



California
Department
Of
Transportation



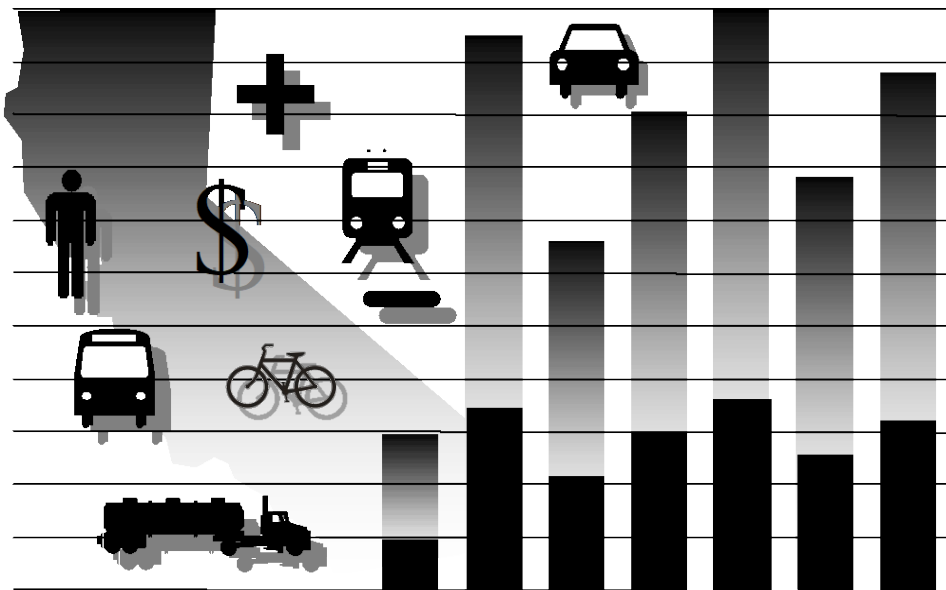
Cal-B/C

Park-and-Ride

Version 7.1

User's Guide and Technical Documentation

November 2019



Acknowledgements

The Cal-B/C Park and Ride (PnR) model was originally developed by System Metrics Group for Caltrans District 12. Cal-B/C PnR is nearly identical to the original District 12 model, which was developed to be compatible with Cal-B/C.

The material included in this user's guide is based upon previous writing and contributions from System Metrics Group and HDR. In many cases, material has been copied verbatim from earlier work.

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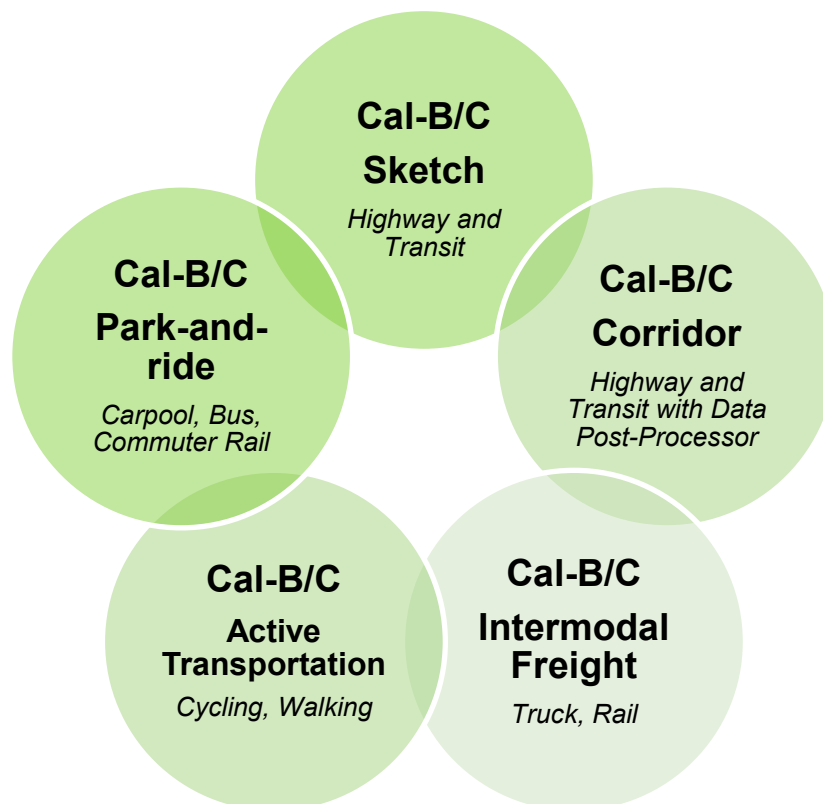
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1. Overview of Cal-B/C

Welcome to California Department of Transportation (Caltrans) California Lifecycle 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

Welcome to the User's Guide for the *California Lifecycle Benefit/Cost Analysis Model (Cal-B/C) Park-and-ride (PnR)*, Version 7.1. Cal-B/C PnR is part of a suite of similarly designed Cal-B/C Microsoft Excel spreadsheet-based tools that can evaluate multi-modal analyses of highway, transit, bicycle, pedestrian, Intelligent Transportation System (ITS), operational improvement, and passenger rail projects. The California Department of Transportation (Caltrans) uses Cal-B/C to conduct benefit-cost analyses (BCAs) of projects proposed for the interregional portion of the State Transportation Improvement Program (STIP), the State Highway Operations and Protection Program (SHOPP) and other ad hoc analyses requiring benefit-cost analysis.

Cal-B/C PnR supports assessments to prioritize park-and-ride lot investments, evaluate alternatives, and compete for project funding. The model follows a similar structure, formatting, and parameters to other models in the Cal-B/C suite of tools. As a result, Cal-B/C PnR can prepare BCAs for park-and-ride lots comparable to those calculated for projects using other Cal-B/C models. When used with other Cal-B/C tools (e.g., Cal-B/C AT for active transportation), the evaluation can include access modes to a park-and-ride lot.

The Cal-B/C PnR captures the benefit methodology similar to other tested tools and methods.¹ In particular, the Cal-B/C PnR contains a number of important enhancements compared to these other methods:

- Estimates the safety, emission, and greenhouse gas benefits of park-and-ride projects
- Calculates fuel and emissions savings based on vehicle operating speed using the same assumptions as other Cal-B/C tools
- Allows the user to specify a future year when a lot reaches capacity (benefits in earlier years are lower since the lot is not at capacity)
- Includes a space to input no build park-and-ride lot information, so park-and-ride lot expansion projects can be analyzed

¹ Washington State Department of Transportation (WSDOT) model, and tool developed to model a series of park-and-ride investments in metropolitan Edinburgh in Scotland.

- Assumes average vehicle occupancy (AVO) is the same for all park-and-ride lot users rather than forcing the model user to estimate many AVO values
- Calculates benefits for park-and-ride lot users that switched from another park-and-ride lot, which is more common in an area with many park-and-ride lots
- Simplifies the input of travel time information
- Assumes that average transit riders and carpoolers wait no more than 10 minutes
- Estimates vehicle-miles traveled (VMT) reductions and the benefits of CO₂ reductions.

The Technical Discussion in Appendix B provides details of the methodologies and analytical framework used for the Cal-B/C PnR model.

3. User Requirements

At a minimum, the user of Cal-B/C PnR should have a working knowledge of spreadsheets, particularly Microsoft Excel. To use Cal-B/C PnR, the reader of this User's Guide must be able to navigate through a multiple-sheet workbook and understand basic principles, functions, and terminology used when discussing spreadsheets

The user should also understand lifecycle benefit-cost analysis and be able to interpret the results of park-and-ride projects. The reader can also refer to the Cal-B/C Resource Guide for additional information on methods and the Cal-B/C Parameters guide for a discussion on data and sources, as needed.

4. Operating System and Software Requirements

Cal-B/C PnR is a Microsoft Excel macro-enabled workbook (.xlsm) called *Cal-B/C 71 PnR*. The file is approximately 600 kilobytes (KB) in size. Although designed for a Windows environment, Cal-B/C PnR should work on all computer platforms running Excel.

5. Model Overview

Cal-B/C PnR is a Microsoft Excel model that allows user to estimate the economic benefits of new park-and-ride lots, park-and-ride lot expansions, and leased lots. The model accounts for benefits for commuter types who use PnR lots to reach a commuter vehicle such as a carpool/van or bus:

- New Transit Riders (users who switch from automobile to express bus)
- Existing Transit Riders (users who switch from local bus to express bus)
- New Carpoolers (users who switch from automobile to carpool)
- Existing Carpoolers (users who switch to a park-and-ride lot that requires less driving).

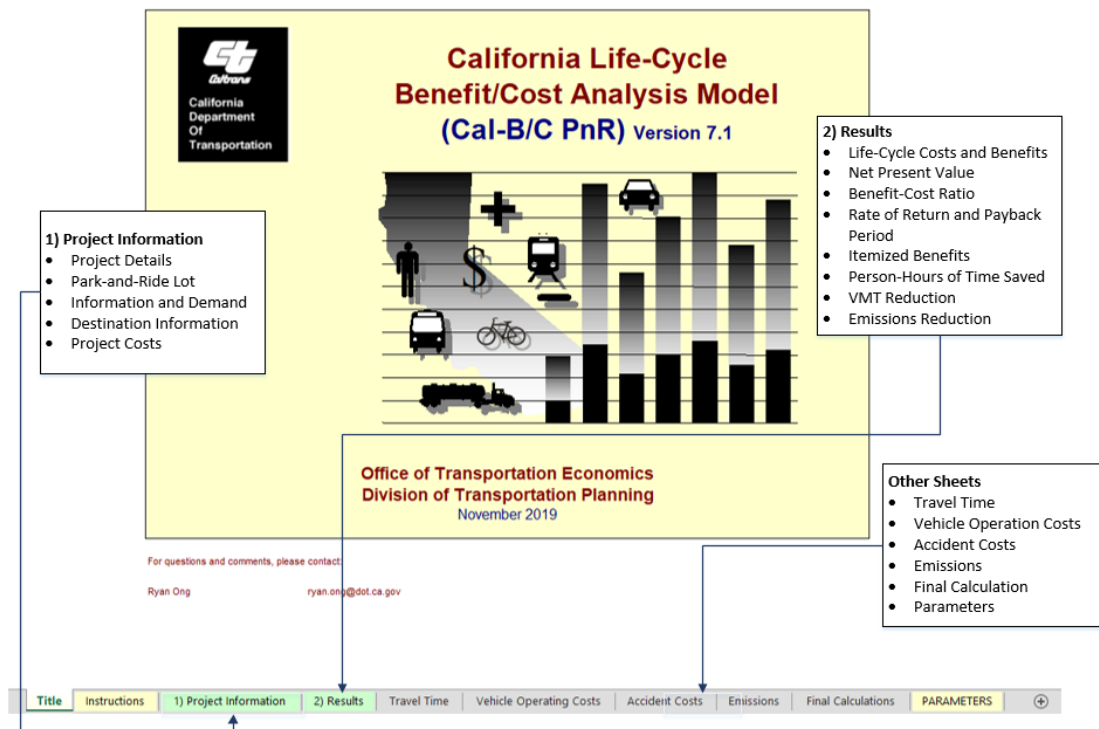
Four categories of benefits are computed for switching to these vehicles at a PnR lot including:

- **Travel time savings** due primarily to faster travel speeds in high occupancy vehicle lanes, and express buses (for transit riders)
- **Vehicle operating cost savings** due primarily to lower costs from more efficient travel at higher speeds and lower out of pocket costs that tradeoff parking costs and bus fare or carpool costs, depending on the commuter type
- **Accident cost savings** due to the lower accident risk associated with fewer passenger vehicle-miles driven, because of commuter types' switch to carpools or buses
- **Emission cost savings** due to the lower level of pollutant emissions from fewer miles driven by passenger vehicles, because of commuter types' switch to carpools or buses.

The Cal-B/C PnR introduces a capability to include up to nine destinations in the benefit-cost analysis. Specifically, the tool includes a macro, which can be run only twice, that allows the user to save the result of the first three destinations and add information for three more destinations. These destinations are used to serve as proxies for typical travel from the park-and-ride lot being analyzed.

The Cal-B/C PnR model consists of a cover page and nine worksheets in an Excel workbook. The user generally needs to refer to only the first three worksheets after the cover page (including one that provides instructions and reference materials) to conduct analyses and produce results. The remaining five worksheets perform calculations or store defaults and economic parameters. Exhibit 2 shows where these sheets are located in Cal-B/C PnR.

Exhibit 2: Cal-B/C Graphical User Interface



Cal-B/C PnR requires few user inputs, but allows the user to enter many more inputs when available. Cells in the worksheet are color-coded. **Green** cells highlight required data (i.e., the user must input values for the model to work or for the specific aspect mode to be incorporated). **Red** cells provide default values, which the user may change if needed. **Blue** cells contain values calculated by the model, which may be changed if detailed data is available.

Following the cover page, the first worksheet, *Instructions*, provides a short description of the steps required in using the Cal-B/C PnR model to perform a basic analysis and hints on how to avoid potential errors.

The *Project Information* worksheet is the main data-entry worksheet. The user enters descriptive information about the project such as:

- Location and project timeline
- Size of the facility (#s of parking spaces)
- Facility daily demand (# of spaces used, and numbers of people reaching by foot or cycle)
- Descriptions of destinations that can be reached by the facility
- Demand for each destination and breakdown of new and existing transit and carpool users
- Travel time differences with and without use of the facility
- Accident rates.

The *Results* worksheet presents the final investment expenditure as well as annualized and lifecycle benefits. This sheet allows the user to decide which of the three calculated benefits to include. Cal-B/C PnR summarizes analysis results on a per-project basis using several measures:

- Lifecycle costs (in millions of dollars)
- Lifecycle 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 over the project)
- Project payback period (in years).

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

- Travel time savings
- Vehicle operating cost savings
- Accident cost savings
- Emission cost savings
- Residual value.²

² Residual value is not a benefit category per se. In fact, it is related to capital costs since it reflects the remaining value of the initial expenditure that remains to be of use for generating benefits. It is included as a benefit only for accounting purposes.

In addition to the model also reports additional results over the 20-year lifecycle and the annual average:

- Person-hours of time saved
- Vehicle miles traveled (VMT) reduction
- Emissions reduction.

Although the model generally requires only inputs in the *Project Information* worksheet, additional changes may be made in the *Parameters* worksheet if the user is more experienced. The *Parameters* worksheet contains all the economic values and rate tables used in the model. The worksheet includes the following parameters:

General Economic Values

- Year of current dollars for model³
- 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, CO₂, NO_x, PM₁₀, SO_x, and VOC
- Automobile, truck, and bus

Rail Emissions Rates

- CO, NO_x, PM₁₀, and VOC
- Passenger train, light rail, and freight locomotive

Emissions Health Costs

- Urban Southern California, urban Northern California, and rural California
- CO, CO_{2e}, NO_x, PM₁₀, SO_x, 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

³ 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 PnR worksheets and walks 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 the data entry process.

PROJECT INFORMATION WORKSHEET

The *Project Information* worksheet is the main data input sheet and, for many projects, it would be the only sheet in which the user must enter input values. Moreover, the user should modify other worksheets only if project specific information is available for the variables calculated or presented on those sheets. The project information worksheet contains four sections, as seen in Exhibit 3 and in the table below.

Section Number	Name of Section	Location of Section in Worksheet (Top Left Cell: Bottom Right Cell)
1A	Project Data	B7 : I17
1B	Park-and-Ride Lot Information	B19 : I32
1C	Destination Information	K7 : R42
1D	Project Costs (in thousands of dollars)	U7 : AF46

Exhibit 3: Project Information Worksheet

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

- Section 1A: Project Data** (Callout box pointing to the top-left area of the worksheet)
- Section 1B: Park-and-Ride Lot Information** (Callout box pointing to the middle-left area)
- Section 1C: Destination Information** (Callout box pointing to the middle-right area)
- Section 1D: Project Costs** (Callout box pointing to the bottom-right area)

Other callouts include:

- Macro for Additional Destinations** (Callout box pointing to a button at the bottom of the Destination Information section)
- Enter all project costs (in today's dollars) in columns 1 to 7. Costs during construction should be entered in the first eight rows. Project costs (including maintenance and operating costs) should be net of costs without project.** (Text at the top right of the Project Costs section)

The worksheet tabs at the bottom are: Title, Instructions, 1) Project Information, 2) Results, Travel Time, Vehicle Operating Costs, Accident Costs, Emissions, Final Calculations, PARAMS...

Project Data

In this section, the user enters data regarding the type of project, the project location, and the length of construction (including project development).

Exhibit 4: Project Information Worksheet – 1A, Project Data

Default: HQ [] PROJECT: Hypothetical Project EA: [] PPRD: []

Enter all project costs (in today's dollars) in columns 1 to 7. Costs during construction should be entered in the first eight rows. Project costs (including maintenance and operating costs) should be net of costs without project.

PROJECT DATA

Type of Project: Select project type from list []

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

Length of Construction Period: [] years

DESTINATION INFORMATION

Destination Description: Destination Name [], Distance from Park-and-Ride Lot [], Distance to Next Lot (miles) [], Parking Cost at Destination (per hour) []

Demand for Travel to Destination: Percent of Lot Users to Destination (Dest 1, Dest 2, Dest 3)

Distribution (percent): New Transit Riders [], Existing Transit Riders [], New Carpoolers [], Existing Carpoolers []

Highway Travel to Destination: (Dest 1, Dest 2, Dest 3)

PROJECT COSTS (enter costs in thousands of dollars)

Year	Project	DIRECT PROJECT COSTS			SUBSEQUENT COSTS			Transit Agency Cost Savings	TOTAL COSTS (in dollars)	
		Initial	Construction	Oper.	Maint.	Rehab.	Mitigation		Constant Dollars	Present Value
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
21									\$0	\$0

1A PROJECT DATA

Type of Project: Select project type from list []

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

Length of Construction Period: [] years

Residual Value in Year 21 (in thousands of dollars) [] Present Value = Euler Value (Constant Dollars) [1 + Real Discount Rate]^{Year}

PROJECT TYPE

The project type selection allows the user to select one of the three types of unique park-and-ride projects. Specifically, the dropdown list provides the following options for the user:

- New Park-and-Ride Lot
- Park-and-Ride Leased Lot
- Park-and-Ride Lot Expansion.

PROJECT LOCATION

The Cal-B/C PnR model considers three unique areas within California (i.e., Northern California Urban, Southern California Urban, or Rural California). The model uses the location information to determine the appropriate accident costs and health costs of transportation emissions parameters to use in calculating the benefits. The user identifies the project location by selecting “1” for Urban Southern California, “2” for Urban Northern California, and “3” for Rural California.

PROJECT TIMELINE

The model requires the user to input the construction period. This information helps determine the total number of years in the study period and determining the present value of costs and benefits.

Park-and-Ride Lot Information

In Section 1B the user enters information regarding the number of parking spaces in the lot, the average vehicle occupancy of lot destinations, and the time that it takes to reach capacity. The user may also highlight the number of cyclists and pedestrians who use the facility. As seen in Exhibit 5, this information is divided by the “No Build” and “Build” scenarios, where the “No Build” scenarios assumes the project does not move forward, while the “Build” scenario assumes the project moves forward and is constructed.

Exhibit 5: Project Information Worksheet – 1B, Park-and-Ride Lot Information

District: **HQ** EA:
 PROJECT: **Hypothetical Project** FPNR:

Enter all project costs (in today's dollars) in columns 1 to 7. Costs during construction should be entered in the first eight rows. Project costs (including maintenance and operating costs) should be net of costs without project.

A PROJECT DATA

Type of Project:

Project Location:

Length of Construction Period: years

C DESTINATION INFORMATION

Destination Description

Destination Name: Dest 1 Dest 2 Dest 3

Distance from Park-and-Ride Lot (miles):

Distance to Next Lot (miles):

Parking Cost at Destination (per Ride):

Demand for Travel to Destination

Percent of Lot Users to Destination:

Distribution

New Transit Riders:

Existing Transit Riders:

New Bicyclists:

Existing Carpoolers:

Highway Travel to Destination

HOV Travel Time (in min): Dest 1 Dest 2 Dest 3

Non-HOV Travel Time (in min):

Assumed 25% HOV with 2.5 vehicle occupancy

D PROJECT COSTS (enter costs in thousands of dollars)

Year	Project Segment	DIRECT PROJECT COSTS		SUBSEQUENT COSTS			Transit Agency Cost Savings	TOTAL COSTS (in dollars)	
		RI	W	Maint/Op.	Rehab.	Mitigation		Constant Dollars	Present Value
Construction Period									
1									
2									
3									
4									
5									
6									
7									
8									
Project Open									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

1B PARK-AND-RIDE LOT INFORMATION

Lot Design

Number of Parking Spaces: No Build Build

Park-and-Ride Demand

Typical Percent Filled (for current or opening year):

Number of Years until Lot Reaches Capacity:

Number of Bicycle/Pedestrian Users:

Average Vehicle Occupancy of Lot Users: No Build Build

Present Value = Future Value Discounted (1 + Real Discount Rate)^{-Year}

Title Instructions 1) Project Information 2) Results Travel Time Vehicle Operating Costs Accident Costs Emissions Final Calculations PARAMS ...

LOT DESIGN

This subsection contains information on the capacity of the existing park-and-ride lot and the proposed capacity with the completion of the project. While the current capacity (i.e., capacity under the “No Build” scenario) is 0 by default, the user can adjust this value as the default assumption is that there is currently no park-and-ride facility/lot.

PARK-AND-RIDE DEMAND

In this subsection, the user defines the demand for the park-and-ride lot under current conditions and the expected demand if the project were constructed. In particular, the user is expected to enter the percentage of the lot capacity used (*Typical Percent Filled*), the time until the facility reaches capacity (*Number of Years until Lot Reaches Capacity*), the number of cyclists and pedestrians (*Number of Bicycle/Pedestrian Users*), as well as the average vehicle occupancy for those who use the facility (*Average Vehicle Occupancy of Lot Users*). It should be noted that while the model by default assumes that there is on average one person per vehicle (among lot users) and the number is to stay the same between the “No Build” and “Build” scenarios, the user has the ability to adjust these numbers to accurately fit the location/project.

Destination Information

In Section 1C, the user is able to provide information on the destinations of park-and-ride users. The information includes distance information, the relative distribution of volume, travel time by mode, accidents, as well as any relevant waiting time and fare costs. These inputs are split by destination as seen in Exhibit 6.

As previously mentioned, this model is able to assess up to nine destinations for the benefit-cost analysis. However, the model can only analyze three destinations at once, and additional destinations will be assessed with the assistance of the imbedded macro.

Exhibit 6: Project Information Worksheet – 1C, Destination Information

District: **HQ** EA:
 Project: **Hypothetical Project** FPO:

Enter all project costs (in today's dollars) in columns 1 to 7. Costs during construction should be entered in the first eight rows. Project costs (including maintenance and operating costs) should be net of costs without project.

PROJECT DATA		DESTINATION INFORMATION			PROJECT COSTS (enter costs in thousands of dollars)										
Type of Project Select project type from list: <input type="text"/> Project Location (see the So. Cal., The N. Cal., or The East) Length of Construction Period: <input type="text"/> year		Destination Description Destination Name: <input type="text"/> Distance from Park-and-Ride Lot (miles): <input type="text"/> Distance to Next Lot (miles): <input type="text"/> Parking Cost at Destination (avg \$/day): <input type="text"/>			Year	Project Support	R / W	Construction	DIRECT PROJECT COSTS		SUBSEQUENT COSTS		Transit Agency Cost Savings	TOTAL COSTS (in dollars)	
PARK-AND-RIDE LOT INFORMATION Lot Design Number of Parking Spaces: <input type="text"/>		1C DESTINATION INFORMATION Destination Description Destination Name: <input type="text"/> Distance from Park-and-Ride Lot (miles): <input type="text"/> Distance to Next Lot (miles): <input type="text"/> Parking Cost at Destination (avg \$/day): <input type="text"/>			Initial	Operating	Maint / Op.	Rehab.	Mitigation	Constant Dollars	Present Value				
Park-and-Ride Demand Typical Percent Filled (for current or open space): <input type="text"/> Number of Years until Lot Reaches Capacity: <input type="text"/> Number of Bicycle/Pedestrian Users: <input type="text"/> Average Vehicle Occupancy of Lot Users: <input type="text"/>		Demand for Travel to Destination Percent of Lot Users to Destination: <input type="text"/>													
		Highway Travel to Destination HOV Travel Time (in min): <input type="text"/> Non-HOV Travel Time (in min): <input type="text"/> Accident Rate (per million vehicle-miles): <input type="text"/> Percent Fatal Accidents (Pct Fat): <input type="text"/> Percent Injury Accidents (Pct Inj): <input type="text"/>													
		Transit Travel to Destination Express Bus: Travel Time (in min): <input type="text"/> Average Fare: <input type="text"/> Headway (in min): <input type="text"/> Local Bus: Travel Time (in min): <input type="text"/> Average Fare: <input type="text"/>													
		Carpool/Vanpool Travel to Destination Average Carpool Size (people/vehicle): <input type="text"/> Average Carpool Wait Time (in min): <input type="text"/>													

DESTINATION DESCRIPTION

This subsection reflects the details surrounding the destinations of park-and-ride users. Specifically, the user is expected to enter information indicating the approximate distance between the park-and-ride lot and the destination, the distance from to the next park-and-ride lot, and the cost of parking at the destination. The distances are used within the model to determine the total vehicle miles traveled (VMT), while the parking costs reflect a component of the out-of-pocketing travel costs.

DEMAND FOR TRAVEL TO DESTINATION

The user indicates the percentage of the park-and-ride lot users traveling to the destination as well as the distribution of the users in terms of:

- New Transit Users
- Existing Transit Riders
- New Carpoolers
- Existing Carpoolers.

These parameters are pivotal within the model to determine the benefits by the user type. The mode and type of users generate different benefits due to the different characteristics of their travel.

HIGHWAY TRAVEL TO DESTINATION

This subsection highlights the average travel time (in minutes) to travel to the destination by taking the highway. The travel time is split between whether or not the user is driving on the HOV lane, and used to determine the travel time savings benefits.

In addition to the travel time, the user is required to enter accident rates (per million vehicle-miles), as well as the percentage of fatal and injury accidents. These accident rates should reflect potential routes or regions. The accident data is used to determine the benefits from avoided accidents by having less vehicles on the highway.

TRANSIT TRAVEL TO DESTINATION

Under the *Transit Travel to Destination*, the user will indicate the fare and average travel time (in minutes) it takes to arrive at the destination by both express bus and local bus. If one of the services is not available to a specific destination, the user can leave that blank. For express buses, the user is also expected to indicate the headway time.

The average travel time by transit and the average wait time for express buses are incorporated to determine the travel time cost savings for new transit riders and existing transit riders. Meanwhile, the fare costs for the transit services are used to determine vehicle operating cost savings for both user types.

CARPOOL/VANPOOL TRAVEL TO DESTINATION

This subsection presents the variables used to determine the total VMT and total wait time for new carpoolers and existing carpoolers. For each destination, the user will enter information on the average carpool size (people per vehicle) and average carpool wait time.

Project Costs

The user enters project construction, operating, right-of-way, 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.⁴ Incremental costs are estimated as the difference between the “Build” costs and the “No Build” costs.

The project costs table contains seven columns for the user to enter cost information in thousands of dollars, as shown in Exhibit 7. All cost values should consider the Year of Current Dollars for Model in the *Parameters* sheet to ensure consistency. For instance, if the Year of Current Dollars for Model is 2016, all cost values should be in 2016 dollars to ensure consistency with the benefit calculations. The model automatically calculates the sum and present value of all costs inputted by the user.

The leftmost column of the project costs table indicates the years throughout the lifecycle separating the construction period and 20-year project life cycle. Cal-B/C PnR can handle up to 8 years of construction, where the number of construction years is determined in the *Project Data*

⁴ Sunk costs are included in federal grant applications as part of the BCA, but not as part of the amount requested.

section. For each year of construction with missing cost data, the message “Must enter a cost” appears in red under the Subsequent Cost Section. Similarly, for each year beyond the construction period, the message “Adjust Construction Period” appears in red under the Subsequent Cost Section if a construction cost is entered.

Exhibit 7: Project Information Worksheet – 1D, Project Costs

DIRECT PROJECT COSTS (IN THOUSANDS OF DOLLARS)

The direct project costs are broken down into *Initial Costs* and *Subsequent Costs*. Their respective composition is as follows:

- *Initial Costs* include:
 - Project support (e.g., engineering design and management costs)
 - Right-of-way acquisition costs
 - Construction costs.

- *Subsequent Costs* include:
 - Maintenance and operating costs
 - Rehabilitation costs (e.g., pavement overlay, truck, track, or station refurbishment).

The *Initial Costs* should reflect the net capital costs required to complete the project, while the *Subsequent Costs* indicate the estimate future incremental maintenance, operating and rehabilitation costs in constant dollars. These costs should be entered in the years they are expected to occur. As previously indicated, these costs should be entered in thousands of dollars.

MITIGATION (IN THOUSANDS OF DOLLARS)

Mitigation costs 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 noise. The user enters these costs in constant dollars during construction and for 20 years after construction is completed.

TOTAL COSTS (IN DOLLARS)

The model calculates the total costs automatically, and presents the total cost in constant dollars and present value for each year. It should be noted that since total costs are denoted in dollars, the previous columns are multiplied by 1000 to convert the values from thousands of dollars to actual values. The project cost table also summarizes the total constant dollar of cost element at the bottom in dollars. Using the *Real Discount Rate* defined in the *Parameters* sheet and the *Current Year* defined in the *Project Data* section, the following formula is used to calculate the present value:

$$\text{Present Value} = \frac{\text{Future Value (in constant dollars)}}{(1 + \text{Real Discount Rate})^{\text{Future Year} - \text{Current Year}}}$$

RESULTS WORKSHEET

The final worksheet covered by this User's Guide is the *Results* worksheet, which provides the benefit-cost assessment results from the Cal-B/C PnR model. Exhibit 8 shows the layout of the output table.

Exhibit 8: Results Worksheet

INVESTMENT ANALYSIS		SUMMARY RESULTS			
Life-Cycle Costs (mil. \$)	\$0.0	ITEMIZED BENEFITS (mil. \$)		Total Over 20 Years	Average Annual
Life-Cycle Benefits (mil. \$)	#N/A	Travel Time Savings	\$0.0	\$0.0	\$0.0
Net Present Value (mil. \$)	#N/A	Veh. Op. Cost Savings	\$0.0	\$0.0	\$0.0
Benefit / Cost Ratio:	N/A	Accident Cost Savings	\$0.0	\$0.0	\$0.0
Rate of Return on Investment:	N/A	Emission Cost Savings	#N/A	#N/A	#N/A
Payback Period:	N/A	Residual Value	\$0.0	\$0.0	\$0.0
		TOTAL BENEFITS	#N/A	#N/A	#N/A
		Person-Hours of Time Saved	0	0	0
		VMT Reduction	0	0	0
Should benefit-cost results include:		EMISSIONS REDUCTION			
1) Induced Travel is not considered		Tons		Value (mil. \$)	
2) Vehicle Operating Costs? (y/n)	<input type="checkbox"/> Y Default = Y	Total Over 20 Years	Average Annual	Total Over 20 Years	Average Annual
3) Accident Costs? (y/n)	<input type="checkbox"/> Y Default = Y	CO Emissions Saved	0	0	#N/A
4) Vehicle Emissions? (y/n)	<input type="checkbox"/> Y Default = Y	CO ₂ Emissions Saved	0	0	#N/A
		NO _x Emissions Saved	0	0	#N/A
		PM ₁₀ Emissions Saved	0	0	#N/A
		PM _{2.5} Emissions Saved	0	0	#N/A
		SO _x Emissions Saved	0	0	#N/A
		VOC Emissions Saved	0	0	#N/A

As seen in the figure above, the bottom left section of the *Results* worksheet allows the user to determine if certain benefits should be included in the benefit-cost analysis. Specifically, the model allows the user to determine if the following benefits should be included:

- Vehicle Operating Cost Savings
- Accident Cost Savings
- Emission Cost Savings.

For the user to decide whether to include or exclude these benefits, a toggle is provided with a binary choice between “Y” and “N,” which represents yes and no respectively. The default setting for all benefits is “Y,” implying that all benefits listed above are included in the default benefit-cost analysis.

Cal-B/C PnR provides various summary results and different calculated project feasibility measures, using a 20-year project lifecycle, which highlight various aspects of a project:

- **Lifecycle Costs** (in millions of dollars) are the present values for all net project costs, including the initial costs and any subsequent costs in real constant dollars.
- **Lifecycle Benefits** (in millions of dollars) are the sum of the present value of the considered benefits of the project.
- **Net Present Value** (in millions of dollars), provides a measurement of project feasibility and is calculated as the difference between the lifecycle benefits and costs. In particular, if the net present value is positive (i.e., the lifecycle benefits are greater than the lifecycle costs), the project is feasible.
- **Benefit / Cost Ratio** highlights the lifecycle benefits relative to the lifecycle costs of a project. A ratio greater than 1 implies the project has positive economic value.
- **Rate of Return on Investment** is defined as the discount rate which would equalize the lifecycle benefits and costs, and provides another measure of project feasibility. If the rate of return on investment is greater than the discount rate used in the model, it implies the project is expected to provide positive economic value. This measurement also allows the user to compare a variety of projects that have different lifecycle benefits or costs, as well as across different time periods.
- **Payback Period** is the number of years it would take the project to recover the initial construction costs, net of any ongoing costs. If the payback period is expected to be longer than the lifecycle of the project, it implies the initial construction costs are not recovered. It should be noted that the payback period has an inverse relationship with the benefit-cost ratio, in that a shorter payback period results in a higher benefit-cost ratio.

Cal-B/C PnR also presents a few additional statistics such as person-hours of time saved, VMT reduction, and emission reduction. For the reduction in emissions, the model presents the reduction by pollutant type. The pollutants considered are: CO, CO₂, NO_x, PM₁₀, PM_{2.5}, SO_x, and VOC. The emissions reductions are presented in both the volume (tons) and value (millions of dollars). Results for volume and value are shown as a grand total over the project lifecycle, as well as an average annual value.

You are now ready to use Cal-B/C PnR to model park-and-ride projects. For more information about how Cal-B/C estimates particular impacts, please see Appendix B.

Appendix A: Project Example

To help you better understand the Cal-B/C PnR model, consider an example project that would construct a new park-and-ride lot. This project, the NB Lincoln Intermodal/Park-and-Ride (PnR) Project, constructs a new park-and-ride lot with 100 parking spaces, complementing a nearby existing park-and-ride lot (SR-55 and Lincoln/Nohl Ranch Road) operating at full capacity. Not only will the new lot be located near a transportation hub with access to local and commuter buses, as well as access to Metrolink transit, but it will also be near a Class 2 bike lane. Specifically, the lot will have access to the OCTA Line 71, 213 and Riverside Transit Line 149.

The initial capital cost for this project is estimated at \$550,000 (or \$5,500 per space) with no land procurement costs as the proposed location is in Caltrans-owned right-of-way. The construction of this new lot is expected to take only a year and cost \$40,000 annually to operate and maintain the new park-and-ride lot.

Once constructed, the new park-and-ride lot will operate at 50 percent utilization. However, the lot will reach capacity in three years. Due to the proximity of the lot to bike lanes, there will be five cyclists using the lot on a daily basis. In addition, the users of this new lot will travel to three destinations: Downtown Los Angeles (LA), Riverside (RIV), and Irvine (OC). Estimates of the specific percentage of users traveling to each destination are available from the Orange County Transportation Analysis Model (OCTAM). For highway travel, the HOV and non-HOV travel times can be found in the Caltrans Performance Measurement System (PeMS), while accident rates, based on county averages, are available in the Caltrans publication *Collision Data on California State Highways*.

STEP 1: Input Project Data into Infrastructure Project Information Worksheet

Data entry for project analysis begins in the *Project Information* worksheet. The worksheet allows the user to input all the background information about the project.

Project Data (Box 1A)

This is the space in which the user should enter the basic project information including the general region of project and the length of construction.

As indicated, the project will build a new park-and-ride lot over a one-year period. Thus, the user should select “New Park-and-ride Lot” under the *Type of Project* and input “1” for the *Length of Construction Period*. Since the project is located in Southern California, the user should also enter “1” for Project Location.

Exhibit 9: Project Data

1A

PROJECT DATA

Type of Project
Select project type from list New Park and Ride Lot

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

Length of Construction Period 1 years

Park-and-Ride Lot Information (Box 1B)

This box includes inputs that provide information about the park-and-ride lot, as well as the demand for the project. As evident in Exhibit 10, the data entered in this section are split between the “No Build” and “Build” scenarios.

Since the project will develop a brand new park-and-ride lot, the user should use the default *Number of Parking Spaces* of “0” under the “No Build” scenario and enter the projected capacity of “100” new parking spaces under the “Build” scenario

Further, the user should leave the “No Build” scenario inputs under *Park-and-Ride Demand* as is and fill out only the “Build” scenario inputs. If the project were an expansion of a current facility, the user would provide “No Build” scenario inputs. There will be 50 percent utilization in the first year of operations and the lot is expected to take three years to reach full capacity, so the user should enter “50%” and “3” under *Typical Percent Filled* and *Number of Years until Lot Reaches Capacity* respectively. The user should also enter “5” under *Number of Bicycle/Pedestrian Users* to reflect the assumption of the five daily cyclist users.

Exhibit 10: Park-and-Ride Lot Information

1B

PARK-AND-RIDE LOT INFORMATION

Lot Design	No Build	Build
Number of Parking Spaces	0	100

Park-and-Ride Demand	No Build	Build
Typical Percent Filled (for current or opening year)	0%	50%
Number of Years until Lot Reaches Capacity	0	3
Number of Bicycle/Pedestrian Users	0	5
Average Vehicle Occupancy of Lot Users	1.00	1.00



Destination Information (Box 1C)

This section allows the user to provide information on up to three destinations to which the lot users are expected to travel. The information includes such variables as travel distances, travel time, out-of-pocket costs, as well as the percentage of users traveling to each destination and the type of users.

For this example, the user will highlight the respective information for lot users traveling from the proposed park-and-ride lot to Irvine (OC), Downtown California (LA), and Riverside (RIV).

Exhibit 11: Destination Information – Overview

1C		DESTINATION INFORMATION		
Destination Description		Dest 1	Dest 2	Dest 3
Destination Name		OC	LA	RIV
Distance from Park-and-Ride Lot (miles)		15.0	42.0	30.0
Distance to Next Lot (miles)		10.0	10.0	10.0
Parking Cost at Destination (avg \$/day)		\$2.00	\$5.00	\$2.00
Demand for Travel to Destination		Dest 1	Dest 2	Dest 3
Percent of Lot Users to Destination		35%	50%	15%
Distribution (percent)	New Transit Riders	50%	0%	0%
	Existing Transit Riders	0%	0%	0%
	New Carpoolers	50%	75%	100%
	Existing Carpoolers	0%	25%	0%
Highway Travel to Destination		Dest 1	Dest 2	Dest 3
HOV Travel Time (in min)		25.0	55.0	28.0
Non-HOV Travel Time (in min)		35.0	73.0	32.0
Accident Rate (per million vehicle-miles)		0.89	0.99	0.77
Percent Fatal Accidents (Pct Fat)		0.4%	0.4%	1.0%
Percent Injury Accidents (Pct Inj)		26.5%	28.3%	33.5%
Transit Travel to Destination		Dest 1	Dest 2	Dest 3
Express Bus	Travel Time (in min)	45.0	0.0	80.0
	Average Fare	\$6.00	\$0.00	\$0.00
	Headway (in min)	10.0	0.0	60.0
Local Bus	Travel Time (in min)	50.0	0.0	0.0
	Average Fare	\$4.00	\$0.00	\$0.00
Carpool/Vanpool Travel to Destination		Dest 1	Dest 2	Dest 3
Average Carpool Size (people/vehicle)		2.0	2.0	2.0
Average Carpool Wait Time (in min)		5.0	7.5	7.5

Destination Description

This area allows the user to provide an abbreviation for each destination, the distance to the destination, the distance to the next lot, and the average daily parking cost at destination.

As seen in Exhibit 12, the example assumes that the proposed park-and-ride lot is 15 miles from OC, 42 miles from LA, and 30 miles from RIV. The example also assumes that, regardless of the destination, it is 10 miles from the proposed park-and-ride lot to the next park-and-ride lot. Parking cost are assumed to be \$2.00 per day in OC and RIV, while parking costs in LA are assumed to be \$5.00 per day.



Exhibit 12: Destination Information – Destination Description

Destination Description	Dest 1	Dest 2	Dest 3
Destination Name	OC	LA	RIV
Distance from Park-and-Ride Lot (miles)	15.0	42.0	30.0
Distance to Next Lot (miles)	10.0	10.0	10.0
Parking Cost at Destination (avg \$/day)	\$2.00	\$5.00	\$2.00

Demand for Travel Destination

This area allows the user to define the percentage of lot users traveling to each destination under the *Percent of Lot Users to Destination*. These values should sum to 100%. The model requires the breakout of type of user by destination under the *Distribution*, which should also sum up to 100% for each destination. These two inputs are key components in determining benefits from park-and-ride projects.

As presented in Exhibit 13, the distribution of users to destinations was determined from travel demand model output. The results of the OCTAM model indicates 35% of the lot users will travel to OC, 50% will travel to LA, and 15% will travel to RIV.

For those traveling to OC, it is assumed that 50% are new transit riders, while the remaining 50% are new carpoolers. For those traveling to LA, it is assumed that 75% are new carpoolers, while 25% are existing carpoolers. Finally, for lot users traveling to RIV, it is assumed that 100% are new carpoolers.

Exhibit 13: Destination Information – Demand for Travel Destination

Demand for Travel to Destination		Dest 1	Dest 2	Dest 3
Percent of Lot Users to Destination		35%	50%	15%
Distribution (percent)	New Transit Riders	50%	0%	0%
	Existing Transit Riders	0%	0%	0%
	New Carpoolers	50%	75%	100%
	Existing Carpoolers	0%	25%	0%

Highway Travel to Destination

This box allows the user to provide the average highway travel time to each destination for vehicles traveling on HOV lanes and for those that are not. For each destination, the user is expected to provide an accident rate (per million vehicle-miles), the percentage of fatal accidents, and the percentage of injury accidents.

All the information relevant to project are presented in Exhibit 14. As previously indicated the travel times were determined through the Caltrans’ Performance Measurement System (PeMS) and accident rates, based on county averages, were obtained from Collision Data on California State Highways.



Exhibit 14: Destination Information – Highway Travel to Destination

Highway Travel to Destination		Dest 1	Dest 2	Dest 3
HOV Travel Time (in min)		25.0	55.0	28.0
Non-HOV Travel Time (in min)		35.0	73.0	32.0
Accident Rate (per million vehicle-miles)		0.89	0.99	0.77
Percent Fatal Accidents (Pct Fat)		0.4%	0.4%	1.0%
Percent Injury Accidents (Pct Inj)		26.5%	28.3%	33.5%

Transit Travel to Destination

This box highlights transit-related inputs for the model. The user is expected to provide details regarding the travel time and the average fare by destination for both express and local buses. For express buses, the headway or wait time also needs to be entered. It should be noted that the user would input transit information only if there are accessible transit services. If there are none, the user would leave this section blank. These factors are used to determine potential travel time savings for new transit users and existing transit users.

As highlighted in Exhibit 15, there are transit services available only for OC and RIV. However, it is assumed that buses are not used by lot users traveling to RIV due to the significantly longer travel time compared to taking the highway.

For those traveling to OC via transit, express buses are expected to take 45 minutes, although users will experience a headway time of 10 minutes. This is comparable to the travel time on local buses to OC, which takes 50 minutes. It is assumed that an express bus to OC from the proposed park-and-ride lot costs \$6.00 per person, while the local bus to OC only costs \$4.00 per person.

Exhibit 15: Destination Information – Transit Travel to Destination

Transit Travel to Destination		Dest 1	Dest 2	Dest 3
Express Bus	Travel Time (in min)	45.0	0.0	80.0
	Average Fare	\$6.00	\$0.00	\$0.00
	Headway (in min)	10.0	0.0	60.0
Local Bus	Travel Time (in min)	50.0	0.0	0.0
	Average Fare	\$4.00	\$0.00	\$0.00

Carpool/Vanpool Travel to Destination

The *Carpool/Vanpool Travel to Destination* section presents the carpool input variables for the user to populate. For each destination, the user should provide the average carpool size and the average wait time per carpool. These factors are applied to determine the marginal change in vehicle volume and the reduction in travel time as these vehicles will be able to use the HOV lanes. Specifically, these variables are used to determine the benefits from new carpool users and existing carpool users.



As presented in Exhibit 16, it is assumed that for all destinations, the average carpool will have two people per vehicle. Carpool users traveling to both LA and RIV are assumed to wait an average of 7.5 minutes, while carpool users traveling to OC assume to wait an average of only 5.0 minutes.

Exhibit 16: Destination Information – Carpool/Vanpool Travel to Destination

<i>Carpool/Vanpool Travel to Destination</i>	Dest 1	Dest 2	Dest 3
Average Carpool Size (people/vehicle)	2.0	2.0	2.0
Average Carpool Wait Time (in min)	5.0	7.5	7.5

Project Costs (Box 1D)

Initial project costs and subsequent on-going costs are entered in this *Project Costs* section. The initial project costs are divided into three categories, project support, right of way acquisition, and construction. Subsequent costs reflect future costs such as rehabilitation costs, as well as on-going maintenance and operating costs. The costs are entered in thousands of dollars and expected to be in constant dollars. Using all the relevant cost information, the model will calculate the total project costs by year in both constant dollars and present value.

The costs assumed for this project can be seen in Exhibit 17. The construction of the new park-and-ride lot costs \$550,000 and is expected to be constructed in one year. In addition, the new park-and-ride lot is expected to have an annual operations and maintenance cost of \$40,000.



Exhibit 17: Project Costs

1D PROJECT COSTS (enter costs in thousands of dollars)									
Col. no.	(1)	(2)	(3)	(4)	(5)	(6)	(7)		
Year	DIRECT PROJECT COSTS			SUBSEQUENT COSTS			Transit Agency Cost Savings	TOTAL COSTS (in dollars)	
	Project Support	R / W	Construction	Maint./ Op.	Rehab.	Mitigation		Constant Dollars	Present Value
Construction Period									
1			\$550					\$550,000	\$550,000
2								0	0
3								0	0
4								0	0
5								0	0
6								0	0
7								0	0
8								0	0
Project Open									
1				\$40				\$40,000	\$38,462
2				\$40				40,000	36,982
3				\$40				40,000	35,560
4				\$40				40,000	34,192
5				\$40				40,000	32,877
6				\$40				40,000	31,613
7				\$40				40,000	30,397
8				\$40				40,000	29,228
9				\$40				40,000	28,103
10				\$40				40,000	27,023
11				\$40				40,000	25,983
12				\$40				40,000	24,984
13				\$40				40,000	24,023
14				\$40				40,000	23,099
15				\$40				40,000	22,211
16				\$40				40,000	21,356
17				\$40				40,000	20,535
18				\$40				40,000	19,745
19				\$40				40,000	18,986
20				\$40				40,000	18,255
Total	\$0	\$0	\$550	\$800	\$0	\$0	\$0	\$1,350,000	\$1,093,613

STEP 2: Review Final Results

Following completion of the first step, the user can review the benefit-cost analysis results for the project in the *Results* worksheet. This worksheet allows the user to see a summary of the final results⁵, with the key metrics such as the Net Present Value and the Benefit/Cost Ratio (BCR) presented in the top left box. The results tab also allows the user to determine whether or not to include or exclude the following benefits:

- Vehicle Operating Cost Savings (*Vehicle Operating Costs*)
- Accident Cost Savings (*Accident Costs*)
- Emission Cost Savings (*Vehicle Emissions*).

The results of this example project are presented in Exhibit 18, which indicates this new park-and-ride lot is expected to generate \$6.1 million in discounted net public benefits and will have a BCR of 6.6. Majority benefits are generated from the *Vehicle Operating Cost Savings*, which is reflective of the projected 22.4 million vehicle-miles reduced as a result of the project.

⁵ More detail results can be seen in the *Final Calculations* tab.



Exhibit 18: Results

2		INVESTMENT ANALYSIS																																																		
		SUMMARY RESULTS																																																		
<table border="1"> <tr> <td>Life-Cycle Costs (mil. \$)</td> <td style="text-align: right;">\$1.1</td> </tr> <tr> <td>Life-Cycle Benefits (mil. \$)</td> <td style="text-align: right;">\$7.2</td> </tr> <tr> <td>Net Present Value (mil. \$)</td> <td style="text-align: right;">\$6.1</td> </tr> <tr> <td>Benefit / Cost Ratio:</td> <td style="text-align: right;">6.6</td> </tr> <tr> <td>Rate of Return on Investment:</td> <td style="text-align: right;">66.1%</td> </tr> <tr> <td>Payback Period:</td> <td style="text-align: right;">2 years</td> </tr> </table>	Life-Cycle Costs (mil. \$)	\$1.1	Life-Cycle Benefits (mil. \$)	\$7.2	Net Present Value (mil. \$)	\$6.1	Benefit / Cost Ratio:	6.6	Rate of Return on Investment:	66.1%	Payback Period:	2 years	<table border="1"> <tr> <th colspan="2" style="text-align: left;">ITEMIZED BENEFITS (mil. \$)</th> <th style="text-align: center;">Total Over 20 Years</th> <th style="text-align: center;">Average Annual</th> </tr> <tr> <td>Travel Time Savings</td> <td></td> <td style="text-align: right;">\$0.5</td> <td style="text-align: right;">\$0.0</td> </tr> <tr> <td>Veh. Op. Cost Savings</td> <td></td> <td style="text-align: right;">\$4.9</td> <td style="text-align: right;">\$0.2</td> </tr> <tr> <td>Accident Cost Savings</td> <td></td> <td style="text-align: right;">\$1.4</td> <td style="text-align: right;">\$0.1</td> </tr> <tr> <td>Emission Cost Savings</td> <td></td> <td style="text-align: right;">\$0.4</td> <td style="text-align: right;">\$0.0</td> </tr> <tr> <td>Residual Value</td> <td></td> <td style="text-align: right;">\$0.0</td> <td></td> </tr> <tr> <td>TOTAL BENEFITS</td> <td></td> <td style="text-align: right;">\$7.2</td> <td></td> </tr> <tr> <td>Person-Hours of Time Saved</td> <td></td> <td style="text-align: right;">55,897</td> <td style="text-align: right;">2,795</td> </tr> <tr> <td>VMT Reduction</td> <td></td> <td style="text-align: right;">22,408,719</td> <td style="text-align: right;">1,120,436</td> </tr> </table>		ITEMIZED BENEFITS (mil. \$)		Total Over 20 Years	Average Annual	Travel Time Savings		\$0.5	\$0.0	Veh. Op. Cost Savings		\$4.9	\$0.2	Accident Cost Savings		\$1.4	\$0.1	Emission Cost Savings		\$0.4	\$0.0	Residual Value		\$0.0		TOTAL BENEFITS		\$7.2		Person-Hours of Time Saved		55,897	2,795	VMT Reduction		22,408,719	1,120,436		
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<p>Should benefit-cost results include:</p> <p>1) Induced Travel is not considered</p> <p>2) Vehicle Operating Costs? (y/n) <input type="text" value="Y"/> <small>Default = Y</small></p> <p>3) Accident Costs? (y/n) <input type="text" value="Y"/> <small>Default = Y</small></p> <p>4) Vehicle Emissions? (y/n) <input type="text" value="Y"/> <small>includes value for CO₂e Default = Y</small></p>	<table border="1"> <thead> <tr> <th rowspan="2"></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>EMISSIONS REDUCTION</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>CO Emissions Saved</td> <td style="text-align: right;">24</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> <tr> <td>CO₂ Emissions Saved</td> <td style="text-align: right;">7,401</td> <td style="text-align: right;">370</td> <td style="text-align: right;">\$0.2</td> <td style="text-align: right;">\$0.0</td> </tr> <tr> <td>NO_x Emissions Saved</td> <td style="text-align: right;">2</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>PM₁₀ Emissions Saved</td> <td style="text-align: right;">0</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>PM_{2.5} 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_x Emissions Saved</td> <td style="text-align: right;">0</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;">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> </tbody> </table>				Tons		Value (mil. \$)		Total Over 20 Years	Average Annual	Total Over 20 Years	Average Annual	EMISSIONS REDUCTION					CO Emissions Saved	24	1	\$0.0	\$0.0	CO ₂ Emissions Saved	7,401	370	\$0.2	\$0.0	NO _x Emissions Saved	2	0	\$0.1	\$0.0	PM ₁₀ Emissions Saved	0	0	\$0.0	\$0.0	PM _{2.5} Emissions Saved	0	0			SO _x Emissions Saved	0	0	\$0.0	\$0.0	VOC Emissions Saved	1	0	\$0.0	\$0.0
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Appendix B: Technical Documentation

BACKGROUND AND SCOPE OF ANALYSIS

These benefits are calculated for four commuter types who use park-and-ride lots including:

- **New Transit Riders**, who switch from automobile to express bus
- **Existing Transit Riders**, who switch from local bus to express bus
- **New Carpoolers**, who switch from automobile to carpool or van
- **Existing Carpoolers**, who switch to a park-and-ride lot that requires less driving.

Four categories of benefits are computed for switching to these vehicles at park-and-ride lots including:⁶

- **Travel time savings** due primarily to faster travel speeds in high occupancy vehicle lanes and express buses (for transit riders).
- **Vehicle operating cost savings** due primarily to lower costs from more efficient travel at higher speeds and lower out-of-pocket costs that tradeoff parking costs and bus fare or carpool costs, depending on the commuter type.
- **Accident cost savings** due to the lower accident risk associated with fewer passenger vehicle-miles driven, because of commuter types' switch to carpools or buses.
- **Emission cost savings** due to the lower level of pollutant emissions from fewer miles driven by passenger vehicles, because of commuter types' switch to carpools or buses.

BENEFIT ESTIMATION

Data requirements for the park-and-ride model differ from other Cal-B/C models because of the specific nature of park-and-ride projects and accordingly involve some differences in calculations. For example, the user enters information on commuter types (e.g., bus riders or carpoolers and whether they are new or existing users), travel times on both normal and HOV lanes, and the distances traveled between the park-and-ride lot and a destination. The user enters other out-of-pocket costs for parking, and bus fare, depending on the project characteristics. In addition, the user must enter accident rates (per million vehicle-miles), as well as the percentage of fatal and injury accidents.

Travel Time Savings

The value of travel time savings for each traveler is a straightforward calculation that combines the estimated time to reach a destination with a value of time. The potential for time savings occurs because a park-and-ride facility enables travelers, especially commuters, to join a vehicle that can travel on lanes at higher speeds or a vehicle closer to their original departure point. A park-and-ride facility facilitates the use of commuter vehicles because it enables drivers to park and then join commuter vehicle. In some cases, the size of the lot can be a limiting factor in the

⁶ Residual value is not listed here because it is not a benefit category. It is only included in the results sheet to keep the original cost estimate free from adjustments at the end of evaluation period (20 years).



number of commuters who can effectively join vehicles. Projects that increase the number of parking spaces can increase the demand for using commuter vehicles. In addition, if a project facilitates reaching the park-and-ride lot by bike or on foot it can increase overall demand without additional vehicle externalities.

Travel time savings for each destination from the park-and-ride facility is determined by differences in travel times on normal and express lanes, or for travelers that switch from local to express buses. In addition, for projects that change the headways of buses, savings in waiting times could occur. Total time savings while traveling on faster lanes are reduced by waiting times to join vehicles. Note that consistent with other Cal-B/C models, this difference is used to estimate benefits only if the project generates positive travel time savings.⁷

The value of travel time is consistent with the standards set among the other Cal-B/C models that account for both waiting and moving times during a trip. In each case, Caltrans establishes a value of time for both in-vehicle travel and waiting time to be 50 percent of the median wage rate.

Cal-B/C computations are replicated for each destination that can be reached from a park-and-ride lot. The value of travel time is summed across all commuter types (i.e., users of carpool/vans and buses by existing and new users), depending on the vehicle options enabled by the park-and-ride project. Each of the commuter types is estimated separately.⁸ Time savings for each commuter type are found from the difference between No Build and Build conditions.

Scale of Impact	Impact Factors	Impact Value per Unit
<ul style="list-style-type: none"> Numbers of commuter types, by destination 	Travel times, by commuter type	Value of time

Scale of Impact: $N^{t,d} \cdot AF$

Where:

- $N^{t,d}$ = Number of daily volume of commuter types (t) and destination (d)
- AF = Annualization Factor equals 365 days.

Numbers of daily commuter types (t) for each vehicle and whether the user is existing or new are estimated for each destination (d). To compute these numbers, first the total number of users at a park-and-ride facility is determined by solving:

$$TotN = S \cdot F \cdot AVO + WB$$

Where:

- TotN = Total number of daily commuters covering all destinations

⁷ If the difference in travel time savings is negative, the benefit is assumed to be zero. The rationale for this is that the new bus riders must have shifted modes for reasons other than travel time savings. Assuming that these new riders are rational, the sum of all benefits must be positive. Since Cal-B/C is unlikely to capture all benefits (e.g., the value of reducing stress by travelers not having to drive, the improved reliability of transit, etc.), the model conservatively estimates that the new transit riders do not receive a benefit.

⁸ Note that a breakdown between existing and new users for each commuter vehicle is not necessary.

- S = Number of additional spaces at a facility, either as a new or expanded facility
- F = Percentage of the spaces that are filled on average.
- AVO = Average vehicle occupancy reaching a park-and-ride facility
- WB = Number of users who walk or bike to a park-and-ride facility.

Second, the number of commuter types to a given destination is computed with a pair of percentages: the share of commuters going to a destination, $Dest^d$, and the share of commuter types, C^t per destination.⁹

$$N^{t,d} = TotN \cdot Dest^d \cdot C^t$$

Where:

$Dest^d$ = Percentages of all users going to a specific destination

C^t = Percentages of commuter types for a given destination.

Impact Factors: $TotT^{t,d} = T^{t,d} - WT^{t,d}$

Where:

- $T^{t,d}$ = Travel times to reach a destination (d) by commuter vehicle type (t)
- $WT^{t,d}$ = Waiting times for a commuter vehicle (t) doing to destination (d).

This approach estimates the total travel time by subtracting the waiting time for a vehicle from in-vehicle travel times. Travel and waiting times differ for each commuter type as shown in the table below. Travel time savings for existing carpool/van commuters occur if a new park-and-ride facility is closer to the origins of their trips. New commuters save time when they travel in commuter vehicles on express lanes. Total time savings for new users subtract waiting times from travel times.

Commuter Type	Scenario	Travel Time	Waiting Time
New – Bus	No Build	Time @ normal speed to destination	Time until next bus
New – Bus	Build	Time @ HOV speed to destination	Time until next bus
Existing – Bus (Local)	No Build	Time @ local bus speed to destination	0
Existing – Bus (Express)	Build	Time @ Expr. bus speed to destination	0
New – Carpool/Van	No Build	Time @ normal speed to destination	0
New – Carpool/Van	Build	Time @ HOV speed to destination	Time until next veh.
Existing – Carpool/Van	No Build	Time @ normal speed to next PnR	0
Existing – Carpool/Van	Build	Time @ HOV speed to next PnR	0

Value of Impact per Unit: VOT

Where:

- VOT = Value of Time, in dollars per hour, by vehicle type and other special conditions

⁹ The sum of percentages of users to all destinations, $Dest^d$, must sum to 100%. In addition, for a given destination, the sum of shares of all commuter types, C^t , must sum to 100%.

Total Value of Time Savings, for all commuter types (t) per destination (d):

$$VTT^d = [N^{t,d} \cdot AF] \cdot TotT^{t,d} \cdot VOT$$

Vehicle Operating Cost Savings

The methodology used in Cal-B/C separates fuel operating costs from non-fuel operating costs. Among the components of vehicle operating costs, the relationship between fuel consumption and speed is the most widely understood and modeled. Since fuel rates are separated from other costs, fuel prices (minus taxes) can be updated without altering consumption rates. Moreover, consumption rates can be updated as revised estimates become available. The methodology for Cal-B/C was developed to be 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.

Fuel consumption data are based on estimates of current average consumption rates. The fuel consumption rates used in Cal-B/C are discussed in the Cal-B/C Parameters Guide. The model determines an appropriate fuel consumption rate based on speed for each project year. Vehicle speed is computed by dividing project distance by travel time. Speed varies by facility type over time. Consumption rates are converted into the total fuel consumed using an estimated VMT based on the number of travelers to each destination. These daily estimates are converted into annual estimates by multiplying by an annualization factor. The result is multiplied by a fixed fuel cost per mile and added to non-fuel costs. Discussion on the costs of fuel and non-fuel usage are discussed in the Cal-B/C Parameters Guide.

The estimate of vehicle operating costs are developed for each commuter type applies a similar set of computations as discussed for travel time savings. The difference for vehicle operating costs is that the valuation metric is based on distance traveled rather than time. Accordingly, the distance to each destination enters the computations.

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

Scale of Impact: $V^{t,d} = N^{t,d} / AVO, AF$

Where:

- $V^{t,d}$ = Daily volume of vehicles of commuter types (t) for each destination (d)
- $N^{t,d}$ = Daily volume of commuter types (t) for each destination (d)
- AVO = Average vehicle occupancy in vehicles, either in passenger or commuter vehicles
- AF = Annualization Factor equals 365 days.

See discussion above for derivation of $N^{t,d}$. $N^{t,d}$ is divided by AVO to determine the number of vehicles traveling to each destination. Depending on the No Build or Build context, AVO is equal to occupancy of passenger vehicles or carpool/van vehicles, respectively.

Impact Factors: $Dist^{t,d}$ · $Fuel^{t,d}$, $Time^{t,d}$

Where:

- $Dist^{t,d}$ = Travel distance to each destination by a commuter vehicle (t) is multiplied by 2 to reflect a roundtrip length
- $Fuel^{t,d}$ = Fuel consumption rates depend on average vehicle speed, $S^{t,d}$
- $S^{t,d}$ = Travel speed is computed by dividing travel distance ($Dist^{t,d}$) by travel time ($Time^{t,d}$) by mode and destination.

Impact Value per Unit: $VOC^{t,d}$

Where

- $VOC^{t,d}$ = Sum of fuel, non-fuel and other out of pocket costs, depending on the commuter type and destination. These costs relate to vehicle use, i.e., Fuel and Non-Fuel Costs, and other out-of-pocket costs by mode. Costs differ by commuter type and scenario.

Commuter Type	Scenario	Highway Vehicle Use	Other Out of Pocket
New – Bus	No Build	0	Local Bus Fare
New – Bus	Build	0	Express Bus Fare
Existing – Bus (local)	No Build	Fuel @ normal speed + Non-Fuel	Parking
Existing – Bus (express)	Build	Fuel @ HOV speed + Non-Fuel	Express Bus Fare
New – Carpool/Van	No Build	Fuel @ normal speed + Non-Fuel	0
New – Carpool/Van	Build	Fuel @ HOV speed + Non-Fuel	0
Existing – Carpool/Van	No Build	Fuel @ normal speed + Non-Fuel	Parking
Existing – Carpool/Van	Build	Fuel @ HOV speed + Non-Fuel	Share of Parking by AVO

Total Value of Vehicle Operating Costs, by mode:

$$VVOC^{t,d} = [V^{t,d} \cdot AF] \cdot [Dist^{t,d} \cdot Fuel^{t,d}] \cdot VOC^{t,d}$$

Accident Cost Savings

Reducing the risk of vehicle accidents is a primary motivation for many highway capital investments or improvement projects. For example, about one-third of total benefits on many projects can be related to a project’s improved safety conditions. Benefits of improved safety are estimated from the estimated reduction in the number or severity of accidents with a project and comparing that number and severity without the project. The monetary values for each type of accident are used to determine a monetized total value of accident risk reduction over time.

Data involved in accident risk reduction analyses principally entail estimating annual accident rates by type with historical data and assuming these rates are reasonable forecasts without a project. With a project, changes could occur with safer infrastructure, lower traffic volumes or both. Accident data are categorized in Cal-B/C as follows:

- **Fatal Accidents:** Total value of a fatal accident accounts for the lives lost, the injuries sustained, and the property damaged in the accident.
- **Injury Accidents:** Valuation of injuries accounts for different severity levels of injuries.
- **Property Damage Only Accidents:** Cal-B/C uses a value for PDO accidents.

Cal-B/C PnR estimates the impact of a transportation project on accident costs by comparing accident costs under No Build and Build scenarios over a 20-year period. Additional information on accident cost methodology is 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
<ul style="list-style-type: none"> • Commuter types by vehicle • Commuter vehicles • Vehicle Occupancy 	Travel distance by destination	Fuel, Non-Fuel operating costs by vehicle type

Scale of Impact: $V^{t,d} = N^{t,d} / AVO, AF$ (See discussion above for derivation of $V^{t,d}$)

Where:

- $V^{t,d}$ = Daily volume of vehicles of commuter types (t) for each destination (d)
- $N^{t,d}$ = Daily volume of commuter types (t) for each destination (d)
- AVO = Average vehicle occupancy in vehicles, either in passenger or commuter vehicles
- AF = Annualization Factor equals 365 days.

Impact Factors: $Dist^{t,d}$

Where:

- $Dist^{t,d}$ = Travel distance to each destination is multiplied by 2 to reflect a roundtrip length

Impact Value per Unit: $ACC^{t,d}$

Where:

- $ACC^{t,d}$ = Sum product of accident frequencies and costs per accident per mile by severity
 $ACC^{t,d} = (FatalAcc^{t,d} \cdot CostFatal^{t,d} + InjAcc^{t,d} \cdot CostInj^{t,d} + PDAcc^{t,d} \cdot CostPD^{t,d})$

$ACC^{t,d}$, accident costs per-mile by commuter vehicle, are derived using incident rates by accident severity (e.g., $FatalAcc^{t,d}$) and the respective cost by severity ($CostFatal^{t,d}$). The table below shows how costs are incurred by commuter type. For instance, a new bus commuter would reduce accident risk for drivers. Existing bus commuters that switch from local to express bus have no change in accident risk. Carpool/van commuters represent a reduction in accident risk based on the lower miles driven in No Build and Build.



Commuter Type	Scenario	Accident Costs
New – Bus	No Build	Highway Accident Costs per Mile – No Build
New – Bus	Build	0
Existing – Bus (local)	No Build	0
Existing – Bus (express)	Build	0
New – Carpool/Van	No Build	Highway Accident Costs per Mile – No Build
New – Carpool/Van	Build	Highway Accident Costs per Mile – Build
Existing – Carpool/Van	No Build	Highway Accident Costs per Mile – No Build
Existing – Carpool/Van	Build	Highway Accident Costs per Mile – Build

Total Value of Accident Risk Reduction, by mode:

$$VAR^{t,d} = [V^{t,d} \cdot AF] \cdot Dist^{t,d} \cdot ACC^{t,d}$$

Emission Cost Savings

Transportation investments also have external consequences on people, whether they use the facilities or not, and the natural environment. Cal-B/C focuses on the environmental impacts associated with result of commuters using a facility.¹⁰ Travel 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.¹¹ In addition, monetized costs of specific pollutants per unit of measure are well-established.

Cal-B/C PnR estimates the benefits of reduced pollutant emissions by comparing the value of emissions costs with and without the transportation project. Air pollutant emissions are estimated based on vehicle-miles traveled and a per-mile emissions rate, which depend on travel speeds.

¹⁰ 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.

¹¹ 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.

The accident cost methodology is discussed further in the Cal-B/C Resource Guide. Additional information on accident valuation parameters is provided in the Cal-B/C Parameters Guide.

Scale of Impact	Impact Factors	Impact Value per Unit
<ul style="list-style-type: none"> Commuter types by vehicle Commuter vehicles Vehicle Occupancy 	Travel distance, by destination	<ul style="list-style-type: none"> Valuation per unit of emissions, by pollutant Emissions rates per vehicle, by pollutant

Scale of Impact: $V^{t,d} = N^{t,d} / AVO, AF$ (See discussion above for derivation of $V^{t,d}$)

Where:

- V_t^d = Daily volume of vehicles by commuter types for each destination (d)
- N_t^d = Daily volume of commuter types by vehicle-users (carpool/van vs. bus and existing vs. new) and destination (d)
- AVO = Average vehicle occupancy in vehicles (see note above on differences between No Build and Build scenarios)
- AF = Annualization Factor equals 365 days.

Impact Factors: $Dist^{t,d}$

Where:

- $Dist^{t,d}$ = Travel distance to each destination is multiplied by 2 to reflect a roundtrip length
- $S^{t,d} = Dist^{t,d} / Time^{t,d}$, determined as a function of travel distance and travel time $Time^{t,d}$ over that distance per commuter vehicle type.

The model calculates emissions benefits for each year by looking up emissions on the basis of the estimated speed for that year. Air pollution emissions for highway projects are calculated given estimates of vehicle travel and speeds.

Impact Value per Unit: $EC^{t,d}$

Where:

- $EC^{t,d}$ = Emissions cost equals the sum product of each pollutant's emissions (*pollutant^m*) rate per mile by mode (m), and costs per pollutant ($VPP_{pollutant}$).¹² The equation is:

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

The table below shows how in-vehicle pollutant emissions costs are incurred by commuter type. For instance, a change in bus type would not result in a change in emissions costs. Carpool/van commuters represent a reduction in emissions costs based on the lower miles driven in the No Build and Build scenarios. In each case, any additional commuters who arrive by biking or walking to the PnR facility, and switched from passenger vehicles would have higher "starting" emissions in the No Build case and zero emissions in the Build case, after they switch.

¹² Emissions rates are a function of vehicle speed, which is a user input.



Commuter Type	Scenario	Running (In-Vehicle) Pollutant Costs
New – Bus	No Build	Pollutant Costs per Mile – No Build
New – Bus	Build	0
Existing – Bus	No Build	0
Existing – Bus	Build	0
New – Carpool/Van	No Build	Pollutant Costs per Mile – No Build
New – Carpool/Van	Build	Pollutant Costs per Mile – Build
Existing – Carpool/Van	No Build	Pollutant Costs per Mile – No Build
Existing – Carpool/Van	Build	Pollutant Costs per Mile – Build

Total Value of Emissions Reduction, by mode:

$$VER^{t,d} = [V^{t,d} \cdot AF] \cdot Dist^{t,d} \cdot EC^{t,d}$$