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Freight Movement in a Major Urban Transportation Corridor**

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

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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<sub>x</sub> 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<sub>x</sub>), 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.

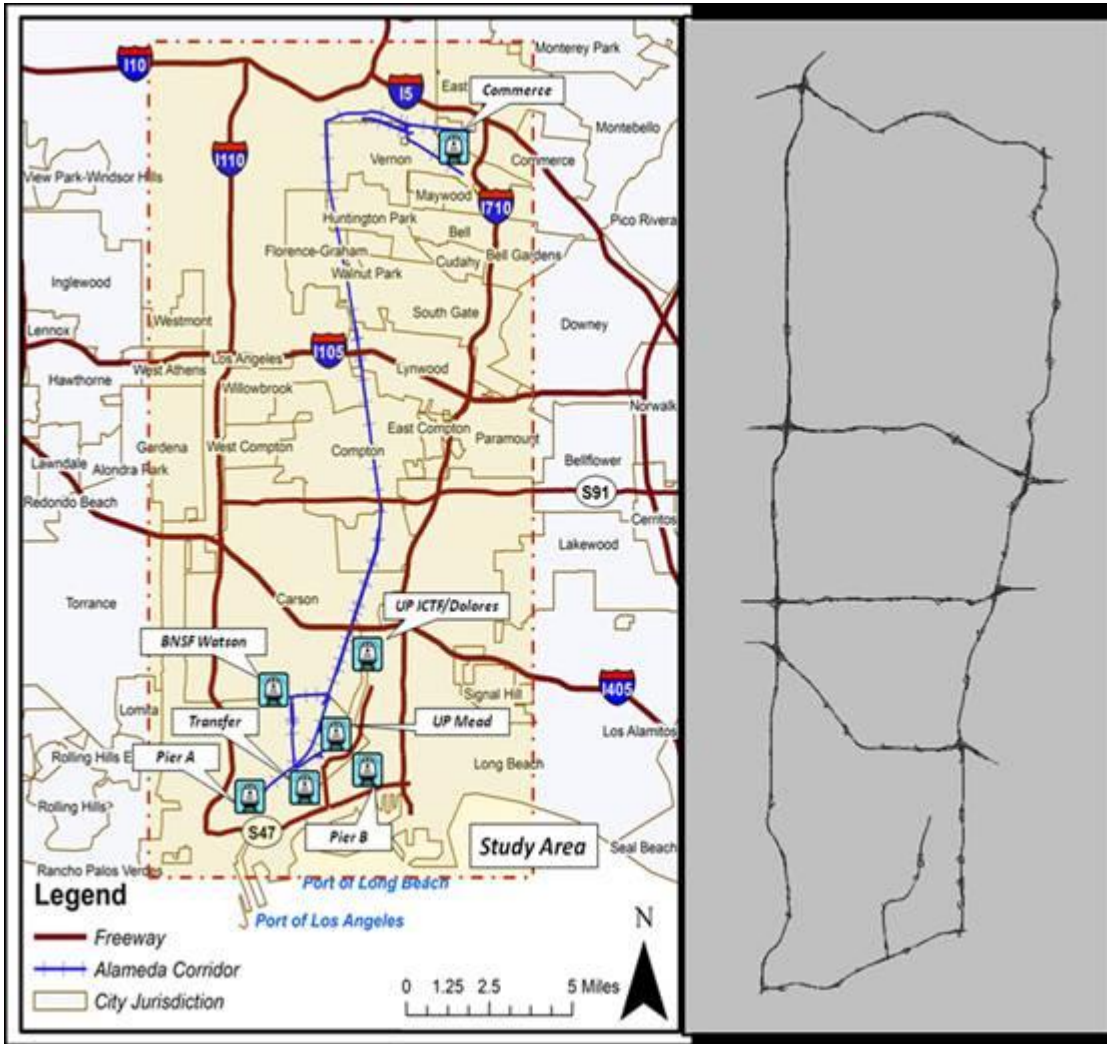
32 The objective of this paper is to start filling this gap for the area that extends from the gates of  
33 the SPBP to downtown Los Angeles (see Figure 1). We analyze both train (12) and vehicle emissions  
34 of NO<sub>x</sub> and PM. For the latter, we focus on the two major freight freeways, the 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

1 Pacific (UP)) provide regional and long-distance transportation services, in addition to a small  
 2 switching railroad (the Pacific Harbor Line PHL).  
 3



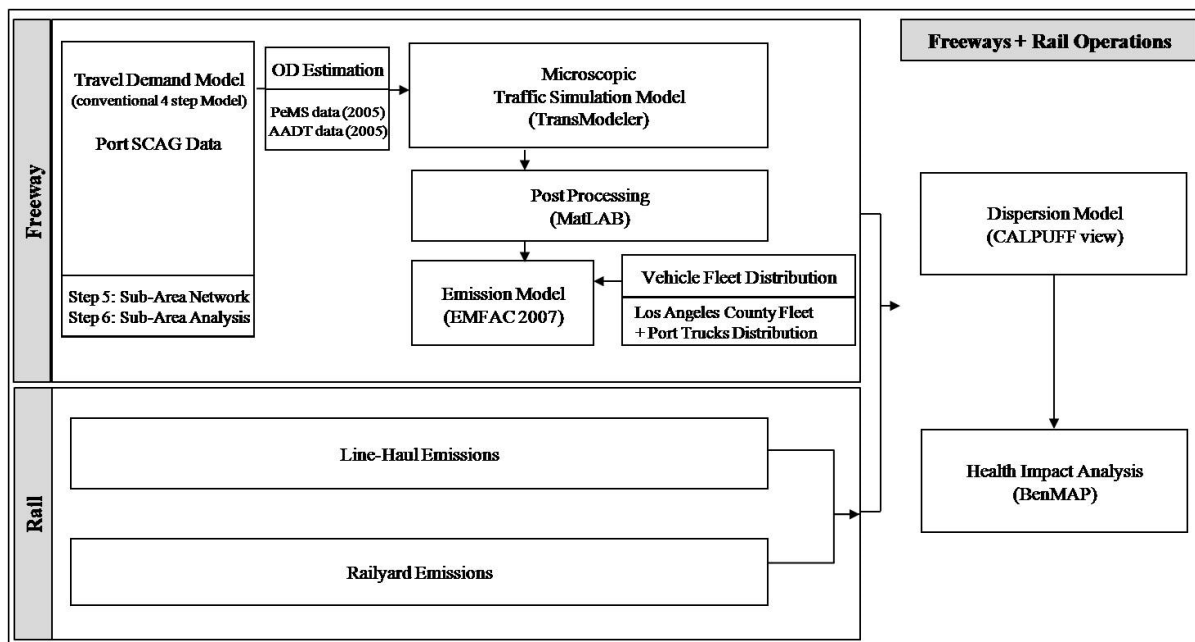
4 **FIGURE 1 Study area (left side) and freeway network in TransModeler (right side).**  
 5  
 6

7 A number of previous studies analyzed different aspects of this freight corridor. Fischer et al.  
 8 (10) examined the implementation of truck-only lanes on the I-710. Park et al. (11) extended their  
 9 analysis by considering both truck-restricted lanes and truck-only lanes on the I-710 using a  
 10 microscopic traffic simulator and a microscopic emissions model (CMEM); they concluded that  
 11 truck-restricted lanes are better than truck-only lanes for improving traffic conditions and air quality.  
 12 Giuliano and O'Brien (25) examined the impacts of extended gate operations of the SPBP called the  
 13 PierPASS program and found a significant temporal shift of cargo trips at the Port area. Rahai (26)  
 14 measured PM concentrations in multiple locations along the Alameda corridor and concluded that  
 15 these concentrations increase by 10~15% when diesel trains are operating. Sangkapichai et al. (12)  
 16 estimated PM and NO<sub>x</sub> emissions from locomotives and railyards in the Alameda railway corridor  
 17 area and applied dispersion models; they found that on the worst day of 2005, and NO<sub>x</sub> emissions  
 18 from train operations exceeded recommended thresholds. Lee et al. (13) proposed a new integrated  
 19 approach for estimating vehicle emission impacts of the I-710 freight corridor using a microscopic-

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

4  
 5 **MODELING EMISSION IMPACTS: AN OVERVIEW**

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



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

17  
 18  
 19 As mentioned above, we analyzed 2005 emissions because CARB’s emission reduction plan for  
 20 goods movement (4) uses 2005 as its base year to assess the impact of various measures over the next  
 21 15 years. Since micro-simulation is very time consuming, we selected a representative day of the  
 22 week, Wednesday, March 9<sup>th</sup>, 2005, based on traffic counts data from Caltrans’ Freeway Performance  
 23 Measurement System, PeMS (17). We then performed a detailed hourly simulation of traffic on our  
 24 network to estimate emissions of various pollutants, including NO<sub>x</sub> and PM.

25  
 26 **FREEWAY**

27 **Microscopic Traffic Simulation**

28 *Tools*

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

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

#### 5 Data

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

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

16 Traffic origin and destination (OD) demand inputs are required for traffic simulation. OD  
 17 demands were obtained from a modified Southern California Association of Governments (SCAG)  
 18 traffic study that combined the existing SCAG travel demand data with stated port truck demand data  
 19 from a survey conducted for the Port of Long Beach (PortSCAG data; 8). The OD demands were then  
 20 adjusted to match traffic flow data every half an hour, which was measured by loop detectors on the I-  
 21 110 and I-710 freeways through PeMS (17). We followed the same approach for OD estimation as in  
 22 our previous study (13). While performing OD estimation, unrealistic vehicle behavior was observed  
 23 locally and corrected using local parameters in traffic models, including car-following model  
 24 parameters and the distribution of critical distance parameter in TransModeler (17).

25 **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

### 1 *Traffic Simulation Results*

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

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

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

19  
20 **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 <sup>(1)</sup>	Near-Dock <sup>(2)</sup>	Off-Dock <sup>(3)</sup>	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%

21 Notes.

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

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

24 <sup>(1)</sup>: With on-dock, containers are directly transferred from a ship to a train.

25 <sup>(2)</sup>: Near-dock refers to facilities located within 5 miles from the SPBP.

26 <sup>(3)</sup>: Off-dock yards are located more than 5 miles from the SPBP (18).

27

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

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

39 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<sub>x</sub>, 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<sub>x</sub> and PM. Heavy duty trucks are the main contributors of NO<sub>x</sub> and PM, which cause adverse public health impacts including, particularly, breathing diseases such as asthma. Approximately 60% and 50% of NO<sub>x</sub> and PM emissions, respectively, are generated by all types of trucks of each lower and upper bound. In particular, over 90% of NO<sub>x</sub> and PM are contributed by heavy duty trucks of all types. Moreover, port trucks contribute 6% for CO, 10% for HC, 35% for NO<sub>x</sub>, 26% of PM<sub>2.5</sub>, and 20% of PM<sub>10</sub> of total emissions.

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

Pollutants (units: kg)		CO**	NO <sub>x</sub> **	HC**	PM <sub>2.5</sub> **	PM <sub>10</sub> **
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

2 Notes.

3 \*: Port trucks are all heavy duty trucks

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

5  
6 **RAIL CORRIDOR**7 To estimate emissions from the railway connected to the SPBP complex, two types of rail emission  
8 sources need to be considered: line-haul, which refers to the movement of cargo over long distances,  
9 and switching, which refers to the assembly and disassembly of trains.10  
11 **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 <sub>10</sub> / locomotive(g)*	PM <sub>10</sub> (g/hr)	PM <sub>10</sub> (kg/day)	PM <sub>10</sub> (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 <sub>x</sub> Emissions of Line-haul						
Segment	Assumed Notch	Emission Factor (g/hr)	NO <sub>x</sub> / locomotive(g)*	NO <sub>x</sub> (g/hr)	NO <sub>x</sub> (kg/day)	NO <sub>x</sub> (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

12 Note: \*PM (or NO<sub>x</sub>)/locomotive = travel time × no. of locomotives/train × no. of train/hour × emission factor13  
14 Sangkapichai et al. (12) estimated emissions of the line-haul and railyards operating in and  
15 around the SPBP complex. In this paper, we follow their assumptions and methods. We focus on the

1 emissions of NO<sub>x</sub> and PM<sub>10</sub> from railyards and line-haul activities. In this section, we present results  
 2 of railyards and line-haul emissions in terms of PM<sub>10</sub>, but it is easy to estimate the corresponding  
 3 PM<sub>2.5</sub> emissions using conversion factors for health impact analyses.

#### 5 **Line-haul Emissions**

6 To estimate line-haul emissions over the Alameda Corridor, the Corridor is split into three segments:  
 7 2 miles in the north, 10 miles in the middle, and 8 miles in the south. Further, it is assumed that the  
 8 trains using these segments move at the speed limit, that there are two trains each hour, and that each  
 9 train is powered by four locomotives.

10 Estimated line-haul emissions in the Alameda Corridor are shown in Table 4. We see that  
 11 49.5 kg and 1,786 kg of PM<sub>10</sub> and NO<sub>x</sub> emissions are generated each day on average by line-haul  
 12 movements. Compared to PM and NO<sub>x</sub> emission from port trucks in Table 3, the amount of PM and  
 13 NO<sub>x</sub> emissions from line-hauling are approximately 35% and 40% less, respectively.

#### 15 **Railyard Emissions**

16 As shown in Figure 1, there are seven railyards in our study area. Railyards generate pollutants from  
 17 various activities: locomotives, drayage trucks, and cargo handling equipment. Currently, two main  
 18 railyards, ICTF/Dolores and “Combined Commerce”, generate about 90% of emissions of PM<sub>10</sub> and  
 19 NO<sub>x</sub>. The emissions of the other five smaller railyards are estimated assuming that their emissions are  
 20 proportional to their area (12). The estimated emissions of the seven railyards are presented in Table 5.

22 **TABLE 5 Estimated Railyard Emissions in the Study Area**

Railyard Locations	Area	Trains only (kg/day)**		Trains only (metric ton/year)	
	(acres)	PM <sub>10</sub>	NO <sub>x</sub>	PM <sub>10</sub>	NO <sub>x</sub>
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

23 Notes.

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

25 \*\* PM<sub>10</sub> and NO<sub>x</sub> emission per day = PM<sub>10</sub> and NO<sub>x</sub> emission per year/365 days

26  
 27 In Table 5, daily PM<sub>10</sub> and NO<sub>x</sub> emissions of train activities from the railyards are  
 28 approximately 10% and 70% less than emissions from line-haul, respectively. Total daily emissions  
 29 from railyards and line-haul are 2,276 kg for NO<sub>x</sub> and 93 kg for PM<sub>10</sub>, which are, respectively, 30%  
 30 less and 22% more than the emissions from port heavy duty trucks shown in Table 3.

#### 32 **FREEWAY AND RAIL CORRIDOR**

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

## 1 **Dispersion Analysis**

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

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

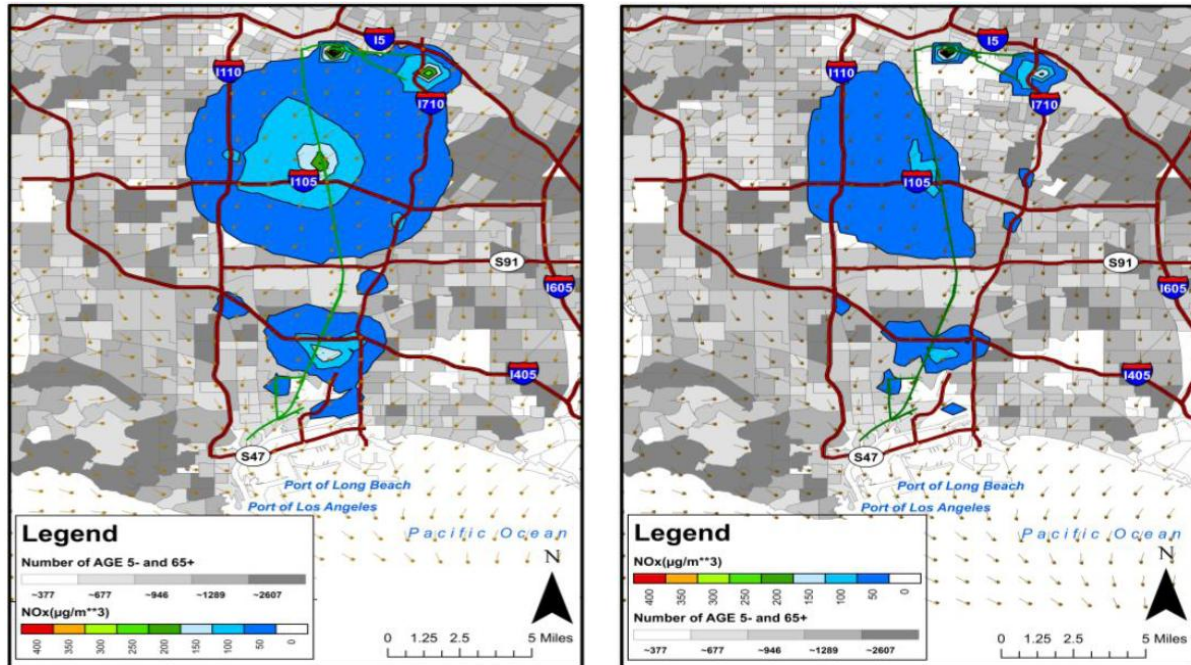
## 13 **Emission Dispersion Results**

14 Dispersions analyses were performed for two seasons: winter (January-March) and summer (July-  
15 September) to consider seasonal variation of meteorological conditions. We also assume that  
16 estimated daily emission rates from freeway and rail operations are constant over each season. The  
17 maximum 24-hour average concentration for both PM<sub>10</sub> and NO<sub>x</sub> is estimated for each season.  
18 Results from emission dispersion are as follows:

- 19 • For winter, the maximum 24-hour average concentrations are 462.7 to 463.1 µg/m<sup>3</sup> for NO<sub>x</sub> and  
20 34.0 to 34.1 µg/m<sup>3</sup> for PM<sub>10</sub> respectively; and
- 21 • For summer, the maximum 24-hour average concentrations are 418.8 to 419.0 µg/m<sup>3</sup> for NO<sub>x</sub> and  
22 24.93 to 24.9 µg/m<sup>3</sup> for PM<sub>10</sub> respectively.

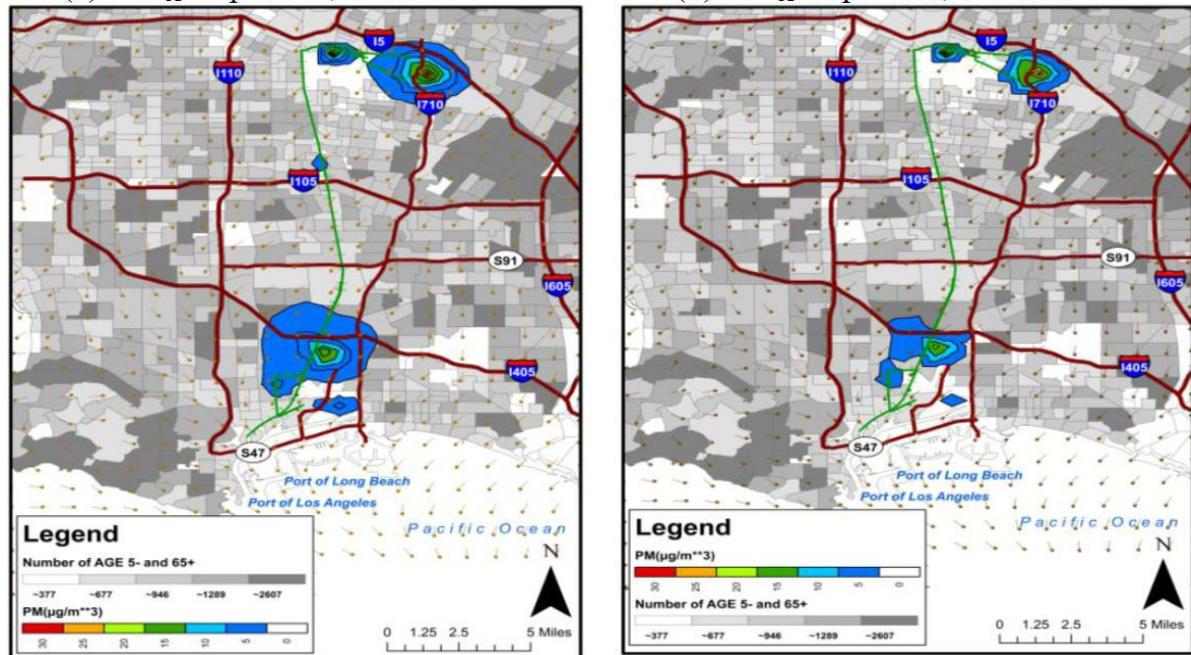
23 Average summer concentrations of both pollutants are lower than winter concentrations even  
24 though the same emission rates are used in the dispersion analysis. These results are therefore driven  
25 by meteorological conditions (wind direction and speed). Figure 3 shows the dispersions of PM<sub>10</sub> and  
26 NO<sub>x</sub> for port trucks, line-haul, and railyards for winter and summer.

27 As shown in Figure 3, the area affected by NO<sub>x</sub> and PM<sub>10</sub> is much larger in the winter than in  
28 the summer. In the winter, NO<sub>x</sub> emissions extend mostly from the SR-91 to the Commerce railyard,  
29 around the I-710, the I-405, and the ICTF railyard. On the other hand, in the summer, NO<sub>x</sub>  
30 concentrates in the area to the left side of the Alameda Corridor and above the SR-91 and the I-110.  
31 For the dispersion of PM<sub>10</sub>, the I-710 close to the I-5, the I-405, the Commerce, and the ICTF are  
32 affected. The affected area (for PM<sub>10</sub>) is slightly larger in the winter than in the summer.  
33 Unsurprisingly, the concentration of pollutants is higher in the areas where freeways, railyards, and  
34 the line-haul are closely located. In our study, the area to the north of the Alameda Corridor and  
35 below the I-5 and the I-710 shows the highest concentration of both pollutants in both seasons. This  
36 can be explained by the cumulative effects of pollutants generated from multiple sources.  
37  
38



(a) NO<sub>x</sub> dispersion, Winter

(b) NO<sub>x</sub> dispersion, Summer



(c) PM dispersion, Winter

(d) PM dispersion, Summer

**FIGURE 3 NO<sub>x</sub> and PM dispersion and wind direction for base case by winter and summer.**

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**Assessing Health Impacts**

To assess the health impacts of NO<sub>x</sub> 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 create 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

1 monetary values for decision making purposes as well. BenMAP relies on local concentrations of air  
 2 pollutants, population distribution, and health impact functions. In our analysis of health impacts, we  
 3 again focus on NO<sub>x</sub> and PM<sub>2.5</sub> for two seasons. Following (23), the results of PM<sub>10</sub> from CALPUFF  
 4 are converted into PM<sub>2.5</sub> using a conversion factor of 0.92.

5  
 6 **Health Impact Results**

7 Aggregated health impact results for NO<sub>x</sub> and PM<sub>2.5</sub> are summarized in Table 6. Asthma exacerbation  
 8 in children aged 5 to 12 years old with four measurements (e.g., missed school days, night-time  
 9 asthma, one or more symptoms, and slow play) were considered for NO<sub>x</sub> exposure. For PM, we  
 10 considered mortality from all causes and chronic bronchitis, which is an inflammation of the main  
 11 airways in the lungs. Unfortunately, the health impact functions of both NO<sub>x</sub> and PM<sub>2.5</sub> do not cover  
 12 all age groups or all important health outcomes. Moreover, the aggregated health impacts results from  
 13 NO<sub>x</sub> exposure are estimated using data collected from six inner cities, which do not include the Los  
 14 Angeles area.

15  
 16 **TABLE 6 Aggregated Health Impacts from NO<sub>x</sub> and PM<sub>2.5</sub> Exposure**

<b>NO<sub>x</sub> Base Scenario</b>					
Units: million Dollars <sup>2)</sup> (no of cases)					
Asthma Exacerbation <sup>1)</sup>	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)
<b>PM<sub>2.5</sub> Base Scenario</b>					
Units: million Dollars <sup>2)</sup> (no of cases)					
PM <sub>2.5</sub> 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)	

17 Notes.

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

19 <sup>2)</sup>: All dollars are converted from 2000 dollars to 2005 dollars using consumer price index (CPI), which is 1.239 (22).

20  
 21 The range of values shown in Table 6 indicates health impact results based on lower and upper bound  
 22 estimates of traffic volumes; we see that the health impact differences between both lower and upper  
 23 bound traffic volumes are very small. The estimated total number of cases and the social costs from  
 24 NO<sub>x</sub> exposure is 191,780 cases and \$37 million in the summer; in the winter, the number of cases and  
 25 the social costs are approximately 10% higher. For PM<sub>2.5</sub> exposure in the summer, the total number of  
 26 mortality cases is 37 and the corresponding social costs reach \$165 million; these estimates increase  
 27 by approximately 25% in the winter. Chronic bronchitis has relatively smaller health impacts than  
 28 mortality, but the estimated social costs are still over \$4 million. A comparison of total costs for NO<sub>x</sub>  
 29 and PM<sub>2.5</sub> shows that the health impacts of PM<sub>2.5</sub> are much larger than those of NO<sub>x</sub>.

## 1 CONCLUSIONS AND FUTURE RESEARCH

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

7 Our analyses focused on two major freight freeways (the I-710 and the I-110), and one  
8 railway corridor (the Alameda Corridor) that serve the nation's busiest port complex. Our analysis of  
9 the 2005 baseline shows that winter is worse than summer in terms of average concentration of PM<sub>10</sub>  
10 and NO<sub>x</sub> pollutants, so winter also exhibits larger health impacts than summer for both pollutants.

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

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