Environmental Impacts of a Major Freight Corridor: A study of the I-710 in California

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ABSTRACT

The San Pedro Bay Ports (SPBP) of Los Angeles and Long Beach in Southern California comprise one of the largest container port complexes in the world. The SPBP contribute significantly to both regional and national economies in California, and the US, respectively. However, the ongoing growth and economic benefits of the SPBP are threatened by negative externalities associated with port operations, particularly increasing congestion and air pollution. The objective of this paper is to explore a new approach to estimating vehicle emission impacts of freight corridor operations related to the port area, particularly those associated with heavy duty diesel trucks. The approach involves use of a microscopic traffic simulation model to capture detailed vehicle trajectories and congestion effects (ultimately including the effects of Intelligent Transportation System strategies), emissions modeling, and modeling the spatial dispersion of pollutants in the corridor, to facilitate estimation of the health and environmental justice impacts of freight corridor operations. In this paper we focus on operation of the I-710 freeway in the Alameda Corridor, leading from the SPBP area for about 20 miles toward Los Angeles. In a parallel effort we are also studying rail operations in the same corridor. In the future both the rail and highway elements will be combined to form an integrated, overall assessment of air quality impacts in the corridor. In this paper, seven scenarios were evaluated in addition to the 2005 Base Scenario: replacement of the current fleet of port heavy duty diesel trucks with zero emission trucks (25%, 50%, and 100% of port trucks), elimination of port heavy duty diesel truck trips (25%, 50%, and 100% reductions) that would correspond to shifting more containers to other modes such as rail, and implementation of a truck restricted-lane on I-710 preventing trucks from using the left most lanes. The results show that fleet replacement with cleaner trucks yields the most emission reductions both quantitatively and spatially.

INTRODUCTION

The San Pedro Bay Ports (SPBP) of Los Angeles and Long Beach in Southern California is one of the major container port complexes in the world: in 2005, for example, the SPBP processed over 40% of the U.S. container trade. The SPBP complex is a major contributor to the economy, at the regional and national levels: a 2007 trade impact study *(1)* released by the Alameda Corridor Transportation Authority (ACTA) shows that over 886,000 California jobs depend on international trade activities conducted through the SPBP, which also generated more than $6.7 billion in state and local tax revenues. Container traffic at the ports has soared in recent years (+65% from 2000 to 2007), and it is expected to continue expanding into the next decade once the economy recovers. One key factor explaining the success of the SPBP is its accessibility, as it is served by two major freeways (the I-710 and the I-110) and by the Alameda Corridor rail line.

However, this growth and its associated economic benefits are threatened by increasing congestion and air pollution. In fact, the SPBP complex is a major contributor to air pollution: one-third of all goods movement emissions statewide are generated in the Los Angeles region. In addition, more than 400 tons of NO, an ozone precursor, are emitted by the SPBP and the associated movement of goods; this represents approximately 10% of the statewide NO inventory *(2)*. Particulate matter (PM) emissions from diesel engines are another problem because PM adversely affects public health, causing respiratory problems and premature death *(3)*. According to the South Coast Air Quality Management District's MATES II study *(4)*, PM emissions are responsible for 70% of the region's lifetime cancer risk from toxic air pollutants.

Air pollution in and out of the port area is generated by a number of sources on the ocean-side (ships), within the ports (heavy equipment for moving containers), and on the land-side (diesel locomotives and heavy diesel trucks for transporting containers). On the land-side, major freight corridors like the I-710 and the I-110 directly connect to the SPBP and carry thousands of trucks per day. In particular, 10% to 30% of the I-710 freight corridor daily volume consists of trucks *(5)*. In addition, approximately 94% of total trucks on the I-710 are related to the SPBP *(6)*.

Widespread concerns about air pollution have led to measures to mitigate air quality in the SPBP area. Recently, California state and local government organizations such as the California Air Resource Board (CARB), the Southern California Association of Governments (SCAG), and the SPBP have proposed strategies for reducing air pollution generated by the movement of goods in and out of the SPBP. These plans, which schedule measures over a time horizon extending until 2020, target emission from ships, commercial harbor craft, locomotives, and trucks. In particular, truck emission reduction strategies include replacing older and damaged trucks or retrofitting truck engines, restricting idling time, or even replacing the whole fleet of port trucks, in addition to corridor upgrades *(2, 7, 8, 9, 10)*. Emission impacts of these strategies were estimated using EMFAC, a macroscopic emission tool developed by the California Air Resources Board (CARB) *(11)*.

However, macroscopic emission models cannot capture the emission impacts of vehicle interactions such as stop-and-go situations or individual vehicle acceleration/decelerations as they rely on average vehicle speeds to estimate emissions. As a result, emissions may be significantly over or underestimate emissions when vehicles are driven in a congested environment, as during a peak period, or when speeds vary significantly *(12, 13)*. In addition, the previously-mentioned emission reduction strategies lack analyses of the dispersion of pollutants, which is critical for understanding their health impacts. Dispersion is affected by different factors including land use and meteorological conditions such as temperature and wind direction and speed.

The objective of this paper is to evaluate vehicle emission impacts, particularly those associated with heavy duty diesel trucks, of freight corridor operations related to the SPBP complex. Several scenarios are examined that relate to emission reduction plans, and these are evaluated using a microscopic-level traffic simulator and emission model. The spatial concentration of the vehicle emissions along the freight corridor is also analyzed.

The paper is organized as follows. First, we present background of I-710 freight corridor and an overview of our methodological framework. We then summarize our methodology and the results of our micro-simulations, our emission estimates and the dispersion of the pollutants considered, before presenting our concluding remarks and suggestions for future work.

BACKGROUND

As shown on Figure 1, the SPBP complex is served by two freeways, in addition to the Alameda corridor. To illustrate the value of our methodology, we focused our efforts on the I-710. This north-south freight corridor stretches approximately 20 miles from the Port of Long Beach to the I-5 interchange. Along the way, the I-710 is crossed by four other major freeways: the I-110, the I-105, the SR-91, and the I-405. The I-710 has three lanes in one direction and four in the other, with a posted speed limit of 55 mph.

Our paper is not the first one to study the I-710 freight corridor. Fischer et al. *(28)* suggested implementing truck-only lanes on the I-710 and examined its feasibility. Park et al. *(29)* evaluated implementing truck-restricted lanes and truck-only lanes using a microscopic traffic simulator and the CMEM emission model. They concluded that truck-restricted lanes are better than truck-only lanes for improving traffic conditions and reducing air pollution. Yang and Regan *(30)* performed a similar study; using a macroscopic traffic simulator and CMEM, they examined two cases: trucks restricted from using the left-most lane and the two left-most lanes. They found that the latter is better for improving traffic flow.

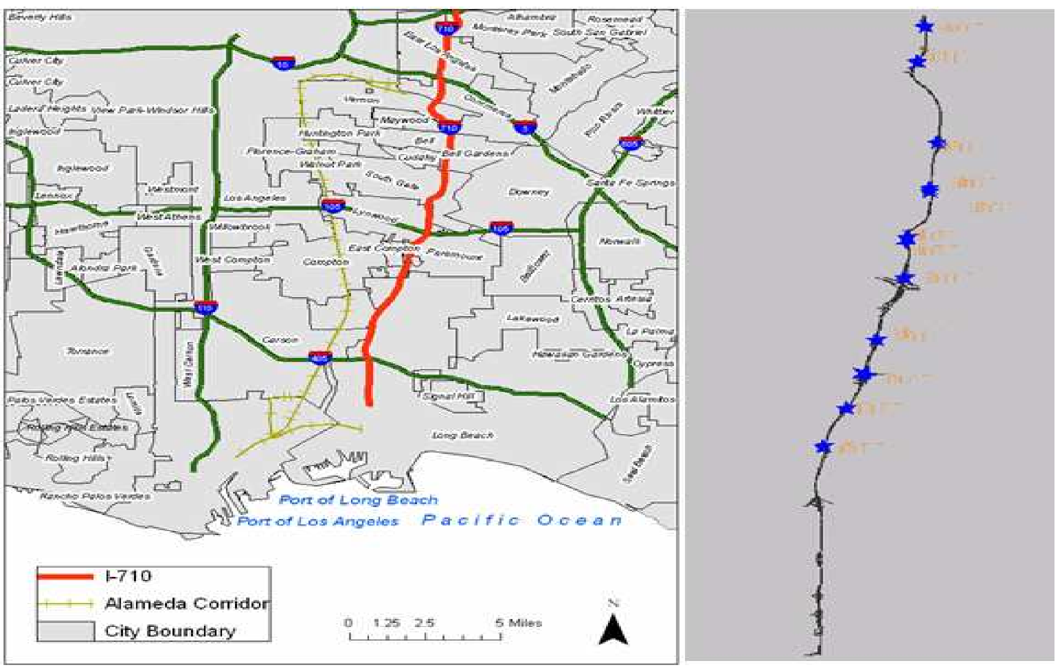


FIGURE 1 Study area (left side) and I-710 network in TransModeler (right side).

MODELING EMISSION IMPACTS: AN OVERVIEW

To analyze the impact of vehicle emissions at a microscopic level, three types of models are required: a microscopic traffic simulation model, a model to generate emissions of various pollutants, and a dispersion model. Figure 2 provides an overview of our approach. For this work, we selected respectively TransModeler, CMEM, and CALPUFF View *(14, 13, 15)*.

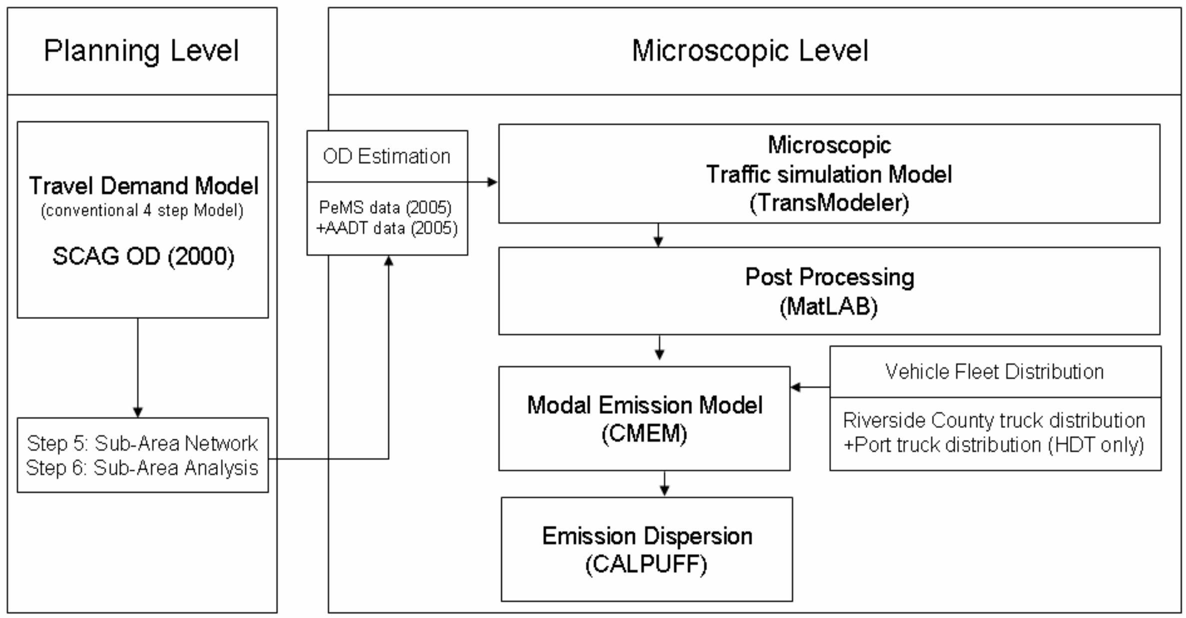


FIGURE 2 Framework of emission analysis at microscopic level.

As a first step, we consider three scenarios: 1) a baseline scenario, based on 2005 data; 2) a truck replacement scenario; and 3) a shift in freight transportation from trucks to trains. Let us describe these scenarios briefly:

- ***Baseline Scenario***
  For consistency with CARB's 2006 "Emission Reduction Plan for Ports and Goods Movement in California" (2), which defined 2005 as its base year to examine the impact of various emission reduction plans, we selected 2005 as our reference year. We decided to model the morning peak hour (7 AM to 8 AM) of Wednesday March 9 2005, which was selected as a typical week day. Our goal here is to first understand the generation of various pollutants by port trucks during the morning peak hour, which is typically worse than the evening one.
- ***Scenario 1: Truck Replacement Strategy***
  One of the measures the SPBP decided to implement recently was to replace older drayage trucks with modern, clean ones (the "clean truck program"). We therefore decided to consider three cases to evaluate the pollution impacts of this approach: Scenarios 1A, 1B, and 1C are respectively assume emission reductions of 25%, 50%, and 100% compared to the 2005 fleet of trucks serving the Ports. For reference, a percentage reduction in emissions would correspond to trucks with "zero emissions" such as fuel-cell vehicles.
- ***Scenario 2: Truck Volume Reduction***
  Another possible strategy to reduce truck traffic and emissions transporting containers to and from the ports is to shift a percentage of containers carried by truck to train or to alternative routes from the I-710 freeway. Indeed, the Alameda corridor is not saturated at this point; it carries approximately 50 trains a day but that number is expected to double over the next 10 years as railway improvements are implemented in various port terminals to accommodate more train traffic. For this scenario, we assume that shifting container traffic from trucks to trains results in 25% (=Scenario 2A), 50% (=Scenario 2B), and 100% (=Scenario 2C) decrease in truck volumes on the I-710 compared to our baseline scenario. 100% port truck volume reduction may not be feasible in the real-world, but we can examine the upper bound of emission reduction.

- ***Scenario 3: Truck Restriction lane***

  The other possibility is to utilize truck operational strategies. Various truck strategies as summarized in the background section can be applicable. In this study, truck restricted lane strategies was selected based on Yang's study *(31)*. He recommended restricting trucks to the two left-most lanes of the I-710. Otherwise, traffic conditions and nature are exactly the same as in the base scenario.

MICROSCOPIC TRAFFIC SIMULATION

Tools

The first step in our analysis is a traffic micro-simulation to understand the impact of congestion on the emissions of various pollutants. In general, microscopic traffic simulators rely on a series of mathematical traffic flow models, including for example, lane changing models such as gap acceptance models, lane selection models, and car-following models. To capture accelerations and decelerations patterns that are essential for better modeling of emissions, it is necessary to track the split second-by- split second movement of each vehicles and their interactions in a network.

Microscopic traffic simulators are now widely used in traffic management, traffic operation/control, traffic impact studies, and Intelligent Transportation Systems (ITS) strategies. They are also starting to be used for evaluating vehicle emissions. For example, a recent study used Paramics, a popular simulation model, and CMEM to study the impacts on emissions of different types of HOV lanes *(16)*. Paramics and CMEM have also been used to study speed control strategies and the resulting emissions of various pollutants *(17)*.

For this study, we selected TransModeler because it offers a number of advantages and it is a leading representative of a new generation of microscopic traffic simulators. First, TransModeler easily generates vehicle trajectory data that can be processed to estimate emissions by common microscopic emission models without any additional programming. Furthermore, TransModeler can easily work with Geographic Information System (GIS) data, which is essential to graphically represent spatial pattern of emission dispersion emerging from our analyses. This is also important as we are planning on analyzing the public health impacts of various mitigation strategies.

Data

To mathematically represent the I-710 network in the traffic simulator, we first extracted coordinates for our basic freeway layout from a GIS layer provided by Caltrans and obtained basic freeway characteristics (such as the number of lanes and speed limits) from the Performance Measurement System (PeMS) *(22)*. For additional details, we relied on maps from TerraServer and GoogleEarth. The TransModeler representation of the I-710 network is shown in the right panel of Figure 2.

Data from Wednesday, March 9, 2005 were selected to represent a typical weekday (Tuesday to Thursday) traffic flow pattern; 2005 is the base year in the SPBP action plan to reduce air pollution (*2*). As mentioned above, 2000 SCAG data provides only two different time periods: AM and PM peak periods. In this study, we modeled morning peak traffic from 7 AM to 8 AM.

For traffic simulation, traffic OD (Origins and Destinations) demand inputs were obtained from the 2000 Southern California Association of Governments (SCAG) traffic study, which is the most comprehensive available for Southern California. It focuses on morning and evening peak hours, and considers six types of vehicles: single occupancy vehicles (SOV), high occupancy vehicles (HOV 2), high occupancy vehicles (HOV 3+), light-duty trucks (LDT), medium-duty trucks (MDT), and heavy duty trucks (HDT). To obtain OD demand specifically for the I-710, sub-area analyses were performed in TransCAD: the sub-area network was extracted from the 2000 SCAG data and OD demand was re-assigned.

The OD demands were then adjusted to match traffic flow data every 15 minutes, which is measured from loop detectors on the I-710 freeway through PeMS. However, traffic flow data from

PeMS are not available for the southernmost section of the I-710 that extends from the Port of Long Beach to the I-405. As an alternative, we used the AADT data provided by Caltrans for this section of the I-710. For O-D estimation, a path-based algorithm was utilized *(32)*, and the commonly-accepted GEH statistic was selected for assessing goodness of fit.

$$GEH = \sqrt{\frac{(M-S)^2}{0.5(M+S)}},$$

where M measures traffic flow (vph) and S is simulated traffic flow (vph).

To obtain an accurate good representation of network traffic conditions, some references (e.g., see (*33*)) recommend that over 85% of selected loop detectors achieve GEH values under 5, but GEH values under 10 are generally acceptable. Results reported herein were obtained with only half of our 40 loop detectors achieving a GEH statistic below 5, but only a handful of the other loop detectors had GEH values above 10. This should be satisfactory given that we are modeling the most congested period of our network and that we are not performing a traffic network calibration for a standard operational traffic modeling problem.

Traffic Simulation Results

Due to the stochastic nature of microscopic traffic simulation (where different types of vehicles are released onto the network according to specified random distributions), we ran each scenario 30 times in TransModeler to obtain a reasonable estimate of mean statistics based on the central limit theorem. Note that results for Scenario 1 and its variations are simply obtained from the base scenario by changing emissions calculations after the traffic simulations (through post-processing).

To track the performance of our network, we follow Boriboonsomsin and Barth *(16*) and consider three statistics: vehicle miles traveled (VMT), vehicle hours traveled (VHT), and average vehicle speed, which is denoted by Q (in mph). In addition, average delay and vehicle proportion of each scenario are described. Table 1 summarizes our traffic simulation results.

TABLE 1 Summary of Traffic Simulation Results

		Base Scenario & Scenario 1	**Scenario 2A**	**Scenario 2B**	**Scenario 2C**	**Scenario 3**
VMT (Vehicle Mile Traveled)		163,989	164,413	164,960	168,892	162,433
VHT (Vehicle Hour Traveled)		5,653	5,430	5,364	5,348	5,612
Q (mph)		29.0	30.3	30.8	31.6	28.9
Avg Delay (second/mile)		266.3	264.1	251.6	213.4	303.4
Vehicle Proportion (%)	LDV	88.0	89.2	90.6	93.2	88.0
	LDT	2.1	2.2	2.2	2.3	2.2
	MDT	3.0	3.1	3.1	3.2	3.0
	HDT	6.9	5.5	4.1	1.3	6.8

Comparing first Scenarios 2A-C with the base case, we see that congestion decreases as Q is slightly higher (29 mph), VMT increases and VHT are lower, so traffic performance is improved. This improvement can be credited to a reduction in the percentage of trucks among all vehicles: it decreases from 12% under the Base Scenario to between 7% and 10% under Scenarios 2A-C. On the other hand, Scenario 3 is slightly worse than the base Scenario: there are already so many trucks on the road that restricting them to the two left-most lanes of the I-710 makes congestion slightly worse.

ESTIMATING EMISSIONS

Microscopic emissions models estimate instantaneous emissions and fuel consumption rates for different vehicles model types, years, and fuel types based on information about speed, acceleration, and grade. As a result, microscopic emissions models can capture the impact on emissions of various pollutants of vehicle interactions. In addition, they can estimate emissions under various traffic operational scenarios such as traffic congestion, traffic signals, and HOV lanes *(18)*.

Comprehensive Modal Emissions Model: CMEM

Currently, two microscopic emissions models are used in the United States: CMEM, which was developed at the University of California, Riverside, and VT-Micro, which was developed by the Virginia Polytechnic Institute and State University (*19*). Since VT-Micro is still under development and has not been officially released at this time, we selected CMEM for this study.

The latest version of CMEM (version 3.01) identifies 28 types of light duty vehicles and 3 types of heavy duty diesel vehicles. For these vehicle classes, it can estimate emissions of carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), and hydrocarbons (HC); it also provides fuel consumption estimates (FC). Unfortunately, CMEM does not yet calculate emissions of particulate matter (PM), nor can it estimate HDDV emissions after the 2002 model year. However, CMEM has been validated for official work, and in steady state conditions its emission estimates are consistent with those of MOBILE and EMFAC, except at very low and very high vehicle speeds *(12)*. To estimate PM emissions in this study, EMFAC was selected even though EMFAC is a macroscopic emission model because particulate matter (PM) is one of the key pollutants of HDDV emissions that has adverse public health effects.

Post Processing

To estimate vehicle emissions, post processing is required as TransModeler and CMEM do not yet have a convenient interface. Moreover, the current version of TransModeler considers only 15 vehicle categories versus 31 in CMEM. To estimate emissions of all CMEM categories, we performed random drawings from a uniform distribution for each vehicle type: light duty vehicles (LDVs), light duty trucks (LDTs), medium duty trucks (MDTs), and heavy duty trucks (HDTs).

In order to estimate vehicle emissions by post processing, we extracted from TransModeler second-by-second information about each vehicle's ID, coordinates, instantaneous speed and acceleration. We then used Matlab to perform the following steps: 1) Convert output from TransModeler into an input format compatible with CMEM; 2) Define detailed vehicle categories from random draws based on a uniform probability distribution, and select a CMEM category for each vehicle from the given cumulative distribution of each vehicle type; and 3) Calculate vehicle emissions using CMEM.

Data for Vehicle Emissions

Vehicle emissions depend on vehicle type, model year, and fuel type. It is therefore essential to specify the fleet distribution of each vehicle category in our study area. The best data we could find in our study area is the September 2005 fleet distribution of Riverside County (*16*), which is in the same air basin as Los Angeles County. We assumed that the fleet distribution of Riverside County is similar to that of I-710 vehicles, except of course for trucks, for which we rely on the distribution in the Port of Long Beach Air Emission Inventory 2005 (see page, 191 in *POLB Air Emission Inventory 200*5**)** *(10)*.

The current version of CMEM cannot capture vehicle emissions for pre-1994 and post-2002 model years of heavy duty trucks. We therefore assumed that pre-1994 trucks belong to HDDV5 and that post-2002 trucks belong to HDDV7 in CMEM. The modified heavy duty truck distribution based on this assumption gave 63.09% HDDV5, 7.87% HDDV6, and 29.4% HDDV7. The distribution of assumed CMEM vehicle categories is shown in Table 2.

TABLE 2 Combined Fleet distribution for Vehicle Emission Estimation in CMEM

CMEM			Demand percentage
Type	**Category**	**Description**	
Car	LDV1	No catalyst	0.39
Car	LDV2	2-way catalyst	0.78
Car	LDV3	3-way catalyst, Carbureted	1.61
Car	LDV4	3-way catalyst, FI>50K miles, low power/weight	6.11
Car	LDV5	3-way catalyst, FI>50K miles, high power/weight	6.11
Car	LDV6	3-way catalyst, FI<50K miles, low power/weight	0.07
Car	LDV7	3-way catalyst, FI<50K miles, high power/weight	0.07
Car	LDV8	Tier 1, >50K miles, low power/weight	5.88
Car	LDV9	Tier 1, >50K miles, high power/weight	5.88
Car	LDV10	Tier 1, < 50K miles, low power/weight	1.85
Car	LDV11	Tier 1, < 50K miles, high power/weight	1.85
Car	LDV24	Tier 1, >100K miles	15.28
Car	LDV26	Ultra-low emission vehicle (ULEV)	7.94
Car	LDV27	Super ultra-low emission vehicle (SULEV) and Partial zero emission vehicle (PZEV)	0.89
Car	LDV19	Runs lean	0.42
Car	LDV20	Runs rich	0.95
Car	LDV21	Misfire	0.84
Car	LDV22	Bad catalyst	0.30
Car	LDV23	Runs very rich	0.21
LDT	LDV12	Pre-1979 (<= 8500 GVW)	0.55
LDT	LDV13	1979 to 1983 (<= 8500 GVW)	0.85
LDT	LDV14	1984 to 1987 (<=8500 GVW)	2.50
LDT	LDV15	1988 to 1993 (<=3750 LVW)	3.38
LDT	LDV16	1988 to 1993 (>3750 LVW)	7.28
LDT	LDV17	Tier 1 LDT 2/3 (3751-5750 LVW or Alt. LVW)	18.21
LDT	LDV18	Tier 1 LDT 4 (6001-8500 GVW, >5750 Alt. LVW)	7.47
LDT	LDV19	Runs lean	0.36
LDT	LDV20	Runs rich	0.72
LDT	LDV21	Misfires	0.76
LDT	LDV22	Bad catalyst	0.26
LDT	LDV23	Runs very rich	0.23
		Total	100.00
MDT	LDV25	Gasoline-powered, LDT(>8500 GVW)	54.28
MDT	LDV40	Disel-Powered, LDT (>8500 GVW)	45.72
		Total	100.00
HDT*	***HDDV5***	***1994 to 1997, 4 stroke, electronic FI***	***63.09****
HDT*	***HDDV6***	***1998, 4 stroke, electronic FI***	***7.87****
HDT*	***HDDV7***	***1999 to 2002, 4 stroke, electronic FI***	***29.04****
		Total	100.00

Notes: FI = fuel injection; GVW = gross vehicle weight; LVW = loaded vehicle weight; LDT = light-duty trucks. Source: Boriboonsomsin, K. and Barth, M.(2008)
*: The Port of Long Beach, Port of Long Beach Air Emissions Inventory 2005 and 2007.

Emission Results

Emission results of all scenarios are summarized in this section. To examine statistical differences of each pollutant between the Base Scenario and each of the other Scenarios, we performed unequal variance t-tests with a significance level of α= 0.05. These tests can be described as follows:

$$H_0: \mu_{\text{EmissionType,Base}} = \mu_{\text{EmissionType,Scenario}}$$

$$H_1: \mu_{\text{EmissionType,Base}} = \mu_{\text{EmissionType,Scenario}}$$

$$t = \frac{\hat{X}_{\text{EmissionType,Base}} - \hat{X}_{\text{EmissionType,Scenario}}}{\sqrt{(\sigma^2_{\text{EmissionType,Base}} / n_{\text{EmissionType,Base}}) + (\sigma^2_{\text{EmissionType,Scenario2}} / n_{\text{EmissionType,Scenario2}})}}$$

where $\hat{X}_{\text{EmissionType,Base}}$ is the average rate of each emission type by scenario; $\sigma^2_{\text{EmissionType,Base}}$ is the variance of each emission type by scenario; and n is the number of observation, here n=30.

Figure 3 gives percentage differences of each pollutant and fuel consumption of each Scenario compared to Base Scenario and the results of hypothesis test as well; Table 3 gives the average emission rate and fuel consumption by vehicle type for the all Scenarios.

As shown in Table 3 and Figure 3, except for NO_x and PM, emissions of all pollutants are dominated by light duty vehicles in the base scenario. In particular, over 85% of CO and HC are generated by passenger cars. In contrast, heavy duty vehicles are the main contributor of NO_x (over 70% of the total), and PM (69.3% of PM emissions). Moreover, NO_x plays an important role creating particulate matter (PM) through various chemical reaction, so it is of concern for public health as it likely plays a role is various breathing diseases such as asthma.

In Figure 3, hypothesis test results show that CO in Scenario 1A, 1B, and 1C, HC in Scenario 2A and 2B, and CO_2, HC, and PM in Scenario 3 are not statistically different from the Base Scenario. In particular, Scenario 1C (100% clean port trucks) shows the largest reduction of emission rate among the all scenarios: CO by 1.7%, HC by 8.8%, NO_x by 64.1%, and PM by 60%, respectively.

On the other hand, CO and HC in Scenario 2 and 3 are relatively higher compared to the Base Scenario because traffic condition of those scenarios-- decreases in VHT and average delay, increases in VMT and number of light duty vehicles-- is relatively improved by the truck volume reduction and truck restricted lane. In other words, light duty vehicles traveled more than base scenario, so CO and HC are relatively increased because CO and HC are mainly dominated by light duty vehicles

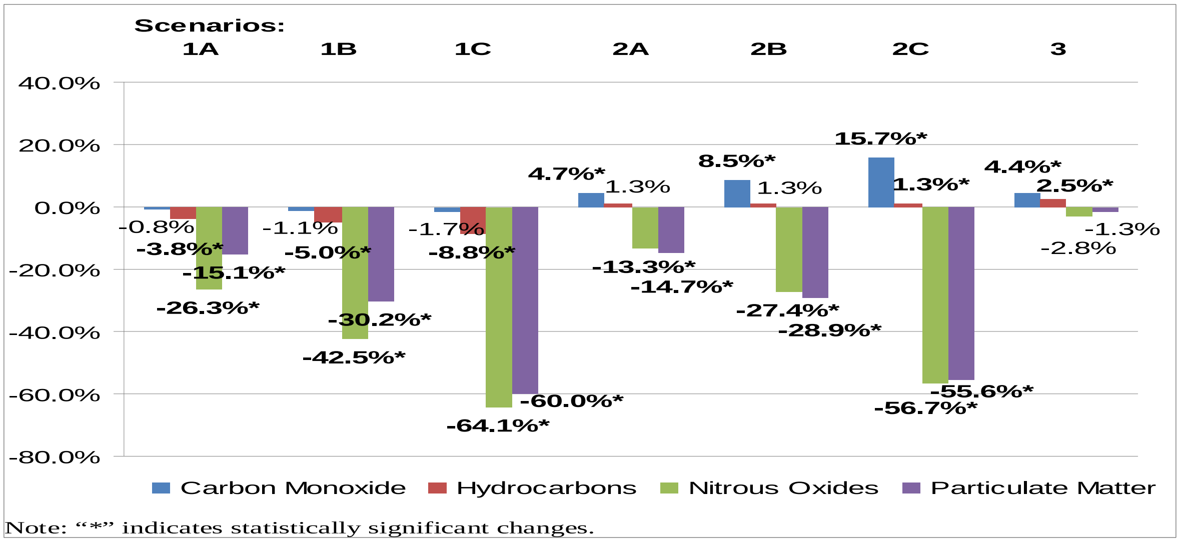


FIGURE 3 Percentage differences of pollutants of each scenario compared to Base Scenario.

TABLE 3 Average Emission Results for all Scenarios

Scenario	Vehicle Type	CMEM (units: kg)			EMFAC
		CO	HC	NOx	PM
Base Scenario	LDV	3,437.4	67.5	93.1	5.6
	LDT	108.7	2.1	3.0	0.1
	MDT	15.3	2.2	20.7	1.1
	HDT	65.6	8.6	340.6	15.6
	Total	**3,627.0**	**80.5**	**457.4**	**22.5**
Scenario 1A 25% of clean port truck	LDV	3,437.4	67.5	93.1	5.6
	LDT	108.7	2.1	3.0	0.1
	MDT	15.3	2.2	20.7	1.1
	HDT	42.4	5.6	220.4	12.3
	Total	**3,603.8**	**77.4**	**337.2**	**19.1**
Scenario 1B 50% of clean port truck	LDV	3,437.4	67.5	93.1	5.6
	LDT	108.7	2.1	3.0	0.1
	MDT	15.3	2.2	20.7	1.1
	HDT	**28.1**	**3.7**	**146.2**	**8.9**
	Total	**3,589.5**	**75.5**	**263.0**	**15.7**
Scenario 1C 100% of clean port truck	LDV	3,437.4	67.5	93.1	5.6
	LDT	108.7	2.1	3.0	0.1
	MDT	15.3	2.2	20.7	1.1
	HDT	9.2	1.2	47.6	2.2
	Total	**3,570.5**	**73.1**	**164.4**	**9.0**
Scenario 2A 25% of port truck volume reduction	LDV	3,613.5	69.5	96.4	5.7
	LDT	117.9	2.3	3.3	0.1
	MDT	15.9	2.3	21.3	1.1
	HDT	51.8	6.7	275.1	12.3
	Total	**3,799.0**	**80.7**	**396.0**	**19.2**
Scenario 2B 50% of port truck volume reduction	LDV	3,762.1	71.1	99.0	5.8
	LDT	120.8	2.3	3.2	0.1
	MDT	16.2	2.3	21.6	1.1
	HDT	38.3	4.9	208.0	9.0
	Total	**3,937.4**	**80.6**	**331.9**	**16.0**
Scenario 2C 100% of port truck volume reduction	LDV	4,046.0	75.2	104.3	5.9
	LDT	128.4	2.4	3.4	0.1
	MDT	17.3	2.4	22.4	1.1
	HDT	11.7	1.5	68.2	2.8
	Total	**4,203.4**	**81.4**	**198.3**	**10.0**
Scenario 3 Truck Restricted lanes	LDV	3,591.4	68.4	95.5	5.6
	LDT	114.4	2.2	3.2	0.1
	MDT	13.9	2.3	20.2	1.1
	HDT	65.4	9.1	324.8	15.4
	Total	**3,785.1**	**81.9**	**443.7**	**22.2**

DISPERSION ANALYSIS

Air quality dispersion models spatially analyze the concentration of pollutants from various sources. EPA has approved several dispersion models for different purposes. In conventional mobile emission dispersion studies, CALINE 4 and CAL3QHR have frequently been applied because their data requirements are moderate and their use is fairly straightforward. These two models have limitations for estimating emission dispersion for large networks and dynamic meteorological changes, however. For that reason, we rely instead on CALPUFF. This software has the capability of treating dynamic point and area sources, it can model complex terrains, and it can calculate concentrations for a wide range of time scales, from an hour to a year. CALPUFF consists of three components: CALMET, which helps process meteorological data, land use, and coordinate system; CALPUFF, which estimates pollutant dispersion; and CALPOST, which helps present CALPUFF results *(20)*. Only a few transportation studies have applied CALPUFF so far (*21*).

Data for Emission Dispersion

CALPUFF requires several types of input data: emission results but also land use and meteorological data *(23)*. Meteorological data in CALMET include surface and upper air data in hourly intervals. 2005 meteorological data provided by the Lakes Environmental Software *(24*) is used in our study.

To calculate emission dispersion, we assumed the I-710 to be a long and narrow area source. The time interval for analyzing average emission dispersion is defined as the morning peak hour (7:00 a.m. to 8:00 a.m.) on March 9 as in TransModeler and CMEM.

Emission Dispersion Results

Emission dispersion results for NOX and PM are summarized in Table 4, in Figure 4 for the Base Scenario, and for Scenario 1C and 3C that provide the largest and second largest emission reductions compared to the Base Scenario. Table 4 also summarizes state and federal health thresholds for PM and NOx (*25*,*26*,*34*,*35*).

TABLE 4 Air Quality Standards for NOx and PM and Estimated Concentrations

Standard	**Index Values**	**Category**	**NO_2 (PPM)**	**PM(μg/m3)**
AQI	0-50	Good	*	0-54
	51-100	Moderate	*	55-154
	100-150	Unhealthy for Sensitive Group	*	155-254
	151-200	Unhealthy	*	255-354
	201-300	Very Unhealthy	0.65-1.24	355-424
	301-500	Hazardous	>1.25	>425
EPA Standard		24 hour	-	150
		Annual	0.053	50
California Standard		24 hour	0.25	50
		Annual	-	20
NO_x and PM Concentration Results from CalPuff				
Scenario	**NO_2 (ppm**)**	**AQI Category**	**PM (μg/m3)**	**AQI Category**
BASE	0.15	*	219.74	Unhealthy for Sensitive Group
Scenario 1(A)	0.11	*	187.01	Unhealthy for Sensitive Group
Scenario 1 (B)	0.085	*	153.57	Moderate
Scenario 1 (C)	0.052	*	88.11	Moderate

Scenario 2 (A)	0.13	*	188.09	Unhealthy for Sensitive Group
Scenario 2 (B)	0.11	*	156.8	Unhealthy for Sensitive Group
Scenario 2 (C)	0.063	*	19.05	Good
Scenario 3	0.145	*	217.22	Unhealthy for Sensitive Group

*: NO2 has no short-term NAAQS and can generate an AQI only above a value of 200
**: part per million (PPM)

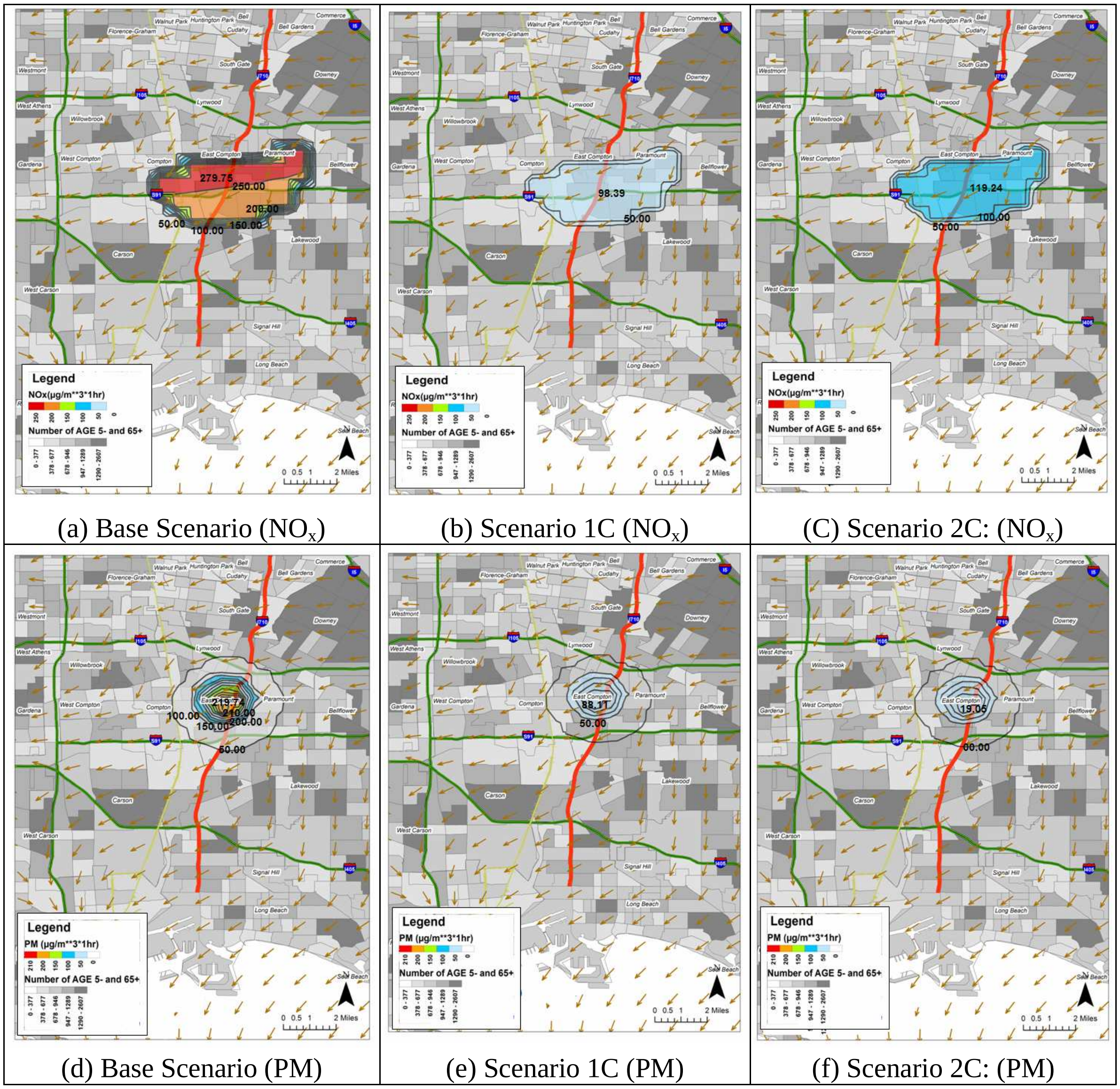
In Table 4, Air Quality Index (AQI) categorizes six common pollutants: O_3, CO_2, CO, SO, PM, and NOx by six levels for reporting daily air quality: good, moderate, unhealthy, very unhealthy, and hazardous. California standard for air quality is much higher than federal standard provided by the EPA.

Figure 4 shows pollution dispersion for the base case along with prevailing wind directions. The maximum NOx and PM concentrations reach 279.75 $\mu g/m^3$ (micrograms per meter cubed) and 219.74 $\mu g/m^3$. Figure 4 also gives information about the exposure of PM and NOx by children under 5 and people over 65, who are most vulnerable to respiratory diseases. The darker colored area indicates higher densities for these two groups. Interestingly, we see that emissions from the I-710 nearly reach the I-110 and SR-91 freeways.

As shown in Table 4 and Figure 4, the smallest NO_x concentration among all scenarios is in Scenario 1C, 100% clean port truck; On the other hand, the smallest concentration of PM is in Scenario 2C, 100% port truck reduction even though PM emissions in Scenario 2C are slightly worse than in Scenario 1C. This means that the emission concentration in the ambient air is affected by metrological conditions such as wind direction and speed.

Air quality standards for NO_x do not provide criteria for short term periods such as 1 to 3 hours. AQI for NO_x only provides two categories: “very unhealthy” and “hazardous,” but we can see that the NO_x concentration in all the scenarios is much less than in the “very unhealthy” category or California standard.

On the other hand, the PM concentration of Base, Scenario 1A, 2A, 2B, and 3 indicate unhealthy levels for a sensitive group: people with heart or lung disease and elderly adults and children. Scenario 1B and 1C give a moderate level of PM concentration, but the concentration is slightly above EPA and California standards. Only Scenario 1C indicates good level for AQI categories.



(a) Base Scenario (NO_x) | (b) Scenario 1C (NO_x) | (C) Scenario 2C: (NO_x)

(d) Base Scenario (PM) | (e) Scenario 1C (PM) | (f) Scenario 2C: (PM)

FIGURE 4 NO_x and PM emission dispersion and wind direction: Base, Scenario 1C and 2C.

CONCLUSIONS AND FUTURE RESEARCH

The objective of this paper was to explore a new approach to estimating vehicle emission impacts of freight corridor operations related to the port area, particularly those associated with heavy duty diesel trucks. The approach involved use of a microscopic traffic simulation model to capture detailed vehicle trajectories and congestion effects (ultimately including the effects of Intelligent Transportation System strategies), emissions modeling, and modeling the spatial dispersion of pollutants in the corridor, to facilitate estimation of the health and environmental justice impacts of freight corridor operations. In this paper we focused on operation of the I-710 freeway in the Alameda Corridor, leading from the SPBP area for about 20 miles toward Los Angeles.

In this paper, seven scenarios were evaluated in addition to the 2005 Base Scenario: replacement of the current fleet of port heavy duty diesel trucks with zero emission trucks (25%, 50%, and 100% of port trucks), elimination of port heavy duty diesel truck trips (25%, 50%, and 100% reductions) that would correspond to shifting more containers to other modes such as rail, and implementation of a truck restricted-lane on I-710 preventing trucks from using the left most lanes. Our current results show that fleet replacement with cleaner (zero emission) trucks yields the most emission reductions both quantitatively and spatially. However, perhaps more importantly implementation of the modeling framework that we proposed and explored in this paper has been proven feasible.

In a parallel effort we are also studying rail operations in the same corridor. In the future both the rail and highway elements will be combined to form an integrated, overall assessment of air quality impacts in the corridor over a 24 hour period.

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