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Publication Date

2010-03-01

University of California Transportation Center
UCTC Research Paper No. UCTC-2010-08 (renumbered as UCTC-FR-2010-08)

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March 2010

Assessing the Environmental and Health Impacts of Port-Related Freight Movement in a Major Urban Transportation Corridor

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Word count: 5,146 + 9*250 (3 figures and 6 tables) = 7,396 words.
Submitted to TRB 2010 Annual Meeting (November 15, 2009)

1 **ABSTRACT**

2 The San Pedro Bay Ports (SPBP) complex of Los Angeles and Long Beach is the largest container
3 port in the U.S., and a very important contributor to both California's and the nation's economies.
4 Although the benefits of the SPBP activities are enjoyed by the whole country, the burden of the
5 congestion and air pollution it generates falls mostly on the shoulders of people who live and work in
6 the transportation corridor serving the SPBP. This corridor includes two busy freeways, the I-710 and
7 the I-110, and a busy rail link, the Alameda corridor. The objective of this paper is to explore an
8 integrated approach for evaluating the environmental and health impacts of freight operations between
9 the SPBP complex and downtown Los Angeles, some 22 miles north. Our integrated approach
10 combines a number of models, including a microscopic traffic simulation model and an emissions
11 model to better estimate the impacts of congestion on air pollution, emission estimates from line-haul
12 and switching train activities, a spatial dispersion model, and a health impact model. We analyze
13 emissions for year 2005, which serves as a baseline in various air pollution inventories of the SPBP
14 complex. Our results show that emissions concentrations are strongly affected by meteorological
15 conditions and seasonal variations (winter is worse than summer); moreover, we found that health
16 impacts from NO_x and PM exposure exceed 200 million dollars, which justifies a number of regional
17 initiatives to improve air quality. Our analysis is a starting point for analyzing the economic efficiency
18 of these initiatives, which include modal shift (from trucks to trains) and the Clean Trucks Program.

1 INTRODUCTION

2 The combined port of Los Angeles and Long Beach, also known as the San Pedro Bay Ports (SPBP),
3 is by far the largest container port area in the U.S., and a very important contributor to both
4 California's and the nation's economies. In 2005, more than 40% of imports and 24% of exports at
5 the national level were handled by the SPBP complex. In addition, over 886,000 jobs are supported by
6 international trade activities indirectly and directly related to the SPBP complex, which generate more
7 than \$6.7 billion in state and local tax revenues (1). Although this year it is down to 2005 levels,
8 container traffic at the SPBP complex increased more than 50% between 2000 and 2008 (from 9.5
9 million TEUs to 14.3 million TEUs) (2, 3).

10 As a result, air pollution and congestion have increased significantly over the last decade.
11 One-third of all emissions from goods movement in the state are generated in the Los Angeles area. In
12 particular, over 400 tons of nitrogen oxides (NO_x), an ozone precursor, are generated by SPBP-related
13 goods movement. Moreover, at least 14 tons per day of diesel particulate matter (PM) were generated
14 from goods movement in the South Coast air basin in 2005 (4). PM emissions have been shown to
15 increase the number of premature deaths and respiratory problems. For example, the American lung
16 association estimates that approximately 3,700 premature deaths per year in California are caused by
17 PM emissions associated with goods movement (9).

18 Concerns about air pollution from the SPBP complex have caused various agencies, including
19 the California Air Resource Board (CARB) and the Southern California Association of Governments
20 (SCAG), along with the ports themselves, to propose strategies for mitigating air pollution generated
21 by the SPBP complex. These emission reduction strategies, which extend until 2020, address multiple
22 emission sources including ships, commercial harbor crafts, locomotives, and trucks. More
23 specifically, emission reduction strategies for trucks aim at replacing older and damaged vehicles,
24 retrofitting truck engines, or imposing truck idling restrictions (4, 5, 6, 7, 8).

25 To quantify the potential benefits of proposed pollution mitigation measures, it is important to
26 first have sound estimates of the actual pollution generated by SPBP complex activities. Our review
27 of official documents suggests that this is not the case, at least not for emissions from drayage trucks
28 and trains serving the SPBP. Indeed, analyses for truck pollution rely on planning models that are
29 unable to capture the impact of congestion on the emission of pollutants. In addition, there does not
30 appear to be any analysis of the dispersion and the health impacts of pollutants emitted by drayage
31 trucks and trains serving the SPBP complex.

32 The objective of this paper is to start filling this gap for the area that extends from the gates of
33 the SPBP to downtown Los Angeles (see Figure 1). We analyze both train (12) and vehicle emissions
34 of NO_x and PM. For the latter, we focus on the two major freight freeways, the I-710 and the I-110,
35 that serve the SPBP complex. Our analysis relies on microscopic simulation, dispersion analysis, and
36 an assessment of the health impacts of air pollutants.

37 This paper is organized as follows. After presenting some background information, we
38 present our methodological framework. We then summarize results of analyses, before presenting our
39 conclusions and suggestions for future work.

41 BACKGROUND

42 As shown on Figure 1, in addition to the Alameda corridor rail link, the SPBP complex is served by
43 two major freeways, the I-710 and the I-110, that are crossed by several other busy freeways (SR-47,
44 SR-91, I-405, I-105, I-5, SR-60, and I-10). Our study area extends from the SPBP gates to downtown
45 Los Angeles, about 22 miles away. The I-110 and especially the I-710 carry thousands of trucks per
46 day, and the Alameda railway corridor handled approximately two trains per hour in 2005. Our study
47 area also includes seven railyards: Commerce, UP ICTF/Dolores, BNSF Watson, Transfer, UP Mead,
48 Pier A, and Pier B. Two major railroads (Burlington Northern and Santa Fe (BNSF) and Union

Pacific (UP)) provide regional and long-distance transportation services, in addition to a small switching railroad (the Pacific Harbor Line PHL).

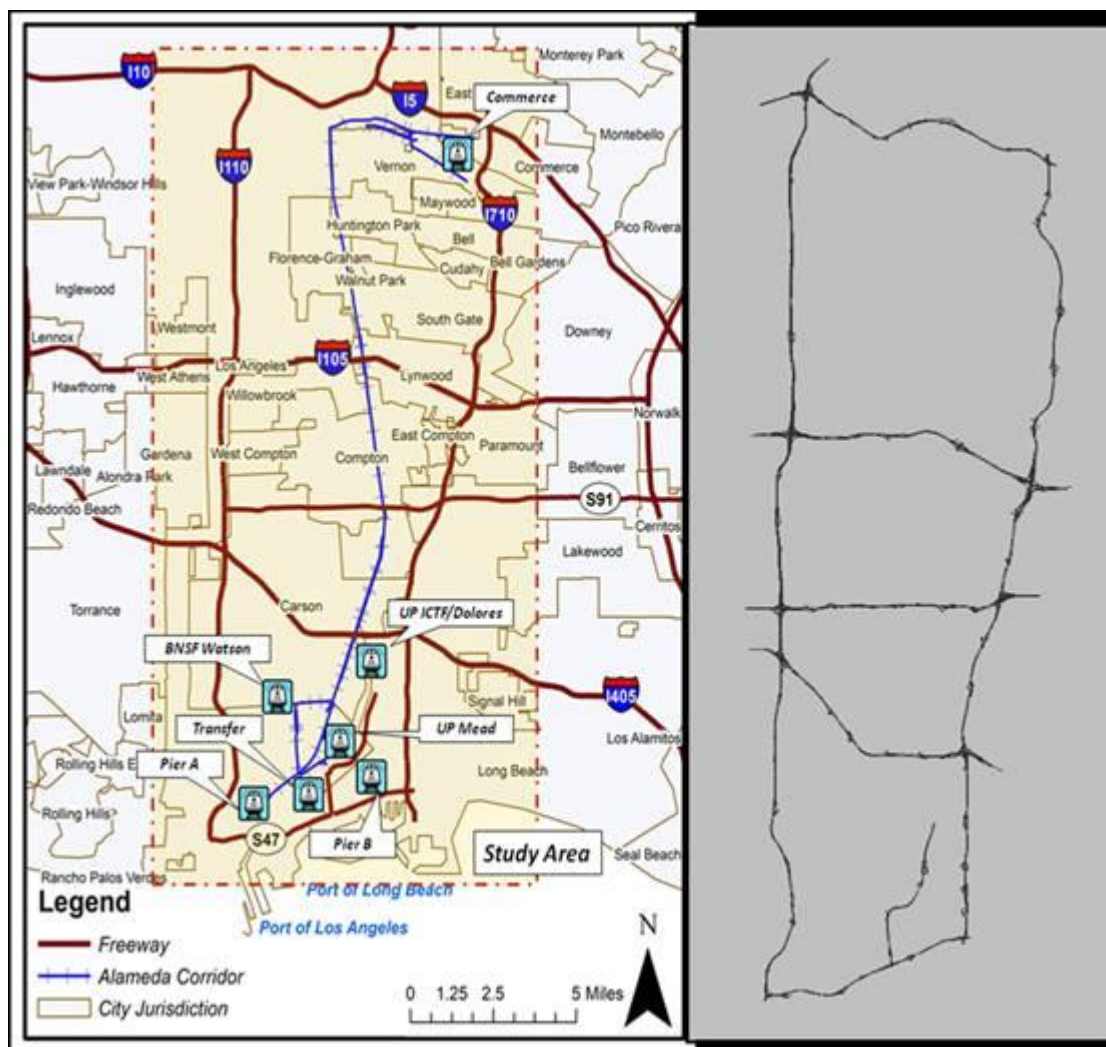


FIGURE 1 Study area (left side) and freeway network in TransModeler (right side).

A number of previous studies analyzed different aspects of this freight corridor. Fischer et al. (10) examined the implementation of truck-only lanes on the I-710. Park et al. (11) extended their analysis by considering both truck-restricted lanes and truck-only lanes on the I-710 using a microscopic traffic simulator and a microscopic emissions model (CMEM); they concluded that truck-restricted lanes are better than truck-only lanes for improving traffic conditions and air quality. Giuliano and O'Brien (25) examined the impacts of extended gate operations of the SPBP called the PierPASS program and found a significant temporal shift of cargo trips at the Port area. Rahai (26) measured PM concentrations in multiple locations along the Alameda corridor and concluded that these concentrations increase by 10~15% when diesel trains are operating. Sangkapichai et al. (12) estimated PM and NO_x emissions from locomotives and railyards in the Alameda railway corridor area and applied dispersion models; they found that on the worst day of 2005, and NO_x emissions from train operations exceeded recommended thresholds. Lee et al. (13) proposed a new integrated approach for estimating vehicle emission impacts of the I-710 freight corridor using a microscopic-

level traffic simulator and an emissions model. They analyzed several scenarios but focused only on one hour of peak hour traffic. This paper combines and expands the studies conducted in (12, 13) to analyze the health impacts of truck and train pollution in the study area.

MODELING EMISSION IMPACTS: AN OVERVIEW

Emissions from trains and freeways were estimated separately to assess their separate impacts. Two models are used to estimate freeway emissions: a microscopic traffic simulation model, TransModeler (14), and an emissions model for generating various pollutants, EMFAC 2007 (15). Train emissions are based on (12, 24). There are few systematic train emission models such as vehicle emissions models, so train emission factors as a function of travel time based on line-haul distance and speed of locomotives are used. After estimating emissions for both trains and drayage trucks on the freeways in our study area, we used a dispersion model, CALPUFF (16), to explore their spatial concentration, which in turn allowed us to assess their impacts on public health using BenMAP (21). Figure 2 presents an overview of our approach.

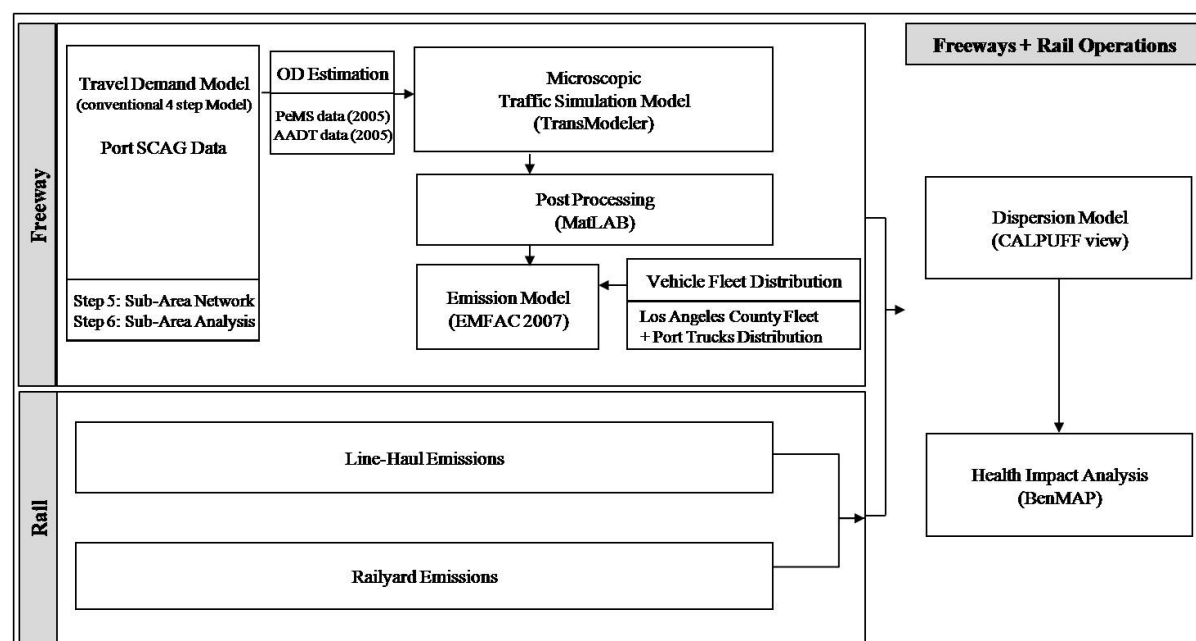


FIGURE 2 Integrated frameworks for our emissions analyses for freeway and rail.

As mentioned above, we analyzed 2005 emissions because CARB's emission reduction plan for goods movement (4) uses 2005 as its base year to assess the impact of various measures over the next 15 years. Since micro-simulation is very time consuming, we selected a representative day of the week, Wednesday, March 9th, 2005, based on traffic counts data from Caltrans' Freeway Performance Measurement System, PeMS (17). We then performed a detailed hourly simulation of traffic on our network to estimate emissions of various pollutants, including NO_x and PM.

FREEWAY

Microscopic Traffic Simulation

Tools

Microscopic traffic simulation is a popular tool in transportation. The main advantage of microscopic tools lies in their ability to represent individual vehicle movements, especially vehicle accelerations and decelerations, which are important for modeling air pollutant emissions. By contrast, traditional

planning models rely only on average hourly speeds, which lead to erroneous emission estimates. For our work, we selected TransModeler because of its capability to represent vehicle movement details, and its easy interface with GIS. We had also used TransModeler successfully on a portion of our current network (the I-710) in a previous study (13).

Data

Since micro-simulation is very time-consuming, simulation of multiple-day traffic was not considered feasible. We examined speed contours for 2005 and selected March 9th 2005 as a typical weekday. In March of 2005, the service time for the SPBP complex extended from 8 AM to 6 PM; in order to capture truck movements just before and after the official service hours, however, we also considered traffic for two hours before and one hour after for a total of 13 hours. A typical weekday can be partitioned in three periods: morning peak, from 6 AM to 9 AM; mid-day, from 9 AM until 3 PM, and afternoon peak, from 3 PM until 7 PM. We then selected one hour from each of these three time periods for our simulations to capture an upper and a lower bound for each time period. They are:

- Upper bounds: 07:00~08:00am (AM), 14:00~15:00 pm (MD), and 17:00~18:00pm (PM);
- Lower bounds: 08:00~09:00am (AM), 11:00~12:00 pm (MD), and 18:00~19:00pm (PM).

Traffic origin and destination (OD) demand inputs are required for traffic simulation. OD demands were obtained from a modified Southern California Association of Governments (SCAG) traffic study that combined the existing SCAG travel demand data with stated port truck demand data from a survey conducted for the Port of Long Beach (PortSCAG data; 8). The OD demands were then adjusted to match traffic flow data every half an hour, which was measured by loop detectors on the I-110 and I-710 freeways through PeMS (17). We followed the same approach for OD estimation as in our previous study (13). While performing OD estimation, unrealistic vehicle behavior was observed locally and corrected using local parameters in traffic models, including car-following model parameters and the distribution of critical distance parameter in TransModeler (17).

TABLE 1 Summary of Traffic Simulation Results

Base Scenario		Upper Bound			Lower Bound		
		AM 7:00~8:00	MD 14:00~15:00	PM 17:00~18:00	AM 8:00~9:00	MD 11:00~12:00	PM 18:00~19:00
VMT		991,309 (10,493.4)	805,217 (34,163.9)	944,881 (12,464.7)	903,365 (8,929.0)	781,651 (6,395.9)	828,368 (2,889.4)
VHT		25,166 (879.6)	20,262 (2,373.6)	20,074 (850.0)	20,631 (901.7)	15,129 (281.6)	14,331 (98.3)
Q (mph)		39.4 (1.7)	39.7 (5.7)	47.1 (2.5)	43.8 (2.2)	51.7 (1.0)	57.8 (0.5)
Number of Vehicles	LDV	159,240 (1.8)	126,293 (644.1)	154,550 (417.4)	147,761 (2.5)	115,514 (582.3)	129,403 (4.8)
	LDT	4,820 (29.2)	4,899 (46.4)	5,337 (67.7)	5,399 (43.8)	4,595 (57.0)	4,356 (41.8)
	MDT	1,892 (31.8)	2,793 (49.3)	1,779 (32.0)	2,123 (41.9)	2,626 (39.8)	1,468 (26.81)
	HDT	1,886 (31.8)	3,433 (50.7)	2,741 (58.7)	2,097 (40.4)	3,193 (45.9)	2,542 (36.9)
	Port*	4,875 (0.4)	5,857 (12.8)	3,584 (49.9)	5,093 (0.4)	5,598 (94.1)	3,101 (0.4)
	Total	172,712 (2.0)	143,275 (712.9)	167,992 (437.1)	162,473 (2.7)	131,527 (668.6)	140,870 (4.5)

Note: Port trucks consist of bobtail, chassis, and container trucks. (): standard deviation

Traffic Simulation Results

Due to the stochastic nature of microscopic traffic simulation models, 30 runs were performed for each hour in TransModeler to obtain a good estimate of mean emissions based on the central limit theorem. Three statistics were considered as performance measures for the traffic simulation: vehicle miles traveled (VMT), vehicle hours traveled (VHT), and average vehicle speed (denoted by Q in mph). A summary of traffic simulation results is presented in Table 1.

As shown in Table 1, the morning peak (7:00~8:00) had, as expected, the largest number of vehicles, VMT, and VHT. Conversely, the mid-day lower bound hour had the smallest total number of vehicles and VMT, but the estimated number of port truck volumes, 5,598, is the second highest. Trucks represent approximately 8% to 9% of total vehicles during both morning and evening peak hours, and this percentage increases to approximately 12% during mid-day.

As mentioned above, truck volumes were adjusted based on PeMS data, but PeMS data does not differentiate between port and non-port trucks. Thus, it is interesting to check whether or not current estimated port truck volumes are reasonable. One approach is to compare monthly TEU (Twenty-foot equivalent unit) statistics of containers reported by the SPBP. Note, however, that available TEU statistics include all goods movements carried by multiple modes: container trucks and trains, so we need to know the intermodal mode split. Table 2 below summarizes the March 2005 TEU statistics and the 2005 direct intermodal mode split for the SPBP complex.

TABLE 2 March 2005 TEU and 2005 Intermodal Mode Split for the SPBP complex

March 2005 TEU of Port of Long Beach and Los Angeles*					
(TEUs)	In Loaded	Out Loaded	Total Loaded	Empties	Total
POLB	210,093	104,519	314,612	151,407	466,019
POLA	255,390	107,453	362,842	162,177	525,020
Total	465,483	211,972	677,454	313,584	991,039
2005 San Pedro Bay Area Direct Intermodal Throughput **					
(TEUs)	On-Dock ⁽¹⁾	Near-Dock ⁽²⁾	Off-Dock ⁽³⁾	Truck	Total
2005	2,934,850	1,081,350	1,689,890	8,488,352	14,194,442
	20.7%	7.6%	11.9%	59.8%	100.0%

Notes.

*: Port of Long Beach and Port of Los Angeles (2,3)

**: San Pedro Bay Ports Rail study update, Executive summary, 2006 (18)

⁽¹⁾: With on-dock, containers are directly transferred from a ship to a train.

⁽²⁾: Near-dock refers to facilities located within 5 miles from the SPBP.

⁽³⁾: Off-dock yards are located more than 5 miles from the SPBP (18).

As shown in Table 2, the total for March 2005 for the SPBP is 991,039 TEUs, but this statistic does not specify TEUs specifically transported by trucks. We know, however, that in 2005, the shares of container trucks was approximately 60%, but near-dock and off-dock operations also involve container truck movements, and so the percentage of containers moved by trucks is approximately 80%. Thus drayage trucks moved approximately 792,831 TEUs during March 2005, which corresponds to 34,470.9 TEUs/day. In addition, container trucks can be divided further into 20-foot and 40-foot units. To convert TEU values to truck numbers, we relied on TEU factors, which range from 1.7 to 1.8 in the SPBP complex (18). When the TEU factor is 1.7, the estimated number of container trucks is:

$$\begin{aligned} \text{Container trucks per day} &= 40\text{-foot truck} + 20\text{-foot truck} \\ &= (34,471 \times 0.7)/2 + (34,471 \times 0.3) = 22,406 \text{ container trucks / day.} \end{aligned}$$

When the TEU factor is 1.8, we find:

$$\text{Container trucks / day} = 40\text{-foot truck} + 20\text{-foot truck}$$

$$= (34,471 \times 0.8)/2 + (34,471 \times 0.2) = 20,682 \text{ container trucks / day.}$$

Thus, the number of container trucks estimated from TEU statistics ranges from 20,682 to 22,406 per day. To compare with the number of container trucks we estimated, we need to estimate container volumes from estimated port truck volumes, which include bobtail, chassis, and container trucks. The number of daily port trucks from our study ranges between 47,984 and 50,769. Based on the PortSCAG data (18), the percentage of container trucks among port truck volumes are between 55% and 60%. If 55% of the estimated port truck volumes are assumed to be container trucks, this represents 26,391 to 27,923 units. If we assume 60%, we obtain 28,790 to 30,461 container trucks.

The estimated container truck volumes from this study vary between 26,391 and 30,461, which is 18% to 47% more than the estimated daily container trucks from TEU statistics (i.e., 20,682 and 22,406). However, TEU statistics that we obtained only provide monthly statistics, not daily and weekly statistics. In other words, if daily and weekly variations of the container truck volumes estimated from TEU statistics are considered, the estimated port truck volumes from this study may suggest the range of the container volumes estimated from TEU statistics.

Estimating Emissions

On-road Emissions Tools

Vehicle emissions models can be classified into two levels: macroscopic (or macro-scale) and microscopic (or micro-scale) emission models. To take advantage of microscopic traffic simulation capturing individual vehicles' speeds and accelerations, using a microscopic emissions model such as CMEM (19) developed at the University of California, Riverside, is recommended. However, CMEM cannot calculate PM emissions, and it cannot estimate heavy duty truck emissions after the 2002 model year. Thus, as an alternative, EMFAC, which is solely used for California, is used. To capture speed variations of each vehicle along the freeways, the average speed of each vehicle based on freeway links of about 1,500 is calculated.

Post Processing

Vehicle emissions were calculated through post processing the EMFAC and TransModeler outputs. TransModeler allows for five vehicle categories versus 24 with 3 fuel types for EMFAC. To estimate emissions of all EMFAC categories, random drawings from a uniform distribution for each vehicle type were performed. Since vehicle emissions depend on vehicle type, model year, and fuel type, it is important to specify the fleet distribution of each vehicle category in the study area. Fortunately, the EMFAC model was developed specifically for California, so it contains information about the distribution of vehicles operating in Los Angeles County. In addition, we used information about the fleet distribution of port heavy duty trucks based on the Port of Long Beach Air Emission Inventory of 2005 (8).

Emission Results

Emission results of all scenarios are summarized in this section. Table 3 presents the average emission rate of CO, NO_x, HC, and PM by vehicle types for 12 port operation hours considered.

As shown in Table 3, over 78 % of CO and HC emissions are generated mainly by passenger cars, with the exception of NO_x and PM. Heavy duty trucks are the main contributors of NO_x and PM, which cause adverse public health impacts including, particularly, breathing diseases such as asthma. Approximately 60% and 50% of NO_x and PM emissions, respectively, are generated by all types of trucks of each lower and upper bound. In particular, over 90% of NO_x and PM are contributed by heavy duty trucks of all types. Moreover, port trucks contribute 6% for CO, 10% for HC, 35% for NO_x, 26% of PM_{2.5}, and 20% of PM₁₀ of total emissions.

TABLE 3 Average Emission Results of Vehicle Types for 12 Hours of Port Operation

Pollutants (units: kg)		CO**	NO _x **	HC**	PM _{2.5} **	PM ₁₀ **
Upper bound	LDV	33,359.7	3,539.7	1,630.5	131.4	261.6
	LDT	1,752.5	241.5	81.8	7.8	13.2
	MDT	943.0	145.9	41.8	3.9	6.4
	HDT	1,632.6	1,954.1	140.3	42.7	50.6
	Port*	2,394.4	2,958.1	199.8	64.4	76.3
	Total	40,082.2	8,839.3	2,094.1	250.3	408.1
Lower bound	LDV	30,208.0	3,240.9	1,441.0	117.7	237.3
	LDT	1,673.4	234.3	75.2	7.2	12.6
	MDT	917.2	144.5	38.9	3.7	6.2
	HDT	1,424.1	1,907.8	109.3	39.7	47.4
	Port*	2,279.1	3,023.4	177.3	63.6	75.7
	Total	36,501.8	8,550.9	1,841.7	231.8	379.2

Notes.

*: Port trucks are all heavy duty trucks

**: 12hours = AM emission × (2hrs) + MD emission × (6hrs) + PM emission × (4hrs)

RAIL CORRIDOR

To estimate emissions from the railway connected to the SPBP complex, two types of rail emission sources need to be considered: line-haul, which refers to the movement of cargo over long distances, and switching, which refers to the assembly and disassembly of trains.

TABLE 4 Estimated Line-haul Emissions in the Study Area

Line-haul Characteristics of Alameda Corridor						
Segment	Distance (mile)	Speed Limits (mph)	Travel Time (hr)	Assumed Notch	Number of locomotives/train	Number of trains/hour
1	8	25	0.32	3	4	2
2	10	40	0.25	5	4	2
3	2	25	0.08	3	4	2
PM Emissions of Line-haul						
Segment	Assumed Notch	Emission Factor (g/hr)	PM ₁₀ /locomotive(g)*	PM ₁₀ (g/hr)	PM ₁₀ (kg/day)	PM ₁₀ (ton/year)
1	3	427	136.6	1093.1	26.2	9.6
2	5	348	87.0	696.0	16.7	6.1
3	3	427	34.2	273.3	6.6	2.4
Total	-	-	-	-	49.5	18.1
NO _x Emissions of Line-haul						
Segment	Assumed Notch	Emission Factor (g/hr)	NO _x /locomotive(g)*	NO _x (g/hr)	NO _x (kg/day)	NO _x (ton/year)
1	3	7,267.0	2,325.4	18,603.5	446.5	163.0
2	5	25,584.0	6,396.0	51,168.0	1,228.0	448.2
3	3	7,267.0	581.4	4,650.9	111.6	40.7
Total	-	-	-	-	1,786.1	651.9

Note: *PM (or NO_x)/locomotive = travel time × no. of locomotives/train × no. of train/hour × emission factor

Sangkapichai et al. (12) estimated emissions of the line-haul and railyards operating in and around the SPBP complex. In this paper, we follow their assumptions and methods. We focus on the

emissions of NO_x and PM₁₀ from railyards and line-haul activities. In this section, we present results of railyards and line-haul emissions in terms of PM₁₀, but it is easy to estimate the corresponding PM_{2.5} emissions using conversion factors for health impact analyses.

Line-haul Emissions

To estimate line-haul emissions over the Alameda Corridor, the Corridor is split into three segments: 2 miles in the north, 10 miles in the middle, and 8 miles in the south. Further, it is assumed that the trains using these segments move at the speed limit, that there are two trains each hour, and that each train is powered by four locomotives.

Estimated line-haul emissions in the Alameda Corridor are shown in Table 4. We see that 49.5 kg and 1,786 kg of PM₁₀ and NO_x emissions are generated each day on average by line-haul movements. Compared to PM and NO_x emission from port trucks in Table 3, the amount of PM and NO_x emissions from line-hauling are approximately 35% and 40% less, respectively.

Railyard Emissions

As shown in Figure 1, there are seven railyards in our study area. Railyards generate pollutants from various activities: locomotives, drayage trucks, and cargo handling equipment. Currently, two main railyards, ICTF/Dolores and “Combined Commerce”, generate about 90% of emissions of PM₁₀ and NO_x. The emissions of the other five smaller railyards are estimated assuming that their emissions are proportional to their area (12). The estimated emissions of the seven railyards are presented in Table 5.

TABLE 5 Estimated Railyard Emissions in the Study Area

Railyard Locations	Area	Trains only (kg/day)**		Trains only (metric ton/year)	
	(acres)	PM ₁₀	NO _x	PM ₁₀	NO _x
Combined Commerce*	530	35.6	312.1	13	113.9
ICTF/Dolores (UP)	233	3.3	137.3	1.2	50.1
Wilmington-Watson (BNSF)	17	1.1	9.9	0.4	3.6
Transfer (PHL)	6	0.3	3.3	0.1	1.2
UP Mead (PHL)	10	0.8	6.0	0.3	2.2
Pier A (PHL)	23	1.6	13.7	0.6	5
Pier B (PHL)	14	0.8	8.5	0.3	3.1
Total	833	43.6	490.7	15.9	179.1

Notes.

*Combined Commerce includes UP Commerce, BNSF Hobart, BNSF Eastern, and BNSF Sheila

** PM₁₀ and NO_x emission per day = PM₁₀ and NO_x emission per year/365 days

In Table 5, daily PM₁₀ and NO_x emissions of train activities from the railyards are approximately 10% and 70% less than emissions from line-haul, respectively. Total daily emissions from railyards and line-haul are 2,276 kg for NO_x and 93 kg for PM₁₀, which are, respectively, 30% less and 22% more than the emissions from port heavy duty trucks shown in Table 3.

FREEWAY AND RAIL CORRIDOR

Emissions from rail and freeways serving the SPBP complex were separately estimated in the previous section. To examine the overall concentration of pollutants and their health impacts near the SPBP area, we combine estimates of air pollutants from freeways, line-haul, and railyards.

Dispersion Analysis

Air quality dispersion models spatially analyze the concentration of pollutants from various sources. Only a few transportation studies have relied on dispersion models so far (12, 13, 27). To model dispersion of air pollutants, we rely on CALPUFF View. This software can model emissions dispersion for large networks and dynamic meteorological conditions. It can also model complex terrains and calculate concentrations for a wide range of time-scales. CALPUFF View consists of three components: CALMET, which processes meteorological data, land use, and coordinate systems; CALPUFF, which estimates pollutant dispersion; and CALPOST, which processes results (16).

To estimate the dispersion of emissions from traffic, freeways were split in segments modeled as area sources (31 in total). For rail, each railyard was modeled as an area source (7 in total) and the Alameda corridor (for line-haul operation) was represented by three segments also modeled by area sources (3 in total).

Emission Dispersion Results

Dispersions analyses were performed for two seasons: winter (January-March) and summer (July-September) to consider seasonal variation of meteorological conditions. We also assume that estimated daily emission rates from freeway and rail operations are constant over each season. The maximum 24-hour average concentration for both PM_{10} and NO_x is estimated for each season. Results from emission dispersion are as follows:

- For winter, the maximum 24-hour average concentrations are 462.7 to 463.1 $\mu g/m^3$ for NO_x and 34.0 to 34.1 $\mu g/m^3$ for PM_{10} respectively; and
- For summer, the maximum 24-hour average concentrations are 418.8 to 419.0 $\mu g/m^3$ for NO_x and 24.93 to 24.9 $\mu g/m^3$ for PM_{10} respectively.

Average summer concentrations of both pollutants are lower than winter concentrations even though the same emission rates are used in the dispersion analysis. These results are therefore driven by meteorological conditions (wind direction and speed). Figure 3 shows the dispersions of PM_{10} and NO_x for port trucks, line-haul, and railyards for winter and summer.

As shown in Figure 3, the area affected by NO_x and PM_{10} is much larger in the winter than in the summer. In the winter, NO_x emissions extend mostly from the SR-91 to the Commerce railyard, around the I-710, the I-405, and the ICTF railyard. On the other hand, in the summer, NO_x concentrates in the area to the left side of the Alameda Corridor and above the SR-91 and the I-110. For the dispersion of PM_{10} , the I-710 close to the I-5, the I-405, the Commerce, and the ICTF are affected. The affected area (for PM_{10}) is slightly larger in the winter than in the summer. Unsurprisingly, the concentration of pollutants is higher in the areas where freeways, railyards, and the line-haul are closely located. In our study, the area to the north of the Alameda Corridor and below the I-5 and the I-710 shows the highest concentration of both pollutants in both seasons. This can be explained by the cumulative effects of pollutants generated from multiple sources.

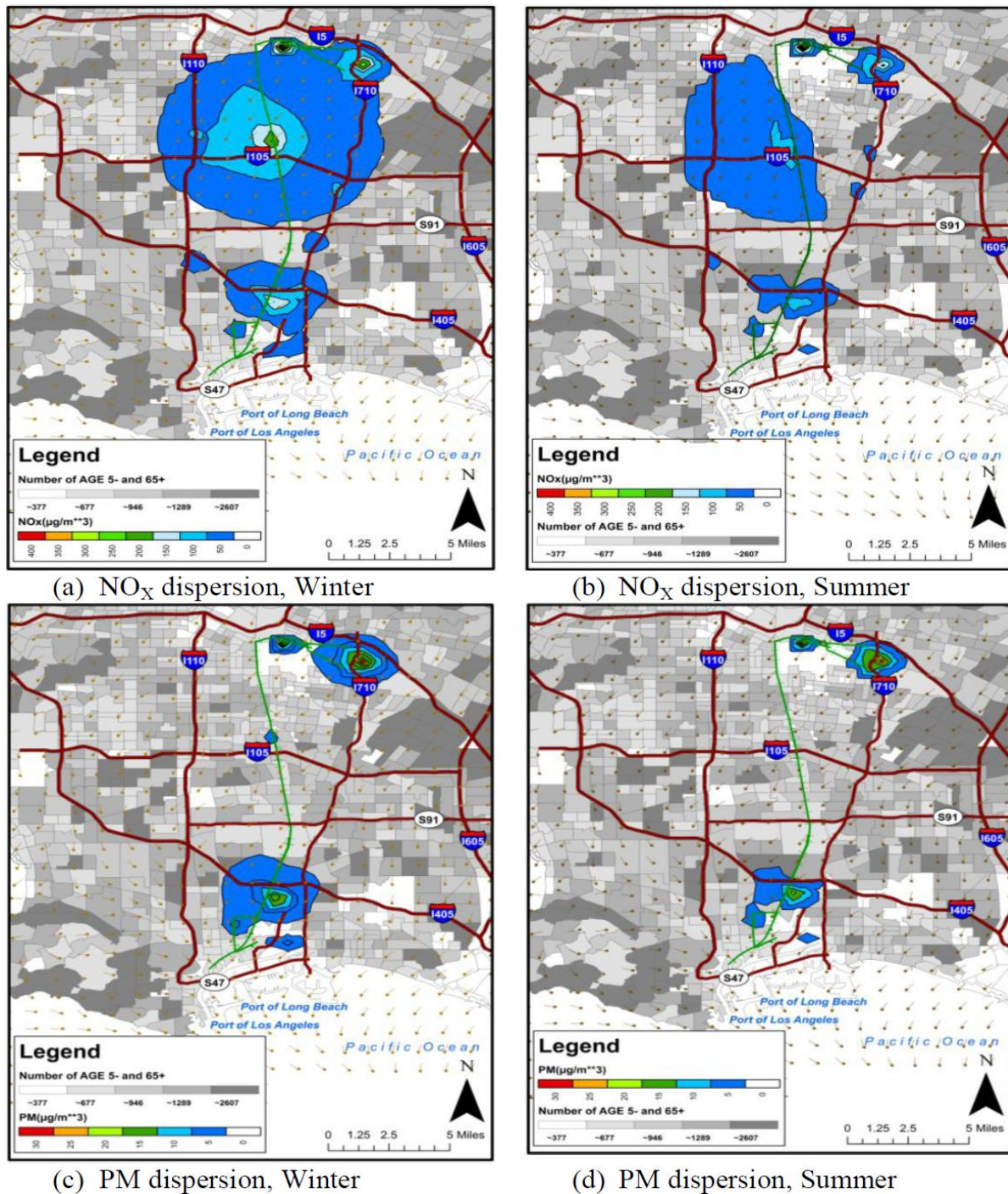


FIGURE 3 NO_x and PM dispersion and wind direction for base case by winter and summer.

Assessing Health Impacts

To assess the health impacts of NO_x and PM emissions from freight operations in the Alameda corridor for the 2005 baseline, we follow (12) and rely on BenMAP (Benefit Mapping and Analysis), which was created by EPA (21).

BenMAP is a GIS-based program that uses health impact functions (see (12)) to estimate changes in benefit associated with changes in pollutants. BenMAP provides health impacts as

monetary values for decision making purposes as well. BenMAP relies on local concentrations of air pollutants, population distribution, and health impact functions. In our analysis of health impacts, we again focus on NO_x and PM_{2.5} for two seasons. Following (23), the results of PM₁₀ from CALPUFF are converted into PM_{2.5} using a conversion factor of 0.92.

Health Impact Results

Aggregated health impact results for NO_x and PM_{2.5} are summarized in Table 6. Asthma exacerbation in children aged 5 to 12 years old with four measurements (e.g., missed school days, night-time asthma, one or more symptoms, and slow play) were considered for NO_x exposure. For PM, we considered mortality from all causes and chronic bronchitis, which is an inflammation of the main airways in the lungs. Unfortunately, the health impact functions of both NO_x and PM_{2.5} do not cover all age groups or all important health outcomes. Moreover, the aggregated health impacts results from NO_x exposure are estimated using data collected from six inner cities, which do not include the Los Angeles area.

TABLE 6 Aggregated Health Impacts from NO_x and PM_{2.5} Exposure

NO_x Base Scenario					
Units: million Dollars ²⁾ (no of cases)					
Asthma Exacerbation ¹⁾	Missed school days	Nighttime Asthma	One or More Symptoms	Slow Play	Total Value (\$2005)
Summer	\$4.17~4.19 (21,562~21,651)	\$8.36~8.39 (43,178~43,361)	\$12.39~12.44 (64,003~64,278)	\$12.05~12.1 (62,230~62,493)	\$37.0~37.1 (190,973~191,783)
Winter	\$4.63~4.64 (23,926~23,990)	\$9.28~9.3 (47,921~48,054)	\$13.75~13.79 (71,042~71,241)	\$13.37~13.41 (69,065~69,256)	\$41.0~41.1 (211,954~212,540)
PM_{2.5} Base Scenario					
Units: million Dollars ²⁾ (no of cases)					
PM _{2.5} Mortality and Chronic Bronchitis	Mortality (Age: 30-65)	Mortality (Age: 65+)	Chronic Bronchitis	Total Value (\$2005)	
Summer	\$84.5~84.9 (12.4~12.5)	\$76.4~76.8 (11.2~11.3)	\$4.11~4.12 (12.52~12.54)	\$165~166 (36.1~36.3)	
Winter	\$112.4~112.5 (16.4~16.5)	\$84.6~84.8 (12.4~12.5)	\$5.39~5.40 (16.41~16.43)	\$202.4~202.7 (45.2~45.4)	

Notes.

¹⁾ Data collected for age Group (5~12) from inner cities including Boston, Chicago, Dallas, New York, Seattle, and Tucson

²⁾ All dollars are converted from 2000 dollars to 2005 dollars using consumer price index (CPI), which is 1.239 (22).

The range of values shown in Table 6 indicates health impact results based on lower and upper bound estimates of traffic volumes; we see that the health impact differences between both lower and upper bound traffic volumes are very small. The estimated total number of cases and the social costs from NO_x exposure is 191,780 cases and \$37 million in the summer; in the winter, the number of cases and the social costs are approximately 10% higher. For PM_{2.5} exposure in the summer, the total number of mortality cases is 37 and the corresponding social costs reach \$165 million; these estimates increase by approximately 25% in the winter. Chronic bronchitis has relatively smaller health impacts than mortality, but the estimated social costs are still over \$4 million. A comparison of total costs for NO_x and PM_{2.5} shows that the health impacts of PM_{2.5} are much larger than those of NO_x.

CONCLUSIONS AND FUTURE RESEARCH

The objective of this paper was to analyze a combined approach to evaluate the environmental and health impacts of freight corridor operations serving the SPBP complex. Our integrated approach combines a microscopic traffic simulation model as well as line-haul and railyard models with an emissions model, a spatial dispersion model, and a health impact model for the estimation of the health impacts of freight corridor operations.

Our analyses focused on two major freight freeways (the I-710 and the I-110), and one railway corridor (the Alameda Corridor) that serve the nation's busiest port complex. Our analysis of the 2005 baseline shows that winter is worse than summer in terms of average concentration of PM₁₀ and NO_x pollutants, so winter also exhibits larger health impacts than summer for both pollutants.

In the future, we will also consider emissions from arterials and evaluate air quality and estimate the combined health impacts of rail and highway operations. We will also strive to better account for secondary PM formation, which are likely to also cause serious health impacts. In addition, we will examine air quality and health impacts of alternative scenarios, including intelligent transportation systems (ITS) strategies, to improve the baseline conditions analyzed in this paper.

ACKNOWLEDGEMENTS

Support for this research from the University of California Transportation Center (Award 65A016-SA5882) is gratefully acknowledged. We would also like to thank Eric Shen and Shashank Patil from the Port of Long Beach for their cooperation and assistance.

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