QUANTIFYING THE IMPACT OF TRUCK ONLY LANES ON VEHICULAR EMISSIONS ON A LIMITED-ACCESS HIGHWAY

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ABSTRACT

Quantifying the Impact of Truck Only Lanes on Vehicular Emissions
on a Limited-Access Highway

Edward Chee Tang

This thesis seeks to estimate CO_2 emissions on a portion of the U.S. 101 highway in San Luis Obispo County before and after construction of a truck only lane on the Cuesta Grade. Towards that aim, the microsimulation software, VISSIM, was used in conjunction with the Environmental Protection Agency's emissions model, MOVES. The microsimulation model was calibrated and validated against historical and present traffic volumes obtained from Caltrans with good results using several validation measures. It was found that CO_2 emissions did decrease between 1998 and 2012 (pre and post lane addition), but this effect was shown to be different for the northbound (uphill) and southbound (downhill) directions. It was shown that the truck lane in the northbound (uphill) direction had a 9.5% decrease in volume with 10.7% decrease in emissions, and the southbound (downhill) direction had a 20.3% increase in volume but 7.4% decrease in emissions. For the northbound (uphill) direction, emissions seemed to correlate more closely with volumes, while the southbound (downhill) direction was less sensitive to these changes.

Keywords: Emissions, Limited-Access Highway, VISSIM, MOVES, Truck Only Lane

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1. INTRODUCTION

Greenhouse gas (GHG) emissions and other pollutants have long impacted global climate, public health, and the economy. Hundreds of studies already explore these effects, but quantifying these emissions is a critical step towards addressing them. In the transportation sector, emissions vary based on the type of vehicle, and simulation is a tool that can help quantify these sources. The transportation sector is a major source of carbon dioxide (CO_2) emissions, being second only to the electric utility sector (EPA, 2014). A few studies have used simulation to estimate emissions (Abou-Senna et al., 2013; Ahn et al., 1998; Chamberlin et al., 2011). Microscopic traffic simulation is a relatively low-cost and effective tool commonly used to create models to evaluate traffic systems under a variety of circumstances. These models are capable of realistically simulating a built and/or planned environment and generate outputs such as travel time, level of service, queuing, and other performance measures. Over various iterations of calibration, models can be improved over time to generate more accurate information. These data are useful to guide decision-makers, planners, and engineers when designing infrastructure in any type of urban or rural environment.

1.1 PROBLEM STATEMENT

1.1.1 Greenhouse Gas Emissions Trends in the United States

The Intergovernmental Panel on Climate Change's (IPCC) latest report shows that global average temperature continues to increase and is at the highest point in recorded history (2014). With increasing mobilization of people and goods over time, the number of vehicle miles traveled (VMT) in the United States has increased. Despite an increasingly efficient vehicle fleet (both in terms of fuel consumption and emissions) and policies aimed at curbing emissions, GHG emissions totaled 6,870 million metric tons of carbon dioxide equivalents, and transportation accounted for 26% of total GHG emissions in the United States. (EPA, 2014). Approximately 72% of total transportation emissions come from limited-access highways and freeways, with more than half of emissions generated from light cars and trucks (Green & Schafer, 2003).

Figure 1 represents transportation's impact on GHG emissions from 1990 – 2014. A slight decline in 2007 shows the effects of the economic recession (higher unemployment resulting in fewer VMT). The trend has remained mostly flat with the subsequent economic recovery, but CO_2 levels are still 16.3% higher than 1990 levels (EPA, 2014). In 2013, the EPA found that freight trucks were responsible for 22.8% of CO_2 emissions from the transportation sector, and cars contributed 42.7% (Figure 2). Given transportation's influence on GHG emissions and climate change, there is continued concern among the federal, state, and local levels to implement policies to reduce transportation emissions. The primary focus of any reductions goals should concentrate on highways and freeways.

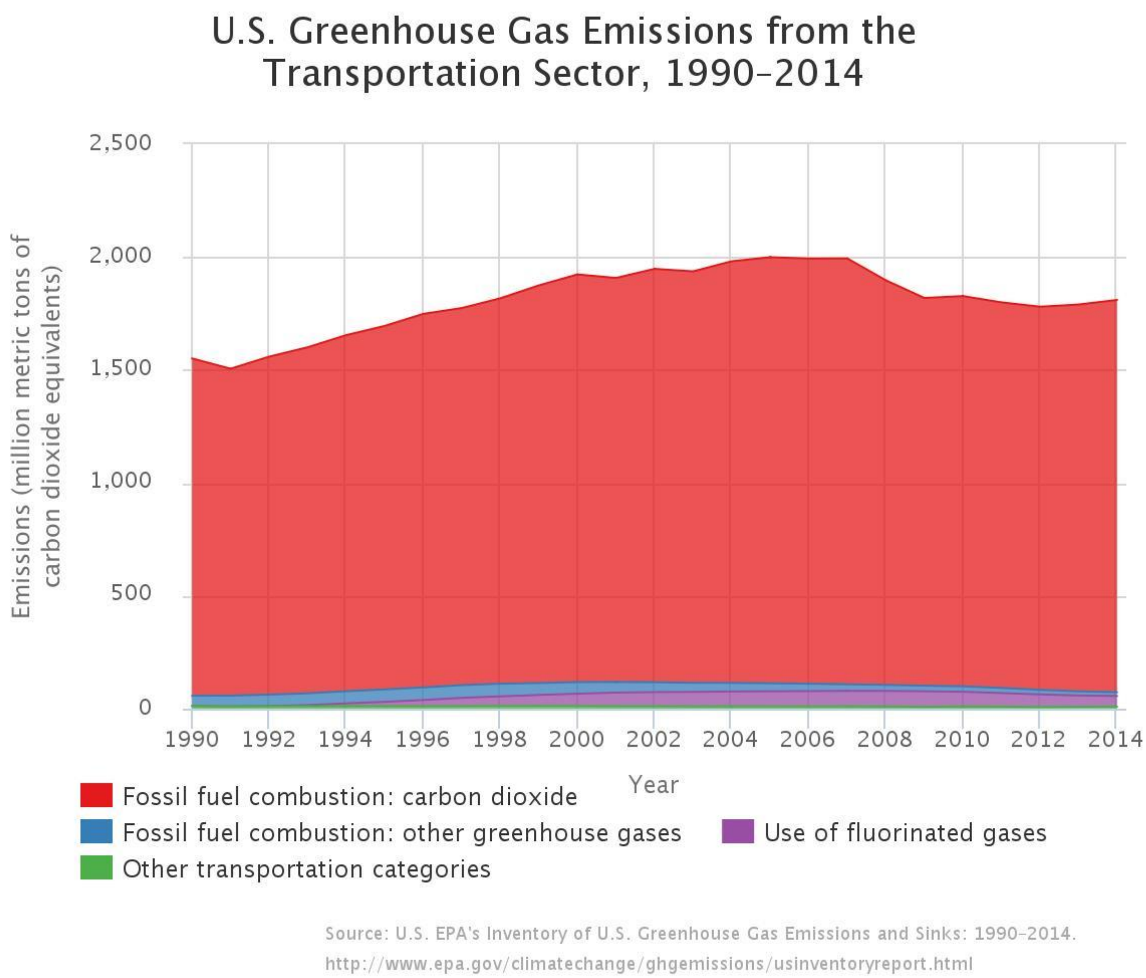


Figure 1. CO_2 emissions trends from the transportation sector.

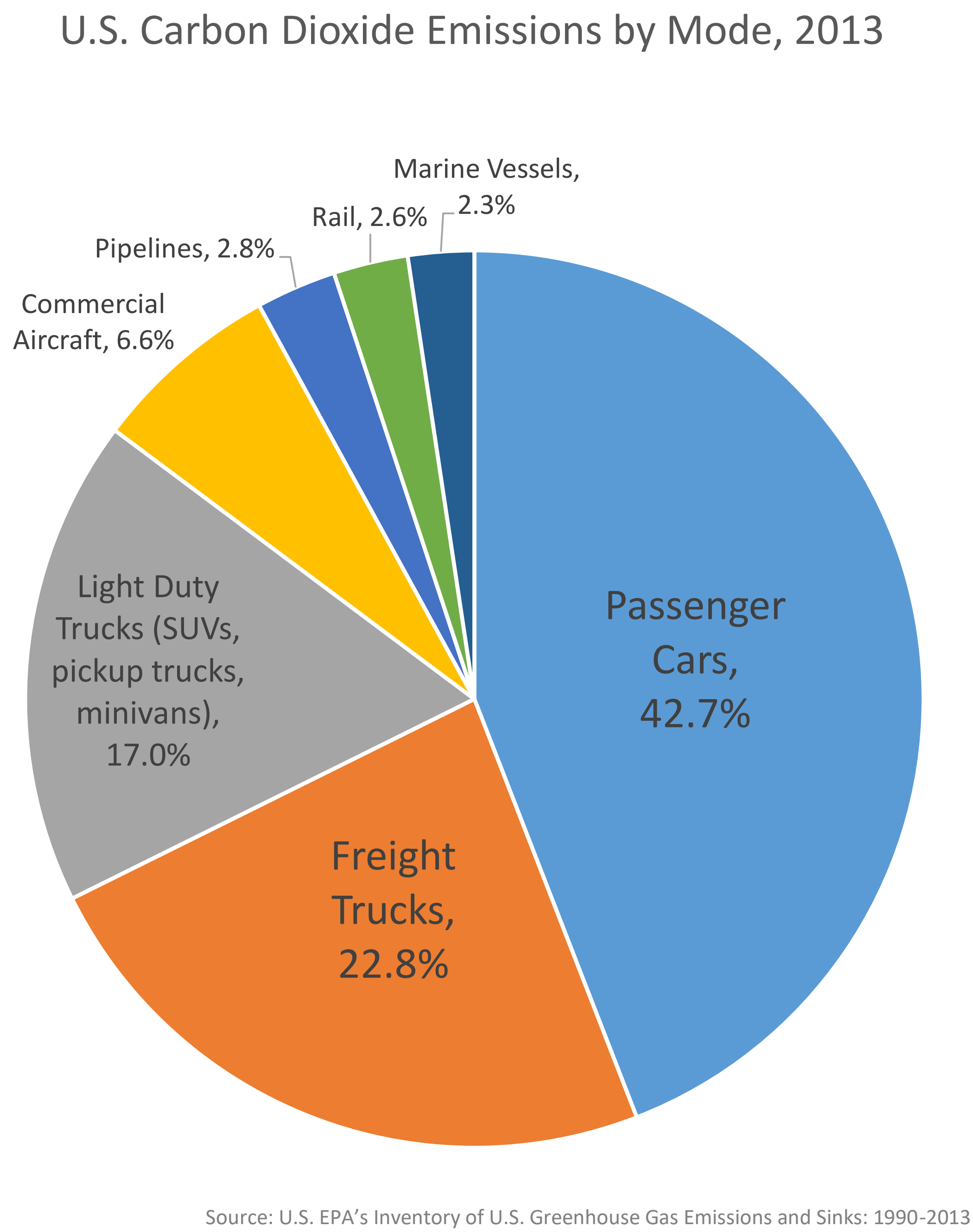


Figure 2. CO_2 emissions by mode

1.1.2 Types of Emissions

Emissions are classified as anthropogenic sources of air pollution and come from many sources. These sources include transportation, energy production, agriculture, manufacturing, and other industrial processes. The EPA has set National Ambient Air Quality Standards (NAAQS) that list six “criteria” air pollutants considered harmful to human health (carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide).

Emissions not considered “criteria” air pollutants are considered GHG. The EPA lists four main GHG (carbon dioxide, methane, nitrous oxide, and fluorinated gases). The impact of each gas on global warming is quantified with a global warming potential (GWP), and these are listed in Table 1. The GWP represents how much energy the emissions of one ton of gas will absorb relative to the reference gas over a given time scale. The reference gas is carbon dioxide and has a GWP of 1.

Table 1. List of GHG and their respective GWP and Lifetime

Greenhouse Gas	GWP	Lifetime in Atmosphere (years)
Carbon Dioxide (CO_2)	1 (reference gas)	> 1000
Methane (CH_4)	28 – 36 over 100 years	~10
Nitrous Oxide (N_2O)	265 – 298 over 100 years	> 100
Fluorinated Gases[1]	-	-
HFCs	12 – 14,800	1 – 270
PFCs	7,390 – 12,200	2,600 – 50,000
NF_3	17,200	740
SF_6	22,800	3,200

[1]Fluorinated gases include hydrofluorocarbons, perfluorocarbons, nitrogen trifluoride, and sulfur hexafluorides

Research has been done to more precisely determine the extent of vehicular emissions. Maness et al. obtained accurate emissions data for a highway by conducting *in-situ* measurements with a test vehicle equipped with a GPS probe and CO_2 sensors (2015). While some research has explored the effects of grades on GHG emissions, this required a similar approach necessitating a properly equipped test vehicle (Cicero-Fernândez et al., 2011; Boriboonson & Barth, 2009). Test vehicles are accurate but can be costly and time-consuming. Estimating GHG emissions on grades can be accomplished more efficiently with microscopic traffic simulation and integrating the results with an emissions model. The latest US EPA emissions model MOVES (Motor Vehicle Emissions Simulator) creates this opportunity. MOVES is a comprehensive GHG emissions model that can estimate CO_2 emissions of nearly any mobile source. Forecasting emissions is also possible with simulation as the model can be calibrated to nearly any scenario.

A plethora of research continues to support evidence that anthropogenic activity contributes to increasing levels of emissions, resulting in localized health problems and global climate change. In the United States, this has been mitigated to some extent by the Clean Air Act passed in 1973. More work is needed to address the rise of GHG emissions, which do not have direct impacts on human health, but have far-reaching impacts on the global scale. Using simulation to estimate GHG emissions is a useful tool for policy-makers to recognize trends in their region and develop goals to reduce emissions.

1.2 OBJECTIVES

U.S. 101 is a corridor that passes through San Luis Obispo but may handle traffic more regional travel from goods and people than local travel. With a valid simulation model that accurately reflects factors such as highway capacity, grades, meteorological conditions, and vehicle volumes and speeds, it is possible to estimate GHG emissions. The objectives of this study are:

- To create a properly calibrated and validated traffic simulation model in VISSIM that reflects PM peak traffic conditions on the Cuesta Grade of U.S. 101 (refer to Section 3 for more details of the study area), including volumes, speeds, and vehicle composition. VISSIM is chosen for its high level of detail and functionality.
- To compute detailed surface CO_2 emissions generated by vehicles during this time period using MOVES. Data gathered from VISSIM will be used as inputs for MOVES.
- To compare surface emissions before-and-after the construction of a truck only lane, to determine any impacts, if any.
- To provide the framework for validating the simulation results through a mobile instrument to perform *in-situ* measurements of CO_2 emissions on the Cuesta Grade. Data from in-situ measurements can be used for further calibration of the future simulation-based emissions model.

2. BACKGROUND AND LITERATURE REVIEW

2.1 SIMULATION IN TRANSPORTATION

2.1.1 Macrosimulation vs. Microsimulation

Simulation can play a significant role in studying and analyzing transportation networks. Whereas collecting real-world data can be expensive and cumbersome, simulation is a relatively cheap, efficient tool that can create reasonably accurate models of traffic congestion, growth, emissions, and changes in infrastructure (signalization, roadway geometry, etc.). Simulation does require data collection for the calibration stage, but this data only needs to be collected once. Macrosimulation and microsimulation are the two approaches that may be adopted in studying the system.

Macrosimulation treats vehicles as an aggregate flow using continuum equations. This approach requires fewer inputs and less effort, but the outputs result in lower levels of detail.

Microsimulation is much more complex and involves modeling individual driver behavior through models for car-following theory, vehicle performance, and lane changing. Microsimulation requires more effort to produce a model but can generate outputs with more information and a higher level of detail. Microsimulation is preferred for emissions modeling because of the varying characteristics that affect output of GHG. For example, different classes of vehicles will have different levels of fuel consumption and emissions rates.

2.1.2 Agent-Based Modeling

Microsimulation lends itself to agent-based modeling in which agents (vehicles) act as autonomous entities that interact with other agents. Jain et al. (2011) find that agent-based modeling is important when simulating real-world behaviors, when agents adapt and change behavior, and when there are dynamic relationships with other agents. Transportation often reflects many of these characteristics in which each vehicle’s behavior is influenced by its own actions and the actions of other vehicles.

2.1.3 PTV VISSIM

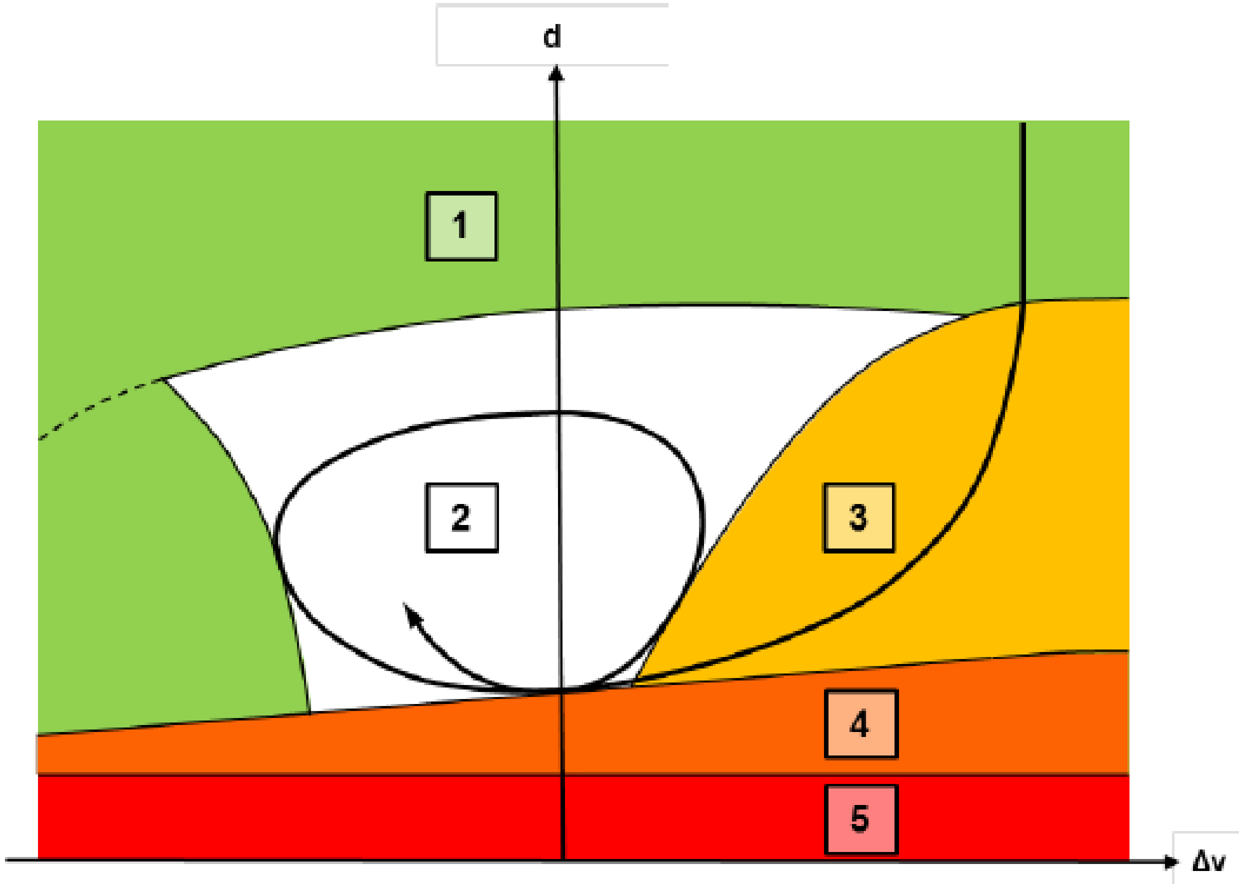
VISSIM was selected for creation of the model due to its ability to conduct microscopic simulations with agent-based modeling. VISSIM was developed in 1992 by PTV Planung Transport Verkehr AG in Karlsruhe, Germany and today is a global market leader in traffic simulation software. VISSIM is one of the most fully featured simulation software packages available. It is capable of accurately modeling emissions, lane changing/merging, car-following, active traffic management, intelligent transportation systems, multiple simulations, and multimodal scenarios. Its outputs can be used to determine various performance measures (e.g. travel times, delay) which can be used as inputs for other programs. The latest available edition of VISSIM, version 8.0 is used for this study.

2.1.3.1 *VISSIM Components and Applications*

VISSIM consists of three main components – traffic simulation, signal modeling, and pedestrian simulation. The traffic simulation component relies on an agent-based microsimulation approach including car-following and lane changing models. Signal modeling incorporates control logic units capable of querying detectors in time steps of 1/10 of a second. Pedestrian simulation uses the Social Force Model described by Helbing and Molnár (1995). In this case, modeling of pedestrians is influenced by their own speed, their desire to maintain spacing between themselves and other objects, and their attraction to other pedestrians or other objects. The study of the Cuesta Grade on U.S. 101 is limited to the traffic simulation component as there are no signals or pedestrians present on this limited-access highway.

2.1.3.2 *Car Following Model*

VISSIM uses the Wiedemann psycho-physical perception model (1974). In this model, the driver of a faster moving vehicle begins to decelerate upon approaching a slower moving vehicle. As a leading vehicle begins to pull away, the driver begins to accelerate again. The moments that these actions occur depend on the driver’s perception threshold which is graphically represented by the Wiedemann model in Figure 3.



Car following model (according to: Wiedemann 1974)

Figure 3. Wiedemann car following model

Each region represents a “state” in which a vehicle may occupy:

1. Free flow state
2. Following state
3. Approaching state
4. Braking state
5. Collision state

The y-axis represents the gap between vehicles and the x-axis shows change in velocity for the driver. Green regions represent acceleration, while yellow, orange, and red regions represent deceleration in varying intensities. A vehicle in the approaching state (region 3) will decrease their velocity as the gap between themselves and the leading vehicle becomes smaller. For example, the free flow state (region 1) shows a large gap between vehicles and a very high increase in velocity. The collision state (region 5) shows a very small gap and therefore a very high decrease in velocity. This attempts to realistically simulate driver behavior, especially on highways and freeways. Panwai and Dia (2005) find that the Wiedemann model used in VISSIM has error comparable to other car-following models; however, it still does not completely replicate field measurements.

2.1.3.3 *Vehicle-Driver Pairs*

In VISSIM, each driver is paired to a vehicle, and the driver's behavior corresponds to the technical aspects of their vehicle. These characteristics include length, maximum speed, and accelerating power. Drivers of heavy trucks will have different behavior than drivers of passenger cars or light-duty trucks. This directly affects any values generated by an emissions model as GHG emissions are heavily influenced by driver behavior such as acceleration.

2.1.4 EPA's MOtor Vehicle Emission Simulator (MOVES)

The EPA first developed a series of models in the late 1970s called MOBILE that could estimate hydrocarbons, nitrogen oxides, and carbon monoxide from various vehicle classes. MOBILE was able to account for local variations such as temperature, humidity, and fuel quality. The EPA used this model for many years at the local, state, and national level – including contribution to the federal Clean Air Act's state implementation plan. In addition, NONROAD was developed to estimate emissions of off-road mobile sources. Both MOBILE and NONROAD were replaced with a single, comprehensive modeling system known today as MOVES.

The EPA developed and currently maintains MOVES, a comprehensive GHG model that can estimate fuel consumption, CO_2, N_2O, CH_4, and other vehicular GHG. MOVES can estimate emissions from nearly any mobile source such as passenger cars, light trucks, heavy trucks, marine vessels, locomotives, and aircraft. While MOBILE was able to estimate emissions from three GHG, today's version of MOVES is capable of estimating 1,018 different criteria air pollutants, GHG, and air toxics (EPA, 2015).

2.2 LITERATURE REVIEW

The literature reviewed below provides background on traffic simulation, emissions modeling, and calibration/validation of these models.

2.2.1 Estimating Aggregate Vehicle Emissions Using Simulation Models

Song et al. (2012) researched the validity of fuel consumption and emissions estimates (CO, HC, and NO_x) generated from a traffic microsimulation model by comparing vehicle-power specific (VSP) distributions created from models and VSP distributions obtained from real-world testing. The researchers collected data using VISSIM 5.20 and gathered second-by-second speed and acceleration data to determine VSP using Equation 1:

$$VSP = v * [1.1a + 9.81 * grade(\%) + 0.132] + 0.000302 * v^3 \qquad (1)$$

where:

v: Vehicle speed (m/s)

a: Vehicle acceleration (m/s^2)

grade (%): Vehicle vertical rise divided by slope length multiplied by 100, which can be assumed to be zero where terrain is flat

Song et al. found that simulated VSP distributions were not consistent with those obtained from real-world testing. The microsimulation model overestimated emissions in low-speed conditions and underestimated emissions in high-speed conditions. In an effort to calibrate the VSP generated by VISSIM, they performed a sensitivity analysis by adjusting parameters such as the speed distribution, acceleration, deceleration, etc. Song et al. found that VSP distributions were not affected by the sensitivity analysis, and emissions could not be accurately predicted using simulated VSP distributions.

Abou-Senna et al. (2013) from the University of Central Florida developed a microscopic traffic simulation model on a limited-access highway (Interstate 4) in Orlando, Florida during the PM Peak Hour. Using the EPA's mobile source emissions model, MOVES, they estimated CO, NO_x, $PM_{2.5}$, PM_{10}, and atmospheric CO_2 based on a variety of inputs. MOVES is capable of emissions modeling on a great level of detail – traffic volumes, average speeds, meteorological conditions, vehicle age, vehicle composition, and fuel type are just some examples of inputs that MOVES can use to generate emissions values. MOVES also generates results on a second-by-second basis. Abou-Senna et al. found that emissions rates were highly sensitive to acceleration at low-speeds (i.e. congestion involving frequent braking and acceleration).

Kilbert (2009) created a traffic simulation and emissions model of the California Polytechnic State University, San Luis Obispo campus. VISSIM was used to create a realistic network of the campus, complete with intersection control and comprehensive routing decisions. Kilbert analyzed the AM Peak Hour and used CMEM (an emissions estimator) to generate aggregate emissions values. The goal of the study was to determine the impact of hypothetical transportation demand management policies on emissions. Kilbert concluded that a decrease in demand has a more significant impact on emissions than increase in “green” vehicles. One limitation of the study is that the emissions values are aggregate values and do not target specific locations of high emissions, such as at intersections with higher incidences of stop and go traffic vs. free flowing corridors. By knowing these emissions hot spots, it is possible to determine whether the land use or road features are contributing to increased demand and/or congestion, resulting in higher emissions.

Chamberlin et al. (2012) discuss best practices when conducting project-level analyses using EPA’s MOVES software. A project-level analysis with MOVES requires interfacing with a traffic microsimulation model and an air dispersion model. The advantage of microsimulation is that it can capture a higher resolution of detail and dynamic behaviors of individual vehicles. Chamberlin et al. discuss the significance of location (specific coordinates) defined in the model for estimating emissions because of inherent variability resulting from network elements such as intersections. A test-bed emissions analysis ($PM_{2.5}$) of an intersection before and after signal optimization was conducted to determine the impacts on emissions. Chamberlin et al. found that using average speed and operating mode distribution (based on VSP) show emissions reductions, and both approaches have similar estimates for fuel consumption. However, the operating mode distribution's results showed greater variability closer to the intersection, more accurately representing variances in acceleration and speed.

2.2.2 Estimating Individual Vehicle Emissions Using Simulation Models

Barth et al. (2004) gathered data from the University of California, Riverside mobile emissions research laboratory to develop a model for estimating heavy-duty diesel (HDD) vehicle emissions. While emissions models for light-duty vehicles (LDV) have been extensively researched and developed, fewer efforts have been made to develop HDD vehicle emissions models even though HDD vehicles can represent a significant portion of emissions. Barth et al. used a test fleet of 11 vehicles using various procedures to capture real-world emissions data. Test procedures included the California Air Resources Board HDD test, dynamometer testing, real-world driving, and customized modal emission cycles developed by the team. Validation consists of data obtained from the dynamometer testing. Of particular interest is that the model can be adapted to test the presence of grades and truck restricted lanes, since the Cuesta Grade involves both of these scenarios.

Increasingly stricter emissions standards for new vehicles have resulted in automakers developing low emitting gasoline powered cars. Barth et al. (2006) from CERT calibrated their CMEM software to include measurements from these low emitting vehicles. Using a similar approach to developing a model for HDD vehicles, a test fleet was utilized on a dynamometer and in real-world driving scenarios. Data from these tests was used to calibrate the model and validated the model results by comparing it to measured tailpipe emissions. Barth et al. found that the model did well to predict emissions, and that existing models poorly predict emissions when compared to empirical data obtained from a dynamometer. However, even on-road measurements differed from the dynamometer tests, highlighting the importance of using real-world data for emissions modeling. They also concluded that extremely low emitting vehicles can have dramatic increases in emissions under high speed conditions. This scenario is not uncommon and should be considered for a comprehensive emissions model.

Nam et al. (2002) equipped a test vehicle with a Portable Emissions Measurements System (PEMS) developed by Ford to measure the impact of driver behavior on vehicle emissions. The test vehicle was driven on an 8.5 mile segment consisting of 17 traffic signals in Oakland County, Southeast Michigan. The researchers drove the vehicle “normally” and “aggressively” to capture different emissions data sets. For the modeled emissions, the researchers used

VISSIM and CMEM with a complex network consisting of a 4 x 5 mile grid. CMEM was calibrated using dynamometer data. Calibrating VISSIM involved creating a virtual vehicle that ran on the same route as the real-world test vehicle. Results showed that while travel times were similar for both normal and aggressive driving styles, fuel consumption and emissions were higher for the aggressive driving style. The VISSIM and CMEM model compared favorably in its generated emissions values, but the authors note that its ability to predict emissions from a low-emitting vehicle was limited.

2.2.3 How Geography and Roadway Characteristics Impact Vehicle Emissions

Chu and Meyer (2009) describe a methodology for estimating emissions reductions of truck only toll lanes. Using the U.S. EPA's MOBILE6.2 emissions model (precursor to MOVES), they measured HC, CO, NO_X, and CO_2 for gasoline and diesel trucks. The software was limited in that it was unable to use speed as an input for estimating CO_2 emissions. The authors used an equation to correlate fuel consumption with CO_2 emissions for more accurate results. Chu and Meyer found that voluntary and mandatory use of truck only toll lanes reduced CO_2 emissions on freeways by around 62%.

Boriboonsomsin and Barth (2009) researched emissions trends for light-duty vehicles when traveling on a grade. The authors gathered CO_2 emissions data by driving a test vehicle, measuring its fuel consumption, and using an empirical formula to determine the emissions generated. The route consisted of a 15 mile segment with average road grade of 4%. Boriboonsomsin and Barth used CMEM to estimate CO_2 emissions. The results showed that fuel economy for light-duty vehicles on flat roads is 15% to 20% better than for the particular segment tested. One limitation acknowledged by the study is that only light-duty vehicles were tested and modeled. Emissions of heavy-duty vehicles, which have a lower power-to-weight ratio, may be more impacted by the presence of grades. Conversely, it is unclear what the effects on hybrid vehicles are.

Papson et al. (2012) used MOVES to predict nitrogen oxides (NO_X) and particulate matter (PM) emissions at congested and uncongested signalized intersections. The researchers used a time-in-mode analysis combining emissions factors for an activity mode (acceleration, deceleration, cruise, idle) with time spent in each mode. The emissions analysis paired MOVES with Synchro to conduct the traffic simulation. Results showed that acceleration was responsible for 46% to 55% of emissions, and cruising accounted for 28% to 47% of emissions. The authors conclude that uniform traffic flow is less sensitive to congestion than expected. In congested uniform traffic flow scenarios, cruise emissions were shown to increase while idling and acceleration emissions decreased. Managing control delay to minimize acceleration is important in reducing vehicle emissions. One limitation acknowledged by the study is the lack of validation for the emissions factors.

2.2.4 Modeling Traffic Emissions Based on Vehicle Type and Driver Behavior

Xie et al. (2010) modeled the emissions of alternatively fueled vehicles (electric, ethanol, and compressed natural gas) using MOVES and PARAMICS microsimulation software. The traffic model was calibrated and validated, and the outputs of PARAMICS were used as inputs for the MOVES software. The network consisted of a segment of Interstate-85 in Greenville, South Carolina. The comprehensive emissions analysis included meteorological information, vehicle age distribution, fuel formulation and supply, and link and link source type. The researchers found a mostly linear relationship between changes in vehicle fuel type to emissions reductions (e.g. switching 40% of transit from diesel to compressed natural gas represented 34% reduction in sulfur dioxide emissions). One limitation of the study is that the analysis segment was relatively short and did not consider other factors (acceleration, grades, congestion, etc.).

Ahn et al. (1998) estimated fuel consumption and emissions (CO, HC, and NO_x) of light-duty vehicles and light-duty trucks using hybrid regression models. The motivation for the study stemmed from the limitations of existing urban models that only used average link speeds, whereas variances in acceleration and speed have a significant effect on fuel consumption and emissions. At the time, EPA's MOBILE6 software did not account for driver-related behaviors on emissions. The researchers collected speed and acceleration data from test vehicles at the Oak Ridge National Laboratory (ORNL). Emissions data obtained from the models were validated against real-world emissions data obtained from EPA's Automotive Testing Laboratories and National Vehicle and Fuels Emission Laboratory. Ahn et al. found that the model was consistent with real-world data with a coefficient of determination over 90 percent.

2.2.5 Validation of Microscopic Traffic Simulation Models with Real Traffic Data

Calibration and validation of models remains an important final step to ensuring that the simulation model performs as expected and can generate reasonable data. Punzo and Simonelli (2005) tested four models of varying complexity against four test vehicles equipped with GPS receivers that recorded position at one tenth second intervals. Validation involved comparison of model results with test vehicle results using the same inputs. Punzo and Simonelli calibrated their results in which they attempted to reproduce a trajectory from vehicles 2, 3, and 4 by using parameters calibrated on the leader vehicle 1. One limitation is that the leading vehicle has no knowledge of the preceding vehicle's trajectory. Punzo and Simonelli find that cross validations showed real world data to perform better using a Root Mean Square Percentage Error (RMSPe) when compared to data collected from a test track. When collecting real traffic data using a test vehicle, it is important to understand that validation may produce different errors even with the same driver. The authors suggest studying driver behavior over a long period of time to recognize how road and traffic characteristics can affect the driver, altering any perceived notions of a controlled study. Statistical measures for comparing results including root mean square error, root mean square percentage error, and Theil's Indicator[2] were used as error testing for both calibration and validation. Conclusions highlighted the importance of real-world data for validation.

[2]Theil's Indicator (U) provides a smooth, normalized error by reducing the impact of large errors. It is bounded according to $0 \le U \le 1$ where $U = 0$ is a perfect fit, or no error.

Helbing et al. (2002) present two traffic simulations models, a local, gas-kinetic-based traffic model and a novel car-following model for use in congested systems. These models were calibrated and validated using data from Dutch freeway A9. They adjusted specific parameters in their model until reaching an optimal fit to the empirical data. They demonstrate that realistic simulation outputs can be obtained by adjusting certain parameters for speed, weather, and even time of day such as rush hour traffic with validation.

2.2.6 Analysis of MOVES and CMEM for Evaluating the Emissions Impacts of an Intersection Control Change

Chamberlin et al. (2011) compared two popular emissions simulators, MOVES and CMEM, by analyzing the emissions estimates based on a test-bed analysis of changing a 3-leg signalized intersection to a roundabout. CO and NO_x were chosen as the outputs for analysis. The microsimulation model used was Paramics. The model used the average speed and link drive schedule approaches in MOVES to generate emissions data. The link drive schedule uses a second-by-second speed profile for a vehicle. Chamberlin et al. found that CMEM estimates CO emissions at 4-6 times higher than MOVES (average speed and link drive schedule approaches), and NOx estimates are lower than the MOVES average speed approach but similar to the link drive approach. While the research does not definitively state which emissions estimator is more accurate or preferred, the authors describe in detail the greater capability of MOVES over CMEM. MOVES is capable of incorporating meteorological data and fuel type, and it relies on data from 62,500 dynamometer test vehicles as opposed to CMEM's 343 vehicles. MOVES can also model more pollutant processes than CMEM and uses statistical modeling of emissions using vehicle specific power and speed. CMEM only uses analytical modeling of the physical processes involving combustion, but it is well understood that fuel consumption and emissions are greatly affected by driver behavior. One limitation of the study is that neither the data from MOVES or CMEM was validated against real-world data.

2.2.7 Discussion of Literature Surveyed

Much research exists that estimate vehicle emissions on the aggregate and/or individual level using microsimulation software in conjunction with emissions modeling software. This paper benefits from the available research in that individual vehicle characteristics are being modeled to determine aggregate emissions on a corridor. The research shows that topography and roadway characteristics affect emissions. A 4% grade can increase light-duty vehicle emissions from 15-20%. Acceleration may account for as much as half of emissions while cruising may account for as little as a third. Validation with real-world traffic data was shown to differ from results obtained from test tracks or dynamometers, highlighting the importance of unforeseen variables that occur in the real world. Between the two major emissions models, MOVES and CMEM, MOVES has greater capability and relies on a larger library of test data than CMEM (62,500 vehicles vs. 343 vehicles). Hence, in this study we chose to use MOVES as the emissions estimator. It would facilitate future comparison with real-world data.

3. SIMULATION MODEL DEVELOPMENT FOR U.S. 101

3.1 AREA OF STUDY

The study area includes the Cuesta Grade of U.S. 101 in San Luis Obispo County. The northbound portion extends from the Monterey St on-ramp (milepost 29.985) in San Luis Obispo to the Junction 58 East (JCT 58) off-ramp (milepost 37.863) in Santa Margarita. The southbound portion extends from the JCT 58 on-ramp to the Monterey St off-ramp. Two models were created to show the before-and-after comparison of the truck only lane on vehicle emissions. Both models include the Monterey and JCT 58 ramps and all stop controlled intersections in between. Operation on the Cuesta Grade is similar to a freeway even though it is technically a multilane highway due to very low volumes from the intersecting roads.

3.1.1 U.S. Route 101

U.S. 101 is a north-south highway that runs along the West Coast of the United States from California to Washington. It passes through several communities and cities in the Central Coast region of California. U.S. 101 varies in geometry but is generally 2 to 3 lanes in each direction. In California, the route connects the Central Coast region with the metropolitan regions of the San Francisco Bay Area and Los Angeles.

3.1.2 Cuesta Grade on U.S. 101

The Cuesta Grade is a portion of the U.S. 101 extending beyond the northern city limits of San Luis Obispo, CA to Santa Margarita, CA (Figure 4).

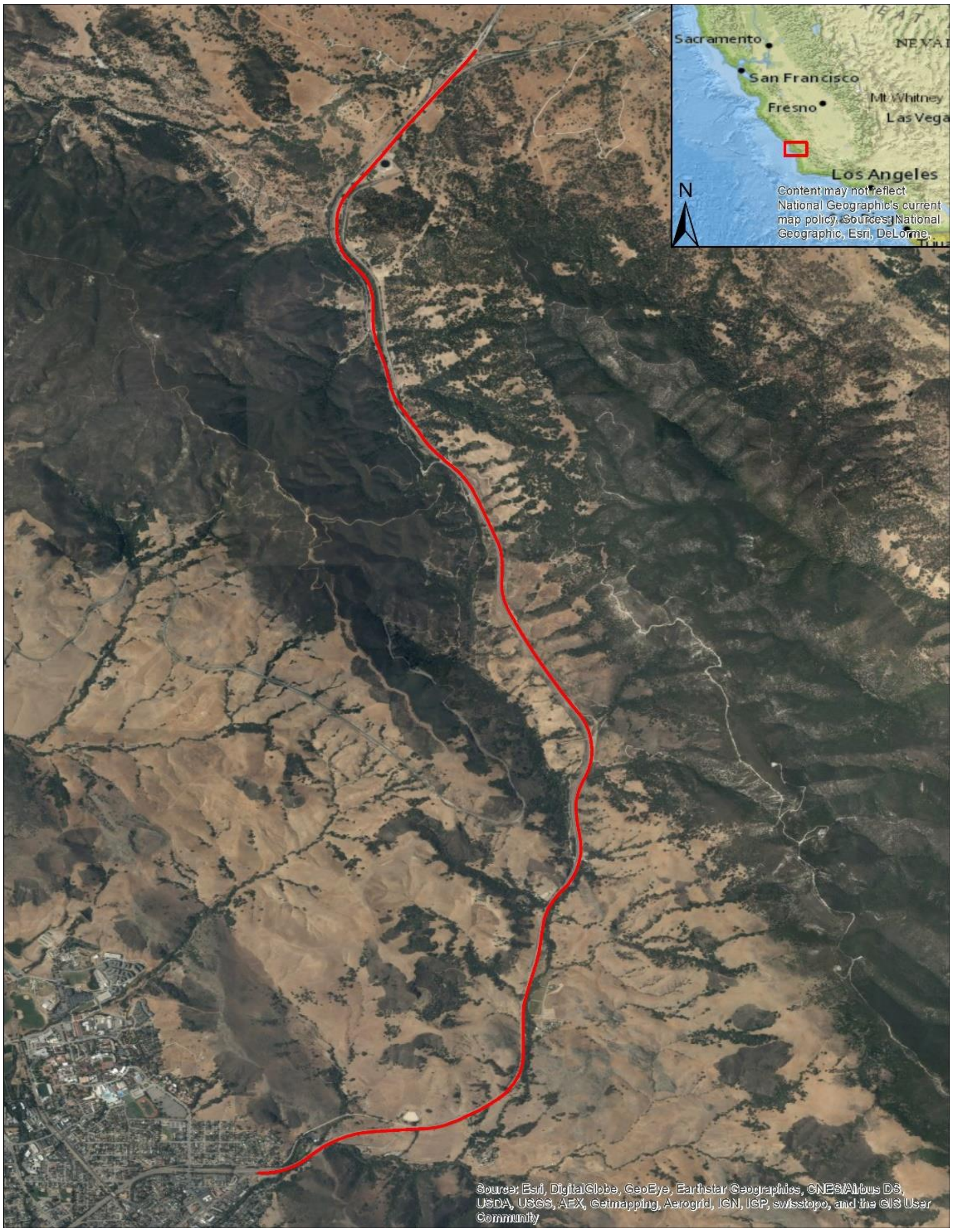


Figure 4. Cuesta grade aerial view

It is a 4-lane limited-access highway with a posted speed limit of 65 mph for cars and light trucks, and a 6-lane limited-access highway with a 35 mph reduced speed limit for heavy goods vehicles (HGV) on the almost 3-mile steep grade section in the southbound direction. Historically, the highway was 4 lanes throughout the entire Cuesta Grade but was widened to 6 lanes. Widening construction started in 1999 and was completed on October 15, 2003. The purpose was to increase capacity as slow moving heavy vehicles on the steep grade often caused congestion (SLOCOG, 2003). Trucks are required to use these lanes and are restricted to a speed limit of 35 mph in the southbound direction, but cars may also use these lanes and have no speed restrictions. According to the literature surveyed, this widening is expected to reduce sudden acceleration resulting in lower vehicle emissions. However, this would be opposite of what one might expect on the city streets. Widening on city streets may encourage greater acceleration and higher traffic volumes, increasing emissions.

The corridor has varying grades with a maximum elevation of 1,522 feet. There are six intersecting roads in the northbound direction (Fox Hollow Road, Reservoir Canyon Road, Vista Del Ciudad, Mt. Lowe Road, Forest Rte 30S11, and Tassajara Creek Road) and five major intersecting roads in the southbound direction (Tassajara Creek Road, Cuesta Springs Road, TV Tower Road, Old Stage Coach Road, and Miossi Road). Additionally, there are two egress only roads in the southbound direction (Old 101 and Hawk Hill Road). Traffic from these roads is limited, and the section operates similarly to a freeway. The PM peak hour is in the northbound direction.

This route serves mostly passenger cars and light trucks with some HGV. The San Luis Obispo Regional Transit Authority provides service via three routes that pass through the Cuesta Grade. Inclement weather includes heavy rain and dense fog during winter months.

3.2 CREATING THE NETWORK

3.2.1 Before-and-After Comparison

To analyze the emissions impact of widening from 4 to 6 lanes, two separate networks were created to represent past and present conditions. Each network has unique volumes, link geometry, and speed distributions. The first network (Network 1) uses data from 1998 to simulate conditions before widening of the Cuesta Grade began construction in 1999. The second network (Network 2) uses data from 2012 to essentially represent current conditions which is the most complete data available at the time from Caltrans.

3.2.2 Road Network

VISSIM includes satellite imagery from Microsoft's Bing Maps which was used as a basis for tracing the network. Links were created in segments along U.S. 101 with different grades assigned to each link. All links were assigned the standard lane width of 12 feet, and the HGV vehicle class is restricted to travel in lane 1. Network 1 uses a 4-lane network throughout the Cuesta Grade, and Network 2 represents the 6-lane portion from milepost 32.545 to 35.255. Road grades were collected in the field starting at Reservoir Canyon Road and 3.35 miles northbound. The remaining grades were collected using Google Earth's elevation profile. Each of these grades were assigned to individual links. The complete network consists of 190 links and 199 connectors for a total of 389 links and connectors and can be found in Appendix A (Appendix A shows network 1 links, network 2 links similar with exception of number of lanes).

3.2.3 Vehicle Data and Composition

To create an accurate emissions model, the number of vehicles and its distribution are needed. Directional volumes from 1998 and 2012 were obtained from Caltrans. Ramp volumes provided by Caltrans are listed in ADT and were converted to peak hour using Equation 2.

$$Peak\ Hour\ Volume = (ADT) * (K - Factor) \qquad (2)$$

where:

ADT: Annual daily traffic

K – Factor: Peak factor

Traffic volumes for the network were determined by studying ramp and highway volumes from Caltrans. A summary of the volume inputs for Networks 1 and 2 are shown in Tables 2 and 3.

Table 2. Northbound Volume Inputs (Vehicles Per Hour)

Road Link	Network 1 (4-lane)	Network 2 (6-lane)
Monterey Street	325	340
NB 101 Start[3]	2,620	2,179
Fox Hollow Road	5	10
Reservoir Canyon Road	5	10
Vista Del Ciudad Road	5	10
Cuesta Springs Road	5	10
Tassajara Creek Road	15	20
Old Stage Coach Road	5	27

Table 3. Southbound Volume Inputs (Vehicles Per Hour)

Road Link	Network 1 (4-lane)	Network 2 (6-lane)
Junction 58 East	190	230
SB 101 Start[3]	1,600	1,865
Tassajara Creek Road	20	20
Cuesta Springs Road	10	15
TV Road	15	15
Old Stage Coach Road	13	13
Hawk Hill Road	11	11

[3]These volumes represent existing input volumes on the highway. All other volumes in Tables 2 and 3 represent ramp volumes.

The methodology for determining input volumes in VISSIM involved these steps:

1) For the northbound direction, use given total PM peak hour volume for the starting point of the network, immediately before the Monterey on-ramp.
2) The northbound volume is determined using the directional split (D Factor).
3) Convert on-ramp ADT to peak hour volumes using Equation 2 (see Assumptions for values used.)
4) Repeat steps 1-3 for southbound direction.

Vehicle compositions varied depending on the year of analysis. Caltrans reported 8% and 9% heavy trucks in 1998 and 2012, respectively, at milepost 30.360 (2016).

3.2.4 Speed Data

VISSIM requires speed distributions to be defined for all vehicle classes. Speed survey data was not available for the Cuesta Grade, and the posted speed limit was used to determine speed distributions for the corridor. Three distributions were created to model the varying speed limits:

1) Cars and light trucks – Minimum speed of 55 mph, maximum speed of 75 mph, 15th percentile speed of 60 mph, and 85th percentile speed of 70 mph (Figure 5).

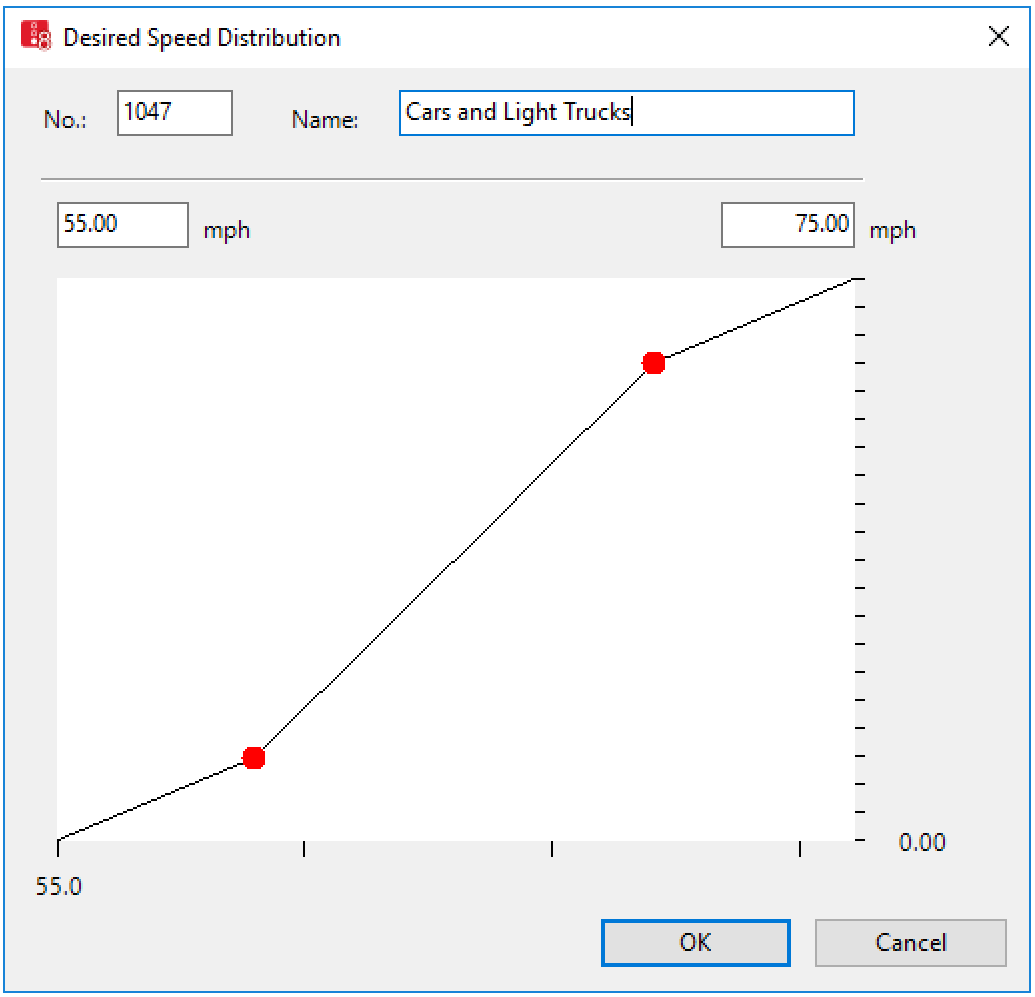


Figure 5. Speed distribution for cars and light trucks

2) HGV – Minimum speed of 50 mph, maximum speed of 65 mph, 15th percentile speed of 55 mph, and 85th percentile speed of 60 mph (Figure 6).

Figure 6. Speed distribution for heavy goods vehicles

3) HGV (Reduced Speed Area) – Minimum speed of 25 mph, maximum speed of 40 mph, 15th percentile speed of 30 mph, and 85th percentile speed of 35 mph (Figure 7).

    a. The reduced speed area is in effect only between mileposts 32.545 and 35.255 for Network 2.

    b. There is no reduced speed area in effect for the northbound direction for either network.

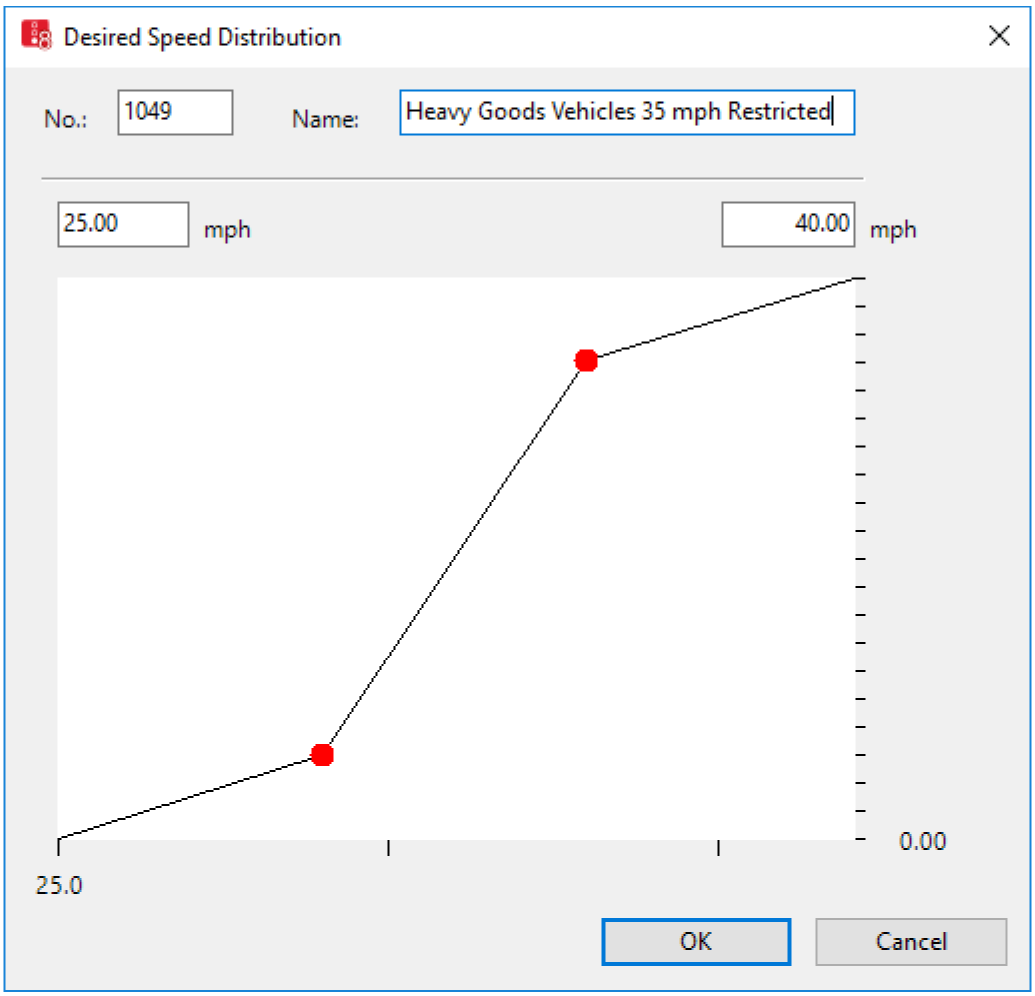


Figure 7. Speed distribution for reduced speed area for HGV

3.2.5 Stop Signs and Conflict Areas

Because the Cuesta Grade is a limited-access highway, several stop-controlled intersections were modeled. Stop signs and conflict areas were assigned to these intersecting roads. Vehicles stop once at the stop sign, move forward, check for potential conflicts, and then finally merge onto the highway. Dwell time distributions for stop signs were not assigned because vehicles are assumed to immediately proceed after stopping when they find a reasonable gap. Conflict areas assigned to merge points prevent vehicles from colliding.

3.2.6 Data Collection Points

In VISSIM, data collectors were placed at strategic locations to collect speed, acceleration, and volumes for both vehicle classes. Data collection points were first placed on each link (in the case of two lanes, one for each lane), and data collection measurements were further defined by specifying the data collection points. For example, the "NB 101 After Monterey" data collection measurement collected data from data collection points 7 and 8 (one for each lane). Figure 8 illustrates each data collection measurement location. These data collection locations were included to ensure that requisite data for emissions estimation were available.

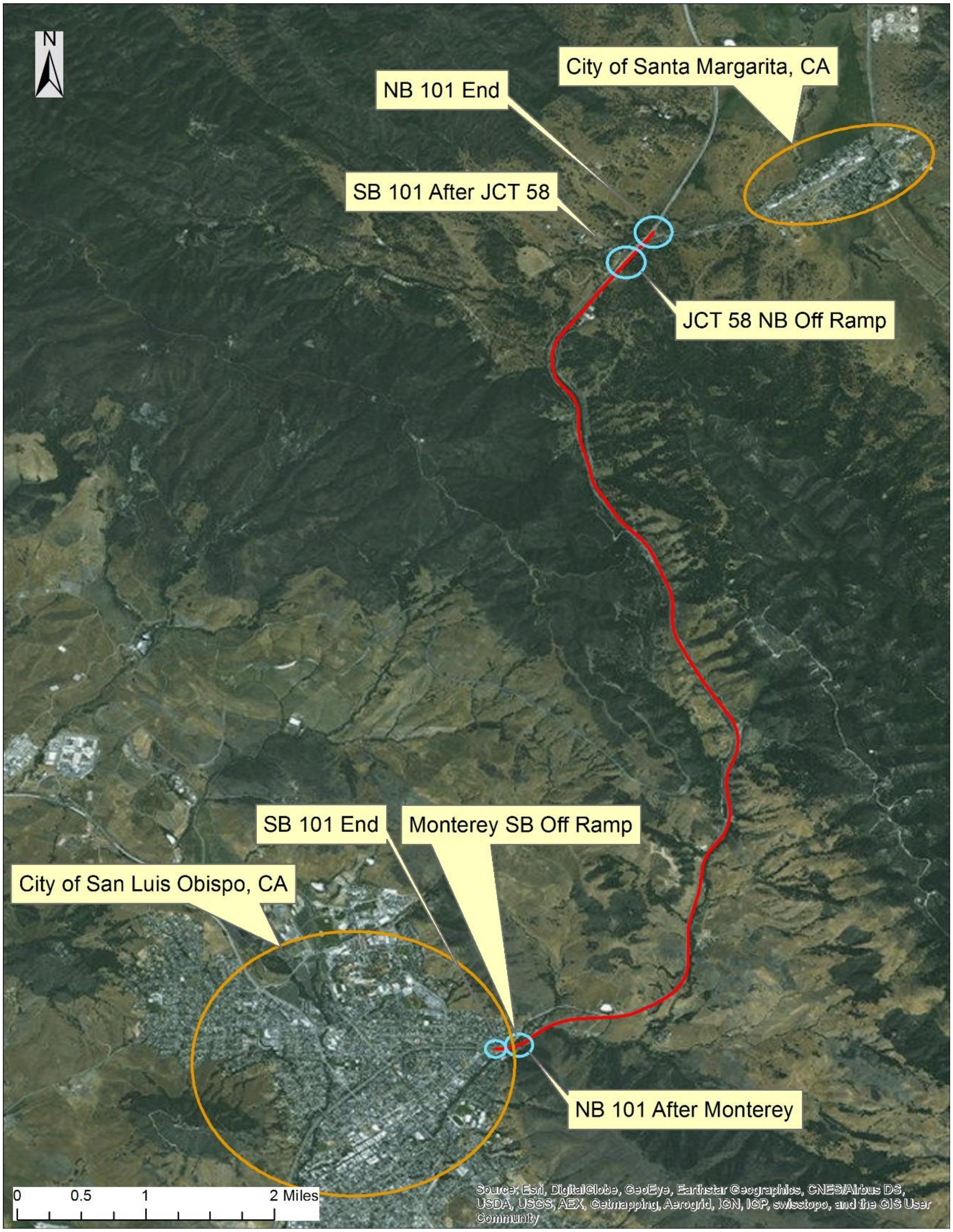


Figure 8. Locations of data collection measurement points

3.2.7 Emissions Modeling

Emissions data were gathered by exporting the simulation results from VISSIM and importing into MOVES software. The data inputs for MOVES include link length, grade, vehicle composition, volume, and vehicle trajectory data which include speed, and acceleration on a link by link basis. Grades were also obtained from field data on a link by link basis. Vehicle composition was obtained from Caltrans and simulated in VISSIM. All other inputs (volume, speed, and acceleration) were separated by vehicle type. All data was then aggregated into 3 sections: before truck lane, truck lane, and after truck lane to compare the effects at each section in 1998 and 2012. Data was not directly collected in the middle section (truck lane) because there was no real traffic data to validate the results. The volumes, speeds, and acceleration used as input for the middle section was the average of the before truck lane and after truck lane values. VIMIS, a custom software package developed by Hatem et al. (2013), was used to integrate between VISSIM and MOVES. This software converts VISSIM files to MOVES files so that emissions estimates can be generated.

3.2.8 Assumptions

Real-world traffic conditions are intricate systems and very difficult to perfectly replicate in simulation. Not all data can be reasonably collected for use in a simulation model. Models and the resulting calibration/validation rely on assumptions to fill these gaps. The VISSIM model being developed for this study relies on the following assumptions:

- *Area of Study* is limited to the Cuesta Grade on U.S. 101 (milepost 29.985 to milepost 37.863) and intersecting roads that do not dead-end to small properties which may not have significant traffic volumes.
- *Time of Study* is limited to the PM peak period (5:00 – 6:00 PM).
- *Time of Simulation* is limited to 70 minutes. A 10-minute time period is used as a warm-up for the simulation.
- *Vehicle Composition* is limited to cars, light trucks, and HGV. Vehicles were not further sub-classified within their vehicle type (i.e. sedans and SUVs are considered to be the cars and light trucks type, respectively). Motorcyclists and regional transit were not included in the model.
- *Traffic Inputs* have several key assumptions:
    - Peak hour volumes may not have been collected during the mid-week (Tuesday – Thursday) due to lack of available data.
    - D Factors were adjusted to match the same peak hour of data collection (60% for 1998, 55% for 2012).
    - Ramp volumes are provided in ADT and converted to peak hour volume using an assumed K Factor of 10%.
    - Traffic volumes were not available for the stop-controlled intersections along the Cuesta Grade corridor. These values were assumed to be between 5-30 vehicles per hour.
- *Speed Distributions* were assumed to be a range based on the posted speed limit and varied between vehicle classes.
- Unless otherwise specified, VISSIM’s default parameters are assumed.

3.3 ORIGIN-DESTINATION MATRIX

An origin-destination matrix (OD matrix) is used to determine where vehicles enter and exit throughout the model. Given the known starting and ending volumes of the Cuesta Grade, assumptions were made for traffic volumes of these stop-controlled intersections. Appendix B shows the OD matrices for the northbound and southbound directions for each network.

4. DATA ANALYSIS AND RESULTS

4.1 CALIBRATION AND VALIDATION

4.1.1 Calibration Parameters

Calibration and validation are important steps to ensure accuracy of the model. The model was calibrated several times until validation showed acceptable level of discrepancy between real and simulated volumes. The data that is known includes the starting and ending volumes of the network. The unknown data includes all volumes in between at the stop-controlled intersections. The model was continually calibrated until validation measures (including GEH statistic) were satisfactory.

4.1.2 Validation

To validate the model, the output data was analyzed and compared to available traffic counts from Caltrans. Several validation techniques were used including the GEH statistic, Root Mean Squared Error (RMSE), and Theil's Indicator.

4.1.2.1 *GEH Statistic*

The GEH Statistic is a formula commonly used to compare two sets of hourly traffic volumes. It was derived empirically by Geoffrey E. Havers in the 1970s and is defined by Equation 3:

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}} \qquad (3)$$

where:

M: Traffic model hourly count

C: Real-world hourly count

It is generally accepted that values less than 5 to have low chance of error, between 5 and 10 medium chance of error, and greater than 10 high chance of error (Wisconsin Department of Transportation, 2014).

4.1.2.2 *Root Mean Squared Error*

The root mean squared error represents the distance of a data point from a fitted line. In this case, the fitted line would be the real-world data, and the data point would be the simulation count. RMSE is bounded between 0 – 1 with 0 representing no error. It is defined by Equation 4:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}} \qquad (4)$$

where:

y_i: Traffic model hourly count

$\hat{y}_i$: Real-world hourly count

n: Number of observations

4.1.2.3 *Theil's Indicator*

Theil's Indicator is used as a measure of forecast accuracy bounded between 0 – 1 with 0 representing perfect forecast. It is defined by equation 5:

$$U = \frac{\left[\frac{1}{n}\sum_{i=1}^{n}(A_i - P_i)^2\right]^{\frac{1}{2}}}{\left[\frac{1}{n}\sum_{i=1}^{n}A_i^2\right]^{\frac{1}{2}} + \left[\frac{1}{n}\sum_{i=1}^{n}P_i^2\right]^{\frac{1}{2}}} \qquad (5)$$

where:

n: Number of observations

A_i: Actual observations

P_i: Predictions

Each validation measure's satisfactory thresholds are summarized in Table 4.

Table 4. Validation Measures and Thresholds

Validation Measure	Threshold
GEH Statistic	5.0
Root Mean Squared Error	0 – 1
Theil's Indicator	0 – 1

4.2 TRAFFIC VOLUMES

A total of 5 simulations were run with the results averaged together. The seed numbers used for the simulation were 18, 23, 28, 33, and 38. The results of the simulation are shown in Tables 5 and 6. A full results output from VISSIM can be found in Appendix C. Volumes were much less in the southbound direction in 1998, while volumes were generally the same in the northbound direction during both time periods. At the beginning of the northbound direction, volumes were 18.8% greater in 1998 vs. 2012. Validation measures revealed acceptable numbers for all data points.

Table 5. Network 1 (4-lane) Traffic Volume Results

	NB 101 After Monterey	JCT 58 NB	NB 101 End	SB 101 After	Monterey SB Off Ramp	SB 101 End	Truck Percentage

		Off Ramp		JCT 58			
Expected Counts	**2940**	**190**	**2385**	**1795**	**325**	**1470**	**8%**
Simulation Counts	**2918.6**	**196**	**2383.6**	**1785.4**	**323**	**1429.4**	**8.7%**
GEH Statistic	**0.40**	**0.43**	**0.03**	**0.23**	**0.11**	**1.07**	**--**
Theil's Indicator	**0.00**	**0.04**	**0.01**	**0.02**	**0.03**	**0.02**	**--**
RMSE	**0.01**	**0.08**	**0.02**	**0.03**	**0.06**	**0.04**	**--**

Table 6. Network 2 (6-lane) Traffic Volume Results

	NB 101 After Monterey	JCT 58 NB Off Ramp	NB 101 End	SB 101 After JCT 58	Monterey SB Off Ramp	SB 101 End	Truck Percentage
Expected Counts	**2475**	**188.6**	**2386.4**	**2151**	**336.3**	**1814.7**	**9%**
Simulation Counts	**2500.2**	**182**	**2358**	**2098**	**335**	**1778.6**	**8.9%**
GEH Statistic	**0.51**	**0.48**	**0.58**	**1.15**	**0.07**	**0.85**	**--**
Theil's Indicator	**0.01**	**0.03**	**0.01**	**0.02**	**0.02**	**0.02**	**--**
RMSE	**0.01**	**0.06**	**0.03**	**0.03**	**0.05**	**0.03**	**--**

4.3 EMISSIONS RESULTS

Averaging the 5 simulation runs in VISSIM, the aggregated data used as MOVES inputs are shown in Table 7, and emissions results are shown in Table 8. Across the whole corridor, results show that total CO_2 emissions were lower in the northbound direction for 2012 and higher for the southbound direction for both study periods, except that the truck lane in the southbound direction showed a 7.4% decrease in emissions. Overall, CO_2 emissions decreased by 6.8% across the whole corridor.

Table 7. Inputs for MOVES Emissions Modeling

	Network 1 (4-lane): 1998 Data					Network 2 (6-lane): 2012 Data				
			Average Speed (mph)					Average Speed (mph)		
Direction	Section	Total Volume	Cars	Trucks	Truck Percentage	Section	Total Volume	Cars	Trucks	Truck Percentage
Northbound (Uphill)	Before Truck Lane	2919	60.06	51.24	8.70	Before Truck Lane	2500	61.12	52.06	8.92
	Truck Lane	2770	46.31	21.23	8.74	Truck Lane	2530	60.96	21.39	8.93
	After Truck Lane	2384	60.26	54.17	8.10	After Truck Lane	2330	60.19	54.81	8.71
Southbound (Downhill)	Before Truck Lane	1785	63.37	56.17	8.29	Before Truck Lane	2098	63.20	55.61	9.01
	Truck Lane	1761	61.67	30.58	8.18	Truck Lane	2118	63.27	30.35	8.97
	After Truck Lane	1429	63.12	55.95	8.05	After Truck Lane	1779	62.44	55.80	8.66

Table 8. MOVES Emissions Estimates

	Network 1 (4-lane): 1998 Data			Network 2 (6-lane): 2012 Data			% Change	
Direction	Section	Length (mi)	CO_2 (kg)	Section	Length (mi)	CO_2 (kg)	Emissions	Volume
Northbound (Uphill)	Before Truck Lane	2.6	5485	Before Truck Lane	2.6	4689	-17.0	-16.8
	Truck Lane	2.75	8445	Truck Lane	2.75	7627	-10.7	-9.5
	After Truck Lane	2.47	3110	After Truck Lane	2.47	3021	-2.9	-2.3
	TOTAL CO_2	**7.82**	**17040**	**TOTAL CO_2**	**7.82**	**15337**	**-11.1**	--
Southbound (Downhill)	Before Truck Lane	2.47	3647	Before Truck Lane	2.47	3750	+2.8	+17.5
	Truck Lane	2.75	3635	Truck Lane	2.75	3386	-7.4	+20.3
	After Truck Lane	2.6	2128	After Truck Lane	2.6	2301	+8.1	+24.5
	TOTAL CO_2	**7.82**	**9410**	**TOTAL CO_2**	**7.82**	**9437**	**+0.3**	--
	TOTAL CORRIDOR CO_2		**26450**	**TOTAL CORRIDOR CO_2**		**24774**	**-6.8**	--

4.4 DISCUSSION

Northbound emissions decreased by 10.7%, and volumes decreased by 9.5% in the truck only lane portion. Southbound emissions decreased by 7.4%, although volumes increased by 20.3% in the same section. While the results showed increased emissions in the northbound direction and decreased emissions in the southbound direction, it is important to note that other factors may have influenced the results. The most apparent is the change in volumes in the northbound direction. However, the southbound emissions reduction was also attributed to the down grade section. Table 8 shows a general correlation between volume and emissions for the northbound direction. In the southbound direction, volume appears less influential on emissions. Southbound emissions may be less sensitive to volume changes because drivers are cruising downhill rather than accelerating uphill. There has been a posted truck speed limit of 35 mph since at least 1998 for this section of road due to the steep grade. Drivers stuck behind trucks in a 2-lane road may accelerate upon passing slow moving trucks, and prior research has shown that acceleration can account for up to half of vehicle emissions (Papson et al., 2012).

5. CONCLUSIONS

5.1 SUMMARY

This thesis sought to estimate CO_2 emissions on a limited-access highway before and after the addition of a truck only lane using a microsimulation tool, VISSIM, with an emissions estimator, MOVES. The data obtained from this research seem to indicate that the truck only lane reduced CO_2 emissions along the Cuesta Grade. One factor to be accounted for is the change in volume which seems to play a much larger role in emissions than roadway features or topography. Additionally, vehicle speeds have a high influence on CO_2 emissions. The truck only lane may be beneficial in situations with high congestion causing vehicles to behave more erratically than cruising smoothly.

5.2 LIMITATIONS

Some limitations of this study should be noted. The car-following model used in VISSIM has been shown in one study to be less accurate than field data, and this thesis did not explore the use of field data to calibrate/validate the simulation model. The literature review highlights the importance of validation against real-world data. Although there is a posted truck speed limit of 35 mph in the southbound (downhill) section, there is no posted limit for trucks in the northbound direction. Due to steep uphill grade in the northbound direction the trucks are traveling slowly regardless of the speed limit. It was apparent in the simulation setting by running two separate simulations for the northbound direction with and without this northbound speed restriction. The truck speed distribution from both simulations showed that there is no significant difference in the travel speed with trucks traveling no more than 22 mph on average (see Appendix C).

5.3 FUTURE SCOPE

While this thesis was an attempt to comprehensively quantify CO_2 emissions before and after the addition of a truck only lane, limitations discussed above should be addressed in future work. VISSIM and MOVES were both used to create the network and estimate emissions. A comparison of different software packages could strengthen this research when compared to real-world data. Estimating emissions for different truck speeds should also be explored as speeds are known to greatly influence emissions. A test vehicle equipped with a probe to conduct *in-situ* measurements would provide greater insight into the accuracy of these emissions estimators. Other emissions should be compared too – such as those described in Section 1 (carbon monoxide, lead, nitrogen dioxide, ozone, particulate pollution, and sulfur dioxide). Additional work could explore the non-peak period to determine the effect, if any, on vehicle emissions.

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APPENDIX A: LIST OF VISSIM LINKS AND GRADIENTS (NETWORK 1)

$VISION
* File:
* Comment:
* Date: 10/24/2016 13:30
* PTV Vissim: 8.00 [09]
*
* Table: Links
*
* NO: No, Number (Unique number of the link or connector)
* NAME: Name, Name (Name of the link or connector)
* NUMLANES: NumLanes, Number of lanes (Number of lanes. The table in the Lanes tab is automatically adjusted.)
* LENGTH2D: Length2D, Length 2D (Length of the link without considering height) [ft]
* GRADIENT: Gradient, Gradient (Uphill and downhill slopes of the connector in percent. Downhill slopes have a negative value. The value impacts the driving behavior via the maximum acceleration and maximum deceleration:
by -0.1 m/s² per gradient percent incline. The maximum accelerating power decreases when the deceleration power increases.
by 0.1 m/s² per gradient percent downgrade. The accelerating power increases when the deceleration power decreases.)
*
* No Name NumLanes Length2D Gradient
*

$LINK:NO	NAME	NUMLANES	LENGTH2D	GRADIENT
1	NB_Grade_1	2	223.36	1.00%
2	NB_Grade_2	2	248.36	0.20%
3	NB_Grade_3	2	248.36	3.68%
4	NB_Grade_4	2	248.36	3.66%
5	NB_Grade_5	2	198.36	4.16%
6	NB_Grade_6	2	348.36	2.48%
7	NB_Grade_7	2	198.36	1.08%
8	NB_Grade_8	2	1048.36	1.84%

9	NB_Grade_9	2	223.36	1.84%
10	NB_Grade_10	2	173.36	1.56%
11	NB_Grade_11	2	248.36	1.88%
12	NB_Grade_12	2	548.36	2.43%
13	NB_Grade_13	2	198.36	3.36%
14	NB_Grade_14	2	448.36	2.38%
15	NB_Grade_15	2	1098.36	1.40%
16	NB_Grade_16	2	273.36	1.40%
17	NB_Grade_17	2	423.36	2.60%
18	NB_Grade_18	2	348.36	2.52%
19	NB_Grade_19	2	273.36	2.88%
20	NB_Grade_20	2	273.36	2.52%
21	NB_Grade_21(1)	2	249.582	4.12%
22	NB_Grade_21(2)	3	93.36	4.12%
23	NB_Grade_22	3	123.36	5.00%
24	NB_Grade_23	3	148.091	6.11%
25	NB_Grade_24	3	198.36	7.08%
26	NB_Grade_25	3	598.534	7.36%
27	NB_Grade_26	3	198.36	7.16%
28	NB_Grade_27	3	23.36	7.16%
29	NB_Grade_28	3	133.36	7.00%
30	NB_Grade_29	3	448.36	7.48%
31	NB_Grade_30	3	483.36	7.12%
32	NB_Grade_31	3	588.36	7.56%
33	NB_Grade_32	3	418.36	6.85%
34	NB_Grade_33	3	918.36	7.40%
35	NB_Grade_34	3	1838.36	6.96%
36	NB_Grade_35	3	1158.36	6.96%
37	NB_Grade_36	3	538.36	7.40%
38	NB_Grade_37	3	1248.36	7.12%
39	NB_Grade_38	3	918.36	6.64%
40	NB_Grade_39	3	498.36	7.68%

41	NB_Grade_40	3	498.36	6.98%
42	NB_Grade_41	3	498.36	6.05%
43	NB_Grade_42	3	498.36	6.28%
44	NB_Grade_43	3	498.36	7.31%
45	NB_Grade_44	3	498.36	5.41%
46	NB_Grade_45	3	423.36	-0.55%
47	NB_Grade_46	3	498.36	-6.95%
48	NB_Grade_47(1)	3	295.628	-7.15%
49	NB_Grade_47(2)	2	98.36	-7.15%
50	NB_Grade_48	2	498.36	-7.08%
51	NB_Grade_49	2	498.36	-5.89%
52	NB_Grade_50	2	498.36	-9.78%
53	NB_Grade_51	2	498.36	-2.86%
54	NB_Grade_52	2	498.36	-2.25%
55	NB_Grade_53	2	498.36	-4.42%
56	NB_Grade_54	2	498.36	-3.19%
57	NB_Grade_55	2	498.36	-2.20%
58	NB_Grade_56	2	498.36	-2.37%
59	NB_Grade_57	2	498.36	-2.10%
60	NB_Grade_58	2	498.36	-2.45%
61	NB_Grade_59	2	498.36	-2.43%
62	NB_Grade_60	2	498.36	-2.40%
63	NB_Grade_61	2	498.36	-4.42%
64	NB_Grade_62	2	498.36	-3.10%
65	NB_Grade_63	2	498.36	-1.34%
66	NB_Grade_64	2	498.36	-0.21%
67	NB_Grade_65	2	495.59	0.84%
68	NB_Grade_66	2	493.388	-2.19%
69	NB_Grade_67	2	497.608	-4.89%
70	NB_Grade_68	2	498.359	-5.05%
71	NB_Grade_69	2	498.36	-3.71%
72	NB_Grade_70	2	498.36	-0.93%

73	NB_Grade_71	2	498.36	-0.92%
74	NB_Grade_72	2	498.36	-0.28%
75	NB_Grade_73	2	498.36	0.16%
76	SB_Grade_1	2	498.36	0.92%
77	SB_Grade_2(1)	2	122.953	0.93%
78	SB_Grade_2(2)	2	401.174	0.93%
79	SB_Grade_3	2	456.407	3.71%
80	SB_Grade_4	2	501.107	5.05%
81	SB_Grade_5	2	498.36	4.89%
82	SB_Grade_6	2	498.36	2.19%
83	SB_Grade_7	2	498.36	-0.84%
84	SB_Grade_8	2	498.36	0.21%
85	SB_Grade_9	2	539.866	1.34%
86	SB_Grade_10	2	530.123	3.10%
87	SB_Grade_11	2	508.814	4.42%
88	SB_Grade_12	2	511.314	2.40%
89	SB_Grade_13	2	502.248	2.43%
90	SB_Grade_14	2	450.144	2.45%
91	SB_Grade_15	2	452.962	2.10%
92	SB_Grade_16	2	482.509	2.37%
93	SB_Grade_17	2	523.244	2.20%
94	SB_Grade_18	2	496.497	3.19%
95	SB_Grade_19	2	500.993	4.42%
96	SB_Grade_20	2	491.838	2.25%
97	SB_Grade_21	2	504.156	2.86%
98	SB_Grade_22	2	523.414	9.78%
99	SB_Grade_23	2	488.557	5.89%
100	SB_Grade_24(1)	2	109.545	7.08%
101	SB_Grade_24(2)	3	297.371	7.08%
102	SB_Grade_25	3	505.487	7.15%
103	SB_Grade_26	3	513.171	6.95%
104	SB_Grade_27	3	423.36	0.55%

105	SB_Grade_28	3	464.902	-5.41%
106	SB_Grade_29	3	498.36	-7.31%
107	SB_Grade_30	3	498.36	-6.28%
108	SB_Grade_31	3	498.36	-6.05%
109	SB_Grade_32	3	494.305	-6.98%
110	SB_Grade_33	3	487.612	-7.68%
111	SB_Grade_34	3	931.211	-6.64%
112	SB_Grade_35	3	1260.492	-7.12%
113	SB_Grade_36	3	536.421	-7.40%
114	SB_Grade_37	3	1167.002	-6.96%
115	SB_Grade_38	3	1815.663	-6.96%
116	SB_Grade_39	3	894.183	-7.40%
117	SB_Grade_40	3	418.989	-6.85%
118	SB_Grade_41	3	606.307	-7.56%
119	SB_Grade_42	3	486.983	-7.12%
120	SB_Grade_43	3	448.172	-7.48%
121	SB_Grade_44	3	125.714	-7.00%
122	SB_Grade_45	3	27.47	-7.16%
123	SB_Grade_46	3	191.735	-7.16%
124	SB_Grade_47	3	584.658	-7.36%
125	SB_Grade_48	3	192.123	-7.08%
126	SB_Grade_49	3	140.844	-6.11%
127	SB_Grade_50	3	123.593	-5.00%
128	SB_Grade_51	3	350.683	-4.12%
129	SB_Grade_52	3	270.943	-2.52%
130	SB_Grade_53(1)	3	105.456	-2.88%
131	SB_Grade_53(2)	2	164.539	-2.88%
132	SB_Grade_54	2	350.498	-2.52%
133	SB_Grade_55	2	425.228	-2.60%
134	SB_Grade_56	2	276.624	-1.40%
135	SB_Grade_57	2	1090.194	-1.40%
136	SB_Grade_58	2	450.126	-2.38%

137	SB_Grade_59	2	203.425	-3.36%
138	SB_Grade_60	2	551.494	-2.43%
139	SB_Grade_61	2	250.773	-1.88%
140	SB_Grade_62	2	167.606	-1.56%
141	SB_Grade_63	2	229.121	-1.84%
142	SB_Grade_64	2	1032.703	-1.84%
143	SB_Grade_65	2	193.239	-1.08%
144	SB_Grade_66	2	340.247	-2.48%
145	SB_Grade_67	2	191.698	-4.16%
146	SB_Grade_68	2	246.491	-3.66%
147	SB_Grade_69	2	250.39	-3.68%
148	SB_Grade_70	2	243.275	-0.20%
149	SB_Grade_71	2	220.99	-1.00%
150	SB_101_Flat	2	5911.95	0.00%
151	NB_101_Flat_1	2	348.129	0.00%
152	NB_101_Flat_2	2	465.526	0.00%
153	NB_101_Flat_3	2	5104.263	0.00%
154	Reservoir_Canyon_Rd_NB_On	1	67.789	0.00%
155	Vista_Del_Ciudad_NB_Off	1	56.986	0.00%
156	Vista_Del_Ciudad_NB_On	1	59.974	0.00%
157	Vista_Del_Ciudad_SB_On	1	489.316	0.00%
158	Cuesta_Springs_Rd_NB_Off	1	49.051	0.00%
159	Cuesta_Springs_Rd_NB_On	1	38.429	0.00%
160	Tassajara_Creek_Rd_NB_Off(1)	1	310.382	0.00%
161	Tassajara_Creek_Rd_NB_Off(2)	1	119.615	0.00%
162	Tassajara_Creek_Rd_NB_Off(3)	1	43.683	0.00%
163	Tassajara_Creek_Rd_NB_On	1	52.701	0.00%
164	Tassajara_Creek_Rd_SB_Off	1	45.415	0.00%
165	Tassajara_Creek_Rd_SB_Off	1	60.83	0.00%
166	Tassajara_Creek_SB_On	1	21.189	0.00%
167	Cuesta_Springs_Rd_SB_Off	1	100.978	0.00%
168	Cuesta_Springs_Rd_SB_On	1	117.373	0.00%

169	TV_Tower_Rd_Off_Lane	1	1051.465	0.00%
170	TV_Road_SB_Off	1	60.192	0.00%
171	TV_Road_SB_On	1	54.704	0.00%
172	Old_101_SB_Off	1	151.798	0.00%
173	Old_Stage_Coach_Rd_SB_Off	1	501.558	0.00%
174	Old_Stage_Coach_Rd_SB_On	1	546.597	0.00%
175	Old_Stage_Coach_Rd_NB_On	1	29.019	0.00%
176	Old_Stage_Coach_Rd_NB_On_Lane	1	581.311	0.00%
177	Hawk_Hill_Rd_SB_Off	1	126.483	0.00%
178	Miossi_Rd_SB_Off	1	479.619	0.00%
179	Hawk_Hill_Rd_SB_On	1	42.094	0.00%
180	Reservoir_Canyon_Rd_SB_Off_Lane	1	264.397	-1.00%
181	Vista_Del_Ciudad_SB_Off_Lane	1	619.878	0.00%
183	TV_Tower_Rd_Off_Lane	1	473.414	0.00%
202	NB_101_Flat_3_Connector	2	3.286	0.00%
203	NB_Grade_1_Connector	2	3.286	1.00%
204	NB_Grade_2_Connector	2	3.286	0.20%
205	NB_Grade_3_Connector	2	3.286	3.68%
206	NB_Grade_4_Connector	2	3.286	3.66%
207	NB_Grade_5_Connector	2	3.286	4.16%
208	NB_Grade_6_Connector	2	3.286	2.48%
209	NB_Grade_7_Connector	2	3.286	1.08%
210	NB_Grade_8_Connector	2	3.286	1.84%
211	NB_Grade_9_Connector	2	3.286	1.84%
212	NB_Grade_10_Connector	2	3.286	1.56%
213	NB_Grade_11_Connector	2	3.286	1.88%
214	NB_Grade_12_Connector	2	3.286	2.43%
215	NB_Grade_13_Connector	2	3.286	3.36%
216	NB_Grade_14_Connector	2	3.286	2.38%
217	NB_Grade_15_Connector	2	3.286	1.40%
218	NB_Grade_16_Connector	2	3.286	1.40%
219	NB_Grade_17_Connector	2	3.286	2.60%

220	NB_Grade_18_Connector	2	3.286	2.52%
221	NB_Grade_19_Connector	2	3.286	2.88%
222	NB_Grade_20_Connector	2	3.286	2.52%
223	NB_Grade_21_Connector(1)	2	30.389	4.12%
224	NB_Grade_21_Connector(2)	3	3.286	4.12%
225	NB_Grade_22_Connector	3	3.286	5.00%
226	NB_Grade_23_Connector	3	3.286	6.11%
227	NB_Grade_24_Connector	3	3.286	7.08%
228	NB_Grade_25_Connector	3	3.286	7.36%
229	NB_Grade_26_Connector	3	3.286	7.16%
230	NB_Grade_27_Connector	3	3.286	7.16%
231	NB_Grade_28_Connector	3	3.286	7.00%
232	NB_Grade_29_Connector	3	3.286	7.48%
233	NB_Grade_30_Connector	3	3.286	7.12%
234	NB_Grade_31_Connector	3	3.286	7.56%
235	NB_Grade_32_Connector	3	3.286	6.85%
236	NB_Grade_33_Connector	3	3.286	7.40%
237	NB_Grade_34_Connector	3	3.286	6.96%
238	NB_Grade_35_Connector	3	3.286	6.96%
239	NB_Grade_36_Connector	3	3.286	7.40%
240	NB_Grade_37_Connector	3	3.286	7.12%
241	NB_Grade_38_Connector	3	3.286	6.64%
242	NB_Grade_39_Connector	3	3.286	7.40%
243	NB_Grade_40_Connector	3	3.286	8.40%
244	NB_Grade_41_Connector	3	3.286	6.30%
245	NB_Grade_42_Connector	3	3.286	6.70%
246	NB_Grade_43_Connector	3	3.286	6.60%
247	NB_Grade_44_Connector	3	3.286	6.30%
248	NB_Grade_45_Connector	3	3.286	3.10%
249	NB_Grade_46_Connector	3	3.283	-6.20%
250	NB_Grade_47_Connector(1)	2	109.261	-6.80%
251	NB_Grade_47_Connector(2)	2	3.286	-6.80%

252	NB_Grade_48_Connector	2	3.286	-7.10%
253	NB_Grade_49_Connector	2	3.286	-6.80%
254	NB_Grade_50_Connector	2	3.286	-10.20%
255	NB_Grade_51_Connector	2	3.286	-5.60%
256	NB_Grade_52_Connector	2	3.286	-1.80%
257	NB_Grade_53_Connector	2	3.286	-7.10%
258	NB_Grade_54_Connector	2	3.286	-4.60%
259	NB_Grade_55_Connector	2	3.286	-3.90%
260	NB_Grade_56_Connector	2	3.286	-2.50%
261	NB_Grade_57_Connector	2	3.286	-4.90%
262	NB_Grade_58_Connector	2	3.286	-3.20%
263	NB_Grade_59_Connector	2	3.286	-2.10%
264	NB_Grade_60_Connector	2	3.286	-3.30%
265	NB_Grade_61_Connector	2	3.286	-6.50%
266	NB_Grade_62_Connector	2	3.286	-3.10%
267	NB_Grade_63_Connector	2	3.286	-3.60%
268	NB_Grade_64_Connector	2	3.434	-2.80%
269	NB_Grade_65_Connector	2	6.471	-2.20%
270	NB_Grade_66_Connector	2	9.286	-3.50%
271	NB_Grade_67_Connector	2	3.286	-5.50%
272	NB_Grade_68_Connector	2	3.286	-4.20%
273	NB_Grade_69_Connector	2	3.286	-2.80%
274	NB_Grade_70_Connector	2	3.286	-1.20%
275	NB_Grade_71_Connector	2	3.286	-2.20%
276	NB_Grade_72_Connector	2	3.286	-1.40%
277	SB_Grade_1_Connector	2	3.286	2.20%
280	SB_Grade_3_Connector	2	3.286	2.80%
281	SB_Grade_4_Connector	2	3.762	4.20%
282	SB_Grade_5_Connector	2	3.286	5.50%
283	SB_Grade_6_Connector	2	3.286	3.50%
284	SB_Grade_7_Connector	2	3.286	2.20%
285	SB_Grade_8_Connector	2	3.286	2.80%

286	SB_Grade_9_Connector	2	12.558	3.60%
287	SB_Grade_10_Connector	2	29.703	3.10%
288	SB_Grade_11_Connector	2	16.408	6.50%
289	SB_Grade_12_Connector	2	16.118	3.30%
290	SB_Grade_13_Connector	2	3.286	2.10%
291	SB_Grade_14_Connector	2	16.203	3.20%
292	SB_Grade_15_Connector	2	14.834	4.90%
293	SB_Grade_16_Connector	2	3.286	2.50%
294	SB_Grade_17_Connector	2	7.328	3.90%
295	SB_Grade_18_Connector	2	13.301	4.60%
296	SB_Grade_19_Connector	2	2.419	7.10%
297	SB_Grade_20_Connector	2	3.286	1.80%
298	SB_Grade_21_Connector	2	13.437	5.60%
299	SB_Grade_22_Connector	2	12.16	10.20%
300	SB_Grade_23_Connector	2	1.902	6.80%
301	SB_Grade_24_Connector(1)	2	96.047	7.10%
302	SB_Grade_24_Connector(2)	3	3.286	7.10%
303	SB_Grade_25_Connector	3	3.286	6.80%
304	SB_Grade_26_Connector	3	3.286	6.20%
305	SB_Grade_27_Connector	3	3.286	-3.10%
306	SB_Grade_28_Connector	3	3.286	-6.30%
307	SB_Grade_29_Connector	3	3.286	-6.60%
308	SB_Grade_30_Connector	3	3.286	-6.70%
309	SB_Grade_31_Connector	3	3.286	-6.30%
310	SB_Grade_32_Connector	3	3.286	-8.40%
311	SB_Grade_33_Connector	3	3.286	-7.40%
312	SB_Grade_34_Connector	3	3.286	-6.64%
313	SB_Grade_35_Connector	3	3.286	-7.12%
314	SB_Grade_36_Connector	3	3.286	-7.40%
315	SB_Grade_37_Connector	3	3.286	-6.96%
316	SB_Grade_38_Connector	3	3.286	-6.96%
317	SB_Grade_39_Connector	3	3.286	-7.40%

318	SB_Grade_40_Connector	3	3.286	-6.85%
319	SB_Grade_41_Connector	3	3.281	-7.56%
320	SB_Grade_42_Connector	3	3.285	-7.12%
321	SB_Grade_43_Connector	3	3.286	-7.48%
322	SB_Grade_44_Connector	3	8.029	-7.00%
323	SB_Grade_45_Connector	3	5.288	-7.16%
324	SB_Grade_46_Connector	3	3.285	-7.16%
325	SB_Grade_47_Connector	3	3.286	-7.36%
326	SB_Grade_48_Connector	3	3.286	-7.08%
327	SB_Grade_49_Connector	3	3.286	-6.11%
328	SB_Grade_50_Connector	3	3.286	-5.00%
329	SB_Grade_51_Connector	3	3.286	-4.12%
330	SB_Grade_52_Connector	3	3.286	-2.52%
331	SB_Grade_53_Connector(1)	2	22.235	-2.88%
332	SB_Grade_53_Connector(2)	2	3.286	-2.88%
333	SB_Grade_54_Connector	2	3.286	-2.52%
334	SB_Grade_55_Connector	2	3.286	-2.60%
335	SB_Grade_56_Connector	2	3.286	-1.40%
336	SB_Grade_57_Connector	2	3.286	-1.40%
337	SB_Grade_58_Connector	2	3.286	-2.38%
338	SB_Grade_59_Connector	2	3.286	-3.36%
339	SB_Grade_60_Connector	2	3.286	-2.43%
340	SB_Grade_61_Connector	2	3.286	-1.88%
341	SB_Grade_62_Connector	2	3.286	-1.56%
342	SB_Grade_63_Connector	2	3.286	-1.84%
343	SB_Grade_64_Connector	2	3.286	-1.84%
344	SB_Grade_65_Connector	2	3.285	-1.08%
345	SB_Grade_66_Connector	2	3.286	-2.48%
346	SB_Grade_67_Connector	2	3.286	-4.16%
347	SB_Grade_68_Connector	2	3.286	-3.66%
348	SB_Grade_69_Connector	2	3.286	-3.68%
349	SB_Grade_70_Connector	2	3.286	-0.20%

350	SB_Grade_71_Connector	2	3.286	-1.00%
400	Fox_Hollow_Rd_NB_On	1	94.88	0.00%
401	Fox_Hollow_Rd_NB_Off	1	41.673	0.00%
402	Reservoir_Canyon_Rd_NB_Off(1)	1	292.74	0.00%
404	Reservoir_Canyon_Rd_NB_Off(2)	1	25.195	0.00%
500	Monterey_NB_On-Ramp	1	321.25	0.00%
501	JCT58_NB_Off-Ramp	1	440.618	0.00%
502	JCT58_SB_On-Ramp	1	502.895	0.00%
503	Monterey_SB_Off-Ramp	1	402.61	0.00%
600	Monterey_NB_On-Ramp_Connector	1	452.845	0.00%
601	JCT58_NB_Off-Ramp_Connector	1	161.922	0.00%
602	JCT58_SB_On-Ramp_Connector	1	398.268	0.00%
603	Monterey_SB_Off-Ramp_Connector	1	103.754	0.00%
10000	Fox_Hollow_Rd_NB_Connector	1	23.988	0.00%
10001	Fox_Hollow_Rd_NB_Off_Connector	1	89.066	0.00%
10002	Reservoir_Canyon_Rd_NB_Off_Connector(2)	1	76.353	0.00%
10003	Reservoir_Canyon_Rd_NB_Off_Connector(1)	1	71.481	0.00%
10004	Reservoir_Canyon_Rd_NB_On_Connector	1	50.33	1.00%
10005	Vista_Del_Ciudad_NB_Off_Connector	1	55.823	0.00%
10006	Vista_Del_Ciudad_NB_On_Connector_RT	1	50.633	7.40%
10007	Vista_Del_Ciudad_SB_On_Connector	1	114.741	0.00%
10008	Vista_Del_Ciudad_SB_On_Connector	1	38.291	-6.85%
10009	Reservoir_Canyon_Rd_SB_On	1	95.431	0.00%
10010	Cuesta_Springs_Rd_NB_Off_Connector	1	25.465	0.00%
10011	Cuesta_Springs_Rd_NB_On_Connector	1	31.091	-6.20%
10012	Tassajara_Creek_Rd_NB_Off_Connector(1)	1	72.956	0.00%
10013	Tassajara_Creek_Rd_NB_Off_Connector(2)	1	46.644	0.00%
10014	Tassajara_Creek_Rd_NB_Off_Connector	1	35.716	0.00%
10015	Tassajara_Creek_Rd_NB_On_Connector	1	31.868	-3.10%
10016	Tassjara_Creek_Connector(1)	1	76.65	0.00%
10017	Tassjara_Creek_Connector(2)	1	75.011	0.00%
10018	Tassjara_Creek_Connector(3)	1	45.061	0.00%

10019	Tassjara_Creek_Connector(4)	1	37.731	0.00%
10020	Tassjara_Creek_Connector(5)	1	61.665	0.00%
10021	Tassjara_Creek_Connector(6)	1	29.622	3.10%
10022	Tassjara_Creek_Connector(7)	1	70.505	-3.10%
10023	Tassajara_Creek_Rd_SB_Off	1	38.748	0.00%
10024	Cuesta_Springs_Rd_SB_Off_Connector	1	24.325	0.00%
10025	Cuesta_Springs_SB_On_Connector	1	50.625	6.20%
10026	TV_Tower_Rd_Off_Lane_Connector	1	104.016	0.00%
10027	TV_Road_On_Lane_Connector	1	53.322	-6.70%
10028	TV_Road_SB_Off_Connector	1	37.698	0.00%
10029	TV_Road_SB_On_Connector	1	24.381	0.00%
10030	Old_101_SB_Off_Connector	1	43.904	0.00%
10031	Old_Stage_Coach_Rd_SB_Off_Connector	1	30.026	0.00%
10032	Old_Stage_Coach_Rd_SB_On_Connector	1	62.396	-6.11%
10033	Old_Stage_Coach_Rd_NB_On_Connector	1	58.986	7.00%
10034	Old_Stage_Coach_Rd_NB_On_Connector	1	97.244	0.00%
10035	Hawk_Hill_Rd_SB_Off_Connector	1	34.244	0.00%
10036	Hawk_Hill_Rd_SB_Off_Connector	1	34.502	0.00%
10037	Hawk_Hill_Rd_SB_On_Connector	1	43.062	0.00%
10038	Cuesta_Springs_Rd_SB_Off_Connector	1	55.749	0.00%
10039	Tassajara_Rd_SB_On_Connector	1	31.252	3.10%
10040	Reservoir_Canyon_Rd_SB_Off_Connector	1	119.146	0.00%
10041	Reservoir_Canyon_Rd_SB_Off_Lane_Connector	1	54.214	-0.20%
10042	Vista_Del_Ciudad_SB_Off_Lane_Connector	1	68.186	0.00%
10043	Vista_Del_Ciudad_SB_Off_Connector	1	120.604	0.00%
10044	SB_Grade_1_Connector	2	23.308	1.20%
10045	SB_Grade_2_Connector	2	5.431	2.80%
10046	NB_101_Flat_2_Connector	2	12.53	0.00%
10047	NB_101_Flat_1_Connector	2	16.146	0.00%

APPENDIX B: ORIGIN-DESTINATION MATRICES

NORTHBOUND Network 1	US 101 Start	Monterey	Fox Hollow	Reservoir Canyon	Vista Del Ciudad	Cuesta Springs	Tassajara Creek East	Tassajara Creek West	Junction 58 East	US 101 North	US 101 South
US 101 Start	0	0	50	50	50	50	50	50	150	2,170	0
Monterey	0	0	5	5	5	5	5	5	50	245	0
Fox Hollow	0	0	0	0	0	0	0	0	0	5	0
Reservoir Canyon	0	0	0	0	0	0	0	0	0	5	0
Vista Del Ciudad	0	0	0	0	0	0	0	0	0	5	0
Cuesta Springs	0	0	0	0	0	0	0	0	0	5	0
Tassajara Creek NB ON	0	0	0	0	0	0	0	5	0	10	0
Tassajara Creek SB ON	0	0	0	0	0	0	5	0	0	0	15
US 101 End	0	0	0	0	0	0	0	0	0	0	0

SOUTHBOUND Network 1	US 101 Start	JCT 58	Tassajara Creek NB Off	Tassajara Creek SB Off	Cuesta Springs	TV Road	Old 101	Old Stage Coach SB Off	Hawk Hill	Miossi	Monterey	US 101 South	US 101 North
US 101 Start	0	0	15	15	10	10	5	5	5	5	280	1,250	0
JCT 58	0	0	0	0	0	0	0	0	0	0	30	160	0
Tassajara Creek SB ON	0	0	0	0	0	0	0	0	0	0	0	0	0
Tassajara Creek NB ON	0	0	0	0	0	0	0	0	0	0	0	0	0
Cuesta Springs	0	0	0	0	0	0	0	0	0	0	5	5	0
TV Road	0	0	0	0	0	0	0	0	0	0	5	10	0
Old Stage Coach SB ON	0	0	0	0	0	0	0	0	0	0	3	10	0

Old Stage Coach NB ON	0	0	0	0	0	0	0	0	0	0	0	0	5
Hawk Hill	0	0	0	0	0	0	0	0	0	0	1	10	0
US 101 End	0	0	0	0	0	0	0	0	0	0	0	0	0

NORTHBOUND Network 2	US 101 Start	Monterey	Fox Hollow	Reservoir Canyon	Vista Del Ciudad	Cuesta Springs	Tassajara Creek East	Tassajara Creek West	Junction 58 East	US 101 North	US 101 South
US 101 Start	0	0	5	5	5	5	5	5	149	2,000	0
Monterey	0	0	1	2	2	5	5	5	40	280	0
Fox Hollow	0	0	0	0	0	0	0	0	0	10	0
Reservoir Canyon	0	0	0	0	0	0	0	0	0	10	0
Vista Del Ciudad	0	0	0	0	0	0	0	0	0	10	0
Cuesta Springs	0	0	0	0	0	0	0	0	0	10	0
Tassajara Creek NB ON	0	0	0	0	0	0	0	5	0	15	0
Tassajara Creek SB ON	0	0	0	0	0	0	5	0	0	0	15
US 101 End	0	0	0	0	0	0	0	0	0	0	0

SOUTHBOUND	US 101 Start	JCT 58	Tassajara Creek NB Off	Tassajara Creek SB Off	Cuesta Springs	TV Road	Old 101	Old Stage Coach SB Off	Hawk Hill	Miossi	Monterey	US 101 South	US 101 North
US 101 Start	0	0	2	2	3	1	2	3	1	1	300	1550	0
JCT 58	0	0	0	0	0	0	0	0	0	0	30	200	0
Tassajara Creek SB ON	0	0	0	0	0	0	0	0	0	0	0	0	0
Tassajara Creek NB ON	0	0	0	0	0	0	0	0	0	0	0	0	0
Cuesta Springs	0	0	0	0	0	0	0	0	0	0	5	10	0
TV Road	0	0	0	0	0	0	0	0	0	0	5	10	0

Old Stage Coach SB ON	0	0	0	0	0	0	0	0	0	0	3	10	0
Old Stage Coach NB ON	0	0	0	0	0	0	0	0	0	0	0	0	27
Hawk Hill	0	0	0	0	0	0	0	0	0	0	1	10	0
US 101 End	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX C: VISSIM DATA COLLECTION OUTPUT

$VISION									
* File:		C:\Users\Edward\Google Drive\Thesis\Data\VISSIM Files\Edward_Tang_Thesis_Before_1998.inpx							
* Comment: Network 1, 35 mph NB Speed Limit									
* Date:		11/12/2016 9:35							
* PTV Vissim:	8.00 [13]								
*									
* Table: Data Collection Results									
*									
* SIMRUN: SimRun, Simulation run									
* TIMEINT: TimeInt, Time interval									
* DATACOLLECTIONMEASUREMENT: DataCollectionMeasurement, Data collection measurement									
* ACCELERATION(10): Acceleration(10), Acceleration (10) (Acceleration of all vehicles of the the data collection measurement in the interval) [ft/s2]									
* ACCELERATION(20): Acceleration(20), Acceleration (20) (Acceleration of all vehicles of the the data collection measurement in the interval) [ft/s2]									
* SPEED(20): Speed(20), Speed (20) (Speed of all vehicles of the the data collection measurement in the interval) [mph]									
* SPEED(10): Speed(10), Speed (10) (Speed of all vehicles of the the data collection measurement in the interval) [mph]									
* VEHS(10): Vehs(10), Vehicles (10) (Count of vehicles of the the data collection measurement in the interval)									
* VEHS(20): Vehs(20), Vehicles (20) (Count of vehicles of the the data collection measurement in the interval)									
* VEHS(ALL): Vehs(All), Vehicles (All) (Count of vehicles of the the data collection measurement in the interval)									
*									

* SimRun	TimeInt	DataCollectionMeasurement	Acceleration(10)	Acceleration(20)	Speed(20)	Speed(10)	Vehs(10)	Vehs(20)	Vehs(All)
*									
$DATACOLLECTIONMEASUREMENTEVALUATION:SIMRUN	TIMEINT	DATACOLLECTIONMEASUREMENT	ACCELERATION(10)	ACCELERATION(20)	SPEED(20)	SPEED(10)	VEHS(10)	VEHS(20)	VEHS(ALL)
1	600-4200	1: NB 101 After Monterey	0.32	0.48	52.23	60.07	2668	242	2910
1	600-4200	2: JCT 58 NB Off Ramp	0.93	0.32	55.72	63.14	170	14	184
1	600-4200	3: NB 101 End	0.42	0.2	54.28	60.48	2149	196	2345
1	600-4200	4: SB 101 After JCT 58	-0.03	-0.41	56.69	63.58	1703	161	1864
1	600-4200	5: Monterey SB Off Ramp	0.84	0.32	56.41	63.66	312	28	340
1	600-4200	6: SB 101 End	0.44	0.37	56.16	62.92	1385	137	1522
1	600-4200	7: NB Truck Lane	0.01	0.15	21.14	46.06	2501	232	2733
1	600-4200	8: SB Truck Lane	-0.09	0.2	30.85	61.37	1679	166	1845
2	600-4200	1: NB 101 After Monterey	0.21	0.33	51.28	60.01	2669	258	2927

2	600-4200	2: JCT 58 NB Off Ramp	1.07	0.38	56.75	63.06	182	20	202
2	600-4200	3: NB 101 End	0.62	0.34	52.3	59.43	2237	197	2434
2	600-4200	4: SB 101 After JCT 58	0.04	-0.35	55.84	63.57	1582	139	1721
2	600-4200	5: Monterey SB Off Ramp	0.93	0.26	56	63.05	265	21	286
2	600-4200	6: SB 101 End	0.42	0.39	55.53	63.04	1287	102	1389
2	600-4200	7: NB Truck Lane	0.03	-0.09	21.1	45.59	2541	247	2788
2	600-4200	8: SB Truck Lane	-0.09	0.22	30.02	62.09	1548	129	1677
3	600-4200	1: NB 101 After Monterey	0.22	0.59	49.99	59.57	2653	285	2938
3	600-4200	2: JCT 58 NB Off Ramp	0.68	0.26	57.82	63.8	194	16	210
3	600-4200	3: NB 101 End	0.42	0.19	54.87	60.9	2129	207	2336
3	600-4200	4: SB 101 After JCT 58	0.02	-0.31	55.94	63.59	1670	162	1832
3	600-4200	5: Monterey SB Off Ramp	0.71	0.37	56.89	63.95	321	22	343

3	600-4200	6: SB 101 End	0.4	0.36	55.69	63.29	1334	114	1448
3	600-4200	7: NB Truck Lane	-0.07	-0.01	20.83	46.36	2536	275	2811
3	600-4200	8: SB Truck Lane	-0.02	0.15	30.63	61.94	1655	153	1808
4	600-4200	1: NB 101 After Monterey	0.31	0.4	51.81	60.07	2674	249	2923
4	600-4200	2: JCT 58 NB Off Ramp	1.01	0.24	58.69	63.76	155	20	175
4	600-4200	3: NB 101 End	0.33	-0.03	55.8	60.7	2205	181	2386
4	600-4200	4: SB 101 After JCT 58	0.03	-0.37	56.04	63.95	1584	129	1713
4	600-4200	5: Monterey SB Off Ramp	0.73	0.16	56.8	63.86	300	19	319
4	600-4200	6: SB 101 End	0.31	0.46	55.9	63.3	1278	106	1384
4	600-4200	7: NB Truck Lane	0.06	-0.02	21.18	46.64	2535	238	2773
4	600-4200	8: SB Truck Lane	-0.07	0.12	30.66	61.67	1586	128	1714
5	600-4200	1: NB 101 After Monterey	0.37	0.49	50.87	59.62	2659	236	2895

5	600-4200	2: JCT 58 NB Off Ramp	0.98	0.25	55.94	63.3	185	24	209
5	600-4200	3: NB 101 End	0.64	0.21	53.58	59.8	2233	184	2417
5	600-4200	4: SB 101 After JCT 58	-0.04	-0.41	56.34	63.42	1647	150	1797
5	600-4200	5: Monterey SB Off Ramp	0.84	0.44	55.55	63.61	303	24	327
5	600-4200	6: SB 101 End	0.38	0.33	56.45	63.04	1289	115	1404
5	600-4200	7: NB Truck Lane	0.05	-0.05	21.88	46.92	2526	220	2746
5	600-4200	8: SB Truck Lane	0.01	0.2	30.77	61.29	1618	144	1762
AVG	600-4200	1: NB 101 After Monterey	0.29	0.46	51.24	59.87	2665	254	2919
AVG	600-4200	2: JCT 58 NB Off Ramp	0.93	0.29	56.98	63.41	177	19	196
AVG	600-4200	3: NB 101 End	0.49	0.18	54.17	60.26	2191	193	2384
AVG	600-4200	4: SB 101 After JCT 58	0	-0.37	56.17	63.62	1637	148	1785
AVG	600-4200	5: Monterey SB Off Ramp	0.81	0.31	56.33	63.63	300	23	323

AVG	600-4200	6: SB 101 End	0.39	0.38	55.95	63.12	1315	115	1429
AVG	600-4200	7: NB Truck Lane	0.02	-0.01	21.23	46.31	2528	242	2770
AVG	600-4200	8: SB Truck Lane	-0.05	0.18	30.58	61.67	1617	144	1761
STDDEV	600-4200	1: NB 101 After Monterey	0.07	0.1	0.87	0.25	8	19	17
STDDEV	600-4200	2: JCT 58 NB Off Ramp	0.15	0.06	1.26	0.35	15	4	16
STDDEV	600-4200	3: NB 101 End	0.13	0.13	1.32	0.62	49	11	43
STDDEV	600-4200	4: SB 101 After JCT 58	0.04	0.04	0.34	0.2	53	14	67
STDDEV	600-4200	5: Monterey SB Off Ramp	0.09	0.11	0.56	0.35	21	3	23
STDDEV	600-4200	6: SB 101 End	0.05	0.05	0.37	0.17	45	14	58
STDDEV	600-4200	7: NB Truck Lane	0.05	0.09	0.39	0.52	16	21	31
STDDEV	600-4200	8: SB Truck Lane	0.04	0.04	0.33	0.35	52	16	68
MIN	600-4200	1: NB 101 After Monterey	0.21	0.33	49.99	59.57	2653	236	2895

MIN	600-4200	2: JCT 58 NB Off Ramp	0.68	0.24	55.72	63.06	155	14	175
MIN	600-4200	3: NB 101 End	0.33	-0.03	52.3	59.43	2129	181	2336
MIN	600-4200	4: SB 101 After JCT 58	-0.04	-0.41	55.84	63.42	1582	129	1713
MIN	600-4200	5: Monterey SB Off Ramp	0.71	0.16	55.55	63.05	265	19	286
MIN	600-4200	6: SB 101 End	0.31	0.33	55.53	62.92	1278	102	1384
MIN	600-4200	7: NB Truck Lane	-0.07	-0.09	20.83	45.59	2501	220	2733
MIN	600-4200	8: SB Truck Lane	-0.09	0.12	30.02	61.29	1548	128	1677
MAX	600-4200	1: NB 101 After Monterey	0.37	0.59	52.23	60.07	2674	285	2938
MAX	600-4200	2: JCT 58 NB Off Ramp	1.07	0.38	58.69	63.8	194	24	210
MAX	600-4200	3: NB 101 End	0.64	0.34	55.8	60.9	2237	207	2434
MAX	600-4200	4: SB 101 After JCT 58	0.04	-0.31	56.69	63.95	1703	162	1864
MAX	600-4200	5: Monterey SB Off Ramp	0.93	0.44	56.89	63.95	321	28	343

MAX	600-4200	6: SB 101 End	0.44	0.46	56.45	63.3	1385	137	1522
MAX	600-4200	7: NB Truck Lane	0.06	0.15	21.88	46.92	2541	275	2811
MAX	600-4200	8: SB Truck Lane	0.01	0.22	30.85	62.09	1679	166	1845

$VISION									
* File:		C:\Users\Edward\Google Drive\Thesis\Data\VISSIM Files\Edward_Tang_Thesis_After_2012.inpx							
* Comment: Network 2, 35 mph NB speed limit									
* Date:		11/12/2016 10:23							
* PTV Vissim:	8.00 [13]								
*									
* Table: Data Collection Results									
*									
* SIMRUN: SimRun, Simulation run									
* TIMEINT: TimeInt, Time interval									
* DATACOLLECTIONMEASUREMENT: DataCollectionMeasurement, Data collection measurement									
* ACCELERATION(10): Acceleration(10), Acceleration (10) (Acceleration of all vehicles of the the data collection measurement in the interval) [ft/s2]									
* ACCELERATION(20): Acceleration(20), Acceleration (20) (Acceleration of all vehicles of the the data collection measurement in the interval) [ft/s2]									
* SPEED(10): Speed(10), Speed (10) (Speed of all vehicles of the the data collection measurement in the interval) [mph]									
* SPEED(20): Speed(20), Speed (20) (Speed of all vehicles of the the data collection measurement in the interval) [mph]									

* VEHS(10): Vehs(10), Vehicles (10) (Count of vehicles of the the data collection measurement in the interval)									
* VEHS(20): Vehs(20), Vehicles (20) (Count of vehicles of the the data collection measurement in the interval)									
* VEHS(ALL): Vehs(All), Vehicles (All) (Count of vehicles of the the data collection measurement in the interval)									
*									
* SimRun	TimeInt	DataCollectionMeasurement	Acceleration(10)	Acceleration(20)	Speed(10)	Speed(20)	Vehs (10)	Vehs (20)	Vehs (All)
*									
$DATACOLLECTIONMEASUREMENTEVALUATION:SIMRUN	TIMEINT	DATACOLLECTIONMEASUREMENT	ACCELERATION(10)	ACCELERATION(20)	SPEED(10)	SPEED(20)	VEHS(10)	VEHS(20)	VEHS (ALL)
1	600-4200	1: NB 101 After Monterey	0.27	0.43	61.5	53.26	2271	223	2494
1	600-4200	2: JCT 58 NB Off Ramp	0.68	0.33	63.8	56.55	158	12	170
1	600-4200	3: NB 101 End	0.33	0.01	60.71	55.25	2093	194	2287
1	600-4200	4: SB 101 After JCT 58	-0.03	-0.36	63.14	55.6	1972	200	2172
1	600-4200	5: Monterey SB Off Ramp	0.73	0.21	63.91	57.32	312	25	337
1	600-4200	6: SB 101 End	0.53	0.28	62.24	56.3	1678	173	1851
1	600-4200	7: NB Truck Lane	-0.02	0.04	61.18	20.87	2297	218	2515

1	600-4200	8: SB Truck Lane	-0.02	-0.11	63.08	30.26	1978	207	2185
2	600-4200	1: NB 101 After Monterey	0.32	0.47	60.64	51.37	2299	233	2532
2	600-4200	2: JCT 58 NB Off Ramp	0.94	0.32	63.05	56.49	149	28	177
2	600-4200	3: NB 101 End	0.53	0.15	59.67	53.91	2153	214	2367
2	600-4200	4: SB 101 After JCT 58	0.03	-0.42	63.31	56.03	1855	185	2040
2	600-4200	5: Monterey SB Off Ramp	0.88	0.18	63.68	56.76	284	21	305
2	600-4200	6: SB 101 End	0.41	0.26	62.53	55.4	1591	149	1740
2	600-4200	7: NB Truck Lane	0.02	0.04	60.44	21.23	2284	240	2524
2	600-4200	8: SB Truck Lane	0	-0.06	63.27	30.38	1875	182	2057
3	600-4200	1: NB 101 After Monterey	0.33	0.44	61.28	51.77	2268	243	2511
3	600-4200	2: JCT 58 NB Off Ramp	0.96	0.51	63.19	56.75	165	15	180
3	600-4200	3: NB 101 End	0.49	0.25	59.67	53.94	2123	221	2344

3	600-4200	4: SB 101 After JCT 58	0.01	-0.31	62.98	54.68	1941	201	2142
3	600-4200	5: Monterey SB Off Ramp	0.83	0.25	63.45	57.33	314	29	343
3	600-4200	6: SB 101 End	0.49	0.29	62.57	55.95	1666	149	1815
3	600-4200	7: NB Truck Lane	0.05	-0.05	60.78	21.6	2316	249	2565
3	600-4200	8: SB Truck Lane	0.06	0	63.16	30.38	1977	199	2176
4	600-4200	1: NB 101 After Monterey	0.26	0.41	61.19	52.54	2286	203	2489
4	600-4200	2: JCT 58 NB Off Ramp	1.07	0.26	63.33	57.38	178	18	196
4	600-4200	3: NB 101 End	0.45	0.15	60.08	55.9	2125	192	2317
4	600-4200	4: SB 101 After JCT 58	0.01	-0.38	63.42	56.01	1875	170	2045
4	600-4200	5: Monterey SB Off Ramp	0.85	0.27	63.52	56.23	324	19	343
4	600-4200	6: SB 101 End	0.42	0.4	62.78	55.67	1599	139	1738
4	600-4200	7: NB Truck Lane	-0.04	0.02	61.17	21.53	2333	212	2545

4	600-4200	8: SB Truck Lane	0.01	-0.08	63.61	29.91	1889	177	2066
5	600-4200	1: NB 101 After Monterey	0.32	0.56	61	51.39	2261	214	2475
5	600-4200	2: JCT 58 NB Off Ramp	0.69	0.35	63.46	56.99	170	17	187
5	600-4200	3: NB 101 End	0.37	0.18	60.81	55.06	2145	192	2337
5	600-4200	4: SB 101 After JCT 58	-0.05	-0.42	63.13	55.75	1904	187	2091
5	600-4200	5: Monterey SB Off Ramp	0.85	0.15	63.91	56.17	323	24	347
5	600-4200	6: SB 101 End	0.58	0.36	62.08	55.66	1590	159	1749
5	600-4200	7: NB Truck Lane	-0.03	-0.04	61.25	21.7	2289	211	2500
5	600-4200	8: SB Truck Lane	-0.02	-0.02	63.24	30.85	1922	183	2105
AVG	600-4200	1: NB 101 After Monterey	0.3	0.46	61.12	52.06	2277	223	2500
AVG	600-4200	2: JCT 58 NB Off Ramp	0.87	0.35	63.37	56.83	164	18	182
AVG	600-4200	3: NB 101 End	0.43	0.15	60.19	54.81	2128	203	2330

AVG	600-4200	4: SB 101 After JCT 58	-0.01	-0.38	63.2	55.61	1909	189	2098
AVG	600-4200	5: Monterey SB Off Ramp	0.83	0.21	63.69	56.76	311	24	335
AVG	600-4200	6: SB 101 End	0.49	0.32	62.44	55.8	1625	154	1779
AVG	600-4200	7: NB Truck Lane	-0.01	0	60.96	21.39	2304	226	2530
AVG	600-4200	8: SB Truck Lane	0.01	-0.05	63.27	30.35	1928	190	2118
STDDEV	600-4200	1: NB 101 After Monterey	0.03	0.06	0.33	0.82	15	16	22
STDDEV	600-4200	2: JCT 58 NB Off Ramp	0.18	0.09	0.29	0.36	11	6	10
STDDEV	600-4200	3: NB 101 End	0.08	0.09	0.55	0.87	23	14	30
STDDEV	600-4200	4: SB 101 After JCT 58	0.03	0.05	0.17	0.55	48	13	58
STDDEV	600-4200	5: Monterey SB Off Ramp	0.06	0.05	0.21	0.56	16	4	17
STDDEV	600-4200	6: SB 101 End	0.07	0.06	0.28	0.34	43	13	51
STDDEV	600-4200	7: NB Truck Lane	0.04	0.04	0.35	0.34	20	17	26

STDDEV	600-4200	8: SB Truck Lane	0.03	0.05	0.2	0.34	48	13	60
MIN	600-4200	1: NB 101 After Monterey	0.26	0.41	60.64	51.37	2261	203	2475
MIN	600-4200	2: JCT 58 NB Off Ramp	0.68	0.26	63.05	56.49	149	12	170
MIN	600-4200	3: NB 101 End	0.33	0.01	59.67	53.91	2093	192	2287
MIN	600-4200	4: SB 101 After JCT 58	-0.05	-0.42	62.98	54.68	1855	170	2040
MIN	600-4200	5: Monterey SB Off Ramp	0.73	0.15	63.45	56.17	284	19	305
MIN	600-4200	6: SB 101 End	0.41	0.26	62.08	55.4	1590	139	1738
MIN	600-4200	7: NB Truck Lane	-0.04	-0.05	60.44	20.87	2284	211	2500
MIN	600-4200	8: SB Truck Lane	-0.02	-0.11	63.08	29.91	1875	177	2057
MAX	600-4200	1: NB 101 After Monterey	0.33	0.56	61.5	53.26	2299	243	2532
MAX	600-4200	2: JCT 58 NB Off Ramp	1.07	0.51	63.8	57.38	178	28	196
MAX	600-4200	3: NB 101 End	0.53	0.25	60.81	55.9	2153	221	2367

MAX	600-420 0	4: SB 101 After JCT 58	0.03	-0.31	63.4 2	56.0 3	197 2	201	2172
MAX	600-420 0	5: Monterey SB Off Ramp	0.88	0.27	63.9 1	57.3 3	324	29	347
MAX	600-420 0	6: SB 101 End	0.58	0.4	62.7 8	56.3	167 8	173	1851
MAX	600-420 0	7: NB Truck Lane	0.05	0.04	61.2 5	21.7	233 3	249	2565
MAX	600-420 0	8: SB Truck Lane	0.06	0	63.6 1	30.8 5	197 8	207	2185

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*									
* SIMRUN: SimRun, Simulation run									
* TIMEINT: TimeInt, Time interval									
* DATACOLLECTIONMEASUREMENT: DataCollectionMeasurement, Data collection measurement									
* ACCELERATION(10): Acceleration(10), Acceleration (10) (Acceleration of all vehicles of the the data collection measurement in the interval) [ft/s2]									

* ACCELERATION(20): Acceleration(20), Acceleration (20) (Acceleration of all vehicles of the the data collection measurement in the interval) [ft/s2]									
* SPEED(20): Speed(20), Speed (20) (Speed of all vehicles of the the data collection measurement in the interval) [mph]									
* SPEED(10): Speed(10), Speed (10) (Speed of all vehicles of the the data collection measurement in the interval) [mph]									
* VEHS(10): Vehs(10), Vehicles (10) (Count of vehicles of the the data collection measurement in the interval)									
* VEHS(20): Vehs(20), Vehicles (20) (Count of vehicles of the the data collection measurement in the interval)									
* VEHS(ALL): Vehs(All), Vehicles (All) (Count of vehicles of the the data collection measurement in the interval)									
*									
* SimRun	TimeInt	DataCollectionMeasurement	Acceleration(10)	Acceleration(20)	Speed(20)	Speed(10)	Vehs(10)	Vehs(20)	Vehs(All)
*									
$DATACOLLECTIONMEASUREMENTEVALUATION:SIMRUN	TIMEINT	DATACOLLECTIONMEASUREMENT	ACCELERATION(10)	ACCELERATION(20)	SPEED(20)	SPEED(10)	VEHS(10)	VEHS(20)	VEHS(ALL)
1	600-4200	1: NB 101 After Monterey	0.32	0.48	52.23	60.07	2668	242	2910
1	600-4200	2: JCT 58 NB Off Ramp	0.89	0.11	56.23	63.39	170	14	184
1	600-4200	3: NB 101 End	0.41	0.18	54.71	60.49	2149	196	2345
1	600-4200	4: SB 101 After JCT 58	-0.03	-0.41	56.69	63.58	1703	161	1864
1	600-4200	5: Monterey SB Off Ramp	0.91	0.31	57.15	63.52	312	28	340

1	600-4200	6: SB 101 End	0.37	0.35	56.26	62.95	1381	137	1518
1	600-4200	7: NB Truck Lane	0.02	0.14	21.13	46.08	2502	232	2734
1	600-4200	8: SB Truck Lane	-0.04	0.2	30.85	61.23	1679	166	1845
2	600-4200	1: NB 101 After Monterey	0.21	0.33	51.28	60.01	2669	258	2927
2	600-4200	2: JCT 58 NB Off Ramp	1.02	0.38	56.75	63.19	182	20	202
2	600-4200	3: NB 101 End	0.58	0.32	52.28	59.55	2237	197	2434
2	600-4200	4: SB 101 After JCT 58	0.04	-0.35	55.84	63.57	1582	139	1721
2	600-4200	5: Monterey SB Off Ramp	0.86	0.32	55.49	63.03	265	21	286
2	600-4200	6: SB 101 End	0.34	0.37	56.02	63.21	1288	102	1390
2	600-4200	7: NB Truck Lane	0.02	-0.1	21.09	45.68	2541	247	2788
2	600-4200	8: SB Truck Lane	-0.01	0.22	30.1	62.23	1549	129	1678
3	600-4200	1: NB 101 After Monterey	0.22	0.59	49.99	59.57	2653	285	2938

3	600-4200	2: JCT 58 NB Off Ramp	0.71	0.3	57.04	64.02	194	16	210
3	600-4200	3: NB 101 End	0.27	0.16	54.95	61.16	2129	207	2336
3	600-4200	4: SB 101 After JCT 58	0.02	-0.31	55.94	63.59	1670	162	1832
3	600-4200	5: Monterey SB Off Ramp	0.77	0.44	57.52	63.84	320	23	343
3	600-4200	6: SB 101 End	0.42	0.41	55.57	63.27	1334	114	1448
3	600-4200	7: NB Truck Lane	-0.11	-0.06	20.87	46.35	2535	275	2810
3	600-4200	8: SB Truck Lane	-0.08	0.14	30.62	61.77	1655	153	1808
4	600-4200	1: NB 101 After Monterey	0.31	0.4	51.81	60.07	2674	249	2923
4	600-4200	2: JCT 58 NB Off Ramp	0.89	0.24	58.69	63.99	155	20	175
4	600-4200	3: NB 101 End	0.3	-0.03	55.78	60.73	2205	181	2386
4	600-4200	4: SB 101 After JCT 58	0.03	-0.37	56.04	63.95	1584	129	1713
4	600-4200	5: Monterey SB Off Ramp	0.87	0.16	56.8	63.74	302	19	321

4	600-4200	6: SB 101 End	0.32	0.43	56.03	63.32	1283	106	1389
4	600-4200	7: NB Truck Lane	0.04	-0.02	21.18	46.58	2535	238	2773
4	600-4200	8: SB Truck Lane	-0.07	0.09	30.59	62.17	1586	128	1714
5	600-4200	1: NB 101 After Monterey	0.37	0.49	50.87	59.62	2659	236	2895
5	600-4200	2: JCT 58 NB Off Ramp	0.97	0.25	55.94	63.36	185	24	209
5	600-4200	3: NB 101 End	0.62	0.16	54.08	60.09	2233	184	2417
5	600-4200	4: SB 101 After JCT 58	-0.04	-0.41	56.34	63.42	1647	150	1797
5	600-4200	5: Monterey SB Off Ramp	0.8	0.37	55.75	63.88	303	24	327
5	600-4200	6: SB 101 End	0.33	0.31	56.42	63.29	1290	115	1405
5	600-4200	7: NB Truck Lane	0.02	-0.04	21.87	46.88	2526	220	2746
5	600-4200	8: SB Truck Lane	-0.02	0.2	30.76	61.34	1618	144	1762
AVG	600-4200	1: NB 101 After Monterey	0.29	0.46	51.24	59.87	2665	254	2919

AVG	600-4200	2: JCT 58 NB Off Ramp	0.9	0.26	56.93	63.59	177	19	196
AVG	600-4200	3: NB 101 End	0.43	0.16	54.36	60.4	2191	193	2384
AVG	600-4200	4: SB 101 After JCT 58	0	-0.37	56.17	63.62	1637	148	1785
AVG	600-4200	5: Monterey SB Off Ramp	0.84	0.32	56.54	63.6	300	23	323
AVG	600-4200	6: SB 101 End	0.36	0.37	56.06	63.21	1315	115	1430
AVG	600-4200	7: NB Truck Lane	0	-0.02	21.23	46.31	2528	242	2770
AVG	600-4200	8: SB Truck Lane	-0.04	0.17	30.58	61.75	1617	144	1761
STDDEV	600-4200	1: NB 101 After Monterey	0.07	0.1	0.87	0.25	8	19	17
STDDEV	600-4200	2: JCT 58 NB Off Ramp	0.12	0.1	1.07	0.38	15	4	16
STDDEV	600-4200	3: NB 101 End	0.16	0.12	1.31	0.61	49	11	43
STDDEV	600-4200	4: SB 101 After JCT 58	0.04	0.04	0.34	0.2	53	14	67
STDDEV	600-4200	5: Monterey SB Off Ramp	0.06	0.11	0.88	0.35	21	3	23

STDDEV	600-4200	6: SB 101 End	0.04	0.05	0.32	0.15	42	14	55
STDDEV	600-4200	7: NB Truck Lane	0.06	0.09	0.38	0.46	15	21	31
STDDEV	600-4200	8: SB Truck Lane	0.03	0.05	0.29	0.46	52	16	68
MIN	600-4200	1: NB 101 After Monterey	0.21	0.33	49.99	59.57	2653	236	2895
MIN	600-4200	2: JCT 58 NB Off Ramp	0.71	0.11	55.94	63.19	155	14	175
MIN	600-4200	3: NB 101 End	0.27	-0.03	52.28	59.55	2129	181	2336
MIN	600-4200	4: SB 101 After JCT 58	-0.04	-0.41	55.84	63.42	1582	129	1713
MIN	600-4200	5: Monterey SB Off Ramp	0.77	0.16	55.49	63.03	265	19	286
MIN	600-4200	6: SB 101 End	0.32	0.31	55.57	62.95	1283	102	1389
MIN	600-4200	7: NB Truck Lane	-0.11	-0.1	20.87	45.68	2502	220	2734
MIN	600-4200	8: SB Truck Lane	-0.08	0.09	30.1	61.23	1549	128	1678
MAX	600-4200	1: NB 101 After Monterey	0.37	0.59	52.23	60.07	2674	285	2938

MAX	600-4200	2: JCT 58 NB Off Ramp	1.02	0.38	58.69	64.02	194	24	210
MAX	600-4200	3: NB 101 End	0.62	0.32	55.78	61.16	2237	207	2434
MAX	600-4200	4: SB 101 After JCT 58	0.04	-0.31	56.69	63.95	1703	162	1864
MAX	600-4200	5: Monterey SB Off Ramp	0.91	0.44	57.52	63.88	320	28	343
MAX	600-4200	6: SB 101 End	0.42	0.43	56.42	63.32	1381	137	1518
MAX	600-4200	7: NB Truck Lane	0.04	0.14	21.87	46.88	2541	275	2810
MAX	600-4200	8: SB Truck Lane	-0.01	0.22	30.85	62.23	1679	166	1845

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* SIMRUN: SimRun, Simulation run									

* TIMEINT: TimeInt, Time interval										
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* VEHS(20): Vehs(20), Vehicles (20) (Count of vehicles of the the data collection measurement in the interval)										
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* SimRun	TimeInt	DataCollectionMeasurement	Acceleration(10)	Acceleration(20)	Speed(10)	Speed(20)	Vehs(10)	Vehs(20)	Vehs(All)
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$DATACOLLECTIONMEASUREMENTEVALUATION:SIMRUN	TIMEINT	DATACOLLECTIONMEASUREMENT	ACCELERATION(10)	ACCELERATION(20)	SPEED(10)	SPEED(20)	VEHS(10)	VEHS(20)	VEHS(ALL)
1	600-4200	1: NB 101 After Monterey	0.27	0.43	61.5	53.26	2271	223	2494
1	600-4200	2: JCT 58 NB Off Ramp	0.7	0.29	63.68	56.89	158	12	170
1	600-4200	3: NB 101 End	0.42	0.12	60.75	54.88	2093	194	2287

1	600-4200	4: SB 101 After JCT 58	-0.03	-0.36	63.14	55.6	1972	200	2172
1	600-4200	5: Monterey SB Off Ramp	0.73	0.21	63.91	57.32	312	25	337
1	600-4200	6: SB 101 End	0.53	0.28	62.24	56.3	1678	173	1851
1	600-4200	7: NB Truck Lane	0	0.01	61.15	20.87	2297	218	2515
1	600-4200	8: SB Truck Lane	-0.02	-0.11	63.08	30.26	1978	207	2185
2	600-4200	1: NB 101 After Monterey	0.32	0.47	60.64	51.37	2299	233	2532
2	600-4200	2: JCT 58 NB Off Ramp	0.82	0.41	63.4	57.59	149	28	177
2	600-4200	3: NB 101 End	0.38	0.22	60.28	54.99	2153	214	2367
2	600-4200	4: SB 101 After JCT 58	0.03	-0.42	63.31	56.03	1855	185	2040
2	600-4200	5: Monterey SB Off Ramp	0.87	0.18	63.68	56.76	284	21	305
2	600-4200	6: SB 101 End	0.42	0.25	62.52	55.4	1591	149	1740
2	600-4200	7: NB Truck Lane	0.04	0.06	60.62	21.08	2284	240	2524

2	600-4200	8: SB Truck Lane	0.01	-0.06	63.27	30.38	1875	182	2057
3	600-4200	1: NB 101 After Monterey	0.33	0.44	61.28	51.77	2268	243	2511
3	600-4200	2: JCT 58 NB Off Ramp	0.89	0.5	62.9	56.86	165	15	180
3	600-4200	3: NB 101 End	0.62	0.31	59.39	54.12	2123	221	2344
3	600-4200	4: SB 101 After JCT 58	0.01	-0.31	62.98	54.68	1941	201	2142
3	600-4200	5: Monterey SB Off Ramp	0.83	0.25	63.45	57.33	314	29	343
3	600-4200	6: SB 101 End	0.49	0.29	62.57	55.95	1666	149	1815
3	600-4200	7: NB Truck Lane	0.03	-0.03	60.59	21.47	2317	249	2566
3	600-4200	8: SB Truck Lane	0.06	0	63.16	30.38	1977	199	2176
4	600-4200	1: NB 101 After Monterey	0.26	0.41	61.19	52.54	2286	203	2489
4	600-4200	2: JCT 58 NB Off Ramp	0.85	0.19	63.64	57.55	178	18	196
4	600-4200	3: NB 101 End	0.35	0.12	60.6	56.24	2126	194	2320

4	600-4200	4: SB 101 After JCT 58	0.01	-0.38	63.42	56.01	1875	170	2045
4	600-4200	5: Monterey SB Off Ramp	0.85	0.27	63.52	56.23	324	19	343
4	600-4200	6: SB 101 End	0.42	0.4	62.78	55.67	1599	139	1738
4	600-4200	7: NB Truck Lane	-0.04	0.02	61.09	21.46	2333	212	2545
4	600-4200	8: SB Truck Lane	0.01	-0.08	63.61	29.91	1889	177	2066
5	600-4200	1: NB 101 After Monterey	0.32	0.56	61	51.39	2261	214	2475
5	600-4200	2: JCT 58 NB Off Ramp	0.97	0.39	62.82	56.68	170	17	187
5	600-4200	3: NB 101 End	0.56	0.28	59.9	53.38	2146	192	2338
5	600-4200	4: SB 101 After JCT 58	-0.05	-0.42	63.13	55.75	1904	187	2091
5	600-4200	5: Monterey SB Off Ramp	0.85	0.15	63.91	56.17	323	24	347
5	600-4200	6: SB 101 End	0.58	0.36	62.08	55.66	1590	159	1749
5	600-4200	7: NB Truck Lane	0	-0.09	61.29	21.64	2289	211	2500

5	600- 420 0	8: SB Truck Lane	-0.02	-0.02	63.2 4	30.8 5	192 2	183	2105
AVG	600- 420 0	1: NB 101 After Monterey	0.3	0.46	61.1 2	52.0 6	227 7	223	2500
AVG	600- 420 0	2: JCT 58 NB Off Ramp	0.85	0.36	63.2 9	57.1 1	164	18	182
AVG	600- 420 0	3: NB 101 End	0.47	0.21	60.1 8	54.7 2	212 8	203	2331
AVG	600- 420 0	4: SB 101 After JCT 58	-0.01	-0.38	63.2	55.6 1	190 9	189	2098
AVG	600- 420 0	5: Monterey SB Off Ramp	0.83	0.21	63.6 9	56.7 6	311	24	335
AVG	600- 420 0	6: SB 101 End	0.49	0.32	62.4 4	55.8	162 5	154	1779
AVG	600- 420 0	7: NB Truck Lane	0.01	0	60.9 5	21.3	230 4	226	2530
AVG	600- 420 0	8: SB Truck Lane	0.01	-0.05	63.2 7	30.3 5	192 8	190	2118
STDDEV	600- 420 0	1: NB 101 After Monterey	0.03	0.06	0.33	0.82	15	16	22
STDDEV	600- 420 0	2: JCT 58 NB Off Ramp	0.1	0.12	0.41	0.43	11	6	10
STDDEV	600- 420 0	3: NB 101 End	0.12	0.09	0.55	1.07	23	13	30

STDDEV	600-4200	4: SB 101 After JCT 58	0.03	0.05	0.17	0.55	48	13	58
STDDEV	600-4200	5: Monterey SB Off Ramp	0.06	0.05	0.21	0.56	16	4	17
STDDEV	600-4200	6: SB 101 End	0.07	0.06	0.28	0.34	43	13	51
STDDEV	600-4200	7: NB Truck Lane	0.03	0.06	0.32	0.32	21	17	26
STDDEV	600-4200	8: SB Truck Lane	0.03	0.05	0.2	0.34	48	13	60
MIN	600-4200	1: NB 101 After Monterey	0.26	0.41	60.64	51.37	2261	203	2475
MIN	600-4200	2: JCT 58 NB Off Ramp	0.7	0.19	62.82	56.68	149	12	170
MIN	600-4200	3: NB 101 End	0.35	0.12	59.39	53.38	2093	192	2287
MIN	600-4200	4: SB 101 After JCT 58	-0.05	-0.42	62.98	54.68	1855	170	2040
MIN	600-4200	5: Monterey SB Off Ramp	0.73	0.15	63.45	56.17	284	19	305
MIN	600-4200	6: SB 101 End	0.42	0.25	62.08	55.4	1590	139	1738
MIN	600-4200	7: NB Truck Lane	-0.04	-0.09	60.59	20.87	2284	211	2500

MIN	600-4200	8: SB Truck Lane	-0.02	-0.11	63.08	29.91	1875	177	2057
MAX	600-4200	1: NB 101 After Monterey	0.33	0.56	61.5	53.26	2299	243	2532
MAX	600-4200	2: JCT 58 NB Off Ramp	0.97	0.5	63.68	57.59	178	28	196
MAX	600-4200	3: NB 101 End	0.62	0.31	60.75	56.24	2153	221	2367
MAX	600-4200	4: SB 101 After JCT 58	0.03	-0.31	63.42	56.03	1972	201	2172
MAX	600-4200	5: Monterey SB Off Ramp	0.87	0.27	63.91	57.33	324	29	347
MAX	600-4200	6: SB 101 End	0.58	0.4	62.78	56.3	1678	173	1851
MAX	600-4200	7: NB Truck Lane	0.04	0.06	61.29	21.64	2333	249	2566
MAX	600-4200	8: SB Truck Lane	0.06	0	63.61	30.85	1978	207	2185