



California  
Department  
Of  
Transportation



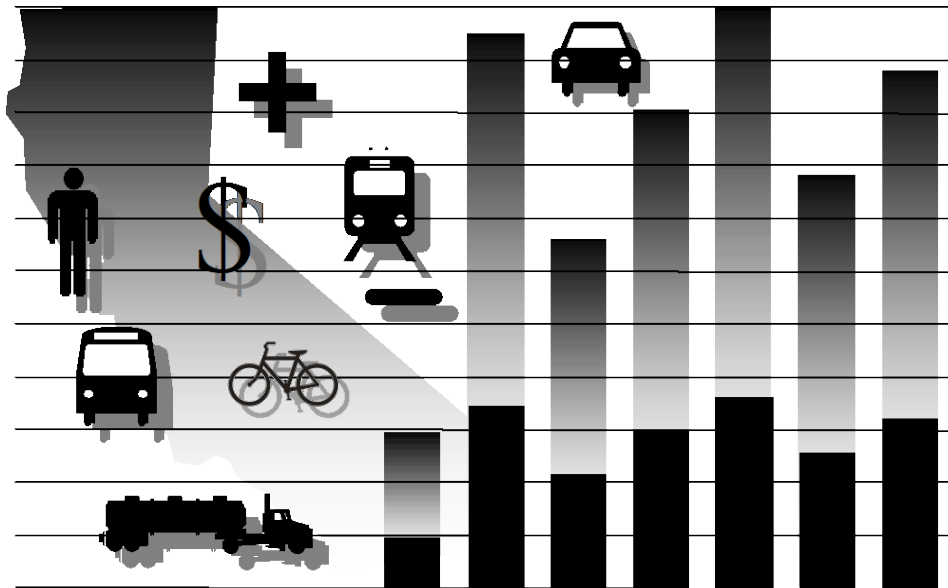
Cal-B/C

Sketch

Version 7.1

*User's Guide and Technical Documentation*

November 2019





## Acknowledgements

The Cal-B/C Sketch model has been developed over a period of more than 20 years. The material included in this user's guide is based upon previous writing and contributions from a number of firms including: Booz|Allen|Hamilton, Hagler Bailly, Parsons Brinckerhoff, System Metrics Group, Cambridge Systematics, HDR, and CLR Analytics. In many cases, material has been copied verbatim from earlier work.



## Table of Contents

<b>1</b>	<b>Overview of Cal-B/C .....</b>	<b>5</b>
<b>2</b>	<b>Introduction to User Guide .....</b>	<b>6</b>
<b>3</b>	<b>User Requirements .....</b>	<b>7</b>
<b>4</b>	<b>Operating System and Software Requirements .....</b>	<b>7</b>
<b>5</b>	<b>Model Overview .....</b>	<b>7</b>
<b>6</b>	<b>Worksheet Details and Project Analysis.....</b>	<b>11</b>
	Project Information Worksheet .....	12
	Project Data .....	13
	Highway Design and Traffic Data .....	16
	Highway Accident Data .....	21
	Rail and Transit Data.....	23
	Project Cost Data .....	25
	Bypass, Intersection, and Truck Only Lane Projects.....	27
	Model Inputs Worksheet.....	29
	Results Worksheet.....	30
	<b>Appendix A: Project Examples .....</b>	<b>33</b>
	Project Example 1: Passenger Rail Improvement.....	33
	Project Example 2: Truck Climbing Lane.....	42
	Project Example 3: Truck Only Lane .....	48
	<b>Appendix B: Overview of Project Types.....</b>	<b>56</b>
	Modeling Features .....	56
	Highway Capacity Expansion Projects .....	59
	General Highway.....	59
	High Occupancy Vehicle and High Occupancy Toll Lane Addition .....	59
	Passing Lanes.....	61
	Bypass Lanes, Intersections, and Truck Only Lanes .....	62
	Pavement Rehabilitation.....	63
	Transit Capacity Expansion.....	64
	Transit System Improvement (Passenger Rail, Light Rail, Bus).....	64
	Rail Crossings.....	65



Operational Improvements .....	68
Auxiliary Lanes .....	68
Freeway Connectors .....	70
HOV Connectors .....	71
HOV Drop Ramps .....	72
Off-Ramp Widening .....	72
On-Ramp Widening .....	74
HOT Lane Conversion and HOV-2 to HOV-3 Conversion .....	74
Transportation Management Projects .....	77
Ramp Metering .....	77
Signal Coordination with Ramp Metering .....	80
Incident Management .....	80
Real-Time Traveler Information .....	81
Arterial Signal Management .....	82
Automatic Transit Vehicle Location and Scheduling .....	83
Transit Vehicle Signal Priority .....	84
Bus Rapid Transit .....	84
<b>Appendix C: Technical Discussion .....</b>	<b>85</b>
Background and Scope of Analysis .....	85
Benefit Estimation .....	86
Travel Time Savings .....	86
Vehicle Operating Cost Savings .....	89
Accident Cost Savings .....	90
Emission Cost Savings .....	92



## List of Exhibits

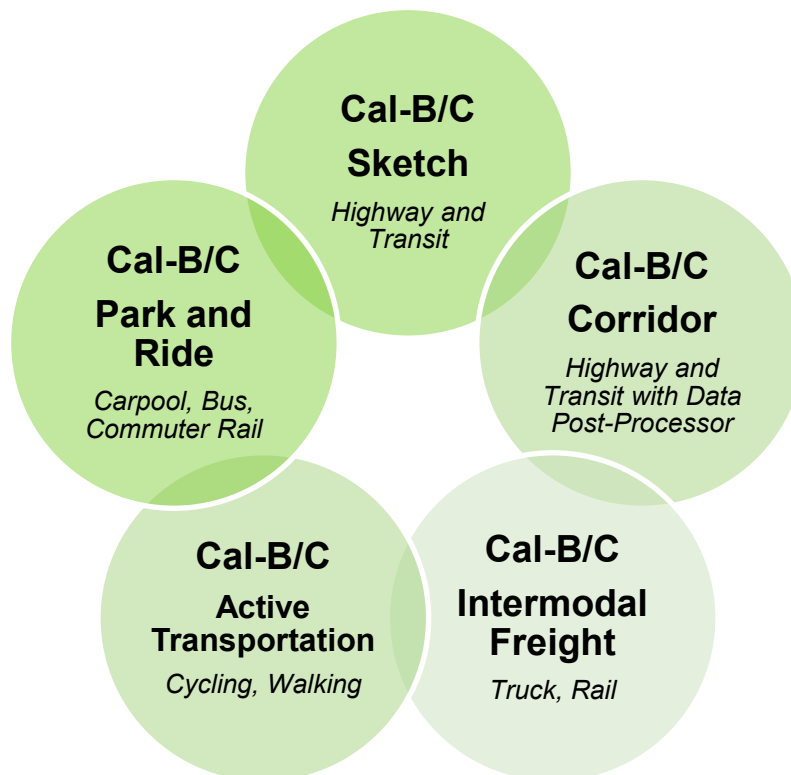
Exhibit 1: Suite of Tools in Cal-B/C Sketch Framework.....	5
Exhibit 2: Cal-B/C Sketch Graphical User Interface .....	9
Exhibit 3: Project Information Worksheet.....	12
Exhibit 4: Project Information – 1A, Project Data.....	13
Exhibit 5: Project Information - 1B, Highway Design And Traffic Data .....	16
Exhibit 6: Project Information - 1C, Highway Accident Data.....	21
Exhibit 7: Project Information - 1D, Rail and Transit Data .....	23
Exhibit 8: Project Information - 1E, Project Costs .....	26
Exhibit 9: Project Information - Bypass and Intersection Analysis Button .....	28
Exhibit 10: Model Inputs Worksheet .....	30
Exhibit 11: Results Worksheet - Final Model Output .....	31
Exhibit 12: Project Information Worksheet Section 1A .....	33
Exhibit 13: Project Information Worksheet Section 1B .....	35
Exhibit 14: Project Information Worksheet Section 1C .....	36
Exhibit 15: Project Information Worksheet Section 1D .....	37
Exhibit 16: Project Information Worksheet Section 1E .....	39
Exhibit 17: Project Information Worksheet Correcting Section 1A.....	39
Exhibit 18: Model Inputs Worksheet Section 2A.....	40
Exhibit 19: Results Worksheet Section 3 .....	41
Exhibit 20: Project Information Worksheet Section 1A .....	42
Exhibit 21: Project Information Worksheet Section 1B .....	43
Exhibit 22: Project Information Worksheet Section 1C .....	45
Exhibit 23: Project Information Worksheet Section 1E .....	46
Exhibit 24: Results Worksheet Section 3 .....	47
Exhibit 25: Project Information Worksheet Section 1A .....	48
Exhibit 26: Project Information Worksheet Section 1B .....	49
Exhibit 27: Project Information Worksheet Section 1C .....	51
Exhibit 28: Model Inputs Worksheet Section 2B.....	52
Exhibit 29: Project Information Worksheet Section 1E .....	53
Exhibit 30: Project Information Worksheet Section 1B .....	54
Exhibit 31: Results Worksheet Section 3 .....	55
Exhibit 32: User Groups Involved in HOV-to-HOT Lane Conversions.....	75
Exhibit 33: Benefit Categories.....	85

# 1. Overview of Cal-B/C

Welcome to California Department of Transportation (Caltrans) California Life-Cycle Benefit/Cost Analysis suite of tools. Caltrans uses this set of spreadsheet-based tools to conduct investment analyses of projects proposed for the interregional portion of the State Transportation Improvement Program (STIP), the State Highway Operations and Protection Program (SHOPP), applications to the Active Transportation Program (ATP), Senate Bill (SB) 1 programs, and other ad hoc analyses requiring benefit-cost analysis.

The original Cal-B/C model focused on highway and transit modes. This model has been updated several times and ultimately renamed as the **Cal-B/C Sketch** model. This model now covers a wide variety of highway and transit physical and operational improvements. Closely related to the Cal-B/C Sketch model is **Cal-B/C Corridor**, which is based on the same platform, but allows the user to post-process travel demand and micro-simulation model data. In addition, several relatively new sketch planning models have been tailored to evaluate active transportation (**Cal-B/C AT**) projects (e.g., biking and walking facilities), park-and-ride (**Cal-B/C PnR**) programs (e.g., commuter parking and ride-sharing facilities), and intermodal freight (**Cal-B/C IF**) improvements (e.g., freight network expansion and terminal efficiency). Exhibit 1 shows all five tools in the Cal-B/C framework, which allows users to consider many different types of projects.

**Exhibit 1: Suite of Tools in Cal-B/C Framework**





All of the tools in the Cal-B/C framework use consistent methods, rely on the same parameters, and produce comparable results. Together, these tools cover multi-modal analyses of highway, transit, bicycle, pedestrian, Intelligent Transportation System (ITS), operational improvement, and passenger rail projects. In addition, there are other versions of the Cal-B/C model available for more experienced analysts. One version incorporates the additional benefits of improved reliability, beyond those of predictable time savings alone, and could be used if the proposed project warrants it. A separate version of Cal-B/C has been developed to enable users to assess the degree to which uncertainty influences project outcomes. Risk analysis is performed on the same model, but with an Excel add-in module called Risk Analyzer that is used to perform Monte Carlo simulation on user-specified parameters.

## 2. Introduction to User Guide

The user's guide for the *Cal-B/C Sketch*, Version 7.1 discusses how the user can analyze highway and transit benefits for a variety of project types. Note that this model is the same as the one previously called *Cal-B/C* with minor changes from Version 6.2 to Version 7.1. Unlike Cal-B/C Corridor, Cal-B/C Sketch allows the user to analyze projects without prior traffic or travel demand modeling. Cal-B/C Sketch incorporates sketch planning methods to assess a wide array of highway, transit, and passenger rail improvement projects. Individual project types are shown in the table below, under four separate classification headings. Background discussion on modeling these project types is included in Appendix B.

Highway Capacity Expansion	Transit Capacity Expansion	Highway Operational Improvement	Transportation Management Systems (TMS)
General Highway	Passenger Rail	Auxiliary Lane	Ramp Metering
HOV or HOT Lane Addition	Light Rail (LRT)	Freeway Connector	Ramp Metering Signal Coordination
Passing Lane	Bus	HOV Connector	Incident Management
Truck Only Lane	Highway-Rail Grade Crossing	HOV Drop Ramp	Traveler Information
Intersection		Off-Ramp Widening	Arterial Signal Management
Bypass		On-Ramp Widening	Transit Vehicle Location (AVL)
Pavement		HOV-2 to HOV-3 Conversion	Transit Vehicle Signal Priority
		HOT Lane Conversion	Bus Rapid Transit (BRT)

To apply Cal-B/C Sketch to a project, the user inputs data defining the type, scope, and cost of the project. The model calculates lifecycle costs, net present value, benefit-cost ratio, internal rate of return, payback period, annual benefits, and lifecycle benefits.

This document is a quick-start guide to introduce the user to important features of Cal-B/C Sketch to support the analysis of projects. While your copy of Cal-B/C Sketch may produce slightly different results from the examples due to updates in economic values, the illustrated examples should provide sufficient information for you to understand data entry and use of the tool.

Several appendices are included to provide additional insight. Appendix A provides detailed discussions on the application of Cal-B/C Sketch to example projects. Appendix B discusses general data entry and estimation considerations for applying the tool to different project types. Appendix C provides a technical discussion on the project benefit calculations. Additional information on economic analysis topics are included in the Cal-B/C Resource Guide. The parameters used in all Cal-B/C models are included in the tools, but further documentation of these parameters is included in the Cal-B/C Parameter Guide.

## 3. User Requirements

At a minimum, the user of Cal-B/C Sketch should have a working knowledge of spreadsheets, particularly Microsoft Excel. To use Cal-B/C Sketch, the reader of this User's Guide must be able to navigate through a multiple-sheet workbook and understand basic principles, functions, and the terminology used when discussing spreadsheets. The user should also understand lifecycle benefit-cost analysis and be able to interpret the results in a transportation planning context. The reader can refer to the Cal-B/C Resource Guide for additional information, as needed.

## 4. Operating System and Software Requirements

Cal-B/C Sketch is a macro-enabled Microsoft Excel workbook called *Cal-BC 71 Sketch.xlsm*. The file is approximately 700 kilobytes (KB) in size. The user can open the file and Excel will automatically prompt the user to save the file to a new name. Although designed for a Windows environment, Cal-B/C Sketch should work on all computer platforms.

## 5. Model Overview

Cal-B/C Sketch is a Microsoft Excel spreadsheet that provides economic benefit-cost analysis for a range of capacity-expansion transportation projects. The model measures, in constant dollars, four categories of benefits that result from highway or transit projects:



- **Travel time savings** due to reduced travel time and new trips
- **Vehicle operating cost savings** from reductions in fuel and non-fuel operating costs across all vehicles
- **Accident cost savings** due safety improvements or reductions in accident risk to fewer vehicles on the road
- **Emission cost savings** from fewer vehicles on the road and fewer miles driven.

Each of these benefits are estimated for a peak (or congested) period and a non-peak (or uncongested period). The distinction is intended to capture the difference in congested and free-flow conditions on the highway as well as different operating characteristics for transit at peak times. Some travel demand models have fixed peak periods, which may not correspond exactly to the congested periods experienced on the highway. Cal-B/C Sketch can accept these data in lieu of congested period data. However, aggregate travel demand model or micro-simulation model data are better evaluated in the form of speed bin or segment level data using Cal-B/C Corridor.

For projects involving highway-rail grade separations or other bottlenecks, a queueing model computes travel speeds with input variables on arrival and departure rates at queues. Highway-rail grade crossing separation projects require addition information on the number of trains and gate down times. Projects involving weaving traffic conditions are evaluated using lookup tables or simple assumptions built into the model. Details for modeling individual project types are found in Appendix B.

The Cal-B/C Sketch Excel workbook consists of a cover page and ten additional worksheets. The user generally needs to refer to only the first four worksheets after the cover page (including one that provides instructions and reference materials) to conduct analyses. The six remaining worksheets perform calculations or store defaults and economic parameters. These pages are shown in Exhibit 2.

**Exhibit 2: Cal-B/C Sketch Graphical User Interface**

The screenshot shows the Cal-B/C Sketch software interface with four callout boxes highlighting key sections:

- 1) Project Information:**
  - Project Description
  - Highway Design and Traffic Data
  - Highway Accident Data
  - Rail and Transit Data
  - Project Costs
- 2) Model Inputs:**
  - Default Speed and Volume Calculations
  - Default Accident Calculations
  - Ramp and Arterial Inputs
  - Annual Person-Trip Verification
- 3) Results:**
  - Life-Cycle Costs and Benefits
  - Net Present Value
  - Benefit-Cost Ratio
  - Rate of Return and Payback
  - Itemized Benefits
  - Other Performance Measures
- Other Sheets:**
  - Travel Time
  - Vehicle Operating Costs
  - Accident Costs
  - Emissions
  - Final Calculations
  - Parameters

The interface includes worksheets for 'HIGHWAY DESIGN AND TRAFFIC DATA', 'Annual Person-Trips', 'Average Vehicle-Miles', 'Average Transit Travel Time', and 'Highway Grade Crossing'. Cells are color-coded: Green for required data, Red for default values, and Blue for calculated values.

Cal-B/C Sketch requires few user inputs, but allows the user to enter many more inputs when available. Cells in the worksheets are color-coded. **Green** cells indicate required data (i.e., the user must input values for the model to work). **Red** cells provide default values, such as average vehicle occupancy, that the user can change if needed. **Blue** cells contain values calculated by the model, which can be changed if detailed data are available. Blue cells contain values that represent changes between No Build and Build scenarios.

The first worksheet after the cover page provides *Instructions*. The instructions include short descriptions of the steps in performing a basic analysis and hints on how to avoid potential pitfalls.

The *Project Information* worksheet is the main data-entry worksheet. The user enters descriptive information about projects, expected traffic demand, accident rates, transit or rail data (for transit or rail projects only), and expected project construction and operating costs. The worksheet also has a button linked to a macro that allows the user to run analyses for bypass and intersection projects.

Caltrans provides Districts with “district input sheets” to use for submitting project information to Caltrans Headquarters. These input worksheets look similar (but are not identical) to the Cal-B/C Sketch project information sheet. For each project, a District is asked to submit relevant data using an input sheet tailored to the specific type of project.

The *Model Inputs* worksheet in Cal-B/C Sketch contains information about the highway speed, volume, number of trips, and accident data used in calculating benefits. This worksheet allows the user to check the highway data that the model estimates from the project information sheet



and to override the calculated values with project-specific information, if such information is available. Some users may have volume and speed projections from regional travel demand models or simulation models. The user can use peak and off-peak period volumes and speeds from these models to override the calculated values produced by Cal-B/C Sketch, but these data are better handled in Cal-B/C Corridor. Cal-B/C Sketch calculates speeds using speed/volume relationships found in the 2010 Highway Capacity Manual.

The *Results* worksheet presents the final investment measures as well as annualized and lifecycle benefits. The sheet allows the user to include the effects of induced travel and vehicle emissions. Cal-B/C Sketch calculates induced travel benefits using consumer surplus theory. Cal-B/C Sketch summarizes analysis results on a per-project basis using several measures:

- Life-cycle costs (in millions of dollars)
- Life-cycle benefits (in millions of dollars)
- Net present value (in millions of dollars)
- Benefit/cost ratio (benefits divided by costs)
- Rate of return on investment (in percent return per year)
- Project payback period (in years).

The model itemizes anticipated benefits (in millions of dollars) for the average year and over the full 20-year lifecycle. The model calculates benefits for:

- Travel time savings
- Vehicle operating cost savings
- Accident cost savings
- Emission cost savings.

The output also summarizes person-hours of time saved and itemizes the tons and value (in millions of dollars) of pollutants by type.

Cal-B/C Sketch estimates the value of CO<sub>2</sub> emissions using a standard value for tons of CO<sub>2</sub> equivalent (CO<sub>2</sub>e). While the model is set up to estimate values only for CO<sub>2</sub>, other greenhouse gases could be valued using equivalency factors.

Experienced users can override default parameters in the *Parameters* worksheets to produce tailored results if detailed information is available for specific projects. The model requires inputs on only the three worksheets previously mentioned, but the parameters and detailed calculation sheets can be accessed to change default values as needed. In the *Results* worksheet, the user can select whether to include induced travel, vehicle operating cost, accident cost, and vehicle emissions in the analysis. Emission cost savings are reported even if they are not included in the benefit-cost evaluation.

The *Parameters* worksheet (the last sheet in Cal-B/C Sketch) contains all of the economic values and rate tables. Adjusting the economic update factor using the Gross Domestic Product (GDP) deflator changes the economic values in the model. This worksheet includes values for:

### General Economic Values

- Year of current dollars for model<sup>1</sup>
- Economic update factor
- Real discount rate

### Highway Operations Measures

- Maximum volume-capacity (v/c) ratio
- Percent ADT in peak period
- Capacity per lane by road type
- Parameters for speed estimation
- Queue departure rates
- Annualization factor

### Active Transportation Parameters

- Travel activity characteristics
- User characteristics
- Trip characteristics
- Journey quality
- Health impacts

### Travel Time Values

- Automobile, truck, and transit
- Out-of-vehicle; incident-related travel

### User Operating Costs

- Fuel cost per gallon
- Non-fuel cost per mile (automobile and truck)

### Highway Accident Costs

- Cost of a fatality
- Cost of an injury (Level A Severe, Level B Moderate, Level C Minor)
- Cost of a highway accident (fatal, injury, PDO)
- Statewide highway accident rates (fatal, injury, PDO)

### Accident Rates and Transit Costs

- Highway injury severity frequency
- Highway accident type distribution
- Light rail and bus accident rates and costs
- Passenger train accident rates and costs
- Highway-rail grade crossing incidents
- Passing lane accident reduction factors

### Highway Emissions Rates

- CO, CO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub>, SO<sub>x</sub>, and VOC
- Automobile, truck, and bus

### Rail Emissions Rates

- CO, NO<sub>x</sub>, PM<sub>10</sub>, and VOC
- Passenger train, light rail, and freight locomotive

### Emissions Health Costs

- Urban Southern California, urban Northern California, and rural California
- CO, CO<sub>2e</sub>, NO<sub>x</sub>, PM<sub>10</sub>, SO<sub>x</sub>, and VOC
- Automobile, truck, and bus

### Other Values

- Demand for travel in peak period
- Fuel consumption rates for autos, trucks, and buses
- Pavement adjustment factors
- Weaving adjustment factors
- Transportation Management System (TMS) adjustment factors

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<sup>1</sup> Measured in real (constant) dollars, which are a measure of monetary value adjusted for inflation.



# 6. Worksheet Details and Project Analysis

The following sections describe the three primary Cal-B/C Sketch worksheets and walk the user through a hypothetical project. The main text in each section introduces the user to an element of the model, and the project examples provide details on how to enter data.

## PROJECT INFORMATION WORKSHEET

The *Project Information* worksheet is the main data input sheet (Exhibit 3). For most projects, this will be the only worksheet you need. The user should modify other worksheets only if project-specific information is available. The *Project Information* worksheet has five sections identified in Exhibit 3 and in the table below. There is also a button to prepare the model for analyzing a second road (bypass road or crossing road) in a bypass or intersection project, or a truck only lane in a truck only lane project.

Section Number	Name of Section	Location of Section in Worksheet (Top Left Cell: Bottom Right Cell)
1A	Project Data	B6:I18
1B	Highway Design and Traffic Data	B20:I62
1C	Highway Accident Data	K6:R22
1D	Rail and Transit Data	K24:R54
1E	Project Costs	U6:AF45
	Second Road Button	K56:R61

Exhibit 3: Project Information Worksheet

The screenshot shows the Project Information Worksheet with several sections highlighted by callout boxes:

- Section 1A: Project Data**: Located in the top left, containing project details like name, location, and length.
- Section 1B: Highway Design and Traffic Data**: Located in the middle left, containing data on highway design, traffic volume, and pavement conditions.
- Section 1C: Highway Accident Data**: Located in the middle right, containing data on accident rates and types.
- Section 1D: Rail and Transit Data**: Located in the bottom middle, containing data on rail and transit services.
- Section 1E: Project Costs**: Located in the bottom right, containing a detailed cost breakdown table.
- Button to analyze multiple roads for bypass and intersection projects**: A button located at the bottom of the worksheet.

The worksheet also includes a 'Project Information Worksheet Tab' at the bottom left and a 'Prepare Model' button at the bottom center.



## Project Data

The user enters information about the project in the project data input section shown in Exhibit 4.

Exhibit 4: Project Information – 1A, Project Data

## Project Type

The model allows the user to identify several project types including:

Highway Capacity Expansion	Transit Capacity Expansion	Highway Operational Improvement	Transportation Management Systems (TMS)
General Highway	Passenger Rail	Auxiliary Lane	Ramp Metering
HOV or HOT Lane Addition	Light Rail (LRT)	Freeway Connector	Ramp Metering Signal Coordination
Passing Lane	Bus	HOV Connector	Incident Management
Intersection	Highway-Rail Grade Crossing	HOV Drop Ramp	Traveler Information
Truck Only Lane		Off-Ramp Widening	Arterial Signal Management
Bypass		On-Ramp Widening	Transit Vehicle Location (AVL)
Queuing*		HOV-2 to HOV-3 Conversion	Transit Vehicle Signal Priority
Pavement		HOT Lane Conversion	Bus Rapid Transit (BRT)

\* The model has the ability to conduct a simple, deterministic queuing analysis for a highway bottleneck. This “project type” is expected to be used for special cases only.

The user selects the project type using a pull-down menu bar. The pull-down options become available when you make F10 the active cell. Making a cell “active” simply means putting the cursor in that cell. Once the cell is active a scroll bar becomes visible for you to select one of the project types.

### ***Project Location***

The model uses this information to estimate emission benefits using values appropriate for each region (i.e., Northern California Urban, Southern California Urban, or Rural). It also selects the appropriate percentage from the demand for travel in peak period table. Although Cal-B/C Sketch currently uses the same peak period percentages for the three regions, the model can accommodate different values if adopted in the future. The user identifies the project location by selecting a “1,” “2,” or “3,” as shown in Exhibit 4.

### ***Length of Construction Period***

This indicates the number of years needed to construct the project and determines the project opening date, which is assumed to occur at the end of the construction period.

### ***One- or Two-Way Data***

This indicates whether the data provided in Section 1B is for travel in one direction or two directions. This input relates to the data entered, not the facility. Data for a single direction can be entered even if a project is proposed for a two-way roadway.

### ***Length of Peak Period(s)***

These data help the model determine peak and non-peak volumes and speeds. Cal-B/C Sketch uses these values to estimate travel time benefits, fuel consumption, and emissions. The length of the peak period should be entered as the number of hours. For example, if the peak period is from 3:00 PM to 7:00 PM along the segment where the project is proposed, then you would put “4” in this input cell to indicate 4 hours (see Exhibit 4). In earlier versions of Cal-B/C, the user could choose peak periods lasting up to only eight hours because the percent of traffic in any given peak hour was fixed. Cal-B/C Sketch allows the user to choose peak periods of any length. A lookup table takes into account the diminishing contribution of each hour to the amount of traffic occurring in the peak period. The table allows different standard values for the three project location regions and two road types. However, the values in the table are currently the same for each region and road type.

## PROJECT EXAMPLE: Add a General Highway Lane

### STEP 1: Project Data

In this project example, which will be used throughout the User's Guide, we are going to "construct" two additional lanes on a 3.9-mile segment of freeway in Northern California. This project was selected because lane additions are common projects, and because this example highlights some basic issues that need to be addressed in benefit-cost analysis. Cal-B/C Sketch should not be viewed as a "black box." Using this tool requires making professional engineering or planning judgments as well as the ability to interpret the outputs appropriately.

To begin the analysis, open the *Project Information* worksheet. Exhibit 4 shows the *Project Data* section for our lane addition. Note that green-colored cells may require data. The red cells provide default values that the user can change.

- (1) **Descriptive Project Information.** The area at the very top of the worksheet provides space to enter the district where the project is being developed, a descriptive project name, the project EA number and the project priority number (PPNO). This information is not required, but it is useful to include for identification purposes when you return later to the project.
- (2) **Type of Project.** Make merged cells F10 through H10 the active selection by clicking on one of those cells. Use the scroll bar at the right to find the "General Highway" project type. This is a required selection for any project.
- (3) **Project Location.** This cell requires you to enter a "1" for urban areas in Southern California, a "2" for urban areas in Northern California, or a "3" for rural areas to determine emissions benefits for the project. Assume that our project is built in Northern California, and put a "2" in this cell. This cell tells the model which tables to reference in the *Emissions* worksheet.
- (4) **Length of Construction Period.** Enter the amount of time needed to construct the project. Assume that this lane addition project will be completed in 2.8 years. Cal-B/C Sketch uses this cell to determine the economic impacts. This number must be a whole number. A project that will take 2.8 years to construct should be entered as the number "3" representing three years. A project taking 2.4 years can be rounded down to two years or up to three years, at the user's discretion, but must be consistent with the cost data entered.

Note that the model evaluates project impacts only after the project is built. For example, a project that begins construction in 2017 and takes three years to complete will not cause any impacts until 2020 when the project opens. The Year 1 impacts occur immediately after the project opens. The Year 20 impacts occur in 2039 for this hypothetical project.

- (5) **One- or Two-Way Data.** Insert the number of directions that traffic flows along the corridor. The default value is "2", representing a project impacting traffic traveling both directions. This means that later we will need to add design and traffic data that reflects both directions.

**Length of Peak Period.** For our project, enter a "4" in this cell to indicate a four-hour peak period. This entry covers both the AM and PM peak periods and should represent typical daily conditions. The peak period helps convert average daily traffic volumes (described in Section 4.1B) into average peak and non-peak volumes and speeds. Speed is an important variable to determine travel time savings, fuel consumption, and emissions.





## Highway Design and Traffic Data

Section 1B, shown in Exhibit 5, is where the user inputs data about the highway components of a transportation project. Most transit-specific elements are added in Section 1D of the Project Information worksheet. In both sections, the user enters data for the No Build and Build situation. In early versions of Cal-B/C, the No Build was called “Existing” or No Build. Likewise, the Build situation was called “New” or “With Project.” Cal-B/C Sketch uses standardized terms of No Build and Build to reduce confusion.

Exhibit 5: Project Information - 1B, Highway Design And Traffic Data

**1B Highway Design and Traffic Data**

Highway Design		No Build	Build
Roadway Type (Fwy, Exp, Conv Hwy)		F	F
Number of General Traffic Lanes			
Number of HOV/HOT Lanes			
HOV Restriction (2 or 3)			
Exclusive ROW for Buses (y/n)		N	
Highway Free-Flow Speed			0
Ramp Design Speed (if aux. lane/off-ramp proj.)		35	35
Length (in miles) Highway Segment		0.0	0.0
Impacted Length		0.0	0.0

Average Daily Traffic		No Build	Build
Current			
Base (Year 1)		0	0
Forecast (Year 20)			0

Average Hourly HOV/HOT Lane Traffic		No Build	Build
Percent of Induced Trips in HOV (if HOT or 2-to-3 conv.)			100%

Percent Traffic in Weave		No Build	Build
Percent Trucks (include RVs, if applicable)		9%	9%

Truck Speed		No Build	Build
Truck Speed			

On-Ramp Volume		Peak	Non-Peak
Hourly Ramp Volume (if aux. lane/on-ramp proj.)		0	0
Metering Strategy (1, 2, 3, or D, if on-ramp proj.)			

Queue Formation (if queuing or grade crossing project)		Year 1	Year 20
Arrival Rate (in vehicles per hour)		0	0
Departure Rate (in vehicles per hour)		0	0

Pavement Condition (if pavement project)		No Build	Build
IRI (inches/mile) Base (Year 1)			
Forecast (Year 20)			

Average Vehicle Occupancy (AVO)		No Build	Build
General Traffic Non-Peak		1.30	1.30
Peak		1.15	1.15
High Occupancy Vehicle (if HOV/HOT lanes)		2.15	2.15

## HIGHWAY DESIGN

This section covers basic information, such as lane configuration, design speed, and section length. The data entered in the highway design section should cover the No Build and Build situations. Separate boxes are provided in most cases:

- **Roadway Type (i.e., Freeway, Expressway, or Conventional Highway)** – The user enters an “F” (freeway), “E” (expressway), or “C” (conventional highway) to indicate the type of roadway affected by the project. These inputs are case sensitive and should be entered in upper case.
- **Number of General Traffic Lanes** – The user provides the number of mainline traffic lanes along the roadway section for the existing condition and any future improvements. The number of mainline general traffic lanes is required for all highway-related project types including on-ramp and auxiliary lanes. Do not include short auxiliary lanes or ramp merge lanes in the count of general traffic lanes - this section is for mainline lanes only. (Note: Projects to construct long auxiliary lanes may be assessed as general traffic lane projects. In these cases, the auxiliary lanes should be included in this count.) Also, note that Cal-B/C Sketch does not allow the user to “phase in” the construction. For example, you cannot construct one lane by Year 1 and another by Year 7. Such a scenario must be analyzed as separate projects.
- **Number of HOV/HOT Lanes** – The user enters the number of HOV or HOT lanes, if they are present or being added. In the case of an HOV-to-HOT lane conversion project, the same number of lanes should be entered in the No Build and Build scenarios.
- **HOV Restriction (2 or 3)** – If HOV or HOT lanes exist, the user must input the vehicle occupancy restriction for using the lanes. The HOV restriction is the minimum number of vehicle occupants. The model accepts only two values: a “2” for a two-person carpool restriction or a “3” when at least three people are required to form a carpool.
- **Exclusive ROW (Right-of-Way) for Buses** – This input is used if the highway section contains an exclusive ROW for buses, commonly known as a busway or bus lanes. In Cal-B/C Sketch an exclusive ROW for buses means that no vehicles other than buses can travel on the lane. This would exclude, for example, the El Monte Busway in the Los Angeles area where 3+ carpools also can travel on the lanes. The model accepts only an “N” for “No” or a “Y” for “Yes”. This input is used by Cal-B/C Sketch to evaluate the emissions impacts.
- **Highway Free-Flow Speed** – Design speed for the highway section. The design speed is often the posted speed limit. The user inputs the existing free-flow speed, and the model assumes that the Build free-flow speed is the same. If the new speed is different from the existing speed, then the user can override the assumed speed by simply typing over the speed in the appropriate cell.
- **Ramp Design Speed (if auxiliary lane/off-ramp project)** – Used for on-ramp, off-ramp, and auxiliary lane projects. In the case of auxiliary lanes, this speed should be entered as the average speed experienced on the auxiliary lane while accelerating (in the case of an on-ramp), merging, or decelerating. As with the highway free-flow speed, the user can override the Build speed as appropriate.

- **Length (in miles)** – The length in miles of the section under analysis. There are two “lengths” that must be accounted for:
  - **Highway Segment** – The project design length.
  - **Impacted Length** – The distance upstream of the highway segment affected by improvements to the highway segment. Cal-B/C Sketch assumes an impacted length based on the project type based on recent research. If the project is an auxiliary lane or off-ramp project the assumed distance is 1,500 feet or 0.28 miles. Freeway connector or HOV operational improvement projects assume an affected length of 3,250 feet or 0.62 miles, while passing lane projects assumed a length of the highway segment length plus three miles. All other projects assume that the impacted length is as long as the project design length. The user can override the assumed value if better data are available.

### **AVERAGE DAILY TRAFFIC (ADT)**

This section contains the user inputs for highway general lane (i.e., mainline) volumes for the “Current” year, the first year after the project has been constructed or implemented (Year 1), and 20 years into the future. Note that the forecast year is the project opening date plus 20 years, not the current date plus 20 years.

The model uses straight-line interpolation to estimate the “Year 1” ADT from the “Current” ADT and the “Year 20” ADT. The values for the No Build and Build scenarios are estimated separately on the basis of the respective “Year 20” volumes. The user can override any of the estimates if better data are available.

The Results sheet has an option to include induced demand in the evaluation. If “Y” for “Yes” is selected, the model calculates the change in consumer surplus associated with the excess of traffic in the Build scenario compared to the No Build scenario. For transit projects, Cal-B/C Sketch assumes that highway demand is inelastic (i.e., no induced demand occurs).

Additional information needed may include (depending on the type of project):

- **Average Hourly HOV/HOT Lane Traffic** – requires that the user enter in current year average hourly HOV/HOT volumes for the segment in question, but only if there is an HOV or HOT lane present. This input can also accommodate HOT lane and HOV-2 to HOV-3 conversion projects. Both project types affect carpool formation and AVO, and can lead to induced demand. For these project types, the user should indicate how much of the new traffic (if the build ADT is larger than the No Build ADT) occurs in the HOV/HOT lane by entering a percentage in the Percent of Induced Trips in HOV box.
- **Percent Traffic in Weave** – estimates the percent of traffic in the highway section that is impacted by an operational improvement for the No Build and Build scenarios. In Cal-B/C Sketch, an operational improvement includes one of the following types: auxiliary lane, freeway or HOV connectors, HOV drop ramp, and on- or off-ramp widening. The model attempts to estimate how many general traffic lanes are affected by weaving. The table below shows the estimated percent of traffic affected by weaving for these project types:



Auxiliary Lane	2 lanes (100% if 1 lane)
On/Off-Ramp	3 lanes (100% if <3 lanes)
Freeway Connector	2.5%
HOV Connector/Drop-Ramps	4%

- Percent Trucks** – includes recreational vehicles and is the percentage of trucks in the traffic flow (i.e., percent of ADT). Recreational vehicles should be included in this figure if they make up a sizeable portion of the traffic. The model assumes a statewide average of 9 percent truck traffic. The user can update this value if better data are available. Caltrans’s Traffic and Vehicle Data Systems in the Division of Traffic Operations publishes the Annual Average Daily Truck Traffic on the California State Highway System – yearly report, often referred to as the “Truck Volumes Book,” provides truck estimates and counts for different locations around the state. Percent truck traffic should be estimated by comparing the vehicle-miles traveled by trucks and all traffic.
- Truck Speed** – the average speed of slow-moving vehicles, such as trucks or recreational vehicles, on a grade when there are no passing lanes. An entry is required for passing lane projects, but this input is needed only for the No Build scenario. Cal-B/C Sketch calculates the automobile speed based on the volume/capacity relationships provided in the 2010 Highway Capacity Manual.

### **ON-RAMP VOLUME**

These data are used for auxiliary lane and on-ramp widening projects and are similar to the ADT input cells, except average hourly volumes are entered rather than daily volumes. An input is required for the average peak hour and non-peak hour. Cal-B/C Sketch uses these data to estimate the volume of traffic affected by weaving for auxiliary lanes. This volume helps evaluate the effectiveness of ramp metering for on-ramp widening projects. If the project is a ramp metering strategy without widening the on-ramp, then no entry needs to be made. The user can override the default values in Cal-B/C Sketch. The model assumes a peak period volume of 1,350 vehicles per hour for auxiliary lanes and 800 vehicles per hour for on-ramps.

**Metering Strategy** is required for on-ramp widening projects in which there is ramp metering. The model requires a “1”, “2”, or “3” to indicate the number of vehicles allowed per green signal. A “D” indicates dual metering.

### **QUEUE FORMATION**

This section conveys the rate at which cars are entering and exiting any existing queue (in vehicles per hour). These numbers are applicable only to highway queuing and rail grade separation projects. For these projects, the user enters the vehicles per hour contributing to the queue in **Arrival Rate**. The arrival rate should be estimated only for the time that the queue grows. The model estimates queue dissipation automatically. More information on the methodology is available in Appendix B. The user enters the vehicles per hour leaving the queue in the **Departure Rate**.

## PROJECT EXAMPLE STEP 2: Highway Design and Traffic Data

Move to the *Highway Design and Traffic Data* section of the *Project Information* worksheet (Exhibit 5).

### (1) Highway Design

- a. *Roadway Type (Fwy, Exp, Conv Hwy)* – Leave the default of F (freeway).
- b. *Number of General Traffic Lanes* - Assume that the mainline currently has eight lanes, and that our project will build two additional lanes, bringing the total for the Build scenario to ten.
- c. *Number of HOV/HOT Lanes* - Assume that the segment has two HOV lanes
- d. *HOV Restriction (2 or 3)* – Assume a 2-person HOV restriction.
- e. *Exclusive ROW for Buses (y/n)* – Assume that this segment has no bus lanes.
- f. *Highway Free-Flow Speed* - Set the free-flow speed to 65 mph. The blue cell with the Build free-flow speed will be set automatically to equal the No Build free-flow speed. The blue color of the cell indicates that this value is estimated and that you may override this speed.
- g. *Ramp Design Speed* – Assume a default value of 35 mph.
- h. *Highway Segment* – The project length is 3.9 miles.
- i. *Impacted Length* – Assume that the impacted length equals the project length of 3.9 miles.

(2) **Average Daily Traffic.** Enter the existing average daily traffic into the cell labeled “Current.” Use a value of 234,000 vehicles per day for this exercise. Also, enter a value of 272,989 vehicles per day for the “Forecast (Year 20)” value in the No Build column. The model automatically calculates the Base (Year 1) value in the No Build column, which should be 239,317 vehicles per day.

Note: The *Results* worksheet has an option to include induced demand in the evaluation. If “Y” for “Yes” is selected, the model calculates the change in consumer surplus associated with the excess traffic in the Build scenario compared to the No Build scenario. For a transit project, Cal-B/C Sketch assumes that highway demand is inelastic (i.e., no induced demand occurs).

(3) **Average Hourly HOV/HOT Lane Traffic.** Update these cells if the project involves HOV or HOT lanes. As with the average daily traffic cells, the user should enter the number of HOV and HOT lanes for both the No Build and the Build scenarios. The model assumes that all lanes are constructed by Year 1. For our project, enter 2,400 vehicles per hour in both columns.

(4) **Percent Trucks.** Leave the default value of nine percent truck traffic.

(5) **Truck Speed.** This information is not needed for our project.

(6) **On-Ramp Volume.** Since this is not an auxiliary lane or on-ramp project, this information is not needed. Leave the default values of zero vehicles per hour.

(7) **Queue Formation.** Since this is not a queuing or grade crossing project, you can ignore this section.

**Average Vehicle Occupancy (AVO).** This is the average number of people per vehicle on the highway. Let’s use the model defaults of 1.30 for the non-peak AVO, 1.15 for the peak AVO, and 2.15 for HOV traffic. Notice that the AVO for HOVs is estimated automatically from the HOV restriction entered earlier.



## PAVEMENT CONDITION

This section outlines condition for the base year (Year 1) during pavement rehabilitation projects. The user inputs the International Roughness Index (IRI) in the No Build and Build scenarios. Cal-B/C Sketch will calculate Year 20 values using standard parameters, but the user can override the IRI value if better information is available for Year 20.

## AVERAGE VEHICLE OCCUPANCY

This section displays default values from the 2010 Statewide Travel Survey and HOV monitoring data. Since many regional agencies have data that are more up-to-date, the user can override the default values.

## Highway Accident Data

This section calculates accident rates for the highway facility as shown in Exhibit 6. Accident rates are estimated for fatal, injury, and property damage only (PDO) accidents from actual count data from the last three years. This section is formatted to correspond to a "Table B" selective accident record retrieval from the Traffic Accident Surveillance and Analysis System (TASAS). The user enters the total number of accidents, the number of fatal accidents, and the number of injury accidents in the "Count" column. Cal-B/C Sketch automatically calculates the number of PDO accidents and the accident rates.

Exhibit 6: Project Information - 1C, Highway Accident Data

**1C HIGHWAY ACCIDENT DATA**

Actual 3-Year Accident Data (from Table B)		
	Count (No.)	Rate
Total Accidents (Tot)	1	0.97
Fatal Accidents (Fat)	0	0.009
Injury Accidents (Inj)	1	0.31
Property Damage Only (PDO) Accidents	0	0.65

Statewide Basic Average Accident Rate		
	No Build	Build
Rate Group		
Accident Rate (per million vehicle-miles)		
Percent Fatal Accidents (Pct Fat)		
Percent Injury Accidents (Pct Inj)		



The “Rate” column, highlighted in gray, displays the accident rates calculated from the count data. An accident rate is simply the annualized count divided by millions of vehicle miles (average daily traffic x highway segment length x 365 days/1,000,000). Since this calculation is based upon the highway segment length for the project and the actual count data may not correspond directly, the user may choose to type over the rates in the gray cells with rates from a Table B.

### PROJECT EXAMPLE STEP 3: Highway Accident Data

Now move to the *Highway Accident Data* section (Section 1C) of the *Project Information* worksheet (Exhibit 6). Cal-B/C Sketch provides the statewide collision averages as the default values. However, assume that we have some highway accident data and projections available for our project.

- (1) For the **Actual 3-Year Accident Data (from Table B)** cells, assume there were 977 accidents on the highway corridor over the past three years. Of these, three were fatal accidents and 230 were injury accidents. Cal-B/C Sketch will calculate the number of PDO accidents automatically. In this example, Cal-B/C Sketch should show 744 property damage only accidents.
- (2) Insert statewide average accident rates per million vehicle-miles for road classifications similar to the existing and proposed facilities. This information can be found in the *Collision Data on California State Highways*. In the annual report, there are a series of tables called the “Basic Average Accident Rate” tables, which provide statewide average rates for highways, intersections, and ramps.

According to the 2006 report, this freeway type has a statewide average accident rate along for our section of 1.07. This same ramp type has a fatality percentage rate of 0.3 percent (should enter as 0.003) and a percent injury accidents of 31 percent. Enter these into Cal-B/C Sketch in the No Build columns of the Statewide Basic Average Accident Rate section. Enter 1.02 in the Accident Rate for the Build scenario, along with 0.3 percent fatal accidents (should enter as 0.003) and 29 percent injury accidents. The Rate Group labels are for information purposes only and not needed to calculate project benefits. We will leave the Rate Group cells empty for this example. The model uses adjustment factors (the ratio of actual rates to statewide rates for existing facility) to estimate accident rates, by accident type, for new road classifications. The *Model Inputs* worksheet presents the results, which the user can edit.

For some specific project types, the inputs and calculations in these cells deviate from the standard evaluation. For intersection and ramp projects, the “Rate” column calculates the highway accident rate as the annualized count divided by millions of vehicles rather than vehicle miles. For rail grade crossing projects, Cal-B/C Sketch allows special inputs because the grade crossing accident data are collected separately from highway accident data. For rail grade separation projects, actual 10-year historical data can be obtained from the Federal Highway-Rail Crossing Accident database. Alternatively, the user can use data from the FRA Web Accident Prediction System (WBAPS). Cal-B/C Sketch can use either source to estimate rail grade separation safety benefits. Details are available in the Appendix B.

Cal-B/C Sketch provides statewide average rates as default values in the case that data specific to the facility are not available. These data come from a special TASAS run titled “2013 Statewide Collision Total Check.” The default rates are particularly valuable for transit projects when roadway accident rates are not available.



Cal-B/C Sketch uses the change in accident rate group to estimate the safety benefits of roadway projects. The model allows the user to specify the appropriate rate groups for the No Build and Build scenarios. This information is for record-keeping purposes only, and the model relies on average accident rate and percentages by accident type provided by the user. The latest information can be found in the annual collision reports, which provide rate group data in the "Basic Accident Rate Tables." There are separate tables for three types of roadway: highways, intersections, and ramps. The tables report accident rate, percent fatal accidents (Pct Fat), and percent injury accidents (Pct Inj).

## Rail and Transit Data

This section of the *Project Information* worksheet is used for transit and rail projects. For these projects, the user must enter additional data items discussed below. For rail grade separation projects, Cal-B/C Sketch provides several additional inputs. If the project is a transit TMS project that lowers agency costs, the user may also enter transit agency costs. Exhibit 7 shows the rail and transit data input section of the *Project Information* worksheet.

Exhibit 7: Project Information - 1D, Rail and Transit Data

**1D RAIL AND TRANSIT DATA**

		No Build	Build
<b>Annual Person-Trips</b>			
Base (Year 1)			
Forecast (Year 20)			
<b>Percent Trips during Peak Period</b>		41%	
<b>Percent New Trips from Parallel Highway</b>			100%
<b>Annual Vehicle-Miles</b>			
Base (Year 1)			
Forecast (Year 20)			
<b>Average Vehicles/Train (if rail project)</b>			
<b>Reduction in Transit Accidents</b>			
<b>Percent Reduction (if safety project)</b>			
<b>Average Transit Travel Time</b>			
In-Vehicle	Non-Peak (in minutes)		0.0
	Peak (in minutes)		0.0
Out-of-Vehicle	Non-Peak (in minutes)	0.0	0.0
	Peak (in minutes)	0.0	0.0
<b>Highway Grade Crossing</b>			
Annual Number of Trains	Current	Year 1	Year 20
Avg. Gate Down Time (in min.)		0	0.0
<b>Transit Agency Costs (if TMS project)</b>			
Annual Capital Expenditure	No Build	Build	
Annual Ops. and Maintenance Expenditure		\$0	\$0



### ***Annual Person Trips***

This refers to passenger trips made during the first year after the project is built (Year 1) and twenty years later (Year 20) for the No Build and Build scenarios. Note that the forecast year is the project completion date plus 20 years, and not the current date plus 20 years.

### ***Percent Trips during Peak Period***

The user provides an estimate of the ratio of peak period ridership to daily ridership. The definition of peak period should correspond to the number of hours in the project data section (Section 1A).

### ***Percent New Trips from Parallel Highway***

Improved transit may attract new trips from parallel highways. The default is set at 100 percent. In practice, the percentage of new transit trips from highways is often between 50 and 80 percent.

### ***Annual Vehicle-Miles***

This is the number of vehicle-miles of transit or rail service operated on the line each year. The user should provide estimates for Year 1 and Year 20 in the No Build and Build scenarios. For passenger rail projects, the user should multiply the figures by the average number of rail cars per train consist.

### ***Average Vehicles/Train***

The user should enter the number of train cars used in an average train. This figure is used in conjunction with the annual vehicle-miles input to estimate emissions.

### ***Reduction in Transit Accidents***

This input provides the percent reduction in transit or rail accidents expected to occur due to a project. The user should enter a value only if the project specifically addresses safety concerns. An increase in transit accidents should be entered as a negative percentage.

### ***Average Transit Travel Time***

Transit travel time has two components: in-vehicle time and out-of-vehicle time. In-vehicle time is the time spent in the bus or train traveling to the rider's destination. Out-of-vehicle time is the time spent walking or driving to the transit or rail stop. It also includes the time waiting for the bus or train to arrive. Research indicates that passengers value their time waiting at transit stops more than they value their in-vehicle time. Cal-B/C Sketch requires that the user to enter peak and non-peak periods for the existing and new facilities.

For TMS projects, insert the average for all transit routes impacted. Cal-B/C Sketch assumes that the Build scenario is the same as the No Build for most projects, with the exception of signal priority and bus rapid transit projects, which reduce travel times.

### ***Highway Grade Crossing***

For Highway Grade Crossing projects, use these fields to enter the current, Year 1, and Year 20 counts for *Annual Number of Trains* and *Average Gate Down Time* (in minutes). Cal-B/C Sketch uses only the Year 1 and Year 20 counts. Year 1 estimates are often unavailable, so the model provides an input for current year to estimate the Year 1 data. The number of trains and average gate time is likely to differ for passenger and freight trains. Data should be collected separately for passenger and freight trains and aggregated prior to inputting in to the model.

### ***Transit Agency Costs***

For TMS projects, Cal-B/C Sketch requires the user to input annual capital, operating, and maintenance expenditures for routes impacted by project. The model calculates cost reductions for the new expenditures due to transit TMS. Cal-B/C Sketch estimates agency cost savings and records them as negative costs.

## **Project Cost Data**

The user enters project construction, operating, mitigation, and other costs in this section of the project information worksheet. All costs should be entered as incremental rather than total costs. Costs already incurred are sunk costs and should not be included in the benefit-cost analysis. Incremental costs are estimated as the difference between the No Build and Build costs.

The project costs table contains seven columns for the user to enter cost information as shown in Exhibit 8. The user should enter these costs in thousands of dollars. All costs should be in 2016 dollars for consistency with the benefit calculations.

The first column indicates the project year during construction and after project opening. The first construction year labeled as “Year 1.” Cal-B/C Sketch can handle up to eight years of construction. The user should enter costs for as many years as were indicted in the Project Data section (Section 1A). The user should also enter subsequent incremental costs (i.e., maintenance, operations, and rehabilitation costs due to the project) for a 20-year period after the project opens. The numbering in the “Year” column restarts at one after the project opens.

Following the construction period, the project opens and there are 20 years during the project operating period. Year 1 (Base Year) described in the previous sections is represented by the “1” under the “Project Opens” header. Year 20 (Forecast Year) is represented by the last row on this data entry form. For each row in the section (i.e., each row in the spreadsheet), the user enters the anticipated costs for the year in current year dollars (in thousands of dollars). The model automatically calculates the sum and present value.



**Exhibit 8: Project Information - 1E, Project Costs**

**Direct Project Costs**

- **Initial Costs** include (a) Project support (e.g., engineering design and management costs), (b) Right-of-way acquisition costs, and (c) Construction costs. Each project should incur no initial project costs after the project opens. Cal-B/C Sketch assumes that all construction funding has been spent by the opening day of the project. The user cannot exceed the number of construction years entered in Section 1A of the project information worksheet. If the user does not enter the construction costs correctly, the model prompts the user for the correct information under subsequent costs. This is illustrated in Exhibit 8.
- **Subsequent Costs** are costs incurred after the project is constructed and open for service. These costs include: (a) Maintenance and operating costs, and (b) Rehabilitation costs (e.g., pavement overlay, vehicle, track, or station refurbishment). The user enters estimates of maintenance, operating and rehabilitation costs in constant dollars.

**Mitigation**

Mitigation costs (in thousands of dollars) include costs to protect communities and the environment from negative impacts. These costs include wetland and community preservation as well as sound walls to reduce highway or rail transit noise. The user enters these costs in constant dollars during construction and for 20 years after construction had been completed.

### *Transit Agency Cost Savings*

The model calculates these costs automatically. This cost element represents savings to a transit agency due to efficiency improvements. For example, signal prioritization projects speed up bus services, which may reduce operating hours and result in lower labor and other operating costs.

### *Total Costs*

The remaining two columns are calculated by the model automatically. These two columns include the project cost in constant dollars and the net present value for each year. Note that the model multiplies the values in the previous columns by 1000, so these values are in dollars (not thousands of dollars). Each column is summarized at the bottom of the section.

## **PROJECT EXAMPLE STEP 4: Project Cost Data**

This is the final data entry required to perform a basic analysis. Users with project-specific information can change any parameter within the model. Please refer to the technical supplement for a more detailed discussion of the model assumptions. Let us continue with our analysis.

- (1) Enter the **Initial Project Costs**. Input cost data for each year that you indicated in the “Length of Construction Period” cell in the “Project Data” (Section 1A) of this worksheet. For this example, since you entered a construction period of three years, you must enter three years of data. Enter \$13,820 in construction costs for Year 1, and \$45,200 in both Years 2 and 3. (Note that these numbers are in thousands, so our example has project costs of over \$100 million). If you fail to enter cost data for the appropriate number of years the worksheet will issue a warning message.
- (2) Now look at the years after the project is constructed and open for service. In our project, we could allocate funding to operate and maintain the project. However, since this is a lane addition over a short distance, we will assume that the incremental costs to maintain and operate the additional lane are minimal.

Before reviewing the results of the model, please review the work done to this point. In the project cost section, you should have a total project cost of \$104,220,000 in constant 2016 dollars. After discounting, this corresponds to a present value of \$99,071,479.

## **Bypass, Intersection, and Truck Only Lane Projects**

Since two roads are involved, bypass and intersection projects require the user to enter two sets of highway data. The model calculates benefits for the first road before the user enters information about the second road. To estimate benefits for the second road, the user clicks the button shown in Exhibit 9. A macro clears the *Project Information* worksheet so it is ready for the user to input information on the second road. The detailed calculations for the first road are lost, so it is good practice to save a copy of the analysis before entering information for the second road. Cal-B/C Sketch uses this same capability for analyzing truck only lanes. The truck only lane are treated as the second road. An example of analyzing truck only lanes is provided in Appendix A.

**Exhibit 9: Project Information - Bypass and Intersection Analysis Button**

The screenshot shows the 'Project Information' section of the Cal-B/C Sketch software. It includes several data entry tabs: PROJECT DATA, HIGHWAY DESIGN AND TRAFFIC DATA, RAIL AND TRANSIT DATA, and PROJECT COSTS. The PROJECT COSTS tab is a large table with columns for INITIAL COSTS, SUBSEQUENT COSTS, and TRANSFER COSTS, broken down by Project Support, R I V, Construction, Op, Rehab, Mitigation, Savings, and various Cost and Value categories. A 'Prepare Model for Second Road' button is highlighted with a callout box.

*Model should be run for both roads for intersection or bypass highway projects, and may be run twice for connectors. Press button below to prepare model to enter data for second road. After data are entered, results reflect total project benefits.*

**Prepare Model for Second Road**

Button resets model to accept data for second road

The macro in the latest version of Cal-B/C Sketch prompts the user to save the model and automatically starts a new copy of the model before moving any data. The user should use this button for bypass and intersection projects. If the user clicks this button for any other type of project, the user must re-open the model and start the analysis again.

For intersection projects, the macro clears the highway information box, so traffic and highway geometric data can be entered for the other (intersecting) road. For bypass projects, the model erases the highway information under the No Build project column and calculates the Build column traffic on the bypass road as the No Build traffic minus the traffic on the existing roads. The user needs to enter only the highway geometric information (e.g., number of lanes, etc.). For bypass projects, the model automatically changes the colors of the green and blue boxes in the highway design and traffic data section (Section 1B) so the user knows what data to enter. For both types of projects, the model retains accident data for the second road, but the user can change this if data specific to second road are available.

For truck only lanes, the model assumes that all trucks use the truck only lanes, so the Build traffic is estimated as the No Build traffic multiplied by one minus the percent trucks. The macro clears the No Build column, since the truck only lane does not currently exist and estimates the Build traffic as the trucks only.

After entering data for the first road, the user should check the speeds and volumes in the *Model Inputs* worksheet. The user should return to the *Project Information* worksheet to click the button. The model cannot calculate induced demand for bypass projects.

## MODEL INPUTS WORKSHEET

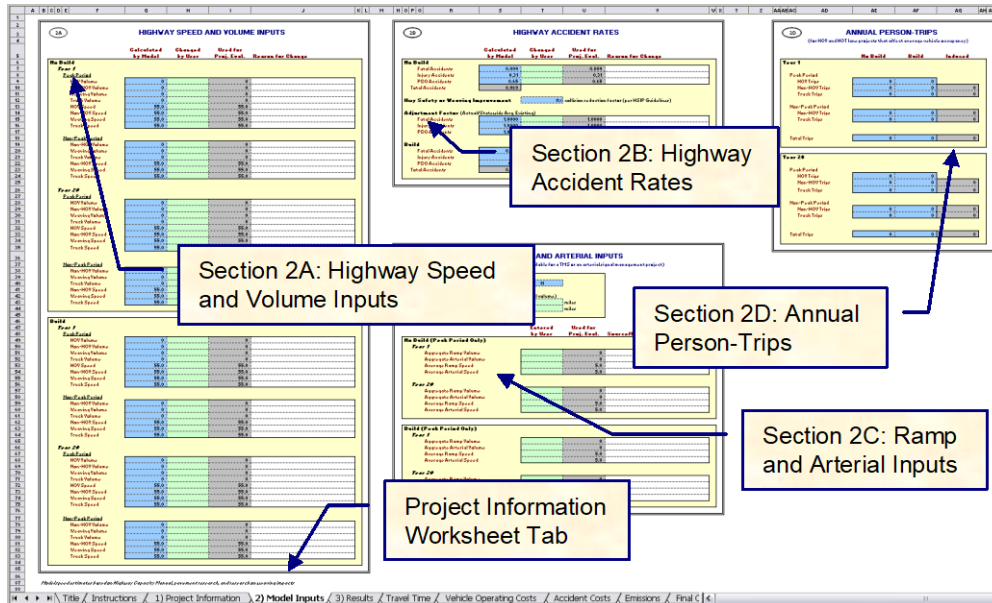
The *Model Inputs* worksheet (Exhibit 10) allows the user to review and replace several values for the benefit-cost analysis. More in-depth data are available for many projects, such as the output of a regional travel demand model or micro-simulation results for a TMS project. If these data are available, the user should override the Cal-B/C Sketch calculations. The model provides three sections in the model inputs worksheet for doing this:

- 2A Highway Speed and Volume Inputs
  - Peak and non-peak periods
  - HOV, non-HOV, weaving, and truck volumes
  - HOV, non-HOV, weaving, and truck speeds.
- 2B Highway Accident Rates and adjustment factors
  - Fatal accidents
  - Injury accidents
  - Property damage only (PDO) accidents.
- 2C Ramp and Arterial Inputs
  - Aggregate ramp or arterial
  - Injury accidents
  - Property damage only (PDO) accidents.

The sheet shows the model estimate and provides space for the user to change the value without disrupting the model defaults. There is also space to input an explanation for the change.

A fourth section (2D) provides annual person-trip data estimated in the model for HOV conversion and HOT lane projects. This information is provided for review purposes only. The user should adjust the ADT and AVO data if the annual person-trip estimates are not as expected

Exhibit 10: Model Inputs Worksheet



For example, Cal-B/C Sketch forecasts Build accident rates by calculating the ratio of current accident rates to the statewide average found in the annual collision report. If a particular stretch of highway has accident rates above the statewide average, the model will forecast Build accident rates to be above the average.

If the project is designed to lower accident rates to the statewide average, the user must manually override the value calculated by the model by changing the accident adjustment factor. The model assumes (through the adjustment factor) that the differential remains the same for the Build facility. The user can change this factor to 1.0 to result in accident rates at the statewide averages for the facility type. The user can control this calculation separately for fatal, injury, and PDO. The Cal-B/C Sketch calculations using the highway safety or weaving improvement percentage are consistent with the collision reduction factors found in the Caltrans Highway Safety Improvement Program (HSIP) Guidelines. The user can use the factors found in the guidelines to estimate the benefits of safety projects.

## RESULTS WORKSHEET

The final worksheet covered in this User's Guide is the *Results* worksheet. This is where Cal-B/C Sketch outputs the results of the benefit-cost assessment. Exhibit 11 shows an example of this output.



Exhibit 11: Results Worksheet - Final Model Output

Excel interface showing the Results worksheet. District: 8. PROJECT: Hypothetical Project, General Highway Improvement. EA: [ ] PPNO: [ ]

### INVESTMENT ANALYSIS SUMMARY RESULTS

<table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td>Life-Cycle Costs (mil. \$)</td><td style="text-align: right;">\$99.1</td></tr> <tr><td>Life-Cycle Benefits (mil. \$)</td><td style="text-align: right;">\$314.9</td></tr> <tr><td>Net Present Value (mil. \$)</td><td style="text-align: right;">\$215.8</td></tr> <tr><td>Benefit / Cost Ratio:</td><td style="text-align: right;">3.2</td></tr> <tr><td>Rate of Return on Investment:</td><td style="text-align: right;">15.4%</td></tr> <tr><td>Payback Period:</td><td style="text-align: right;">8 years</td></tr> </table>	Life-Cycle Costs (mil. \$)	\$99.1	Life-Cycle Benefits (mil. \$)	\$314.9	Net Present Value (mil. \$)	\$215.8	Benefit / Cost Ratio:	3.2	Rate of Return on Investment:	15.4%	Payback Period:	8 years	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th rowspan="2">ITEMIZED BENEFITS (mil. \$)</th> <th>Passenger</th> <th>Freight</th> <th>Total Over</th> <th>Average</th> </tr> <tr> <th>Benefits</th> <th>Benefits</th> <th>20 Years</th> <th>Annual</th> </tr> </thead> <tbody> <tr><td>Travel Time Savings</td><td style="text-align: right;">\$227.5</td><td style="text-align: right;">\$51.4</td><td style="text-align: right;">\$278.9</td><td style="text-align: right;">\$13.9</td></tr> <tr><td>Veh. Op. Cost Savings</td><td style="text-align: right;">\$7.4</td><td style="text-align: right;">\$0.0</td><td style="text-align: right;">\$7.5</td><td style="text-align: right;">\$0.4</td></tr> <tr><td>Accident Cost Savings</td><td style="text-align: right;">\$22.1</td><td style="text-align: right;">\$2.2</td><td style="text-align: right;">\$24.3</td><td style="text-align: right;">\$1.2</td></tr> <tr><td>Emission Cost Savings</td><td style="text-align: right;">\$1.2</td><td style="text-align: right;">\$3.0</td><td style="text-align: right;">\$4.2</td><td style="text-align: right;">\$0.2</td></tr> <tr><td><b>TOTAL BENEFITS</b></td><td style="text-align: right;"><b>\$258.2</b></td><td style="text-align: right;"><b>\$56.6</b></td><td style="text-align: right;"><b>\$314.9</b></td><td style="text-align: right;"><b>\$15.7</b></td></tr> </tbody> </table> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td>Person-Hours of Time Saved</td> <td style="text-align: right;">32,469,377</td> <td style="text-align: right;">1,623,469</td> </tr> </table>	ITEMIZED BENEFITS (mil. \$)	Passenger	Freight	Total Over	Average	Benefits	Benefits	20 Years	Annual	Travel Time Savings	\$227.5	\$51.4	\$278.9	\$13.9	Veh. Op. Cost Savings	\$7.4	\$0.0	\$7.5	\$0.4	Accident Cost Savings	\$22.1	\$2.2	\$24.3	\$1.2	Emission Cost Savings	\$1.2	\$3.0	\$4.2	\$0.2	<b>TOTAL BENEFITS</b>	<b>\$258.2</b>	<b>\$56.6</b>	<b>\$314.9</b>	<b>\$15.7</b>	Person-Hours of Time Saved	32,469,377	1,623,469
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<p><b>Should benefit-cost results include:</b></p> <p>1) Induced Travel? (y/n) <input type="text" value="Y"/> (Default = Y)</p> <p>2) Vehicle Operating Costs? (y/n) <input type="text" value="Y"/> (Default = Y)</p> <p>3) Accident Costs? (y/n) <input type="text" value="Y"/> (Default = Y)</p> <p>4) Vehicle Emissions? (y/n) <input type="text" value="Y"/> (Default = Y) <small>includes value for CO<sub>2</sub>e</small></p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th rowspan="2">EMISSIONS REDUCTION</th> <th colspan="2">Tons</th> <th colspan="2">Value (mil. \$)</th> </tr> <tr> <th>Total Over 20 Years</th> <th>Average Annual</th> <th>Total Over 20 Years</th> <th>Average Annual</th> </tr> </thead> <tbody> <tr><td>CO Emissions Saved</td><td style="text-align: right;">461</td><td style="text-align: right;">23</td><td style="text-align: right;">\$0.0</td><td style="text-align: right;">\$0.0</td></tr> <tr><td>CO<sub>2</sub> Emissions Saved</td><td style="text-align: right;">81,856</td><td style="text-align: right;">4,093</td><td style="text-align: right;">\$2.2</td><td style="text-align: right;">\$0.1</td></tr> <tr><td>NO<sub>x</sub> Emissions Saved</td><td style="text-align: right;">194</td><td style="text-align: right;">10</td><td style="text-align: right;">\$2.1</td><td style="text-align: right;">\$0.1</td></tr> <tr><td>PM<sub>10</sub> Emissions Saved</td><td style="text-align: right;">0</td><td style="text-align: right;">0</td><td style="text-align: right;">-\$0.1</td><td style="text-align: right;">-\$0.0</td></tr> <tr><td>PM<sub>2.5</sub> Emissions Saved</td><td style="text-align: right;">0</td><td style="text-align: right;">0</td><td></td><td></td></tr> <tr><td>SO<sub>x</sub> Emissions Saved</td><td style="text-align: right;">1</td><td style="text-align: right;">0</td><td style="text-align: right;">\$0.0</td><td style="text-align: right;">\$0.0</td></tr> <tr><td>VOC Emissions Saved</td><td style="text-align: right;">25</td><td style="text-align: right;">1</td><td style="text-align: right;">\$0.0</td><td style="text-align: right;">\$0.0</td></tr> </tbody> </table>	EMISSIONS REDUCTION	Tons		Value (mil. \$)		Total Over 20 Years	Average Annual	Total Over 20 Years	Average Annual	CO Emissions Saved	461	23	\$0.0	\$0.0	CO <sub>2</sub> Emissions Saved	81,856	4,093	\$2.2	\$0.1	NO <sub>x</sub> Emissions Saved	194	10	\$2.1	\$0.1	PM <sub>10</sub> Emissions Saved	0	0	-\$0.1	-\$0.0	PM <sub>2.5</sub> Emissions Saved	0	0			SO <sub>x</sub> Emissions Saved	1	0	\$0.0	\$0.0	VOC Emissions Saved	25	1	\$0.0	\$0.0
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Title | Instructions | 1) Project Information | 2) Model inputs | 3) Results | Travel Time | Vehicle Operating Costs | Accident Costs | Emissions | Final Calculations | PARAMETERS

At the bottom of the *Results* worksheet, the user can control which benefits are included. All four user benefits, except for travel time savings can be selectively included or excluded. The travel time savings are always included since they typically comprise the majority of project benefits. The default setting for all benefits is “Y,” which means that the benefits are included in the benefit-cost analysis. The exclusion of emissions will eliminate benefits from the benefit-cost calculation, but the itemized emissions are still reported separately. Any change to a toggle setting for a bypass, intersection, or truck only lane project should be made before the button is pushed to prepare the model for the other road. Including or excluding benefits affects the current road only.

Cal-B/C Sketch provides several summary results, which highlight different aspects of the project:

- **Life-Cycle Costs** are the present values of all net project costs, including initial and subsequent costs in real current dollars.
- **Life-Cycle Benefits** are the sum of the present value benefits for the project.
- **Net Present Value** equals the lifecycle benefits minus the lifecycle costs. The value of benefits exceeds the value of costs for a project with a positive net present value.
- **Benefit/Cost Ratio** shows the benefits relative to the costs of a project. A project with a benefit-cost ratio greater than one has a positive economic value.
- **Rate of Return on Investment** is the discount rate at which benefits and costs are equal. For a project with a rate of return greater than the discount rate, the benefits are greater than costs and the project has a positive economic value. The user can use rate



of return to compare projects with different costs and different benefit flows over different time periods. This is particularly useful for project staging.

- **Payback Period** is the number of years it takes for the net benefits (lifecycle benefits minus lifecycle costs) to equal the initial construction costs. For a project with a payback period longer than the lifecycle of the project, initial construction costs are not recovered. The payback period varies inversely with the benefit-cost ratio. A shorter payback period yields a higher benefit-cost ratio.

The model calculates these results over the standard 20-year project lifecycle. Cal-B/C Sketch itemizes each of the four user benefits for both person trips and freight trips and displays the annualized and lifecycle user benefits. The annualized benefit is calculated as the lifecycle benefit divided by twenty.

Below the itemized project benefits, Cal-B/C Sketch displays:

- **Person-Hours of Time Saved** shows the reduction in person-hours of travel time due to the project. A positive value indicates a net benefit.
- **Emissions Reduction** shows the itemized change in emissions for CO, CO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>x</sub>, and VOC. A positive value indicates a reduction in emissions, while a negative value indicates an increase in emissions. Changes in emissions are reported in tons and millions of dollars. PM<sub>2.5</sub> is reported only in tons because a generally accepted economic value was not available for this model version.

You are now ready to use Cal-B/C Sketch to model highway, rail or transit improvement projects. For more information about how Cal-B/C Sketch estimates particular impacts, please see the Appendix B.

### **PROJECT EXAMPLE: Complete**

The project input has been completed, we have double-checked our data, and we are ready to review the results. Having completed the data entry means that we have completed the *Project Information* worksheet and the *Model Inputs* worksheet. The results are shown in the investment analysis summary (Exhibit 11).

# APPENDIX A: Project Examples

## PROJECT EXAMPLE 1: PASSENGER RAIL IMPROVEMENT

Open the *Project Information* worksheet to begin an analysis. Exhibit 12 shows the *Project Data* section for a passenger rail improvement project. Green cells are cells that require data input. The red cells provide default values that the user can change.

Exhibit 12: Project Information Worksheet Section 1A

The screenshot shows a worksheet titled "PROJECT DATA" with a tab labeled "1A". The form contains the following fields:

- Type of Project:** "Select project type from list" with a dropdown menu showing "Passenger Rail". A note above says "Enter data in both sections 1B & 1E".
- Project Location:** "(enter 1 for So. Cal., 2 for No. Cal., or 3 for rural)" with a dropdown menu showing "1".
- Length of Construction Period:** "2" years.
- One- or Two-Way Data:** "2" enter 1 or 2.
- Length of Peak Period(s):** "(up to 24 hrs: 5 hours) Current".

- 1) **Type of Project.** Select the "Passenger Rail" project type.
- 2) **Project Location.** This cell requires you to enter a "1" for Southern California urban areas, a "2" for Northern California urban areas, or a "3" for rural areas in order to determine emissions benefits for the project. Assume that our project is being built in Southern California and put a "1" in this cell. This cell tells the model which emissions tables to reference.
- 3) **Length of Construction Period.** Enter the amount of time needed to construct the project. Assume that our rail project will be completed in two years. The model evaluates project impacts only after the project is built. For example, a project begun in 2017 that takes five years to complete would not cause any impacts until 2022 when the project opens. The Year 1 impacts occur in 2022. The Year 20 impacts would occur in 2041 for this hypothetical project. Cal-B/C Sketch uses this cell to determine the economic impacts. The entry must be a whole number. For example, a project that will take eight months to construct should be entered as "1", representing one year. A project taking two years and five months can be rounded down to two years or up to three years, at the user's discretion, but the entry in this cell must be consistent with the cost data entered.
- 4) **One- or Two-Way Data.** Enter the number of directions across which traffic flows along this corridor. In this case, leave the default value of "2".
- 5) **Length of Peak Period(s).** For our project, enter a "5" in this cell to represent a five-hour daily peak travel period (including both the AM and PM peak periods). The peak period length helps convert average daily traffic volumes into average peak and non-peak volumes and speeds. Speed is a key determinant in travel time savings, fuel consumption, and emissions.

Now move to the *Highway Design and Traffic Data* section of the project information worksheet.

- 6) **Highway Design.** Assume that the highway parallel to the rail project has six general traffic lanes and no HOV lanes in both directions (i.e., three lanes per direction). Set the free-flow speed to 55 mph. Make sure that the Build number of lanes is the same as the No Build. Otherwise, the model will not produce the correct results for this rail project. (A lane addition project requires that the Build number of lanes be greater than the No Build number.) The model does not allow the user to “phase in” the construction. For example, you cannot construct one lane in Year 1 and another in Year 7. Such a scenario must be analyzed as separate projects.

The blue cell for the Build free-flow speed will be set automatically to the No Build free-flow speed. The blue cell indicates that you may override this speed if you determine that the free-flow speed in Build is different from the No Build free-flow speed.

The *Length* cells determine the distance that the project will influence. In our example, assume that the project is an interregional rail project along a 50-mile corridor. The *Impacted Length* applies only to passing lane and operational improvement projects. This is because adding a truck climbing or passing lane improves traffic flow not only on the segment where the lane is located, but also upstream of the new lane.

- 7) **Average Daily Traffic.** Enter the existing average daily traffic into the cell labeled “Current.” Use a value of 130,000 for this exercise. Also, enter a value of 267,800 vehicles per day for the forecast year. Note: The forecast year is the project opening date plus 20 years, NOT the current date plus 20 years.

The model calculates the “Base (Year 1)” value in the No Build column. The model uses straight-line interpolation to estimate the Year 1 volume from the current year volume and the Year 20 volume. If you have more accurate data for Year 1, you can override the values calculated by the model.

Notice that the No Build and Build scenario volumes are the same for the passenger rail project. The model requires the user to assume a constant volume for highway demand, unless demand on the highway is expected to increase due to the rail project. We take the shift from highway to rail into account when we input the transit information. The model will correctly calculate the benefits associated with mode shifts to rail, although it is not apparent on this input screen.

Note: the *Results* worksheet has an option to include induced demand in the evaluation. If “Y” for “Yes” is selected, the model calculates the change in consumer surplus associated with the extra traffic in the Build scenario compared to the No Build scenario. For a transit project, Cal-B/C Sketch assumes that highway demand is inelastic (i.e., no induced demand occurs).

Exhibit 13: Project Information Worksheet Section 1B

1B		<b>HIGHWAY DESIGN AND TRAFFIC DATA</b>	
<b>Highway Design</b>			
		No Build	Build
Roadway Type (Fwy, Exp, Conv Hwy)		F	F
Number of General Traffic Lanes		6	6
Number of HOV/HOT Lanes			
HOV Restriction (2 or 3)			
Exclusive ROW for Buses (y/n)		N	
Highway Free-Flow Speed		55	55
Ramp Design Speed (if aux. lane/off-ramp proj.)		35	35
Length (in miles) Highway Segment		50.0	50.0
Impacted Length		50.0	50.0
<b>Average Daily Traffic</b>			
Current		130,000	
		No Build	Build
Base (Year 1)		143,124	143,124
Forecast (Year 20)		267,800	267,800
<b>Average Hourly HOV/HOT Lane Traffic</b>			
Percent of Induced Trips in HOV (if HOT or 2-to-3 conv.)			0
			100%
<b>Percent Traffic in Weave</b>			
			0.0%
<b>Percent Trucks</b> (include RVs, if applicable)			
		9%	9%
<b>Truck Speed</b>			
<b>On-Ramp Volume</b>			
		Peak	Non-Peak
Hourly Ramp Volume (if aux. lane/on-ramp proj.)		0	0
Metering Strategy (1, 2, 3, or D, if on-ramp proj.)			
<b>Queue Formation</b> (if queuing or grade crossing project)			
		Year 1	Year 20
Arrival Rate (in vehicles per hour)		0	0
Departure Rate (in vehicles per hour)		0	0
<b>Pavement Condition</b> (if pavement project)			
		No Build	Build
IRI (inches/mile) Base (Year 1)			
Forecast (Year 20)			
<b>Average Vehicle Occupancy (AVO)</b>			
		No Build	Build
General Traffic Non-Peak		1.30	1.23
Peak		1.15	1.08
High Occupancy Vehicle (if HOV/HOT lanes)		2.15	2.15

8) **Average Hourly HOV/HOT Lane Traffic.** Update these cells only if there are HOV or HOT lanes along the corridor. As with the average daily traffic cells, these cells require the No Build number of HOV/HOT lanes and the future number of HOV/HOT lanes when the project is completed. The model assumes that all lanes are constructed by Year 1.

- 9) **Percent Trucks.** Enter the percent truck composition of the traffic stream. The model assumes a nine percent truck composition for both No Build and Build project scenarios.
- 10) **Truck Speed.** We do not need this information for our passenger rail project. For passing lane projects, trucks travel this speed on a grade when there is no passing lane. Cal-B/C Sketch calculates the automobile speed based on the volume and capacity of the roadway using volume/capacity relationships provided in the 2010 Highway Capacity Manual. Trucks may have a much slower speed on grades where a passing lane project is to be constructed. Leave this cell empty for our project.
- 11) **Average Vehicle Occupancy (AVO).** This is the average number of people per vehicle on the highway. Let us use the model default of 1.30 for the non-peak AVO and 1.15 for the peak AVO in the No Build scenario. Assume a slight reduction in AVO to 1.23 for the off-peak and 1.08 for the peak as travelers use more transit in the Build scenario.

The model has the statewide averages already entered. Assume, however, that we have some highway accident data and projections available for our project as shown in Exhibit 14.

**Exhibit 14: Project Information Worksheet Section 1C**

1C HIGHWAY ACCIDENT DATA		
<b>Actual 3-Year Accident Data (from Table B)</b>		
	Count (No.)	Rate
Total Accidents (Tot)	6310	0.89
Fatal Accidents (Fat)	71	0.010
Injury Accidents (Inj)	1872	0.26
Property Damage Only (PDO) Accidents	4367	0.61
<b>Statewide Basic Average Accident Rate</b>		
	No Build	Build
Rate Group		
Accident Rate (per million vehicle-miles)	0.80	0.80
Percent Fatal Accidents (Pct Fat)	2%	2%
Percent Injury Accidents (Pct Inj)	32%	32%

- 12) In the **Actual 3-Year Accident Data (from Table B)** cells, assume there were 6,310 accidents on the parallel highway corridor over the past three years: 71 fatal accidents, 1,872 injury accidents, and 4,367 PDO accidents. This may seem like a lot of accidents, but remember that this is the three-year total over a 50-mile corridor.
- 13) Insert **statewide average accident rates** per million vehicle-miles for road classifications similar to the existing and proposed facilities. Include Base Rate and ADT factors, where applicable. Also, insert statewide percent of accidents that are fatal and injury accidents for road classifications similar to No Build and Build facilities. The model uses adjustment factors (the ratio of actual rates to statewide rates for existing facility) to estimate accident rates, by accident type, for new road classifications. The *Model Inputs* worksheet presents results that the user can edit.



For our project, assume that overall accident rates will remain the same (at 0.80 accidents per million vehicle-miles). Also assume the percentage of fatal accidents will remain the same at two percent and the percent injury accidents will hold constant at 32 percent.

The **rail and transit data** (Section 1D), as shown in Exhibit 15, is where we do most of our data entry for the rail project. Assume that we are implementing the project to improve train safety, travel times, and frequency of service. Such project may require some right-of-way improvements, signaling improvements, and additional passenger train cars.

**Exhibit 15: Project Information Worksheet Section 1D**

1D RAIL AND TRANSIT DATA			
<b>Annual Person-Trips</b>			
		No Build	Build
Base (Year 1)		310,000	400,000
Forecast (Year 20)		460,000	600,000
<b>Percent Trips during Peak Period</b>		60%	
<b>Percent New Trips from Parallel Highway</b>			65%
<b>Annual Vehicle-Miles</b>			
		No Build	Build
Base (Year 1)		532,000	740,000
Forecast (Year 20)		532,000	740,000
<b>Average Vehicles/Train</b> (if rail project)		3	4
<b>Reduction in Transit Accidents</b>			
Percent Reduction (if safety project)		5%	
<b>Average Transit Travel Time</b>			
		No Build	Build
In-Vehicle	Non-Peak (in minutes)	50.0	50.0
	Peak (in minutes)	45.0	45.0
Out-of-Vehicle	Non-Peak (in minutes)	15.0	15.0
	Peak (in minutes)	10.0	10.0
<b>Highway Grade Crossing</b>			
		Current	Year 1
Annual Number of Trains			0
Avg. Gate Down Time (in min.)			0.0
<b>Transit Agency Costs</b> (if TMS project)			
		No Build	Build
Annual Capital Expenditure			\$0
Annual Ops. and Maintenance Expenditure			\$0

- 14) **Annual Person-Trips.** While we entered current and Forecast (Year 20) average daily traffic for the parallel highway, we input Base (Year 1) and Forecast (Year 20) estimates for transit demand. Input the demand data as shown in Exhibit 15.
- 15) **Percent Trips during Peak Period.** This is where you estimate the ratio of peak period to daily ridership. In our example, assume that 60 percent of all transit trips on the line will occur during the five-hour peak period.
- 16) **Percent New Trips from Parallel Highway.** Typically, improved passenger rail services attract some new trips from the parallel highway. In practice, the percentage of new transit trips coming from highways falls somewhere between 50 percent and 80 percent. Let's assume that our new line will bring 65 percent of its new passengers from the highway.

- 17) **Annual Vehicle-Miles.** This is the number of vehicle-miles operated on the passenger rail line per year. Assume 532,000 revenue miles for Years 1 and 20 in the No Build scenario and 740,000 for the Build scenario.
- 18) **Average Vehicles per Train.** Enter the number of train cars that will be used on an average train consist during the day. In our example, we assume that each train will add an average of one car per train during the day increasing from three cars in the No Build scenario to four for our project. This means that some trains may have three cars, but others may have five or more per consist depending on the demand.
- 19) **Reduction in Transit Accidents.** If you are building a safety project, enter the percent reduction in transit accidents expected due to the project. Assume that this project includes grade-crossing improvements to increase vehicle and pedestrian safety, which leads to a five-percent reduction in train incidents.
- 20) **Average Transit Travel Time.** This is where you enter the average travel time required to make a trip on transit or rail. The transit travel time represents the total travel time by transit and includes the waiting time for the transit vehicle, transfer time, and the in-transit time. Enter the values as shown in Exhibit 15.
- 21) **Transit Agency Costs.** Since there is no Transportation Management System (TMS) component to this project, leave this section blank. For a TMS project, however, Cal-B/C Sketch requires that the user input annual capital, operating, and maintenance expenditures for routes impacted by the project. The model calculates cost reductions for the new expenditures due to transit TMS. Agency cost savings are estimated automatically as a negative cost.

Now we are at the final data entry step required to perform a basic analysis. If the user has project-specific information, they can change any parameter within the model. Please refer to the Cal-B/C Resources Guide for a more detailed discussion of the model assumptions. Let us continue with our analysis. Exhibit 16 shows the data that we will enter for this project.

- 22) **Initial Project Costs.** Enter the project costs for Years 1 through 3 as shown in Exhibit 16. Note the error message received after entering the data for Year 2. It says, "Adjust Construction Period" (look at the white space under the "Subsequent Cost" columns). Our construction dollars are being spent over three years, yet we indicated in Section 1A of the Project Information worksheet that construction would last only two years. Go back to the Project Information sheet and make the change as shown in Exhibit 17. Notice that the ADT estimated for Year 1 increases, since the additional construction year allows traffic to grow an additional year. Year 20 does not increase because this was a fixed user entry. You could change this entry as well if there were an error. For our example, we will not change the Year 20 traffic, because we simply made a mistake in typing in the number of construction years.

Exhibit 16: Project Information Worksheet Section 1E

1E PROJECT COSTS (enter costs in thousands of dollars)									
Col. no.	(1)	(2)	(3)	(4)	(5)	(6)	(7)		
Year	DIRECT PROJECT COSTS			SUBSEQUENT COSTS		Mitigation	Transit Agency Cost Savings	TOTAL COSTS (in dollars)	
	Project Support	R / W	Construction	Maint./ Op.	Rehab.			Constant Dollars	Present Value
<b>Construction Period</b>									
1	\$500	\$4,000	\$6,000			250		\$10,750,000	\$10,750,000
2	400		12,750			500		13,650,000	13,125,000
3	200		12,750			800		13,750,000	12,712,648
4								0	0
5								0	0
6								0	0
7								0	0
8								0	0
<b>Project Open</b>									
1				\$175				\$175,000	\$161,797
2				175				175,000	155,574
3				175				175,000	149,591
4				175				175,000	143,837
5				175				175,000	138,305
6				175				175,000	132,986
7				175				175,000	127,871
8				175				175,000	122,953
9				175				175,000	118,224
10				175	2,000			2,175,000	1,412,839
11				175				175,000	109,304
12				175				175,000	105,100
13				175				175,000	101,058
14				175				175,000	97,171
15				175				175,000	93,434
16				175				175,000	89,840
17				175				175,000	86,385
18				175				175,000	83,062
19				175				175,000	79,868
20				175				175,000	76,796
<b>Total</b>	\$1,100	\$4,000	\$31,500	\$3,500	\$2,000	\$1,550	\$0	\$43,650,000	\$40,173,644

Exhibit 17: Project Information Worksheet Correcting Section 1A

1A PROJECT DATA

**Type of Project**  
Select project type from list: Passenger Rail

**Project Location** (enter 1 for So. Cal., 2 for No. Cal., or 3 for rural):

**Length of Construction Period**  
One- or Two-Way Data: 3 years

**Length of Peak Period(s)** (up to 24 hrs): 5 hours

Enter data in both sections 1B & 1E

Change to "3" years

23) Now look at the years after the project is constructed and open for service. In our project, we will have to allocate funding to operate and maintain the project. These project maintenance and operating costs are the incremental costs required to operate the additional service, not the costs to operate the total service on the alignment. If we were to increase service on an existing rail line, we would subtract the cost required to operate the current route (i.e., the No Build scenario) from the cost to operate the Build scenario.





24) Before examining the results of the model, please review the work done to this point. In the project cost section, you should have a total project cost of \$43.7 million with a net present value of \$40.2 million.

We have completed the *Project Information* worksheet, but assume for our example that we have additional volume information from a regional travel demand model. In particular, we have more detailed estimates of peak and off-peak volumes. In the Model Inputs sheet, the average daily volume is broken into peak and non-peak volumes as shown in Exhibit 18.

**Exhibit 18: Model Inputs Worksheet Section 2A**

2A HIGHWAY SPEED AND VOLUME INPUTS				
	Calculated by Model	Changed by User	Used for Proj. Eval.	Reason for Change
<b>No Build</b>				
<b>Year 1</b>				
<b>Peak Period</b>				
HOV Volume	0		0	
Non-HOV Volume	52,488	41,267	41,267	
Weaving Volume	0		0	
Truck Volume	5,191	4,081	4,081	
HOV Speed	55.0		55.0	
Non-HOV Speed	54.3		54.3	
Weaving Speed	55.0		55.0	
Truck Speed	54.3		54.3	
<b>Non-Peak Period</b>				
Non-HOV Volume	77,755	91,425	91,425	
Weaving Volume	0		0	
Truck Volume	7,690	9,042	9,042	
Non-HOV Speed	55.0		55.0	
Weaving Speed	55.0		55.0	
Truck Speed	55.0		55.0	
<b>Year 20</b>				
<b>Peak Period</b>				
HOV Volume	0		0	
Non-HOV Volume	98,210	74,274	74,274	
Weaving Volume	0		0	
Truck Volume	9,713	7,346	7,346	
HOV Speed	55.0		55.0	
Non-HOV Speed	10.3		10.3	
Weaving Speed	55.0		55.0	
Truck Speed	10.3		10.3	
<b>Non-Peak Period</b>				
Non-HOV Volume	145,488	164,550	164,550	
Weaving Volume	0		0	
Truck Volume	14,389	16,274	16,274	
Non-HOV Speed	53.9		53.9	
Weaving Speed	55.0		55.0	
Truck Speed	53.9		53.9	
<b>Build</b>				
<b>Year 1</b>				
<b>Peak Period</b>				
HOV Volume	0		0	
Non-HOV Volume	52,404	41,185	41,185	
Weaving Volume	0		0	
Truck Volume	5,191	4,081	4,081	
HOV Speed	55.0		55.0	
Non-HOV Speed	54.4		54.4	
Weaving Speed	55.0		55.0	
Truck Speed	54.4		54.4	
<b>Non-Peak Period</b>				
Non-HOV Volume	77,706	91,376	91,376	
Weaving Volume	0		0	
Truck Volume	7,690	9,042	9,042	
Non-HOV Speed	55.0		55.0	
Weaving Speed	55.0		55.0	
Truck Speed	55.0		55.0	
<b>Year 20</b>				
<b>Peak Period</b>				
HOV Volume	0		0	
Non-HOV Volume	98,080	74,147	74,147	
Weaving Volume	0		0	
Truck Volume	9,713	7,346	7,346	
HOV Speed	55.0		55.0	
Non-HOV Speed	10.4		10.4	
Weaving Speed	55.0		55.0	
Truck Speed	10.4		10.4	
<b>Non-Peak Period</b>				
Non-HOV Volume	145,411	164,475	164,475	
Weaving Volume	0		0	
Truck Volume	14,389	16,274	16,274	
Non-HOV Speed	53.9		53.9	
Weaving Speed	55.0		55.0	
Truck Speed	53.9		53.9	



25) Fill in the Non-HOV and Truck Volume cells in the “Changed by User” column with the values shown in Exhibit 18.

Note: the total volume in the “Used for Proj. Eval.” field for each section should equal the total volume on the highway.

Now, we have completed our project input, have double-checked our data, and are ready to review the results. Having completed the data entry means that we have completed the *Project Information* worksheet and the *Model Inputs* worksheet. The results are shown in the investment analysis summary (Exhibit 19).

**Exhibit 19: Results Worksheet Section 3**

3

### INVESTMENT ANALYSIS

#### SUMMARY RESULTS

<b>Life-Cycle Costs (mil. \$)</b> <input style="width: 80%;" type="text" value="\$40.0"/> <b>Life-Cycle Benefits (mil. \$)</b> <input style="width: 80%;" type="text" value="\$71.3"/> <b>Net Present Value (mil. \$)</b> <input style="width: 80%;" type="text" value="\$31.3"/>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">ITEMIZED BENEFITS (mil. \$)</th> <th style="text-align: center;">Passenger Benefits</th> <th style="text-align: center;">Freight Benefits</th> <th style="text-align: center;">Total Over 20 Years</th> <th style="text-align: center;">Average Annual</th> </tr> </thead> <tbody> <tr> <td>Travel Time Savings</td> <td style="text-align: right;">\$38.0</td> <td style="text-align: right;">\$7.3</td> <td style="text-align: right;">\$45.3</td> <td style="text-align: right;">\$2.3</td> </tr> <tr> <td>Veh. Op. Cost Savings</td> <td style="text-align: right;">\$20.2</td> <td style="text-align: right;">\$1.6</td> <td style="text-align: right;">\$21.8</td> <td style="text-align: right;">\$1.1</td> </tr> <tr> <td>Accident Cost Savings</td> <td style="text-align: right;">\$4.3</td> <td style="text-align: right;">\$0.0</td> <td style="text-align: right;">\$4.3</td> <td style="text-align: right;">\$0.2</td> </tr> <tr> <td>Emission Cost Savings</td> <td style="text-align: right;">-\$3.3</td> <td style="text-align: right;">\$3.2</td> <td style="text-align: right;">-\$0.1</td> <td style="text-align: right;">-\$0.0</td> </tr> <tr> <td><b>TOTAL BENEFITS</b></td> <td style="text-align: right;"><b>\$59.2</b></td> <td style="text-align: right;"><b>\$12.1</b></td> <td style="text-align: right;"><b>\$71.3</b></td> <td style="text-align: right;"><b>\$3.6</b></td> </tr> </tbody> </table>	ITEMIZED BENEFITS (mil. \$)	Passenger Benefits	Freight Benefits	Total Over 20 Years	Average Annual	Travel Time Savings	\$38.0	\$7.3	\$45.3	\$2.3	Veh. Op. Cost Savings	\$20.2	\$1.6	\$21.8	\$1.1	Accident Cost Savings	\$4.3	\$0.0	\$4.3	\$0.2	Emission Cost Savings	-\$3.3	\$3.2	-\$0.1	-\$0.0	<b>TOTAL BENEFITS</b>	<b>\$59.2</b>	<b>\$12.1</b>	<b>\$71.3</b>	<b>\$3.6</b>
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<b>TOTAL BENEFITS</b>	<b>\$59.2</b>	<b>\$12.1</b>	<b>\$71.3</b>	<b>\$3.6</b>																											

<b>Benefit / Cost Ratio:</b> <input style="width: 80%;" type="text" value="1.8"/>  <b>Rate of Return on Investment:</b> <input style="width: 80%;" type="text" value="8.0%"/>  <b>Payback Period:</b> <input style="width: 80%;" type="text" value="16 years"/>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 70%;"><b>Person-Hours of Time Saved</b></td> <td style="width: 15%; text-align: right;"><input style="width: 80%;" type="text" value="6,489,664"/></td> <td style="width: 15%; text-align: right;"><input style="width: 80%;" type="text" value="324,483"/></td> </tr> </table>	<b>Person-Hours of Time Saved</b>	<input style="width: 80%;" type="text" value="6,489,664"/>	<input style="width: 80%;" type="text" value="324,483"/>
<b>Person-Hours of Time Saved</b>	<input style="width: 80%;" type="text" value="6,489,664"/>	<input style="width: 80%;" type="text" value="324,483"/>		

<p><b>Should benefit-cost results include:</b></p> <p>1) Induced Travel? (y/n) <input style="width: 80%;" type="text" value="Y"/> <small style="color: red;">Default = Y</small></p> <p>2) Vehicle Operating Costs? (y/n) <input style="width: 80%;" type="text" value="Y"/> <small style="color: red;">Default = Y</small></p> <p>3) Accident Costs? (y/n) <input style="width: 80%;" type="text" value="Y"/> <small style="color: red;">Default = Y</small></p> <p>4) Vehicle Emissions? (y/n) <input style="width: 80%;" type="text" value="Y"/> <small style="color: red;">Default = Y</small> <small>includes value for CO<sub>2e</sub></small></p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th rowspan="2" style="text-align: left;">EMISSIONS REDUCTION</th> <th colspan="2" style="text-align: center;">Tons</th> <th colspan="2" style="text-align: center;">Value (mil. \$)</th> </tr> <tr> <th style="text-align: center;">Total Over 20 Years</th> <th style="text-align: center;">Average Annual</th> <th style="text-align: center;">Total Over 20 Years</th> <th style="text-align: center;">Average Annual</th> </tr> </thead> <tbody> <tr> <td>CO Emissions Saved</td> <td style="text-align: right;">139</td> <td style="text-align: right;">7</td> <td style="text-align: right;">\$0.0</td> <td style="text-align: right;">\$0.0</td> </tr> <tr> <td>CO<sub>2</sub> Emissions Saved</td> <td style="text-align: right;">69,914</td> <td style="text-align: right;">3,496</td> <td style="text-align: right;">\$1.8</td> <td style="text-align: right;">\$0.1</td> </tr> <tr> <td>NO<sub>x</sub> Emissions Saved</td> <td style="text-align: right;">47</td> <td style="text-align: right;">2</td> <td style="text-align: right;">\$0.4</td> <td style="text-align: right;">\$0.0</td> </tr> <tr> <td>PM<sub>10</sub> Emissions Saved</td> <td style="text-align: right;">-7</td> <td style="text-align: right;">0</td> <td style="text-align: right;">-\$2.5</td> <td style="text-align: right;">-\$0.1</td> </tr> <tr> <td>PM<sub>2.5</sub> Emissions Saved</td> <td style="text-align: right;">0</td> <td style="text-align: right;">0</td> <td></td> <td></td> </tr> <tr> <td>SO<sub>x</sub> Emissions Saved</td> <td style="text-align: right;">1</td> <td style="text-align: right;">0</td> <td style="text-align: right;">\$0.1</td> <td style="text-align: right;">\$0.0</td> </tr> <tr> <td>VOC Emissions Saved</td> <td style="text-align: right;">9</td> <td style="text-align: right;">0</td> <td style="text-align: right;">\$0.0</td> <td style="text-align: right;">\$0.0</td> </tr> </tbody> </table>	EMISSIONS REDUCTION	Tons		Value (mil. \$)		Total Over 20 Years	Average Annual	Total Over 20 Years	Average Annual	CO Emissions Saved	139	7	\$0.0	\$0.0	CO <sub>2</sub> Emissions Saved	69,914	3,496	\$1.8	\$0.1	NO <sub>x</sub> Emissions Saved	47	2	\$0.4	\$0.0	PM <sub>10</sub> Emissions Saved	-7	0	-\$2.5	-\$0.1	PM <sub>2.5</sub> Emissions Saved	0	0			SO <sub>x</sub> Emissions Saved	1	0	\$0.1	\$0.0	VOC Emissions Saved	9	0	\$0.0	\$0.0
EMISSIONS REDUCTION	Tons		Value (mil. \$)																																										
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VOC Emissions Saved	9	0	\$0.0	\$0.0																																									

## PROJECT EXAMPLE 2: TRUCK CLIMBING LANE

Open the *Project Information* worksheet to begin an analysis. Exhibit 20 shows the *Project Data* section for a truck climbing lane improvement project. Green cells are cells that require data input. The red cells provide default values that the user can change.

Exhibit 20: Project Information Worksheet Section 1A

1A PROJECT DATA	
<b>Type of Project</b> Select project type from list	Passing Lane
<b>Project Location</b> (enter 1 for So. Cal., 2 for No. Cal., or 3 for rural)	1
<b>Length of Construction Period</b> One- or Two-Way Data	1 years 2 enter 1 or 2
<b>Length of Peak Period(s)</b> (up to 24 hrs)	Current 2 hours

- Type of Project.** Select the “Passing Lane” project type.
- Project Location.** This cell requires you to enter a “1” for Southern California urban areas, a “2” for Northern California urban areas, or a “3” for rural areas in order to determine emissions benefits for the project. This project is being built in Southern California so put a “1” in this cell. This cell tells the model which emissions values to reference since emissions vary by location.
- Length of Construction Period.** Enter the amount of time needed to construct the project. Assume that the climbing lanes will be completed in one year. As described previously, Cal-B/C Sketch evaluates project impacts only after project has been constructed and is open. Cal-B/C Sketch uses this cell to determine the economic benefits. The entry must be a whole number. For example, a project that will take eight months to construct should be entered as “1”, representing one year. A project taking two years and five months can be rounded down to two years or up to three years at the user’s discretion, but the entry in this cell must be consistent with the cost data entered.
- One- or Two-Way Data.** Enter the number of directions across which traffic flows along this corridor. In this case, leave the default value of “2”.
- Length of Peak Period(s).** For our project, enter a “2” to represent a two-hour daily peak travel period (including both the AM and PM peak periods). The peak period length helps convert average daily traffic volumes into average peak and non-peak volumes and speeds. Speed is an important variable to determine travel time savings, fuel consumption, and emissions.

Now move to the *Highway Design and Traffic Data* section of the project information worksheet (Exhibit 21).

Exhibit 21: Project Information Worksheet Section 1B

1B <b>HIGHWAY DESIGN AND TRAFFIC DATA</b>		
<b>Highway Design</b>		
	No Build	Build
Roadway Type (Fwy, Exp, Conv Hwy)	F	F
Number of General Traffic Lanes	3	4
Number of HOV/HOT Lanes		
HOV Restriction (2 or 3)		
Exclusive ROW for Buses (y/n)	N	
Highway Free-Flow Speed	65	65
Ramp Design Speed (if aux. lane/off-ramp proj.)	35	35
Length (in miles) Highway Segment	6.7	6.7
Impacted Length	9.7	9.7
<b>Average Daily Traffic</b>		
Current	85,000	
	No Build	Build
Base (Year 1)	86,750	86,750
Forecast (Year 20)	120,000	120,000
<b>Average Hourly HOV/HOT Lane Traffic</b>		
	0	0
Percent of Induced Trips in HOV (if HOT or 2-to-3 conv.)		100%
<b>Percent Traffic in Weave</b>		
		0.0%
<b>Percent Trucks</b> (include RVs, if applicable)		
	13%	13%
<b>Truck Speed</b>		
	55	
<b>On-Ramp Volume</b>		
	Peak	Non-Peak
Hourly Ramp Volume (if aux. lane/on-ramp proj.)	0	0
Metering Strategy (1, 2, 3, or D, if on-ramp proj.)		
<b>Queue Formation</b> (if queuing or grade crossing project)		
	Year 1	Year 20
Arrival Rate (in vehicles per hour)	0	0
Departure Rate (in vehicles per hour)	0	0
<b>Pavement Condition</b> (if pavement project)		
	No Build	Build
IRI (inches/mile) Base (Year 1)		
Forecast (Year 20)		
<b>Average Vehicle Occupancy (AVO)</b>		
	No Build	Build
General Traffic Non-Peak	1.30	1.30
Peak	1.15	1.15
High Occupancy Vehicle (if HOV/HOT lanes)	2.15	2.15

- 6) **Highway Design.** Assume that the highway has three (3) general traffic lanes and no HOV or HOT lanes in the project direction. Set the free-flow speed to 65 mph. In this project, we are adding truck climbing lanes, so enter a “4” into the Build number of lanes. Note that Cal-B/C Sketch does not allow the user to “phase in” the construction. For example, you cannot construct one lane in Year 1 and another in Year 7. Such a scenario must be analyzed as separate projects.

The blue cell for the Build free-flow speed will be set automatically to the No Build free-flow speed. The blue cell indicates that you may override this speed if you determine that the free-flow speed in Build is different from the No Build free-flow speed.

The *Length* cells determine the distance that the project will influence. This project calls for a new lane along a 6.7 stretch of highway. Note how the *Impacted Length* changes because of the project. Cal-B/C Sketch assumes that truck climbing lanes will have an impact three-miles upstream of the project. This is because adding the climbing lane improves traffic flow not only on the segment where it is located, but also upstream of the new lane. The user can change this parameter, if needed.

- 7) **Average Daily Traffic.** Enter the existing average daily traffic into the cell labeled “Current.” Use a value of 85,000 for this exercise. Also, enter a value of 120,000 vehicles per day for the forecast year. Note: The forecast year is the project opening date plus 20 years, NOT the current date plus 20 years.

The model calculates the “Base (Year 1)” value in the No Build column. The model uses straight-line interpolation to estimate the Year 1 volume from the current year volume and the Year 20 volume. If you have more accurate data for Year 1, you can override the values calculated by the model.

Notice that the No Build and Build scenario volumes are the same for the project. The model requires the user to assume a constant volume for highway demand, unless demand on the highway is expected to increase due to the project.

Note: the *Results* worksheet has an option to include induced demand in the evaluation. If “Y” for “Yes” is selected, the model calculates the change in consumer surplus associated with the extra traffic in the Build scenario compared to the No Build scenario.

- 8) **Average Hourly HOV/HOT Lane Traffic.** Update these cells only if there are HOV or HOT lanes along the corridor. For our example, we will leave these cells blank because there are no HOV or HOT lanes along the road.
- 9) **Percent Trucks.** Enter the percent truck composition of the traffic stream. The model assumes a nine percent truck composition for both the No Build and Build project scenarios as a default. However, this is a very busy truck corridor so type a “13” in the red cell. Note that this cell is formatted as a percentage.
- 10) **Truck Speed.** For truck climbing projects, trucks travel on grades at the speed entered when there is no passing lane. Cal-B/C Sketch calculates the automobile speed based on the volume and capacity of the roadway using volume/capacity relationships provided in the 2010 Highway Capacity Manual. Trucks may have a much slower speed on grades where the truck climbing lane is constructed. Leave this cell empty for our project. For our example, the truck speed is 55 mph.
- 11) **Average Vehicle Occupancy (AVO).** This is the average number of people per vehicle on the highway. Let us use the model default of 1.30 for the non-peak AVO and 1.15 for the peak AVO in the No Build scenario. There should be no change in AVO since this is a truck project.

For highway accident data, Cal-B/C Sketch has statewide averages built in. However, we have some highway accident data and projections available for our project (as shown in Exhibit 22).

**Exhibit 22: Project Information Worksheet Section 1C**

1C <b>HIGHWAY ACCIDENT DATA</b>		
<b>Actual 3-Year Accident Data (from Table B)</b>		
	Count (No.)	Rate
Total Accidents (Tot)	221	0.35
Fatal Accidents (Fat)	4	0.006
Injury Accidents (Inj)	49	0.08
Property Damage Only (PDO) Accidents	168	0.27
<b>Statewide Basic Average Accident Rate</b>		
	No Build	Build
Rate Group		
Accident Rate (per million vehicle-miles)	0.80	0.70
Percent Fatal Accidents (Pct Fat)	1.1%	1.1%
Percent Injury Accidents (Pct Inj)	29.0%	32.2%

12) In the **Actual 3-Year Accident Data (from Table B)** cells, assume there were 221 accidents on the parallel highway corridor over the past three years: 4 fatal accidents, 49 injury accidents, and 168 PDO accidents (Note: PDO accidents are calculated in the blue cell by taking the total accidents and subtracting fatal and injury accidents).

13) Insert statewide average accident rates per million vehicle-miles for road classifications similar to the existing and proposed facilities. Include Base Rate and ADT factors, where applicable. Also, insert statewide percent of accidents that are fatal and injury accidents for road classifications similar to No Build and Build facilities. The model uses adjustment factors (the ratio of actual rates to statewide rates for existing facility) to estimate accident rates by accident type for new road classifications. The Model Inputs worksheet presents results that the user can edit.

For our project, assume that overall accident rates will decline from 0.80 to 0.70 between the No Build and the Build scenarios. Assume the percentage of fatal accidents will remain the same at 1.1 percent, but that the percent of injury accidents will increase from 29.0 to 32.2 percent.

Since this is a truck climbing lane project, the rail and transit data box (Section 1D) will not need to be updated.

Now we are at the final data entry step required to perform a basic analysis. Any parameter in the model can be changed to reflect project-specific information available. Please refer to the Appendix B for a more detailed discussion of the model assumptions. Let us continue with our analysis. Exhibit 23 shows the project cost data that we will enter for this project.

14) Enter the **Initial Project Costs**. Enter the project costs for Year 1 as shown in Exhibit 23 on the next page.



Exhibit 23: Project Information Worksheet Section 1E

1E PROJECT COSTS (enter costs in thousands of dollars)									
Col. no.	(1)	(2)	(3)	(4)	(5)	(6)	(7)		
Year	DIRECT PROJECT COSTS			SUBSEQUENT COSTS		Mitigation	Transit Agency Cost Savings	TOTAL COSTS (in dollars)	
	Project Support	R / W	Construction	Maint./ Op.	Rehab.			Constant Dollars	Present Value
<b>Construction Period</b>									
1			\$55,340					\$55,340,000	\$55,340,000
2								0	0
3								0	0
4								0	0
5								0	0
6								0	0
7								0	0
8								0	0
<b>Project Open</b>									
1								\$0	\$0
2								0	0
3								0	0
4								0	0
5								0	0
6								0	0
7								0	0
8								0	0
9								0	0
10								0	0
11								0	0
12								0	0
13								0	0
14								0	0
15								0	0
16								0	0
17								0	0
18								0	0
19								0	0
20								0	0
<b>Total</b>	\$0	\$0	\$55,340	\$0	\$0	\$0	\$0	\$55,340,000	\$55,340,000

15) Before examining the results of the model, please review the work done to this point. In the project cost section, you should have a total project cost of \$54.34 million.

We have completed the *Project Information* worksheet and will not update the *Model Inputs* worksheet since we do not have better data available from a model.

We have completed our project input, have double-checked our data, and are ready to review the results. Having completed the data entry means that we have completed the *Project Information* worksheet and the *Model Inputs* worksheet. The results are shown in the investment analysis summary in Exhibit 24.



Exhibit 24: Results Worksheet Section 3

3

### INVESTMENT ANALYSIS

#### SUMMARY RESULTS

Life-Cycle Costs (mil. \$)	\$55.3
Life-Cycle Benefits (mil. \$)	\$1,032.8
Net Present Value (mil. \$)	\$977.4
Benefit / Cost Ratio: <input style="width: 50px;" type="text" value="18.7"/>	
Rate of Return on Investment: <input style="width: 50px;" type="text" value="68.0%"/>	
Payback Period: <input style="width: 50px;" type="text" value="2 years"/>	

ITEMIZED BENEFITS (mil. \$)	Passenger Benefits	Freight Benefits	Total Over 20 Years	Average Annual
Travel Time Savings	\$616.1	\$155.3	\$771.4	\$38.6
Veh. Op. Cost Savings	\$25.5	\$12.7	\$38.2	\$1.9
Accident Cost Savings	\$168.5	\$25.2	\$193.7	\$9.7
Emission Cost Savings	\$4.0	\$25.5	\$29.5	\$1.5
<b>TOTAL BENEFITS</b>	<b>\$814.1</b>	<b>\$218.6</b>	<b>\$1,032.8</b>	<b>\$51.6</b>
Person-Hours of Time Saved			84,999,470	4,249,973

**Should benefit-cost results include:**

1) Induced Travel? (y/n)   
Default = Y

2) Vehicle Operating Costs? (y/n)   
Default = Y

3) Accident Costs? (y/n)   
Default = Y

4) Vehicle Emissions? (y/n)   
Default = Y  
includes value for CO<sub>2</sub>e

	Tons		Value (mil. \$)	
	Total Over 20 Years	Average Annual	Total Over 20 Years	Average Annual
<b>EMISSIONS REDUCTION</b>				
CO Emissions Saved	667	33	\$0.1	\$0.0
CO <sub>2</sub> Emissions Saved	206,330	10,316	\$5.6	\$0.3
NO <sub>x</sub> Emissions Saved	647	32	\$22.5	\$1.1
PM <sub>10</sub> Emissions Saved	3	0	\$0.9	\$0.0
PM <sub>2.5</sub> Emissions Saved	3	0		
SO <sub>x</sub> Emissions Saved	2	0	\$0.2	\$0.0
VOC Emissions Saved	66	3	\$0.2	\$0.0

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47



## PROJECT EXAMPLE 3: TRUCK ONLY LANE

Open the *Project Information* worksheet to begin an analysis. Exhibit 25 shows the *Project Data* section for a truck only lane improvement project. Green cells are cells that require data input. The red cells provide default values that the user can change.

Exhibit 25: Project Information Worksheet Section 1A

1A PROJECT DATA	
<b>Type of Project</b> Select project type from list	Remember to run macro for truck lane Truck Only Lane
<b>Project Location</b> (enter 1 for So. Cal., 2 for No. Cal., or 3 for rural)	1
<b>Length of Construction Period</b> One- or Two-Way Data	4 years 1 enter 1 or 2
<b>Length of Peak Period(s)</b> (up to 24 hrs)	Current 6 hours

- Type of Project.** Select the “Truck Only Lane” project type.
- Project Location.** This cell requires you to enter a “1” for Southern California urban areas, a “2” for Northern California urban areas, or a “3” for rural areas in order to determine emissions benefits for the project. This project is being built in Southern California so put a “1” in this cell. This cell tells the model which emissions table to reference since emissions vary by location.
- Length of Construction Period.** Enter the amount of time needed to construct the project. Assume that the truck only lane will be completed in four years. As described previously, Cal-B/C Sketch evaluates project impacts only after project has been constructed and is open. Cal-B/C Sketch uses this cell to determine the economic benefits. The entry must be a whole number. For example, a project that will take eight months to construct should be entered as “1”, representing one year. A project taking two years and five months can be rounded down to two years or up to three years at the user’s discretion, but the entry in this cell must be consistent with the cost data entered.
- One- or Two-Way Data.** Enter the number of directions across which traffic flows along this corridor. In this case, the project concerns only the northbound section of a highway, so enter a value of “1”.
- Length of Peak Period(s).** For our project, enter a “6” to represent a six-hour daily peak travel period (including both the AM and PM peak periods). The peak period length helps convert average daily traffic volumes into average peak and non-peak volumes and speeds. Speed is an important variable to determine travel time savings, fuel consumption, and emissions.

Now move to the *Highway Design and Traffic Data* section of the *Project Information* worksheet (see Exhibit 26).

**Exhibit 26: Project Information Worksheet Section 1B**

1B

**HIGHWAY DESIGN AND TRAFFIC DATA**

<b>Highway Design</b>		No Build	Build
Roadway Type (Fwy, Exp, Conv Hwy)		F	F
Number of General Traffic Lanes		4	4
Number of HOV/HOT Lanes			
HOV Restriction (2 or 3)			
Exclusive ROW for Buses (y/n)		N	
Highway Free-Flow Speed		65	65
Ramp Design Speed (if aux. lane/off-ramp proj.)		35	35
Length (in miles) Highway Segment		5.0	5.0
Impacted Length		5.0	5.0

<b>Average Daily Traffic</b>		No Build	Build
Current		105,000	
Base (Year 1)		108,600	94,482
Forecast (Year 20)		125,700	109,359
<b>Average Hourly HOV/HOT Lane Traffic</b>			0
Percent of Induced Trips in HOV (if HOT or 2-to-3 conv.)			100%
<b>Percent Traffic in Weave</b>			0.0%
<b>Percent Trucks</b> (include RVs, if applicable)		13%	0%
<b>Truck Speed</b>			

<b>On-Ramp Volume</b>		Peak	Non-Peak
Hourly Ramp Volume (if aux. lane/on-ramp proj.)		0	0
Metering Strategy (1, 2, 3, or D, if on-ramp proj.)			

<b>Queue Formation</b> (if queuing or grade crossing project)		Year 1	Year 20
Arrival Rate (in vehicles per hour)		0	0
Departure Rate (in vehicles per hour)		0	0

<b>Pavement Condition</b> (if pavement project)		No Build	Build
IRI (inches/mile) Base (Year 1)			
Forecast (Year 20)			

<b>Average Vehicle Occupancy (AVO)</b>		No Build	Build
General Traffic Non-Peak		1.30	1.30
Peak		1.15	1.15
High Occupancy Vehicle (if HOV/HOT lanes)		2.15	2.15

6) **Highway Design.** Assume that the highway has four general traffic lanes and no HOV or HOT lanes in the project direction. Set the free-flow speed to 65 mph. In this project, we are adding a separate truck only lane, but not any additional general traffic lanes, so the Build number of lanes is also “4.”

The blue cell for the Build free-flow speed will be set automatically to the No Build free-flow speed. The blue cell indicates that you may override this speed if you determine that the free-flow speed in Build is different from the No Build free-flow speed.

The *Length* cells determine the distance that the project will influence. This project calls for a truck only lane along a five mile stretch of highway. Note that the *Impacted Length* is the same as the *Length*, because Cal-B/C Sketch does not assume that truck only lanes will have an impact upstream or downstream of the project. The user can change this parameter, but for now leave the default value.

- 7) **Average Daily Traffic.** Enter the existing average daily traffic into the cell labeled “Current.” Use a value of 105,000 for this exercise. Also, enter a value of 125,700 vehicles per day for the forecast year. Note: the forecast year is the project opening date plus 20 years, NOT the current date plus 20 years.

The model can calculate the “Base (Year 1)” value in the No Build column using straight-line interpolation to estimate the Year 1 volume from the current year volume and the Year 20 volume. For this exercise, we will use this interpolated value.

Notice that the No Build and Build scenario volumes are not the same for a project with truck only lanes. The model assumes that all truck traffic will divert from the general lanes to the new truck only lane, and the ADT values calculated for the Build scenario reflects only non-truck traffic using the existing lanes. The user can override these values if a different assumption is more accurate.

Note: the *Results* worksheet has an option to include induced demand in the evaluation, but Cal-B/C Sketch is unable to calculate induced demand for truck only lanes.

- 8) **Average Hourly HOV/HOT Lane Traffic.** Update these cells only if there are HOV or HOT lanes along the corridor. As with the average daily traffic cells, these cells require the No Build number of HOV/HOT lanes and the future number of HOV/HOT lanes when the project is completed. The model assumes that all lanes are constructed by Year 1.
- 9) **Percent Trucks.** Enter the percent truck composition of the traffic stream, and note that this cell is formatted as a percentage. The model assumes a nine percent truck composition for the No Build scenario as a default, and assumes zero percent for the Build project scenario, because of the shift in truck traffic from general lanes to the truck only lane. However, this is a very busy truck corridor, so type a “13” in the red cell.
- 10) **Truck Speed.** For some projects, trucks may travel at much slower speeds than other traffic. Leave this cell empty for our project. This allows the model to estimate truck speeds depending on traffic flow.
- 11) **Average Vehicle Occupancy (AVO).** This is the average number of people per vehicle on the highway. Let’s use the model default of 1.30 for the non-peak AVO and 1.15 for the peak AVO in the No Build scenario. There should be no change in AVO since this is a truck project.
- 12) For highway accident data, Cal-B/C Sketch has statewide averages built in. However, we have some highway accident data and projections available for our project (as shown in Exhibit 27).



**Exhibit 27: Project Information Worksheet Section 1C**

1C

**HIGHWAY ACCIDENT DATA**

<b>Actual 3-Year Accident Data (from Table B)</b>		
	Count (No.)	Rate
Total Accidents (Tot)	237	0.40
Fatal Accidents (Fat)	2	0.003
Injury Accidents (Inj)	64	0.11
Property Damage Only (PDO) Accidents	171	0.29

<b>Statewide Basic Average Accident Rate</b>		
Rate Group	No Build	Build
Accident Rate (per million vehicle-miles)		
Percent Fatal Accidents (Pct Fat)		
Percent Injury Accidents (Pct Inj)		

13) In the **Actual 3-Year Accident Data (from Table B)** cells, assume there were 237 accidents on the parallel highway corridor over the past three years: 2 fatal accidents, 64 injury accidents, and 171 PDO accidents. (Note: PDO accidents can be calculated in the blue cell by taking the total accidents and subtracting fatal and injury accidents.)

If available, insert statewide average accident rates per million vehicle-miles for road classifications similar to the existing and proposed facilities. Include Base Rate and ADT factors, where applicable. Also, insert statewide percent of accidents that are fatal and injury accidents for road classifications similar to No Build and Build facilities. The model uses adjustment factors (the ratio of actual rates to statewide rates for existing facility) to estimate accident rates by accident type for new road classifications. The *Model Inputs* worksheet presents results that the user can edit.

For this example, we do not have accident rates per million vehicle miles available, so we will leave these cells blank. The user can enter alternate accident rates and factors in Exhibit 28, in the *Model Inputs* worksheet.



Exhibit 28: Model Inputs Worksheet Section 2B

2B

**HIGHWAY ACCIDENT RATES**

	Calculated by Model	Changed by User	Used for Proj. Eval.	Reason for Change
<b>No Build</b>				
Fatal Accidents	0.003		0.003	
Injury Accidents	0.11		0.11	
PDO Accidents	0.30		0.30	
Total Accidents	0.413			
<b>Hwy Safety or Weaving Improvement</b>		10% collision reduction factor (per HSIP Guidelines)		
<b>Adjustment Factor (Actual/Statewide Avg. Existing)</b>				
Fatal Accidents	0.9000		0.9000	
Injury Accidents	0.9000		0.9000	
PDO Accidents	0.9000		0.9000	
<b>Build</b>				
Fatal Accidents	0.003		0.003	
Injury Accidents	0.10		0.10	
PDO Accidents	0.27		0.27	
Total Accidents	0.372			

14) **Highway Safety or Weaving Improvement.** We may assume that the addition of a truck only lane will eliminate accidents that involve both vehicles and trucks, since truck and vehicle traffic will be separated on this section of road. Let vehicle-truck accidents comprise 10 percent of all motor vehicle accidents on this highway, resulting in a 10 percent reduction in accidents. Enter “10” as the collision reduction factor. Note that this cell is formatted as a percentage.

Since this is a truck only lane project, the rail and transit data box (Section 1D) of the *Project Information* worksheet will not need to be updated.

Now, we are almost finished with the first part of data entry required to perform a truck only analysis. Any parameter in the model can be changed to reflect project-specific information available. Please refer to the technical supplement for a more detailed discussion of the model assumptions.

15) Enter the **Initial Project Costs**. Enter the project costs for Years 1 through 4 as shown in Exhibit 29.

16) Before moving on to enter data for the truck only lane, please review the work done to this point. In the project cost section, you should have a total project cost of about \$94.1 million (net present value of \$87.5 million).

We have completed the *Project Information* worksheet and the *Model Inputs* worksheet. To see how to enter more specific model data in the *Model Inputs* worksheet for another project, please review the earlier rail project.



**Exhibit 29: Project Information Worksheet Section 1E**

1E **PROJECT COSTS (enter costs in thousands of dollars)**

Col. no.	(1)	(2)	(3)	(4)	(5)	(6)	(7)		
Year	DIRECT PROJECT COSTS			SUBSEQUENT COSTS		Mitigation	Transit Agency Cost Savings	TOTAL COSTS (in dollars)	
	Project Support	R / W	Construction	Maint./ Op.	Rehab.			Constant Dollars	Present Value
<b>Construction Period</b>									
1	\$4,000	\$300	\$0					\$4,300,000	\$4,300,000
2	2,000	800	30,000					32,800,000	31,538,462
3	900		35,000					35,900,000	33,191,568
4	100		20,000					20,100,000	17,868,827
5								0	0
6								0	0
7								0	0
8								0	0
<b>Project Open</b>									
1				\$50				\$50,000	\$42,740
2				\$50				50,000	41,096
3				\$50				50,000	39,516
4				\$50				50,000	37,996
5				\$50				50,000	36,535
6				\$50				50,000	35,129
7				\$50				50,000	33,778
8				\$50				50,000	32,479
9				\$50				50,000	31,230
10				\$50				50,000	30,029
11				\$50				50,000	28,874
12				\$50				50,000	27,763
13				\$50				50,000	26,695
14				\$50				50,000	25,669
15				\$50				50,000	24,681
16				\$50				50,000	23,732
17				\$50				50,000	22,819
18				\$50				50,000	21,942
19				\$50				50,000	21,098
20				\$50				50,000	20,286
<b>Total</b>	\$7,000	\$1,100	\$85,000	\$1,000	\$0	\$0	\$0	\$94,100,000	\$87,502,944

The first part of the project input has been completed and we are ready to add the data for the truck only lane. In the *Project Information* worksheet, click the gray button beneath the rail and transit data box (Section 1D), labeled “Prepare Model for Second Road.” Enter a name for the project (without a file extension, “Project\_TOL” for example) and click save. The macro saves the current file, data, and results under the name specified with “Part1” appended (e.g., “Project\_TOL.Part1.xlsm”), and creates another file (e.g., “Project\_TOL.Part2.xlsm”) for the truck only lane input and results.

Most of the *Project Data* should not change between the general lanes and the truck only lane: the type of project, location, construction period, and roadway type (one- or two-way) should remain constant. The user could change the length of peak period(s) if desired, but for this example it will remain the same.

In the *Highway Design and Traffic Data* section of the project information worksheet (Exhibit 30) there are a couple data points the user may specify for the truck only lane.



**Exhibit 30: Project Information Worksheet Section 1B**

1B

**HIGHWAY DESIGN AND TRAFFIC DATA**

<b>Highway Design</b>		No Build	Build
Roadway Type (Fwy, Exp, Conv Hwy)			F
Number of Truck Lanes		0	1
Number of HOV/HOT Lanes			
HOV Restriction (2 or 3)			
Exclusive ROW for Buses (y/n)			
Truck Lane Free-Flow Speed			65
Ramp Design Speed (if aux. lane/off-ramp proj.)			
Length (in miles) Highway Segment			5.0
Impacted Length			5.0

<b>Average Daily Traffic</b>		No Build	Build
Current			
Base (Year 1)			14,118
Forecast (Year 20)			16,341

<b>Average Hourly HOV/HOT Lane Traffic</b>		No Build	Build
Percent of Induced Trips in HOV (if HOT or 2-to-3 conv.)			

<b>Percent Traffic in Weave</b>		No Build	Build
Percent Trucks (include RVs, if applicable)			100%

<b>Truck Speed</b>		No Build	Build

<b>On-Ramp Volume</b>		Peak	Non-Peak
Hourly Ramp Volume (if aux. lane/on-ramp proj.)			
Metering Strategy (1, 2, 3, or D, if on-ramp proj.)			

<b>Queue Formation</b> (if queuing or grade crossing project)		Year 1	Year 20
Arrival Rate (in vehicles per hour)			
Departure Rate (in vehicles per hour)			

<b>Pavement Condition</b> (if pavement project)		No Build	Build
IRI (inches/mile) Base (Year 1)			
Forecast (Year 20)			

<b>Average Vehicle Occupancy (AVO)</b>		No Build	Build
General Traffic Non-Peak		1.30	1.30
Peak		1.15	1.15
High Occupancy Vehicle (if HOV/HOT lanes)		2.15	2.15

17) **Highway Design.** Assume that the project builds one truck only lane along the highway. The model assumes the free-flow speed is equal to the one previously set. For this example that is 65 mph. The user can change this if necessary.

Note that many of the No Build scenario cells are empty because this additional “road” (the truck only lane) doesn’t exist in the No Build scenario, so there are no highway design specifications to place here.

18) **Average Daily Traffic.** If there are more accurate data available, enter the values for the base year and the forecast year. For this example, we will leave the Cal-B/C Sketch modeled values, which are calculated as the truck volumes based on the traffic levels and truck percentage from the No Build” scenario data inputs from Part 1.



The remaining inputs in this section and the *Highway Accident Data* section can be updated by the user. The accident data and project cost data entered in Part 1 are carried over and can remain the same. For this example, the only change required is entering the 10 percent collision reduction in the *Highway Accident Rates* section in the Model Inputs worksheet, to mirror the reduction specified in Part 1. Note that the change in accident rates from the No Build to the Build need not always be the same between the general use lanes and the truck only lanes.

We have completed project input for both roads, have double-checked our data, and are ready to review the results. Having completed the data entry means that we have completed the *Project Information* worksheet and the *Model Inputs* worksheet for both roads (or in the truck only lanes case, both lane types on the road). The results are shown in the investment analysis summary in Exhibit 31.

**Exhibit 31: Results Worksheet Section 3**

3

**INVESTMENT ANALYSIS**  
SUMMARY RESULTS

Life-Cycle Costs (mil. \$)	\$87.5
Life-Cycle Benefits (mil. \$)	\$261.1
Net Present Value (mil. \$)	\$173.6
Benefit / Cost Ratio:	3.0
Rate of Return on Investment:	14.1%
Payback Period:	8 years

ITEMIZED BENEFITS (mil. \$)	Passenger	Freight	Total Over	Average
	Benefits	Benefits	20 Years	Annual
Travel Time Savings	\$159.7	\$65.4	\$225.1	\$11.3
Veh. Op. Cost Savings	\$9.2	\$2.5	\$11.7	\$0.6
Accident Cost Savings	\$11.5	\$1.7	\$13.2	\$0.7
Emission Cost Savings	\$1.7	\$9.4	\$11.1	\$0.6
<b>TOTAL BENEFITS</b>	<b>\$182.1</b>	<b>\$79.1</b>	<b>\$261.1</b>	<b>\$13.1</b>
Person-Hours of Time Saved			25,386,753	1,269,338

**Should benefit-cost results include:**

1) Induced Travel? (y/n)	<input type="text" value="Y"/>	Default = Y
2) Vehicle Operating Costs? (y/n)	<input type="text" value="Y"/>	Default = Y
3) Accident Costs? (y/n)	<input type="text" value="Y"/>	Default = Y
4) Vehicle Emissions? (y/n) includes value for CO <sub>2</sub> e	<input type="text" value="Y"/>	Default = Y

EMISSIONS REDUCTION	Tons		Value (mil. \$)	
	Total Over 20 Years	Average Annual	Total Over 20 Years	Average Annual
CO Emissions Saved	359	18	\$0.0	\$0.0
CO <sub>2</sub> Emissions Saved	108,692	5,435	\$2.9	\$0.1
NO <sub>x</sub> Emissions Saved	228	11	\$8.0	\$0.4
PM <sub>10</sub> Emissions Saved	0	0	-\$0.1	-\$0.0
PM <sub>2.5</sub> Emissions Saved	0	0		
SO <sub>x</sub> Emissions Saved	1	0	\$0.1	\$0.0
VOC Emissions Saved	27	1	\$0.1	\$0.0





## APPENDIX B: Overview of Project Types

This section provides additional information on the data and calculation methodologies in Cal-B/C Sketch by project type. As a general reminder to the reader, this appendix provides a concise description of data and methods and is not meant to be exhaustive. If additional information is sought on methods and their sources and derivations, the user should consult the Cal-B/C Resource Guide. If additional information is needed about parameters used for assessing these project types, the user should review the Cal-B/C Parameters Guide.

This Appendix discusses user entry and analytical methods for the different project types handled by the Cal-B/C Sketch model. The project types are organized into several categories as shown by the headings in the following table:

Highway Capacity Expansion	Transit Capacity Expansion	Highway Operational Improvement	Transportation Management Systems (TMS)
General Highway	Passenger Rail	Auxiliary Lane	Ramp Metering
Truck Only Lane	Light Rail (LRT)	Freeway Connector	Ramp Metering Signal Coordination
Intersection	Bus	HOV Connector	Incident Management
Bypass	Highway-Rail Grade Crossing	HOV Drop Ramp	Traveler Information
HOV or HOT Lane Addition		Off-Ramp Widening	Arterial Signal Management
Passing Lane		On-Ramp Widening	Transit Vehicle Location (AVL)
Pavement		HOV-2 to HOV-3 Conversion	Transit Vehicle Signal Priority
		HOT Lane Conversion	Bus Rapid Transit (BRT)

### MODELING FEATURES

Before discussing individual project types below, several features of the modeling process are presented here because they are common to many of the project types:

- Peak Period Impacts** – Cal-B/C Sketch accounts for a number of differences in costs of traveling during peak and non-peak periods by estimating benefits separately. A fundamental differentiating factor for peak period travel is defined by the user who enters: (a) average daily traffic (ADT) data for Year 1, (b) length of the peak period, and (c) average vehicle occupancy in the peak period. Cal-B/C Sketch has a lookup table for the percent of traffic associated with peak periods of different lengths based on California household travel surveys. The percent of daily traffic occurring during a five-hour peak period is assumed to be about 40 percent.

Since highway volume and speed data may not be available by time of day, and because methodologies for estimating speeds from volumes may vary by agency and district, Cal-

B/C Sketch calculates speed and volume in each traveling period with standardized inputs and methods. The resulting speed and volume by period, as computed with user inputs, can be adjusted by the user, if project-specific data are available. If a user overrides a calculated speed, the user should provide a reason for the change.

- **Network Effects** – In some cases, a single project is potentially large enough to have network effects or at least inter-related elements. Cal-B/C Sketch handles such cases by taking an extended corridor approach in which the impact areas aggregates all roadway, transit and related sub-projects together. The user is responsible for developing aggregated values for volumes, travel characteristics, accident rates, etc. The only exception to this are projects involving: (a) Interchange projects; (b) Bypass projects; and (c) Truck only lanes. These projects require running a macro (see Section 6, above) to account for two different roadways.

If a projects meet is better represented as a network of separate facilities, the user should consider running a travel demand model or microsimulation model first and then entering the results into Cal-B/C Corridor. Details on Cal-B/C Corridor can be found in a separate user's guide. Alternatively, Cal-B/C Sketch could be set up with facility-specific affected areas in separate models so the results of individual projects could be added together by the user.

- **Weaving** – Cal-B/C Sketch analyzes changes in performance of sections that experience roadway weaving for several project types (e.g., auxiliary lanes, freeway connectors, HOV Connectors, and HOV drop ramp projects). The analysis is focused primarily on estimating the change in travel speeds within the influence area of the weaving section. For the project types, the weaving section's influence area is generally assumed to consist of the right-most two lanes. The weaving distance, in miles, is assumed to be similar to the distance provided for on-ramp merges, which the California Highway Design Manual establishes at 1083 feet. The length of the area that affects traffic in neighboring lanes by merging is assumed to be 1500 feet on the highway.

The approach for estimating impacts adapts the American Association of Highway and Transportation Officials (AASHTO) – Highway Capacity Model (HCM) Redbook method (for auxiliary lane projects) and speed estimates derived from Texas simulations (for freeway connector, HOV connector, and HOV drop ramp projects). A primary driver in this method is to determine the flow rates of vehicles *already on* or otherwise *entering* the weaving section. Estimated volumes of traffic involved in weaving affected area are project-type dependent and computed as:

- **Auxiliary lanes** - the model estimates the percent weaving traffic as two (to account for the two right-most lanes) divided by the number of lanes in one direction and the ramp volume.
- **Off-ramp widening projects** - the percent weaving traffic is estimated as three (to account for the two tight-most lanes plus the off ramp) divided by the number of lanes in one direction.

Travel speeds in the No Build and Build scenarios are calculated with the same BPR curve that is applied throughout the Cal-B/C Sketch model. Speeds for the weaving vehicles are estimated on the Model Inputs Sheet and includes a 10-percent correction factor on AASHTO estimates, which was established by researchers testing the accuracy of the AASHTO estimates. More details can be found in the Cal-B/C Resources Guide. Travel time, emissions rates, and vehicle operating costs per vehicle are determined as a function of travel speeds and, in some cases, other factors.

While Cal-B/C Sketch does not include safety benefits from weaving improvements, due to a lack of evidence, the model includes a data entry area to enable the user to account for safety improvements on a percentage basis, if the user has a way to estimate these improvements. The default for the safety improvement is set to zero percent.

- **Queueing** - Cal-B/C Sketch calculates the benefits of relieving bottlenecks with a difference of travel speeds and time in the No Build and Build scenarios, where relevant. Highway-rail grade separations are a special application of this method. In the No Build scenario, a deterministic queuing model is used to estimate the time spent in a queue and speed traveled. The build case includes an assumption that the proposed project removes the bottleneck completely and travel speeds can be estimated with a standard Bureau of Public Roads (BPR) model. Planners and engineers should use traffic models and other design techniques to determine the best configuration that removes a queue prior to running Cal-B/C. If a proposed project does not fully remove a queue, the methodology in Cal-B/C Sketch overestimates the benefits of the project (since the model assumes the queue is fully removed). This methodology requires key inputs:
  - **Highway Free-Flow Speed (in mph)** – A variable used to estimate the travel times under free-flow conditions and representing the potential for difference with and without a traffic queue. It can be estimated as the posted speed limit.
  - **Arrival Rate (in vehicles per hour)** – This variable affects the rate of queue formation. Cal-B/C Sketch automatically calculates the arrival rate during queuing dissipation by assuming it is equal to the arrival rate during the non-peak period.
  - **Departure Rate (from a queue)** – Cal-B/C Sketch uses a departure rate lookup table for this value based on research findings.

The arrival rates and departure rates are needed for both Year 1 and Year 20. The speed and volume calculations for Year 20 are more complicated than those for Year 1 due to implicit peak spreading. Cal-B/C Sketch assumes that the arrival rates grow between Year 1 and Year 20 by the same percentage that ADT grows. This assumption can be overridden by the user. Higher arrival rates increases the number of vehicles affected and the average delay per vehicle for Year 20 must be calculated with modified formulas that take into account the peak spreading.

Cal-B/C Sketch estimates benefits for vehicle operating costs and emission cost savings in the No Build case using the estimated speeds rather than idling speeds. Accident cost

savings from projects that eliminate queues use the usual procedures. While such projects may lower accident rates due to reductions in weaving or raise accident rates due to increased speeds, evidence was not found in the research.

## HIGHWAY CAPACITY EXPANSION PROJECTS

Highway capacity expansion projects involve adding lanes or other features that provide additional capacity on roadways. Cal-B/C Sketch includes the following types of highway capacity expansion projects:

- General Highway
- High Occupancy Vehicle Lane Addition
- High Occupancy Toll Lane Addition
- Passing Lanes
- Bypass Lanes
- Intersections
- Truck Only Lanes.

Although not a highway capacity expansion project, Cal-B/C Sketch also includes pavement projects and queuing analysis (described earlier) in this project list.

### General Highway

General highway projects consist of investments that improve traffic flow and safety. Impacts to these projects are a direct function of the volume of traffic and types of vehicles that are using the facility. This category of projects has remained an option for the user to select and is generally applicable to lane additions. For other types of projects, the user should identify the specific project type being considered because some model functions and parameters are tailored to the project type. Some of the key types of data that the user will enter include:

- Highway design and traffic data (e.g., number of general traffic lanes by type, estimated free-flow speed, and length of highway segment and affected areas)
- Three-year accident data for facility
- Statewide accident rates for existing and new highway facility.

In general, Cal-B/C Sketch is designed to measure the four primary categories of benefits including: (a) travel time savings, (b) vehicle operating cost savings, (c) accident cost savings, and (d) emission cost savings. The user has the option of including or excluding the valuation of vehicle emission impacts and induced demand in the analysis.

### High Occupancy Vehicle and High Occupancy Toll Lane Addition

High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) projects are principally different from general highway projects during peak periods and thus primarily benefit commuters. During these periods, users benefit from commuter lanes because they operate as *separate highway*

*facilities*, which due to lower traffic volumes, can accommodate higher speeds. An HOV lane is usually restricted to vehicles with 2+ or 3+ occupants. By contrast, HOT lanes enable riders to join the restricted lanes by paying a toll if they do not have the required number of occupants.

Cal-B/C Sketch calculates benefits for HOV and HOT lanes by accounting for changes in travel time, vehicle operating costs, accident costs, and emissions costs. Required data include peak period and facility-specific speed, traffic volume, average vehicle occupancy (AVO), and capacity estimates in the current and forecast years. Most of the user inputs for these commuter lane analyses are similar to those for the general highway improvement case, discussed above. For instance, it is assumed that free-flow speeds on the HOV and HOT lanes and on the conventional lanes are equal.

Cal-B/C Sketch uses the average hourly HOV traffic to separate the peak period traffic into HOV and non-HOV volumes. The number of HOV lanes is used to calculate the capacity of the HOV facility, assuming a per-lane capacity of 1500 vehicles per hour for HOV lanes. Note that this capacity is lower than that for general purpose lanes.

Total travel costs are computed for each facility following a standard methodology. These effects are summed and added to non-peak period effects. The total effects with the project are compared to those without the project to estimate the project benefits. Using the traffic volumes, lane capacities, and free-flow speeds, the model calculates average vehicle speeds in the HOV and HOT lanes and general purpose lanes for the peak period. The model assumes that HOV and HOT lanes do not affect non-peak period speeds. Travel time savings are a function of the number of people using the facility and are estimated separately for HOVs and non-HOVs. For each group of vehicles, travel time savings are calculated using the appropriate volume, average vehicle speed, and AVO in the peak period. Travel time savings are calculated separately in the non-peak period.

The model assumes that all affected traffic is entered by the user. If the user enters higher traffic volumes in the Build scenario than in the No Build scenario, the model assumes that additional traffic is induced travel. By improving the flow of traffic in all lanes, HOV lanes could induce or divert additional non-HOV traffic to take advantage of the capacity freed by HOVs. The model calculates the associated benefits using consumer surplus theory.<sup>2</sup> The user has the option of ignoring the benefits due to induced travel.<sup>3</sup>

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<sup>2</sup> Under consumer surplus theory, the economic benefit to new travelers is equal to the change in consumer surplus (the area under the demand curve, but above the equilibrium price). Cal-B/C Sketch calculates the value of induced demand as 0.5 multiplied by the reduction in travel time and the number of additional travelers.

<sup>3</sup> This methodology ignores potential complicating situations. HOV lanes could attract existing HOVs from other roads or cause non-HOV travelers on other roads to form carpools and use the HOV lanes. Estimating these effects requires more complex analyses and the use of Cal-B/C Corridor.

## Passing Lanes

Passing/climbing lane projects remove heavy or slow vehicles (e.g., heavy trucks and recreational vehicles) from existing lanes, thereby improving the flow of traffic for the remaining vehicles (See Appendix A for an example of a truck climbing lane). With a passing/climbing lane, average speeds increase and accident rates drop because faster vehicles no longer need to pass slow vehicles by moving into the on-coming lane of traffic. Cal-B/C Sketch accounts for benefits in passing/climbing lane projects by:

- Computing separate benefits for normal and slow vehicles (i.e., trucks or recreational vehicles)
- Adjusting the length of the highway segment affected by the project
- Using a lower average speed in the absence of passing/climbing lanes
- Reducing accident rates in the Build scenario.

Cal-B/C Sketch captures improvements in vehicle operating costs and emissions attributable to increasing average speeds. Note that although passing lanes may reduce the variability of speeds, there was not sufficient evidence in the research to include this feature in Cal-B/C Sketch. The model accounts for changes in vehicle operating costs and emissions only through changes in average speeds.

Modeling the impact of these types of projects incorporates research that suggests that substantial time savings occur downstream of passing/climbing lanes. Accordingly, the model calculates a default “effective length” for passing/climbing lanes by adding three miles to the project length. Three miles was chosen as the default distance to represent the average length at which approximately half of the time savings are lost. This value was estimated from published research on experience using a TWOPAS simulation model. The user can change the default effective length to capture project-specific conditions. If micro-simulation data are available, the user should use Cal-B/C Corridor to estimate project benefits.

Cal-B/C Sketch calculates benefits separately for slow vehicles and other vehicles, since passing/climbing lanes benefit these two classes of vehicles differently. The user is asked to input the percentage of trucks to determine the percentage of traffic that consists of slow vehicles. If recreational vehicles make up a significant proportion of slow vehicles, recreational vehicles should be included in the truck percentage. The remaining vehicles are assumed to be affected by the slow traffic.

In the No Build scenario, the presence of slow vehicles reduces overall average speeds. The speed of slower trucks (and recreational vehicles, if appropriate) is a user input. It is expected that the desired speed of delayed vehicles is the free-flow speed for the facility. The percentage of vehicles delayed by slow vehicles depends on the traffic volume, the speed differential, and several other variables. However, the research suggests that approximately 50 percent of non-slow moving vehicles are delayed in the absence of passing lanes.

The model assumes that the average speed of non-slow vehicles is the midpoint of the truck speed and the speed the model would normally calculate (i.e., free-flow speed adjusted by the

volume-to-capacity ratio). The user can change the speeds calculated by the model if micro-simulation models are available. These models generally require significant data on grades and roadway characteristics that are generally not available.

In the Build scenario, the model assumes that non-slow vehicles are able to reach their desired speed over the effective length of the project, so the average speed for these vehicles is the speed the model would normally calculate (i.e., free-flow speed adjusted by the volume-to-capacity ratio). Slow vehicle speeds are not affected by the project and remain the same.

As a result of these calculations, the model has speed and VMT (traffic volume multiplied by the project length) for slow vehicles and other vehicles in the No Build and Build scenarios. Effects for slow vehicles and other vehicles are calculated and summed to get total effects with and without the project. All effects are calculated using the standard procedures with the exception of accident rates.

Accident rates are expected to decline with the implementation of passing lanes. For the No Build scenario, the observed accident rate for the roadway is used. For the Build scenario, accident rates are calculated based upon facility classification, and are adjusted using the percent reductions found from research. Details can be found in the Cal-B.C Reference Guide.

## **Bypass Lanes, Intersections, and Truck Only Lanes**

The analyses for bypass lanes, intersections and truck only lanes requires significant differences in the benefit calculations compared to general highway projects. Primarily, these project types involve modeling changes on two separate roadway facilities. While intersections involve two highways in different directions, bypass lanes entail an entirely new roadway (in the Build scenario) that is compared with an existing roadway from which traffic is diverted. Truck only lanes separate trucks from other vehicles into separate lanes that function like entirely different facilities. As a result, truck only lanes function like bypass projects. The only difference is that the “bypass” happens to be located next to the general purpose lanes in the case of truck only lanes. To accommodate this more complex set-up, the model includes an Excel macro function that prompts the user to enter second set of data after information is entered about the first roadway. The use of this macro is discussed in Section 6 of the user’s guide.

For interchange projects, the model prompts the user to input data for traffic on the mainline and the intersecting roadway. In this manner, appropriate volumes and speeds are used for each roadway effected by the project. The model assumes that other streets and roads are not affected, since information on these facilities are frequently not available to Caltrans and the effects are expected to be minor relative to the mainline and intersecting road.

Cal-B/C Sketch uses a similar approach for modeling bypass projects. Bypass projects require effects to be considered on both the existing highway and the bypass. Cal-B/C Sketch prompts the user to enter traffic data with and without the project for the existing highway. The model calculates traffic volumes for the bypass by assuming that traffic not using the existing roadway in the Build case uses the bypass. The user must enter the number of lanes separately for the bypass so that benefits are calculated properly.

As indicated in the project example in Appendix A, truck only lanes represent separated facilities that are dedicated lanes for trucks. In function, these facilities are no different from HOV or HOT lanes, except that the permitted vehicles are trucks, not high occupancy passenger vehicles. From a modeling standpoint, the truck lanes are similar to bypasses in Cal-B/C Sketch.

The model has incorporated a macro for truck only projects to more accurately reflect categories of data entry. For example, the macro changes the data entry page to request data on truck volume, numbers of truck lanes and free-flow speed on truck lanes. Results from the dedicated truck lanes are combined with results for the remaining highway users.

## Pavement Rehabilitation

Cal-B/C Sketch estimates the benefits of pavement improvements using data available in the Caltrans Advanced Pavement Management System (APMS). The APMS is used by Caltrans to catalog pavement conditions, determining where repairs are needed, prioritizing projects, and estimating fiscal needs for system repair. Cal-B/C Sketch accounts for changes in pavement quality on user costs associated with (a) travel speed, (b) fuel consumption, and (c) non-fuel costs.

Cal-B/C Sketch captures the user benefits associated with a pavement improvement using pavement roughness as measured by the International Roughness Index (IRI) in inches/meter. Incorporating the evaluation of pavement rehabilitation projects requires additional assumptions:

- **Rule-of-thumb deterioration curves for pavement** – Roadway pavement deteriorates under the Build and the No Build scenarios. The deterioration curves describe the likely state of the pavement in Year 20 under different vehicle loadings. It is expected that the user inputs future road roughness information. However, deterioration curves are available if this information is not known.
- **Adjustment to the speed calculations** – This accounts for changes in pavement condition due to pavement rehabilitation projects. Rougher pavement generally results in lower vehicle operating speeds. A lookup table adjusts the speed predicted in the Cal-B/C Sketch speed calculation module on the basis of pavement conditions.
- **Adjustment to fuel consumption costs** – A lookup table is used to calculate vehicle operating costs. Rougher pavement leads to greater friction and fuel consumption. The Cal-B/C Sketch fuel consumption table already considers speed. For pavement rehabilitation projects, the results of the fuel consumption table are adjusted on the basis of road roughness.
- **Adjustment to non-fuel consumption costs** – A modification to non-fuel costs for roadway rehabilitation projects is based upon changes in road roughness. Although the research shows a fairly wide range of estimates, rougher pavement generally results in greater vehicle wear and tear and higher maintenance costs. A lookup table based upon road roughness is used to adjust non-fuel costs. These changes capture the effect of pavement condition on travel times, vehicle operation costs, and emissions for pavement



projects. The effect of pavement condition on accident costs depends on local weather conditions, but is fairly slight and not included in Cal-B/C Sketch.

To analyze pavement rehabilitation projects, the user begins by selecting a pavement project as the project type. The No Build and Build scenarios of pavement rehabilitation compare current versus improved states. In order to project potential user benefits, the user costs of the two scenarios are compared, assuming that no other improvements are made (including routine maintenance). Since pavement is generally maintained in California, the model compares scenarios with pavement quality well outside the range typically experienced.

The user is asked to provide an IRI value for Year 1 and Year 20, both with and without the rehabilitation project. If the user does not know the expected IRI in Year 20, the model will calculate the value. Cal-B/C Sketch calculates the Year 20 IRI using decay relationships. The rate of decay varies by traffic loads – light, medium, or heavy - over the roadway segment in question. The pavement decay rates incorporate wear caused by potholes, cracking and patching, deformation, the environment, and age. IRI values for each year over the 20 year project life are interpolated using the Year 1 and Year 20 IRI values. These decay rates represent "rules of thumb" and should be replaced by area-specific data, if available.

Cal-B/C Sketch currently accounts for changes in user costs for variable pavement conditions. Since information on the average IRI for the entire State Highway System were not available during Cal-B/C Sketch development, the user cost calculations are calibrated at a value of 175 inches/mile - the point at which pavement roughness deteriorates from fair to poor and user costs increase. Using a higher IRI calibration results in a conservative estimate of user benefits for pavement projects.

To capture the influence of pavement quality on vehicle operating speeds, Cal-B/C Sketch adjusts the speeds calculated in the model (based upon volumes using the BPR curve) and assumed to occur at an IRI of 175 inches/mile. Separate adjustment factors are applied for cars and trucks. For cars, speeds remain unchanged from earlier Cal-B/C calculations for IRI values up to 250 inches/mile, while truck speeds are increased over existing model calculations for IRI values of 150 inches/mile and less. Non-fuel costs are not modified for IRI values of up to 125 inches/mile for both cars and trucks. Non-fuel operating costs are calibrated to 125 inches/mile, since the research suggests that this is when non-fuel costs begin to increase above the average for excellent and good pavement.

## **TRANSIT CAPACITY EXPANSION**

Transit capacity expansion projects allow transit agencies to carry additional passengers. Cal-B/C Sketch includes the following types of transit capacity expansion projects:

- Passenger Rail
- Light Rail
- Bus.

Although highway rail-grade crossings improve highways rather than transit, Cal-B/C Sketch includes this project type as a transit capacity expansion because it involved railways.

## Transit System Improvement (Passenger Rail, Light Rail, Bus)

Cal-B/C Sketch handles a variety of transit capacity expansion projects in much the same way. Whether the project entails passenger rail, light rail (LRT) or buses, the same type of data are required as inputs to an identical set of questions (see the passenger rail project example in Appendix A). The primary difference between projects actually relates to the type of improvement. For example, some transit improvements are beneficial primarily to existing riders, other projects can increase demand for new users, and still others can improve conditions for both. Benefits certainly accrue to the transit users, otherwise they would not use that mode. In addition, where diversion to transit causes a shift of users from roadways, benefits can accrue to remaining road users because of lower magnitude of driving externalities (e.g., congestion and safety).

Key inputs for estimating benefits include:

- Annual person trips
- Percent trips occurring during peak period
- Percent trips originating on parallel highway
- Annual vehicle-miles
- Average vehicles per train
- Transit accident reduction
- Average travel time on transit.

The user also enters information about parallel highway facilities for most transit projects (other than rail crossings).

## Rail Crossings

Rail grade separation projects differ from other transit projects because they involve direct impacts on roadway users, not the rail transit system itself. The primary impacts for road users are reductions in idling delays for vehicles that lead to benefits associated with time savings, vehicle operating costs, emissions, and safety.

Project impacts associated with changes in idling are computed with a built-in queueing model for automobiles and trucks. The simplified queue formation and dissipation assumes a constant hourly arrival rate and a completely clear queue between trains. The hourly arrival rate is calculated by dividing ADT by 12 hours to reflect the fact that impacts are more likely to occur during the day. Separate delays for the peak and non-peak periods are not included since train frequencies are difficult to obtain and could lead to false precision on period-specific changes.

A key user input is the average gate down time per train. Ideally, this information is obtained from direct field observations. However, these observations are complicated by the fact that freight trains may not be regularly scheduled and substantial variation can occur throughout a week,

month, or year. Passenger trains may also have schedules that vary, but the number of passenger trains is not likely to have a substantial impact on the overall benefit-cost calculation.

The gate down time is a primary determinant of the benefit-cost ratio for grade crossing projects. The impact of the gate down time is a geometric function, so doubling the gate down time more than doubles the delays at a grade crossing. In choosing appropriate gate down times, the user should consider the variations over a year and select gate down times that approximate the average delays experienced. This can be determined by testing different, reasonable gate down times and selecting the one that produces average delays. The gate down times should be supported by field observations.<sup>4</sup>

Factors that influence queueing effects include:

- **Number of Traffic Lanes (No Build)** – While the model uses these data to calculate speeds using a BPR curve for most project types, the number of lanes are used to estimate the queue departure rate for rail grade separation projects. The *Parameters* page has a standard per lane departure rate. This rate is multiplied by the number of lanes to determine the overall departure rate for a project.
- **Highway Posted Speed Limit (in mph)** – This input is needed to calculate vehicle operating and emissions costs in the Build case.
- **Annual Number of Trains** – This input is used to calculate the number of times that queues form. Since the number of train movements is easier to collect by operator, the Cal-B/C input sheets ask for separate freight and passenger rail operations information. The Cal-B/C Sketch user is expected to combine the information before entering the data in the model.
- **Average Gate-Down Time (in minutes)** – The gate down time determines the length of time that queues form and delays occur. These data could be inputs or estimated from the average train length and speed. Track charts provide information to calculate average speeds, but average train length is more difficult to estimate. Since average gate down time can be observed directly, Cal-B/C Sketch asks for this as an input. As with the annual number of trains, the gate down time varies dramatically between passenger and freight trains. Passenger trains tend to be much shorter and pass intersections more quickly. The user should enter information separately by freight and passenger rail operations.
- **Number of Highway-Grade Crossing Accidents** – Rail grade crossing accident data are collected and reported separately from normal highway accident data, so this information is not available in TASAS. The Federal Railroad Administration (FRA) collects rail grade crossing accident data for the area immediately around the intersection of the rail right-of-way and the highway. Actual 10-year historical data can be obtained from the FRA Highway-

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<sup>4</sup> If field observations are unavailable, reasonable gate down times may be calculated using the following equation:

$$T_G = \frac{\text{Average Train Length} + 12 \text{ feet} \times \text{Lanes}}{\text{Average Train Speed}} + 0.6 \text{ minutes}$$

This calculation assumes lane widths of 12 feet and a warning time of 0.6 minutes to account for the time before and after the train passes when vehicles are unable to cross.

Rail Crossing Accident Database. Alternatively, the FRA has a Web Accident Prediction System (WBAPS) that uses site specific data and a computer model to predict grade crossing accident levels. Cal-B/C Sketch can use either data source to estimate highway grade crossing safety benefits. If WBAPS data are used, Cal-B/C Sketch multiplies the predicted collisions by statewide average numbers of fatalities and injuries per collision. These averages were calculated from ten years of FRA accident data for California grade crossings. If 10-year historical data are used, Cal-B/C Sketch divides the figures by 10 to annualize the data.

- **Number of Highway Accidents** – The highway-grade crossing accident rates capture the accidents due to the intersection of the highway and the railway, which the grade separation project eliminates. A less likely benefit is that the grade crossing changes the basic configuration of the highway and lowers the accident rate for the overall highway. This benefit can be reflected in a change in the TASAS rate group for the roadway. Cal-B/C Sketch allows the TASAS accident reduction to be captured by entering the TASAS data on the *Project Information* page. After the highway accident rate information on the *Model Inputs* page is entered as “changed by user,” the TASAS data can be replaced by highway-grade crossing accident data. In this manner, both sets of safety benefits are included in the analysis. The highway TASAS data is not expected to be used often to assess project benefits.
- **Annual Average Daily Traffic (ADT)** – ADT is needed to estimate the arrival rate for automobiles and trucks at the grade crossing. The arrival rate determines queue growth.
- **Percent Trucks** – The model uses this value to separate truck and automobile benefits.
- **Vehicle Departure Rate** – Cal-B/C Sketch incorporates the vehicle departure rates found in research as a lookup table in the parameters page: 1,800 vehicles per hour for highways and 1,400 vehicles per hour for arterials. Cal-B/C Sketch is rarely used to assess collectors and local roads, but the research documented in the Cal-B/C Resources Guide provides values that can be used: 900 vehicles per hour for collectors and 700 vehicles per hour for local roads. These values have not been incorporated in Cal-B/C Sketch and must be changed manually.
- **Idling Speed (in mph)** – Cal-B/C Sketch needs a speed to estimate vehicle operating costs and emissions for time spent in queues at rail grade crossings. Consistent with other modeling standards, the idling speed is set to 5 mph to produce the best estimate of idling emissions using EMFAC data.

In addition to the travel time savings associated with reduced queues, benefits are also computed for fuel consumption and emissions costs based on change in vehicle delays. Computations use lookup tables for fuel consumption and emissions at crossings that assume a five mph travel speed and an “implied” distance. The implied distance equals the distance traveled at five mph over the estimated delay time. In this manner, fuel consumption and idling emissions are estimated for the same amount of time as the delay occurs. This methodology is intended to capture the combination of idling and acceleration, but it is likely to overestimate fuel consumption and emissions. Since the same error occurs for both the Build and the No Build, the overestimation is somewhat mitigated.

Cal-B/C Sketch estimates accident cost savings by comparing the number of automobiles and trucks involved in grade crossing accidents (as reported in the FRA Highway-Rail Crossing Accident Database) in the No Build case to the number of accidents in the Build case. Cal-B/C Sketch uses the same assumption as Illinois DOT that the grade separation eliminates all accidents at the rail crossing. Cal-B/C Sketch does not estimate any benefits due to eliminating delays after a grade-crossing accidents. Accidents at rail grade crossings typically close the railway and the highway, which causes large delays on both. The cost of the delay to freight railroads varies considerably and depends on the type of freight transported along the rail corridor. Since information on the type of freight and average accident duration is difficult to obtain, these benefits are ignored.

Grade crossing benefits should be estimated separately for passenger and freight trains and combined at the end of the analysis. In practice, the gate down times are short for passenger trains and the schedules are infrequent. As a result, the benefits associated with passenger trains are minimal. The user can ignore passenger trains and capture most of the benefits by simply modeling the freight trains. However, passenger trains should be included if they are an important factor at a crossing.

Cal-B/C Sketch can approximate the benefits of consolidating crossings. Consolidation occurs when some crossings are closed, while others are grade separated. To estimate these benefits, the user should input the total number of lanes for all crossings and the total traffic for all crossings as if they were a single crossing. This approach ignores any additional travel time associated detours, but it would be difficult to obtain this information (and equilibrium travel patterns) without additional detailed analysis.

## OPERATIONAL IMPROVEMENTS

Operational improvements allow agencies to get more productivity or throughput on highways without expanding the system. Cal-B/C Sketch includes the following types of operational improvements:

- Auxiliary Lanes
- Freeway Connectors
- HOV Connectors
- HOV Drop Ramps
- Off-Ramp Widening
- On-Ramp Widening
- HOT Lane Conversion
- HOV-2 to HOV-3 Conversion.

### Auxiliary Lanes

Cal-B/C Sketch analyzes benefits of new auxiliary lanes as simple weaving sections. Cal-B/C Sketch uses formulas originally developed in AASHTO's 2000 Highway Capacity Manual (HCM)

to estimate speeds in the No Build and Build scenarios. Cal-B/C Sketch adjusts the HCM results by 10 percent to account for an under-prediction of highway speeds identified in academic research. Further information on this adjustment can be found in the Cal-B/C Resources Guide.

Key factors that influence an auxiliary lane include:

- **Ramp design speed** – The design speed (in mph) for the on-ramp that the auxiliary lane extends is used to estimate the speeds of traffic involved in weaving.
- **Percent of highway traffic involved in weaving** – This factor establishes the volume of traffic on the mainline highway that is involved in weaving (in vehicles per hour). Cal-B/C Sketch provides a default value for this percentage by assuming that only traffic in the two right-most lanes are involved in weaving and that traffic is evenly dispersed across all lanes. Cal-B/C Sketch also assumes that the user enters information for one direction only, so the percentage is calculated as two divided by the number of lanes.
- **Hourly on-ramp volume** - The volume at the auxiliary lane on-ramp in vehicles per hour (vph) during a typical peak and non-peak hour is provided as a default value for peak periods of 1350 vph or separately estimated by the user.<sup>5</sup> This volume compares with a 300 meters auxiliary lane, whenever ramp volumes exceed 1500 vph – a value consistent with the California Highway Design Manual. The model estimates non-peak period hourly ramp volumes using the peak period input, the length of the peak period input, and the percent ADT occurring during a typical peak hour. This results in a default of 556 vph if the 1350 vph default is not changed.
- **Length of the project** – The No Build length (in miles) should equal the on-ramp without the auxiliary lane whereas in the Build scenario, the length should equal the on-ramp plus the auxiliary lane.
- **Length of the area affected by the auxiliary lane** – The user enters the distance over which speeds on the highway are improved by the auxiliary lane. The model includes a default of 1500 feet.

Travel time benefits are calculated using the method contained in the AASHTO HCM documentation for analyzing simple ramp weaves. The model calculates both before and after speeds for trucks and other weaving vehicles. Speeds are calculated separately using for No Build and Build segment lengths. The user can change the speeds estimated by the model in the “Model Inputs” sheet if project-specific data are available from simulation models. A correction factor of 10 percent is applied to account for under-predictions of speeds.

Cal-B/C Sketch assumes that all trucks on the highway are influenced by weaving since trucks and other heavy vehicles must remain in the two right-most lanes of the highway. The remaining percentage of traffic that is influenced by weaving on the highway is assigned to a category of vehicles called “weaving vehicles.” The volume of traffic on the on-ramp is added to this category, since these vehicles are also involved in the weave.

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<sup>5</sup> This value is based on the average capacity of a freeway ramp according to the AASHTO Redbook (which lists capacities between 1300 vph for ramps in the urban core and 1400 vph in rural, suburban, and other urban areas).

Changes in vehicle operating costs and emissions are estimated as a function in speed improvements that result from auxiliary lanes facilitating weaving. Benefits are estimated over the affected area. Operating cost and emission rates are not adjusted. Cal-B/C Sketch allows safety rates to be adjusted by a percentage entered by the user on the *Model Inputs* page.

The Cal-B/C Sketch methodology ignores potential induced demand from parallel arterials. The methodology also does not consider the impacts of lane configuration, the spacing of intersections, and other factors that may influence the effectiveness of auxiliary lanes.

## Freeway Connectors

Cal-B/C Sketch provides a methodology for estimating the benefit of two types of freeway connector projects: (a) adjustments that improve major weaving sections; and (b) geometric corrections on existing connectors. Cal-B/C Sketch allows the user to enter data for both roads using a macro that prepares data for a second road.

### *Weaving Improvements*

For freeway connector projects that improve weaving at both ends of the connector, the user must analyze each weaving section separately in Cal-B/C Sketch.<sup>6</sup> Speed and volume data for traffic in the weaving section can be developed through simplified methods or from output of simulation models. If microsimulation outputs are available, the user should estimate the benefits using Cal-B/C Corridor rather than Cal-B/C Sketch. If the user chooses to use Cal-B/C Sketch, these data should be entered in the *Model Inputs* sheet.

The model can also estimate speed changes due to weaving using simple rules of thumb. The model calculates the No Build speeds using a lookup table that provides percent reductions in speed. Details on the lookup table are provide in the Cal-B/C Resource Guide. The user must enter a percentage of traffic on the highway that is affected by weaving. The model provides a default of 2.5 percent, but the user can modify this percentage if better data are available. The percent weaving represents the number of vehicles initiating weaving movements that impact every other vehicle on the highway.

Travel time impacts are estimated from No Build and Build speeds. These speeds are estimated using the lookup table and the percent weaving (or inputted by the user in the *Model Inputs* sheet with data from a simulation model). If the lookup method is used, Cal-B/C Sketch uses the lookup table to estimate speeds for the No Build scenario only. Build scenario speeds are estimated using the standard BPR curves found in Cal-B/C Sketch. This approach assumes that the new freeway connector corrects the weaving problem. If this is not the case, the user must adjust the speeds in the Build scenario.

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<sup>6</sup> Unlike auxiliary lanes, traffic is not separated into weaving and non-weaving vehicles since all vehicles on the highway are impacted by weaving.

Safety benefits are calculated using the safety improvement factor. Since the default is set to 0 percent, most projects will not have safety benefits. However, the user can override this default value if project-specific information or more up-to-date research is available.

### ***Geometric Corrections***

For these projects, the user must enter the No Build and Build design speeds for the project as the actual speeds. These adjustments can be made on the *Model Inputs* worksheet of Cal-B/C Sketch. The model estimates travel time savings from the changes in travel time estimated from these speeds.

Cal-B/C Sketch estimates emissions and vehicle operating cost benefits from any change in speed in the No Build and Build scenarios. The rates do not change. Safety benefits are calculated from statewide accident rates associated with the before and after facility types. The user must enter the statewide accident rates by accident type for the before and after facility types.

## **HOV Connectors**

HOV connectors are similar to general freeway connectors, except that only HOVs can use them. Cal-B/C Sketch analyzes HOV connectors in a manner similar to the one used for freeway connectors that improve weaving. The user must analyze each weaving section separately for HOV connector projects that improve weaving at both ends of the connectors. Cal-B/C Sketch allows the user to enter data for both sections using a macro that prepares data for a second road.

The inputs for HOV connector projects are also similar to those for freeway connector projects that improve weaving. However, the user must enter the HOV lane volume and the average vehicle occupancy (AVO) restriction for HOV lanes to estimate benefits correctly. The user must also provide the percentage of HOV traffic that connects between the two highways. As with general freeway connectors, the user must analyze the impacts on each freeway separately and add the benefits, while making sure not to count benefits and costs twice.

The use of detailed microsimulation data is the preferred approach to estimating the benefits of these projects. In this case, the user should enter the data into Cal-B/C Corridor. If the user does not have detailed microsimulation data, Cal-B/C Sketch provides rule-of-thumb data in the lookup table for freeway connectors, which also includes a column for HOV connectors and HOV drop ramps. Information about this lookup table can be found in the Cal-B/C Resources Guide.

The model separates weaving HOV traffic from other HOV traffic, so that the benefits can be estimated separately. The user should enter the percent weaving as the percentage of HOV traffic that is weaving (i.e., using the HOV connector). The model provides a default value of four percent. The weaving HOVs are treated in the model as weaving vehicles, while the other HOVs are treated as HOVs. However, the travel time benefits for both groups are calculated using the appropriate AVO for HOVs. The weaving affects both the weaving HOVs (“weaving vehicles”) and the other vehicles on the mainline freeway. The speeds calculated from the lookup table are used



for weaving vehicles and non-HOVs. Speeds for HOVs (those that remain in the HOV lanes) are calculated using the standard BPR curve in Cal-B/C Sketch.

Vehicle operating and emission cost savings are calculated using the same method as for freeway connectors. Safety benefits are estimated using the change in connector types (if one occurs), since HOV-specific rates are not available.

Cal-B/C Sketch assumes that all HOVs connecting between freeways use the HOV connector. The model ignores any positive or negative impact of the HOV lane on through HOV traffic. Cal-B/C Sketch also ignores the impact on existing freeway connectors caused by diverting HOVs to HOV connectors.

## HOV Drop Ramps

HOV drop ramps function similarly to HOV connectors, except that they allow HOV lane users direct access on and off the freeway rather than direct access to another HOV lane. As a result, Cal-B/C Sketch models HOV drop ramps using the same methodology as HOV connectors. Each side of the freeway and each on-ramp and off-ramp are analyzed as separate projects. Benefits and costs can be summed across projects if the user wants a benefit-cost ratio for the full set of improvements.

The user inputs for HOV drop ramps are the same as for HOV freeway connectors, except that the user must provide the percent of HOV traffic exiting or entering the freeway rather than the percent of HOV traffic connecting between highways. Cal-B/C Sketch calculates the benefits of HOV drop ramps similar to those for HOV freeway connectors. The user can also enter detailed speed and volume data on the *Model Inputs* worksheet if these data are available from simulation models or detailed studies. Alternatively, the user can enter these data into Cal-B/C Corridor.

Cal-B/C Sketch ignores the impact on existing general purpose on-ramps and off-ramps caused by diverting HOVs to HOV drop ramps. The model also ignores any impact HOV drop ramps have on HOV through traffic. The model assumes that all HOVs entering or exiting the highway use the HOV drop ramps.

## Off-Ramp Widening

Off-ramp widening projects benefit highway users by reducing queues and associated weaving at the junction of highways with off-ramps. In the No Build scenario, Cal-B/C Sketch assumes that queuing at the off-ramp spills onto the highway causing vehicles in the right-most lane to merge.

Cal-B/C Sketch models these projects in a manner similar to that for auxiliary lanes for travel time, vehicle operating cost, and emissions reductions. The model assumes that traffic in the right-most lane merges into other highway lanes to avoid the queue that extends from the off-ramp onto the mainline freeway. The right-most lane operates like an on-ramp and the next two lanes are influenced by merging as would occur for the two right-most lanes with an auxiliary lane. Off-ramp widening projects also provide safety benefits due to reduced end of queue collisions. Except for safety, the user benefits of off-ramp widening and auxiliary lanes are modeled similarly.

Key factors that influence the benefits of these projects include:

- **Ramp design speed** – Ramp design speeds are used to estimate the speeds of traffic involved in weaving. For an off-ramp widening project, this is the approaching speed for traffic in the right-most highway lane. A default value of 35 mph is provided to reflect a typical ramp design speed in California. Unless the user has a better estimate of the approach speed for traffic in the rightmost lane (value should be less than the highway free-flow speed due to weaving), this default value should remain unchanged.
- **Percent of mainline highway traffic involved in weaving** (in vehicles per hour) – Cal-B/C Sketch provides a default value for this percentage by assuming that traffic in the three right-most lanes (the right-most lane plus the two neighboring lanes) are involved in weaving and that traffic is evenly dispersed across all lanes. Cal-B/C Sketch also assumes that users enter information for one direction only, so the percentage is calculated as three divided by the number of lanes. Note that the on-ramp volume is not needed for off-ramp widening projects as it is for auxiliary lane projects, since the right-most lane is assumed to function like an on-ramp.
- **Weaving distance** – This distance (in miles) relates to the length that traffic in the right-most lane must travel to merge into the two next lanes and avoid the end of the off-ramp queue. While this distance can be influenced by many factors, such as curvature, sight distance, weather, and driver aggressiveness, the typical distance is probably similar to the distance provided for on-ramp merges. The Cal-B/C Sketch model uses a fixed value of 1083 feet for on-ramps, based on the California Highway Design Manual.
- **Length of the area affected by weaving** – This value reflects the distance over which traffic in neighboring lanes is affected by merging from the right-most lane. As for auxiliary lanes, the model provides a default impact area of 1500 feet on the highway.

Cal-B/C Sketch estimates the impacts of off-ramp widening as similar to those for auxiliary lanes. Travel time benefits are calculated using the HCM method for analyzing simple ramp weaves and includes a correction factor of 10 percent for under-predictions of speeds. Documentation of this 10 percent correction can be found in the Cal-B/C Resources Guide. Cal-B/C Sketch assumes that all trucks on the highway are influenced by weaving. The remaining percentage of traffic that is influenced by weaving on the highway is assigned to vehicle category called “weaving vehicles.”

The model calculates speeds for trucks and other weaving vehicles in the No Build scenario using the default length of the acceleration lane, discussed above. Speeds for other vehicles are calculated using the standard Cal-B/C Sketch method (BPR curve). Travel time benefits are estimated over the affected area (default = 1500 feet). Users can change the speeds estimated by the model in the *Model Inputs* worksheet if project-specific data are available from simulation models. However, benefits are better estimated in Cal-B/C Corridor if simulation data are available.

Benefit estimation includes a computation to account for changes in vehicle operating costs and emissions as a function in speed improvements that result from auxiliary lanes facilitating weaving. Benefits are estimated over the affected area. Operating cost and emission rates are not adjusted in the Build scenario. For safety benefits, accident rates are assumed to be reduced

by half based on research findings. This assumption is included in the parameters section of the model and can be adjusted by the user. More details on this methodology can be found in the Cal-B/C Resources Guide.

## On-Ramp Widening

Cal-B/C Sketch estimates the benefits of on-ramp widening as improving the quality of ramp metering. Widened on-ramps provide increased storage facilities for vehicles waiting for ramp meters and reduce the chance of ramp metering benefits being reduced by queue control strategies. The benefits of increase storage capacity are estimated as the benefits of the ramp metering strategy on the corridor lost due to inefficient ramp metering and queue control.

The benefits of on-ramp widening are estimated by calculating the benefits of ramp metering along the corridors. These benefits are multiplied by the percent improvement in metering quality to determine the benefits due to on-ramp widening. Key factors that influence the benefits of these projects include:

- **Hourly ramp volume** – This value reflects the on-ramp volume during the peak period and is used to determine the quality of ramp metering.
- **Cars per green signal** – The number of cars that are allowed per each green of the ramp meter signal.

Cal-B/C Sketch estimates the benefits of ramp metering on the corridor using the methodology outlined for ramp metering. The benefits are estimated using the same methodology as found in the Caltrans TMS Master Plan for upstream adaptive queue control. However, an adjustment is made in the speed and volume adjustment factors. With ramp metering, the project adds ramp metering to a corridor that does not have metering. With on-ramp widening, the corridor already has ramp metering. This metering needs to be “turned off” in the No Build scenario, so the factors are reversed. The estimated benefits are multiplied by 100 percent minus the percentage of metering availability (metering quality). The resulting benefits indicate the difference between existing ramp metering and improved ramp metering and are presented as the benefits of ramp storage.

The model assumes that the primary reason for widening the on-ramp is to improve the efficiency of ramp metering by reducing the need for queue control. It is also assumed that ramp metering already exists on the corridor. If not, the addition of TMS field elements to accommodate ramp metering strategies should be analyzed as a separate project. In addition, Cal-B/C Sketch assumes that the benefits of on-ramp widening occur only during the peak period.

## HOT Lane Conversion and HOV-2 to HOV-3 Conversion

The HOT lane conversion project type is similar to the HOV lane addition project type, but it requires an additional assessment of user groups and the potential for benefits. User groups are defined in Exhibit 32 by their choice of taking a HOT lane in the Build scenario. Induced trips, as will be discussed below, is an important generator of value from these projects. For most project types, Cal-B/C Sketch estimates benefits on the basis of user groups defined by how the vehicles

are being operated rather than where the vehicles are located. As an example, Cal-B/C Sketch expects the user to input an HOV volume in the No Build case for an HOV lane addition project even if no HOV lane exists in the No Build case. This HOV volume represents the number of vehicles that *would have* qualified as HOVs if a lane existed. Since a HOT lane involves some SOV vehicles becoming toll paying vehicles that use the HOT lane, Cal-B/S Sketch needs to consider where the vehicles are located to evaluate the benefits of a HOT lane.

**Exhibit 32: User Groups Involved in HOV-to-HOT Lane Conversions**

User Group	No Build Location	Build Location	Potential for Induced Trips
1. SOV → SOV	GP	GP	Possible
2. SOV → Toll Paying	GP	HOV	Possible
3. HOV-3 → HOV-3	HOV	HOV	Unlikely
HOV-2 → Toll Paying	HOV	HOV	Unlikely
4. HOV-2 → General Purpose	HOV	GP	Unlikely

GP = General Purpose Lanes

HOV = HOV Lanes

Benefit estimation relies on a consumer surplus approach when induced demand occurs. HOT lanes can induce additional demand among single occupancy vehicles (SOVs). The prospect of free-flow conditions on HOT lanes may encourage additional SOVs to pay a toll and use the corridor. It may also encourage some SOVs to be occasional HOT lane users. In this case, a proportion of these additional users will use the general purpose lanes on a given day, so the induced travel appears in both the HOT lanes and the general purpose lanes. However, the other user groups are unlikely to have induced demand, because they previously had the option of using HOV lanes. Additional HOV-2s would not be encouraged to pay for HOT lane use – a privilege that was previously free. If the HOT lane provides more free-flow conditions on the HOT lane, there may be a few induced HOV-3s (new trips, not HOV-2s that decide to form HOV-3 carpools). Cal-B/C Sketch ignores this induced travel because it is likely to be small.

The estimation of consumer surplus requires Cal-B/C Sketch to calculate changes in trips, based on changes in AVO, between the No Build and Build scenarios. Cal-B/C Sketch explicitly calculates the number of trips in the travel time benefit page before estimating the travel time and induced travel benefits. Cal-B/C Sketch also has a table in the model inputs page, so the user can verify that the values of AVO, average daily traffic (ADT), hourly HOV volume, and percent trucks produce the expected annual number of person-trips.

Since induced trips can occur on the general purpose lanes or the HOT lanes, the user must enter the percent of induced trips occurring on the HOT lanes. The model assumes that 100 percent of the trips occur on the HOT lanes, but the user can change this percentage. The adjustment for where the induced travel occurs is made in the non-HOV and truck induced benefit calculations, which subtract the entire benefit when induced demand is excluded and half of the benefit when induced demand is included. The full and half benefits are excluded because the entire travel time benefit was included in the travel time calculation and this needs to be adjusted by the “rule of one-half” (i.e., consumer surplus is half the travel time benefit).

Factors in the Cal-B/C Sketch model that influence the benefits of HOT lane conversions include:

- **Average Vehicle Occupancy (AVO)** – Detailed estimates of vehicle occupancies are required for general purpose HOV and HOT lanes. Although districts survey existing HOV lanes, these data are often inadequate to predict the impact of an HOV-to-HOT lane conversion or the addition of a HOT lane on vehicle occupancy. Cal-B/C Sketch requires the user to specify AVO data on the project input page. In addition, the model user should verify that the inputted AVO are consistent with the appropriate number of trips made in the No Build and Build scenarios.<sup>7</sup>
- **Travel Demand Elasticity** – Analyses of HOV and HOT lanes must incorporate the demand response of users' choices for high-occupancy lanes over general purpose lanes. This elasticity of demand is particularly important for HOT lanes. The Cal-B/C Sketch approach assumes that the elasticity is estimated correctly outside the model. Since the demand elasticity is particular to each HOT lane setting and other factors, Cal-B/C Sketch operates on the assumption that demand elasticities for HOT lane projects continue to be estimated outside Cal-B/C Sketch. Data submitted for Cal-B/C Sketch should be reviewed carefully to ensure that the same (implied) demand elasticities are used to forecast revenues and estimate project benefits.
- **Toll-Paying Users** – Vehicles that lack the minimum number of occupants can pay tolls to join HOT lanes. To estimate the demand for toll-paying users, the Cal-B/C Sketch model recognizes that some current SOVs will choose to pay tolls and use the HOT lanes and thus experience different build conditions than the SOVs that remain in the normal lanes. HOV-3s (including vehicles with more than 3 people) continue to qualify for HOT lane use in a HOT lane conversion. Depending on whether there is an HOV requirement change, HOV-2s may not qualify for HOT lane use. If HOV-2s are required to pay tolls, some may chose to remain in the HOT lanes, while others choose to use the general purpose lanes and pay no toll. Like the HOV-3s, the HOV-2s that choose to pay tolls remain in the HOT lanes and experience travel conditions in the HOT lanes in the No Build and Build scenarios. Since HOV-3s and toll-paying HOV-2 experience the same travel conditions, they can be collapsed into a single group.
- **BPR parameters** – Cal-B/C Sketch incorporates parameter values in the BPR model for HOTs lanes to establish a close connection between travel speeds in these lanes and traffic volumes, particularly as the volumes approach and surpass 1500 vphpl.
- **Lane Capacity** – The Cal-B/C Sketch model includes a separate lane capacity to use in the BPR curves for HOV and HOT lanes. This capacity is set at 1600 vphpl as a default.
- **Free-Flow Speed** – Cal-B/C Sketch uses a single free-flow speed for the general purpose lane and the HOV and HOT lane speed calculations.

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<sup>7</sup> This input data should be checked carefully to make sure they are not inflated to produce higher project benefits. For HOV-2-to-HOV-3 conversions, Cal-B/C Sketch solves for the peak period general traffic AVO that ensures the number of trips remains unchanged. However, in the case of HOT lane conversions, the additional opportunities for SOVs may lead to induced demand (i.e., more trips in aggregate).

The Cal-B/C Sketch model estimates benefits for HOT lanes using methods applied to other project types. For example, vehicle operating and emission cost savings use the same approach for fuel consumption and emissions parameters associated with fixed speeds. While HOV and HOT lanes have the potential to influence vehicle operating costs and emissions through speed cycling as a result of merging, no research could be found to parameterize this impact. In addition, the model does not include default values for safety and relies on users to establish project-specific data. Cal-B/C Sketch excludes toll revenues from the benefit-cost evaluation because they are transfers from users to the operating agency. Finally, although commuter lane violations can impact operational performance and the estimation of benefits for individual user groups, Cal-B/C Sketch does not adjust any input data for potential violation rates. It is assumed that these are correctly included in the forecasted traffic volumes.

## TRANSPORTATION MANAGEMENT PROJECTS

Transportation management projects, also called intelligent transportation system (ITS) projects, use information and control strategies to help agencies to manage the system for greater performance. These strategies can apply to both highways and transit. Cal-B/C Sketch includes the following types of transportation management projects:

- Ramp Metering
- Signal Coordination with Ramp Metering
- Incident Management
- Real-Time Traveler Information
- Arterial Signal Management
- Automatic Transit Vehicle Location and Scheduling
- Transit Vehicle Signal Priority.

In addition, Cal-B/C Sketch includes bus rapid transit as a transportation management project type because the methodology to model bus rapid transit is similar to transit vehicle signal priority.

### Ramp Metering

Cal-B/C Sketch is designed to estimate the benefits of implementing simple ramp metering strategies on corridors that do not currently have ramp metering. The analysis framework is designed to make the best use of basic data on traffic activity, but if detailed micro-simulation data are available, the user can override default values for highway speeds and volumes estimated by the model. A more detailed analysis can be conducted in Cal-B/C Corridor and this is the preferred analysis tool if micro-simulation data are available.

In Cal-B/C Sketch, a critical entry for the user to establish a data entry mode comes from answering yes or no to the question: “Is detailed data available?” The model automatically selects yes if the user enters any data in the boxes for ramps and arterials. If yes is entered, the model estimates benefits for the ramps and arterials using data provided by the user. If no is entered, the model estimates benefits for the ramps and arterials as percentages of the highway benefits using the default values from the Caltrans TMS Master Plan. Caltrans prepared the original TMS

Master Plan in 2002 to make the business case for TMS investments in California. Cal-B/C estimates benefits consistent with the TMS business case analysis.

More details on the Cal-B/S Sketch methods are described below and in the Cal-B/C Resource Guide.

### ***Case 1: Detailed Data Is Available***

Cal-B/C Sketch typically estimates detailed volume and speed data for highway projects from simple inputs and presents the results for the user to verify in the *Model Inputs* worksheet of the model. Speeds are calculated using a standard BPR curve. When detailed data are available, the model calculates the user benefits on the ramps and arterials using the standard Cal-B/C Sketch methodology, but with the ramp and arterial speeds and volumes. Cal-B/C Sketch includes a statewide accident rate for arterials in the parameters section of the model. This rate is used to calculate safety benefits on the arterials. Although the user can change the accident rate, the model uses the same accident rate for the No Build and Build scenario so benefits are a function of the change in vehicle-miles traveled only.

Key inputs that affect benefits include:

- **Highway speeds and volumes** – The user needs to input speeds in mph and volumes in vehicles for the peak period in Year 1 and Year 20 in the No Build and Build scenario. The information provided for the “peak period” should reflect the hours the metering is active and that were modeled. The data can be for a single highway or several in aggregate, depending on what was modeled in the micro-simulation providing the data.<sup>8</sup>
- **Aggregate ramp length** – The length of on-ramps along the corridor should be consistent with the length coded in the model providing input data rather than the actual design length, so that travel time estimates on the ramps are accurate. The user can estimate the appropriate aggregate ramp length by dividing the total vehicle-miles traveled (VMT) on the ramps by the total ramp volume.
- **Ramp speeds and volumes** – Cal-B/C Sketch estimates benefits only for the peak period (i.e., when the metering is active) regardless of the actual hours or length of the period. The user should input speeds in mph and volumes in vehicles in Year 1 and Year 20 in the No Build and Build scenarios and in aggregate for all ramps modeled.
- **Aggregate arterial length** – The total length of arterials along the corridor can relate to a single arterial or an entire network, depending on what was modeled in the micro-simulation model. The user can estimate the appropriate aggregate arterial length by dividing the total vehicle-miles traveled (VMT) on the arterials in the simulation network by the total volume on the arterials.

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<sup>8</sup> Note to users: this information should be input into the detailed highway data in Box 2A of the “Model Inputs” sheet. Cal-B/C Sketch estimates speeds and volumes using the TMS Master Plan rules of thumb, but these data can be overridden by the user entering data in the green cells.

- **Arterial speeds and volumes** – The user should input speeds in mph and peak period volumes in Year 1 and Year 20 in the No Build and Build scenarios in aggregate for the arterial(s).

### *Case 2: Detailed Data Is Not Available*

If detailed data are not available for ramp metering project, Cal-B/C Sketch calculates highway speeds and volumes similar to other project types. However, they are adjusted to account for the ramp metering impacts using rule of thumb percentages consistent with the TMS Master Plan. The speed and volume adjustments are found in a lookup table in the parameters section of the model. The user can review and adjust these estimates in the *Model Inputs* section (although this is not recommend if detailed data are not available). Key factors in the model include:

- **Number of hours of ramp metering operation** – This value should equal the duration of the active ramp metering hours. To check these data, the average percent of average daily traffic (ADT) that occurs during a peak hour (found in the parameters section of the model) must be adjusted so that the total percent of ADT calculated for ramp metering operation is correct.
- **Number of lanes** – This variable accounts for the portion of the freeway impacted by ramp metering.
- **Average daily traffic** – The user should enter in the model the average daily traffic as would be entered for other highway projects. If the user chose to enter highway volumes for the ramp operating period only, then the length of the peak period and the percent ADT during a peak hour should be adjusted so that the peak period equals 100 percent of ADT.
- **Highway capacity per lane** – Cal-B/C Sketch includes a default for the per-lane capacity of a highway (i.e., 2000 vehicles per hour per lane, vphpl). The user should not change this capacity, even if ramp metering is expected to affect the capacity. Cal-B/C Sketch estimates speeds using a BPR curve calibrated to 2000 vphpl and adjusts these speeds for ramp metering impacts using rules of thumb consistent with the TMS Master Plan. Adjustments to the highway capacity will change the speeds estimated.
- **Number of metered on-ramps** – Although this information is not needed for Cal-B/C Sketch, it should be provided by Caltrans districts so the capital, operating, and maintenance costs provided can be compared to those in the TMS Baseline Inventory.

Travel time savings for the highway section are calculated using the resulting speed and volume data. The detailed calculations also include estimates of benefits (or dis-benefits) occurring on ramps and arterials. These are estimated as percentages of the benefits occurring on the highway since detailed ramp and arterial data are not available. The default values used to estimate these benefits are included in the parameters and are consistent with the TMS Master Plan. The final benefit calculation is adjusted using an adjustment factor.

Benefits for vehicle operating cost savings, accident cost savings, and emission cost savings are calculated in a similar manner. The model uses the speed and volume data found on the *Model Inputs* worksheet to estimate highway benefits using the standard Cal-B/C Sketch methodology. Ramp and arterial benefits and dis-benefits are added as percentages of the highway benefits



and the final benefit calculation is adjusted. The impact of ramp metering on the number of accidents is calculated as a 30-percent decrease in the overall highway accident rate based on research findings documented in the Cal-B/C Resource Guide.

Cal-B/C Sketch assumes that the project has been scoped correctly to include the field elements and associated costs to implement ramp metering strategies fully. The TMS Master Plan takes a corridor approach to ramp metering deployment. This is also consistent with Caltrans' direction towards corridor planning. However, unlike some of the other improvements analyzed in Cal-B/C Sketch ramp metering could be deployed discontinuously (and have few benefits). For example, a length of highway corridor may have five on-ramps, but only three of these are equipped with ramp metering capabilities. Cal-B/C Sketch assumes that the user has entered data for homogenous (metered or not) segments.

Arterial facilities may experience different accident rates than the highway. Cal-B/C Sketch assumes that the accident rate on the arterials equal the statewide average and that ramp metering does not affect the arterial accident rate. Vehicle operating cost and emission rates are assumed to be the same across all three facilities: highway, ramps, and arterials. The default TMS adjustments include very conservative assumptions about emissions at ramps to make sure benefits are not overstated.

## Signal Coordination with Ramp Metering

The analysis framework for signal coordination with ramp metering is nearly identical to the methodology for ramp metering. As with ramp metering, the user may enter detailed data for the highway, ramps, and arterials and the model estimates benefits from these inputs. If detailed data are not available, the model estimates benefits using the rules of thumb developed in the TMS Master Plan, which has separate adjustments for ramp metering and signal coordination with ramp metering.

The impact calculation is the same as for ramp metering. However, the safety benefits do not include the 30 percent reduction in accident rates, since these are assumed to have already occurred with the initial implementation of ramp metering. The default speed and volume adjustments for signal coordination with ramp metering are consistent with the TMS Master Plan and differ from those for ramp metering alone.

The model makes the same assumptions for signal coordination with ramp metering as for ramp metering alone. However, the signal coordination component of the deployment is assumed to be operated only in coordination with the ramp metering components. Therefore, the signal coordination is assumed to be operational during the identical time periods that the ramp meters are operational. In addition, Cal-B/C Sketch assumes that ramp metering has been implemented prior to the coordination with signal management.

## Incident Management

The analysis framework for incident management projects is nearly identical to the methodology for ramp metering. As with ramp metering, the user may enter detailed data for the highway,

ramps, and arterials and the model estimates benefits from these inputs. If detailed data are not available, the model estimates benefits using the rules of thumb developed in the TMS Master Plan, which has different adjustments for incident management projects.

The impacts of incident management projects are calculated in a manner nearly identical to that for ramp metering with the following adjustments:

- Cal-B/C Sketch includes a default set of speed and volume adjustments for incident management projects that are consistent with the TMS Master Plan and differ from ramp metering.
- The model estimates the change in accident severity – not as an overall decrease in the number of accidents – but as a reduction in severity. The number of fatality accidents is reduced by 21 percent and the reduction is added to the total number of injury accidents in the Build scenario. The TMS Master Plan did not include estimation of accident benefits to be conservative in the benefit estimation.

For travel time savings, incident-related delay is monetized at three times the value of time to reflect the premium associated with uncertainty. Cal-B/C Sketch assumes that the project has been scoped correctly to include the field elements and associated costs to implement incident management strategies fully. Also, since arterial facilities may experience different accident rates than the highway, Cal-B/C Sketch assumes that the accident rate on the arterials equal the statewide average and that incident management does not affect the arterial accident rate. Finally, vehicle operating cost and emissions rates are assumed to be the same across all three facilities: highway, ramps, and arterials.

## Real-Time Traveler Information

A number of TMS field elements can be deployed and used in association with providing travelers with real-time traveler information, such as Highway Advisory Radio (HAR), Changeable Message Signs (CMS), and Interactive Traveler Information Systems including Telephone-Based and Web/Internet-Based Traveler Information Systems and Kiosks. The Cal-B/C Sketch model evaluates real-time traveler information as an overall corridor strategy rather than the sum of benefits associated with individual separate field elements.

The analysis framework for traveler information projects is nearly identical to the methodology for ramp metering. As with ramp metering, the user may enter detailed data for the highway, ramps, and arterials and the model estimates benefits from these inputs. If detailed data are not available, the model estimates benefits using the rules of thumb developed in the Caltrans TMS Master Plan, which has different adjustments for traveler information projects.

The impacts of incident management projects are calculated in a manner nearly identical to that for ramp metering except that the default set of speed and volume adjustments for traveler information projects are different from those for ramp metering and consistent with the TMS Master Plan.

Cal-B/C Sketch assumes that the project has been scoped correctly to include the field elements and associated costs to implement incident management strategies fully. Cal-B/C Sketch assumes that the accident rate on arterials equal the statewide average and that incident management does not affect the arterial accident rate. Also, vehicle operating cost and emissions rates are assumed to be the same across all facilities: highway, ramps, and arterials.

The resulting impacts on accidents, emissions, and vehicle operating costs should be carefully compared with observed results from real-world before and after studies of traveler information systems. These impacts of these systems have often been shown to be small in magnitude.

## Arterial Signal Management

Arterial signal management projects can include any of the following types of signal improvements: isolated fixed-time traffic signals, isolated traffic actuated signals, pre-set corridor signal coordination, actuated corridor signal coordination, and central control signal coordination. However, Cal-B/C Sketch does not include rules of thumb to estimate the benefits of these projects. They require complex modeling that is better handled in a signal optimization model. The user must first run signal optimization models and enter the results into Cal-B/C Sketch to conduct the economic assessment. While Cal-B/C Sketch supports the input of high-level information (as described below), arterial signal management projects are better evaluated in Cal-B/C Corridor using the results of the signal optimization models.

If the user chooses to use Cal-B/C Sketch, the model allows detailed speed and volume data to be entered for arterials on the *Model Inputs* worksheet. When the Arterial Signal Management project type is selected, Cal-B/C Sketch automatically prompts users to enter a variety of data that influence benefits including:

- **Aggregate segment length** – The aggregate segment length for the project that includes signal optimization along a corridor and may include cross-streets, if the optimization model includes this traffic. The segment length can be calculated as vehicle-miles traveled divided by the total volume.
- **Speed and volume data** – The user must enter speed and volume data for Year 1 and Year 20 with and without the project. Cal-B/C Sketch accepts arterial data for the peak period only. If only all-day data are available, these can be inputted in place of the peak period data and the peak period percent in the Parameters section can be modified to be 100 percent. If both peak and non-peak data are available and substantially different, the peak and non-peak analyses must be conducted separately and added.

The impact to travel time is calculated as the difference in delay between the No Build and Build scenarios. Note that if vehicle-hours of delay data are available, they can be entered directly into the detailed travel time calculation tables for arterials. Impacts to emissions and vehicle operating costs are calculated using the existing Cal-B/C Sketch methodology, based on any changes in speeds inputted by the user. If the speeds are unadjusted, no impacts to these measures are calculated. Accident impacts are estimated using standard Cal-B/C Sketch methodology, based on any changes in speeds or accident rates inputted by the user. If the speeds or accident rates are unadjusted, no impacts to these measures are calculated. The analysis does not account for

any traffic diversion to/from parallel roadways, or impacts to cross streets as a result of the project implementation, unless those impacts are included in the signal optimization analysis.

## Automatic Transit Vehicle Location and Scheduling

Cal-B/C Sketch evaluates transit TMS projects in terms of aggregate transit benefits. The user inputs include average transit travel time for in-vehicle and out-of-vehicle time. The user must input travel times in the No Build and Build scenarios. These inputs can often be obtained from regional travel models. The user may also choose to evaluate the impacts of automatic transit vehicle location and scheduling systems on transit costs. Efficiency gains due to the deployment may result in a decrease in agency capital or operating/maintenance costs. If the user chooses to include these cost reductions in the analysis, the user must enter the annual capital expenditure and the annual operations and maintenance expenditure for the transit agency. The user may also choose to adjust other transit vehicle parameters including annual vehicle-miles or the percent reduction in transit accidents. Impacts such as transit vehicle emissions and accidents are not analyzed by the framework unless the user modifies these figures.

Travel time impacts for automatic transit vehicle location and scheduling systems are calculated by comparing the travel time in the No Build and Build scenarios. Cal-B/C Sketch includes a default reduction to in-vehicle and out-of-vehicle travel time of 15 percent in the Build scenario. This default is included in the parameters section of the model and can be changed by the user. The user may also change the Build scenario travel times estimated by the model in the *Project Information* worksheet.

In-vehicle and out-of-vehicle travel times are multiplied by the Annual Transit Person Trips to calculate the travel time for the Build scenario. The user should make sure to only enter information on transit trips or routes that are affected by the project. If these routes are substantially different, then they must be analyzed separately.

Impacts on travel time for other modes due to a shift in trips to transit are calculated using the existing Cal-B/C Sketch analysis, assuming the user has entered a value in the Percent New Trips for Parallel Highway. The monetization of travel time benefits calculates in-vehicle and out-of-vehicle time separately because impacts to these performance measures are valued differently. For example,

- In-vehicle travel time is monetized using the standard travel time value applied in Cal-B/C models.
- Out-of-vehicle travel time is monetized using a value twice times the standard value of travel time. This increased valuation reflects the uncertainty, exposure to weather conditions, and concerns for security that may accompany out-of-vehicle wait times.

Changes in agency costs are calculated only if the user provides the required inputs. If these data are provided, the model applies a default two percent reduction to the *Annual Capital Expenditure* figure and applies a default eight percent reduction to the *Annual Operations and Maintenance Expenditure* figure. The resulting reductions are summed and included as a negative cost in the Project Cost calculations. *Annual Capital Cost Savings* represent a reduction in the amount of

funding required for vehicle purchases and other transit infrastructure. *Annual Operations and Maintenance Cost Savings* represent a reduction in the amount of funding required for fuel, labor, maintenance, and other continuing costs.

The valuation of benefits for emissions and accidents is consistent with other Cal-B/C Sketch methods. Emission and accident cost savings are calculated if the user indicates any changes in transit vehicle-miles of travel or accident rates. Accident and emissions benefits are assumed to be a product of a reduction in vehicle-miles traveled. Reductions in rates are not considered.

## Transit Vehicle Signal Priority

The methodology for estimating the benefits of signal priority projects is the same as for other transit TMS projects, but some of the default values are different. The user inputs for transit vehicle signal priority are the same as those for automatic transit vehicle location and scheduling systems, except that transit agency expenditure information is not needed. Signal priority projects do not result in agency cost savings.

Travel time impacts for transit vehicle signal priority are calculated as for automatic transit vehicle location and scheduling systems. However, the travel time impacts for these projects are limited to in-vehicle time only. Research by the California Partners for Advanced Transportation Technology (PATH) on bus rapid transit included transit vehicle signal priority as a component of bus rapid transit. The PATH research found that bus rapid transit systems produce aggregate savings to in-vehicle travel times of 29 percent and that one-third of this is due to the signal priority component. Cal-B/C Sketch includes a default in-vehicle travel time improvement of 10 percent for transit vehicle signal priority systems. The default value can be changed in the *Parameters* section of the model. Cal-B/C Sketch assumes that travel time benefits for non-transit arterial traffic and cross traffic cancel and ignore modeling any impacts to these travelers.

Emission and accident cost savings are calculated using the standard Cal-B/C Sketch methodology related to changes in transit vehicle-miles of travel or accident rates.

## Bus Rapid Transit

The Cal-B/C Sketch examines transit TMS projects in terms of aggregate transit benefits. The user inputs for bus rapid transit are identical to those for transit vehicle signal priority projects. Benefit estimation follows standard Cal-B/C Sketch methodologies. The travel time impacts for bus rapid transit projects are calculated the same as they are for signal priority projects. Cal-B/C Sketch includes a default reduction in in-vehicle travel time of 29 percent.<sup>9</sup> Out-of-vehicle travel times are not impacted. Emission and accident reduction cost savings are calculated using the standard Cal-B/C Sketch methodology applied to any user input changes in transit vehicle-miles of travel or accident rates. Cal-B/C Sketch assumes that travel time benefits for non-transit arterial traffic and cross traffic cancel and ignore modeling any impacts to these travelers.

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<sup>9</sup> This default is based on the PATH research into bus rapid transit systems and can be changed by the user in the parameters section of the model.



# Appendix C: Technical Discussion

## BACKGROUND AND SCOPE OF ANALYSIS

Similar to other Cal-B/C models, Cal-B/C Sketch measures, in real-dollar terms, four primary categories of benefits that result from highway and transit projects:

- Travel time savings
- Vehicle operating cost savings (VOC)
- Accident cost savings
- Emission cost savings.

Benefits are estimated for a peak (or congested) period and a non-peak (or un-congested period) for travel on some types of facilities and vehicles (Exhibit 33). The distinction is intended to capture the difference in benefits during congested and free-flow conditions on the highway as well as different operating characteristics for transit at peak times of the day. It is understood that some travel demand models have set peak periods that do not necessarily correspond to the congested period on the highway. Cal-B/C Sketch can accept these data in lieu of congested period data.

**Exhibit 33: Benefit Categories**

Facility / Vehicle Type	Benefit Category			
	Travel Time	VOC	Safety	Emissions
<b>Highway</b>				
Arterial	P	P	P	P
HOV	P	P	P	P
Non-HOV	P,NP	P,NP	P,NP	P,NP
Ramp	P			P
Truck	P,NP	P,NP	P,NP	P,NP
Weaving	P,NP	P,NP	P,NP	P,NP
<b>Transit</b>				
In-Vehicle Transit (All Vehicles)	P,NP		Combined	
Out-of-Vehicle Transit (All Vehicles)	P,NP			
Light Rail				Combined
Passenger Rail				Combined
Bus				P, NP

Note: P= peak period, and NP = Non-Peak Period

Benefits for each type of category are computed for all project types with a few exceptions:

- Transit – Includes in- and out-of-vehicle time
- Auxiliary Lanes – Accident risk reduction depends on user-input
- Pavement Rehabilitation – No accident risk reduction.

## BENEFIT ESTIMATION

This section discusses the data and formulas for computing each of the benefit categories. Due to variety of differences in computing benefits for each the facility and vehicle types and conditions shown in Exhibit 33, the discussion is limited to a more general overview. For example, the value of time savings essentially consists of the product of three factors: vehicle volume, time savings per vehicle, and value of time per vehicle. These three factors all contribute to estimating the value of time savings across the facility types, vehicle types, and travel periods that could be impacted by a proposed project, even if the units of measure of these factors differ. Where important and relevant, differences among user inputs, default parameters and any intermediate computations to determine key factors for computing the benefit categories are discussed in Appendix B.

### Travel Time Savings

Projects that reduce travel time through projects, operational improvements or transit are typically a core rationale for most roadway projects. Cal-B/C Sketch estimates delay reduction benefits for each mode and project type, as applicable, using standard valuation methods for any time savings over the life of the project. Time savings are computed as the difference in travel time for all travelers between No Build and Build scenarios. For passenger vehicles, the number of travelers accounts for the estimated average vehicle occupancy (AVO). The model calculates travel times for highway travelers based on estimates of roadway speeds and distances traveled. Since speeds vary over the course of the day, separate calculations of travel time are conducted for peak and non-peak periods. Annual benefits, based on and time savings in the Build scenario, are the present value of a twenty-year project life.

Cal-B/C Sketch assumes that the number of travelers in the No Build and Build scenarios are the same, but the user can enter different values if they have project-specific information that suggests travelers will make new trips (i.e., induced demand) as a result of the project. For instance, an HOV lane project may induce users to take trips they would normally avoid because of congestion.

The value of time savings is assumed, as standard practice, to be derived from the median wage rate. Since the values of time for people in passenger vehicles and trucks differ, benefits are also computed separately for these vehicles. In addition, the values of time for transit travelers includes estimates of time savings for both in- and out-of-vehicle time. Travel time benefits are calculated for (a) existing transit riders; and (b) new transit riders that from a parallel highway. For new transit riders from a parallel highway, the benefit is calculated based on the travel time difference between the highway and transit for the Build scenario.<sup>10</sup>

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<sup>10</sup> Note that complications can arise if the difference in travel time is negative (i.e., the travel time is smaller on the parallel highway than on transit). In this unusual case, the benefit is assumed to be zero. Since the new transit riders must have shifted models for reasons other than travel time savings and assuming that these new riders are rational in their decision making, the sum of these benefits must be positive. Accordingly, since this model may not capture all



Cal-B/C Sketch generally follows the U.S. DOT guidance for estimating the value of time for each mode. The value of time for trucks is estimated as 100 percent of the California average Transportation and Utilities wage rate plus benefits. The value of off-the-clock highway travel is calculated at 50 percent of the wage rate.<sup>11</sup> Also, U.S. DOT recommends using 50 percent of the wage rate for the value of in-vehicle travel time and 100 percent for walking and waiting time.<sup>12</sup>

Travel time savings can be calculated only for travelers that had travel times before the project was built (i.e., existing travelers). The model calculates travel time savings associated with existing travelers as the change in travel time multiplied by the number of travelers in the No Build scenario. Induced travelers do not have time savings because they were not making trips prior to the project being built. However, they do receive a benefit for making a trip or they would not be making the trips. The model values this benefit using a standard economic technique—consumer surplus theory.

Consumer surplus is the area under the demand curve and above the equilibrium price. This area equals the amount that customers (travelers) would be willing to pay above what they must pay. The change in consumer surplus is frequently used in welfare economics to estimate the benefit that new customers (travelers) receive. Cal-B/C Sketch calculates the value of induced demand as 0.5 multiplied by the reduction in travel time and the number of additional travelers. The model uses travel time as the price of travel since most travelers are not likely to consider accidents, emissions, or operating costs when making decisions.

Computations of the value of travel time savings are presented in three parts: scale of impact, impact factors, and impact value. In each case, the computations show the value of travel time and the value of time savings are the difference between No Build and Build conditions. Discussion is generalized for (a) all modes (passenger vehicle, trucks, and all types of transit); (b) all facilities (HOV, Non-HOV, ramp, weaving, arterials); and periods (peak, non-peak). In cases where variables or calculations differ among modes or context, additional notes are provided.

Scale of Impact	Impact Factors	Impact Value per Unit
Numbers of travelers by mode, facility, and period	Travel times, by mode and facility, and period	Value of time

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potential benefits (e.g., the value of reducing ones stress by not having to drive, the improved reliability of transit, etc.), the model conservatively estimates that the new transit riders do not receive a benefit, not a negative one.

<sup>11</sup> Due to the difficulty in measuring the value of stress due to congestion, Cal-B/C Sketch follows the U.S. DOT methodology and ignores any potential difference in the value of time per individual between peak and non-peak periods.

<sup>12</sup> However, the value of the disutility associated with transit travel is likely to be lower than that for private vehicles, because transit users may have the ability to spend their time doing something else, such as reading, while riding transit. Rather than require users to estimate in-vehicle time and waiting time separately for transit, Cal-B/C Sketch simplifies the methodology and uses 50 percent for all transit travel time (in-vehicle and waiting).



### Scale of Impact: $N^m \cdot AF$

Where:

- $N_{\text{period}}^{\text{mode}}$  = Number of travelers by mode and period or scenario
  - AF = Annualization Factor, equals 365 days with a standardized definition of a daily trip
- For passenger vehicle travelers, the number of travelers adjusts the number of vehicles  $V^P$  by the AVO, average vehicle occupancy, as shown:

$$N^P = V^P \cdot AVO$$

As discussed above, AVO is an important parameter in estimating benefits of projects that convert lanes to HOV, HOT, or change the minimum number of persons in a vehicle operating in a HOV lane.

For transit travelers, the model user enters a *total* number of transit travelers  $TN^T$  that is then adjusted by the percentage that travel in the peak ( $P_P$ ) and off-peak period ( $1-P_P$ ) to determine the numbers of transit travelers in each period. The peak transit travelers are determined as:

- $N_P^T = TN^T \cdot P_P$  [Peak Period Travelers]
- $N_N^T = TN^T \cdot (1 - P_P)$  [Non-Peak Period Travelers]

In addition, to account for the value of new transit travelers who shifted from a highway facility, the model computes the number of mode shift users in both the peak ( $N_P^{TS}$ ) and non-peak periods ( $N_N^{TS}$ ). The number of mode shift transit travelers is computed as the difference in transit trips between No Build (N) and Build (B) scenarios ( $N_{B,P}^T$  and  $N_{NB,P}^T$ , respectively), multiplied by the percentage of travelers who shift from a parallel highway ( $P_S$ ). For example, the number of mode shift transit travelers in the peak period is computed as:

$$N_P^{TS} = (N_{B,P}^T - N_{NB,P}^T) \cdot P_S$$

The model user has the control of whether to include this value or not. It is only applicable for certain types of improvements.

### Impact Factors: Dist

Where:

- Dist = Mean distance traveled on project length per trip by mode

### Impact Value per Unit: VOT

Where

- VOT = Value of time, in dollars per hour, varies by mode.

Note that as mentioned above, the value of time savings for induced transit riders is assumed to be half that of existing travelers.

**Total Value of Travel Time Savings, by mode =**

$$VTT^m = N^m \cdot AF \cdot \text{Dist} \cdot VOT$$



## Vehicle Operating Cost Savings

The methodology for computing operating costs in Cal-B/C Sketch is relatively simple and based upon the most recent, available data. The accuracy of a more complex model would likely be offset by the resources needed for gathering and estimating data. The overall separates fuel and non-fuel operating costs. An important feature in estimating the fuel component of VOC is the relationship between fuel consumption and speed. Since fuel rates are separated from other costs, fuel prices (minus taxes) can be updated without altering consumption rates.

The model computes fuel costs by looking up the appropriate fuel consumption rate per mile, for estimated speeds in the No Build and Build scenarios. Any difference in speed leads to differences in fuel consumption over the entire project length for each vehicle. In addition, if the model entails a change in pavement conditions, the model accounts for a change in vehicle costs under different pavement quality conditions. Overall, separate fuel consumption factors would be expected for passenger vehicles and trucks under peak and non-peak periods, as well as in highway, arterials and weaving lanes.

Non-fuel cost estimates are based upon American Automobile Association (AAA) estimates plus depreciation. These costs are applied to the change in vehicle-miles traveled (VMT) for each year of the project. VMT is calculated as annual traffic multiplied by the length of highway affected by the project.

Transit vehicle operating costs are not included since costs are borne by transit operators as a component of operation and maintenance costs. Since operation and maintenance costs are a component of total project cost, these are captured in the "cost" part of benefit-cost analysis. Therefore, reductions in transit vehicle operating costs are not counted as a benefit (i.e., cost savings) by the model. The model accounts only for savings on the consumer side, and not on the operator side.

However, transit projects that generate induced travelers from a parallel highway would gain from a lower VOC. The potential decrease in highway VOC, caused by a reduction in buses, is negligible and, therefore, is not incorporated into the highway model. All VOC savings to the remaining highway motorists are assumed to come from the reduction in other vehicle (non-bus) traffic.

Scale of Impact	Impact Factors	Impact Value per Unit
<ul style="list-style-type: none"> <li>Numbers of vehicles, by type</li> </ul>	<ul style="list-style-type: none"> <li>Travel distance by destination</li> <li>Vehicle speed, by facility type</li> </ul>	Fuel, non-fuel operating costs by vehicle type

### Scale of Impact: $V^t \cdot AF$

Where:

- $V^t$  = Daily volume of vehicles by types (t)
- AF = Annualization Factor equals 365 days

### Impact Factors: $Dist^t \cdot Fuel^t, S^t$

Where:

- $Dist^t$  = Travel distance is limited to the length of the project, by vehicle type t
- $Fuel^t$  = Fuel consumption rates, based on average vehicle speed,  $S^t$ , by vehicle type (t)
- $S^t$  = Travel speed, as provided by the tool user, for a given roadway and in No Build and Build scenarios, by vehicle type (t)

### Impact Value per Unit: $VOC^t$

Where

- $VOC^t$  = Sum of fuel and non-fuel costs, depending on the vehicle type t.

<p><b>Total Value of Vehicle Operating Costs, by mode:</b></p> $VVOC^t = [V^t \cdot AF] \cdot [Dist^t \cdot Fuel^t] \cdot VOC^t$
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## Accident Cost Savings

Accident cost savings from transportation projects are computed by determining the difference in anticipated accident costs between the No Build and Build scenarios. Accident costs are associated with accident rates and costs per event over the lifetime of a project, which is twenty years in Cal-B/C Sketch. Individual projects may improve or adversely impact vehicle accidents, so the net result may be positive or negative.

Cal-B/C Sketch uses data on costs per accident and accident rates from the best available sources. In some cases, separate accident rates are developed for passenger vehicles and trucks under peak and non-peak periods, as well as in highway, arterials and weaving lanes. The user provides data on accident rates by type (total, fatalities, and injuries) and the model solves for property damage only accidents as the difference between the sum of fatalities and injuries and total accidents. The data entered by the user reflects three years of historical accidents.

For transit projects, accidents could decline on a parallel highway due to drivers that change modes to transit. The value of this change in accident rates are calculated in the same manner as a highway-only project.<sup>13</sup> Since the user may not know accident rates for parallel highway facilities, Cal-B/C Sketch provides the statewide average highway accident rates for each accident type. The user can adjust these rates if the three-year accident data are known for the parallel highway.

The project may also impact the occurrence of accidents on transit. Cal-B/C Sketch calculates transit accident costs as a function of vehicle-miles operated. The model uses default accident

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<sup>13</sup> In most cases, users can assume that the transit project does not affect accident rates on the parallel highway and simply use the default rates (statewide averages) for both scenarios. Therefore, changes in the number of accidents are due solely to reductions in the number of vehicles using the highway. However, model users can specify different accident rates for the two scenarios, if they have more information.

rates based on U.S. DOT national averages. Since these statistics are tabulated by event (i.e., number of fatalities, injuries, and accidents), Cal-B/C Sketch calculates the value of transit accidents per event rather than by accident severity. That is, for rail modes, train-miles must be converted to vehicle-miles using the average number of vehicles per train.

Since some transit improvements may enhance safety, Cal-B/C Sketch allows the user to reduce accident rates. The user is asked to input the percent reduction in accidents anticipated as a result of the project. Since Cal-B/C Sketch calculates accident costs as a function of vehicle-miles operated, a transit project that increases vehicle-miles operated (either by extending the system or adding service), but does not improve transit safety will result in a dis-benefit for transit accident costs. However, such a project is likely to result in a decrease in accident costs on the parallel highway. Cal-B/C Sketch captures both effects.

The estimation of intersection safety benefits is presented below in three parts: scale of impact, factors in assessing impact per unit, and value of impact. Data to compute these benefits are described in Appendix C. Additional information on accident cost methodology are contained in the Cal-B/C Resource Guide. Additional information on valuation parameters is provided in the Cal-B/C Parameters Guide.

Scale of Impact	Impact Factors	Impact Value per Unit
Numbers of vehicles, by type	Travel distance	<ul style="list-style-type: none"> <li>• Accident rates, by severity</li> <li>• Accident costs, by severity</li> </ul>

**Scale of Impact:  $V^t \cdot AF$**

Where:

- $V^t$  = Daily volume of vehicles by types (t)
- AF = Annualization Factor equals 365 days

**Impact Factors:  $Dist^t$**

Where:

- $Dist^t$  = Travel distance is limited to the length of the project, by vehicle type t

**Impact Value per Unit:  $ACC^t$**

Where:

- $ACC^t$  =Sum product of accident frequencies per mile and costs per accident, by severity

$$ACC^t = (FatalAcc^t \cdot CostFatal^t + InjAcc^t \cdot CostInj^t + PDAcc^t \cdot CostPD^t)$$

$ACC^t$  , accident costs per-mile by vehicle, is derived using incident rates by accident severity (e.g.,  $FatalAcc^t$ ) and the respective cost by severity ( $CostFatal^t$ ).

**Total Value of Accident Risk Reduction, by mode:**

$$VAR^t = [V^t \cdot AF] \cdot Dist^t \cdot ACC^t$$

## Emission Cost Savings

Transportation investments have external consequences on people, whether they use the facility or not, and the natural environment. Cal-B/C Sketch focuses on the environmental impacts associated with result of travelers using the facility.<sup>14</sup> Changes related to travel speeds, vehicle trip-making, or diversion of trips all have implications for air pollution and greenhouse gas emissions.

The adverse health effects of vehicle emissions are probably the most significant environmental costs of travel. Enough is known about these effects to incorporate them readily into benefit-cost analyses. Vehicle emissions generally fall into two categories:

- Air Pollutant Emissions: Motor vehicles emit pollutants, such as carbon monoxide (CO), oxides of nitrogen (NOX), volatile organic compounds (VOC), particulate matter (PM), and oxides of sulfur (SOX).
- Greenhouse Gas Emissions (GHG): Fuel consumption releases gases that trap heat within the Earth's atmosphere, of which carbon dioxide is the most important.

The physical volumes of air-pollutants and greenhouse gas emissions resulting from travel are readily quantified since emission rates are well understood.<sup>15</sup> In addition, monetized costs of specific pollutants per unit of measure are well-established. It is important to note that a transportation project could yield benefits or dis-benefits since air pollutant emissions are based on travel volumes and speeds. Cal-B/C Sketch computes emissions benefits separately for each vehicle type and determines net benefits by comparing the value of emissions in the No Build and Build scenarios.

For highway projects, Cal-B/C Sketch incorporates separate analyses for peak and non-peak periods because emission rates vary with vehicle speeds, and the relationship is non-linear. A small change in daily average speed (e.g., 28 mph to 34 mph) may represent a very significant speed change during the peak period (e.g., 15 mph to 30 mph), and a relatively small speed change during the non-peak period. Because the emissions rate for a pollutant like NOx is highest at low speeds and at very high speeds, the peak period speed change could result in an overall reduction in the emission rate; calculating effects based on the average daily speed suggests an increase in the emissions rate. Using a single average speed over the course of the day to estimate air pollution effects is misleading.

<sup>14</sup> Construction activity can affect the environment directly through equipment emissions and noise, or indirectly by causing increased traffic congestion and vehicle emissions during the construction period.

<sup>15</sup> Other environmental effects are less significant, less understood, or difficult to quantify and value. As a result, these effects tend to be excluded from benefit-cost models. Ignored effects include: noise, hazardous materials incidents, and upstream fuel effects.

Separate emission rates were developed for automobiles and trucks using the California Air Resources Board, EMFAC emissions model. The emission rates for automobiles and trucks are based upon composite emission rates across vehicle classes (as required), for several pollutants: CO, NOX, VOC, PM<sub>10</sub>, and PM<sub>1.5</sub> from vehicle exhaust, and brake and tire wear. The emissions model provides default values for the percent of vehicles in each vehicle category (e.g., light-duty gas vehicles, light-duty diesel vehicles, light-duty gas trucks) for each year of analysis (the fleet mix assumptions change over time). Emission rates are expected to change over time as the vehicle fleet changes. Cal-B/C Sketch uses a simplified approach to address emission rate changes: current emissions rates are used for the first seven years of project benefits, and a twenty-year forecast is used for the remaining thirteen years.<sup>16</sup> Cal-B/C Sketch uses separate values for starting and running emissions.

Investment in transit projects may result in net emission benefits or dis-benefits, depending on whether the emissions reduction from new transit riders who shift modes from highway vehicles is sufficient to offset any new emissions generated by the transit project. The reduction in highway emissions is calculated using the methodology for highway projects and considers peak and non-peak emissions separately (based upon differences in average speeds). Since electric rail transit generates emissions through power-plant emissions, which do not vary by time of day, the model considers peak and non-peak differences only for transit projects involving buses.

For a transit project in an area with no existing transit service, No Build emissions are zero, and the change in emissions is equal to the project's emissions. In the case of a transit improvement project, it is necessary to examine the emission levels with and without the improvement in order to assess the incremental emissions associated with the improvement. The calculations vary with the emission characteristics and rates for different transit modes. For example:

- **Passenger Rail** (e.g., commuter rail or other diesel-electric locomotive powered train service): Cal-B/C Sketch uses rates were derived from locomotive emissions per brake horsepower hour, horsepower ratings, load factors, and average speeds using CARB estimates. These rates are expressed in grams per train-mile assuming a single locomotive train set, and can be converted with a unit conversion to tons per vehicle-mile and by dividing emission rates by the number of vehicles or cars per train.
- **Light Rail** (e.g., electric-power generated trains): Cal-B/C Sketch recognizes that the pollution from these vehicles is emitted from power plants that generate electricity used by the trains. Power plant emissions have been converted to emissions per LRT vehicle-mile, based upon LRT traction power, energy consumption, the mix of power generation methods in California, and their respective emissions per mega-watt hour. This methodology is based on work completed by the California Air Resources Board, the California Energy Commission, and the South Coast Air Quality Management District. Rates are expressed in tons per vehicle-mile as opposed to train-mile.
- **Bus**: Buses generally travel on roadways with other vehicles, and their average speeds reflect those of the surrounding traffic. In most cases, Cal-B/C Sketch assumes that the

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<sup>16</sup> Each year that the parameters are updated changes the current and forecast year for the emissions rates.

bus speed is the same as that of prevailing traffic, to take into account congestion effects. However, if a particular bus project has dedicated lanes or facilities, the model calculates emissions based upon the speed of that facility.

Scale of Impact	Impact Factors	Value of Impact per Unit
Numbers of vehicles, by type	<ul style="list-style-type: none"> <li>• Travel distance</li> <li>• Vehicle speed, by facility type</li> </ul>	<ul style="list-style-type: none"> <li>• Valuation per unit of emissions, by pollutant</li> <li>• Running and starting emissions rates per vehicle, by pollutant</li> </ul>

### Scale of Impact: $V^t \cdot AF$

Where:

- $V^t$  = Daily volume of vehicles by types (t)
- AF = Annualization Factor equals 365 days

### Impact Factors: $Dist^t$

Where:

- $Dist^t$  = Travel distance is limited to the length of the project, by vehicle type t
- $S^t$  = Travel speed, as provided by the tool user, for a given roadway and in No Build and Build scenarios, by vehicle type (t)

### Impact Value per Unit: $EC^t$

Where:

- $EC^t$  = Emissions cost equals the sum product of each pollutant's emissions (*pollutant*<sup>t</sup>) rate per mile by vehicle type (t), and costs per pollutant ( $VPP_{pollutant}$ ).<sup>17</sup> The equation is:

$$EC^t = (CO^t \cdot VPP_{CO} + CO_2^t \cdot VPP_{CO_2} + NO_X^t \cdot VPP_{NO} + PM_{10}^t \cdot VPP_{PM_{10}} + SO_X^t \cdot VPP_{SO} + VOC^t \cdot VPP_{VOC})$$

### Total Value of Emissions Reduction, by mode:

$$VER^t = [V^t \cdot AF] \cdot Dist^t \cdot EC^t$$

<sup>17</sup> Emissions rates are a function of vehicle speed, which is a user input.