California Air Resources Board

Quantification Methodology

California High-Speed Rail Authority
High-Speed Rail Project

California Climate Investments

Final
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Section A. Introduction

California Climate Investments is a statewide initiative that puts billions of Cap-and-Trade dollars to work facilitating greenhouse gas (GHG) emissions reductions; strengthening the economy; improving public health and the environment; and providing benefits to residents of disadvantaged communities, low-income communities, and low-income households, collectively referred to as "priority populations." Where applicable and to the extent feasible, California Climate Investments must maximize economic, environmental, and public health co-benefits to the State.

The California Air Resources Board (CARB) is responsible for providing guidance on estimating the net GHG benefits and co-benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). This guidance includes quantification methodologies, co-benefit assessment methodologies, and benefits calculator tools. CARB develops these methodologies and tools, in consultation with administering agencies, based on the project types and activities eligible for funding by each administering agency, as reflected in the *program expenditure records*.

The California High-Speed Rail Authority (CHSRA or Authority) is responsible for planning, designing, building, and operating California's high-speed rail (HSR) system. Provision 10 of Item 2665-306-6043 of Senate Bill (SB) 1029 (Committee on Budget, Chapter 152, Statutes of 2012) directs the Authority to analyze the GHG impacts of the HSR system. Additionally, the Authority is required by Public Utilities Code Sec. 185033 to prepare, publish, adopt, and submit a Business Plan to the California Legislature every two years. The Authority's Business Plan is an overarching policy document used to inform the Legislature, the public, and stakeholders of the project's implementation and assist the Legislature in making policy decisions regarding the HSR system.

For the Authority, CARB staff developed this HSR Quantification Methodology to summarize the quantification approach used by the Authority to estimate the net GHG emissions reductions and air pollutant emissions co-benefits from operation of the HSR system. This Quantification Methodology summarizes the approach developed by the Authority and used to estimate net emissions reductions associated with transportation mode shifts from low-occupancy vehicles and airplanes to the lower-emitting HSR system during HSR system operation. In accordance with the California Environmental Quality Act and the National Environmental Policy Act, the Authority prepared a programmatic Environmental Impact Report/Environmental Impact Statement (EIR/EIS) for the entire HSR system.[i] The programmatic EIR/EIS considers the comprehensive nature and scope of the proposed HSR system; this Quantification Methodology only considers the evaluation of the net emissions

[i] California High-Speed Rail Authority (2005). *Program EIR/EIS Documents for the Statewide High-Speed Rail System (Tier 1) webpage*.

reductions associated with the *operation* of the HSR system, as described in Section B.

For GGRF reporting purposes for the *Annual Report to the Legislature* (Annual Report) and companion materials, the Authority will report to CARB the total net GHG emissions reductions and air pollutant emissions co-benefits estimated using the approach and methods outlined in this Quantification Methodology. If any of the methods or equations used in the estimation of GHG emissions reductions and air pollutant emissions co-benefits are updated, CARB, in consultation with the Authority, will review and update this Quantification Methodology, as necessary. Any changes to the approach or methods, and resulting changes to estimates, may not be captured in the Annual Report or companion materials until this Quantification Methodology has been updated.

California High-Speed Rail Project

The goal of the HSR system is to connect San Francisco and the Los Angeles Basin and eventually extend to Sacramento and San Diego, totaling 800 miles with up to 24 stations. The HSR system reduces GHG and air pollutant emissions by:

- Shifting travel from cars and airplanes to the HSR system;
- Shifting from higher-emitting energy sources and petroleum-based fuels to 100 percent solar energy and battery storage sources for rail operations;
- Implementing a multi-faceted tree planting program; and
- Mitigating emissions from the construction phase through strict, binding requirements on construction contractors.

Business Plan and Ridership Forecasts

The Authority is required to prepare, publish, adopt, and submit a Business Plan to the California Legislature every two years. Each Business Plan summarizes the progress made over the past two years, including updates to available funding and financing, ridership and revenue forecasts, and risk management information. The business plans are available on the Authority's *Business Plans webpage*.

The Authority provides updated ridership forecasts for the Business Plan every two years using the California Rail Ridership Model (CRRM), a new model that replaced the previously used Business Plan Model (BPM) Version 3. The new model was developed by the Authority in collaboration with the California Department of Transportation (Caltrans) Division of Rail and Mass Transportation to reflect, in more detail and with an updated database, the effects of an integrated high-speed rail network in California, and to evaluate impacts on connecting rail and transit services in the State. These forecasts are produced by the Authority in consultation with the Ridership Technical Advisory Panel and the Authority's Peer Review Group.

Sustainability Report

In addition to the Business Plan, the Authority publishes an annual Sustainability Report that provides a summary of the program's performance and progress—including information on business and management, energy, natural resources, sustainable infrastructure, and communities. The reports are available on the Authority's *Sustainability Report webpage*.

Methodology Development

CARB, in consultation with the Authority, developed this Quantification Methodology consistent with the guiding implementation principles of California Climate Investments, per the *California Climate Investments Funding Guidelines*. This Quantification Methodology summarizes the approach used by the Authority to estimate the GHG emissions reductions and air pollutant emissions co-benefits for HSR operations over a 50-year period. The Authority developed the approach used to estimate outcomes and to track results of the HSR system. CARB released the Draft HSR Quantification Methodology for public comment on March 22, 2024. This Final HSR Quantification Methodology has been updated to address public comments, where appropriate, and for consistency with updates to the Authority's approach.

This Quantification Methodology summarizes the ridership model, methods, and emission factors used in the Authority's approach and associated with:

- Mode shift from low-occupancy auto vehicle miles traveled (VMT) to the HSR system;
- Mode shift from air travel to the HSR system; and
- Shift from higher-emitting energy sources and petroleum-based fuels to 100 percent solar energy sources and battery storage for rail operations.

While data and inputs are continually updated by the Authority, the methods and equations used in the Authority's approach are presented in this document. These methods and equations are provided in greater detail in Section B of this document. CARB staff have determined the approach used by the Authority is reasonable for estimating GHG emissions reductions and air pollutant emissions co-benefits associated with operation of the HSR system.

Updates

Updates to the methods, models, and reports on the HSR system are presented by the Authority in each subsequent Business Plan and supporting documentation, as applicable. The Authority updates the CRRM as needed to incorporate more recent input data, new variables, and adjustments, among other considerations. If any of the methods or equations used in the estimation of GHG emissions reductions and air pollutant emissions co-benefits are updated, CARB, in consultation with the Authority, will review and update this Quantification Methodology, as necessary.

Program Assistance

Stakeholders should use the following resources for additional questions and comments:

- Questions on this document should be sent to the *GGRF program email*.
- For more information on CARB's efforts to support implementation of California Climate Investments, see the *California Climate Investments homepage*.
- Questions pertaining to the HSR and the Authority should be sent to the main *HSR email*.

Section B. Methods

General Approach

This section describes the methods used by the Authority to estimate the net GHG emissions reductions and air pollutant emissions co-benefits from operation of the HSR system. The estimated net GHG emissions reduction and air pollutant emissions co-benefits result from reductions in auto VMT and air travel, as estimated by the CRRM, as well as emissions generated from energy production to operate and maintain the HSR system.

This Quantification Methodology summarizes the Authority's approach used to estimate the net emissions reductions associated with:

- Mode shift from low-occupancy auto VMT to the HSR system;
- Mode shift from air travel to the HSR system; and
- 100 percent shift from higher emitting energy sources and petroleum-based fuels to solar generation and battery storage for rail operations.

In general, the net emissions reductions are estimated using the following approach:

Equation 1. General Approach to Quantification – Total Emissions Reductions

$$Total\ Emissions\ Reductions = Emissions\ Reductions_{Auto\ VMT} + Emissions\ Reductions_{Air\ Travel}$$

Table 1. Variable Definitions for Equation 1

Variable	Variable Definition	Units
Total Emissions Reductions	Total emissions reductions for the HSR system	MT CO_2e
Emissions $Reductions_{Auto\ VMT}$	Emissions reductions associated with mode shift from low-occupancy auto VMT to the HSR system	MT CO_2e
Emissions $Reductions_{Air\ Travel}$	Emissions reductions associated with mode shift from air travel to the HSR system	MT CO_2e

Equation 2. General Approach to Quantification – Net Emissions Reductions

$$Net\ Emissions\ Reductions = Total\ Emissions\ Reductions\ -\ Emissions_{Energy\ Use}$$

Table 2. Variable Definitions for Equation 2

Variable	Variable Definition	Units
Net Emissions Reductions	Net emissions reductions for the HSR system	MT CO_2e
Total Emissions Reductions	Total emissions reductions for the HSR system	MT CO_2e
$Emissions_{Energy\ Use}$	Emissions from energy to operate the HSR system	MT CO_2e

NOTE: GHG emissions for site preparation, upstream[ii] emissions from materials, or any mitigation activities (e.g., sequestration from tree planting) are not included in the Authority's net GHG emissions reduction estimate, nor were they evaluated by CARB staff for the purposes of this Quantification Methodology.

[ii] "Upstream" is used in the context of life cycle assessment, and pertains to feedstock materials and energy associated with the production, processing, and delivery of infrastructure materials.

Tools

The Authority's approach to estimate the net GHG emissions reductions and air pollutant emissions co-benefits from operation of the HSR system relied on project-specific outputs from the latest version of the CRRM and CARB Mobile Source Emission Factor Model (EMFAC).[iii]

The Authority used the CRRM to produce ridership and revenue forecasts for different service options of the HSR system. The CRRM is a 4-step travel demand model that incorporates HSR and all other travel mode network assumptions, socioeconomic data, and travel behavior and preference data, among other inputs, to project ridership and revenue for future forecast years. The CRRM has undergone multiple rounds of calibration and validation, and the model incorporates the latest industry best practices, data, surveys, and methodologies. A more detailed overview of the methods applied in the CRRM is located in Appendix A of this document; the full model documentation can be found on the Authority's *Ridership and Revenue Forecasting webpage*.

The Authority used EMFAC to develop vehicle emissions factors for estimating GHG emissions reduction and air pollutant emissions co-benefits. Unless otherwise specified, the Authority uses "well-to-wheel" factors when quantifying emissions estimates. EMFAC is used statewide, subject to regular updates to incorporate new information, and available free of charge to anyone with internet access on the *EMFAC webpage*.

[iii] The Authority uses the latest available version of the EMFAC model that has been approved by the U.S. Environmental Protection Agency.

A. Emissions Reduction Estimates from Auto Mode Shift

The Authority estimated the emissions reductions that result from the mode shift of low-occupancy vehicles to the HSR system using the reduction in statewide auto VMT from the CRRM and auto emission factors from EMFAC. The emissions reduction estimates from auto VMT reductions are estimated using Equation 3.

Equation 3. Emissions Reductions from Auto Mode Shift

$$Emissions\ Reductions_{Auto\ VMT} = \sum_{i}^{i+50} [Annual\ VMT_{CRRM}\ x\ EF_{Auto}]_i \times \left[\frac{CVMT}{Total\ VMT}\right]_i$$

Table 3. Variable Definitions for Equation 3

Variable	Variable Definition	Units
Emissions $Reductions_{Auto\ VMT}$	Total emissions reductions from reduced auto VMT	MT CO_2e
i	The operation year (over a 50-year quantification period)	Year
Annual VMT_{CRRM}	Reduced annual auto VMT, as calculated from the CRRM	Miles
EF_{Auto}	Weighted annual auto emission factor, using Equation 4	MT CO_2e/ mile
CVMT	Conventionally-fueled vehicle miles traveled by speed, vehicle, and fuel type	Miles
Total VMT	Total vehicle miles traveled	Miles

The CRRM forecasts statewide long-distance travel behavior, including long-distance travel by low-occupancy vehicles, in build and no-build scenarios. The model was developed and calibrated on 2018 base year conditions with the capability of forecasting travel demand for future years 2030, 2040, and 2050. Annual VMT reductions are calculated by subtracting total VMT in the HSR-build scenario from total VMT in the no-build scenario.

The Authority developed the annual auto emission factors using a weighted average by VMT for gasoline and diesel fuel types using Equation 4.

Equation 4. Annual Auto Emissions Factor

$$EF_{Auto} = \sum_{i}^{i+50}\left[\frac{(CVMT * E_{RUNEX} * CF)_{LDA} + (CVMT * E_{RUNEX} * CF)_{LDT1} + (CVMT * E_{RUNEX} * CF)_{LDT2}}{Total\ CVMT}\right]_i$$

Table 4. Variable Definitions for Equation 4

Variable	Variable Definition	Units
EF_{Auto}	Weighted annual auto emission factor	MT CO_2e/mile
i	The operation year (over a 50-year quantification period)	Year
CVMT	Conventionally-fueled vehicle miles traveled by speed, vehicle, and fuel type	Miles
E_{RUNEX}	Emissions rate by speed, vehicle, and fuel type	MT CO_2e/mile
CF	Conversion factor[iv]	Varies
Total CVMT	Total conventionally-fueled vehicle miles traveled	Miles

EMFAC provides emissions factors in two modes: stabilized running mode (RUNEX) and start mode (STREX). For carbon dioxide (CO_2), RUNEX provides tailpipe emissions rates for the vehicle after it has reached optimal running temperature, while STREX provides emission rates for the vehicle during the first 100 seconds of operation after the engine has been started, when engine and/or catalyst may not have achieved their optimal operating temperature range. Additionally, EMFAC categorizes passenger vehicles as light-duty autos (LDA), light-duty trucks (LDT1 and LDT2), and medium-duty vehicles (MDV).

The Authority developed annual statewide emission factors using RUNEX CO_2 emission rates for LDA, LDT1 and LDT2. The Authority excluded STREX emission rates and the MDV category from the analysis to reflect expected travel modes. EMFAC currently does not project emission rates beyond 2050; therefore, the developed emission factors used in the analysis remain constant at the 2050 emission rate for years beyond 2050. Similar calculations were performed to estimate methane (CH_4) and nitrous oxide (N_2O) emissions using EMFAC data. The Authority's estimates include consideration for zero-emission vehicle and plug-in hybrid electric vehicle

[iv] Emission rates are multiplied by 10^{-6} to convert grams to metric tons (MT) and 2.2046×10^{-3} to convert grams to pounds (lbs.).

electricity consumption using the electricity consumption data from EMFAC. The Authority used emissions factors based on CARB's emissions inventory data, developed based on the grid mix using total system electric generation from the California Energy Commission[v] and GHG emissions from the CARB inventory.[vi]

The Authority incorporates the "well-to-tank" portion of the estimate using emission factors based on the latest version of the California Air Resources Board CA-GREET Model.[vii]

The Authority includes fugitive road dust emissions in its roadway estimates.[viii] The Authority estimates these emissions using CARB's emission inventory methodology for Entrained Road Travel, Paved Road Dust, which expands upon the U.S. Environmental Protection Agency AP-42 methodology and provides California-specific values.

[v] California Energy Commission (2021). *Total System Electric Generation*.
[vi] California Air Resources Board (2023). *California GHG Emissions Inventory Data.*
[vii] California Air Resources Board (2019). *CA-GREET 3.0*.
[viii] California Air Resources Board (2021). *Entrained Road Travel, Paved Road Dust*.

B. Emissions Reduction Estimates from Airplane Travel Mode Shift

The Authority estimated the emissions reductions that result from the mode shift of air trips to the HSR system based on the reduction in statewide air travel from the CRRM and emission factors from the EMEP/EEA Guidebook[ix] and CA-GREET3.0.[vii] The emissions reduction estimates from air travel reductions are estimated using Equation 5.

Equation 5. GHG Emissions Reductions from Airplane Mode Shift

$$Emissions\ Reductions_{Air\ Travel} = \sum_{i}^{i+50} [(Annual\ Air\ Trips_{CRRM} / Air\ Passengers)\ x\ EF_{Plane}]_i$$

Table 5. Variable Definitions for Equation 5

Variable	Variable Definition	Units
Emissions $Reductions_{Air\ Travel}$	Total emissions reductions from reduced air travel	MT CO_2e
i	The operation year (over a 50-year quantification period)	Year
Annual air $Trips_{CRRM}$	Annual air-passengers diverted to the HSR system, as calculated from the CRRM	Passengers
Air Passengers	Number of air passengers per flight (for each modeled year i), as calculated from the CRRM and based on Bureau of Transportation Statistics (BTS) data[x]	Air Passengers/ flight
EF_{Plane}	Emission factor for airplane trips from the 2023 EMEP/EEA Guidebook and CA-GREET3.0[xi]	MT CO_2e/flight

Similar to auto VMT reductions, air-passenger trip reductions are estimated from CRRM forecasts in build and no-build scenarios for future years 2030, 2040, and 2050. Air-passenger trip reductions are the number of passengers that shift from air travel to the HSR system. Air-passenger trip reductions are used to estimate the number of airplane flights reduced which results in airline fuel use reductions. Airplane flights reduced are based on the average number of passengers per flight

[ix] European Environment Agency (2023). *2023 EMEP/EEA Guidebook.*
[x] Bureau of Transportation (2023). *Bureau of Transportation Statistics*.
[xi] Emission factors are multiplied by 10^{-6} to convert grams to metric tons (MT) and $2.2046x10^{-3}$ to convert grams to pounds (lbs).

between SFO and LAX according to BTS. Emission factors in the datasets are provided by airplane type.

The Authority applies a weighted average of these emission factors based on the percent of passengers per airplane type according to BTS to determine an overall emission factor in units of $MTCO_2e$ per flight. This is assumed to remain constant over the modeled time period. The updated fuel consumption estimates are based on the EMEP/EEA Guidebook. The fuel consumption estimates are then multiplied by the appropriate conversion factor.

The Authority incorporates the “well-to-pump” portion of the estimate using emission factors based on the latest CARB CA-GREET Model.[vii]

C. Emissions Estimates from Energy Usage

The Authority estimated the emissions from the operation and maintenance of the HSR system using the amount of energy needed annually to operate and maintain the HSR system, and the emission factors for the production of renewable energy used to operate the HSR system. The emissions associated with the operation of the HSR system are estimated using Equation 6.

Equation 6. Emissions from Energy Usage

$$Emissions_{Energy} = \sum_{i}^{i+50} [Annual\ Energy_{CRRM}\ x\ EF_{Renewable}]_i$$

Table 6. Variable Definitions for Equation 6

Variable	Variable Definition	Units
$Emissions_{Energy}$	Total emissions from energy to operate the HSR system	MT CO_2e
i	The operation year (over a 50-year quantification period)	Year
Annual $Energy_{CRRM}$	Annual energy required to operate the HSR system, as calculated from the CRRM	GWh
$EF_{Renewable}$	Emission factor for renewable energy[xii]	MT CO_2e/ GWh

Emission factors for renewable energy were taken from the 2013 Climate Registry Default Emission Factors.[xiii]

The estimated energy needed for future years to operate and maintain the HSR system includes energy for maintenance facilities, station facilities, revenue train-miles, and non-revenue train-miles (deadheading). The Authority has committed to shift from higher-emitting energy sources and petroleum-based fuels to 100 percent solar energy and battery storage sources for rail operations.[xiv]

[xii] Emission factors are multiplied by 10^{-6} to convert grams to metric tons (MT) and $2.2046x10^{-3}$ to convert grams to pounds (lbs).
[xiii] The Climate Registry (2013). *Climate Registry Default Emission Factors*.
[xiv] California High Speed Rail Authority (2023). *Sustainability Report*.

D. Net Emissions Reduction Estimates

The net emissions reductions for the HSR system, which is equal to the sum of each of the emissions reductions minus the sum of emissions (estimated from Equations 3 to 6), is estimated using Equation 7.

Equation 7. Net Emissions Reductions

$$Net\ Emissions\ Reductions = \sum Emissions\ Reductions_{Auto\ VMT} + \sum Emissions\ Reductions_{Air\ Travel} - \sum Emissions_{Energy}$$

Table 7. Variable Definitions for Equation 7

Variable	Variable Definition	Units
Net Emissions Reductions	Net emissions reductions for the HSR system	MT CO_2e
Emissions $Reductions_{Auto\ VMT}$	Total emissions reductions from reduced auto VMT, using Equations 3 and 4	MT CO_2e
Emissions $Reductions_{Air\ Travel}$	Total emissions reductions from reduced air travel, using Equation 5	MT CO_2e
$Emissions_{Energy}$	Total emissions from energy to operate the HSR system, using Equation 6	MT CO_2e

Appendix A. Ridership and Revenue Forecasting Model

The Authority has been developing and enhancing their travel demand forecast tools for over 15 years. Prior Business Plans and supporting documentation produced by the Authority used the BPM for travel demand forecasting. The more robust CRRM completed its first round of calibration in June 2022, and following a more granular re-calibration, the CRRM was deployed to generate HSR ridership and revenue forecasts for future year base case scenarios published in the 2024 Business Plan. The CRRM generates more robust estimates than the previous BPM (Version 3) due to enhanced access/egress from the core network and a new technique known as the pivot process, in which observed 2018 base year data is used to scale future year forecasts. The CRRM incorporates HSR and all other long-distance travel mode network assumptions, socioeconomic data, and travel behavior and preference data, among other inputs, to project ridership and revenue for future years 2030, 2040, and 2050.

The CRRM was developed by the Authority in collaboration with the Caltrans Division of Rail and Mass Transportation to reflect, in more detail and with an updated database, the effects of an integrated high-speed rail network in California, and to evaluate impacts on connecting rail and transit services in the State. The ridership model forecasts are also reviewed by an independent financial advisory firm specializing in infrastructure projects.

The CRRM is updated, as needed, to incorporate most recent socioeconomic data, new variables that better reflect travel behavior, and adjustments to transit access network and station locations, among other considerations.

Model Overview

The CRRM forecasts statewide travel in a given year for various model scenarios and captures travel within California as well as between California and neighboring states. Distances are calculated in the model using a detailed representation of the highway and transit network.

The model estimates trip frequency, destination choice, access/egress, and main mode choice stratified by trip purpose and time of day. Trip purposes include:

- **Home-based Business** – Includes all business travel to locations other than a traveler's normal place of work.
- **Home-based Commute** – Includes all travel to a person's regular place of work. Note that a person might work from home three or more days per week, but travel to an assigned office more than 50 miles from their home one or two days per week; such travel is included in the commute category.
- **Home-based Leisure** – Includes all trips made for recreation, vacations, leisure, or entertainment in which one trip end is the traveler's home.

- **Home-based Other** – Includes all trips made for other purposes, such as school, visiting friends or relatives, medical, personal business, weddings, and funerals in which one trip end is the traveler's home.
- **Non-home Based** – Includes trips in which neither the origin nor the destination of a trip is at a traveler's home.

The CRRM models trips made via auto, bus, air, conventional rail (intercity, commuter, and interstate), high-speed rail, and a combination of these modes. Access and egress mode choices include auto, taxi, and transit (including walking). The CRRM forecasts trips in five time periods:

- **Weekday AM Peak** – 06:00 – 10:00
- **Weekday Midday** – 10:00 – 15:00
- **Weekday PM Peak** – 15:00 – 19:00
- **Weekday Evening** – 19:00 – 00:00
- **Average Weekend** – 06:00 – 00:00

The CRRM is a 4-step travel demand model in which forecasted trips are assigned to modes, times of day, and network links and nodes. These network links include highway, flight, conventional rail, and high-speed rail networks. The long-distance trip frequency estimates account for induced demand resulting from improved accessibility due to the HSR system. Likewise, the destination choice estimates account for induced HSR corridor travel resulting from diversion from other corridors.

Modeled Scenarios

The CRRM pivots from 2018 data to forecast future travel demand for three scenarios: business as usual (BAU) and two build scenarios (Valley to Valley and Phase 1). Each scenario contains new future year assumptions for socioeconomic data, network alignments, service plans, stopping patterns, and fare structures for HSR services and connecting HSR bus services (when applicable). The BAU, or no-build scenario, models future conditions in the absence of HSR services. The Valley to Valley scenario includes HSR service between the San Francisco Bay Area and Bakersfield, with connecting HSR bus service to the Los Angeles Basin. The Phase 1 scenario includes HSR infrastructure and service to connect the San Francisco Bay Area and the Los Angeles Basin. This scenario includes three different service types: express, limited, and default.

Fare Analysis

After generating the total number of trips generated and attracted in each zone of the model, the CRRM works to link the productions and attractions to create trips. This is done through a "gravity model" that takes the form of a deterrence function that disincentivizes travel as distance, time, or costs increase; this function is calibrated with observed data to match trip length distributions by purpose. Finally, the CRRM's Choice Model takes as input the travel time and cost to assign the mode, representing the impact of time and cost on travel behavior decisions. Fares, a critical component of travel costs, have been updated since the 2020 Business Plan through a detailed fare sensitivity analysis. The new fare policy for Valley to Valley and Phase 1 includes fare differentiation by service type in which express, limited, and default services were tested using different fare assumptions. The fare elasticities were found to be reasonable and indicate variability by market, such that long-distance markets have higher fare elasticity than short-distance markets. This updated fare structure was input to the CRRM to model the build scenarios.

Model Runs

The CRRM is run several times for each scenario to produce base case and risk analysis forecasts. Data from these runs are used in linear regression models to approximate relationships between the HSR ridership and revenue, and model parameters. Monte Carlo simulations provide distributions of a range of HSR ridership and revenue forecasts, and the relative impact of each risk factor. Overall, these distributions show the projected high, medium, and low ridership forecasts, as presented in the Authority's Business Plans and supporting documentation.

The full model documentation and technical reports on ridership and revenue forecasting and risk analysis are available on the Authority's *Ridership and Revenue Forecasting webpage*.