp**. Traffic at the Broadway off-ramp in the 6:30 a.m. to 11:00 a.m. is expected to experience congestion.
3. **University On-Ramp.** Operational issues associated with the interchange University Interchange.
4. **Quebec Interchange.** Operational issues associated with the Quebec interchange.
5. **I-25 Congestion.** I-25 northbound is forecast to be highly congested, which will affect traffic on eastbound C-470 attempting to get onto I-25, resulting in a traffic spillback that extends back to Santa Fe.
6. **C-470 Express Toll Lanes.** The ETL Performance is expected to be affected by the I-25 congestion discussed in Item 4.

2035 Ultimate

Figure 8.5 illustrates the expected traffic operations for the Ultimate Concept for eastbound C-470 in 2035 a.m. peak period. The longer express toll lane project with two express toll lanes results in a similar congestion pattern to the 2035 Interim RAMP concept.

1. **Eastbound C-470 Mainline around Wadsworth.** The traffic demand is expected to be more than the two lanes of traffic can handle prior to the start of the express toll lanes. A queue of traffic is expected to build up back towards Kipling and beyond.
2. **Broadway Off-Ramp**. Traffic at the Broadway off-ramp in the 6:30 a.m. to 10:00 a.m. is expected to experience congestion.
3. **University On-Ramp.** Operational issues associated with the interchange at University.
4. **I-25 Congestion.** I-25 northbound is expected to be highly congested, which will affect 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 express toll lanes have minimal congestion as compared to interim concept. The positive impact of two ETL's from Lucent to I-25 are realized.

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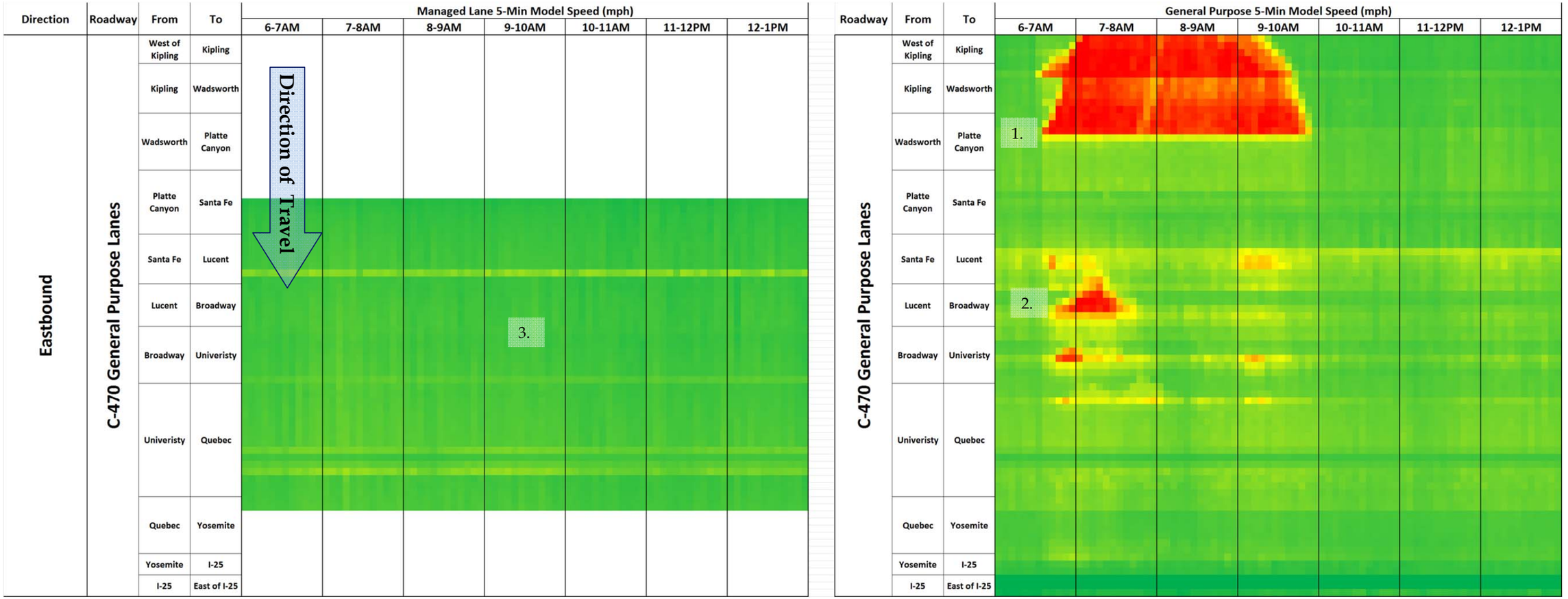
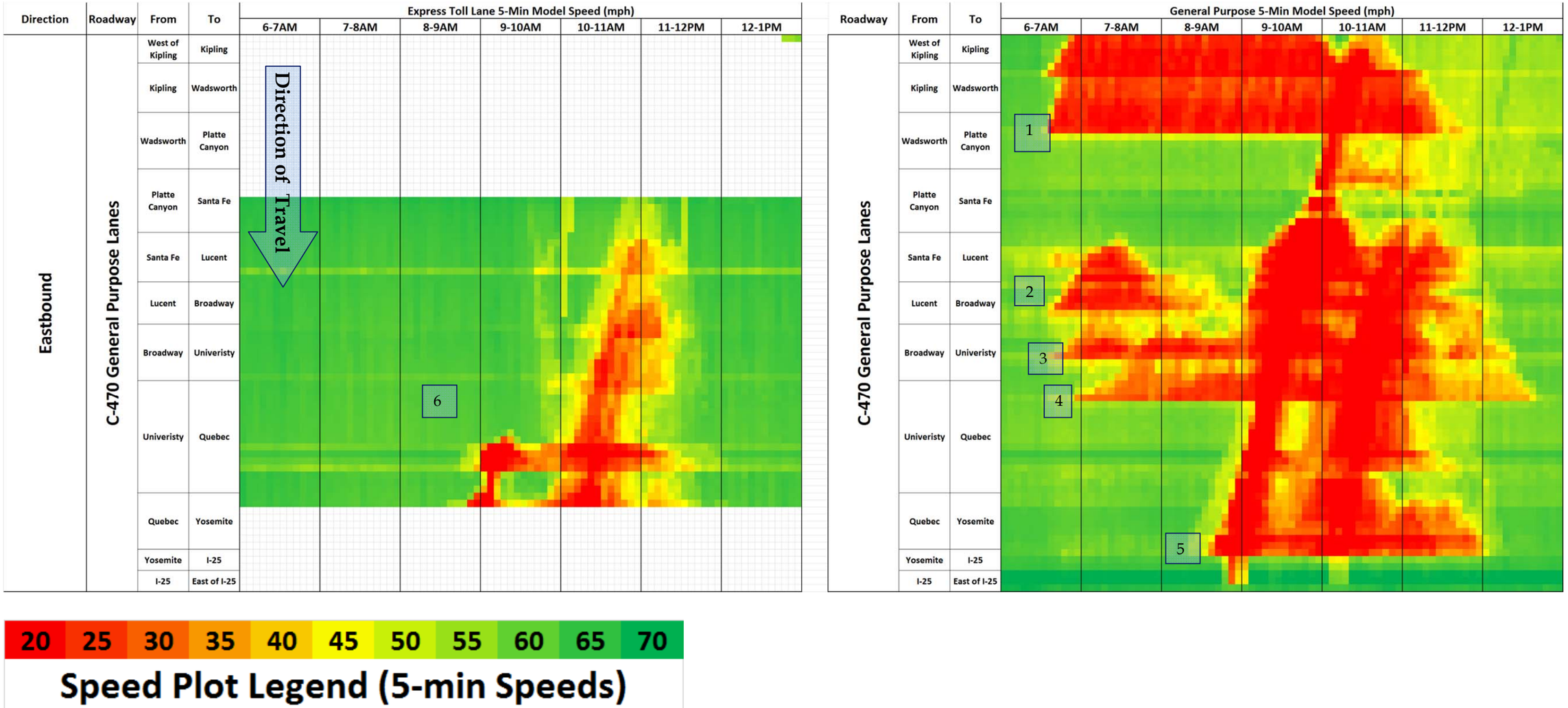
Figure 8.3 2018 A.M. Peak Eastbound C-470 *Interim* RAMP Concept Speed Maps



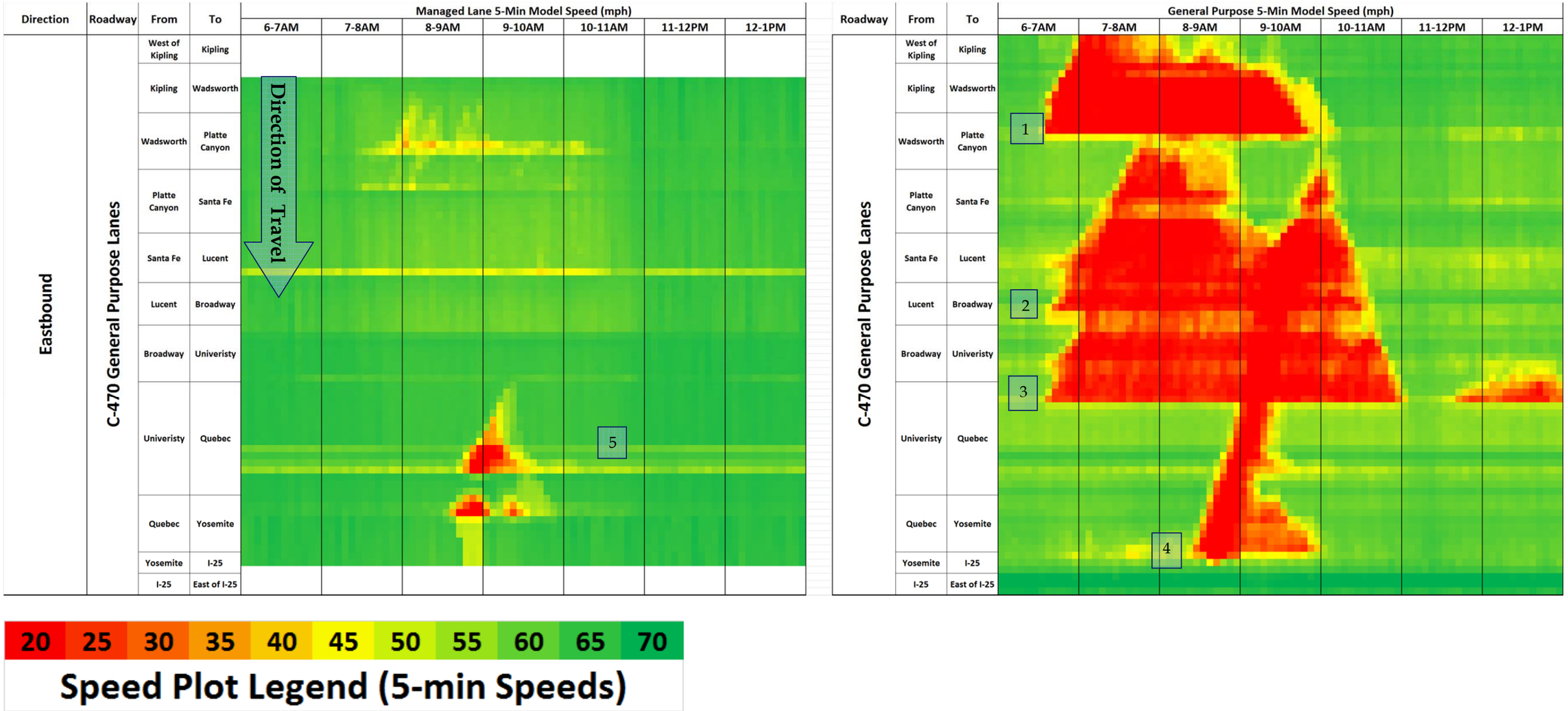
Source: Cambridge Systematics, Inc.

Figure 8.4 2035 A.M. Peak Eastbound C-470 *Interim* RAMP Concept Speed Maps



Source: Cambridge Systematics, Inc.

Figure 8.5 2035 A.M. Peak Eastbound C-470 *Ultimate* Concept Speed Maps



Source: Cambridge Systematics, Inc.

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8.4 WESTBOUND C-470

Westbound C-470 traffic operations are significantly different than the Eastbound direction in that westbound currently is the most congested direction in the afternoon peak and that westbound traffic heads away from the bottleneck on I-25. As a result, the Project Management Team added direct ramps to the design to allow traffic to pay to bypass congestion between I-25 and Quebec.

Westbound Forecast Traffic Volumes

Table 8.4 summarize forecast total seven-hour p.m. peak-period traffic volumes on C-470 at locations after an ETL ingress or egress point. In 2018 the percentage of total traffic using the ETL is forecast to range from 5 percent to 23 percent, in 2025 the percentage growth is expected to range from 8 percent to 28 percent, in 2035 the range is from 12 percent to 35 percent. The ultimate configuration shows stable growth up to as much 31 percent, with a higher percentage of traffic in Zone 3 than what occurs in the Interim RAMP concept.

Westbound Travel-Time Savings

Travel-time savings were computed from the VISSIM model. Table 8.5 summarizes a representative peak half hour of 4:00 to 4:30 p.m. travel time by tolling zones. The Interim and Ultimate concepts include three tolling zones, and the interim is one segment shorter than the Ultimate Concept (the extension to Kipling is not included).

Table 8.4 Forecast Westbound C-470 Screenline Volumes by Model Year Fixed I Pricing Scenario Seven-Hour P.M. Peak Period

	Segment		2018 RAMP			2025 RAMP			2035 RAMP			2035 Ultimate		
	No.	Description	ETL	GP	Percentage ETL	ETL	GP	Percentage ETL	ETL	GP	Percentage ETL	ETL	GP	Percentage ETL
Zone 1	1	Yosemite to Quebec	5,327	24,167	18%	6,716	24,759	21%	8,408	23,923	26%	7,389	25,457	22%
	2	Quebec to Colorado	6,235	20,413	23%	7,885	20,317	28%	10,124	18,984	35%	9,234	20,113	31%
Zone 2	3	Colorado to University	3,065	18,708	14%	4,375	19,032	19%	6,299	17,856	26%	6,070	18,334	25%
	4	University to Broadway	1,958	25,448	7%	2,954	26,426	10%	4,408	26,508	14%	4,383	26,690	14%
	5	Broadway to Lucent	2,742	18,831	13%	3,772	19,564	16%	5,654	19,263	23%	5,818	19,276	23%
Zone 3	6	Lucent to Wadsworth	1,337	23,044	5%	2,018	24,575	8%	3,365	25,415	12%	3,818	25,108	13%
	7	Wadsworth to Kipling										2,667	22,841	10%

Source: Cambridge Systematics, Inc.

Table 8.5 Westbound C-470: Interim Fixed II Models (lowest toll $) – Weighted Travel-Time Comparison ETL verse GP Lanes
1:00 p.m. to 8:00 p.m.

		Travel Times (Minutes)			
		2018 RAMP	2025 RAMP	2035 RAMP	2035 Ultimate
Zone 1	GP	53.6	49.9	35.7	28.9
	ETL	7.6	4.2	3.8	3.1
	savings	46.1	45.7	31.9	25.8
Zone 2	GP	13.2	14.0	14.1	13.1
	ETL	6.5	6.5	6.4	6.0
	savings	6.7	7.5	7.6	7.1
Zone 3	GP	5.5	6.7	13.2	14.2
	ETL	4.6	4.9	5.0	4.9
	savings	0.8	1.8	8.2	9.3
Total	GP	72.3	70.7	63.0	56.2
	ETL	18.7	15.6	15.3	14.0
	savings	53.6	55.0	47.7	42.1

Westbound Speed Contours

The p.m. peak period is the peak direction for Westbound C-470. Figures 8.6 through 8.8 are speed flow plots of the VISSIM model results for the mainline freeway in both the general purpose lanes and in the express toll lanes.

2018 Interim Conditions

Figure 8.6 is the speed map for 2018 Westbound C-470 Fixed Pricing Scenario I in the p.m. peak period. The primary issue is the congestion on C-470 general purpose lanes from I-25 to west of Quebec interchange. This bottleneck has been an issue throughout the study process. The addition of the direct ramp connections have provided an opportunity for traffic to bypass the congestion. The speeds in the Express Toll lanes are 45 mph or better throughout the peak period.

A secondary issue that is not significant in 2018 is the congestion around the terminus of the ETL near Wadsworth where the number of lanes are reduced from three to two lanes. While the congestion is notable it is not widespread.

2035 Interim Conditions

Figure 8.7 is the speed map for 2035 Westbound C-470 Fixed Pricing Scenario 1 in the p.m. peak period. The same issues that were observed in the 2018 analysis also occur in 2035, however they are far more intense. The Wadsworth egress area congestion is expected to extend back to the Quebec

interchange area. The congestion from I-25 to Quebec is expected to be very similar to the 2018 condition.

The express toll lane operations are forecast to remain at 45 mph and above, with one potential issue being the congestion on the general purpose lanes at the Lucent area ingress/egress opening. It appears that the congestion is contained to the GP lanes and does not have an impact on the ETL performance.

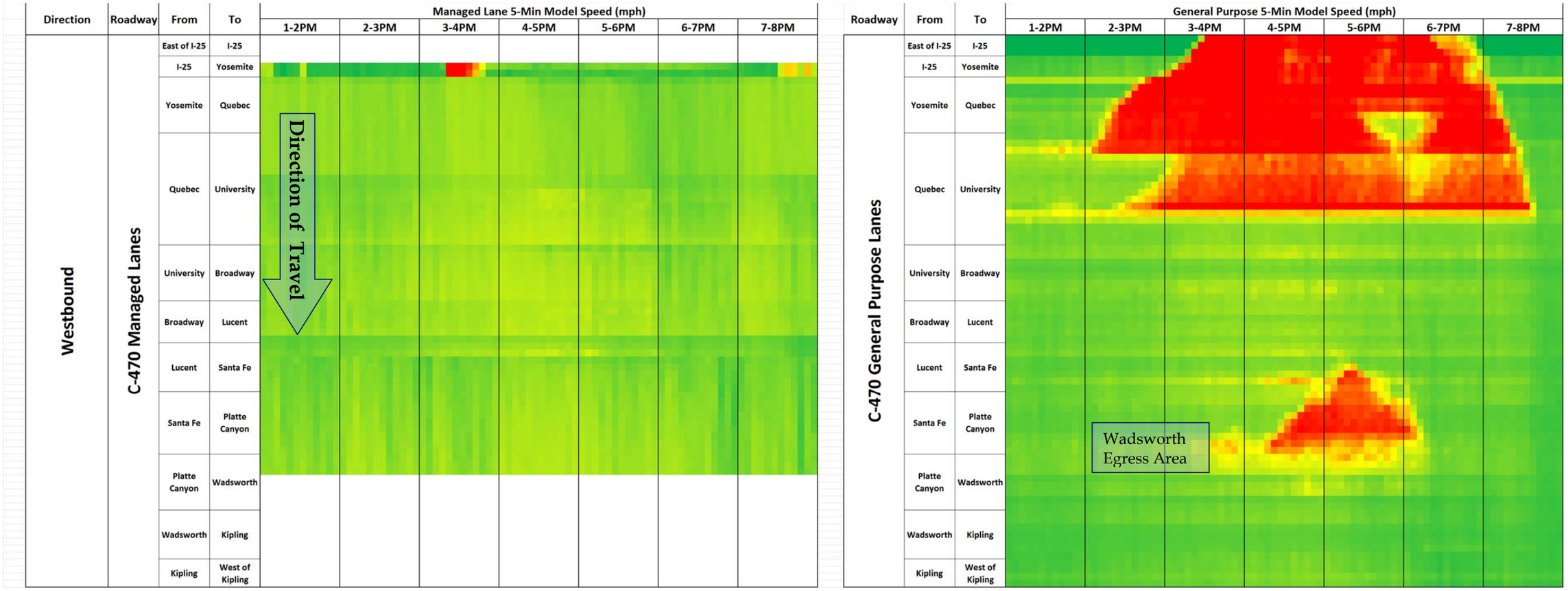
2035 Ultimate Conditions

Figure 8.8 is the speed map for 2035 Westbound C-470 Ultimate concept Fixed Pricing Scenario I in the p.m. peak period. The overall pattern is expected to be similar to the 2035 Interim RAMP concept. The area between the Wadsworth Egress and the Wadsworth Interchange has gone through design testing with the design team to determine the optimal design, even with the optimal design for the egress there are congestion issues that will need further mitigation.

Wadsworth Egress Areas

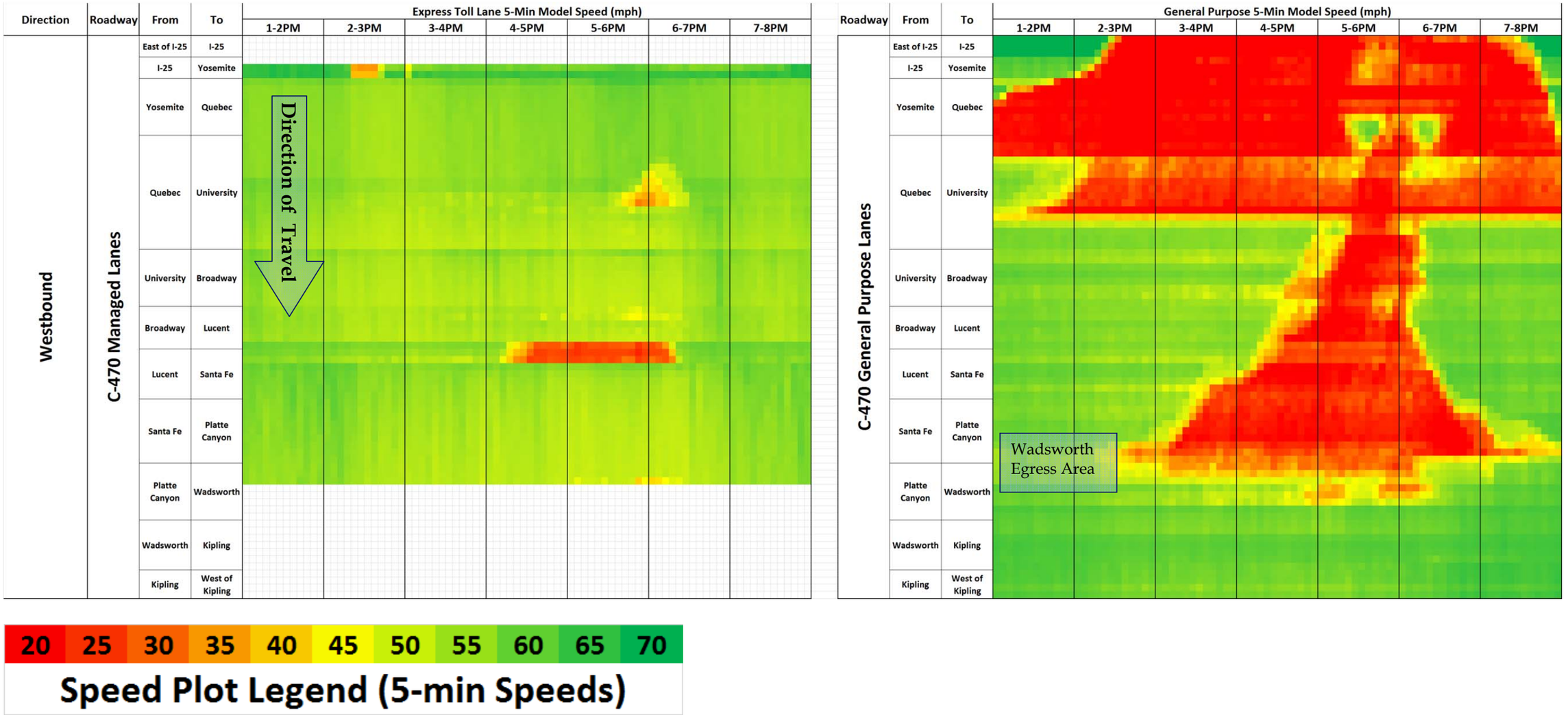
The westbound egress (last egress in the Ramp Interim Concept) upstream of the Wadsworth Interchange has been subject of design mitigation. The major challenge is the reduction of lanes that occurs in that location; there are two general purpose lanes and one express toll lane that reduce to two general purpose lanes. Figures 8.6 through 8.8 highlight the location of the egress location and the resulting queue of traffic (red areas) that build upstream of this location. In spite of the mitigation efforts there remains residual congestion. There are two possible mitigations, one is adding additional pavement, e.g., extending the general purpose lanes, the other mitigation is to refine tolls to encourage more use of the ETL at that location. Both of these ideas should be explored in future studies.

Figure 8.6 2018 P.M. Peak Westbound C-470 *Interim* RAMP Concept Speed Maps



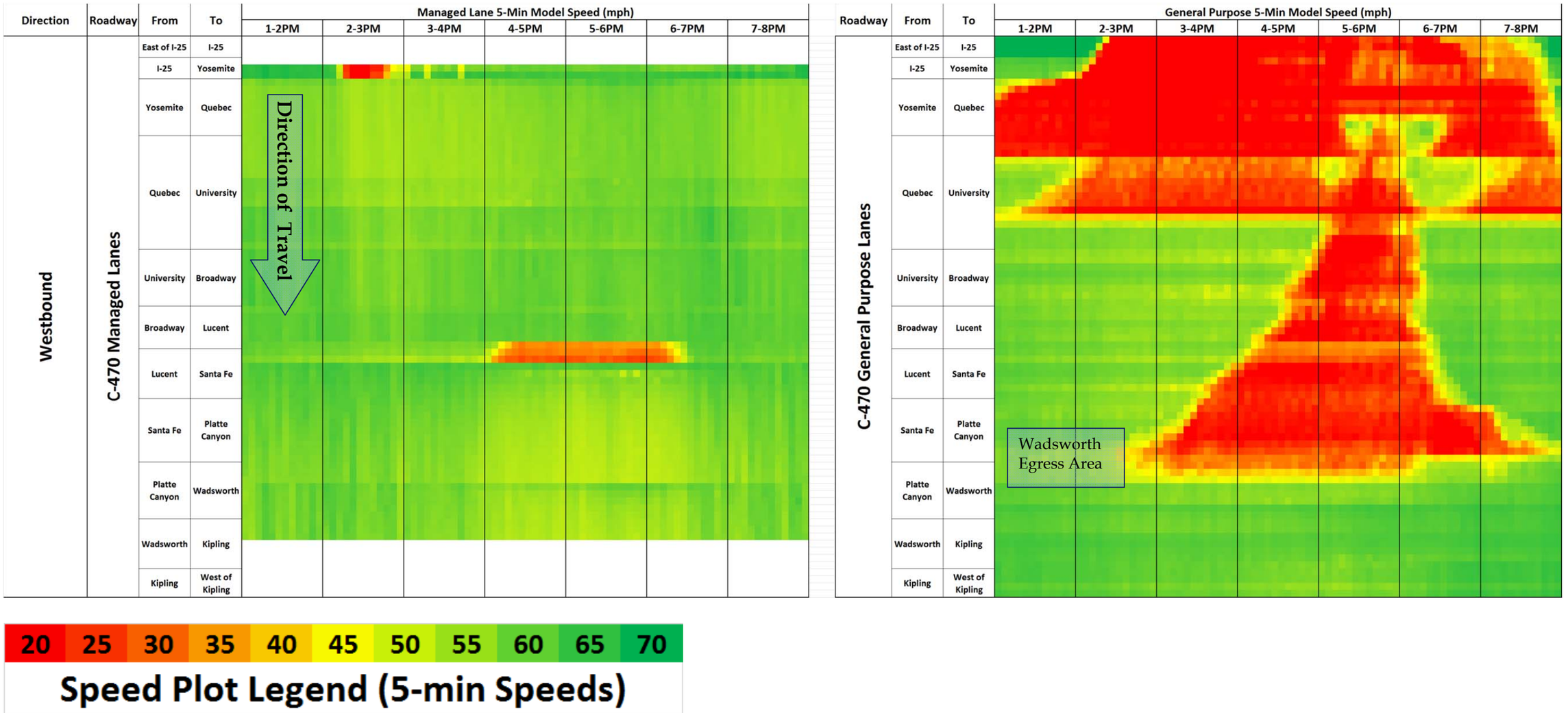
Source: Cambridge Systematics, Inc.

Figure 8.7 2035 P.M. Peak Westbound C-470 *Interim* RAMP Concept Speed Maps



Source: Cambridge Systematics, Inc.

Figure 8.8 2035 P.M. Peak Westbound C-470 *Ultimate* Concept Speed Maps



Source: Cambridge Systematics, Inc.

9.0 HOV 3+ Exemption

A policy consideration for the C-470 express toll lane project is a toll exemption for High-Occupancy Vehicles (HOV). In order to inform this discussion Cambridge Systematics conducted an analysis of the Interim Ramp Project with a toll exemption of HOV 3+ vehicles. The modeling procedure was the same as the previous traffic modeling work for the Level II Traffic and Revenue Study. For comparative purposes we used the Interim RAMP concept configuration and the same pricing as the Fixed I scenario. We assumed that HOV3+ vehicles would employ the use of a switchable transponder that would allow the vehicle to declare that it is eligible for the HOV exemption.

The trip tables (traffic demands) were the same for both scenarios with and without HOV exemptions. Those trip tables already included a breakdown of vehicles by classification. The classification breakdown was part of DRCOG's regional demand model. Table 9.1 is a summary of the percentages of vehicle occupancy classifications within the C-470 Study area. The forecast HOV 3+ percentages range from 1.7 percent in 2018 to 1.4 percent in 2035.

Table 9.1 Forecast Traffic Composition by Occupancy
14-Hour Trip Tables

	Traffic Composition Percentage		
Vehicle Category	2018[a]	2025	2035
Single Occupant	93.4%	93.9%	94.3%
HOV 2	4.8%	4.6%	4.3%
HOV 3+	1.7%	1.5%	1.4%
Total	100.0%	100.0%	100.0%

Source: FOCUS Regional Demand Model.

[a] 2018 Revenue Results do not include ramp up assumptions.

9.1 HOV 3+ Exempt Gross Revenue Forecasts

The effect of the HOV 3+ exemption on forecast gross revenue ranged from a reduction 3.4 percent in 2018 to 2.0 percent in 2035. The overall 30-year revenue stream impact was a reduction 2.0 percent. The change in paid transactions ranged from a decrease of 3.7 percent in 2018 to an increase of 1.2 percent in 2035. Overall in 30 years the paid transactions are expected to be 2.6 percent less than the non exempt scenario. Figures 9.1 and 9.2 are charts that illustrate the Gross revenue and transactions by modeled year.

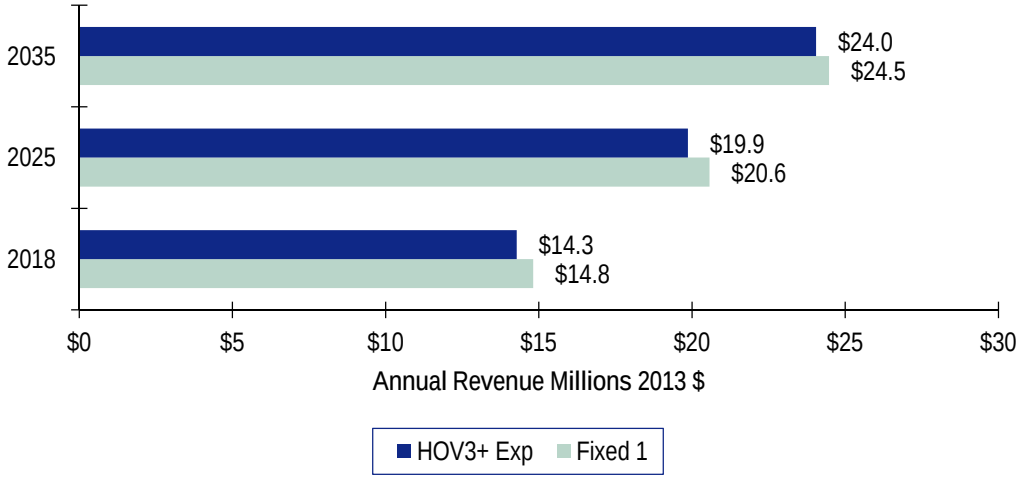
Table 9.2 Revenue and Transaction Comparisons

Pricing Scenario	2018[a]	2025	2035	30 Year
Revenue (millions of 2013$)				
Fixed I: Closest to dynamic	$14.8	$20.6	$24.5	$658.5
Fixed I: HOV3+ Exemption	$14.3	$19.9	$24.0	$643.5
Percent Difference	(3.4%)	(3.4%)	(2.0%)	(2.3%)
Annual Transactions (millions)				
Fixed I: Closest to dynamic	5.4	7.1	8.1	226.5
Fixed I: HOV3+ Exemption	5.2	6.9	8.2	220.7
Percent Difference	(3.7%)	(2.8%)	+1.2%	(2.6%)

Source: Cambridge Systematics, Inc.

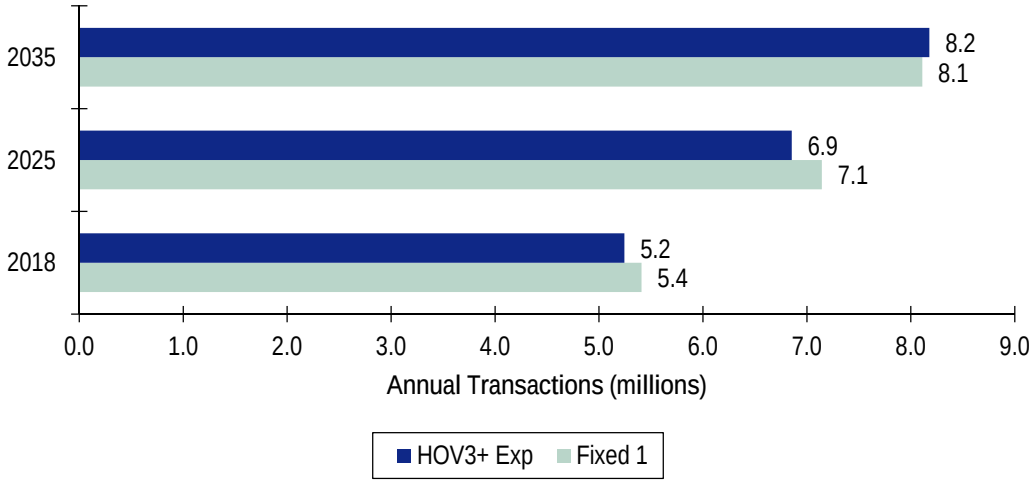
[a] 2018 Revenue Results do not include ramp up assumptions.

Figure 9.1 Annual Revenue Comparisons HOV3+ Exempt versus Nonexempt



Source: Cambridge Systematics, Inc.

Figure 9.2 Annual Transaction Comparisons HOV3+ Exempt versus Nonexempt



Source: Cambridge Systematics, Inc.

9.2 HOV 3+ Exempt Performance Comparisons

The difference in system performance between the HOV 3+ exempt and non exempt scenarios is summarized by year in Table 9.3. The VMT is nearly identical, which results from using the same trip tables. There were noticeable differences in VHT, with higher VHT indicating a poorer performance. In 2018, the VHT was nearly identical with a slightly better performance with the HOV 3+ scenario. However in the later years, there was a noticeable difference in performance with the HOV 3+ exempt scenario ***not*** performing as well as the no exemption scenario.

Table 9.3 VMT/VHT Comparisons HOV 3+ Exempt versus No Exemption

	VMT Millions		VHT Thousands	
Year/Scenario	A.M.	P.M.	A.M.	P.M.
2018				
2018 Interim FP I	1.44	1.52	32.0	39.5
2018 HOV 3+ Exempt	1.44	1.51	31.9	39.3
2025				
2025 Interim FP I	1.58	1.69	53.0	48.5
2025 HOV 3+ Exempt	1.58	1.69	55.9	48.7
2035				
2035 Interim FP I	1.71	1.82	60.8	58.1
2035 HOV 3+ Exempt	1.69	1.82	64.8	57.8

Source: Cambridge Systematics, Inc.

9.3 HOV 3+ EXEMPT-COST IMPLICATIONS

The differences in toll rates between the HOV 3+ exempt and nonexempt model scenarios were minimal. While these differences in gross revenue were small, the added costs of enforcement of HOV 3+ could be significant. There is no technology available that can accurately count the number of passengers and conduct enforcement on violations. As a result there are two primary impacts to the net revenue. The first is added costs to have State Patrol personnel out in the field conducting enforcement, the second is the added leakage in revenue caused by the misuse of the switchable transponders (either intentional or unintentional). These issues would need to be explored by others preparing the Concept of Operations and financial analysis.

10.0 Westbound C-470 Enhancements

The Ultimate Project configuration was reduced as a result of funding limitations. The RAMP Interim Concept described in Section 5.0 reflects the project that was reduced to match available funding. It is the desire of the C-470 Corridor Coalition to achieve the 2035 Ultimate Concept as soon as possible.

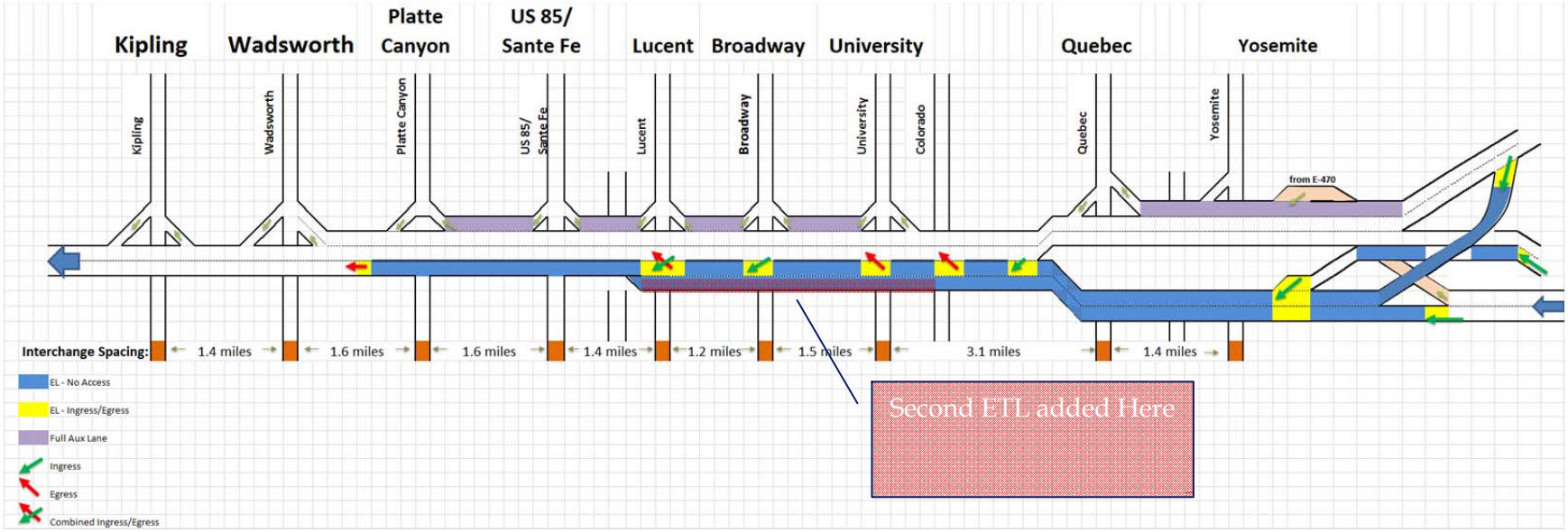
Through the course of the study process, the analysis shows that completing the project in the westbound direction provides the most value.

The inclusion of the Direct Ramp Connections from I-25 helped confirm that point. There are two remaining project elements for the westbound direction that will complete the 2035 Ultimate Concept in the westbound direction. The first priority should be to extend the two lane ETL section from near the University area to Lucent, and the second priority should be to extend the one lane section from Wadsworth to Kipling. Cambridge Systematics analyzed these two concepts in VISSIM for the 2025 p.m. peak condition using Fixed Pricing I tolls. The two models were compared to the Interim RAMP concept.

10.1 ENHANCEMENT DESIGN CONCEPTS

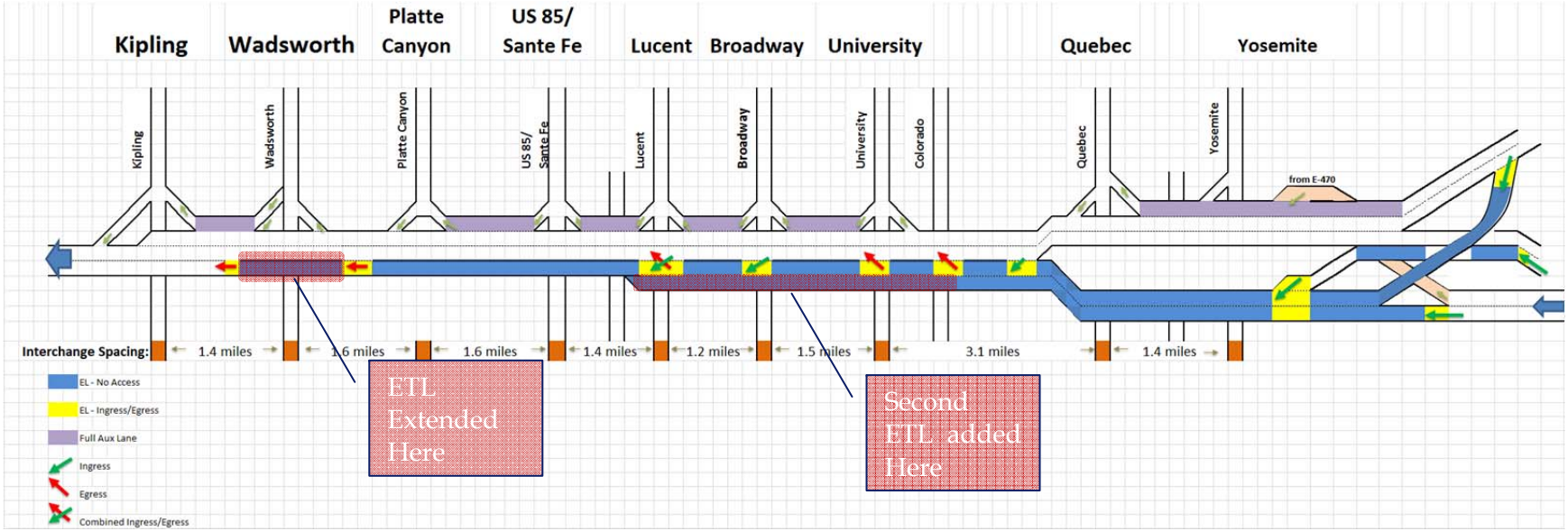
The two concepts are illustrated in Figures 10.1 and 10.2. Figure 10.1 show the Enhancement Elements that were tested.

Figure 10.1 Westbound Interim Ramp Concept with Two Express Toll Lanes to Lucent



Source: Cambridge Systematics, Inc.

Figure 10.2 Westbound Interim Ramp Concept with Two Express Toll Lanes to Lucent, One Lane to Kipling

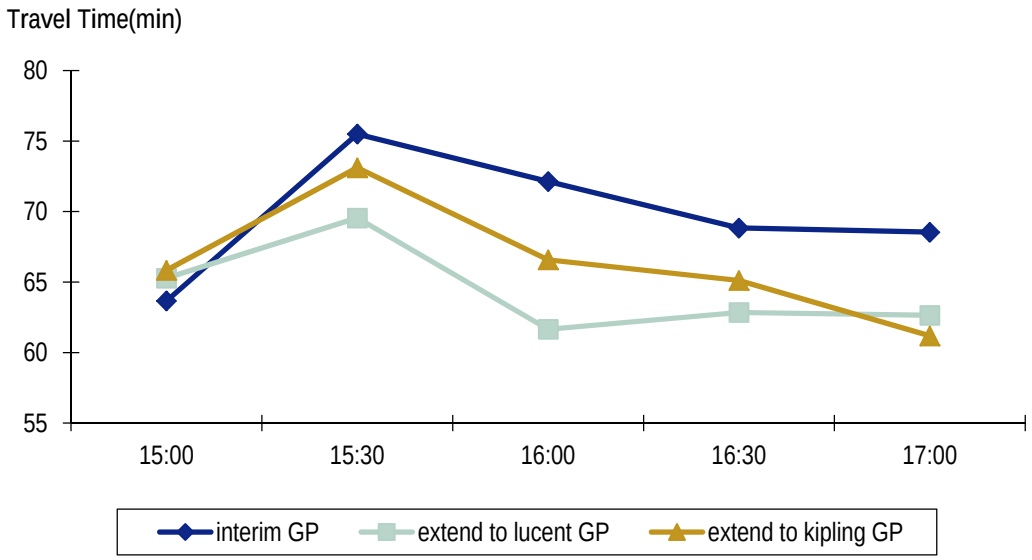


Source: Cambridge Systematics, Inc.

10.2 WESTBOUND TRAFFIC PERFORMANCE

The traffic performance in the westbound direction differs between the three options, which can be distilled down to the differences in General Purpose Lane performance. The travel times in the ETL's between the three options were very similar, the end to end travel time in the ETL was around 20 minutes. Figure 10.3 is a chart of end-to-end travel-time comparisons between the three scenarios. The improvements in travel time with the additional express toll lanes are as much as 15 minutes. With additional Tolling Price adjustments (lower prices) the overall system could be improved further.

Figure 10.3 Average Travel-Time Comparison in Westbound General Purpose Lanes



Source: Cambridge Systematics, Inc.

10.1 REVENUE

The revenue changes as a result of the improvements and the same toll prices was reduced revenue and a similar number of transactions. Table 10.1 is a summary of the total revenue and transactions for the Westbound Direction for the 2025 p.m. peak period. The values were not annualized and are provided for a comparison only.

Table 10.1 2025 P.M. Peak Westbound Revenue and Transaction Comparisons

Scenario	Seven-Hour Revenue	Seven-Hour Transactions
Ramp Interim Concept	$36,563	9,135
Extended to Lucent	$32,948	9,115
Extended to Kipling	$33,711	9,157

Source: Cambridge Systematics, Inc.

The three models used the same toll prices, the differences in revenue the reason why the revenue was higher in the Interim RAMP Concept while the number of transactions were very similar has to do with the congestion in the General Purpose lanes, since the travel time was 10-15 minutes longer in the RAMP Interim Concept Model, more traffic was willing to pay higher tolls. So while the seven-hour total transactions were similar there was more usage during higher toll rates.