A MICROSIMULATION OF TRAFFIC, PARKING, AND
EMISSIONS AT CALIFORNIA POLYTECHNIC STATE
UNIVERSITY- SAN LUIS OBISPO

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by
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ABSTRACT

A MICROSIMULATION OF TRAFFIC, PARKING, AND EMISSIONS AT CALIFORNIA POLYTECHNIC STATE UNIVERSITY- SAN LUIS OBISPO

Steven Michael Kilbert

Traffic and parking congestion are significant issues at many universities nationwide. The delays experienced result in wasted time, money, and fuel for students, faculty and staff, not to mention the negative contributions to the environment. This paper quantifies the amount of vehicle emissions generated during an average morning peak hour in the university environment. Using VISSIM and CMEM microsimulation packages, a model is created for California Polytechnic State University- San Luis Obispo to aggregate the collective transportation behaviors and practices of the campus and recognize the implications these behaviors pose on the transportation network as a whole. Reasonable estimates are generated for overall HC, CO, and NO_x type emissions as well as fuel consumption. Scenarios are proposed which reflect the sensitivity of outputs to key input parameters. The findings of this research can be useful for future campus planning and the ideas can be extended to similar environments with traffic and parking problems such as business parks, corporate campuses, downtown districts, and special event venues.

Keywords: Microsimulation, Emissions, VISSIM, CMEM, University Traffic and Parking

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Mrs. Kilbert was a devout teacher and educator of mathematics and computers in Mercer County, Pennsylvania.

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1. Introduction

1.1 Simulation

Simulation is a tool for analyzing the design and operation of a system. Whether the system is an assembly line, a machine shop, a service counter, or a road network, the use of simulation allows for a deeper level of thought that investigates the logic of how and why operations occur the way they do, which may normally be taken for granted. Simulation involves creating a replicate model of a system by taking into account its inputs, outputs, and any potential variability. Once a valid model is constructed, the simulation can then be used to analyze the system and its problems and generate statistics on key performance measures.

Furthermore, the simulation can also be used to test changes or modifications to a system in an “off-line” mode, where the actual system is unaffected. In recent years, simulation has been applied to investigate and alleviate many transportation problems.

1.2 Cal Poly- San Luis Obispo

California Polytechnic State University (Cal Poly) is a high-ranking polytechnic university for both undergraduate and graduate students and is part of the 23 campus California State University system.

Located in San Luis Obispo (population 44,000) along the central coast of California, Cal Poly boasts an enrollment of just over 18,000 undergraduates and 1000 graduates. Additionally, Cal Poly employs over 2900 faculty members and staff. Cal Poly houses approximately 6000 undergraduates each year and attracts many visitors as a key venue for many sporting events and the performing arts.

1.3 Problem Statement

With a high demand for excellent education and entertainment, traffic and parking congestion on campus have long been issues and will continue to be with future growth. Not only do delays affect students, faculty, staff, and visitors, but they also generate emissions harmful to the environment. As a leading institution in many disciplines including engineering, there is a strong push to make the Cal Poly campus a leader in terms of being “green”. This philosophy was emphasized in 2010 in the words of former Cal Poly President Warren J. Baker: “As a polytechnic university, it is at the core of our mission to examine the ways in which knowledge may be applied to improve society, manage scarce resources, and protect and preserve our environment. Sustainability is a high priority for the university and a key issue that should cut across all we do, including teaching, research, and the practices we engage in on the campus” (Multari 2010).

With regards to transportation, Cal Poly, as well as the California State University system, lacks a model sufficient enough to aggregate the current behaviors of its motorists and recognize the implications posed by the interactions of these behaviors. Transportation is an integral component to Cal Poly’s impact on the environment and its sustainability efforts, as it contributes to approximately 40% of campus greenhouse gas emissions. Yet, transportation remains less quantified and less visited in comparison to the campus’s efforts in other areas of sustainability such as water quality, energy consumption, and land development (Multari 2010). Without a model of the current transportation environment, Cal Poly also doesn’t have adequate means to forecast the effects of future growth and policy and may see increased difficulty in adhering to new environmental legislation.

1.4 Objectives

The use of simulation can help the campus recognize the collective behaviors and patterns of transportation present on campus and the implications these behaviors pose to the transportation network as a whole.

With analysis of a valid simulation model, it is possible to determine which components of a network generate the most “waste” and hypothetically test solutions to eliminate this “waste”. “Waste” can have many different meanings in a transportation network whether it is excessive vehicle emissions, inappropriate traffic control devices, poor road geometry, or the generation of conflicting movements.

The objectives of this study are:

- To create a simulation model that mimics the real life traffic situation seen on Cal Poly’s campus during one of its heaviest peak periods
- To quantify the physical emissions generated by vehicles during this particular time period
- To determine the sensitivity of results based on fluctuation of several key input parameters
- To determine the potential effect of some select campus transportation policies anticipated in Cal Poly’s near-future

1.5 Assumptions

Due to the complexity of simulation modeling and microscopic traffic simulation in particular, a “perfect” model is nearly impossible to achieve. It is important to note that no models are correct, but some are useful (Colvin 2009). Models may be deemed useful if they adhere to stated objectives and are capable of generating the key performance metrics required at a reasonable level of accuracy. The VISSIM model described in this study relies on the following assumptions:

- *Area of Study* is limited to the Cal Poly campus and several nearby streets and intersections (See [Area of Study](#) for more information including closures, areas of construction, and streets limited to certain traffic only)
- *Time of Study* is limited to the AM Peak Hour (7:30AM-8:30AM) on an average weekday (Tuesday, Wednesday, or Thursday)
- *Time of Simulation* is limited to the AM Peak Hour plus 15 minutes prior. The 15-minute time period between 7:15AM and 7:30AM is primarily used for ease of integrating public transit schedules that are observed within the area of study
- *Warm-up time is assumed to be negligible*: The traffic flows before 7:30AM are not significant to influence traffic soon thereafter. Flows begin almost exclusively at 7:30AM
- *Peak hour vehicle inputs* are generated on a random basis which generates a somewhat uniform flow among smaller time intervals forming the peak hour. In reality, the flow during these smaller time intervals may not be so uniform.
- *Pedestrian traffic* is not accounted for due to modeling complexity and limitations with the current version of software; the exception to this is the pedestrian vehicle class which is modeled at two signalized crosswalks
- The *iterative matrix balancing process* which is part of the gravity model is based off the distribution of attractions. The common state of the practice used in transportation planning is based off the distribution of productions. Both methods generate close to the same results, however.
- *Dynamic Routing* is not included in the model. Dynamic routing is used in conjunction with the dynamic assignment module to re-route vehicles to different parking lots when lots reach become

full or reach a certain occupancy level. During the time period of study, the need for dynamic routing rarely exists. The only exception occurs when a couple lots are filled within 5-10 minutes of the simulation end, where small queues of vehicles begin to build. The impact of these queues is essentially negligible given that the flow of most traffic is not impacted.

- *Off-campus signalized intersections* of Foothill & California, Foothill & Santa Rosa, and Highway 1 & Highland are modeled as 4-way stops for transit vehicles only. Vehicle ingress/egress points reside inside these intersections, so most vehicles do not encounter them (See [Traffic Signals](#) for more information).
- *Railroads* and the crossing at Foothill Blvd and California Blvd is not included in the model
- Specific assumptions concerning *vehicle types modeled* as well as traffic compositions, vehicle classes, and vehicle color distributions are discussed further in [5.3 Vehicle Data](#)
- The *California Blvd entrance* to Cal Poly does not accommodate 100% of the demand it generates for all random seeds and under different scenarios. This is somewhat realistic in that traffic is often backed-up along California Blvd to the intersections of Foothill Blvd or Hathway Ave
- Specific assumptions associated with the *emissions model (CMEM)* are specified in [5.9 Emissions Modeling](#)
- Unless otherwise specified in [5. Developing a Model for Cal Poly](#), VISSIM's default parameters are assumed

2. Background

2.1 Cal Poly's Road Network

Cal Poly's road network is essentially horseshoe-shaped, where N Perimeter Road spans the northern part of the horseshoe and S Perimeter Rd spans the southern part of the horseshoe, with the horseshoe opening facing west. There are six entrances to Cal Poly (Grand Ave, Foothill Blvd, Cuesta Ave, California Blvd, Highland Dr, and Stenner Creek Rd) which are serviced largely from two nearby highways (CA-1 and Highway 101). The campus has two sets of traffic signals used for pedestrian crossings, while most other intersections are controlled by stop-signs or the right-of-way. The campus experiences congestion near the tops of the hours each weekday due to large volumes of pedestrians crossing streets to get to class.

Additionally, the campus tends to have several peak hours between the morning, midday, and evening.

2.2 Cal Poly's Parking System

Cal Poly's parking system is somewhat impacted. The campus contains 8792 parking spaces (Cal Poly UPD, March 2010). Approximately 3492 spaces are available for campus residents, along with 2992 spaces for general parking, 1410 spaces for staff parking, and 183 for disabled drivers. There are approximately 62 spots with short-term time limits along with 342 parking meters which run at a rate of \$1.50 USD per hour. Forty-eight spots are available for loading, 8 for commuter programs, and 200 for equipment loading and state vehicles. There are approximately 7500 parking permits in use each quarter.

2.3 Current Trends at Cal Poly

With its continued growth, Cal Poly has several construction projects underway and has witnessed the completion of several others in recent years. Currently under construction are a new Center for Science, a new Meat Processing Center, the Simpson Strong-Tie, redevelopment of a central chiller plant, and expansion of the Recreation Center.

The campus has witnessed the completion of the following in recent years:

- *June 2010*- Completed construction of the new Technology Park
- *June 2010*- Completed renovation of the University Union Plaza

- *September 2009-* S. Perimeter drive was closed to thru traffic between Grand Avenue and Cuesta Ave in accordance with a campus master plan as an effort to make the core of campus more pedestrian-friendly
- *October 2008-* Completion of Construction Innovations Center
- *Fall 2008-* Completed construction of the Poly Canyon Village Apartments development
- *Fall 2007-* Completed construction of Engineering IV and nearby parking area
- *Fall 2006-* California Boulevard was re-opened as a thru street between North Perimeter and Campus Way after completion of the new Alex G. Spanos stadium which extends over California Boulevard
- *September 2004-* Completed construction of the Cerro Vista Apartment Complex

Figure 2.1: Commuter Parking Permits per Student at Cal Poly (Multari 2010)

Several years ago, Cal Poly was recognized among the best workplaces for commuters according to an annual study conducted by the National Center for Transit Research at the University of South Florida. Since then Cal Poly has taken several more steps to improve its transportation system, despite the lack of a sufficient model or evaluation tool. Based on 2009 data in Cal Poly's third biennial report on sustainability, Cal Poly has witnessed a significant decrease in the number of parking permits sold (Figure 2.1) and a significant increase in transit ridership. The decline in parking permit sales is attributed to an

increase in on-campus housing (Figure 2.2), increased parking costs, the relocation of parking lots further from the campus core, increased fuel costs, a recessionary economy, and continued promotion of alternative forms of transportation. Increased transit ridership (Figure 2.3) is attributed to the increase in on-campus housing, the decrease in attractiveness of parking on campus, increased transit capacity and hours of operation, and the continued ability for current members of the Cal Poly community to ride city transit for free. Cal Poly also has increased the size of its vanpool program and experimented with the introduction of several ZipCars which allow subscribed members to rent a car on an hourly basis directly from campus for a flat rate which includes insurance and fuel. These improvements are significant, but a simulation model can help us further recognize opportunities and determine to what extent it is worth continuing practices similar to these. This could further help the campus with the future attainment of proper awards or recognition.

Figure 2.2: Percentage of Cal Poly Student Population living On-Campus (Multari 2010)

Figure 2.3: Cal Poly SLO Transit Ridership (Multari 2010)

2.4 Growth vs. Traffic Reduction

A common argument in transportation is whether a transportation system is improved despite the continued growth of an area. Quite often the additional demand generated from growth can harm and possibly even offset the efforts taken to improve traffic congestion or reduce vehicle emissions. This makes improvements to transportation that much more difficult. Regardless of efforts made, it is important to consider the impact of a “do nothing” alternative which is still subject to growth and additional congestion that can often lead to an even worse transportation state. Any improvements that can be made are important, but improvements that can hold despite increased growth, can really have a significant impact.

2.5 Simulation in Transportation

In recent years, simulation has been applied to transportation to solve many problems such as traffic congestion, traffic growth, signal control optimization, public transit priorities, and predicting driver reactions to certain stimuli. There are two approaches used in transportation simulations: macrosimulation and microsimulation. In macrosimulation, the flow of vehicles on a road is treated as a homogenous entity like fluid flowing through a pipe. In microsimulation, the movements of individual vehicles are captured and system analysis is achieved by aggregating the collective behaviors of all vehicles (Ramasamy 2002).

Screenshots of animation (Figure 2.4) show the visual differences between both of these types.

Microsimulation takes into account the interactions and interdependencies of motorists and is preferred over macrosimulation because it can capture a breakdown of flow that macrosimulation would be unable to cope with. Macrosimulation can be preferred over microsimulation however, because it is cheaper, computes faster, and vehicle-specific information may not be important to the problem at-hand. In this study, we use microsimulation because it is available at the university and because the high-level of detail is desired to mimic traffic issues at Cal Poly, especially with regard to vehicle emissions.

Figure 2.4: Visual Comparison of Types of Transportation Simulation (PTV Vision 2007)

2.5.1 Agent Based Modeling

Within microsimulation, the concept of agent-based modeling can also be applied. In an agent-based model, entities act as autonomous agents that have their own rules for behavior and are affected by interaction with other agents. Some agents are smart in that they can learn from their experiences and environments. In transportation microsimulation, agents are often driver-vehicle pairs, whose behaviors are influenced by interactions with other driver-vehicle pairs.

2.6 VISSIM

VISSIM is an agent-based microsimulation software first pioneered in 1992 by PTV-AG in Karlsruhe, Germany. It is now produced in the U.S. by PTV America in Portland, Oregon and is a leading program for multi-modal traffic flow modeling. VISSIM features state-of-the-art animation, emissions analysis and playback controls, as well as inputs and outputs to many other programs. In the past, VISSIM has been used for many applications such as:

- Development, evaluation, and fine-tuning of signal priority logic
- Evaluation and optimization of traffic operations in a combined network of coordinated and actuated traffic signals
- Analysis of slow speed weaving and merging areas
- Route choice dependent questions such as the impact of a variable message sign or the potential of traffic diversion into neighborhoods
- Modeling and simulating flows of pedestrians along streets and inside buildings (VISSIM v5.20 User Manual 2009)

One of the latest editions of the software, version 5.20 is used in our study at Cal Poly.

2.6.1 VISSIM Components

VISSIM is made up of two main components—a traffic simulator and a signal state generator. The traffic simulator is a microscopic traffic flow simulation model including car following and lane changing logic. The signal state generator is a signal control software polling detector information from the traffic simulator on a discrete time basis (down to 1/10 of a second) to determine the signal status for the following time step and return this data to the traffic simulator (VISSIM User Manual 2009).

2.6.2 Car Following/Lane-Changing Methodology

VISSIM is one of the most accurate tools for traffic simulation modeling because of the methodology of how vehicles move through a road network. VISSIM uses the psycho-physical driver behavior model pioneered by Rainer Wiedemann in 1974. As opposed to simple models which use constant speeds or deterministic car following logic, Wiedemann's model views the interaction of vehicles as an iterative process of acceleration and deceleration. This is built off the basic idea that a driver of a faster vehicle starts to decelerate as he/she reaches their individual perception threshold of a slower moving vehicle. When the driver slows down, he/she does not know the speed of the neighboring vehicle, so he/she drops to a speed just below that of the neighboring vehicle until another threshold is reached where he/she begins accelerating again. This iterative process is repeated until speed is matched or conditions change. The variation in driver thresholds is accounted for in stochastic distributions of speed and spacing which are updated periodically based on changes in aggregate driver behavior and improvements in vehicle technology and capabilities.

2.6.3 Vehicle-Driver Pairs

VISSIM is agent-based in that drivers are paired with vehicles to travel through a network. Each driver has their own behavior characteristics which are controlled by their current state in the simulation and the capabilities of the vehicles they are paired with. The behavior of a driver-vehicle pair can change quite often during simulation based on the current situation and behaviors of nearby motorists.

2.7 Emissions

Given the increases of global climate change and the continued acquisition of health problems due to environmental stimuli, emissions generated by the human race and its behaviors continue to be a growing concern for the future of mankind.

2.7.1 Types of Emissions

Air pollutants are emitted from a variety of sources including stationary fuel combustion, industrial processes, highway vehicles, and non-road sources. Pollutants from these sources enter the atmosphere in the forms of solids, liquids and gases and either stay in those states or react with other matter. Pollution has become a major concern when the concentration of these constituents in a portion of the atmosphere reaches a level of imbalance at which some biological processes are disturbed and cannot be carried out as they normally would. Although pollution mostly impacts the environment on a local level, some global effects are beginning to be noticed. Perhaps the best known example of this is global climate change which is a result of greenhouse gas emissions. Greenhouse gas emissions are generated by the combustion of fossil fuels combined with deforestation which leads to an over-concentration of carbon dioxide, a gas that often traps heat in the atmosphere.

According to National Ambient Air Quality Standards (NAAQSs), there are six main types of pollutants, known as criteria pollutants. Five of these pollutants (particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and particulate lead) are considered primary pollutants, in that their generation can directly affect the atmosphere. Ozone, on the other hand, is classified as a secondary pollutant in that it is not directly emitted, but is formed by chemical reactions in the atmosphere between sunlight, volatile organic compounds (VOCs) and nitrous oxides. VOCs such as hydrocarbons as well as nitrous oxides are emitted directly from the same variety of sources but only pose a risk if they react in the atmosphere to form ozone compounds. It is important to know that the ozone compound (O_3) of concern exists in the lower atmosphere (troposphere) in the form of smog and is different from the ozone in the upper atmosphere that protects us from the sun. Pollutants are often classified into categories that account for primary pollutants and pollutants that trigger the creation of ozone. These categories include particulate matter, sulfur oxides, nitrogen oxides, and volatile organic compounds (VOCs). Particulate matter generally takes the form of fine dusts, noncombustible ash, and incompletely burned soot. Sulfur and

nitrogen oxides describe several compounds that combine either sulfur or nitrogen with different quantities of oxygen. Common compounds in these classes are nitrogen monoxide, nitrogen dioxide, and sulfur dioxide. VOCs can take the form of hydrocarbons, which are compounds that contain only hydrogen and/or carbon atoms, as well as aldehydes, ketones, and chlorinated solvents (Cooper 2002).

2.7.2 Emissions in the United States

In the United States, the Environmental Protection Agency (EPA) is tasked with the duties of monitoring pollution and improving the quality of the environment and has been historically successful in making the United States a world leader in pollution control. According to the EPA in 2000, the United States generates somewhere between 10-33% of the world's emissions, depending on the type of pollutant. Emissions and their impact in the United States began to be recognized sometime after the Great Depression when their existence increased rapidly. It wasn't until legislation was passed in 1970 that emissions began to decline. According to EPA estimates in 2000, this decreasing trend has slowed and could perhaps be reversing itself in the near future (Cooper 2002). A more recent report on air quality from the EPA in 2010 based off of data from 2008 (Figure 2.5) still shows reduction for most types of emissions, with the exception of carbon dioxide which has increased approximately 20% from 1990 to 2008 (Figure 2.6). The nationwide spike in fuel prices and the economic recession of 2008 is a significant factor in these trends and future trends.

Source Category	PM _{2.5}	PM ₁₀	NH ₃	SO ₂	NO _x	VOC	CO	Lead
Stationary Fuel Combustion	-773	-813	+43	-10,490	-5,323	+445	-228	-0.42
Industrial and Other Processes	-343	-217	-446	-731	-144	-3,150	-442	-2.80
Highway Vehicles	-213	-216	+153	-439	-4,386	-5,970	-71,389	-0.42
Non-Road Mobile	-17	-24	-28	+85	+474	-76	-3,411	-0.27
Total Change	-1,346	-1,270	-278	-11,575	-9,379	-8,751	-75,470	-3.91
Percent Change (1990 vs. 2008)	-58%	-39%	-6%	-50%	-36%	-35%	-53%	-79%

Figure 2.5: Rates of Change for Pollutant Types by Source Category in the United States from 1990-2008 (U.S. EPA 2010)

Figure 2.6: Rate of Change for Carbon Dioxide Emissions in the United States in Relation to other Growth Indicators from 1990-2008 (U.S. EPA 2010)

Figure 2.7: Breakdown of Pollutant Emissions by Source Category (U.S. EPA 2010)

The above chart (Figure 2.7) from 2008 shows the percent of emissions of each pollutant type attributed to one of four source categories. Based on this data, the EPA has made several estimates regarding current emissions:

- Approximately 70% of SO₂ emissions are sourced from electric utilities
- Approximately over 80% of ammonia emissions (NH₃) are the result of agricultural processes or operations
- Approximately 50% of VOC emissions are generated from either solvents or highway vehicles

The EPA has also made several estimates for emissions not specified in the above chart:

- Approximately 94% of CO₂ emissions are the result of the combustion of fossil fuels which include electricity generation, transportation, industrial processes, and residential or commercial processes. Electricity generation accounts for about 42% share of CO₂ emissions while transportation accounts for nearly one-third (33%) of CO₂ emissions.
- Approximately 64% of CH₄ (methane) emissions result from livestock, landfills and natural gas systems while coal mining and manure management comprise approximately 10% and 8 % , respectively.

2.7.3 Emissions in San Luis Obispo County

The San Luis Obispo County Air Pollution Control District is the local agency charged with working to protect the health of over 265,000 county residents by preserving good air quality. It is responsible for ensuring the county's air meets standards established by the California Air Resources Board and the US EPA (San Luis Obispo Air Pollution Control District 2008). The monitoring and control of pollution on a local basis is important, especially since most pollutants affect the environment and people on a local level. The county has historically maintained a "good" air quality rating and adheres to most state or federal standards. Sources of pollution in the county (see Figure 2.8 below) are largely attributed to transportation due to its size and relative lack of industry compared to more urban areas. This graph focuses on sources specific to generation of reactive organic gases and nitrogen oxides.

Figure 2.8: Air Pollution Sources in San Luis Obispo County (San Luis Obispo County Air Pollution Control District 2008)

The county currently has the most difficulty meeting federal and state standards for PM-10 emissions, which refers to particulate matter on the order of ten micrometers in size, a type of emission which is largely influenced by transportation.

2.7.4 Emissions & Transportation

As seen from both US and San Luis Obispo County statistics, transportation is a large contributor to emissions. In fact, the United States has more cars per capita than any other nation. According to EPA statistics from 2008, highway and non-road mobile sources constitute about 80% of national carbon monoxide emissions and 33 % of carbon dioxide emissions (US EPA 2010). In addition to these emissions, nitrous oxides (NO_x), volatile organic compounds (VOCs), sulfur dioxide and particulate matter are also pollutants of concern sourced from transportation. Particulate matter results because even the best internal combustion engine does not fully burn 100% of its fuel.

There are many factors that influence the amount of vehicle emissions generated. These factors can be divided into vehicle factors and environmental conditions. In terms of vehicle factors, the amount of emissions generated is influenced by the design and operating features of the engine, the operational and maintenance practices of the driver, fuel consumption, and add-on pollution control technology. Vehicles have been continually improved over the years with technology that controlled the flow rate of fuel to the engine as well as catalytic converters which treat exhaust emissions so they are less harmful. Catalytic converters help control exhaust emissions particularly by oxidizing CO and VOCs to form CO₂ and water and reducing nitrous oxides to nitrogen and oxygen gas. In terms of environmental factors, the amount of emissions generated is influenced by the density of the ambient air, temperature, soak time (time since last engine start), and the secondary load placed on the engine by factors such as air conditioning.

Transportation air pollution is difficult to control in that arises from a large number of small, diverse, decentralized sources which are highly mobile and close to receptors (people living and working in areas near vehicles). Furthermore, the automobile has long been an economic status symbol and driving one is integral to many lifestyles. The growth of transportation is also very large, which often offsets any attempts to reduce emissions. On an international level, the significance of mobile source pollution is growing at an even faster rate than industrial pollution (Cooper 2002). Achieving success in controlling emissions can be best reached through continual advances in vehicle technology, stricter legislation, and transportation control measures. Simulation is an excellent tool for analyzing the impacts of all three of these methods.

3. Review of Literature

The following section is a literature review of related studies in traffic simulation and emissions modeling.

Additional literature is reviewed in [Appendix R: Additional Background Information](#).

3.1 UCF Simulation Using Paramics

Shankar Ramasamy, a graduate student at the University of Central Florida, used PARAMICS software and its dynamic assignment module to model the congested UCF road network in 2002 during the AM and PM Peak hours. PARAMICS is another leading simulation software for modeling traffic and transportation made by Quadstone Limited of Edinburgh, United Kingdom. Ramasamy's model was used to assess what geometric and operational improvements could improve safety and efficiency on UCF's campus. He found that congestion could improve by widening a main thoroughfare to four lanes and adding a traffic signal. This plan, however, may generate additional commuter traffic not intended for the campus, which provided light to the idea of an off-campus satellite parking area with shuttle service. Additionally, Ramasamy found that the campus could significantly improve in terms of bicycling and carpooling.

3.2 Environmental Impacts of Traffic Management & Control

As part of IEEE's 2009 International Conference on Energy and Environment Technology, researchers from the School of Transportation at Nanjing, China's Southeast University presented a study which evaluated traffic management and control as a transportation planning strategy with consideration of the environment. Specifically, they compared policies with emphasis on mitigating traffic congestion and emphasis on mitigating traffic emissions—policies which are usually different and often conflict. They used VISSIM microscopic simulation software to simulate the use of a central or side bus lane along North Taiping Road as a traffic mitigation measure. The Comprehensive Modal Emissions Model (CMEM) was used to capture the behavior of vehicles from the simulation to generate key emissions statistics. Using gray system theory and analytic hierarchy process (AHP) analysis, the researchers analyzed several indices corresponding to policies mitigating traffic congestion and traffic emissions. In the case of a central bus lane, traffic congestion indices were significantly improved while the use of a side bus lane tended to improve vehicle emission statistics instead. They concluded an ideal model should try to optimize both policies of traffic mitigation and traffic emissions and the most ideal solution should be sought by using an

analysis such as AHP, where weights are assigned to different evaluation parameters which convey performance.

3.3 Flow Improvements & Vehicle Emissions

In 2005, Robert Noland and Mohammed Quddus, researchers at the Center for Transport Studies at London's Imperial College used VISSIM microsimulation and the comprehensive modal emissions model (CMEM) to study flow improvements and vehicle emissions. Their objective was to determine the affect in terms of vehicle emissions of increasing the availability of road space as a measure to smooth traffic flow. Based on economic theory, many previous studies suggested that adding lanes to a major roadway as a traffic mitigation measure reduced travel times which generated additional "induced" demand. With this additional induced demand, some argue that emissions are increased while others argue that the reduction of stop-and-go traffic and the improved smoothening of traffic flow do, in fact, reduce emissions despite the additional induced demand. The researchers chose CMEM for emissions modeling because of its ability to account for second-by-second accelerations and calculated the break-even points for emissions of carbon monoxide (CO), carbon dioxide (CO₂), nitrous oxides (NO_x) and hydrocarbons (HCs) generated along a hypothetical roadway representative of a typical thoroughfare in the United Kingdom. They found in most cases that a mitigating measure of widening a two lane segment to three lanes increased traffic to a point where any emission reduction benefits were offset. They found this result to be even more significant with traffic compositions consisting of greater mixes of newer and cleaner vehicle models since the low emissions generated by those models has more difficulty offsetting the impact of its demand increases.

3.4 Simulation of Emergency Vehicle Routing

Mansoor Mollaghasemi and Mohamed Abdel-Aty, both faculty members at the University of Central Florida, developed an emergency response model in 2003 for use at Orlando International Airport. They used PARAMICS and its dynamic assignment module to evaluate emergency vehicle routing strategies from several nearby fire stations during the PM Peak Hour, should an incident occur at Orlando International. The use of a microscopic simulation tool was important in their study because of the inability to test emergency situations in the field. They were able to determine which fire stations were capable of the shortest response times given a variety of traffic conditions. In applying scenarios, they also were able to determine different priorities for response based on variable incident locations at the airport.

3.5 Development of a Microscopic Modal Emissions Model

Under sponsorship of the National Cooperative Highway Research Program, researchers from the University of California at Riverside, the University of Michigan and the Lawrence Berkeley National Laboratory, developed a comprehensive model for modal emissions (CMEM) in 1998. The resulting model was developed to evaluate operational improvements that are more ‘microscopic’ in nature, as opposed to the standard models of the time such as EMFAC and MOBILE which evaluate emissions and operations at a more regional level (Scora 2006). In order to create CMEM at a microscopic level, researchers decided to create a model based on various states of vehicles such as properly functioning, deteriorating, malfunctioning. Furthermore, they chose to study different operating modes for vehicles such as acceleration, deceleration, and steady-state cruising on a second-by-second basis. Using a physical-load based approach, researchers collected data from approximately 340 vehicles of a variety of types. Three test cycles were completed for each vehicle: 1) a 3-bag FTP test, a high speed cycle (US06), and a modal emission cycle (MEC01). Based on the results of these tests and all assumptions made, a model was developed to quantify vehicle tailpipe emissions as a function fuel rate, engine-out emissions indices, and time-dependent catalyst fractions (CPFs). This model is presently the most accurate of any microscopic software for estimating vehicle emissions.

4. System Overview

4.1 Model Development Process

The following figure describes the model development process that is selected for carrying out the transportation simulation. Feedback loops can exist between any two steps in the process, regardless of sequence.

Figure 4.1: Model Development Process

4.2 Key Inputs

There are three main types of inputs to the simulation model—road network data, vehicle data, and travel demand data. From an economics perspective, the road network constitutes supply (the spaces available to be occupied by vehicles) while the trip-making habits of motorists constitute demand.

4.2.1 Road Network Data

Constructing the road network involves replicating the current layout of streets, intersections, parking lots and other roadway features located in the area of study within the VISSIM modeling environment. An accurate model of the current road network is necessary for predicting traffic behavior and for testing potential changes to the transportation system.

The first step in creating a road network in VISSIM is creating the links (streets) and connectors (intersection movements). VISSIM features the ability to load and scale satellite photos as background images so links and connectors can easily be overlaid on top. This eliminates the need to collect mass

amounts of geometric data and provides a realistic aerial visualization of the area of study. Spline points enable the ability to trace actual curvatures in links and connectors. In creating the connectors at intersections, it is important to know the lane configurations at each approach and departure and which approaches map to which departures. Equally important is the width of lanes and lengths (capacities) of dedicated turn lanes or turn pockets. This data can be obtained through observations in the field.

Once a road network is created, it is necessary to create speed distributions that the vehicles will follow. Speed distributions are used in the model in the form of desired speed decisions and reduced speed decisions. Desired speed decisions describe the ranges of speeds vehicles travel on a particular stretch of roadway or when entering a new segment of roadway. Desired speed decisions typically oscillate around the speed limit during free-flow conditions. Reduced speed decisions are used for sharp curves, or entering congested areas such as schools where speed is temporarily reduced. Speed distributions in VISSIM can be normal or empirical in nature and can be obtained from field studies or law enforcement statistics. They can also be estimated using rules-of-thumb based on professional expertise.

Besides speed distributions, traffic control devices and their operating rules also need to be input to the model. Signalized intersections require signal heads and the input of signal timing plans. With placement of loop detectors in the pavement, actuated signals can also be modeled. At any intersection, it is good practice to specify operating rules for areas where collisions may occur. Conflict Areas in VISSIM can be created when paths branch, cross or merge to determine which paths have priority and which paths must yield. At a 4-way stop intersection, VISSIM's Priority Rules are used to determine the order in which stopped vehicles proceed.

When a dynamic assignment module is used (see [Creating an Abstract Model](#)), the placement of parking lots and nodes are also important. Parking lots and nodes are used to define the zones in dynamic assignment where trips are either produced or attracted. Parking lots describe ingress/egress points within these zones while nodes are used to identify intersections or areas of the network where paths can diverge.

4.2.2 Travel Demand Modeling

Travel Demand Modeling is a process used to forecast the volume of traffic that will use a given transportation element in the future. Traditionally, the process of travel demand modeling involves four key phases- trip generation, trip distribution, mode choice, and trip assignment. Trip Generation quantifies the number of people making trips and for what purposes they make trips. Trip Distribution then determines where these trips begin and end, depending on which locations attract and produce trips. Mode choice determines which modes of transportation are used to make these trips and can often be rooted in utility theories. Finally, trip assignment determines which routes will be taken by which persons to get from each possible origin to each possible destination. Travel demand is determined by aggregating the trips of all people in an area. For the purposes of this simulation, the phase of Trip Generation is covered by the existing habits of motorists. This could change, however, with the introductions of new developments on or around the Cal Poly campus. Trip Distribution serves as a key input to the simulation model for traffic volumes and also affects Trip Assignment in the model. Mode Choice is not a large factor because each mode is analyzed separately.

4.2.3 Vehicle Data

Vehicle inputs in VISSIM are drawn from traffic compositions. Traffic compositions are usually derived from field studies that quantify how many vehicles of different types travel in the area of study. Traffic compositions can be composed of one or more vehicle classes or types. Vehicle Types can be composed of multiple vehicle makes, models and colors, while vehicle classes can encompass one or more vehicle types. Vehicle Model distributions are defined as groups of vehicles which share the same color distribution, acceleration/deceleration profiles, occupancies, and widths. Figure 4.2 below shows breakdown for determining proper vehicle inputs.

Figure 4.2: Outline for Determining Vehicle Classifications in VISSIM (PTV Vision 2010)

A final input to the model is routing information which describes the paths vehicles take from one point to another. Specific routing information can be applied to certain vehicle types or vehicle classes (heavy vehicles, tall vehicles, carpools, etc.) within VISSIM. The routing information is considered in traffic assignment stage of travel demand modeling.

4.3 Trip Distribution

Trip Distribution is a key process for input to the simulation model because it estimates the number of trips going from place to place in the road network and serves as a basis for Trip Assignment. The most commonly used method for Trip Distribution is the Gravity Model.

4.3.1 Gravity Model

The gravity model applies the gravitational concepts of Isaac Newton to the problem of distributing traffic throughout an urban area. In order to apply the Gravity Model, the area of study must be divided into Traffic Analysis Zones (TAZs). Each zone represents an area with similar characteristics or purposes. Zones are often divided by physical barriers such as highways, arterials, railroads, fences, or other geographical features. The gravity model converts totals of trip productions and trip attractions from each

of these zones into trip interchanges. Similar to the Newtonian gravitational concept, the Gravity Model is based off two principal assumptions:

- A trip produced in a zone is more likely to be attracted to an attraction zone with a higher number of attractions (stronger pull)
- A trip produced in a zone is more likely to be attracted to an attraction zone that is physically closer to it (minimum distance)

The standard form of the gravity model is as follows:

$$T_{ij} = P_i * (A_j F_{ij} K_{ij} / \sum A_j F_{ij} K_{ij})$$

Where;

T_{ij} = trips produced in zone I and attracted to zone j

P_i = total trip production at i

A_j = total trip production at j

F_{ij} = friction or travel time factor (calibration term) for interchange ij

K_{ij} = socioeconomic adjustment factor for interchange ij

4.3.2 Friction Factor

The friction factor is typically an inverse function of impedance describing the spatial separation between zones. It is most often measured by travel time. The total travel time between zones can be calculated by dividing the minimum path distance by the posted speed limits along the route. The equation for the friction factor is as follows:

$$F_{ij} = 1/t_{ij}^c$$

Where;

C = calibration factor

T_{ij} = travel time between I and j

In order to achieve a proper value for the friction factor, the gravity model is calibrated and adjustments to the friction factor, if needed, can be made to the calibration coefficient, c .

4.3.3 Gravity Model Calibration

The following steps are necessary to calibrate the gravity model:

1. Determine the number of trips generated from the origins

2. Determine the number of trips ending at the destinations
3. Create table of productions & attractions
4. Create table of travel time between zones
5. Create table of friction factors
6. Create table of $A \cdot F \cdot K$ terms
7. Insert terms into Gravity Model equation to determine trip counts
8. Assemble these trip counts in an OD (Origin/Destination) matrix
9. Adjust the attraction/production factors and revise the table. Repeat until all calculated attractions and productions are within 5% of each of the anticipated attractions and productions.

4.4 Trip Assignment

The process of trip assignment uses travel demand data generated in the OD matrix to determine which routes will be taken by which vehicles to get from each possible origin to each possible destination.

Traffic assignment usually is applied with some type of route choice model, which is a specific case of discrete choice modeling or theory. In route choice modeling, a set of potential routes is generated and alternative routes are selected by drivers using certain evaluation criteria such as travel time, travel distance, and cost.

4.4.1 Dynamic Assignment

The standard procedure for traffic assignment is static assignment. In static assignment, a route choice model is applied where drivers are placed on routes within their network. The shortcoming of static assignment is that it fails to account for fluctuations in demand throughout the study period and changes in the road network. In VISSIM, an alternative exists in dynamic assignment which can account for these changes. Dynamic assignment makes routing in large networks easier than static assignment because there is no need to manually code each possible route and route split. Dynamic assignment is able to generate routes on its own and evaluate routes according to criteria which can be modified globally or locally. Dynamic assignment can also be more accurate than static routing in a large network because of the error involved in modeling multiple routes and multiple decision points.

4.4.2 Dynamic Assignment in VISSIM

In VISSIM, dynamic assignment is based off an iterated simulation of microscopic traffic flow. This means that drivers chose their routes through the network almost continuously based on the experiences they have experienced or are experiencing along the route, as opposed to making only one decision at the start or a few decisions at a few key points. In this learning process there are several assumptions:

- Not every driver-vehicle pair uses the best route to get from their origin to their destination so it is important to consider all routes. However, these less attractive routes are typically used by a minor percentage of vehicle-driver pairs. Some of these routes may become negligible depending on travel demand and the existence of free-flow conditions.
- Different sub-route alternatives may become attractive along a route based on current traffic conditions even if they barely affect the motorist's overall travel time or distance. These decisions are captured in the iterative microscopic simulation.
- Based on past routing decisions, VISSIM builds an archive of past routing decisions. In the case that traffic situations are replicated, these routing decisions may be applied. This parallels the assumption that drivers will behave according to habits from past experiences and not always make simultaneous routing decisions.
- Based on past travel times, VISSIM creates a better model of anticipated general costs to the driver which improves cost modeling and helps determine when drivers behave according to habit versus when they are evoked to change their routing decision (if a driver's cost threshold for a route is exceeded, they will chose an alternative route).
- The route choice portion of dynamic assignment is captured using a variation of the Logit model based on the concept of general cost (VISSIM User Manual v5.20 2009).

The following diagram describes how the Dynamic Assignment process works in VISSIM:

Figure 4.3: Logic of Dynamic Assignment in VISSIM (PTV Vision 2010)

4.4.3 Creating an Abstract Model

Based on the layout of the model, VISSIM constructs an abstract idea of the road network where intersections are nodes and the roads between intersections are edges of an abstract graph. This level of abstraction is more suitable for modeling human understanding of route choice and makes for more efficient modeling. To picture this in an everyday use, if someone were to tell their friend how to get to their house, they would describe a series of intersections and turning movements (abstracted view) but not necessarily get into detail about the length to travel along a certain link or which lanes to choose (detailed view).

In order for VISSIM to construct an abstract idea of the road network, it is necessary to create zones that correspond to those referenced in the OD matrix. Zones are modeled as parking lots in VISSIM and can be one of two types: zone connectors or abstract parking lots. Zone connectors are used to model origin and

destination points where traffic enters/exits the network without using real parking while abstract parking lots are used to model origin and destination points where traffic enters/exits an actual parking lot.

Abstract parking lots contain additional parameters for capacity and initial occupancy. Parking lots can only be placed on links and it is not uncommon to have multiple parking lots per zone. Nodes are used to model any areas of the road network where paths could diverge, including the entrances/exits to parking lots and the network (nodes are placed beyond the parking lots). Edges are formed either within a node or between two nodes and serve as building blocks forming routes (sequences of routing decisions).

4.4.4 Cost & Route Choice Models

Travel time may be a key factor for influencing route choice, but travel distance and financial cost should not be discounted, even if they do not change with the simulation. Because of this, VISSIM models general cost as a combination of these factors according to the equation

$$\text{General Cost} = \alpha * \text{travel time} + \beta * \text{travel distance} + \gamma * \text{financial cost} + \Sigma \text{supplement2}$$

where α , β , and γ are coefficients that can be weighted for different vehicle types by the user. Supplement2 can be used to add any additional cost without a weighted coefficient. General costs are calculated for each edge in the network. General costs for routes are determined by summing the general costs of all edges forming those routes. The general costs of routes are used in the simulation to determine the most attractive routes for vehicles to travel on.

To access how attractive a route is for a driver-vehicle pair, we can invert the general cost function into a utility function. That is, if C_j represents the general cost of route j , then the utility of route j can be described by the function $U_j = 1/C_j$. As mentioned above, the general cost for route j is a summation of the general costs of all edges forming route j .

In discrete choice modeling, the most theoretically correct and widely used function for utility is the Logit function. Figure 4.4 shows the utility function used in VISSIM to determine the utility of a route.

$$p(R_j) = \frac{e^{\mu U_j}}{\sum_i e^{\mu U_i}}$$

where
 U_j = utility of route j
 $p(R_j)$ = probability of route j to be chosen
 μ = sensitivity factor of the model (>0)

Figure 4.4: Logit Function for Utility of Routes (PTV Vision 2010)

In this function, μ is a sensitivity factor that determines how much influence is generated by differences in utilities (i.e. a large μ indicates a high account for different utilities while a low μ indicates a low account for different utilities to the point that differences in utility seem negligible). If this Logit function is combined with the previous utility function, we end up with a situation where the model considers the difference between 5 and 10 minutes of travel time to be the same as the difference between 105 and 110 minutes. This is because the Logit function is invariant against translation and considers only the absolute difference of the utilities (VISSIM v5.20 User Manual 2009). To accommodate for this shortcoming, VISSIM uses the more-appropriate Kirchoff Distribution Formula:

$$p(R_j) = \frac{U_j^k}{\sum_i U_i^k}$$

where
 U_j = utility of route j
 $p(R_j)$ = probability of route j to be chosen
 k = sensitivity of the model

Figure 4.5: Kirchoff Distribution Formula for Utility of Routes (PTV Vision 2010)

In this function, k is a sensitivity factor that determines the same influence of the differences in utilities except the relative difference in utility is determined by the distribution. The Kirchoff Formula can be expressed as a Logit function if the utility function is transformed to logarithmic form:

$$p(R_j) = \frac{U_j^k}{\sum_i U_i^k} = \frac{e^{k \cdot \log U_j}}{\sum_i e^{k \cdot \log U_i}} = \frac{e^{-k \cdot \log C_j}}{\sum_i e^{-k \log C_i}}$$

where C_j is the general cost of route j .

Figure 4.6: Kirchoff Distribution Formula Expressed as a Logit Function (PTV Vision 2010)

This function is used in VISSIM for route choice.

4.4.5 Parking Lot Selection

When a zone used in dynamic assignment is comprised of multiple parking lots, it becomes necessary for a driver-vehicle pair bound to that zone to select a specific parking lot. Like route choice modeling, parking lot selection is also a special case of discrete choice modeling. Parking lot selection can be influenced by many factors such as out-of-pocket cost, past and current availability of parking spaces, closeness to final destination, distance from current position, geometry of spaces, and shade availability. VISSIM has a utility function based off of cost, attraction, distance to center of zone, distance from current vehicle position, and availability of free spaces. Users can weight these different factors with coefficients of their choosing and determine utility functions for specific vehicle types and decision situations in their models. The cost component draws from the general cost function while the attraction component draws from the attraction parameter specified for each parking lot. A Logit function is used for parking lot selection to determine choice probabilities for each parking lot. The sensitivity of this function can be set based on altering a Logit scaling factor.

4.5 Verification

Verification is the process of determining whether the simulation model correctly represents the conceptual idea of the actual system. It asks the question, *is the model built right for its intended purpose?* In the case of a transportation simulation, the conceptual idea of the actual system refers to the defined road network and its layout on which traffic will operate. The conceptual idea of the actual system is determined by what is needed to accomplish the objectives of simulation. The process of matching demand components associated with a transportation system is referred to as calibration, which is discussed later.

There are several techniques which can be used for model verification. These include:

- Inspecting output for reasonable results
- Watching animation for correct behavior
- Use software functionality to trace and debug incorrect behavior

4.6 Calibration & Validation

Calibration is the process by which the demand components of a microscopic simulation model are refined and adjusted to match conditions observed in the field. Components often include release counts, turning movement volumes, queue lengths, travel times, delays, traffic speed, and traffic density. Calibration of these components improves a model's accuracy and its ability to replicate the system being studied.

Without a well-calibrated model, the validity of processes such as predicting future behavior or modeling alternate scenarios is compromised.

Due to the stochastic nature of simulation models, a large number of simulation runs are to be conducted for calibration of the model and estimation of the measures of effectiveness with reasonable accuracy (Mollaghasemi 2003). Each simulation runs with a different "random seed" which utilizes the same operational conditions but generates slightly different results.

A seed value is essentially a starting value for a random number generator. When a random seed is chosen to run a simulation, a random number generator assigns values for certain parameters based off stochastic (probabilistic) distributions either built in to the software or provided by the user. In a microscopic traffic simulation, the random number generator generates values for parameters such as car following, lane changing, driver behavior, route choice, and release of demand which can occur as often as every time-step. When the same random seed is used repeatedly, the simulation returns the same exact results, provided the network has not been modified. When different random seeds are used from run to run, the simulation returns different results based on a differing values assigned to parameters.

A reasonable amount of accuracy is defined by the modeler according to their objectives and the performance metrics they wish to obtain. Most modelers conduct multiple simulation runs, each with different random seeds and draw upon statistical tests to determine appropriate levels of confidence or criteria for acceptance in comparing their simulation data to field-obtained data. It is important to note that perfect calibration is impossible to achieve and the extent of the calibration effort should be limited to only what is required in order for the modeler to create a "good enough" representation of a system and the

performance metrics of interest. When this “good enough” representation of a system is achieved, the model’s validity for its intended purpose can be assumed.

4.7 Emissions Modeling

Microscopic traffic simulation can be used as a tool to quantify many measures of performance for a road network, including vehicle emissions. A valid microscopic simulation model captures some of the key parameters and behaviors which generate vehicle emissions on a relatively small time scale, which cannot be achieved by higher-level macroscopic models. Some of these parameters include current speed, acceleration, trajectory, and power.

Emissions data can be generated either by the microsimulation program itself or through an outside program that uses the data from simulation. The current version of VISSIM (v5.30) in the United States provides an emissions output module which provides emissions statistics associated with several types of evaluation files. The emissions statistics associated with a majority of the types of these evaluation files are contingent on certain parameters and filters specified via the Emissions API, or application programming interface. The Emissions API requires programming knowledge in C++. The emissions statistics generated in the node-type evaluation file are an exception to using the API, in that those emissions statistics are generated based off of delay, similar to the processes used in Transyt 7, a simulation program designed for signal timing and optimization.

There are several outside programs which also can estimate emissions based on data generated from another source, such as simulations, field studies, or surveys. Many of these packages are developed to quantify the emissions generated under certain governmental jurisdictions and determine compliance (or lack thereof) with current articles of legislation. Many of these packages are also based off data from extensive emission test results. The U.S. Environmental Protection Agency’s (EPA) Office of Transportation and Air Quality (OTAQ) currently provides a software called MOVES (Motor Vehicle Emissions Simulator), which is a recent replacement for their past software held names such as MOBILE5, MOBILE6, and MOBILE6a. The most current version of MOVES software is MOVES2010a and is available online (<http://www.epa.gov/otaq/models/moves/index.htm>).

A software called EMFAC (EMission FACtors) is currently available in the state of California. Developed by the California Air Resources Board, EMFAC is used to quantify emissions from all types of motor

vehicles operating on all types of roads (freeways, highways, local roads) within the state of California. This model is more specific for the current conditions and legislation present in California that MOVES cannot account for accurately enough. The most current version is EMFAC2007 and is available online (http://www.arb.ca.gov/msei/onroad/latest_version.htm). Both EMFAC and MOVES are based off of standardized driving cycles and changes in average speeds.

Another software is called the Comprehensive Modal Emissions Model (CMEM). CMEM was first developed in 1999 as the result of a four-year research project (see [Development of a Microscopic Modal Emissions Model](#) in [Review of Literature](#)) by the National Cooperative Highway Research Program (NCHRP). CMEM is better suited for modeling emissions for smaller regions, and is also very effective in capturing the activities of different vehicle operating modes (e.g. idling, accelerating, decelerating, steady-state cruising, operation of A/C, etc.), which is a shortcoming of models like MOBILE or EMFAC which are based only on standardized driving cycles and average speeds. Information on CMEM software is available online (<http://www.cert.ucr.edu/cmeme/>) and can be ordered from the University of California-Riverside for a nominal fee. CMEM is continually improved and has been funded by the US EPA since 1999.

5.2 Creating the Network

5.2.1 Satellite Imagery

To create the Cal Poly environment, numerous screenshots of satellite imagery are taken from Google Earth of both the campus and its surrounding areas. Each screenshot has to be scaled in VISSIM based on an existing distance and then placed so its position corresponds with adjacent images (see Figure 5.2). Due to the impracticality of measuring existing distances, the ruler tool in Google Earth is used to measure approximate distances between key landmarks. If the scaled distances do not coordinate well with other images, they are rescaled in order to minimize the level of distortion. The main purpose of the imagery is to show the road network and accurately scale the areas where links will be placed.

Figure 5.2: Assemblage of Satellite Imagery for the Cal Poly Network

5.2.2 Road Network

After the background imagery is assembled, the road network is constructed by tracing road links along the imagery. Connectors are created for each intersection based on the lane configurations from the satellite imagery which are verified for accuracy by diagrams collected from field study. In some cases, the satellite

imagery is outdated and new configurations are created based off diagrams from the field study. These cases are mostly limited to the residential areas of Poly Canyon Village. The entrances and exits to major parking lots are also added to the model for later use. The complete network (Figure 5.3) includes 505 links, 789 connectors, and 5 lay-by transit stops for a total of 1299 links/connectors. A complete listing of the links can be found in [Appendix A](#). Most links are given standard lane widths of 12ft. Based on prior experiences driving on the campus, there are a few instances (mainly near the residential areas) where lane widths are modified to shorter widths.

Figure 5.3: Screenshot of Links and Connectors forming the Cal Poly Network

5.2.3 Speed Data

To add speed data to the model, interviews are conducted with personnel from Cal Poly's University Police Department. Officers supplied data on the 85th percentile speeds along key roads and gave estimated ranges for speeds based on their first-hand experiences in the field. For off-campus links, speed data is obtained from the City of San Luis Obispo. Using these data sources in combination with firsthand knowledge from driving in the network, several empirical speed distributions are constructed.

These distributions capture the actual ranges of speeds and proportions of vehicles running at those speeds. In the simulation environment, speed distributions are more valued for input than speed limits as they capture what typically happens in the network, instead what should happen in the network.

Below (Figure 5.4) is a sample of an empirical distribution used for several links in the campus core. This distribution has a minimum speed of 15 mph, a maximum speed of 30 mph, a 20th percentile speed of 20 mph, and an 85th percentile speed of 25 mph which corresponds to the posted speed limit. Vehicles crossing a speed decision in the road network that corresponds with this distribution are assigned a desired speed based on their driving behavior parameters and upon crossing a decision line, will seek to reach this desired speed. Vehicles will not always reach their desired speeds in simulation due to current conditions, lengths of speed decisions, and response to traffic control devices.

Figure 5.4: Sample Speed Distribution for Areas of Cal Poly's Core

In total, 80 speed decisions are created for the network based on 21 empirical speed distributions. A complete listing of the speed decisions and speed distributions used in the model can be found in [Appendix B](#).

5.2.4 Traffic Signals

The Cal Poly campus has two traffic signals in operation which are used for pedestrian crossings. These signals are located by the Yosemite Residences on Grand Ave and by Mustang Stadium on California Boulevard. Each signal operates two phases—a primary phase for vehicle traffic and a secondary phase for pedestrian crossing. In VISSIM, each is modeled as a Ring-Barrier Signal Controller where barriers are used to separate each phase and rings are used to describe signal groups. Each signal group corresponds to a movement or set of movements that is permitted at the same time. The signal timing plans below (Figures 5.5 and 5.6) indicate the timing parameters and signal groups. Being actuated, these signals change based on traffic being detected upstream, just as loop detectors function for real actuated signal controllers. The timing parameters are estimated from field observations and are verified for sufficient accuracy by watching animations with traffic where simulation speed equal to real time speed.

Figure 5.5: Signal Timing Parameters for California Blvd Pedestrian Crosswalk

Figure 5.6: Signal Timing Parameters for Grand Ave Pedestrian Crosswalk

The area of study also includes several signals that are present at intersections outside campus boundaries. These signals include Foothill & California, Foothill & Santa Rosa, and Hwy 1 & Highland. However, since the ingress and egress points for vehicles in the network are placed inside these intersections, the functioning and timing of these signal controllers is not critical to the network performance metrics of interest. The only traffic that passes these intersections comes in the form of transit vehicles. A four-way stop is modeled at these intersections, solely for the purpose of better animation.

5.2.5 Intersections, Conflict Areas, and Priority Rules

The Cal Poly network modeled contains approximately 100 intersections and about 25 merge/branch areas. The right-of-way rules for these areas are specified through Conflict Areas and Priority Rules. In total, there are 1217 right-of-way rules used in the Cal Poly network; 917 of these rules exist as conflict areas while the remaining 246 exist as Priority Rules. The conflict areas are used at intersections with 2 and 3-way stop controls as well as the 25 merge/branch areas. The priority rules are used at 4-way stop intersections and lay-by transit stops. The campus contains four intersections with four-way stop control: Highland & University, N Perimeter & Via Carta, N Perimeter & University, and Grand & Slack. As mentioned previously, there are several normally signalized intersections outside the campus that are

modeled as 4-way stops for purposes of transit use only. These intersections, therefore, do not contain right-of-way priority rules.

5.2.6 Stop Signs

Stop Signs are an integral part of campus traffic. In VISSIM, stop signs are placed on a per-lane basis.

When vehicles reach a stop sign, they stop for one time step and then proceed with their trip, unless a dwell time distribution is specified. The Cal Poly network contains approximately 184 stop signs. Three of these stop signs are used to model parking kiosks located at the Grand, Highland, and California entrances to campus. For these, the empirical dwell time distribution seen in Figure 5.7 is assumed, which is based off field observations observed during a traffic study at the Grand Avenue entrance.

Figure 5.7: Sample Dwell Time Distribution for Grand Ave Parking Kiosk

This distribution assumes a minimum service time of 30 seconds, a maximum service time of 300 seconds (5 minutes), and a 50% percentile of 240 seconds (4 minutes). A complete listing of the stop signs in the Cal Poly model can be found in [Appendix C](#).

5.2.7 Nodes & Parking Lots

In order for the Dynamic Assignment module to function correctly, nodes and parking lots are also defined for the road network. In the Cal Poly network, a total of 117 nodes and 178 parking lots are specified. Of these nodes, approximately 128 are used for intersections and 43 are used to define parking areas. Of the 178 parking lots, 12 of are used for the each of the six entrances and exits to the network. The remaining

166 are used for the entrances and exits of parking areas on campus. The specific placement and position of all parking lots and nodes in the simulation helps to define traffic analysis zones which are used for Dynamic Assignment.

5.2.8 Transit Stops

In order to create transit routes and schedules, transit stops are also defined for the network. Transit stops can either be on-street stops or lay-by stops. Lay-by stops are created by making a specific pocket lane adjacent to the slowest lane of traffic. The Cal Poly network contains 11 transit stops at the following locations:

- Northbound Grand Avenue @ Performing Arts Center (lay-by)
- Southbound Grand Avenue @ Performing Arts Center (lay-by)
- Northbound Grand Avenue @ McCollum St
- Southbound Grand Avenue @ McCollum St
- Eastbound Entrance Way @ Robert Kennedy Library (lay-by)
- Westbound Entrance Way @ Robert Kennedy Library
- Westbound Highland Dr @ Mt. Bishop Rd
- Southbound Santa Rosa St. @ Foothill Blvd
- Eastbound Foothill Blvd @ Casa St (lay-by)
- Westbound Foothill Blvd @ Casa St
- Northbound California Blvd @ Taft St

5.3 Vehicle Data

5.3.1 Automobiles

In order to create appropriate animations and generate accurate emissions estimates for the model, it is necessary to understand the distribution of vehicle types on campus. A survey study of 4954 vehicles was conducted at campus parking lots over the course of several weekdays to determine the appropriate proportions of different vehicle types driven on campus. Compared to the estimated population of vehicles on campus (7331 parking permits sold), our sample is a significant estimator of the true proportions of vehicle types present in the Cal Poly population. The survey involved over 1000 vehicles from each use permit use type. For ease of modeling, these vehicle distributions are combined into one overall traffic composition. Table 5.1 summarizes the findings of the sampling study. The pie chart in Figure 5.8 shows the distribution of vehicles belonging to each of nine vehicle types associated with this traffic composition.

Table 5.1: Results of Vehicle Types Sampling Study

Vehicle Type	Use Type					Use Type			
	Staff	Residents	General	Total		Staff	Residents	General	Overall
Economy/Hybrid	78	75	75	228		6.66%	3.780%	4.17%	4.60%
Compact	249	611	472	1332		21.26%	30.796%	26.24%	26.89%
Mid-Size	265	427	371	1063		22.63%	21.522%	20.62%	21.46%
Full-Size	28	51	59	138		2.39%	2.571%	3.28%	2.79%
Small SUV	166	311	268	745		14.18%	15.675%	14.90%	15.04%
Large SUV	68	57	37	162		5.81%	2.873%	2.06%	3.27%
Truck	128	270	331	729		10.93%	13.609%	18.40%	14.72%
Sport	48	73	88	209		4.10%	3.679%	4.89%	4.22%
Wagon/Crossover/Van	141	109	98	348		12.04%	5.494%	5.45%	7.02%
Sample Size	1171	1984	1799	4954		1171	1984	1799	4954

Figure 5.8: Pie Chart of Vehicle Types at Cal Poly

In VISSIM, each defined vehicle type shares common acceleration and deceleration profiles, power specification, and weight distributions. Grouping vehicles by vehicle type is convenient for emissions analysis since it is highly infeasible to model the large number of vehicle makes and models currently in operation. Generally, the performance and emissions of most vehicles of a certain type do not vary drastically (e.g. A Toyota Camry will have very similar performance and emissions to a Honda Accord. Likewise, a Nissan Sentra will have very similar performance and emissions to a Ford Focus.) Within each vehicle type category, graphics of several representative vehicles and body colors are selected for representation in animation.

For the Cal Poly network, the nine vehicle types shown in the above pie chart are defined. The chart below shows sample vehicles for each vehicle type.

Table 5.2: Sample Vehicles for Each Vehicle Type Category

Vehicle Type	Sample Vehicle Models
Economy/Hybrid	Geo Metro, Honda Civic Hybrid, Mini Cooper, Toyota Prius
Compact	Ford Focus, Honda Civic, Mazda 3, Nissan Sentra, Toyota Corolla
Mid-Size	Ford Fusion, Honda Accord, Nissan Altima, Mazda 6, Toyota Camry
Full-Size	Ford Taurus, Infiniti M, Toyota Avalon, Volkswagen Passat
Small SUV	Ford Escape, Ford Explorer, Honda CR-V, Hyundai Santa Fe, Nissan Xterra
Large SUV	Chevrolet Tahoe, GMC Suburban, Ford Expedition, Honda Pilot
Truck	Ford Ranger, Ford F150, Nissan Titan, Toyota Tacoma, Toyota Tundra
Sport	Chevrolet Camaro, Chevrolet Corvette, Ford Mustang, Nissan Z
Wagon/Crossover/Van	Chevrolet Express, Ford Windstar, Ford Edge, Honda Element, Nissan Murano, Plymouth Voyager, Subaru Forester, Toyota Venza

Several assumptions are made in terms of vehicles in the network:

- *Only motorized vehicles* are modeled. Non-motorized vehicles such as bicycles, scooters, and skateboards are not included
- *State, Delivery & Emergency Vehicles* are not accounted for in the simulation model. This includes all Cal Poly service vehicles, campus deliveries (mail, parcels, freight, food service), law enforcement, ambulances, fire engines, paramedics
- *Contractor Vehicles* are included in the simulation model. It is assumed they will use available parking lots
- *Modeling of transit lines* is limited to standard SLO Transit and RTA routes traveling within the network

5.3.2 Public Transit

The area of study includes many public transit lines, which are incorporated into the simulation model. The City of San Luis Obispo's bus system, SLO Transit, operates Routes 4, 5, 6a, and 6b within the area of study, while the County of San Luis Obispo's bus system, Regional Transit Authority (RTA), operates Routes 9, 10, and 12a. Table 5.3 describes these routes, their stops, and operating schedules.

Table 5.3: Public Transit Routes in the Cal Poly Network

Transit & Route #	Enters Network	Leaves Network	Interval	Stops
SLO Transit- Route 4	7:20AM @ Foothill Blvd EB	7:32AM @ Grand Ave SB	Every 30 min	Foothill @ Casa
				Entrance @ Kennedy Library*
				Grand Ave @ PAC
				Grand Ave @ McCollum
SLO Transit- Route 5	7:26AM @ Grand Ave NB	7:39AM @ Foothill Blvd WB	Every 30 min	Grand Ave @ McCollum
				Grand Ave @ PAC*
				Entrance @ Kennedy Library
				Foothill @ Casa
SLO Transit- Route 6b/6a**	7:20 AM @ California Blvd NB	7:42AM @ Highland Dr WB	Every 30 min	California @ Taft
				Entrance @ Kennedy Library*
				Highland @ Mt. Bishop Rd
				Entrance @ Kennedy Library*
SLO Transit- Route 6a/6b**	7:25AM @ Casa St NB	7:36AM @ Grand Ave SB	Every 30 min	Grand Ave @ PAC
				Gran Ave @ McCollum
RTA- Route 9 SB	7:15AM @ Grand Ave NB	7:23AM @ Foothil Blvd WB	Commuter Schedule	Entrance @ Kennedy Library
RTA- Route 10 NB	7:20AM @ Foothill Blvd EB	7:32AM @ Grand Ave SB	Commuter Schedule	Entrance @ Kennedy Library
RTA- Route 12NB	7:36AM @ Foothill Blvd EB	7:45AM @ Grand Ave SB	Every 60 min	Foothill @ Casa
RTA- Route 12SB	7:25AM @ Hwy 1 SB	7:35AM @ Hwy 1 SB	Every 60 min	Entrance @ Kennedy Library
				Foothill @ Santa Rosa
* Denotes time stop				
**Route 6A becomes Route 6B at Kennedy Library				
**Route 6B becomes Route 6A at Kennedy Library				

5.4.1 Zone Definition

Figure 5.9: Traffic Analysis Zones for Cal Poly

Table 5.4: Names & Descriptions of Traffic Analysis Zones for Cal Poly

Zone #	Type	Zone Name	Capacity (spaces)
1	Entrance/Exit	Stenner Creek Rd	1 lane
2	Entrance/Exit	Highland Dr	2 lanes
3	Entrance/Exit	California Blvd	1 lane
4	Entrance/Exit	California/Campus	1 lane
5	Entrance/Exit	Foothill/Crandall	1 lane
6	Entrance/Exit	Grand Ave	2 lanes
7	Structure	G-5 (Grand Ave Structure)	911
8	Lot(s)	G1	504
9	Lot(s)	G2	109
10	Lot(s)	R1	838
11	Lot(s)	R2	837
12	Structure	R3	932
13	Structure	R4	962
14	Lot(s)	H1/Crops/Dairy/Poultry	518
15	Lot(s)	H2	340
16	Lot(s)	H4	405
17	Street	H10	58
18	Lot(s)	H11	28
19	Lot(s)	H12	436
20	Lot(s)	H13	43
21	Lot(s)	H14/H15 Sports Complex/Ornamental Horticulture	440
22	Lot(s)	H16	565
23	Lot(s)	C2 & College Ave	271
24	Lot(s)	C3	50
25	Street	C4	87
26	Lot(s)	C5	15
27	Lot(s)	C6/Graphics & Power/Cohan Center/Polyview Dr	70
28	Lot(s)	C7	150
29	Lot(s)	A1	66
30	Street	Dexter Rd/Engineering 13/Foundation	21
31	Street	Mountain Lane/Grand Ave	19
32	Street	Poly Canyon Village-Canyon Circle, Vista Caballo, Village Dr	62
33	Street	Cerro Vista Loop	55
		Sum	8792

5.4.2 Data Collection

Since most traffic tends to enter campus from zones external to Cal Poly, a good estimate of vehicle counts entering/leaving campus is required. Field data is collected for an average Tuesday during the Fall 2010 quarter at the Grand Avenue entrance to Cal Poly (Zone 6). Grand Avenue is specifically chosen because its volume is the largest historically. Due to lack of available resources and the infeasibility of collecting data for all zones, however, the data collection is limited to just this entrance. Data is collected in 15-minute increments from 7:30AM until 9:00PM and assembled in terms of possible peak hours. The graph in Figure 5.10 shows the volume for each possible peak hour beginning with 7:30AM-8:30AM until 8:00PM-9:00PM.

Figure 5.10: Summary of Potential Peak Hours from Grand Ave Field Study

Based on this field study, there are several peak hours determined for the campus. During the AM hours, peak volumes are observed from 7:30AM-8:30AM, 8:30AM-9:30AM, and 10:15-11:15AM. During the midday hours, peak volumes are observed from 11:30AM-12:30PM and 12:45PM-1:45PM. During the PM hours, peak volumes are observed from 4:00PM-5:00PM, 5:30PM-6:00PM, and 7:30PM-8:30PM. The AM peak hours tended to have a large amount of inbound traffic while the PM peak hours tended to have a large amount of outbound traffic. The midday peak hours tended to have a large amount of traffic in both directions, but not as large in magnitude as the inbound or outbound volumes witnessed in the AM or PM. A detailed summary of the field study is available in [Appendix E](#).

5.4.3 Define Study Period

Based on the field data and for purposes of simplifying modeling efforts, the AM peak hour from 7:30AM-8:30AM was chosen for the simulation model. This peak hour has the highest overall volume of any peak hour and best captures the transportation for multiple types of Cal Poly personnel (e.g. students going to school, faculty & staff going to work, visitors arriving for the day).

5.4.4 Determining Productions/Attractions

A good estimate for AM Peak volumes for the external zones is attained by pooling field study data with historical data from Cal Poly and the City of San Luis Obispo and applying heuristic methods. The history of campus projects and road closures is accounted for to properly consider historical data.

The heuristic approach used involves the following steps:

1. Estimate overall split of campus traffic among the entrance/exits to campus based on available data
2. Based on the volume from the Grand Ave field study, calculate the volumes associated with each entrance/exit
3. Based on the inbound/outbound splits from the Grand Ave field study, calculate the volumes of inbound/outbound traffic for each entrance/exit
4. Based on firsthand knowledge of campus, capacities and attractiveness of zones, determine split of inbound traffic for each entrance/exit to interior zones
5. Based on firsthand knowledge of campus, capacities and attractiveness of zones, determine split of outbound traffic for each entrance/exit from interior zones
6. Apply the splits from Steps 4 & 5 and calculate volumes for all cases. Sum the attractions and productions of internal zones
7. Use the data from Steps 3 & 6 to assemble a matrix of Productions and Attractions

Table 5.5 below summarizes the results of Steps 1-3.

Table 5.5: Volumes of Inbound/Outbound Traffic for each Entrance/Exit to Cal Poly

External Zone		Grand Avenue (6)		Highland Blvd (2)		California Blvd (3)		Campus Way (4)		Foothill/Crandall (5)		Stenner Creek (1)		Totals
Split of Campus Traffic		34%		23%		28%		10%		3%		2%		100%
Total Volume		750		507		618		221		66		44		2206
Inbound Split	Outbound Split	85.47%	14.53%	85.47%	14.53%	85.47%	14.53%	85.47%	14.53%	85.47%	14.53%	85.47%	14.53%	
Inbound Vol	Outbound Vol	641	109	434	74	528	90	189	32	57	10	38	6	2206

In applying Steps 4-5, it is assumed there are no trips between zones internal to the campus. That is, all trips made occur between one zone external to campus and one zone internal to campus. Table 5.6 shows the split of trips of inbound traffic to potential interior zones. The volume of traffic assigned to each zone is based on several factors including quantity and availability of parking, use types (general, residential, staff, temporary), proximity to campus buildings, and any out-of-pocket costs (parking fees). Table 5.7 shows the split of trips of outbound traffic from interior zones by applying the same methodology.

Table 5.8: Production and Attraction Matrix for the Cal Poly Network

Production/Attractions Matrix		
AM Peak Hr	7:30 AM	8:30 AM
Zone	Productions	Attractions
1 (Stenner)	38	6
2 (Highland)	434	74
3 (California)	528	90
4 (Campus)	189	32
5 (Crandall)	57	10
6 (Grand)	641	109
Sum	1887	321
7 (GStruct)	66	440
8 (G1)	4	45
9 (G2)*	0	0
10 (R1)	17	13
11 (R2)	9	8
12 (R3)	14	10
13 (R4)	14	11
14 (Ag)	15	77
15 (H2)	29	187
16 (H4)	2	225
17 (H10)	11	39
18 (H11)	2	27
19 (H12)	52	222
20 (H13)	0.4	7
21 (Mixed)	2	33
22 (H16)	11	56
23 (Mixed)	40	198
24 (C3)	2	36
25 (C4)	8	55
26 (C5)	0.3	5
27 (Mixed)	2	17
28 (C7)	1	133
29 (A1)	12	28
30 (Mixed)	0.3	8
31 (Mixed)	1	1
32 (PCV)	4	3
33 (Cerro)	3	3
Sum	321	1887

5.4.5 Creating the Origin/Destination Matrix

After the creation of the Production/Attraction matrix, the rest of the gravity model is applied to create an Origin/Destination matrix. This includes the creation of a travel time matrix, an impedance matrix, and an adjustment factor matrix.

Travel time (minutes) is computed by dividing a zone-to-zone driving distance (miles) by the speed limit(s) posted along the shortest path (miles per hour) and multiplying by 60 minutes per hour. A travel time

matrix is created by carrying these calculations out for each zone pair. Distances are measured with precision down to hundredths of a mile. In the case that the path between a pair of zones contains multiple links or multiple speed limits, travel time is computed as the sum of travel times for all links or changes in speed limit. As an example, the travel time between Highland Drive (Zone 2) and H12 Parking (Zone 22) is calculated with the formula $\text{Travel Time} = ((0.45/25) + (0.4/30)) * 60$, where the path between Zones 2 and 22 is composed of 2 segments: one segment for 0.45 miles with a speed limit of 25mph and the other segment for 0.40 miles with a speed of 30 mph. For the Cal Poly network, several pairs of zones do not physically have paths between them or have paths that are very impractical and are likely to never be used. In these cases, an infinite travel time is assumed for the zone pair which suggests the demand between these zones is essentially negligible. The travel time matrix is shown in Table 5.9.

Based on the travel times matrix, an impedance matrix is constructed. Impedance is a measure of resistance to vehicle travel which is derived from the inverse of travel time, according to the formula mentioned previously (see [Friction Factor](#)). The constant in the formula, c is assumed to be 2 for this case. For the several pairs of zones where infinite travel times are assumed, friction factors for these pairs are equal to zero. When factored in to the gravity model equation used to create the Origin-Destination matrix, these pairs will generate zero demand because of multiplication of this zero friction factor. The impedance matrix is shown in Table 5.10.

For purposes of simplicity, an adjustment factor matrix for capturing the influence socioeconomic factors is not used in the Cal Poly model. This equates to using a matrix where the socioeconomic adjustment factors for all zone pairs are equal to one.

Finally, the Origin/Destination matrix is assembled by applying the gravity model formula as mentioned previously in [Gravity Model](#). This matrix describes the volumes of vehicles (demand) traveling between each origin-destination pair. The calculations for each zone pair are done by distributing attractions and can be found in [Appendix F](#). The Origin/Destination matrix created is shown in Table 5.11.

Table 5.9: Travel Times Matrix for the Cal Poly Network

[illegible]

Table 5.10: Friction Factors Matrix for the Cal Poly Network

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		1 (Stenner)	2 (Highland)	3 (California)	4 (Campus)	5 (Crandall)	6 (Grand)	7 (GStruct)	8 (G1)	9 (G2)*	10 (R1)	11 (R2)	12 (R3)	13 (R4)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							</

Table 5.11: Origin/Destination Matrix for the Cal Poly Network's AM Peak Hour

		Origins																																	Destinations	Zone 9 (G2) closed temperature for construction
		OO Mark - Iteration #1																																		
		1 (Stenner)	2 (Highland)	3 (California)	4 (Campus)	5 (Crandall)	6 (Grand)	7 (GStruct)	8 (G1)	9 (G2)*	10 (R1)	11 (R2)	12 (R3)	13 (R4)	14 (Ag)	15 (H2)	16 (H4)	17 (H10)	18 (H11)	19 (H12)	20 (H13)	21 (Mixed)	22 (H16)	23 (Mixed)	24 (C3)	25 (C4)	26 (C5)	27 (Mixed)	28 (C7)	29 (A1)	30 (Mixed)	31 (Mixed)	32 (PCV)	33 (Cerro)		
Target	6.00	74.00	94.00	32.00	10.00	109.00	440.00	45.00	0.00	13.00	8.00	10.00	11.00	77.00	187.00	225.00	39.00	27.00	222.00	7.00	33.00	56.00	198.00	36.00	55.00	5.00	17.00	133.00	28.00	8.00	1.00	3.00	3.00			
Zone 9 (G2) closed temperature for construction	6.00	74.00	94.00	32.00	10.00	109.00	440.00	45.00	0.00	13.00	8.00	10.00	11.00	77.00	187.00	225.00	39.00	27.00	222.00	7.00	33.00	56.00	198.00	36.00	55.00	5.00	17.00	133.00	28.00	8.00	1.00	3.00	3.00			

5.4.6 Balancing the OD Matrix

After the Origin/Destination matrix is created it needs to be balanced. Balancing is an iterative process where the matrix values are multiplied by factors to more closely match column or row totals. This process repeats until a stopping rule is satisfied. These factors are determined by comparing column or row totals to current values. Every time a column factor is used, the rows will become imbalanced while every time a row factor is used, the columns will become unbalanced. Thus, each iteration involves alternating between column and row factors to multiply the matrix by.

For the purposes of the Cal Poly model, a stopping rule is set when all productions and attractions are within 25% of their target values (sum/target ratios greater than 0.75 and less than 1.25). It took 7 iterations to reach conditions that met this rule. Since the first matrix is created by distributing attractions (which were therefore balanced), getting to the second matrix is achieved by computing row factors and multiplying the matrix by them to balance productions. The following iteration is achieved by computing column factors and multiplying the matrix by them to re-balance attractions. This alternation continues until the stopping rule is satisfied in Iteration #7. The different iterations of the balancing process can be seen in Tables 5.12-5.17.

Table 5.12: Iteration #2 of the Origin/Destination Matrix for the Cal Poly Network

		COLUMBIA UNIVERSITY																																			
		Destinations																																			
		1 (Stenner)	2 (Highland)	3 (California)	4 (Campus)	5 (Crandall)	6 (Grand)	7 (GStruct)	8 (G1)	9 (G2)*	10 (R1)	11 (R2)	12 (R3)	13 (R4)	14 (Ag)	15 (H2)	16 (H4)	17 (H10)	18 (H11)	19 (H12)	20 (H13)	21 (Mixed)	22 (H16)	23 (Mixed)	24 (C3)	25 (C4)	26 (C5)	27 (Mixed)	28 (C7)	29 (A1)	30 (Mixed)	31 (Mixed)	32 (PCV)	33 (Cerro)	Totals	Target	
Origins		18 (Stenner)	0.00	0.00	0.00	0.00	0.00	0.00	1.83	0.13	0.00	0.19	0.01	0.33	0.51	12.11	4.34	4.82	0.96	0.61	6.05	0.27	1.18	1.35	0.00	0.00	0.35	0.06	0.00	1.89	0.41	0.20	0.01	0.12	0.08	38	38
2 (Highland)	0.00	0.00	0.00	9.68	0.00	0.00	0.00	15.69	1.06	0.00	1.75	0.12	3.17	4.29	27.44	64.08	15.65	9.67	102.30	2.60	13.42	25.81	0.00	0.00	5.85	1.20	3.20	34.66	4.31	2.48	0.09	0.99	0.69	434	434		
3 (California)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.46	1.15	0.00	1.76	0.13	3.05	4.89	39.09	80.81	61.97	14.05	8.30	91.21	2.96	13.77	23.01	0.00	0.00	50.35	3.95	0.00	101.25	4.31	3.62	0.10	1.10	0.72	528	528	
4 (Campus)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	189	189		
5 (Crandall)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	55.01	0.07	0.00	1.93	0.00	0.00	0.00	0.00	0.00	57	57	
6 (Grand)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.72	3.42	0.00	7.89	6.19	3.63	2.93	12.36	34.47	91.61	10.55	9.12	43.36	1.67	7.34	10.94	0.00	0.00	2.17	0.25	5.94	7.76	16.32	2.06	0.66	0.92	1.40	641	641	
7 (GStruct)	0.72	6.54	6.08	0.00	0.00	52.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	66	66	
8 (G1)	0.03	0.28	0.26	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4	4	
9 (G2*)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	
10 (R1)	0.47	4.55	4.05	0.00	0.00	7.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17	17	
11 (R2)	0.05	0.40	0.39	0.00	0.00	8.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9	9	
12 (R3)	0.58	5.85	4.99	0.00	0.00	2.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14	14	
13 (R4)	0.73	4.99	6.57	0.00	0.00	1.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14	14	
14 (Ag)	2.18	5.26	6.64	0.00	0.00	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15	15	
15 (H2)	0.68	14.16	11.94	0.00	0.00	2.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29	29		
16 (H4)	0.06	0.81	0.69	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2	2	
17 (H10)	0.30	5.21	4.24	0.00	0.00	1.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11	11	
18 (H11)	0.05	0.92	0.70	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2	2	
19 (H12)	1.44	25.89	20.44	0.00	0.00	4.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52	52		
20 (H13)	0.02	0.17	0.17	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	
21 (Mixed)	0.08	0.91	0.83	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2	2	
22 (H16)	0.30	5.48	4.32	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11	11	
23 (Mixed)	0.00	0.00	0.00	13.78	76.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40	40	
24 (C3)	0.00	0.00	0.00	1.98	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2	2	
25 (C4)	0.05	0.91	6.91	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8	8	
26 (C5)	0.00	0.07	0.22	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.3	0	
27 (Mixed)	0.00	0.77	0.00	0.24	0.44	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2	2	
28 (C7)	0.01	0.27	0.69	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	1	
29 (A1)	0.32	3.48	3.12	0.00	0.00	5.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12	12	
30 (Mixed)	0.01	0.11	0.14	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.3	0	
31 (Mixed)	0.02	0.21	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	1	
32 (PCV)	0.18	1.63	1.61	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4	4	
33 (Cerro)	0.11	1.06	0.99	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3	3	
Sum	8	90	86	26	27	95	361	37	0	12	6	10	12	91	205	222	41	28	243	8	36	61	203	36	59	5	16	146	25	8	1	3	3	3	3	3	
Target	6	74	90	32	10	109	440	45	0	13	8	10	11	77	187	225	39	27	222	7	33	56	198	36	55	5	17	133	28	8	1	3	3	3	3		
Column Totals	0.7155	0.8233	1.0455	1.2462	0.3748	1.1476	12.181	1.2310		1.1216	1.2410	0.9826	0.9467	0.8461	0.9143	1.0113	0.9461	0.9751	0.9139	0.9331	0.9243	0.9139	0.9743	1.0121	0.9366	0.9156	1.0393	0.9137	1.1105	0.9567	1.1666	0.9595	1.0396				
Zone 9 (G2) closed temporarily for reconstruction																																					

Table 5.14: Iteration #4 of the Origin/Destination Matrix for the Cal Poly Network

[illegible]

Table 5.15: Iteration #5 of the Origin/Destination Matrix for the Cal Poly Network

[illegible]

Table 5.16: Iteration #6 of the Origin/Destination Matrix for the Cal Poly Network

[illegible]

Table 5.17: Iteration #7 of the Origin/Destination Matrix for the Cal Poly Network

		OD Matrix- Iteration #7																																						
		Destinations																																						
		Origins																																						
Zone #	IGZ	1 (Stenner)	2 (Highland)	3 (California)	4 (Campus)	5 (Crandall)	6 (Grand)	7 (GStruct)	8 (G1)	9 (G2)*	10 (R1)	11 (R2)	12 (R3)	13 (R4)	14 (Ag)	15 (H2)	16 (H4)	17 (H10)	18 (H11)	19 (H12)	20 (H13)	21 (Mixed)	22 (H16)	23 (Mixed)	24 (C3)	25 (C4)	26 (C5)	27 (Mixed)	28 (C7)	29 (A1)	30 (Mixed)	31 (Mixed)	32 (PCV)	33 (Cerro)	Totals	Target				
6	74	90	32	10	109	440	45	0	13	8	10	11	77	187	225	39	27	222	7	33	56	198	36	55	5	17	133	28	8	1	3	3								
Zone 9 (G2) closed temporarily for construction																																								

5.5 Application of Dynamic Assignment: Trip Assignment

For purposes of traffic assignment, dynamic assignment is chosen over static assignment due to its responsiveness to fluctuations in demand and changes to the network as well as the ability to accommodate a large size network like Cal Poly's. Based on stochastic distributions of driver parameters and current operating conditions in the simulation, driver-vehicle pairs make decisions on their routes almost continuously as described previously in [Dynamic Assignment in VISSIM](#). The Origin/Destination matrix created from application of the gravity model is used as an input to VISSIM's dynamic assignment module in the form of an .FMA text file.

5.5.1 Defining the Abstract Model

In order for the dynamic assignment module to function properly, an abstract model is constructed from the previously created nodes and parking lots (see [Nodes & Parking Lots](#)), which were strategically placed according to the rules specified in VISSIM's v5.30 user manual. In addition to placement, it is necessary to assign each of the parking lots to their corresponding zones and properly define their types. The 12 parking lots used for each of the six entrances and exits to the Cal Poly network are classified as Zone Connectors while the remaining lots are specified as Abstract Parking Lots. Abstract Parking Lots are chosen for campus parking lots instead of Real Parking Spaces to simplify modeling efforts and because they are better suited for modeling the human understanding of route choice. Therefore, the model does not capture the traffic within parking lot aisles nor the choice of particular parking spaces within parking lots.

5.5.2 Additional Parking Lot Parameters

There are several other parameters that must be specified for each parking lot: capacities, attraction factors, and relative flows. These parameters are especially important for the cases where a zone is comprised of multiple parking lots.

The capacity of a parking lot is defined as the number of vehicles the parking lot can support at any given time. Capacities are only defined for abstract parking lots. For zone connectors, capacities are not specified and can be determined in simulation by the maximum flow rate of vehicles across all lanes of the parking lot. Table 5.18 below shows the capacities for all parking lots on campus. There is a discrepancy of 20 parking spaces in this figure compared to Table 5.4 which has the correct totals for simulation. This

discrepancy is due to the addition of 10 parking spaces at the swine unit (Zone 21) and the omission of 30 parking spaces along Polyview Dr (Zone 27) due to current construction.

Attraction is measure of how likely vehicles are to utilize a certain parking lot. Similar to attraction for zones, attraction for parking lots is determined based on factors such as quantity and availability of parking, use types, proximity to campus buildings and any out-of-pocket costs (parking fees) incurred. Attraction factors are considered in VISSIM's Logit Model for parking lot selection (see [Parking Lot Choice Parameters](#)) and are only defined for entrance parking lots.

For Cal Poly's network, a heuristic approach is used to determine attraction factors for parking lots in zones containing multiple parking lots. Highly attractive lots are given an attraction value of "5" while less-attractive lots are given attraction values less than 5. These values are calibrated to obtain suitable probabilities based on the Logit function for parking lot selection. Attraction is not significant in cases where a zone has only one parking lot, as all vehicles attracted to that zone are automatically attracted to the parking lot associated with it. Attraction factors can be applied to both zone connectors and abstract parking lots, although they are only needed in this model for abstract parking lots internal to the campus. The attraction factors for Cal Poly's model are shown below in Table 5.19.

Table 5.18: Listing of Parking Lots & Capacities for the Cal Poly Network

Cal Poly Parking Lots Capacities				
Lot Description	Zone #	Capacity	# Entrances	# Exits
G-5 (Grand Ave Structure) Lower Levels	7	711	1	1
G-5 (Grand Ave Structure) Upper Level	7	200	1	1
G1	8	504	2	1
G2*	9	109	2	2
R1 (Bottom Level)	10	25	1	1
R1 (Middle Level)	10	290	4	4
R1 (Top Levels)	10	523	3	3
R2	11	837	1	1
R3	12	932	1	1
R4- Upper Levels	13	762	1	1
R4- Bottom Level	13	200	1	1
H1 Crops	14	30	1	1
H1 Main	14	336	2	2
Crops	14	38	1	1
Dairy	14	90	1	1
Poultry	14	24	1	1
H2- Engineering IV South	15	137	1	1
H2- Engineering IV North	15	84	1	1
H2- Highland & University	15	81	1	1
H2- Highland Dr	15	38	1	1
H4- BRAE	16	60	2	2
H4 Main	16	194	1	1
H4- Village Dr*	16	8	1	1
H4- Triangle*	16	143	2	2
H10	17	58	1	1
H11	18	28	1	2
H12	19	436	6	6
H13	20	43	1	1
H14- Lower	21	234	4	4
H14- Upper	21	75	3	3
H14- Lower Equine	21	28	1	1
H14- Upper Equine	21	28	1	1
H15- Sports Complex	21	47	1	1
H14- Lower Horticulture	21	10	1	1
H14- Upper Horticulture	21	14	1	1
H14- Swine	21	10	1	1
H14- Arboretum	21	4	1	1
H16	22	565	2	2
C2 Main	23	110	1	1
C2 - Cuesta Ave	23	41	1	1
C2- Childrens Center Main	23	21	2	2
C2- Childrens Center Side	23	9	1	1
C2- Health Center	23	14	1	1
College Ave	23	76	1	1
C3	24	50	1	1
C4- California Blvd East	25	61	1	1
C4- California Blvd West	25	26	1	1
C5	26	15	1	1
C6- Campus Dining	27	21	1	1
Power	27	2	1	1
Cohan Center*	27	17	1	1
C7	28	150	1	1
A1	29	66	1	1
Dexter Rd	30	4	1	1
Cal Poly Foundation	30	14	1	1
Engineering 13	30	3	1	1
Grand Ave	31	9	1	1
Mountain Lane	31	10	1	1
Poly Canyon Village- Canyon Circle/Village Dr	32	31	1	1
Poly Canyon Village- Vista Caballo West*	32	20	1	1
Poly Canyon Village- Vista Caballo- East*	32	11	1	1
Lower Cerro Vista	33	25	1	1
Upper Cerro Vista	33	30	1	1
Sum		8772		
*H4 lots are grouped together in simulation for simplification				
*Polyview Dr excluded from model due to construction				
*G2 lot is temporarily closed due to construction				

Table 5.19: Attraction Factors for Parking Lots in the Cal Poly Network

Attraction Factors for Parking Lots					
2 possible decisions			6 possible decisions		
Zone	Lot Possibilities	Attraction	Zone	Lot Possibilities	Attraction
7	G5 Structure- Top Floor	3.5	19	H12 Main Entrance	5
7	G5 Structure- Lower Levels	5	19	H12 Row 1	1
8	Pacheco Entrance	2	19	H12 Row 2	1
8	Grand Entrance	5	19	H12 Row 3	1
9	Slack Entrance	5	19	H12 Row 4	1
9	Hathway Entrance	4.3	19	H12 Row 5	1
13	R4 Main Entrance	5			
13	R4 Bottom Entrance	3			
22	H16 Lower Entrance	5	Zone	7 possible decisions	
22	H16 Upper Entrance	3		Lot Possibilities	Attraction
25	California Blvd East	5	23	C2 Main	5
25	California Blvd West	3.75	23	Cuesta Ave	5
31	Mountain Lane	5	23	College Ave	5
31	Grand Ave	4	23	Childrens Center Side	3
33	Cerro Vista Lower	5	23	Childrens Center West	4
33	Cerro Vista Upper	4.8	23	Childrens Center East	3
			23	Health Center	4
	3 possible decisions			8 possible decisions	
Zone	Lot Possibilities	Attraction	Zone	Lot Possibilities	Attraction
27	Campus Dining	4.75	10	R1 Lower	4
27	Power	3	10	R1 Middle Muir	5
27	Cohan Center	5	10	R1 Middle Trinity	5
30	Dexter	5	10	R1 Middle Lower Cerro	5
30	Foundation	5	10	R1 Middle Upper Cerro	5
30	Engineering 13	5	10	R1 Upper Fremont	5
32	Canyon Circle/Village	4.8	10	R1 Upper Lower Cerro	4.75
32	Vista Caballo West	5	10	R1 Upper Upper Cerro	4.75
32	Vista Caballo East	4.4			
				14 possible decisions	
	4 possible decisions		Zone	Lot Possibilities	Attraction
Zone	Lot Possibilities	Attraction	21	H14 Lower	5
15	H2 Creek	4.25	21	H14 Upper	4
15	H2 Engineering IV	5	21	H14 Sports Complex R1	2
15	H2 Engineering IV Meters	3	21	H14 Sports Complex R2	2
15	H2 Highland/University	4.25	21	H14 Upper Baseball	2
			21	H14 Upper Baseball Sports Complex R1	1
	5 possible decisions		21	H14 Upper Baseball Sports Complex R2	1
Zone	Lot Possibilities	Attraction	21	H14 Lower Equine	2
14	H1 Crops	5	21	H14 Upper Equine	2
14	H1 Main Upper	3	21	H14 Arboretum	1
14	H1 Main Lower	4.5	21	H14 Swine	1
14	Dairy	4.1	21	H14 Lower Horticulture	2
14	Poultry	4.1	21	H14 Upper Horticulture	2.5
16	H4 Main	4	21	H15 Sports Complex	2
16	H4 Foundation Shasta	5			
16	H4 Foundation North	4			
16	H4 BRAE West	5			
16	H4 BRAE East	5			

Relative flows are essentially the equivalent to attraction factors for exit parking lots. VISSIM defines the relative flow of a parking lot as the percentage of the zone's demand that uses a certain exit parking lot to leave the zone. Relative flows are defined only for exiting lots in zones with multiple parking lots to distribute the flow of outbound traffic. Relative flows are not significant in cases where a zone has only one parking lot associated with it and are assigned a default value of "1". Relative flows are also assigned a default value of "0" for entrance lots, indicating the need to use an attraction factor. Relative flows can

be applied to both zone connectors and abstract parking lots. Unlike attraction factors, relative flows do not factor in to any Logit function.

For Cal Poly's network, a heuristic approach is used to determine relative flows for parking lots based on the relative capacities of parking lots.

5.5.3 Route Choice Parameters

As mentioned in [Cost & Route Choice Models](#), VISSIM uses a variation of the Logit model for cost and route choice decisions. This model requires the input of cost coefficients for travel time (seconds), distance (feet), and link cost (\$). A model is required for each vehicle type category.

For the Cal Poly network, it is necessary to input cost coefficients for models for each of the nine vehicle types. It is assumed that the route choice parameters do not vary significantly between the vehicle classes seen on campus, so all nine models are assigned the same cost coefficients.

Figure 5.11: Cost Coefficients for Route Choice Model for All Vehicle Types

As seen in the Figure 5.11, a coefficient of "1" is assigned to travel time. This is because travel time seems to be the most important parameter to Cal Poly motorists traveling to work or school. Distance is not factored in because the Cal Poly network contains little choice in terms of paths between origins and destinations; therefore there are few distances to compare. Link cost is not factored into the model since there are no tolls or fees associated with any campus links.

5.5.4 Parking Lot Selection Parameters

As mentioned in [Parking Lot Selection](#), VISSIM uses a variation of the Logit model for parking lot selection to distribute traffic between parking lots, especially in zones with multiple parking lots. This model requires the input of coefficients for cost, attraction, distance to center of zone, distance from current vehicle position, and availability of free space. A model is required for each vehicle type category.

For the Cal Poly network, it is necessary to input coefficients for models for each of the nine vehicle types. It is assumed that the parking lot choice parameters do not vary significantly between the vehicle classes seen on campus, so all nine models are assigned the same cost coefficients.

Parking Lot Selection

Decision Situation: Departure from Parking lot

0.000 * Parking Cost

+ 1.000 * Attraction

+ 0.000 * Distance from desired zone [ft]

+ 0.000 * Distance from current position [ft]

+ 0.000 * Current parking availability

= Efficiency

OK Cancel

Figure 5.12: Coefficients for Parking Lot Selection for All Vehicle Types

As seen in Figure 5.12, a cost efficient of “1” is assigned to attraction. All parameters are deemed important to Cal Poly’s network, but for simplification purposes and ease of calculations, it seemed easier to lump all of them into one attraction factor. The attraction factors assigned to each parking lot (see [Additional Parking Lot Parameters](#)) are tabulated with a Logit Model in Excel to compute utilities and probabilities for each parking lot. These calculations are verified for accuracy by placing data collection points at the entrances to several parking lots. The attraction factors are calibrated until the probabilities matched firsthand knowledge of vehicles distributed to each parking lot. The spreadsheet calculation of parking lots utilities and probabilities can be found in [Appendix G](#).

5.6 Defining Simulation Run Parameters

After the definition and creation of the road network, vehicle types, and travel demand, the simulation model is able to be run. The simulation parameters for the Cal Poly network are shown below in Figure 5.13.

Traffic is defined to flow on the right-side of the road. The simulation will begin at 7:15AM and last until 8:30AM, a duration of 4500 seconds. As mentioned previously, vehicle demand is generated between 7:30AM and 8:30AM during the peak hour. The period between 7:15AM and 7:30AM is used to situate transit vehicles in the network according to their devised schedules. A simulation resolution of “2” was assumed for simulation resolution, which is used for smoothness in animation. A random seed of “42” was chosen at random for the baseline model to initiate the calculation of parameters stochastic in nature. This seed is varied later for statistical purposes in estimating variability. The simulation speed indicates the speed at which the simulation runs. For quick computation, this speed shown is to the maximum speed possible based on the ability to process with two processing cores. The simulation speed was varied for purposes of watching the animation at speeds more representative of real-time operations.

The screenshot shows a 'Simulation Parameters' dialog box with the following settings:

- Comment:** Cal Poly AM Peak 7:30-8:30AM
- Traffic regulations:** ☒ Right-side Traffic, ☐ Left-side Traffic
- Period:** 4500 Simulation seconds
- Start Time:** 07:15:00 [hh:mm:ss]
- Start Date:** [YYYYMMDD]
- Simulation resolution:** 2 Time step(s) / Sim. sec.
- Random Seed:** 42
- Simulation speed:** ☐ 10.0 Sim. sec. / s, ☒ maximum
- Break at:** 0 Simulation seconds
- Number of cores:** 2 Cores

At the bottom are 'OK' and 'Cancel' buttons.

Figure 5.13: Simulation Run Parameters for the Cal Poly Network

5.7 Verification

As mentioned in [Verification](#) as part of the [System Overview](#), verification is the process of determining whether the transportation simulation model is built correctly for its intended purpose. For the Cal Poly network, verification is used to determine if the model is built correctly to portray realistic traffic conditions during a peak hour, to quantify emissions generated, and to perform sensitivity analysis on how these emissions change with changes in different parameters. Verification is done in two phases: as the model was being built and after the model is built.

As the model was being built, verification was done continuously using software functionality to trace and debug incorrect behavior. Common errors witnessed during construction included the following:

- Improper placement of stop signs and speed decisions
- Improper generation of abstract network due to incorrect node or parking lot settings
- Improper input parameters
- Use of obsolete cost or route choice files

These errors were corrected by trial and error testing and discussions with software and transportation professionals.

After the model is built, verification is done by inspecting network components for accuracy and observing behavior shown with VISSIM's state-of-the-art animation. This is done for traffic signals, stop signs, road geometry, parking lot geometry, and operating speeds. The proper placement of stop sign components is a good example of verification techniques used. Using a different view perspective, the placement of stop signs is verified to ensure stop signs were placed on links and not on connectors within an intersection. In watching the animation, behavior is verified by ensuring vehicles stop where they need to stop, stop as long as they need to, and proceed according to the correct right-of-way rules. In addition to checking network components, a double check is done to ensure all intersection configurations matched sketches obtained from field study.

5.8 Calibration/Validation

5.8.1 Calibration Parameters

As mentioned in [Calibration & Validation](#) in the [System Overview](#), calibration is the process by which the demand components of a microscopic simulation model are refined and adjusted to match conditions observed in the field. The Cal Poly model is calibrated by refining and adjusting turning movement counts based on field data collected at key intersections from the interior of campus. The key intersections of Highland & University, North Perimeter & Village Dr, Grand & Deer, and Grand & Pacheco are chosen for key intersections for calibration since they represent areas of campus where many paths converge and diverge. The field data for these intersections was collected on average weekdays during November 2010 during the AM Peak Hour and can be reviewed in [Appendix I](#).

A total of ten random seeds are selected at random to capture the overall variability of simulation parameters. After each simulation run based on one of these random seeds, turning movements at the four key intersections are collected from the simulation for analysis. The number of random seeds is limited to ten random seeds due to the lengthy cycle times required to run each of the simulations, aggregate, filter, and summarize turning movement data, and make changes to the model for future iterations.

5.8.2 GEH Statistics

Once the turning movements are collected for all intersections and all ten runs of an iteration, the average volumes are computed. In order to define a reasonable amount of accuracy, GEH statistics are used for comparing average turning movement volumes to the data collected from field studies. GEH statistics are commonly used in transportation analysis and simulation to compare two sets of traffic volumes. They are computed from an empirical formula whose mathematical form is similar to that of a Chi-squared test as seen below in Figure 5.14.

$$GEH = \sqrt{\frac{2(M - C)^2}{M + C}} \quad \text{where}$$

M = hourly traffic volume from simulation model and
C = hourly traffic volume observed in real-world

Figure 5.14: Formula for Calculation of GEH Statistics to Compare Average Volumes

This formula does not follow a linear form due to the large variation in traffic volumes and therefore avoids several pitfalls associated with using simple percentages to compare volumes. Although not a true statistical test, GEH statistics have been proven useful in field practice (Wikipedia 2010).

5.8.3 Validation & Changes Made in Calibration

For calibration of Cal Poly's model, a reasonable accuracy is assumed to be achieved when GEH statistics for all 30 turning movements are less than five. These statistics are satisfied after five successful iterations of changes as shown by the summary below in Table 5.20. Approximately four iteration cycles were completed which did not yield improvements in GEH statistics and are omitted in this report.

Table 5.20: Summary of GEH Statistics for Calibration of the Cal Poly Model

Summary of GEH Statistics								
	Movement	VISSIM Notation	GEH Statistic- Initial	GEH Statistic- Iteration #1	GEH Statistic- Iteration #2	GEH Statistic- Iteration #3	GEH Statistic- Iteration #4	GEH Statistic- Iteration #5
Highland & University	EbL	W-N	3.48	3.21	1.12	1.16	1.23	0.99
	EbT	W-E	8.66	8.76	2.96	3.23	2.01	2.37
	EbR	W-S	6.74	6.72	0.16	0.42	0.74	0.48
	WbR	E-N	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	WbT	E-W	7.78	1.51	1.50	1.33	0.95	0.95
	WbL	E-S	0.17	0.70	0.75	0.47	0.04	0.04
	NbL	S-W	0.37	0.09	0.27	0.46	0.01	0.17
	NbT	S-N	0.60	0.56	0.56	0.60	0.05	0.65
	NbR	S-E	0.42	0.96	0.94	2.17	2.63	2.61
	SbL	N-E	1.41	1.21	1.41	1.41	1.41	1.41
	SbT	N-S	1.10	1.00	1.00	1.00	1.26	1.26
	SbR	N-W	3.55	3.26	3.58	3.58	3.49	3.49
N Perimeter & Village Dr	WbT	SE-W	0.73	4.69	4.63	5.64	5.26	4.94
	WbR	SE-NE	8.35	8.05	8.16	6.10	3.91	3.49
	EbT	W-SE	3.20	3.10	1.29	3.53	2.88	3.03
	EbL	W-NE	0.85	0.29	3.21	3.00	1.29	2.39
	SbR	NE-W	1.09	0.91	0.91	0.73	0.91	1.06
	SbL	NE-SE	1.47	2.09	4.99	3.59	0.10	0.14
Grand & Deer	NbT	SE-NW	3.95	0.43	0.41	1.99	2.13	2.10
	NbR	SE-NE	8.17	0.39	0.50	2.11	2.51	2.47
	SbT	NW-SE	2.77	4.66	4.33	5.85	3.49	3.54
	SbL	NW-NE	2.45	2.45	2.45	2.45	2.45	2.45
	WbR	NE-NW	2.00	1.23	1.23	1.01	2.00	2.00
	WbL	NE-SE	0.74	2.96	1.18	4.12	1.41	1.45
Grand & Pacheco	NbL	SE-SW	0.64	0.64	0.62	0.64	0.70	0.69
	SbR	NW-SW	0.37	0.65	0.14	0.47	0.37	0.33
	EbL	SW-NW	2.61	2.12	2.02	2.09	0.88	0.88
	EbR	SW-SE	4.50	4.30	4.24	4.20	0.81	0.91
	NbT	SE-NW	0.07	0.11	0.13	2.92	2.96	2.90
	SbT	NW-SE	3.71	4.92	5.18	5.03	4.21	4.20
				GEH Statistic is greater than 5				

The red highlights in Table 5.20 indicate turning movements and iterations where GEH statistics exceeded the acceptable value of five. Different iterations are only classified as successful when the number of GEH

statistics greater than five has decreased. The statistics for each simulation run and random seed are provided for all iterations in [Appendix J](#).

In order to generate additional iterations, heuristic approaches are used to strategically change volumes in the Origin/Destination matrix which targets the reduction of GEH statistics for certain turning movements.

A summary of the overall changes made from all iterations is available below in Table 5.21.

Table 5.21: Summary of Changes Made During Calibration of the Cal Poly Model

Summary of Changes			
From Zone	To Zone	Volume	Volume
		Pre-Calibration	Post-Calibration
1 (Stenner)	15 (H2)	4	2
1 (Stenner)	16 (H4)	5	1
2 (Highland)	12 (R3)	3	4
2 (Highland)	13 (R4)	3	5
2 (Highland)	15 (H2)	80	51
2 (Highland)	16 (H4)	71	43
2 (Highland)	17 (H10)	16	9
2 (Highland)	18 (H11)	10	6
2 (Highland)	19 (H12)	96	146
2 (Highland)	21 (Mixed)	13	20
2 (Highland)	22 (H16)	24	36
2 (Highland)	32 (Cerro)	1	2
3 (California)	12 (R3)	3	5
3 (California)	13 (R4)	5	7
3 (California)	15 (H2)	77	49
3 (California)	16 (H4)	69	41
3 (California)	17 (H10)	14	8
3 (California)	18 (H11)	9	5
3 (California)	19 (H12)	87	131
3 (California)	21 (Mixed)	13	19
3 (California)	22 (H16)	22	33
3 (California)	32 (Cerro)	1	2
6 (Grand)	10 (R1)	8	10
6 (Grand)	12 (R3)	3	5
6 (Grand)	13 (R4)	2	4
6 (Grand)	15 (H2)	26	20
6 (Grand)	16 (H4)	80	131
6 (Grand)	17 (H10)	8	5
6 (Grand)	18 (H11)	8	5
6 (Grand)	21 (Mixed)	6	7
6 (Grand)	32 (Cerro)	1	2
6 (Grand)	33 (PCV)	1	2
7 (GStruct)	2 (Highland)	4	7
7 (GStruct)	3 (California)	5	8
7 (GStruct)	6 (Grand)	57	30
12 (R3)	2 (Highland)	5	1
12 (R3)	3 (California)	5	1
13 (R4)	2 (Highland)	4	1
13 (R4)	3 (California)	7	2
19 (H12)	2 (Highland)	22	6
19 (H12)	3 (California)	22	7
22 (H16)	2 (Highland)	5	2
22 (H16)	3 (California)	5	2
27 (Mixed)	2 (Highland)	0	1
27 (Mixed)	4 (Campus)	1	0
27 (Mixed)	5 (Crandall)	1	0
27 (Mixed)	6 (Grand)	0	1
32 (Cerro)	3 (California)	2	1

5.9 Emissions Modeling

Because of its ability to quantify emissions for different vehicle operating states on a second-by-second time scale, UC Riverside's CMEM v3.01 (see [Emissions Modeling](#) in [System Overview](#)) is chosen for modeling emissions based on simulation outputs from VISSIM. CMEM also makes for easier processing as data can be parsed from simulation output to suitable text input without the use of extensive programming. More specifically, the command line version of CMEM for light duty vehicles is used for Cal Poly's network.

5.9.1 CMEM LDV CLI Overview

This version of CMEM is outlined in Figure 5.15 below. The version runs in batch mode based off a command line interface in Microsoft DOS.

Figure 5.15: Outline of the Selected Version of the Comprehensive Modal Emissions Model Used for Modeling Emissions During Cal Poly's AM Peak Hour (Scora 2006)

As seen in the figure, an executable file takes the inputs of three text files (Model Control File, Vehicle Definition File and Vehicle Activity file) to generate two output text files (Vehicle Emission File and Vehicle Summary File). An additional output text file, the Model Run file (not shown), contains a summary of all settings and parameters used. The Model Control input file is used for inputting run settings such as units of measure, which emissions to output, and any newly created or modified vehicle categories or parameters. The Vehicle Definition file contains a listing of all vehicles used in the model as well as their corresponding CMEM vehicle category, soak time, and humidity levels. The Vehicle Activity file contains second-by-second data on vehicle activities as obtained from simulation. These activities include current speed, acceleration, grade, and secondary loads (e.g. A/C) present. The Vehicle Emission file contains second-by-second emissions data in a time & vehicle ordered format. The Vehicle Summary file contains a summary of miles traveled per vehicle and emissions generated per mile.

5.9.2 Vehicle Category Mapping

In order to create a valid Vehicle Definition input file, it is necessary to adopt CMEM vehicle categories.

Table 5.22 below shows the vehicle categories used in the current version of CMEM.

Adopting CMEM categories is accomplished by mapping the vehicle types used in VISSIM to suitable matches in CMEM. A heuristic approach is used for the mapping process according to the following steps:

1. Determine which CMEM vehicle categories match specific VISSIM vehicle types
2. For each VISSIM vehicle type, determine the splits (percentage) of vehicles likely to belong to each CMEM vehicle category
3. Based on simulation output, create a unique list of all vehicles from the current simulation run
4. Apply the splits of vehicles for each VISSIM category to determine which CMEM vehicle category each vehicle in the unique list is assigned to
5. Apply these assignments to the Vehicle Definition input file

Table 5.22: Vehicle Categories in CMEM v3.01

Vehicle Categories in CMEM v3.01				
	Category #	Vehicle Type	Title	Description
Normal Emitting Vehicles	1	Cars/Trucks	No Catalyst	All cars/trucks made between 1972-1974, <8500 GVW
	2	Cars/Trucks	2-way Catalyst	All cars/trucks made between 1975-1979, <8500 GVW
	3	Cars	3-way Catalyst, Carbureted	Some cars made between 1981-1990; decreasing gradually over the years
	4	Cars	3-way Catalyst, FI, high miles, low power/weight	power/weight <0.039hp/lb, >50k miles, 1981-1993 model years
	5	Cars	3-way Catalyst, FI, high miles, high power/weight	power/weight >0.039hp/lb, >50k miles, 1981-1993 model years
	6	Cars	3-way Catalyst, FI, low miles, low power/weight	power/weight <0.039hp/lb, <50k miles, 1981-1993 model years
	7	Cars	3-way Catalyst, FI, low miles, high power/weight	power/weight >0.039hp/lb, <50k miles, 1981-1993 model years
	8	Cars/Trucks	Tier 1, high miles, low power/weight	1994-present model years; trucks less than 3750 GVW, >50k miles, power/weight <0.042 hp/lb
	9	Cars/Trucks	Tier 1, high miles, high power/weight	1994-present model years; trucks less than 3750 GVW, >50k miles, power/weight >0.042 hp/lb
	10	Cars/Trucks	Tier 1, low miles, low power/weight	1994-present model years; trucks less than 3750 GVW, <50k miles, power/weight <0.042 hp/lb
	11	Cars/Trucks	Tier 1, low miles, high power/weight	1994-present model years; trucks less than 3750 GVW, <50k miles, power/weight >0.042 hp/lb
	24	Cars/Trucks	Tier 1, super high mileage	1994-present model years; >100k miles regardless of weight or power/weight ratio
Low Emitting Vehicles	26	Cars	Ultra Low Emission Vehicles	Per Certification
	27	Cars	Super Ultra Low Emission Vehicles	Per Certification
Normal Emitting Trucks	12	Trucks	Pre 1979	
	13	Trucks	1979-1983	<8500 GVW
	14	Trucks	1984-1987	<8500 GVW
	15	Trucks	1988-1993	<3750 LVW
	16	Trucks	1988-1993	>3750 LVW
	17	Trucks	Tier 1 Truck, LDT 2/3	3750-5750 LVW or Alt LVW
	18	Trucks	Tier 1 Truck, LDT 4	6001-8500 GVW, >5750 Alt LVW
	25	Trucks	Truck, Gasoline Powered, >8500 GVW	
	40	Trucks	Truck, Diesel Powered, >8500 GVW	
High Emitting Vehicles	19	Cars/Trucks	Runs lean	
	20	Cars/Trucks	Runs rich	
	21	Cars/Trucks	Misfire	
	22	Cars/Trucks	Bad catalyst	
	23	Cars/Trucks	Runs very rich	

Steps 1 & 2 are summarized below in Table 5.23 and Table 5.24. Table 5.23 shows the matching vehicle categories and splits while Table 5.24 shows the balance of vehicles fitting each VISSIM and CMEM category. Steps 3-4 are computed in Excel for each simulation run. Due to the numerous quantities of data in these files, it is not feasible to include them in this report. A sample of one of these is available in [Appendix K](#) with the accompanying formulas used.

Table 5.23: Vehicle Mapping Splits for Cal Poly's AM Peak Hour

Vehicle Mapping Splits					
<u>VISSIM Vehicle Category 1- Economy/Hybrid</u>		<u>VISSIM Vehicle Category 4- Full Size</u>		<u>VISSIM Vehicle Category 7- Truck</u>	
CMEM Category	Split of Volume	CMEM Category	Split of Volume	CMEM Category	Split of Volume
26	70%	4	2%	8	4%
27	30%	5	2%	9	4%
		6	0.5%	10	3.5%
		7	0.5%	11	3.5%
		8	9%	15	3%
<u>VISSIM Vehicle Category 2- Compact</u>		9	9%	16	2%
CMEM Category	Split of Volume	10	8.5%	17	25%
4	4%	11	8.5%	18	4%
6	1%	24	50%	24	40%
8	20%	19-23	10%; 2% each	25	0.5%
10	5%			40	0.5%
24	35%	<u>VISSIM Vehicle Category 5- Small SUV</u>		19-23	10%; 2% each
26	20%	CMEM Category	Split of Volume		
27	5%	8	15%	<u>VISSIM Vehicle Category 8- Sport</u>	
19-23	10%; 2% each	10	15%	CMEM Category	Split of Volume
		15	7%	5	4%
<u>VISSIM Vehicle Category 3- Mid Size</u>		16	3%	7	1%
CMEM Category	Split of Volume	17	10%	9	25%
4	2%	24	40%	11	10%
5	2%	19-23	10%; 2% each	24	50%
6	0.5%			19-23	10%; 2% each
7	0.5%	<u>VISSIM Vehicle Category 6- Large SUV</u>			
8	10%	CMEM Category	Split of Volume	<u>VISSIM Vehicle Category 9- Wagon/Crossover/ Van</u>	
9	10%	16	5%	CMEM Category	Split of Volume
10	10%	17	30%	4	8%
11	10%	18	5%	6	2%
24	45%	24	50%	8	20%
19-23	10%; 2% each	19-23	10%; 2% each	10	10%
				24	50%
				19-23	10%; 2% each

Table 5.24: Balance of Vehicle Type Categories in VISSIM and CMEM

Balance of Categories After Vehicle Mapping																															
		CMEM Category																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	40	Total Vehicles	% of Total
VISSIM Category	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	68	160	0	228	4.60%
	2	0	0	0	53	0	13	0	266	0	67	0	0	0	0	0	0	0	0	27	27	27	27	27	466	0	266	67	0	1332	26.85%
	3	0	0	0	21	21	5	5	106	106	106	106	0	0	0	0	0	0	0	21	21	21	21	21	478	0	0	0	0	1063	21.43%
	4	0	0	0	3	3	1	1	14	14	14	14	0	0	0	0	0	0	0	3	3	3	3	3	69	0	0	0	0	145	2.92%
	5	0	0	0	0	0	0	0	112	0	112	0	0	0	0	52	22	75	0	15	15	15	15	15	298	0	0	0	0	745	15.02%
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	49	8	3	3	3	3	3	81	0	0	0	0	162	3.27%
	7	0	0	0	0	0	0	0	29	29	26	26	0	0	0	22	15	182	29	15	15	15	15	15	292	4	0	0	4	729	14.69%
	8	0	0	0	0	8	0	2	0	52	0	21	0	0	0	0	0	0	0	4	4	4	4	4	105	0	0	0	0	209	4.21%
	9	0	0	0	28	0	7	0	70	0	35	0	0	0	0	0	0	0	0	7	7	7	7	7	174	0	0	0	0	348	7.01%
Total Vehicles		0	0	0	105	32	26	8	597	202	359	167	0	0	0	74	45	305	37	95	95	95	95	95	1963	4	335	226	4		
% of Total		0.0%	0.0%	0.0%	2.1%	0.7%	0.5%	0.2%	12.0%	4.1%	7.2%	3.4%	0.0%	0.0%	0.0%	1.5%	0.9%	6.2%	0.8%	1.9%	1.9%	1.9%	1.9%	1.9%	39.6%	0.1%	6.7%	4.6%	0.1%		

5.9.3 Generation of CMEM Results

In order to generate proper emission data in CMEM, the following procedure (including vehicle category mapping) is used for each simulation run:

1. In VISSIM, enable evaluation by Vehicle Record. Configure the evaluation file to record data on a second-by-second basis and to include data fields for time, vehicle ID, vehicle category and category number, speed, acceleration, and gradient.
2. Run the simulation
3. Open the output file (.fzp)
4. Copy vehicle data to create a separate file for vehicle category mapping
5. In this separate file, filter data to obtain a unique list of vehicles involved in the simulation
6. Map vehicles from VISSIM categories to CMEM categories by applying the defined splits
7. Add additional columns and fill these with soak time and humidity values
8. Copy data for vehicle number, CMEM category, soak time, and humidity to a text file and save as a Vehicle Definition File
9. Eliminate the columns for vehicle category in the original output file
10. Add a column to this file and fill it with data on secondary load values
11. Sort data according to time order first, and vehicle ID order second
12. Copy data for time, vehicle ID, velocity, acceleration, gradient, and secondary load to a text file and save as a Vehicle Activity File
13. Create a separate text file and save as a Model Control File. Write to this file settings for the simulation
14. Add headers to the Vehicle Definition and Vehicle Activity files
15. Run the CMEM model in batch mode
16. Open the Vehicle Emissions Summary file (-smb)
17. Multiply miles traveled per vehicle by emissions generated per mile
18. Sum data over all vehicles to obtain emissions levels in grams per mile

5.9.3 Assumptions

In using CMEM for emissions modeling, the following assumptions are made:

- Secondary load is equal to “1”. Defined in CMEM as a binary, secondary loads are either applied or not applied to each vehicle. A value of “1” indicates secondary loads are present for the vehicle (e.g. A/C, heater) and are applied based on statistics for the vehicle type
- For mapping, vehicles are assigned a random number based on a random number generator. This random number is looked up in an array to determine a VISSIM vehicle’s CMEM vehicle category based on previously defined vehicle mapping splits. It is assumed that the random number generator in Excel is truly random.
- Soak time (minutes) is randomly distributed between 0 and 1440. Soak time describes the time since the vehicle was last used where a zero value is equivalent to a hot stabilized operation and 1440 is equivalent to a cold start.
- Humidity is assumed to be “75” for all vehicles. A value of “75” is the default value in CMEM and represents operating conditions at 75 degrees and 40% humidity. This assumption has an affect on emissions of nitrous oxides.
- Default vehicle categories and associated parameters for CMEM are used
- All gradients are set to zero. Therefore, the Cal Poly network is assumed to be flat.

6. Results

6.1 Initial Findings

A total of ten simulations based on ten random seeds are run for Cal Poly's AM Peak Hour in both VISSIM and then CMEM. The VISSIM portion of these simulations runs off the same random seeds used in calibration and validation, but with updated volumes. The data is then parsed through Excel for input to CMEM. CMEM's outputs are then summarized and recorded. Table 6.1 shows the quantity of fuel consumed and each type pollutant type (HC, CO, NOx) emitted for each of the ten random seeds as well as the average, minimum, and maximum values.

Table 6.1: Summary of Total Emissions for Cal Poly's AM Peak Hour

Summary of Total Emissions for Cal Poly AM Peak Hour (7:30AM-8:30AM)				
Description	HC (g)	CO (g)	NOx (g)	Fuel Used (g)
Random Seed 42	7,899	99,778	7,818	459,741
Random Seed 13	7,954	100,134	8,047	437,277
Random Seed 24	7,755	95,641	7,709	419,332
Random Seed 500	7,634	95,978	7,971	427,265
Random Seed 6	7,808	95,724	7,942	426,537
Random Seed 2	7,839	96,511	7,852	436,597
Random Seed 266	7,401	91,378	7,526	390,937
Random Seed 681	7,603	96,327	7,877	423,037
Random Seed 67	7,853	99,118	7,878	449,183
Random Seed 52	7,643	94,415	7,822	414,065
Minimum	7,401	91,378	7,526	390,937
Average	7,739	96,500	7,844	428,397
Maximum	7,954	100,134	8,047	459,741

6.2 Statistics

6.2.1 Number of Runs

Based on these runs, the number of runs required to determine a suitable confidence level for each performance metric is calculated using the following equation in Figure 6.1:

$$n_r \geq \frac{s^2 z^2 \alpha/2}{\epsilon^2}$$

where:

s^2 = variance (based on trial runs)

$z^2 \alpha/2$ = threshold value for a 100(1- α) percent confidence interval

n_r = number of runs required

ϵ = maximum error of the estimate

Figure 6.1: Formula for Calculating the Sufficient Number of Runs for Simulation (Harrell 2004)

This calculation is used for each performance metric. For all performance metrics, a 95% confidence level ($\alpha/2 = 0.0025$, $\alpha = 0.05$) is chosen which corresponds to a z-value of 1.96. The maximum error of the estimate (ϵ) is assumed to be 3% of the mean for each performance metric. The number of runs resulting from each calculation is rounded up to the nearest whole number.

As seen in Table 6.2, the minimum number of runs calculated for HC, CO, NOx, and Fuel Used are 2, 4, 2, and 9, respectively. Since all of these values are less than ten, the ten runs previously used should be sufficient to create a 95% confidence interval for each of the performance metrics.

Table 6.2: Calculation of the Sufficient Number of Runs for Simulation by Performance Metric

Calculating Sufficient Number of Runs				
Emission Type	HC (g)	CO (g)	NOx (g)	Fuel Used (g)
Average	7,739	96,500	7,844	428,397
Standard Deviation (g)	167	2,646	145	19,105
Variance (g ²)	28025	7003527	21083	364993436
$z_{(\alpha/2)}$ for 95% confidence level	1.96	1.96	1.96	1.96
$z^2_{(\alpha/2)}$ for 95% confidence level	3.8416	3.8416	3.8416	3.8416
ϵ (g)	232.16	2895.01	235.33	12851.91
Number of Runs Required (n_r)	2.00	3.21	1.46	8.49
Number of Runs Required (n_r) Rounded	2	4	2	9

6.2.2 T-Test of Confidence Intervals

Given previous calculations, 95% confidence intervals are generated based off the original 10 runs. A t-test for confidence intervals is chosen because of the small sample sizes ($n=10$) for each performance metric and because the means and standard deviations of each population are unknown. Using Minitab statistical software, the confidence intervals for each performance metric are generated as seen below in Figure 6.2.

2/1/2011 12:12:49 PM					
Welcome to Minitab, press F1 for help.					
One-Sample T: HC (g)					
Variable	N	Mean	StDev	SE Mean	95% CI
HC (g)	10	7738.8	167.4	52.9	(7619.1, 7858.6)
One-Sample T: CO (g)					
Variable	N	Mean	StDev	SE Mean	95% CI
CO (g)	10	96500	2646	837	(94607, 98393)
One-Sample T: NOx (g)					
Variable	N	Mean	StDev	SE Mean	95% CI
NOx (g)	10	7844.4	145.2	45.9	(7740.5, 7948.3)
One-Sample T: Fuel Use (g)					
Variable	N	Mean	StDev	SE Mean	95% CI
Fuel Use (g)	10	428397	19105	6041	(414730, 442064)
2/5/2011 4:45:34 PM					

Figure 6.2: T-Test Confidence Intervals of Means for Performance Metrics

6.3 Analysis by Emission Type

Figure 6.3: Bar Graph of HC Emissions by Random Seed

Figure 6.3 shows the HC emissions generated by each of the random seeds. Hydrocarbons are a type of volatile organic compound (VOC) which influences the development of ozone compounds in the lower atmosphere. Approximately 50% of HC emissions nationally are sourced from motor vehicles. The quantity of hydrocarbons (HCs) emitted during an average Cal Poly AM Peak hour ranges from approximately 7,400-7,950 grams with an average of a little above 7,700 grams. Based on the t-test for confidence intervals, the true mean is 95% likely to be between 7,619-7,858 grams.

On a vehicle-trip basis, the average HC emissions during the AM Peak Hour equates to about 3.5 grams per vehicle-trip. Using the rule of thumb that the peak hour typically constitutes 10% of daily demand, the quantity of HCs emitted on an average weekday at Cal Poly could be about 74,000-80,000 grams.

Figure 6.4: Bar Graph of CO Emissions by Random Seed

Figure 6.4 shows the CO emissions generated by each of the random seeds. Carbon monoxide is a criteria pollutant that immediately affects the atmosphere. Approximately 60% of CO emissions nationally are sourced from on-road motor vehicles. The quantity of carbon monoxide emitted during an average Cal Poly AM Peak hour ranges from approximately 91,400-100,100 grams with an average of approximately 96,500 grams. Based on the t-test for confidence intervals, the true mean is 95% likely to be between 94,607-98,393 grams.

On a vehicle-trip basis, the average CO emissions during the AM Peak Hour equates to about 44 grams per vehicle-trip. Using the rule of thumb that the peak hour typically constitutes 10% of daily demand, the quantity of carbon monoxide emitted on an average weekday at Cal Poly could be about 941,000-1,001,000 grams.

Figure 6.5: Bar Graph of NO_x Emissions by Random Seed

Figure 6.5 shows the NO_x (nitrogenous oxide) emissions generated by each of the random seeds. Nitrogen monoxide in particular, is a criteria pollutant that immediately affects the atmosphere. Approximately 30% of NO_x emissions nationally are sourced from on-road motor vehicles. The quantity of nitrogenous oxides emitted during an average Cal Poly AM Peak hour ranges from approximately 7,550-8,050 grams with an average of approximately 7,850 grams. Based on the t-test for confidence intervals, the true mean is 95% likely to be between 7,740-7,948 grams.

On a vehicle-trip basis, the average NO_x emissions during the AM Peak Hour equates to about 3.6 grams per vehicle-trip. Using the rule of thumb that the peak hour typically constitutes 10% of daily demand, the quantity of nitrogenous oxides emitted on an average weekday at Cal Poly could be about 77,400-79,480 grams.

Figure 6.6: Bar Graph of Fuel Consumption by Random Seed

Figure 6.6 shows the total fuel consumption generated by each of the random seeds. The quantity of fuel consumed is an important factor in the efficiency of any internal combustion engine. Depending on the mixture of air and fuel, the internal combustion process is the key to both vehicle performance and emissions. The quantity of fuel consumed during an average Cal Poly AM Peak hour ranges from approximately 391,000-460,000 grams with an average of approximately 428,500 grams. This equates to approximately 151 gallons consumed. Based on the t-test for confidence intervals, the true mean is 95% likely to be between 414,730-442,064 grams (146-156 gallons).

On a vehicle-trip basis, the average fuel consumption during the AM Peak Hour equates to about 197 grams per vehicle-trip. This equates to approximately 0.07 gallons per vehicle trip, assuming the density of 0.75 grams per cubic centimeter for 87 octane gasoline. Using the rule of thumb that the peak hour typically constitutes 10% of daily demand, the quantity of fuel consumed on an average weekday at Cal Poly could be about 3,910,000-4,600,000 grams (1377-1620 gallons).

6.4 Total Emissions & Analysis

Based on these simulation runs and all assumptions made, the total quantity of emissions (HCs, CO, and NO_x) generated by transportation at Cal Poly during the AM Peak Hour is estimated to be between 106,350-116,100 grams. Using the rule of thumb that the peak hour typically constitutes 10% of daily demand, the total quantity of emissions on an average weekday at Cal Poly could be about 1,063,500-1,161,000 grams.

It is guessed that these totals **significantly underestimate** the total emissions generated by vehicles at Cal Poly due to the following factors:

- *Not all emissions types are accounted for:* This model excludes the emissions of carbon dioxide (CO₂), particulate matter (PM-5 and PM-10), sulfur oxides (SO_x), and ammonia (NH₄). Although their role is not as significant as that of the types of emissions modeled, they still influence total emissions.
- *Traffic during the AM Peak Hour is largely uni-directional:* The AM Peak Hour is largely composed of inbound trips to Cal Poly, unlike other peak hours during the midday or evening where trips are more bi-directional. The amount of time vehicles spend in the network can increase with greater spatial density of traffic (bi-directional). Also, dwell times for stop-controlled intersections can increase with increased multi-directional traffic due to the increased likelihood of conflicting movements.
- *The impact of pedestrian traffic is largely underestimated:* The impact of pedestrians crossing main campus thoroughfares is a significant impedance factor to vehicle traffic, especially when class meetings begin and end. A greater impedance increases idle times of vehicles which generate additional emissions
- *In many cases, the California Blvd entrance to Cal Poly is congested to the point that not all vehicles in demand are able to enter the network:* This phenomenon is commonly seen with vehicle traffic backing up to Foothill Blvd and Hathway Ave. Since vehicles enter the network at the entrance to campus, the off-campus effects of traffic and emissions are not captured.
- *The slight slope of campus roads is not captured in the model.* The existence of gradients on links can further increase emissions as they require vehicles to exert additional power.

7. Sensitivity Analysis

Sensitivity analysis is a systematic study of how the findings of a model change with variation of key input parameters. Sensitivity analysis is important because it helps determine the dynamics of a model and relative importance of key input parameters to each other. For the simulations used to model Cal Poly's AM Peak hour, sensitivity analysis is conducted for changes in demand and changes in the share of "green" vehicles being operated.

These analyses are performed using one random seed (Random Seed #42) which generates approximately the same driver-behavior parameters in each simulation run. The key inputs of demand and share of "green" vehicles being operated change in each scenario run, but the methodology and calculations particular to random seed #42 remain unchanged. One random seed is chosen to establish a common basis for comparison as well as minimize the lengthy cycle time required to process multiple seeds for each scenario.

7.1 Demand Sensitivity

In almost any market or economy, supply and demand are critical in accessing the value of products and services. The value of transportation, in particular, is accessed by the demand for trips and the means (roads) by which these trips can be made. Since supply is typically more fixed and difficult to change, changes in demand are very important to transportation economics and are chosen for sensitivity analysis. Furthermore, changes in demand can capture the influence many factors may have on the system.

The sensitivity of demand on vehicle emissions and fuel consumption is examined in several scenarios for Cal Poly's AM Peak Hour. A 0% change in demand is used as a baseline case where approximately 2174 vehicle-trips are made. This corresponds to the data generated previously for random seed 42. From there, demand is both increased and decreased by 10%, 20% and 50%. Comparisons are stated as percent changes relative to the baseline because relative changes are easier to comprehend than absolute changes. The changes in each scenario are done independent of each other. Table 7.1 below shows a summary of all demand sensitivity scenarios

Table 7.1: Summary of Demand Sensitivity for Cal Poly's AM Peak Hour

Demand Sensitivity				
% Change in Demand	% Change in HC Emissions	% Change in NOx Emissions	% Change in CO Emissions	% Change in Fuel Consumption
-50%	-51.64%	-49.57%	-50.80%	-56.18%
-20%	-18.73%	-16.22%	-18.99%	-26.66%
-10%	-6.57%	-10.22%	-7.85%	-15.61%
0%	0.00%	0.00%	0.00%	0.00%
10%	5.32%	2.99%	1.99%	4.04%
20%	12.06%	7.16%	7.21%	7.89%
50%	30.20%	27.05%	29.68%	77.97%

7.1.1 Scenario 1: Increase Demand 10%

In the first scenario, Cal Poly's AM Peak Hour demand is increased by approximately 10% to 2360 vehicle-trips. This increase in demand causes an approximate 2-5% increase in vehicle emissions and a 4% increase in fuel consumption.

7.1.2 Scenario 2: Decrease Demand 10%

In the second scenario, Cal Poly's AM Peak Hour demand is decreased by approximately 10% to 1953 vehicle-trips. This decrease in demand causes an approximate 6-11% decrease in vehicle emissions and 15% decrease in fuel consumption.

7.1.3 Scenario 3: Increase Demand 20%

In the third scenario, Cal Poly's AM Peak Hour demand is increased by approximately 20% to 2607 vehicle-trips. This increase in demand causes an approximate 7-12% increase in vehicle emissions and an 8% increase in fuel consumption.

7.1.4 Scenario 4: Decrease Demand 20%

In the fourth scenario, Cal Poly's AM Peak Hour demand is decreased by approximately 20% to 1747 vehicle-trips. This decrease in demand causes an approximate 16-19% decrease in vehicle emissions and 27% decrease in fuel consumption.

7.1.5 Scenario 5: Increase Demand 50%

In the fifth scenario, Cal Poly's AM Peak Hour demand is increased by approximately 50% to 3261 vehicle-trips. This increase in demand causes an approximate 27-30% increase in vehicle emissions and a 78% increase in fuel consumption.

7.1.6 Scenario 6: Decrease Demand 50%

In the sixth scenario, Cal Poly's AM Peak Hour demand is decreased by approximately 50% to 1087 vehicle-trips. This decrease in demand causes an approximate 49-52% decrease in vehicle emissions and 56% decrease in fuel consumption.

7.1.7 Overall Analysis

The sensitivity plot in Figure 7.1 shows all six scenarios for demand sensitivity.

Figure 7.1: Sensitivity Plot showing how Demand Impacts Emissions and Consumption for Cal Poly's AM Peak Hour

Based on this plot the following conclusions are made:

- Emissions and fuel consumption increase with increases in demand; decrease with decreases in demand
- Fuel consumption seems to be more responsive to changes in demand than vehicle emissions
- Vehicle emissions of each type seem to change similarly due to demand
- Decreases in demand seem to decrease emissions more dynamically than increases in demand seem to increase emissions. This is evidenced by steeper slopes for lines on the left-side of the graph and flatter slopes for lines on the right-side of the graph. This is not as apparent in the figure unless the scale is clearly accounted for.
- A decrease in demand seems to decrease fuel consumption and emissions more dynamically than an increase in vehicle demand seems to increase fuel consumption. In the case of fuel consumption, this trend seems to reverse, however, when demand is increased or decreased more

than 35%. This may be due to the fact that Cal Poly's network cannot cope with 50% demand increases without experiencing excessive congestion. This is suggested by the animation during this run and the inability of the network to converge in a timely manner. The trend may also be connected to the set of driver behavior parameters generated by random seed 42 which cannot cope with the change.

- The sharp increase in fuel consumption with an increase of demand by 50% may have been caused by errors in testing

7.2 Sensitivity of Share of Green Vehicles

According to a 2008 study by J.D. Power & Associates, the sale of hybrid and diesel vehicles in the United States is projected to increase three-fold by the year 2015. This increase could mean the current market share of hybrid vehicles would increase from 2.2% as seen in year 2007 to 7% by year 2015 (Hybridcars.com 2008). Given Cal Poly's recent push for growth in the use of hybrid vehicles, policies and special programs emphasizing the increase in the share of "green" vehicles are likely to be integral in future campus planning and decisions. Currently, approximately 4-8% of private vehicles operated by students, faculty, and staff are "green" vehicles, provided the underlying assumptions made in determining vehicle categories in VISSIM and CMEM. This is slightly higher than the national average. A three-fold increase could mean market shares of "green" vehicles of around 12-24% for Cal Poly.

The sensitivity of the share of "green" vehicles in operation on vehicle emissions and fuel consumption is examined in several scenarios for Cal Poly's AM Peak Hour. A 0% change in "green" vehicle share is used as a baseline case where approximately 100 vehicle-trips (4.60%) are made by "green" vehicles. This corresponds to the data generated previously for random seed 42. From there, the share of "green" vehicles is increased by 20%, 50%, 100%, and 200% to test claims suggested by the J.D. Power & Associates study and anticipated policy at Cal Poly. When the market share of "green" vehicles increases, the market share of all other vehicles categories decreases slightly, provided the assumption that demand is unchanged. Comparisons are stated as percent changes relative to the baseline because relative changes are easier to comprehend than absolute changes. The changes in each scenario are done independent of each other. Table 7.2 below shows a summary of all demand sensitivity scenarios.

Table 7.2: Summary of Share of "Green" Vehicles Sensitivity for Cal Poly's AM Peak Hour

Sensitivity of Share of "Green" Vehicles				
% Increase in Green Vehicles	% Change in HC Emissions	% Change in NOx Emissions	% Change in CO Emissions	% Change in Fuel Consumption
0%	0.00%	0.00%	0.00%	0.00%
20%	-1.97%	2.23%	-0.39%	-1.94%
50%	-2.44%	1.86%	-1.76%	0.43%
100%	-2.91%	3.76%	-3.62%	0.59%
200%	-4.51%	10.59%	-6.21%	-2.08%

7.2.1 Scenario 7: Increase Share of Green Vehicles by 20%

In the seventh scenario, the share of “green” vehicles operating during Cal Poly’s AM Peak Hour is increased by approximately 20% to 120 vehicle-trips (5.53% market share). This increase causes an approximate 0-2% decrease in HC and CO emissions, a 2% increase in NO_x emissions, and a 2% decrease in fuel consumption.

7.2.2 Scenario 8: Increase Share of Green Vehicles by 50%

In the eighth scenario, the share of “green” vehicles operating during Cal Poly’s AM Peak Hour is increased by approximately 50% to 150 vehicle-trips (6.90% market share). This increase causes an approximate 1-3% decrease in HC and CO emissions, a 2% increase in NO_x emissions, and a 0% change in fuel consumption.

7.2.3 Scenario 9: Increase Share of Green Vehicles by 100%

In the ninth scenario, the share of “green” vehicles operating during Cal Poly’s AM Peak Hour is increased by approximately 100% to 200 vehicle-trips (9.20% market share). This increase causes an approximate 2-4% decrease in HC and CO emissions, a 4% increase in NO_x emissions, and a 1% increase in fuel consumption.

7.2.4 Scenario 10: Increase Share of Green Vehicles by 200%

In the tenth scenario, the share of “green” vehicles operating during Cal Poly’s AM Peak Hour is increased by approximately 200% (or tripled) to 300 vehicle-trips (13.81% market share). This increase causes an approximate 4-7% decrease in HC and CO emissions, an 11% increase in NO_x emissions, and a 2% decrease in fuel consumption.

7.2.5 Overall Analysis

The sensitivity plot in Figure 7.2 shows all four scenarios for share of “green” vehicles sensitivity.

Figure 7.2: Sensitivity Plot showing how Share of "Green" Vehicles Impacts Emissions and Consumption for Cal Poly's AM Peak Hour

Based on this plot the following conclusions are made:

- Increases in the share of “green” vehicles suggests slight decreases in HC and CO emissions
- Increases in the share of “green” vehicles suggests little to no change in fuel consumption
- Increases in the share of “green” vehicles suggest slight increases in NOx emissions. This phenomenon is traced to CMEM vehicle categories. In vehicle mapping, 100% of vehicles belonging to the economy/hybrid vehicle class in VISSIM are mapped to CMEM categories 26-ULEV (Ultra Low Emission Vehicle) and 27-SULEV (Super Ultra Low Emission Vehicle). An additional 25% of the compact class is also mapped to these categories. The greater majority of vehicles are in CMEM category 26- ULEV which seems to comprise about 35% of overall NO_x emissions in the base scenario, provided the default settings in CMEM. When the share of “green” vehicles increases, the share of category 26 vehicles increases, resulting in increased NO_x emissions.

- Some “green” vehicles are fueled on diesel which has been known to increase NO_x emissions more significantly than unleaded gasoline.
- In comparison to the previous sensitivity plot, demand seems to more dynamically influence vehicle emissions and fuel consumption than the share of “green” vehicles does. This is evidenced by steeper slopes and wider scales for the vertical axis in the demand sensitivity plot.
- If both changes in demand and the share of “green” vehicles are made simultaneously, a decrease in emissions from increasing the share of green vehicles may likely be offset by the increase in emissions associated with an increase in demand.
- The results for vehicle emissions and fuel consumption may have been influenced by errors in testing

8. Opportunities for Further Improvement

There are many opportunities to expand and improve the accuracy of the model created for Cal Poly. Such opportunities include the following:

- Modeling of *pedestrian* crosswalks and their impact on campus circulation
- Modeling the campus with *demand matrices based on smaller time intervals*. The campus can experience large fluctuations in demand within a period of 10-15 minutes as commonly seen during passing periods
- Modeling of the campus during *other peak periods of demand* (e.g. midday, evening)
- Modeling of *additional vehicle categories* such as motorcycles, bicycles and campus service vehicles
- Further *stratification of demand by different vehicle use types* (e.g. Staff demand has its own schedule and unique set of potential parking destinations)
- Capture the *emissions associated with searching for open/desired parking spaces* within campus lots
- Study the *impact technology can have in influence parking decisions* (parking management systems)
- Implementation of *improved cost and route choice parameters*
- *Expansion of model* to include more outlying areas of San Luis Obispo including freeway interchanges
- Modeling of *physical & geometric changes stated or anticipated* in Cal Poly's Master Plan
- *Increased data collection* for entrances/exits to campus and parking lots
- *Modeling of special policies* implemented for traffic and parking for special campus events
- Implementing an *updated version of VISSIM or CMEM software*
- Investigating *how a simulation of Cal Poly's emissions differs through use of different software or methodology*
- *Compare simulation emissions statistics with those gathered from a field test* using FTP bag procedures

9. Conclusions

The use of simulation has been useful in helping the Cal Poly campus recognize the collective behaviors and patterns of transportation present on campus and the implications these behaviors pose to the transportation network as a whole. A simulation model was created which mimics the real life traffic situation seen on Cal Poly's campus during the AM Peak Hour from 7:30-8:30AM. The model was created using leading software packages VISSIM and CMEM, and contains a reasonable level of accuracy for estimating the physical emissions generated by vehicles during this time period.

Based on assumptions made, the total quantity of emissions (HCs, CO, and NOx) currently generated by transportation at Cal Poly during the AM Peak Hour is estimated to be between 106,350-116,100 grams. In particular, the average amount of HC emissions is estimated to be between 7619-7858 grams, the average amount of CO emissions is estimated to be between 94,607-98,393 grams, and the average amount of NOx emissions is estimated to be between 7740-7948 grams. Each of these estimates is made at a confidence level of 95%. In addition, the quantity of fuel consumed during the AM Peak hour is estimated to be between 414,730-442,064 grams with 95% confidence.

In addition to the current estimates for the AM Peak Hour, scenarios were performed to see the sensitivity of emissions relative to changes in demand and the share of 'green' vehicles present on campus. These scenarios found that emissions and fuel consumption increased with increased demand at a rate of about half the increase of demand. Emissions and fuel consumption had mixed results for increases in the share of 'green' vehicles.

The findings of this study can serve as a basis for future decisions in campus planning such as determining parking fees, promotion of alternative forms of transportation (e.g. 'green' vehicles, public transit, walking, bicycling). The study can be extended to study other applications on campus such as areas of congestion, and the impact of design and operational changes as well as the sensitivity of other key parameters. Additionally, the methods used in this study could be useful in similar environments such as business parks, corporate campuses, and downtown districts.

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Appendices

Appendix A: Listing of Links Forming the Network

The following is a list of all links forming the Cal Poly network:

• Cabrillo Highway (CA-1)	• Grand Ave	• Pinnacles Rd
• California Blvd	• E Foothill Blvd	• Poly Canyon Rd
• Campus Way	• Foothill Blvd	• N Poly View Dr
• Canyon Circle Dr	• Hathway Ave	• S Poly View Dr
• Casa St	• Highland Dr	• E Safety Way
• Carpenter St	• Kentucky St	• W Safety Way
• Cerro Vista Circle	• Klamath Rd	• Santa Rosa St
• Circle Dr	• Longview Ln	• Slack St
• College Ave	• Monte Vista Pl	• Sports Complex Dr
• Crandall Way	• Mountain Ln	• Stenner Creek Rd
• Cuesta Ave	• Mt Bishop Rd	• Truckee Rd
• Deer Rd	• Pacheco Way	• University Dr
• Dexter	• N Perimeter	• US-101
• Entrance Way	• S Perimeter	• Via Carta

Appendix B: Listing of Speed Decisions & Distributions

The following is a list of the locations where speed decisions are located in the Cal Poly network. Each of these speed decisions corresponds to speed distributions based on the appropriate range of speeds the proceeding section accommodates.

- Highland Dr entrance
- Highland Dr exit
- Highland Dr inbound @ Crops Unit
- Stenner Creek Rd entrance
- Grand Ave entrance
- S Perimeter Northbound @ Grand Ave
- Deer Road inbound to residential areas
- Mountain Ln inbound to residential areas
- Klamath Rd southbound from Cerro Vista
- Cerro Vista circle entrance
- Truckee westbound from top of Cerro Vista
- Village Dr northbound just north of Truckee intersection
- Truckee westbound just west of Village Dr intersection
- University Dr northbound just north of N Perimeter
- University Dr southbound just south of Highland Dr
- Via Carta northbound just north of Campus Market
- Highland Dr eastbound just east of University Dr
- Highland Dr westbound after Via Carta connector
- Highland Dr westbound just west of University Dr
- Highland Dr eastbound just east of California Blvd
- Highland Dr eastbound just east of Mt Bishop Rd
- California Blvd southbound just south of Highland Dr
- Mt Bishop Rd northbound
- Mt Bishop Rd southbound
- Stenner Creek Road exit
- Sports Complex Dr
- Village Dr eastbound just east of Via Carta
- Pinnacles Rd westbound
- University Dr @ Kennedy Library
- N Perimeter between Via Carta & University
- Via Carta southbound just south of N Perimeter
- Truckee Rd eastbound just east of E Safety Dr
- Grand Ave northbound (off-campus)
- Grand Ave southbound (off-campus)
- Klamath Rd northbound
- N Perimeter westbound just south of Village Dr
- Village Dr between N Perimeter & Truckee
- E Safety Dr
- W Safety Dr
- Canyon Circle Dr counter-clockwise
- Canyon Circle Dr clockwise
- Vista Caballo eastbound
- Vista Caballo westbound
- Village Dr northbound within Poly Canyon Village
- Village Dr southbound within Poly Canyon Village
- Village Dr exiting Poly Canyon Village to the west
- Pinnacles Rd eastbound
- Via Carta southbound just south of Village Dr
- Via Carta southbound just south of Sports Complex Dr
- Via Carta northbound near lot exits
- Via Carta southbound near lot exits
- Highland Dr westbound between California Blvd and Mt Bishop Rd
- Highland Dr outbound @ Crops Unit
- S Perimeter between College Ave and Cuesta Ave
- College Ave outbound
- Campus Way eastbound
- Foothill/Crandall entrance
- Pacheco Way inbound
- Pacheco Way southbound
- College Ave begin
- Cuesta Ave @ Powerhouse
- Campus Way entrance
- California Blvd entrance
- California Blvd northbound @ C5 Parking
- California Blvd southbound @ C5 Parking
- Foothill/Crandall entrance

The following diagrams describe the empirical speed distributions used in the Cal Poly network. Each is scaled on the x-axis from the minimum speed to the maximum speed and on the y-axis with proportion of vehicles.

Appendix C: Listing of Stop Signs

The following is a list of stop signs used in the Cal Poly network:

4-Way Stops:

- Highland & University
- N Perimeter & University
- N Perimeter & Via Carta
- Grand & Slack
- Truckee Rd & Village Dr (Conflict Areas used instead of Priority Rules)
- Campus Way & Cuesta Ave & C2 Children's Center Parking (Conflict Areas used instead of Priority Rules)
- Foothill Blvd & California Blvd
- CA-1 (Cabrillo Hwy) & Highland Dr

3-Way Stops:

- Deer Rd & Klamath Rd
- Klamath Rd & R1 Parking (Muir)
- N Perimeter & Village Dr
- Grand Ave & S Perimeter
- N Perimeter & E Safety Way
- California Blvd & Highland Dr
- California Blvd & C5 Parking
- California Blvd & Campus Way
- S Perimeter & Cuesta Ave
- Carpenter St & Hathway Ave
- Hathway Ave & Kentucky St
- Hathway Ave & Longview Ln & G2 Parking
- Slack St & Longview Ln

2-Way Stops:

- Klamath Rd & Mountain Ln
- Klamath Rd & Truckee Rd & Cerro Vista Circle Entrance
- Truckee Rd & E Safety Way
- H14 Lower Parking & H 16 Upper Parking & Via Carta
- H14 Baseball Parking Row 1 & Sports Complex Dr
- H14 Baseball Parking Row 2 & Sports Complex Dr
- S Perimeter @ Graphic Arts
- S Perimeter & Via Carta

1-Way Stops:

- G2 Parking @ Slack St
- R2 Parking @ Grand Ave
- G1 Parking @ Grand Ave
- Pacheco Way @ Grand Ave
- PAC Circle @ Pacheco Way
- Deer Rd @ Grand Ave
- R1 Parking (Fremont) @ Klamath Rd
- Cerro Vista Circle End @ Truckee Rd

- A1 Parking Exit (North Row) @ N Perimeter
- Tahoe Rd @ S Perimeter
- W Safety Way @ N Perimeter
- H4 BRAE Parking @ W Safety Way
- H4 Triangle Parking @ Truckee Rd
- H4 BRAE Parking @ Via Carta
- H2 Engineering @ University Dr
- H12 Parking @ Via Carta
- H16 Lower Parking @ Via Carta
- Pinnacles Rd @ Via Carta
- H12 Row 1 Parking @ Pinnacles Rd
- H12 Row 2 Parking @ Pinnacles Rd
- H12 Row 3 Parking @ Pinnacles Rd
- H12 Row 4 Parking @ Pinnacles Rd
- H12 Row 5 Parking @ Pinnacles Rd
- H14 Upper Parking @ Via Carta
- Sports Complex Dr @ Via Carta
- H15 Parking @ Sports Complex Dr
- H14 Baseball Parking @ Via Carta
- H14 Lower Equine Parking @ Via Carta
- H14 Upper Equine Parking @ Via Carta
- Village Dr @ Via Carta
- Canyon Circle Dr (North) @ Village Dr
- Canyon Circle Dr (South) @ Village Dr
- R4 Parking (West) @ Canyon Circle Dr
- R4 Parking (East) @ Canyon Circle Dr
- Vista Caballo @ Village Dr
- Vista Caballo @ Canyon Circle Dr
- R3 Parking @ Village Dr
- H2 Creek Parking @ Highland Dr
- Dexter Rd @ Entrance Way
- Entrance Way @ California Blvd
- Grand Ave Parking Kiosk
- California Blvd Parking Kiosk
- Highland Dr Parking Kiosk
- C3 Parking @ Campus Way
- S Perimeter @ College Ave
- C2 Children's Center @ Campus Way
- Campus Way & Crandall Way (Health Center)
- E Foothill Blvd @ Crandall Way
- Carpenter St @ E Foothill Blvd
- Monte Vista Pl @ California Blvd
- Casa St @ Foothill Blvd
- Mt Bishop Rd @ Highland Dr
- Stenner Creek Rd @ CA-1 (Cabrillo Hwy)
- Mt Bishop Rd @ Stenner Creek Rd
- Dairy Parking @ Mt Bishop Rd
- H1 Main Parking @ Mt Bishop Rd
- H1 Lower Parking @ Mt Bishop Rd
- H1 Crops Parking @ Mt Bishop Rd

Appendix D: Maps of Transit Routes in the Cal Poly Network

The following pictures show the transit routes within the Cal Poly network as described previously.

SLO Transit- Route 4

SLO-Transit Route 5

SLO-Transit- Route 6A/6B

SLO-Transit Route 6B/6A

RTA- Route 9 NB

RTA- Route 10

RTA- Route 12 NB

RTA- Route12 SB

Appendix E: Data Collection Summaries

The table below summarizes inbound and outbound volumes collected at the Grand Avenue entrance to Cal

Poly in 15-minute increments. The accompanying graph shows these volumes with respect to time of day.

Intersection: Grand/Slack Observer: S. Kilbert Dates (Day of Week): 10/05/10 (Tuesday), 10/12/10 (Tuesday), 10/19/10 (Tuesday) Spans of about 5 hours were studied on each of these days and assembled to create the "average day" shown below								
Begin Time	End Time	Inbound	Outbound	% Inbound	% Outbound	Flow Rate IB (veh/hr)	Flow Rate OB (veh/hr)	Flow Rate Overall (veh/hr)
7:30 AM	7:45 AM	184	33	84.79%	15.21%	736	132	604
7:40 AM	8:00 AM	258	31	89.27%	10.73%	1032	124	908
8:00 AM	8:15 AM	122	28	81.33%	18.67%	488	112	376
8:15 AM	8:30 AM	77	17	81.91%	18.09%	308	68	240
8:30 AM	8:45 AM	116	27	81.12%	18.88%	464	108	356
8:45 AM	9:00 AM	235	29	89.02%	10.98%	940	116	824
9:00 AM	9:15 AM	106	65	61.99%	38.01%	424	260	164
9:15 AM	9:30 AM	83	28	74.77%	25.23%	332	112	220
9:30 AM	9:45 AM	84	60	58.33%	41.67%	336	240	96
9:45 AM	10:00 AM	102	50	67.11%	32.89%	408	200	208
10:00 AM	10:15 AM	47	57	45.19%	54.81%	188	228	-40
10:15 AM	10:30 AM	69	50	57.98%	42.02%	276	200	76
10:30 AM	10:45 AM	68	41	62.39%	37.61%	272	164	108
10:45 AM	11:00 AM	74	56	56.92%	43.08%	296	224	72
11:00 AM	11:15 AM	64	100	39.02%	60.98%	256	400	-144
11:15 AM	11:30 AM	49	36	57.65%	42.35%	196	144	52
11:30 AM	11:45 AM	124	65	65.61%	34.39%	496	260	236
11:45 AM	12:00 PM	183	79	69.85%	30.15%	732	316	416
12:00 PM	12:15 PM	87	107	44.85%	55.15%	348	428	-80
12:15 PM	12:30 PM	54	72	42.86%	57.14%	216	288	-72
12:30 PM	12:45 PM	54	76	41.54%	58.46%	216	304	-88
12:45 PM	1:00 PM	99	39	71.74%	28.26%	396	156	240
1:00 PM	1:15 PM	79	110	41.80%	58.20%	316	440	-124
1:15 PM	1:30 PM	91	69	56.88%	43.13%	364	276	88
1:30 PM	1:45 PM	76	88	46.34%	53.66%	304	352	-48
1:45 PM	2:00 PM	97	92	51.32%	48.68%	388	368	20
2:00 PM	2:15 PM	69	122	36.13%	63.87%	276	488	-212
2:15 PM	2:30 PM	60	115	34.29%	65.71%	240	460	-220
2:30 PM	2:45 PM	73	88	45.34%	54.66%	292	352	-60
2:45 PM	3:00 PM	93	90	50.82%	49.18%	372	360	12
3:00 PM	3:15 PM	52	150	25.74%	74.26%	208	600	-392
3:15 PM	3:30 PM	42	105	28.57%	71.43%	168	420	-252
3:30 PM	3:45 PM	82	90	47.67%	52.33%	328	360	-32
3:45 PM	4:00 PM	100	101	49.75%	50.25%	400	404	-4
4:00 PM	4:15 PM	80	212	27.40%	72.60%	320	848	-528
4:15 PM	4:30 PM	69	183	27.38%	72.62%	276	732	-456
4:30 PM	4:45 PM	81	158	33.89%	66.11%	324	632	-308
4:45 PM	5:00 PM	71	134	34.63%	65.37%	284	536	-252
5:00 PM	5:15 PM	47	213	18.08%	81.92%	188	852	-664
5:15 PM	5:30 PM	41	135	23.30%	76.70%	164	540	-376
5:30 PM	5:45 PM	67	125	34.90%	65.10%	268	500	-232
5:45 PM	6:00 PM	110	139	44.18%	55.82%	440	556	-116

6:00 PM	6:15 PM	68	223	23.37%	76.63%	272	892	-620
6:15 PM	6:30 PM	53	198	21.12%	78.88%	212	792	-580
6:30 PM	6:45 PM	49	105	31.82%	68.18%	196	420	-224
6:45 PM	7:00 PM	80	91	46.78%	53.22%	320	364	-44
7:00 PM	7:15 PM	61	92	39.87%	60.13%	244	368	-124
7:15 PM	7:30 PM	48	85	36.09%	63.91%	192	340	-148
7:30 PM	7:45 PM	72	110	39.56%	60.44%	288	440	-152
7:45 PM	8:00 PM	92	135	40.53%	59.47%	368	540	-172
8:00 PM	8:15 PM	63	118	34.81%	65.19%	252	472	-220
8:15 PM	8:30 PM	58	97	37.42%	62.58%	232	388	-156
8:30 PM	8:45 PM	51	62	45.13%	54.87%	204	248	-44
8:45 PM	9:00 PM	38	48	44.19%	55.81%	152	192	-40
Totals		4368	4996	46.65%	53.35%			

The table below shows all potential peak hours for the Grand Ave Entrance to Cal Poly. The hours highlighted are classified as peak hours according to the key at the bottom of the table. As mentioned in the report body, the AM Peak Hour between 7:30AM-8:30AM is chosen for analysis.

Potential Peak Hours for Grand Avenue Entrance					
Hour Begin	Hour End	Volume IB	Volume OB	Total Volume	Net Volume
7:30 AM	8:30 AM	641	-109	750	532
7:45 AM	8:45 AM	573	-103	676	470
8:00 AM	9:00 AM	550	-101	651	449
8:15 AM	9:15 AM	534	-138	672	396
8:30 AM	9:30 AM	540	-149	689	391
8:45 AM	9:45 AM	508	-182	690	326
9:00 AM	10:00 AM	375	-203	578	172
9:15 AM	10:15 AM	316	-195	511	121
9:30 AM	10:30 AM	302	-217	519	85
9:45 AM	10:45 AM	286	-198	484	88
10:00 AM	11:00 AM	258	-204	462	54
10:15 AM	11:15 AM	275	-247	522	28
10:30 AM	11:30 AM	255	-233	488	22

10:45 AM	11:45 AM	311	-257	568	54
11:00 AM	12:00 PM	420	-280	700	140
11:15 AM	12:15 PM	443	-287	730	156
11:30 AM	12:30 PM	448	-323	771	125
11:45 AM	12:45 PM	378	-334	712	44
12:00 PM	1:00 PM	294	-294	588	0
12:15 PM	1:15 PM	286	-297	583	-11
12:30 PM	1:30 PM	323	-294	617	29
12:45 PM	1:45 PM	345	-306	651	39
1:00 PM	2:00 PM	343	-359	702	-16
1:15 PM	2:15 PM	333	-371	704	-38
1:30 PM	2:30 PM	302	-417	719	-115
1:45 PM	2:45 PM	299	-417	716	-118
2:00 PM	3:00 PM	295	-415	710	-120
2:15 PM	3:15 PM	278	-443	721	-165
2:30 PM	3:30 PM	260	-433	693	-173
2:45 PM	3:45 PM	269	-435	704	-166
3:00 PM	4:00 PM	276	-446	722	-170
3:15 PM	4:15 PM	304	-508	812	-204
3:30 PM	4:30 PM	331	-586	917	-255
3:45 PM	4:45 PM	330	-654	984	-324
4:00 PM	5:00 PM	301	-687	988	-386
4:15 PM	5:15 PM	268	-688	956	-420
4:30 PM	5:30 PM	240	-640	880	-400
4:45 PM	5:45 PM	226	-607	833	-381
5:00 PM	6:00 PM	265	-612	877	-347
5:15 PM	6:15 PM	286	-622	908	-336
5:30 PM	6:30 PM	298	-685	983	-387
5:45 PM	6:45 PM	280	-665	945	-385
6:00 PM	7:00 PM	250	-617	867	-367
6:15 PM	7:15 PM	243	-486	729	-243
6:30 PM	7:30 PM	238	-373	611	-135
6:45 PM	7:45 PM	261	-378	639	-117
7:00 PM	8:00 PM	273	-422	695	-149
7:15 PM	8:15 PM	275	-448	723	-173
7:30 PM	8:30 PM	285	-460	745	-175
7:45 PM	8:45 PM	264	-412	676	-148
8:00 PM	9:00 PM	210	-325	535	-115
	AM Peak Hour				
	Midday Peak Hour				
	PM Peak Hour				

Appendix F: OD Matrix Setup Calculations (Partial Sample)

The calculations below are used to form the Origin/Destination matrix used for Cal Poly's AM Peak Hour.

The notations and calculations correspond to the gravity model formula:

$$T_{ij} = P_i * (A_j F_{ij} K_{ij} / \sum A_j F_{ij} K_{ij})$$

Where;

T_{ij} = trips produced in zone i and attracted to zone j

P_i = total trip production at i

A_j = total trip production at j

F_{ij} = friction or travel time factor (calibration term) for interchange ij

K_{ij} = socioeconomic adjustment factor for interchange ij

Since attractions are distributed, each table is based off one j value (destination) with multiple calculations for each corresponding i value (origins). Due to the large size of this table, only a sample of calculations is provided.

Distribute Attractions

j=1	PiFi1	PiFi1/Sum(PiFi1)	Aj=1	Ti1	
i=1	0.0000	0.0000	6	0.00	T11
i=2	0.0004	0.0000	6	0.00	T21
i=3	0.0005	0.0000	6	0.00	T31
i=4	0.0002	0.0000	6	0.00	T41
i=5	0.0001	0.0000	6	0.00	T51
i=6	0.0006	0.0000	6	0.00	T61
i=7	2.4597	0.1456	6	0.87	T71
i=8	0.1450	0.0086	6	0.05	T81
i=9	0.0000	0.0000	6	0.00	T91
i=10	0.6966	0.0412	6	0.25	T101
i=11	0.3175	0.0188	6	0.11	T111
i=12	0.4910	0.0291	6	0.17	T121
i=13	0.5737	0.0340	6	0.20	T131
i=14	3.3756	0.1998	6	1.20	T141
i=15	2.2729	0.1346	6	0.81	T151
i=16	0.1062	0.0063	6	0.04	T161
i=17	0.6393	0.0378	6	0.23	T171
i=18	0.1190	0.0070	6	0.04	T181
i=19	3.2827	0.1943	6	1.17	T191
i=20	0.0191	0.0011	6	0.01	T201
i=21	0.0984	0.0058	6	0.03	T211
i=22	0.6944	0.0411	6	0.25	T221
i=23	0.0000	0.0000	6	0.00	T231
i=24	0.0000	0.0000	6	0.00	T241
i=25	0.5869	0.0347	6	0.21	T251
i=26	0.0245	0.0014	6	0.01	T261
i=27	0.0000	0.0000	6	0.00	T271

i=28	0.0763	0.0045	6	0.03	T281
i=29	0.6033	0.0357	6	0.21	T291
i=30	0.0229	0.0014	6	0.01	T301
i=31	0.0410	0.0024	6	0.01	T311
i=32	0.1403	0.0083	6	0.05	T321
i=33	0.1036	0.0061	6	0.04	T331
Sum	16.8918	1.0000		6.0000	

j=2	PiFi2	PiFi2/Sum(PiFi2)	Aj=2	Ti2	
i=1	0.0000	0.0000	74	0.00	T12
i=2	0.0004	0.0000	74	0.00	T22
i=3	0.0005	0.0000	74	0.00	T32
i=4	0.0002	0.0000	74	0.00	T42
i=5	0.0001	0.0000	74	0.00	T52
i=6	0.0006	0.0000	74	0.00	T62
i=7	5.5773	0.1077	74	7.97	T72
i=8	0.3156	0.0061	74	0.45	T82
i=9	0.0000	0.0000	74	0.00	T92
i=10	1.6602	0.0321	74	2.37	T102
i=11	0.6823	0.0132	74	0.97	T112
i=12	1.2401	0.0239	74	1.77	T122
i=13	0.9736	0.0188	74	1.39	T132
i=14	2.0275	0.0392	74	2.90	T142
i=15	11.7952	0.2278	74	16.86	T152
i=16	0.3742	0.0072	74	0.53	T162
i=17	2.7500	0.0531	74	3.93	T172
i=18	0.5000	0.0097	74	0.71	T182
i=19	14.7125	0.2841	74	21.02	T192
i=20	0.0496	0.0010	74	0.07	T202
i=21	0.2959	0.0057	74	0.42	T212
i=22	3.1123	0.0601	74	4.45	T222
i=23	0.0000	0.0000	74	0.00	T232
i=24	0.0000	0.0000	74	0.00	T242
i=25	2.5826	0.0499	74	3.69	T252
i=26	0.1298	0.0025	74	0.19	T262
i=27	0.2703	0.0052	74	0.39	T272
i=28	0.3718	0.0072	74	0.53	T282
i=29	1.6220	0.0313	74	2.32	T292
i=30	0.0750	0.0014	74	0.11	T302
i=31	0.1054	0.0020	74	0.15	T312
i=32	0.3156	0.0061	74	0.45	T322
i=33	0.2421	0.0047	74	0.35	T332
Sum	51.7829	1.0000		74.00	

...   .

Same	Trend	Continues	Same	Trend	Continues
j=33	PiFi33	PiFi33/Sum(PiFi33)	Aj=33	Ti33	
i=1	1.3129	0.0067	3	0.02	T133
i=2	35.0271	0.1787	3	0.54	T233
i=3	44.6187	0.2276	3	0.68	T333
i=4	0.0002	0.0000	3	0.00	T433
i=5	0.0001	0.0000	3	0.00	T533
i=6	115.0891	0.5870	3	1.76	T633
i=7	0.0001	0.0000	3	0.00	T733

i=8	0.0000	0.0000	3	0.00	T833
i=9	0.0000	0.0000	3	0.00	T933
i=10	0.0000	0.0000	3	0.00	T1033
i=11	0.0000	0.0000	3	0.00	T1133
i=12	0.0000	0.0000	3	0.00	T1233
i=13	0.0000	0.0000	3	0.00	T1333
i=14	0.0000	0.0000	3	0.00	T1433
i=15	0.0000	0.0000	3	0.00	T1533
i=16	0.0000	0.0000	3	0.00	T1633
i=17	0.0000	0.0000	3	0.00	T1733
i=18	0.0000	0.0000	3	0.00	T1833
i=19	0.0001	0.0000	3	0.00	T1933
i=20	0.0000	0.0000	3	0.00	T2033
i=21	0.0000	0.0000	3	0.00	T2133
i=22	0.0000	0.0000	3	0.00	T2233
i=23	0.0000	0.0000	3	0.00	T2333
i=24	0.0000	0.0000	3	0.00	T2433
i=25	0.0000	0.0000	3	0.00	T2533
i=26	0.0000	0.0000	3	0.00	T2633
i=27	0.0000	0.0000	3	0.00	T2733
i=28	0.0000	0.0000	3	0.00	T2833
i=29	0.0000	0.0000	3	0.00	T2933
i=30	0.0000	0.0000	3	0.00	T3033
i=31	0.0000	0.0000	3	0.00	T3133
i=32	0.0000	0.0000	3	0.00	T3233
i=33	0.0000	0.0000	3	0.00	T3333
Sum	196.0483	1.0000		3.0000	

Appendix G: Calculation of Parking Lot Utilities & Probabilities

The table below shows the calculation of parking lot utilities and their associated probabilities in Excel using the Logit function for parking lot selection as follows:

Probability of choosing lot $i = e^{(\text{utility}(i))} / \sum \text{from } i=1 \text{ to } n \text{ of } e^{(\text{utility}(i))}$

Where:

Utility (i) = (0*Parking Cost(i)) + (1*Attraction(i)) + (0*Distance from desired zone(i)) + (0*Distance from current position(i)) + (0*current parking availability(i))

Calculations are shown on a possible-decision basis, that is, zones that share a common number of parking lots are grouped together. Zones with a few parking lots split their probabilities only a few ways while zones with many parking lots split their probabilities many ways.

Parking Lot Utilities and Probabilities					
<u>Assumption:</u> All utilities and probabilities are calculated with an attraction coefficient of "1" in the Logit equation. All other coefficients are equal to "0".					
The sum of probabilities for all parking lots belonging to a particular lot is equal to 100%					
	2 possible decisions			Simulation Results for Verifying Excel Calculations	
Zone	Lot Possibilities	Utility	Probability	Vehicle Count	Percentage (of Zone Traffic)
7	G5 Structure- Top Floor	3.5	18.24%	65	15.44%
7	G5 Structure- Lower Levels	5	81.76%	356	84.56%
8	Pacheco Entrance	2	4.74%	3	6.98%
8	Grand Entrance	5	95.26%	40	93.02%
9	Slack Entrance	5	66.82%	0	unused
9	Hathway Entrance	4.3	33.18%	0	unused
13	R4 Main Entrance	5	88.08%	10	100.00%
13	R4 Bottom Entrance	3	11.92%	0	0.00%
22	H16 Lower Entrance	5	88.08%	39	81.25%
22	H16 Upper Entrance	3	11.92%	9	18.75%
25	California Blvd East	5	77.73%	40	76.92%
25	California Blvd West	3.75	22.27%	12	23.08%
31	Mountain Lane	5	73.11%	0	0.00%
31	Grand Ave	4	26.89%	1	100.00%
33	Cerro Vista Lower	5	54.98%	0	0.00%
33	Cerro Vista Upper	4.8	45.02%	2	100.00%
	3 possible decisions				
Zone	Lot Possibilities	Utility	Probability		
27	Campus Dining	4.75	40.69%		
27	Power	3	7.07%		
27	Cohan Center	5	52.24%		
30	Dexter	5	33.33%		
30	Foundation	5	33.33%		
30	Engineering 13	5	33.33%		
32	Canyon Circle/Village	4.8	34.58%		

32	Vista Caballo West	5	42.24%		
32	Vista Caballo East	4.4	23.18%		
	<u>4 possible decisions</u>				
Zone	Lot Possibilities	Utility	Probability		
15	H2 Creek	4.25	22.71%		
15	H2 Engineering IV	5	48.08%		
15	H2 Engineering IV Meters	3	6.51%		
15	H2 Highland/University	4.25	22.71%		
	<u>5 possible decisions</u>				
Zone	Lot Possibilities	Utility	Probability		
14	H1 Crops	5	39.14%		
14	H1 Main Upper	3	5.30%		
14	H1 Main Lower	4.5	23.74%		
14	Dairy	4.1	15.91%		
14	Poultry	4.1	15.91%		
16	H4 Main	4	9.85%		
16	H4 Foundation Shasta	5	26.77%		
16	H4 Foundation North	4	9.85%		
16	H4 BRAE West	5	26.77%		
16	H4 BRAE East	5	26.77%		
	<u>6 possible decisions</u>				
Zone	Lot Possibilities	Utility	Probability		
19	H12 Main Entrance	5	91.61%		
19	H12 Row 1	1	1.68%		
19	H12 Row 2	1	1.68%		
19	H12 Row 3	1	1.68%		
19	H12 Row 4	1	1.68%		
19	H12 Row 5	1	1.68%		
	<u>7 possible decisions</u>				
Zone	Lot Possibilities	Utility	Probability		
23	C2 Main	5	24.96%		
23	Cuesta Ave	5	24.96%		
23	College Ave	5	24.96%		
23	Children's Center Side	3	3.38%		
23	Children's Center West	4	9.18%		
23	Children's Center East	3	3.38%		
23	Health Center	4	9.18%		
	<u>8 possible decisions</u>				
Zone	Lot Possibilities	Utility	Probability		
10	R1 Lower	4	5.31%		
10	R1 Middle Muir	5	14.43%		
10	R1 Middle Trinity	5	14.43%		
10	R1 Middle Lower Cerro	5	14.43%		
10	R1 Middle Upper Cerro	5	14.43%		
10	R1 Upper Fremont	5	14.43%		
10	R1 Upper Lower Cerro	4.75	11.23%		
10	R1 Upper Upper Cerro	4.75	11.23%		
	<u>14 possible decisions</u>				
Zone	Lot Possibilities	Utility	Probability		

21	H14 Lower	5	53.43%		
21	H14 Upper	4	19.65%		
21	H14 Sports Complex R1	2	2.66%		
21	H14 Sports Complex R2	2	2.66%		
21	H14 Upper Baseball	2	2.66%		
21	H14 Upper Baseball Sports Complex R1	1	0.98%		
21	H14 Upper Baseball Sports Complex R2	1	0.98%		
21	H14 Lower Equine	2	2.66%		
21	H14 Upper Equine	2	2.66%		
21	H14 Arboretum	1	0.98%		
21	H14 Swine	1	0.98%		
21	H14 Lower Horticulture	2	2.66%		
21	H14 Upper Horticulture	2.5	4.39%		
21	H15 Sports Complex	2	2.66%		

Appendix H: Intersection Configuration for Model Verification

The following sketches are intersection configurations which are used in model development and verification.

N. Perimeter Rd / Navy Way / University   Entrance way / Navy way / Dexter   California Blvd. / Entrance way

California Blvd / Monte Vista Pl.

California Blvd. / E. Foothill

E. Foothill Blvd. / Casa St.

Appendix I: Data Collection Summaries for Key Interior Intersections

The following tables are summaries of the traffic studies done at key intersections interior to the campus.

These studies are done at Grand/Pacheco/Deer, Highland/University and N Perimeter/Village Dr.

INPUT WORKSHEET												
General Information						Site Information						
Analyst: <u>S. Kilbert</u>						Intersection: <u>Grand Ave / Pacheco / Deer Rd</u>						
Agency or Company: _____						Area Type: ☐ CBD ☒ Other						
Date Performed: <u>Tues 11/16/10</u>						Jurisdiction: <u>Cal Poly - San Luis Obispo</u>						
Analysis Time Period: <u>7:30 AM - 8:30 AM</u>						Analysis Year: <u>2010</u>						
Intersection Geometry												
Volume and Timing Input												
	EB			WB			NB			SB		
	LT	TH	RT ¹	LT	TH	RT ¹	LT	TH	RT ¹	LT	TH	RT ¹
Volume, V (veh/h)	14	N/A	31	13	N/A	2	366	213	12	3	63	40
% heavy vehicles, % HV												
Peak-hour factor, PHF												
Pretimed (P) or actuated (A)												
Start-up lost time, I ₁ (s)												
Extension of effective green time, e (s)												
Arrival type, AT												
Approach pedestrian volume, ² V _{ped} (p/h)												
Approach bicycle volume, ² V _{bic} (bicycles/h)												
Parking (Y or N)												
Parking maneuvers, N _{pm} (maneuvers/h)												
Bus stopping, N _b (buses/h)												
Min. timing for pedestrians, ³ G _p (s)												
Signal Phasing Plan												
D I A G R A M	01	02	03	04	05	06	07	08				
Timing	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =			
	Protected turns			Permitted turns Pedestrian			Cycle length, C = ____ s					
Notes												
1. RT volumes, as shown, exclude RTOR.												
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.												
3. Refer to Equation 16-2.												

591 inbound to campus from Grand
 406 into GS garage / PAC loading (366 from Grand, 40 from campus core)
 15 into residences via Deer Rd (12 from Grand, 3 from campus core)
 15 out from residences via Deer Rd (13+2)
 107 leaving campus

INPUT WORKSHEET													
General Information							Site Information						
Analyst: <u>S Kilbert</u>							Intersection: <u>Highland/University</u>						
Agency or Company: _____							Area Type: ☐ CBD ☐ Other						
Date Performed: <u>Wed 11/17/10</u>							Jurisdiction: <u>Cal Poly-San Luis Obispo</u>						
Analysis Time Period: <u>7:30AM-8:30AM</u>							Analysis Year: <u>2010</u>						
Intersection Geometry													
• = Pedestrian Button — = Lane Width — = Through — = Right — = Left — = Through + Right — = Left + Through — = Left + Right — = Left + Through + Right													
Volume and Timing Input													
	EB			WB			NB			SB			
	LT	TH	RT ¹	LT	TH	RT ¹	LT	TH	RT ¹	LT	TH	RT ¹	
Volume, V (veh/h)	16	413	215	6	22	0	77	4	45	1	0	0	
% heavy vehicles, % HV							64% (S)		22% (N)				
Peak-hour factor, PHF	0.97												
Pretimed (P) or actuated (A)													
Start-up lost time, l ₁ (s)													
Extension of effective green time, e (s)													
Arrival type, AT													
Approach pedestrian volume, ² V _{ped} (p/h)										183			
Approach bicycle volume, ² V _{bic} (bicycles/h)													
Parking (Y or N)													
Parking maneuvers, N _{pm} (maneuvers/h)													
Bus stopping, N _g (buses/h)													
Min. timing for pedestrians, ³ G _p (s)													
Signal Phasing Plan													
D I A G R A M	01	02	03	04	05	06	07	08					
Timing	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =				
→ Protected turns → Permitted turns Pedestrian Cycle length, C = ____ s													
Notes 1. RT volumes, as shown, exclude RTOR. 2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach. 3. Refer to Equation 16-2.													

642 inbound on Highland
 459 toward Via Carta parking / PCV
 219 toward campus core

INPUT WORKSHEET												
General Information					Site Information							
Analyst: <u>S. Kilbert</u>					Intersection: <u>N Perimeter/Village Dr.</u>							
Agency or Company: _____					Area Type: ☐ CBD ☒ Other							
Date Performed: <u>11/18/10 Thurs</u>					Jurisdiction: <u>Cal Poly - San Luis Obispo</u>							
Analysis Time Period: <u>7:30 - 8:30 AM</u>					Analysis Year: <u>2010</u>							
Intersection Geometry												
Volume and Timing Input												
	EB			WB			NB			SB		
	LT	TH	RT ¹	LT	TH	RT ¹	LT	TH	RT ¹	LT	TH	RT ¹
Volume, V (veh/h)	28	77	N/A	N/A	105	94				25	N/A	14
% heavy vehicles, % HV	5.2%			3.8%								
Peak-hour factor, PHF												
Pretimed (P) or actuated (A)												
Start-up lost time, I ₁ (s)												
Extension of effective green time, e (s)												
Arrival type, AT												
Approach pedestrian volume, ² v _{ped} (p/h)	26			41			4			230		
Approach bicycle volume, ² v _{bic} (bicycles/h)				3						1		
Parking (Y or N)												
Parking maneuvers, N _m (maneuvers/h)												
Bus stopping, N _b (buses/h)												
Min. timing for pedestrians, ³ C _p (s)												
Signal Phasing Plan												
D I A G R A M	01	02	03	04	05	06	07	08				
	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =				
Protected turns			Permitted turns Pedestrian			Cycle length, C = _____ s						
Notes												
1. RT volumes, as shown, exclude RTOR.												
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.												
3. Refer to Equation 16-2.												

Appendix J: Calibration Summaries by Iteration

The following tables show summaries for each iteration of calibration. Ten random seeds are assumed for each of the 30 turning movements. The cells highlighted in red indicate GEH statistics in excess of the threshold of “5”.

Calibration- Initial Summary																
	Movement	VISSIM Notation	Simulation	Actual	GEH Statistic	Seed 42	Seed 13	Seed 24	Seed 500	Seed 6	Seed 2	Seed 67	Seed 681	Seed 266	Seed 52	Average
Highland & University	EbL	W-N	33.3	16	3.4844773	38	37	30	29	29	32	31	31	44	32	33.3
	EbT	W-E	254.7	413	8.6637363	263	263	238	264	269	271	258	243	217	261	254.7
	EbR	W-S	323.3	213	6.7357601	332	337	304	335	326	353	339	322	261	324	323.3
	WbR	E-N	0	0	#DIV/0!	0	0	0	0	0	0	0	0	0	0	0
	WbT	E-W	76.6	22	2.7762315	76	78	77	77	78	74	75	78	77	76	76.6
	WbL	E-S	5.6	6	0.166091	4	6	4	6	6	5	7	6	5	7	5.6
	NbL	S-W	73.8	77	0.3685228	75	69	77	73	78	72	74	71	74	75	73.8
	NbT	S-N	5.3	4	0.6028606	0	6	7	7	5	4	6	6	5	7	5.3
	NbR	S-E	42.2	45	0.4240478	44	43	41	42	44	40	43	44	41	40	42.2
	SbL	N-E	0	1	1.4142136	0	0	0	0	0	0	0	0	0	0	0
	SbT	N-S	0.6	0	1.0954451	0	0	1	0	0	2	0	1	1	1	0.6
	SbR	N-W	6.3	0	3.5496479	7	6	2	6	9	5	9	9	4	6	6.3
N Perimeter & Village Dr	WbT	SE-W	113.6	106	0.7252912	126	110	128	109	109	119	106	106	109	114	113.6
	WbR	SE-NE	28.6	94	8.3530967	37	25	19	27	27	28	33	26	36	28	28.6
	EbT	W-SE	51.4	77	3.1950117	52	50	47	54	54	55	51	50	48	53	51.4
	EbL	W-NE	23.7	28	0.8457426	25	23	20	22	22	30	22	27	21	25	23.7
	SbR	NE-W	10.2	14	1.0924232	13	10	8	11	11	12	8	11	6	12	10.2
	SbL	NE-SE	32.9	25	1.4682595	35	37	31	32	32	34	37	33	27	31	32.9
	NbT	SE-NW	171.2	227	3.9545636	190	161	176	168	179	169	168	164	177	160	171.2
	NbR	SE-NE	61.5	12	8.1653824	46	74	57	66	54	59	60	70	56	73	61.5
	SbT	NW-SE	76.7	103	2.7745765	80	77	74	79	74	81	78	78	68	78	76.7
	SbL	NW-NE	0	3	2.4494897	0	0	0	0	0	0	0	0	0	0	0
	WbR	NE-NW	0	2	2	0	0	0	0	0	0	0	0	0	0	0
	WbL	NE-SE	15.8	13	0.7378648	17	19	19	17	15	14	14	12	17	14	15.8
Grand & Pacheco	NbL	SE-SW	378.4	366	0.6427373	378	383	382	383	379	378	370	377	370	384	378.4
	SbR	NW-SW	42.4	40	0.3739062	46	44	44	47	40	45	42	40	33	43	42.4
	EbL	SW-NW	5.8	14	2.6061311	7	6	4	5	7	3	6	6	6	8	5.8
	EbR	SW-SE	61.6	31	4.4970833	60	61	62	62	60	65	62	62	61	61	61.6
	NbT	SE-NW	226	225	0.0665927	228	228	228	228	225	224	222	227	226	224	226
	SbT	NW-SE	50.1	80	3.707213	51	52	49	49	49	50	50	50	52	49	50.1
Calibration- Iteration #1 Summary																
	Movement	VISSIM Notation	Simulation	Actual	GEH Statistic	Seed 42	Seed 13	Seed 24	Seed 500	Seed 6	Seed 2	Seed 67	Seed 681	Seed 266	Seed 52	Average
Highland & University	EbL	W-N	31.7	16	3.2148111	32	35	41	22	27	33	37	24	41	25	31.7
	EbT	W-E	253.1	413	8.7618083	267	253	263	242	268	249	251	219	262	257	253.1
	EbR	W-S	323	213	6.7193154	333	326	337	331	332	308	313	290	335	325	323
	WbR	E-N	0	0	#DIV/0!	0	0	0	0	0	0	0	0	0	0	0
	WbT	E-W	29.7	22	1.5144692	31	27	30	29	29	31	28	30	33	29	29.7
	WbL	E-S	4.4	6	0.7016464	3	5	4	4	6	5	4	4	4	5	4.4
	NbL	S-W	77.8	77	0.0909326	79	81	78	78	75	75	76	78	77	81	77.8
	NbT	S-N	5.2	4	0.5595029	4	4	5	2	5	8	3	6	7	5.2	5.2
	NbR	S-E	38.8	45	0.9578217	38	39	40	37	39	37	34	42	42	40	38.8
	SbL	N-E	0.1	1	1.2135598	0	0	0	1	0	0	0	0	0	0	0.1
	SbT	N-S	0.5	0	1	0	1	0	1	0	1	0	1	1	0	0.5
	SbR	N-W	5.3	0	3.2557641	4	7	6	0	8	7	7	7	5	2	5.3
N Perimeter & Village Dr	WbT	SE-W	160.1	106	4.6901834	160	165	168	155	160	158	153	156	164	162	160.1
	WbR	SE-NE	30.5	94	8.048259	38	26	26	29	27	24	37	37	34	27	30.5
	EbT	W-SE	52.1	77	3.0992116	51	52	53	52	54	50	52	48	55	54	52.1
	EbL	W-NE	26.5	28	0.2873479	28	28	29	31	28	20	26	23	25	27	26.5
	SbR	NE-W	10.8	14	0.9087389	9	10	12	11	15	10	7	10	11	13	10.8
	SbL	NE-SE	15.6	25	2.0863148	13	19	19	10	10	16	12	18	22	17	15.6
	NbT	SE-NW	220.5	227	0.4345421	225	216	224	221	218	212	221	224	223	221	220.5
	NbR	SE-NE	13.4	12	0.3928495	13	20	11	11	15	17	10	11	8	18	13.4
	SbT	NW-SE	60.8	103	4.6630546	56	64	61	57	57	58	68	60	62	65	60.8
	SbL	NW-NE	0	3	2.4494897	0	0	0	0	0	0	0	0	0	0	0
	WbR	NE-NW	0.6	2	1.2278812	2	1	0	0	0	1	1	0	1	0	0.6
	WbL	NE-SE	26.1	13	2.9627698	23	28	27	29	34	25	23	27	23	22	26.1
Grand & Pacheco	NbL	SE-SW	378.3	366	0.6375968	378	382	384	379	375	374	375	375	376	385	378.3
	SbR	NW-SW	44.2	40	0.6473039	41	45	45	46	45	42	41	42	48	47	44.2
	EbL	SW-NW	7.1	14	2.1243343	8	8	7	8	8	5	6	6	7	8	7.1
	EbR	SW-SE	60	31	4.299246	59	60	59	60	60	61	61	60	62	58	60
	NbT	SE-NW	226.7	225	0.1131199	230	228	228	224	224	224	226	228	225	230	226.7
	SbT	NW-SE	41.6	80	4.9246961	38	47	43	40	46	40	40	45	37	40	41.6

Calibration- Iteration #2 Summary																	
	Movement	VISSIM Notation	Simulation	Actual	GEH Statistic	Seed 42	Seed 13	Seed 24	Seed 500	Seed 6	Seed 2	Seed 67	Seed 681	Seed 266	Seed 52	Average	
Highland & University	EDL	W-N	20.8	16	1.1190058	18	18	29	14	21	25	20	18	22	23	20.8	
	EbT	W-E	355	413	2.9598001	368	364	359	309	367	387	350	328	349	369	355	
	EbR	W-S	210.6	213	0.1649105	221	211	220	184	220	219	208	207	198	218	210.6	
	WbR	E-N	0	0	#DIV/0!	0	0	0	0	0	0	0	0	0	0	0	
	WbT	E-W	29.6	22	1.4962485	29	29	31	28	31	33	26	28	31	30	29.6	
	WbL	E-S	4.3	6	0.7491095	3	4	5	4	5	4	6	5	4	3	4.3	
	NbL	S-W	79.4	77	0.2713988	81	84	80	79	77	78	78	80	75	82	79.4	
	NbT	S-N	5.2	4	0.5595029	4	4	5	2	5	8	3	6	8	7	5.2	
	NbR	S-E	38.9	45	0.9418112	38	40	40	37	39	37	34	42	42	40	38.9	
	SbL	N-E	0	1	1.4142136	0	0	0	0	0	0	0	0	0	0	0	0
	SbT	N-S	0.5	0	1	0	1	0	1	0	1	0	1	1	0	0.5	
	SbR	N-W	6.4	0	3.5777088	4	7	6	11	8	7	7	7	5	2	6.4	
N Perimeter & Village Dr	WbT	SE-W	159.3	106	4.6277893	160	163	167	157	158	158	153	154	162	161	159.3	
	WbR	SE-NE	29.8	94	8.1599914	38	24	25	27	29	23	37	35	32	28	29.8	
	EbT	W-SE	66.1	77	1.2886105	66	67	70	62	68	66	66	66	62	68	66.1	
	EbL	W-NE	13.4	28	3.208985	14	12	15	7	14	16	15	16	13	12	13.4	
	SbR	NE-W	10.8	14	0.9087389	9	12	13	8	15	10	9	10	8	14	10.8	
	SbL	NE-SE	5.5	25	4.9934383	4	6	5	4	2	5	10	5	7	7	5.5	
Grand & Deer	NbT	SE-NW	220.9	227	0.4076189	226	215	226	221	218	216	222	221	224	220	220.9	
	NbR	SE-NE	13.8	12	0.5011614	14	21	11	12	14	16	9	15	8	18	13.8	
	SbT	NW-SE	63.5	103	4.3291733	63	66	63	59	62	61	66	65	62	68	63.5	
	SbL	NW-NE	0	3	2.4494897	0	0	0	0	0	0	0	0	0	0	0	0
	WbR	NE-NW	0.6	2	1.2278812	2	1	0	0	0	1	1	0	1	0	0.6	
	WbL	NE-SE	17.6	13	1.176013	15	16	17	19	21	17	16	20	17	18	17.6	
Grand & Pacheco	NbL	SE-SW	378	366	0.622171	377	383	384	379	374	375	374	375	375	384	378	
	SbR	NW-SW	40.9	40	0.1415087	39	41	43	38	41	42	38	41	38	48	40.9	
	EbL	SW-NW	7.4	14	2.0176789	8	8	7	8	8	6	7	6	8	8	7.4	
	EbR	SW-SE	59.5	31	4.2367766	58	60	59	59	60	60	60	60	61	58	59.5	
	NbT	SE-NW	227	225	0.133038	232	228	230	225	223	226	224	229	224	229	227	
	SbT	NW-SE	39.9	80	5.1790461	38	41	37	40	41	35	44	44	41	38	39.9	
Calibration- Iteration #3 Summary																	
	Movement	VISSIM Notation	Simulation	Actual	GEH Statistic	Seed 42	Seed 13	Seed 24	Seed 500	Seed 6	Seed 2	Seed 67	Seed 681	Seed 266	Seed 52	Average	
Highland & University	EDL	W-N	21	16	1.1624764	15	27	22	19	22	19	16	24	25	21	21	
	EbT	W-E	350	413	3.225472	338	322	380	369	369	365	346	360	323	328	350	
	EbR	W-S	219.2	213	0.4217589	229	190	234	233	225	223	224	226	200	208	219.2	
	WbR	E-N	0	0	#DIV/0!	0	0	0	0	0	0	0	0	0	0	0	
	WbT	E-W	28.7	22	1.3307174	26	29	28	28	29	30	26	28	33	30	28.7	
	WbL	E-S	4.9	6	0.4711882	5	4	6	5	6	4	6	5	3	5	4.9	
	NbL	S-W	81.1	77	0.4611401	79	83	75	80	79	78	86	86	82	83	81.1	
	NbT	S-N	5.3	4	0.6028606	7	6	3	4	9	6	3	5	1	9	5.3	
	NbR	S-E	31.6	45	2.1652369	28	32	34	34	30	26	33	31	37	31	31.6	
	SbL	N-E	0	1	1.4142136	0	0	0	0	0	0	0	0	0	0	0	0
	SbT	N-S	0.5	0	1	0	1	0	1	0	1	0	1	1	0	0.5	
	SbR	N-W	6.4	0	3.5777088	4	7	6	11	8	7	7	7	5	2	6.4	
N Perimeter & Village Dr	WbT	SE-W	172.5	106	5.6353909	174	172	174	179	169	172	171	166	177	171	172.5	
	WbR	SE-NE	43.4	94	6.1048099	40	51	43	39	44	41	48	45	40	43	43.4	
	EbT	W-SE	49	77	3.5276684	52	42	54	52	51	50	50	40	46	53	49	
	EbL	W-NE	14.2	28	3.0042624	13	15	14	7	18	13	15	12	16	19	14.2	
	SbR	NE-W	11.4	14	0.7295776	13	11	12	10	11	12	9	12	11	13	11.4	
	SbL	NE-SE	10	25	3.5856858	5	10	11	13	9	14	8	13	9	8	10	
Grand & Deer	NbT	SE-NW	258	227	1.9907	256	261	261	256	262	255	255	263	254	257	258	
	NbR	SE-NE	20.5	12	2.1085905	26	19	17	20	18	18	18	20	26	23	20.5	
	SbT	NW-SE	51.6	103	5.846196	51	50	54	55	53	56	49	45	47	56	51.6	
	SbL	NW-NE	0	3	2.4494897	0	0	0	0	0	0	0	0	0	0	0	0
	WbR	NE-NW	0.8	2	1.0141851	2	1	0	0	0	2	2	0	1	0	0.8	
	WbL	NE-SE	32.7	13	4.1211946	34	29	38	34	31	34	33	41	27	26	32.7	
Grand & Pacheco	NbL	SE-SW	378.4	366	0.6427373	381	382	385	380	371	373	377	378	369	388	378.4	
	SbR	NW-SW	43	40	0.4656903	43	37	49	49	43	46	40	45	36	42	43	
	EbL	SW-NW	7.2	14	2.0886034	8	8	7	8	8	6	6	6	7	8	7.2	
	EbR	SW-SE	59.2	31	4.1991447	59	58	59	59	58	60	60	60	59	60	59.2	
	NbT	SE-NW	271	225	2.9210029	273	271	272	267	271	267	269	276	273	271	271	
	SbT	NW-SE	40.9	80	5.0289649	42	42	43	40	41	43	42	38	38	40	40.9	

Calibration-Iteration #4 Summary																	
	Movement	VISSIM Notation	Simulation	Actual	GEH Statistic	Seed 42	Seed 13	Seed 24	Seed 500	Seed 6	Seed 2	Seed 67	Seed 681	Seed 266	Seed 52	Average	
Highland & University	EBL	W-N	21.3	16	1.2272596	20	18	20	20	21	22	24	20	32	16	21.3	
	EBT	W-E	373.1	413	2.0125607	385	387	354	385	368	374	373	374	352	379	373.1	
	EBR	W-S	224	213	0.7441611	233	236	199	238	222	219	224	233	206	230	224	
	WbR	E-N	0	0	#DIV/0!	0	0	0	0	0	0	0	0	0	0	0	
	WbT	E-W	26.7	22	0.9524636	26	26	26	27	28	27	25	27	28	27	26.7	
	WbL	E-S	5.9	6	0.040996	7	6	4	5	7	5	6	6	7	6	5.9	
	NbL	S-W	77.1	77	0.0113924	73	77	80	73	75	79	75	81	81	77	77.1	
	NbT	S-N	4.1	4	0.0496904	3	4	6	4	3	2	3	6	5	5	4.1	
	NbR	S-E	29	45	2.6303838	28	30	26	29	31	35	28	25	30	28	29	
	SbL	N-E	0	1	1.4142136	0	0	0	0	0	0	0	0	0	0	0	0
	SbT	N-S	0.8	0	1.2649111	0	1	0	2	0	1	1	2	1	0	0.8	
	SbR	N-W	6.1	0	3.4928498	4	7	6	10	8	7	6	6	5	2	6.1	
N Perimeter & Village Dr	WbT	SE-W	167.5	106	5.2591002	162	172	165	168	160	173	157	169	174	175	167.5	
	WbR	SE-NE	59.7	94	3.9126607	61	59	67	59	60	51	63	67	58	52	59.7	
	EBT	W-SE	53.7	77	2.8822598	46	53	43	52	57	55	54	62	56	59	53.7	
	EBL	W-NE	21.6	28	1.2851509	21	25	23	25	23	19	20	19	14	27	21.6	
	SbR	NE-W	10.8	14	0.9087389	9	10	11	9	14	11	9	12	10	13	10.8	
	SbL	NE-SE	25.5	25	0.0995037	34	24	24	31	18	29	23	19	27	26	25.5	
Grand & Deer	NbT	SE-NW	260.2	227	2.1271565	257	264	264	264	259	254	260	265	261	254	260.2	
	NbR	SE-NE	22.4	12	2.5076627	28	23	15	20	21	24	23	22	20	28	22.4	
	SbT	NW-SE	70.5	103	3.4893828	68	70	59	75	68	77	70	72	74	72	70.5	
	SbL	NW-NE	0	3	2.4494897	0	0	0	0	0	0	0	0	0	0	0	0
	WbR	NE-NW	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
	WbL	NE-SE	18.6	13	1.4088329	20	18	25	17	17	17	19	19	18	16	18.6	
Grand & Pacheco	NbL	SE-SW	379.5	366	0.6992379	381	384	384	377	377	373	378	378	376	387	379.5	
	SbR	NW-SW	42.4	40	0.3739062	41	40	38	49	39	46	41	43	44	43	42.4	
	EBL	SW-NW	10.9	14	0.8785713	10	11	12	11	11	10	9	12	13	10	10.9	
	EbR	SW-SE	35.7	31	0.8138604	37	35	35	34	37	37	38	34	35	35	35.7	
	NbT	SE-NW	271.6	225	2.9573148	274	276	268	272	268	271	274	274	268	271	271.6	
	SbT	NW-SE	46.5	80	4.2122539	47	48	46	43	46	47	48	47	48	45	46.5	
Calibration-Iteration #5 Summary																	
	Movement	VISSIM Notation	Simulation	Actual	GEH Statistic	Seed 42	Seed 13	Seed 24	Seed 500	Seed 6	Seed 2	Seed 67	Seed 681	Seed 266	Seed 52	Average	
Highland & University	EBL	W-N	20.2	16	0.987211	19	26	21	20	20	22	19	15	24	16	20.2	
	EBT	W-E	366.3	413	2.3658082	385	369	372	368	370	355	364	338	374	368	366.3	
	EBR	W-S	220.1	213	0.4824799	232	226	211	218	219	216	228	205	231	215	220.1	
	WbR	E-N	0	0	#DIV/0!	0	0	0	0	0	0	0	0	0	0	0	0
	WbT	E-W	26.7	22	0.9524636	26	26	26	27	28	27	25	27	28	27	26.7	
	WbL	E-S	6.1	6	0.0406558	7	6	4	5	7	6	7	6	7	6	6.1	
	NbL	S-W	75.5	77	0.1717795	74	77	78	70	73	73	74	81	80	75	75.5	
	NbT	S-N	2.8	4	0.6507914	3	2	5	3	1	2	2	3	3	4	2.8	
	NbR	S-E	29.1	45	2.6121795	29	30	25	30	31	35	28	25	30	28	29.1	
	SbL	N-E	0	1	1.4142136	0	0	0	0	0	0	0	0	0	0	0	0
	SbT	N-S	0.8	0	1.2649111	0	1	0	2	0	1	1	2	1	0	0.8	
	SbR	N-W	6.1	0	3.4928498	4	7	6	10	8	7	6	6	5	2	6.1	
N Perimeter & Village Dr	WbT	SE-W	163.3	106	4.9380041	161	171	161	166	158	168	149	162	166	171	163.3	
	WbR	SE-NE	63.1	94	3.4864656	65	61	72	63	63	52	65	71	63	56	63.1	
	EBT	W-SE	52.6	77	3.0311144	49	52	45	52	57	55	50	53	57	56	52.6	
	EBL	W-NE	16.7	28	2.3902299	15	16	21	22	20	14	11	15	18	15	16.7	
	SbR	NE-W	10.3	14	1.0614843	9	9	12	7	13	10	8	11	11	13	10.3	
	SbL	NE-SE	25.7	25	0.1390302	31	24	28	30	17	29	25	14	32	27	25.7	
Grand & Deer	NbT	SE-NW	259.8	227	2.1023913	260	264	265	261	261	255	251	265	261	255	259.8	
	NbR	SE-NE	22.2	12	2.4666193	25	22	15	20	21	26	24	22	21	26	22.2	
	SbT	NW-SE	70.1	103	3.536408	67	70	64	73	66	77	71	59	82	72	70.1	
	SbL	NW-NE	0	3	2.4494897	0	0	0	0	0	0	0	0	0	0	0	0
	WbR	NE-NW	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
	WbL	NE-SE	18.8	13	1.4545526	20	18	23	18	20	19	19	21	15	15	18.8	
Grand & Pacheco	NbL	SE-SW	379.3	366	0.6889712	381	383	385	377	376	375	368	380	379	389	379.3	
	SbR	NW-SW	42.1	40	0.3277651	40	41	42	46	39	47	42	34	48	42	42.1	
	EBL	SW-NW	10.9	14	0.8785713	10	11	12	11	11	10	9	12	13	10	10.9	
	EbR	SW-SE	36.3	31	0.9136573	37	36	36	34	37	37	39	35	35	37	36.3	
	NbT	SE-NW	270.6	225	2.8967712	274	274	269	269	270	271	266	274	269	270	270.6	
	SbT	NW-SE	46.6	80	4.198021	46	47	45	45	47	48	48	46	49	45	46.6	

Appendix K: Sample Vehicle Mapping Calculations for Emissions Modeling

The following table shows sample calculations for taking a unique list of vehicles in the simulation and mapping them to CMEM vehicle categories using a random number generator.

Vehicle Mapping Calculations															Insert Into Vehicle Definition File			
VehNr	Type	VehTypeName	Rand	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5	Cat 6	Cat 7	Cat 8	Cat 9	Merge		Veh ID	Veh Cat	Soak	Humidity
1	3	Mid-Size	4	0	0	5	0	0	0	0	0	0	5		1	5	1014	75
2	2	Compact	157	0	26	0	0	0	0	0	0	0	26		2	26	292	75
3	2	Compact	41	0	8	0	0	0	0	0	0	0	8		3	8	826	75
4	3	Mid-Size	199	0	0	23	0	0	0	0	0	0	23		4	23	836	75
5	9	Wagon/Crossover/Minivan/Van	198	0	0	0	0	0	0	0	0	23	23		5	23	659	75
6	7	Truck	158	0	0	0	0	0	0	24	0	0	24		6	24	1389	75
7	2	Compact	43	0	8	0	0	0	0	0	0	0	8		7	8	1195	75
8	2	Compact	72	0	24	0	0	0	0	0	0	0	24		8	24	369	75
9	9	Wagon/Crossover/Minivan/Van	10	0	0	0	0	0	0	0	0	4	4		9	4	613	75
10	2	Compact	40	0	8	0	0	0	0	0	0	0	8		10	8	951	75
11	2	Compact	74	0	24	0	0	0	0	0	0	0	24		11	24	320	75
12	2	Compact	184	0	20	0	0	0	0	0	0	0	20		12	20	1217	75
13	5	SmallSUV	188	0	0	0	0	21	0	0	0	0	21		13	21	552	75
14	8	Sport	186	0	0	0	0	0	0	0	20	0	20		14	20	151	75
15	3	Mid-Size	83	0	0	11	0	0	0	0	0	0	11		15	11	1026	75
16	2	Compact	31	0	8	0	0	0	0	0	0	0	8		16	8	1148	75
17	3	Mid-Size	26	0	0	8	0	0	0	0	0	0	8		17	8	992	75
18	7	Truck	51	0	0	0	0	0	0	17	0	0	17		18	17	1405	75
19	5	SmallSUV	160	0	0	0	0	24	0	0	0	0	24		19	24	890	75
20	2	Compact	168	0	26	0	0	0	0	0	0	0	26		20	26	1021	75
21	9	Wagon/Crossover/Minivan/Van	21	0	0	0	0	0	0	0	0	8	8		21	8	1143	75
22	2	Compact	181	0	19	0	0	0	0	0	0	0	19		22	19	615	75
23	7	Truck	106	0	0	0	0	0	0	24	0	0	24		23	24	205	75
24	5	SmallSUV	69	0	0	0	0	15	0	0	0	0	15		24	15	907	75
25	2	Compact	134	0	26	0	0	0	0	0	0	0	26		25	26	998	75
26	8	Sport	149	0	0	0	0	0	0	0	24	0	24		26	24	1326	75
27	2	Compact	65	0	24	0	0	0	0	0	0	0	24		27	24	995	75
28	5	SmallSUV	72	0	0	0	0	15	0	0	0	0	15		28	15	1394	75
29	2	Compact	40	0	8	0	0	0	0	0	0	0	8		29	8	315	75
30	2	Compact	178	0	27	0	0	0	0	0	0	0	27		30	27	718	75
31	7	Truck	61	0	0	0	0	0	0	17	0	0	17		31	17	109	75
32	2	Compact	108	0	24	0	0	0	0	0	0	0	24		32	24	787	75
33	5	SmallSUV	46	0	0	0	0	10	0	0	0	0	10		33	10	1244	75
34	8	Sport	164	0	0	0	0	0	0	0	24	0	24		34	24	199	75
35	7	Truck	142	0	0	0	0	0	0	24	0	0	24		35	24	418	75
36	3	Mid-Size	174	0	0	24	0	0	0	0	0	0	24		36	24	496	75
37	2	Compact	65	0	24	0	0	0	0	0	0	0	24		37	24	823	75
38	5	SmallSUV	109	0	0	0	0	24	0	0	0	0	24		38	24	1170	75
39	3	Mid-Size	77	0	0	11	0	0	0	0	0	0	11		39	11	306	75
40	3	Mid-Size	128	0	0	24	0	0	0	0	0	0	24		40	24	661	75
41	3	Mid-Size	121	0	0	24	0	0	0	0	0	0	24		41	24	1067	75
42	3	Mid-Size	34	0	0	9	0	0	0	0	0	0	9		42	9	1274	75
43	4	Full-Size	122	0	0	0	24	0	0	0	0	0	24		43	24	471	75
44	5	SmallSUV	3	0	0	0	0	8	0	0	0	0	8		44	8	532	75
45	7	Truck	38	0	0	0	0	0	0	16	0	0	16		45	16	400	75

...Same Idea Continues...

2120	2	Compact		166		0	26	0	0	0	0	0	0	26	2120	26	1211	75
2121	5	SmallSUV		63		0	0	0	0	15	0	0	0	15	2121	15	974	75
2122	5	SmallSUV		190		0	0	0	0	21	0	0	0	21	2122	21	755	75
2123	7	Truck		81		0	0	0	0	0	17	0	0	17	2123	17	376	75
2124	2	Compact		136		0	26	0	0	0	0	0	0	26	2124	26	402	75
2125	2	Compact		118		0	24	0	0	0	0	0	0	24	2125	24	113	75
2126	5	SmallSUV		20		0	0	0	0	8	0	0	0	8	2126	8	1301	75
2127	7	Truck		193		0	0	0	0	0	22	0	0	22	2127	22	231	75
2128	7	Truck		24		0	0	0	0	0	11	0	0	11	2128	11	1104	75
2129	3	Mid-Size		78		0	0	11	0	0	0	0	0	11	2129	11	1367	75
2130	3	Mid-Size		59		0	0	10	0	0	0	0	0	10	2130	10	294	75
2131	3	Mid-Size		152		0	0	24	0	0	0	0	0	24	2131	24	930	75
2132	7	Truck		166		0	0	0	0	0	24	0	0	24	2132	24	926	75
2133	2	Compact		119		0	24	0	0	0	0	0	0	24	2133	24	929	75
2134	7	Truck		24		0	0	0	0	0	11	0	0	11	2134	11	833	75
2135	6	LargeSUV		29		0	0	0	0	17	0	0	0	17	2135	17	1070	75
2136	2	Compact		172		0	27	0	0	0	0	0	0	27	2136	27	1433	75
2137	3	Mid-Size		25		0	0	8	0	0	0	0	0	8	2137	8	230	75
2138	9	Wagon/Crossover/Minivan/Van		175		0	0	0	0	0	0	0	24	24	2138	24	507	75
2139	8	Sport		79		0	0	0	0	0	0	11	0	11	2139	11	872	75
2140	2	Compact		47		0	8	0	0	0	0	0	0	8	2140	8	570	75
2141	3	Mid-Size		140		0	0	24	0	0	0	0	0	24	2141	24	177	75
2142	5	SmallSUV		57		0	0	0	0	10	0	0	0	10	2142	10	1198	75
2143	2	Compact		146		0	26	0	0	0	0	0	0	26	2143	26	575	75
2144	2	Compact		41		0	8	0	0	0	0	0	0	8	2144	8	471	75
2145	3	Mid-Size		125		0	0	24	0	0	0	0	0	24	2145	24	134	75
2146	5	SmallSUV		138		0	0	0	0	24	0	0	0	24	2146	24	960	75
2147	9	Wagon/Crossover/Minivan/Van		50		0	0	0	0	0	0	0	8	8	2147	8	478	75
2148	9	Wagon/Crossover/Minivan/Van		152		0	0	0	0	0	0	0	24	24	2148	24	241	75
2149	9	Wagon/Crossover/Minivan/Van		156		0	0	0	0	0	0	0	24	24	2149	24	383	75
2150	3	Mid-Size		163		0	0	24	0	0	0	0	0	24	2150	24	1188	75
2151	2	Compact		133		0	26	0	0	0	0	0	0	26	2151	26	82	75
2152	2	Compact		66		0	24	0	0	0	0	0	0	24	2152	24	281	75
2153	9	Wagon/Crossover/Minivan/Van		87		0	0	0	0	0	0	0	24	24	2153	24	248	75
2154	4	Full-Size		185		0	0	0	20	0	0	0	0	20	2154	20	101	75
2155	5	SmallSUV		121		0	0	0	0	24	0	0	0	24	2155	24	449	75
2156	5	SmallSUV		74		0	0	0	0	16	0	0	0	16	2156	16	946	75
2157	2	Compact		95		0	24	0	0	0	0	0	0	24	2157	24	519	75
2158	2	Compact		107		0	24	0	0	0	0	0	0	24	2158	24	322	75
2159	7	Truck		148		0	0	0	0	0	24	0	0	24	2159	24	850	75
2160	6	LargeSUV		125		0	0	0	0	0	24	0	0	24	2160	24	129	75
2161	7	Truck		181		0	0	0	0	0	19	0	0	19	2161	19	1421	75
2162	7	Truck		89		0	0	0	0	0	17	0	0	17	2162	17	521	75
2163	2	Compact		137		0	26	0	0	0	0	0	0	26	2163	26	1147	75
2164	4	Full-Size		21		0	0	0	8	0	0	0	0	8	2164	8	906	75
2165	7	Truck		163		0	0	0	0	0	24	0	0	24	2165	24	1164	75
2166	3	Mid-Size		143		0	0	24	0	0	0	0	0	24	2166	24	1191	75
2167	1	Economy/Hybrid		33		26	0	0	0	0	0	0	0	26	2167	26	537	75
2168	9	Wagon/Crossover/Minivan/Van		30		0	0	0	0	0	0	0	8	8	2168	8	566	75
2169	5	SmallSUV		193		0	0	0	0	22	0	0	0	22	2169	22	788	75
2170	2	Compact		38		0	8	0	0	0	0	0	0	8	2170	8	946	75
2171	3	Mid-Size		20		0	0	8	0	0	0	0	0	8	2171	8	271	75
2172	1	Economy/Hybrid		110		27	0	0	0	0	0	0	0	27	2172	27	836	75
2173	7	Truck		195		0	0	0	0	0	22	0	0	22	2173	22	1129	75
2174	9	Wagon/Crossover/Minivan/Van		64		0	0	0	0	0	0	0	10	10	2174	10	1371	75

The following formulas are used for each column of VISSIM categories 1-9 as well as the Merge column.

- =IF(\$F3=1,LOOKUP(\$I3,{0,60},{26,27}),0)
- =IF(\$F3=2,LOOKUP(\$I3,{0,8,10,50,60,130,170,180,184,188,192,196},{4,6,8,10,24,26,27,19,20,21,22,23}),0)
- =IF(\$F3=3,LOOKUP(\$I3,{0,4,8,9,10,30,50,70,90,180,184,188,192,196},{4,5,6,7,8,9,10,11,24,19,20,21,22,23}),0)
- =IF(\$F3=4,LOOKUP(\$I3,{0,4,8,9,10,28,46,63,80,180,184,188,192,196},{4,5,6,7,8,9,10,11,24,19,20,21,22,23}),0)

- =IF(\$F3=5,LOOKUP(\$I3,{0,30,60,74,80,100,180,184,188,192,196},{8,10,15,16,17,24,19,20,21,22,23}),0)
- =IF(\$F3=6,LOOKUP(\$I3,{0,10,70,80,180,184,188,192,196},{16,17,18,24,19,20,21,22,23}),0)
- =IF(\$F3=7,LOOKUP(\$I3,{0,8,16,23,30,36,40,90,98,178,179,180,184,188,192,196},{8,9,10,11,15,16,17,18,24,25,40,19,20,21,22,23}),0)
- =IF(\$F3=8,LOOKUP(\$I3,{0,8,10,60,80,180,184,188,192,196},{5,7,9,11,24,19,20,21,22,23}),0)
- =IF(\$F3=9,LOOKUP(\$I3,{0,16,20,60,80,180,184,188,192,196},{4,6,8,10,24,19,20,21,22,23}),0)
- =IF(VALUE(K3)<>0,K3,IF(VALUE(L3)<>0,L3,IF(VALUE(M3)<>0,M3,IF(VALUE(N3)<>0,N3,IF(VALUE(O3)<>0,O3,IF(VALUE(P3)<>0,P3,IF(VALUE(Q3)<>0,Q3,IF(VALUE(R3)<>0,R3,IF(VALUE(S3)<>0,S3))))))))))

Appendix L: Sample CMEM Model Control File

The text below is a partial sample of the Vehicle Definition File (-def) which is generated as an input to CMEM. It contains a summary of vehicles and their associated categories as well as parameters (soak time and humidity) which are specific to individual vehicles.

```
# Control File for VISSIM16 Batch Model v1
```

```
IN_UNITS = ENGLISH
```

```
OUT_UNITS = ENGLISH
```

```
CO2_OUT = on
```

Appendix M: Partial Sample CMEM Vehicle Definition File

The text below is a partial sample of the Vehicle Definition File (-def) which is generated as an input to CMEM. It contains a summary of vehicles and their associated categories as well as parameters (soak time and humidity) which are specific to individual vehicles.

```
# Vehicle Definition File for VISSIM16 Batch Model v1
```

```
# ID Category Soak Humidity
```

1	10	967	75
2	10	161	75
3	26	413	75
4	8	57	75
5	24	1237	75
6	17	466	75
7	26	1076	75
8	22	862	75
9	22	1340	75
10	26	133	75
11	10	895	75
12	8	844	75
13	24	875	75
14	19	684	75
15	11	73	75
16	20	686	75
17	10	1074	75
18	18	203	75
19	24	142	75
20	26	1115	75
21	24	344	75
22	24	678	75
23	17	1282	75
24	10	783	75
25	24	1106	75
26	24	993	75
27	24	1056	75
28	17	1148	75
29	24	63	75
30	8	558	75
31	24	1107	75
32	8	1	75
33	10	497	75
34	5	441	75
35	24	1368	75
36	11	473	75
37	24	954	75
38	24	104	75

39	24	257	75
40	24	959	75
41	10	284	75
42	9	460	75
43	24	173	75
44	24	567	75
45	8	1219	75
.	.	.	.
.	.	.	.
(Similar trend continues)			
.	.	.	.
.	.	.	.
2150	21	1439	75
2151	24	985	75
2152	24	1292	75
2153	22	393	75
2154	10	1400	75
2155	24	68	75
2156	10	734	75
2157	23	88	75
2158	24	359	75
2159	17	543	75
2160	16	1249	75
2161	17	897	75
2162	24	8	75
2163	10	1301	75
2164	24	511	75
2165	15	1024	75
2166	21	1204	75
2167	26	669	75
2168	24	1147	75
2169	10	842	75
2170	4	1367	75
2171	24	1027	75
2172	26	339	75
2173	24	964	75
2174	24	1099	75

Appendix N: Partial Sample CMEM Vehicle Activity File

The text below is a partial sample of the Vehicle Activity File (-atb) which is generated as an input to

CMEM. It contains a summary of second-by-second vehicle activity which is ordered by time and then

vehicle ID.

Vehicle Activity File for VISSIM16 Batch Model v1

Time, ID, Vel, Acc, Grade, Sload

902,1000,24.58,0.84,0,1

903,1000,24.36,-0.21,0,1

904,237,19.78,0.91,0,1

904,1000,24.31,-0.05,0,1

905,237,20.4,0.91,0,1

905,1000,24.29,-0.01,0,1

906,237,20.4,-0.91,0,1

906,1000,24.29,0,0,1

907,237,26.64,9.01,0,1

907,1000,24.29,0,0,1

908,237,32.01,7.06,0,1

908,1000,24.29,0,0,1

909,237,33.52,0.91,0,1

909,1000,24.29,0,0,1

910,237,34.15,0.91,0,1

910,238,26.52,0.8,0,1

910,239,10.01,0.89,0,1

910,1000,24.29,0,0,1

911,237,34.77,0.91,0,1

911,238,27.06,0.8,0,1
 911,239,10.61,0.89,0,1
 911,1000,24.29,0,0,1
 912,237,35.39,0.91,0,1
 912,238,32.31,7.53,0,1
 912,239,11.22,0.89,0,1
 912,240,19.96,0.61,0,1
 912,1000,24.29,0,0,1
 913,237,34.77,-0.91,0,1
 913,238,37.12,6.89,0,1
 913,239,10.61,-0.89,0,1
 913,240,20.37,0.61,0,1
 913,1000,24.29,0,0,1
 913,1186,21.81,0.76,0,1
 913,1709,30.29,0.5,0,1
 914,237,34.15,-0.91,0,1
 914,238,39.37,0.8,0,1
 914,239,13.81,10.26,0,1
 914,240,23.15,7.53,0,1
 914,241,15.82,0.41,0,1
 914,1000,23.75,-1.59,0,1
 914,1186,22.32,0.76,0,1
 914,1709,30.64,0.5,0,1
 915,237,33.52,-0.91,0,1
 915,238,39.91,0.8,0,1
 915,239,20.38,9.45,0,1
 915,240,27.93,6.86,0,1
 915,241,16.1,0.41,0,1
 915,1000,18.96,-8.85,0,1
 915,1186,22.83,0.76,0,1
 915,1187,20.8,-0.07,0,1
 915,1709,30.98,0.5,0,1
 915,1710,33.48,-0.27,0,1
 916,237,33.52,0.91,0,1
 916,238,40.46,0.8,0,1
 916,239,24.89,4.42,0,1
 916,240,32.32,6.31,0,1
 916,241,16.38,0.41,0,1
 916,1000,12.93,-8.85,0,1
 916,1186,22.32,-0.76,0,1
 916,1187,20.51,-0.84,0,1
 916,1709,31.32,0.5,0,1
 916,1710,33.33,-0.21,0,1
 917,237,34.15,0.91,0,1
 917,238,41.08,0,1
 917,239,25.5,0.89,0,1
 917,240,32.74,0.61,0,1
 917,241,18.81,6.74,0,1
 917,1000,6.9,-8.85,0,1
 917,1186,21.81,-0.76,0,1
 917,1187,19.94,-0.84,0,1
 917,1709,31.66,0.5,0,1
 917,1710,33.22,-0.15,0,1
 918,237,34.77,0.91,0,1
 918,238,41.54,0.8,0,1
 918,239,26.1,0.89,0,1
 918,240,33.16,0.61,0,1
 918,241,23.11,6.19,0,1
 918,242,23.6,0.85,0,1
 918,1000,2.2,-4.94,0,1
 918,1186,21.61,-0.19,0,1
 918,1187,19.37,-0.84,0,1
 918,1709,31.32,-0.5,0,1
 918,1710,33.13,-0.15,0,1
 919,171,3.91,11.48,0,1
 919,237,35.39,0.91,0,1
 919,238,42.09,0.8,0,1
 919,239,26.71,0.89,0,1
 919,240,33.57,0.61,0,1
 919,241,27.07,5.66,0,1

919,242,24.18,0.85,0,1
 919,243,15.94,0.6,0,1
 919,1000,0.95,-2.02,0,1
 919,1186,23.97,7.02,0,1
 919,1187,19.94,0.84,0,1
 919,1709,30.98,-0.5,0,1
 919,1710,33,-0.21,0,1
 920,171,10.09,8.77,0,1
 920,237,34.77,-0.91,0,1
 920,238,42.09,-0.8,0,1
 920,239,27.31,0.89,0,1
 920,240,33.99,0.61,0,1
 920,241,27.35,0.41,0,1
 920,242,29.88,8.18,0,1
 920,243,16.35,0.6,0,1
 920,1000,0,-1.28,0,1
 920,1186,28.45,6.43,0,1
 920,1187,20.51,0.84,0,1
 920,1709,30.64,-0.5,0,1
 920,1710,32.81,-0.3,0,1
 . . .
 . . .
 (Similar Trend Continues)
 . . .
 . . .
 4498,6,14.8,0,0,1
 4498,18,21.17,0,0,1
 4498,19,3.09,9.07,0,1
 4498,69,23.58,0,0,1
 4498,103,28.38,6.15,0,1
 4498,132,0,0,0,1
 4498,134,0,0,0,1
 4498,135,1.59,-1.69,0,1
 4498,161,0,0,0,1
 4498,187,26.8,0,0,1
 4498,230,0,0,0,1
 4498,231,0,0,0,1
 4498,234,18.45,-8.16,0,1
 4498,236,18.77,2.68,0,1
 4498,255,0,0,0,1
 4498,260,0,0,0,1
 4498,381,0,0,0,1
 4498,784,0,0,0,1
 4498,848,0,0,0,1
 4498,911,30.62,-2.34,0,1
 4498,912,14.09,-7.59,0,1
 4498,915,5.37,0,0,1
 4498,917,24.29,0,0,1
 4498,918,20.74,0,0,1
 4498,919,2.21,-8.01,0,1
 4498,920,5.46,-0.07,0,1
 4498,921,12.86,8.52,0,1
 4498,923,18.75,0,0,1
 4498,924,6.03,-0.02,0,1
 4498,925,4.57,11.42,0,1
 4498,926,11.52,0,0,1
 4498,927,11.04,-11.32,0,1
 4498,928,24.92,0.01,0,1
 4498,929,20.4,-0.8,0,1
 4498,930,20.17,-0.45,0,1
 4498,931,26.8,-2.38,0,1
 4498,932,30.76,0,0,1
 4498,933,29.44,-0.47,0,1
 4498,934,0,-0.37,0,1
 4498,935,36.17,-2.36,0,1
 4498,936,23.84,6.11,0,1
 4498,937,0.8,-2.19,0,1
 4498,938,35.67,0.49,0,1
 4498,939,31.51,0,0,1
 4498,940,28.78,-0.48,0,1

4498,941,37.83,-0.63,0,1
4498,942,35.48,-0.32,0,1
4498,943,38.28,0.81,0,1
4498,1160,0,0,0,1
4498,1167,0,0,0,1
4498,1180,0,0,0,1
4498,1181,0.46,-1.58,0,1
4498,1183,24.93,0,0,1
4498,1184,10.39,-8.43,0,1
4498,1185,20.66,0.5,0,1
4498,1519,0,0,0,1
4498,1590,2.93,0,0,1
4498,1594,21.59,6.86,0,1
4498,1595,27.2,0,0,1
4498,1598,15.54,-8.5,0,1
4498,1600,7.62,10.88,0,1
4498,1601,3.32,-0.31,0,1
4498,1604,0,0,0,1
4498,1606,2.07,-1.16,0,1
4498,1607,16.16,-0.74,0,1
4498,1608,37.38,0.43,0,1
4498,1609,26.32,-1.31,0,1
4498,1610,31.77,-0.13,0,1
4498,1613,0,-0.13,0,1
4498,1614,26.4,0,0,1
4498,1615,11.53,-7.02,0,1
4498,1616,4.5,-2.54,0,1
4498,1617,3.77,6.53,0,1
4498,1618,3.07,-0.54,0,1
4498,1619,4.92,10.8,0,1
4498,1620,2.27,-3.84,0,1
4498,1621,3.79,-0.02,0,1
4498,1622,4.02,-0.29,0,1
4498,1623,0,0,0,1
4498,1624,4.69,-0.48,0,1
4498,1625,2.65,0.97,0,1
4498,1626,2.01,-0.22,0,1
4498,1627,2.29,-0.15,0,1
4498,1628,2.48,-0.01,0,1
4498,1629,2.47,0.24,0,1
4498,1630,2.36,-0.36,0,1
4498,1631,1.96,0.87,0,1
4498,1632,8.17,-0.31,0,1
4498,1633,5.86,-0.08,0,1
4498,1634,0,0,0,1
4498,1635,0,0,0,1
4498,1636,0,0,0,1
4498,1637,0,0,0,1
4498,1638,0,0,0,1
4498,1639,0,0,0,1
4498,1640,0,0,0,1
4498,1641,0,0,0,1
4498,1642,0,0,0,1
4498,1643,0,0,0,1
4498,1644,0,0,0,1
4498,1645,0.72,-1.07,0,1
4498,1646,2.49,-1.7,0,1
4498,1647,5.11,6.97,0,1
4498,1648,1.93,-3.21,0,1
4498,1649,3.08,-0.66,0,1
4498,1650,2.26,-1.01,0,1
4498,1651,3.18,-0.61,0,1
4498,1652,1.83,-3.2,0,1
4498,1653,2.38,1.22,0,1
4498,1654,2,-1.04,0,1
4498,1655,2.5,1.48,0,1
4498,1656,1.24,-1.5,0,1
4498,1657,5.14,6,0,1
4498,1658,3.72,-0.23,0,1
4498,1659,4.31,-0.3,0,1

4498,2080,0,0,1
4498,2117,16.79,-2.05,0,1
4498,2118,20.95,-0.8,0,1
4498,2119,20.39,-3.69,0,1
4498,2120,23.27,8.12,0,1
4498,2121,1.39,-0.77,0,1
4498,2122,3.31,-1.61,0,1
4498,2124,12.95,8.58,0,1
4498,2125,29.72,-1.59,0,1
4498,2126,0.95,-0.62,0,1
4498,2127,2.33,2.48,0,1
4498,2128,3.04,-1.31,0,1
4498,2129,14.13,-0.95,0,1
4498,2130,12.57,-1.54,0,1
4498,2132,25.93,-1.9,0,1
4498,2133,27.17,-0.46,0,1
4498,2134,19.7,9,0,1
4498,2135,6.27,6.91,0,1
4498,2136,20.88,-0.15,0,1
4498,2137,24.4,-0.13,0,1
4498,2138,25.45,-0.57,0,1
4498,2139,34.34,-0.5,0,1
4498,2140,34.32,0.65,0,1
4498,2141,30.62,-0.89,0,1
4498,2142,32.29,0.77,0,1
4498,2173,23.63,-1.77,0,1
4498,2174,37.88,-0.85,0,1
4499,6,14.8,0,0,1
4499,18,21.17,0,0,1
4499,19,1.71,-1.75,0,1
4499,69,23.58,0,0,1
4499,103,32.01,4.72,0,1
4499,132,0,0,0,1
4499,134,0,0,0,1
4499,135,0.3,-1.77,0,1
4499,161,0,0,0,1
4499,187,25.44,-3.99,0,1
4499,230,0,0,0,1
4499,231,0,0,0,1
4499,234,13.7,-7.16,0,1
4499,236,15.3,-7.55,0,1
4499,255,0,0,0,1
4499,260,0,0,0,1
4499,381,0,0,0,1
4499,784,0,0,0,1
4499,848,0,0,0,1
4499,911,25.02,-8.49,0,1
4499,912,8.92,-7.59,0,1
4499,915,5.37,0,0,1
4499,917,24.29,0,0,1
4499,918,20.74,0,0,1
4499,919,1.04,-1.82,0,1
4499,920,5.4,-0.08,0,1
4499,921,18.16,7.58,0,1
4499,923,18.39,-0.5,0,1
4499,924,6.02,-0.02,0,1
4499,925,5.79,-3.96,0,1
4499,926,11.52,0,0,1
4499,927,3.32,-11.32,0,1
4499,928,24.92,0,0,1
4499,929,19.86,-0.8,0,1
4499,930,15.19,-7.59,0,1
4499,931,22.15,-6.96,0,1
4499,932,30.76,0,0,1
4499,933,29.09,-0.53,0,1
4499,934,3.66,10.75,0,1
4499,935,34.7,-3.93,0,1
4499,936,25.4,1.53,0,1
4499,937,0,-0.53,0,1
4499,938,35.79,0.12,0,1

4499,939,31.51,0,0,1
4499,940,28.45,-0.48,0,1
4499,941,37.4,-0.63,0,1
4499,942,35.25,-0.36,0,1
4499,943,37.73,-0.81,0,1
4499,1160,0,0,0,1
4499,1167,0,0,0,1
4499,1180,0,0,0,1
4499,1181,0,-0.09,0,1
4499,1183,24.93,0,0,1
4499,1184,4.64,-8.43,0,1
4499,1185,21.05,0,1
4499,1519,0,0,0,1
4499,1590,2.91,-0.03,0,1
4499,1594,22.35,-4.34,0,1
4499,1595,27.2,0,0,1
4499,1598,9.75,-8.5,0,1
4499,1600,14.34,9.49,0,1
4499,1601,2.22,-1.36,0,1
4499,1604,0,0,0,1
4499,1606,1.48,-0.54,0,1
4499,1607,15.62,-0.8,0,1
4499,1608,37.67,0.43,0,1
4499,1609,25.63,-1.28,0,1
4499,1610,31.66,-0.17,0,1
4499,1614,24.96,-4.23,0,1
4499,1615,6.75,-7.02,0,1
4499,1616,2.76,-2.54,0,1
4499,1617,3.2,1.05,0,1
4499,1618,1.79,-3.22,0,1
4499,1619,4.18,-1.13,0,1
4499,1620,1.78,-1.13,0,1
4499,1621,5.24,6.78,0,1
4499,1622,2.43,-2.66,0,1
4499,1623,0,0,0,1
4499,1624,3.27,-2.18,0,1
4499,1625,3.54,-2.01,0,1
4499,1626,3.27,2.13,0,1
4499,1627,2.14,-0.14,0,1
4499,1628,2.36,-0.34,0,1
4499,1629,2.46,-0.01,0,1
4499,1630,2.13,-0.31,0,1
4499,1631,2.16,0.02,0,1
4499,1632,7.84,-0.46,0,1
4499,1633,5.77,-0.12,0,1
4499,1634,1.86,5.44,0,1
4499,1635,0,0,0,1
4499,1636,0,0,0,1
4499,1637,0,0,0,1
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4499,1641,0,0,0,1
4499,1642,0,0,0,1
4499,1643,0,0,0,1
4499,1644,0,0,0,1
4499,1645,0,-1,0,1
4499,1646,1.14,-1.91,0,1
4499,1647,3.62,-2.14,0,1
4499,1648,3.27,-2.44,0,1
4499,1649,1.57,-0.44,0,1
4499,1650,4.81,5.82,0,1
4499,1651,2.39,-0.61,0,1
4499,1652,4.51,-0.28,0,1
4499,1653,3.99,-0.36,0,1
4499,1654,1.65,-0.44,0,1
4499,1655,4.33,-1.42,0,1
4499,1656,2.81,4.71,0,1
4499,1657,2.88,-1.64,0,1
4499,1658,1.97,-5.01,0,1

4499,1659,4.07,-0.29,0,1
4499,2080,0,0,0,1
4499,2117,11.62,-7.58,0,1
4499,2118,20.41,-0.8,0,1
4499,2119,14.78,-8.23,0,1
4499,2120,21.96,-4,0,1
4499,2121,0.57,-1.26,0,1
4499,2122,2.49,-1.19,0,1
4499,2124,18.29,7.63,0,1
4499,2125,31.55,1.8,0,1
4499,2126,5.96,10.73,0,1
4499,2127,2.83,1.81,0,1
4499,2128,2.65,-0.74,0,1
4499,2129,13.42,-1.05,0,1
4499,2130,11.41,-1.72,0,1
4499,2132,24.96,-1.83,0,1
4499,2133,26.83,-0.51,0,1
4499,2134,23.8,7.18,0,1
4499,2135,3.53,-4.02,0,1
4499,2136,20.49,-0.57,0,1
4499,2137,24.3,-0.15,0,1
4499,2138,25.06,-0.57,0,1
4499,2139,33.97,-0.55,0,1
4499,2140,34.77,0.65,0,1
4499,2141,30.01,-0.89,0,1
4499,2142,32.81,0.77,0,1
4499,2143,31.14,-0.08,0,1
4499,2173,22.31,-2.01,0,1
4499,2174,37.3,-0.85,0,1
4500,6,14.8,0,0,1
4500,18,21.17,0,0,1
4500,19,1.15,-0.68,0,1
4500,69,21.17,-5.16,0,1
4500,103,33.22,1.18,0,1
4500,132,0,0,0,1
4500,134,0,0,0,1
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4500,161,0,0,0,1
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4500,381,0,0,0,1
4500,784,0,0,0,1
4500,848,0,0,0,1
4500,911,20.16,-5.49,0,1
4500,912,3.74,-7.59,0,1
4500,915,5.37,0,0,1
4500,917,22.19,-4.9,0,1
4500,918,17.1,-8.04,0,1
4500,919,0,-1.36,0,1
4500,920,5.35,-0.08,0,1
4500,921,22.69,6.08,0,1
4500,923,16.69,-2.51,0,1
4500,924,6,-0.03,0,1
4500,925,3.09,-3.96,0,1
4500,926,11.52,0,0,1
4500,927,0.42,-4.56,0,1
4500,928,24.92,0,0,1
4500,929,19.31,-0.8,0,1
4500,930,14.87,7.3,0,1
4500,931,18.13,-4.55,0,1
4500,932,30.76,0,0,1
4500,933,26.95,-3.05,0,1
4500,934,10.36,9.5,0,1
4500,935,30.61,-4.34,0,1
4500,936,25.79,0.38,0,1

4500,937,2.79,8.19,0,1
4500,938,31.79,-5.26,0,1
4500,939,30.49,-1.31,0,1
4500,940,28.13,-0.48,0,1
4500,941,36.97,-0.63,0,1
4500,942,34.98,-0.39,0,1
4500,943,37.18,-0.81,0,1
4500,1160,0,0,0,1
4500,1167,0,0,0,1
4500,1180,0,0,0,1
4500,1181,0,0,0,1
4500,1183,24.93,0,0,1
4500,1184,1.68,-1.64,0,1
4500,1185,21.26,0.25,0,1
4500,1519,0,0,0,1
4500,1590,4.43,4.55,0,1
4500,1594,19.23,-4.66,0,1
4500,1595,25.04,-4.9,0,1
4500,1598,3.95,-8.5,0,1
4500,1600,20.24,8.4,0,1
4500,1601,3.64,4.1,0,1
4500,1604,0,0,0,1
4500,1606,4.67,9.36,0,1
4500,1607,15.05,-0.85,0,1
4500,1608,37.97,0.43,0,1
4500,1609,24.97,-1.01,0,1
4500,1610,31.52,-0.22,0,1
4500,1614,19.48,-9.38,0,1
4500,1615,2.24,-6.21,0,1
4500,1616,1.5,-1.2,0,1
4500,1617,5.26,6.11,0,1
4500,1618,1.67,-0.12,0,1
4500,1619,2.5,-0.74,0,1
4500,1620,2.76,-4.39,0,1
4500,1621,3.17,-2.13,0,1
4500,1622,1.86,-3.95,0,1
4500,1623,0,0,0,1
4500,1624,3.12,-0.18,0,1
4500,1625,3.52,-0.04,0,1
4500,1626,3.81,-0.03,0,1
4500,1627,3.07,2.78,0,1
4500,1628,2.27,-0.09,0,1
4500,1629,2.46,-0.01,0,1
4500,1630,1.98,-0.17,0,1
4500,1631,2.16,0,0,1
4500,1632,7.6,-0.23,0,1
4500,1633,5.71,-0.07,0,1
4500,1634,4.32,5.85,0,1
4500,1635,1.23,3.6,0,1
4500,1636,0,0,0,1
4500,1637,0,0,0,1
4500,1638,0,0,0,1
4500,1639,0,0,0,1
4500,1640,0,0,0,1
4500,1641,0,0,0,1
4500,1642,0,0,0,1
4500,1643,0,0,0,1
4500,1644,0,0,0,1
4500,1645,0,0,0,1
4500,1646,0.31,-0.65,0,1
4500,1647,2.87,-6.46,0,1
4500,1648,5.31,8.14,0,1
4500,1649,4.54,11.33,0,1
4500,1650,2.66,-2.88,0,1
4500,1651,0.97,-3.71,0,1
4500,1652,3.78,-1.73,0,1
4500,1653,3.57,-0.65,0,1
4500,1654,2.16,2.07,0,1
4500,1655,3.27,-1.69,0,1
4500,1656,3.66,4.04,0,1

4500,1657,2.07,-1.93,0,1
 4500,1658,4.59,-2.29,0,1
 4500,1659,11,9.83,0,1
 4500,2080,0,0,0,1
 4500,2117,6.45,-7.58,0,1
 4500,2118,19.86,-0.8,0,1
 4500,2119,9.17,-8.23,0,1
 4500,2120,16.96,-8.46,0,1
 4500,2121,0,-0.51,0,1
 4500,2122,1.67,-1.19,0,1
 4500,2124,14.96,-4.99,0,1
 4500,2125,32.01,0.45,0,1
 4500,2126,4.1,-2.73,0,1
 4500,2127,2.79,-0.12,0,1
 4500,2128,2.36,-0.42,0,1
 4500,2129,12.66,-1.13,0,1
 4500,2130,10.17,-1.86,0,1
 4500,2132,24.02,-1.44,0,1
 4500,2133,26.42,-0.64,0,1
 4500,2134,28.38,6.57,0,1
 4500,2135,1.64,-1.53,0,1
 4500,2136,20.1,-0.57,0,1
 4500,2137,24.18,-0.19,0,1
 4500,2138,24.67,-0.57,0,1
 4500,2139,33.58,-0.6,0,1
 4500,2140,34.32,-0.65,0,1
 4500,2141,28.53,-3.46,0,1
 4500,2142,33.34,0.77,0,1
 4500,2143,30.52,-0.92,0,1
 4500,2173,20.77,-2.34,0,1
 4500,2174,36.71,-0.85,0,1

Appendix O: Partial Sample CMEM Vehicle Model Run File

The text below is a partial sample of the Vehicle Model Run File (-rnb) which is generated by CMEM. It contains a summary of the input and output files, vehicle IDs and settings, and category parameters.

```

*           Comprehensive Modal Emissions Model           *
*                                     *
*           Version 2.02  August  2001           *
*                                     *
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*                                     *
*                                     *
*****
  
```

Input Files

Control File: test2-ctb
Activity File: test2-atb
Definition File: test2-def

Output Files

Model Run File: test2-rnb
Summary File: test2-smb
Sec-by-Sec File: test2-ssb

Id 1: Using given acceleration
Id 2: Using given acceleration
Id 3: Using given acceleration
Id 4: Using given acceleration
Id 5: Using given acceleration
Id 6: Using given acceleration
Id 7: Using given acceleration
Id 8: Using given acceleration
Id 9: Using given acceleration
Id 10: Using given acceleration
.....(Same trend continues)....
Id 2164: Using given acceleration
Id 2165: Using given acceleration
Id 2166: Using given acceleration
Id 2167: Using given acceleration
Id 2168: Using given acceleration
Id 2169: Using given acceleration
Id 2170: Using given acceleration
Id 2171: Using given acceleration
Id 2172: Using given acceleration
Id 2173: Using given acceleration
Id 2174: Using given acceleration
IN_UNITS set to ENGLISH
OUT_UNITS set to ENGLISH

Overwritten Parameters by Category

Id Categories

Id 1 Category set to 10
Id 2 Category set to 10
Id 3 Category set to 26
Id 4 Category set to 8
Id 5 Category set to 24
Id 6 Category set to 17
Id 7 Category set to 26
Id 8 Category set to 22
Id 9 Category set to 22
Id 10 Category set to 26
.....(Same trend continues)....

Id Fuel Type

Id 1 Fuel Type set to gasoline
Id 2 Fuel Type set to gasoline
Id 3 Fuel Type set to gasoline
Id 4 Fuel Type set to gasoline
Id 5 Fuel Type set to gasoline
Id 6 Fuel Type set to gasoline
Id 7 Fuel Type set to gasoline
Id 8 Fuel Type set to gasoline
Id 9 Fuel Type set to gasoline
Id 10 Fuel Type set to gasoline
.....(Same Trend Continues)....

Id 1

Condition Parameters

Tsoak = 967

SH = 75.00

Vehicle Parameters

Ed = 2.14
Masslb = 2955.36
Trlhp = 11.51
S = 38.15
Nm = 3218
Qm = 125.42
Zmax = 108.21
Np = 5011
Idle = 871.00
ng = 4
Sload = 3.42

Calibrated Parameters

K_0 = 0.2364
Edt3 = 0.1000
C0 = 3.6929
aCO = 0.0908
aHC = 0.0095
rHC = 0.0028
aNO1 = 0.0363
aNO2 = 0.0325
FRNO1 = -0.3061
FRNO2 = 0.1849
MAXCO = 99.9749
MAXHC = 99.8272
MAXNO = 99.8460
bCO = 0.0958
cCO = 0.9564
bHC = 0.0213
cHC = 0.3568
bNO = 0.8650
cNO = 1.4750
Lamb_0 = 1.2348
lam_m = 0.1228
Pscale = 1.3120
maxhc = 0.0631
hc_jk = 4.8037
r_R = 0.3006
spd_th = 106.3888
rO2 = 50.4484
COB1 = 9.3302
HCB1 = 10.4121
NOB1 = 6.2056
lam_cold = 1.1454
csHC = 4.5515
csNO = 4.8408
Tlamb = 50.2254
id = 0.0716
Csoak_co = 280.6832
Csoak_hc = 15.1177
Csoak_no = 399.9964
Bcat_co = 224.8712
Bcat_hc = 239.9966
Bcat_no = 0.2637
Edt1 = 0.9178
NH3_b = 100.0000
NH3_s1 = 2.0000
NH3_s2 = 3.4000
NH3_i = 0.0450

Id 2

Condition Parameters

Tsoak = 161
SH = 75.00

Vehicle Parameters

Ed = 2.14
 Masslb = 2955.36
 Trlhp = 11.51
 S = 38.15
 Nm = 3218
 Qm = 125.42
 Zmax = 108.21
 Np = 5011
 Idle = 871.00
 ng = 4
 Sload = 3.42

Calibrated Parameters

K_0 = 0.2364
 Edt3 = 0.1000
 C0 = 3.6929
 aCO = 0.0908
 aHC = 0.0095
 rHC = 0.0028
 aNO1 = 0.0363
 aNO2 = 0.0325
 FRNO1 = -0.3061
 FRNO2 = 0.1849
 MAXCO = 99.9749
 MAXHC = 99.8272
 MAXNO = 99.8460
 bCO = 0.0958
 cCO = 0.9564
 bHC = 0.0213
 cHC = 0.3568
 bNO = 0.8650
 cNO = 1.4750
 Lamb_0 = 1.2348
 lam_m = 0.1228
 Pscale = 1.3120
 maxhc = 0.0631
 hc_jk = 4.8037
 r_R = 0.3006
 spd_th = 106.3888
 rO2 = 50.4484
 COB1 = 9.3302
 HCB1 = 10.4121
 NOB1 = 6.2056
 lam_cold = 1.1454
 csHC = 4.5515
 csNO = 4.8408
 Tlamb = 50.2254
 id = 0.0716
 Csoak_co = 280.6832
 Csoak_hc = 15.1177
 Csoak_no = 399.9964
 Bcat_co = 224.8712
 Bcat_hc = 239.9966
 Bcat_no = 0.2637
 Edt1 = 0.9178
 NH3_b = 100.0000
 NH3_s1 = 2.0000
 NH3_s2 = 3.4000
 NH3_i = 0.0450

Id 3

Condition Parameters

Tsoak = 413
 SH = 75.00

Vehicle Parameters

Ed = 2.50
 Masslb = 3118.00
 Trlhp = 12.14

S = 25.39
 Nm = 3300
 Qm = 142.00
 Zmax = 153.50
 Np = 5250
 Idle = 967.00
 ng = 4
 Sload = 0.00

Calibrated Parameters

K_0 = 0.1628
 Edt3 = 0.0998
 C0 = 3.4397
 aCO = 0.0439
 aHC = 0.0001
 rHC = 0.0121
 aNO1 = 0.0259
 aNO2 = 0.0210
 FRNO1 = -0.4770
 FRNO2 = 0.4501
 MAXCO = 99.9000
 MAXHC = 99.9000
 MAXNO = 99.9000
 bCO = 0.0558
 cCO = 0.0702
 bHC = 0.0114
 cHC = 0.5523
 bNO = 3.5263
 cNO = 1.8926
 Lamb_0 = 1.2640
 lam_m = 0.9000
 Pscale = 1.7869
 maxhc = 0.0000
 hc_jk = 0.5000
 r_R = 0.1090
 spd_th = 2.4502
 rO2 = 1.0000
 COB1 = 1.2778
 HCB1 = 257.3869
 NOB1 = 255.7078
 lam_cold = 1.2500
 csHC = 12.3901
 csNO = 72.8559
 Tlamb = 37.6651
 id = 0.1155
 Csoak_co = 253.0160
 Csoak_hc = 200.0023
 Csoak_no = 20.1941
 Bcat_co = 133.0843
 Bcat_hc = 239.9024
 Bcat_no = 132.0022
 Edt1 = 0.8265
 NH3_b = 100.0000
 NH3_s1 = 2.0000
 NH3_s2 = 3.4000
 NH3_i = 0.0450
 ...(Same Trend Continues)...

Appendix P: Partial Sample CMEM Vehicle Summary File

The chart below is a partial sample of the Emissions Summary file (-smb) which is generated by CMEM.

The first half contains a summary of miles traveled per vehicle and the second half contains a summary of emissions per vehicle in grams per mile.

Batch Run Emission Summary File

Distances Traveled (miles)

Id 1 traveled	1.24
Id 2 traveled	1.38
Id 3 traveled	1.39
Id 4 traveled	1.64
Id 5 traveled	1.79
Id 6 traveled	0.28
Id 7 traveled	0.88
Id 8 traveled	0.86
Id 9 traveled	1.09
Id 10 traveled	2.78

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(Same trend continues)

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Id 2164 traveled	1.59
Id 2165 traveled	1.19
Id 2166 traveled	1.67
Id 2167 traveled	0.21
Id 2168 traveled	1.59
Id 2169 traveled	2.11
Id 2170 traveled	0.21
Id 2171 traveled	1.49
Id 2172 traveled	1.47
Id 2173 traveled	1.39
Id 2174 traveled	0.19

Emissions Summary (grams/mile)

Id	Cat	HC	CO	NOx	fuel
1	10	1.433	55.39	3.13	260.4
2	10	0.405	6.86	1.16	222.2
3	26	0.762	2.32	20.04	174.3
4	8	0.850	74.49	1.97	230.3
5	24	1.371	23.16	2.06	232.5
6	17	9.735	81.00	9.39	342.6
7	26	0.870	11.40	39.79	214.5
8	22	9.796	119.78	8.17	246.3
9	22	18.227	179.88	11.16	410.5
10	26	0.150	0.92	7.85	138.9

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(Same trend continues)

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2164	24	1.912	19.15	1.24	196.6
2165	15	4.450	31.61	1.88	149.2
2166	21	3.890	40.36	2.17	188.5
2167	26	10.416	9.39	2.52	54.8
2168	24	2.239	46.34	2.11	210.8
2169	10	1.287	34.42	1.12	188.2
2170	4	15.266	52.60	3.24	101.6
2171	24	2.144	19.87	1.73	174.8
2172	26	1.162	7.15	18.17	155.9
2173	24	1.463	41.39	2.17	168.4
2174	24	8.762	58.19	7.22	122.5

Appendix Q: Partial Sample Emissions Summary Output

When the product of miles traveled and emissions per mile is taken, the result is the total emission per

vehicle. These emissions are summed to obtain total emissions for a simulation run or scenario. The table

below shows a partial summary of total emissions per vehicle as well as the summation of all rows.

Emissions Id	Summary Cat	HC	CO	NOx	fuel
1	10	1.77692	68.6836	3.8812	322.896
2	10	0.5589	9.4668	1.6008	306.636
3	26	1.05918	3.2248	27.8556	242.277
4	8	1.394	122.1636	3.2308	377.692
5	24	2.45409	41.4564	3.6874	416.175
6	17	2.7258	22.68	2.6292	95.928
7	26	0.7656	10.032	35.0152	188.76
8	22	8.42456	103.0108	7.0262	211.818
9	22	19.86743	196.0692	12.1644	447.445
10	26	0.417	2.5576	21.823	386.142
Similar Trend Continues	.....	.....	.....	.....	.....
2164	24	3.04008	30.4485	1.9716	312.594
2165	15	5.2955	37.6159	2.2372	177.548
2166	21	6.4963	67.4012	3.6239	314.795
2167	26	2.18736	1.9719	0.5292	11.508
2168	24	3.56001	73.6806	3.3549	335.172
2169	10	2.71557	72.6262	2.3632	397.102
2170	4	3.20586	11.046	0.6804	21.336
2171	24	3.19456	29.6063	2.5777	260.452
2172	26	1.70814	10.5105	26.7099	229.173
2173	24	2.03357	57.5321	3.0163	234.076
2174	24	1.66478	11.0561	1.3718	23.275
Totals		7975.08	99435.92	7629.258	436854.3

Appendix R: Additional Background Information

The following studies relate to measuring emissions and parking decisions.

Emissions Modeling

In 2009, a team of researchers from North Carolina State University studied vehicle-specific emissions based on field measurements of hot-stabilized tailpipe measurements using portable emissions measurement system (PEMS) devices. This research was done to create knowledge for more effective air-quality management and to improve emissions estimates at the microscale level.

More specifically, the researchers focused on evaluating alternative microscale models based on externally observable variables (EOVs) versus internally observable variables (IOVs) as well as vehicle-specific models versus fleet average models. They compared the data in these microscale models to data collected in the field from PEMS devices which captured emissions levels of nitrogen monoxide (NO), hydrocarbons (HC), carbon monoxide (CO) and carbon dioxide (CO₂). In modeling IOVs, the researchers used engine speed and manifold absolute pressure (MAP) data to calculate emissions because they are significant factors in fuel injection control and are strongly influenced by vehicle dynamics (Frey, Zhang, & Roupail 2010). A vehicle specific power (VSP) modal approach was used to model EOVs because of the strong positive relationship of vehicle emissions to fuel use. The VSP approach uses speed, acceleration, and road grade as EOVs, from which emissions were calculated.

By using parity plots to compare predicted versus actual emissions levels, it was found that the IOV models were fairly accurate in predicting emissions levels but ineffective at being precise and capturing variability among different vehicles. On the other hand, the EOv models were found to be less accurate and less precise at predicting emissions levels than the IOV models. The researchers also concluded that EOv models may be more practical in simulation, since IOVs are not usually available for use in simulation models. The efficiency of each vehicle's catalytic converter is a lurking variable that influences tailpipe emissions and the IOV and EOv models, but it was unexplored because it was difficult to quantify with the resources at hand. In comparing vehicle specific models and fleet average models to validated emissions, the researchers found little difference in which model was used. The fleet average models seemed to capture most variability.

Parking Decisions

In 2002, researchers from the University of Massachusetts at Amherst, Virginia Tech, and 3M collaborated to study behavior rules that determine drivers' choices of parking lots. In particular, they designed a simulated driving environment where test subjects made decisions on where to park as they passed a variable message sign. This sign displayed counts of vacancies for several nearby lots downstream.

Previous studies had indicated that drivers made parking decisions based off the expected utility of parking in the current lot and the next available lot. If the driver determined the current lot was full, they would have to make a decision to visit the next available lot and compute another expected utility. One of three main objectives made up a driver's expected utility: 1) minimize expected travel time (METT), 2) minimize walking distance (MWD), 3) maximize parking availability (MPA). Depending on which objective a driver favored, their expected utility function led to different outcomes. The researchers tested multiple versions of the expected utility theory and found that the objective to minimize expected travel time (METT) was most prominent. They found weakness in their tests in that participants may choose different combinations of objectives from one scenario to the next (some data sets indicated a key objective was to minimize walking distance).

To test a hypothesis that drivers make parking decisions based on a partially-computed probability in conjunction with the cognitive load of the driving task, the researchers proposed a lexicographic decision rule. This rule stated that a driver would first consider their destination lot or lot closest to their destination. If the indicated number of open spaces in the destination lot was at or above some criterion, x_d , then they would park in that lot. Otherwise they would park elsewhere and the process would repeat itself with each additional lot until they driver chose a lot. The criterion, x_d , varied inversely with the distance to the next available lot downstream;--the further away the next open lot, the smaller the criterion (Hester, Fischer, & Collura, 2002). In testing this hypothesis the researchers found the lexicographic strategy was more accurate in determining drivers' parking decisions because it employed both multiple objectives (METT and MWD are accounted for in a driver's initial lot choice before interacting with the sign). The researchers also acknowledged several other variables of potential influence: driver familiarity, cognitive load, driver age, weather, and driver disabilities.