

# **ADVANCES IN PROJECT LEVEL ANALYSES**

## **FINAL REPORT**

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## ACRONYMS AND ABBREVIATIONS

CO	carbon monoxide
CRT3	Continuously Regenerating Technology 3
CS	Cambridge Systematics, Inc.
DOTs	Departments of Transportation
DPF	Diesel Particulate Filter
EPA	U.S. Environmental Protection Agency
FHWA	Federal Highway Administration
ft.	feet
GHG	greenhouse gas
HC	hydrocarbon
HCM	Highway Capacity Manual
I-805	Interstate 805
ICM	Integrated Corridor Management
MOVES	Motor Vehicle Emission Simulator
mph	miles per hour
MPOs	Metropolitan Planning Organizations
NHPN	National Highway Planning Network
NO <sub>x</sub>	oxides of nitrogen
PM	particulate matter
SIPs	State Implementation Plans
V/C	volume-to-capacity
VMT	vehicle miles traveled
VOCs	volatile organic compounds
VSP	vehicle-specific power

## CHAPTER I. INTRODUCTION

### A. BACKGROUND

In December 2009, the U.S. Environmental Protection Agency (EPA) released a final version of its Motor Vehicle Emission Simulator (MOVES) model. This new model will be required to be used in the future State Implementation Plans (SIPs) and transportation conformity analyses and will play a critical role in estimating greenhouse gas (GHG) emissions. MOVES represents a significant departure from the MOBILE software, giving air agencies, state Departments of Transportation (DOTs), and Metropolitan Planning Organizations (MPOs) the ability to transform mobile source emissions modeling and travel demand forecasting by taking advantage of the significant detail in vehicle speed and acceleration data that can be used by the MOVES model. While in the short term, some of the MOBILE inputs can be converted to comparable MOVES inputs, in the longer term, EPA expects that transportation agencies will begin to collect or make use of existing data that can better take advantage of the full capabilities of the MOVES model.

MOVES can be run at three different scales: national, county, or project. At the national scale, EPA's default national database is used along with default state and local allocation factors. This scale does not require the input of any local information. At the county scale, the user must input county-specific information such as vehicle miles traveled (VMT), vehicle age distributions, and average speed distributions (among other inputs). At the project scale, some of this same information is required. However, in addition, the project scale requires that information at the link level be input, such as link-level driving schedules or operating mode distributions.<sup>1</sup> While running MOVES at this scale does require more detailed information, if this type of information is available, the resulting MOVES emissions or emission rates should be much more appropriate for the specific situation than applying county-level emission rates. Use of the inputs of the project level scale allow the user to fully define how travel is occurring on a specific roadway link at a specific time leading to more representative and accurate emission calculations. This is important in areas where emissions from a specific project are being evaluated and the travel on the roadway links of the project do not follow typical driving patterns.

In many cases, transportation modelers have already developed the data needed for input at the project scale of MOVES. However, when using the MOBILE models, these data needed to be aggregated to determine an average speed or average speed distribution. With MOVES, these detailed travel data can be used explicitly. The challenge for researchers and analysts in the transportation and air quality communities is to develop standard methods to process these available sources of data in an efficient manner to optimize the capabilities of MOVES and to improve the emissions and air quality modeling required for SIP and transportation conformity analyses, including project-level analyses.

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<sup>1</sup>The MOVES operating mode distribution allows the user to define the amount of travel time spent in various operating modes including: braking, idling, coasting, cruising/accelerating within various speed ranges and at various ranges of vehicle specific power (VSP), etc.

## B. PROJECT OVERVIEW

The project objective was to perform research and develop usable tools that can assist transportation and air quality modelers in preparing project-level emission analyses that take advantage of the capabilities of the MOVES model. In this project, the consulting team developed several sets of MOVES files detailing operating mode profiles (which are sometimes referred to here as vehicle-specific power [VSP] profiles) that simulate different types of driving conditions such as those on ramps, interchanges, freeway incidents, and signalized arterials under different levels of congestion as well as the effects of ramp metering and signal control. In addition, this project report also describes another set of MOVES files that can be used to model the unique conditions that occur at intermodal facilities and ports, capturing important activities such as idling, for the specific types of vehicles (trucks) used at these types of facilities. Finally, this report provides a demonstration of how these files can be used in MOVES. The example for which this demonstration is provided is an evaluation of emission reduction strategies that can be used to reduce truck emissions in and around port terminals.

The information in this report and the associated MOVES files may provide alternatives to using default MOVES data for many project-level evaluations. Plus, the methods used in this project to generate MOVES files can be observed by others seeking to link microsimulation models and MOVES directly in order to develop data sets that are representative of travel conditions specific to their projects.

Chapter II of this report summarizes the microsimulation modeling that was performed to develop VSP profiles under this project. This includes the modeling of a variety of congestion conditions as well as the modeling of VSP profiles specific to conditions at ports or intermodal facilities. This chapter also documents the MOVES VSP files that have been provided to the Federal Highway Administration (FHWA) as part of this project.

Chapter III provides information on how the VSP profiles developed for use in project-level modeling of various congestion conditions could be applied to a user's project level MOVES modeling.

Chapters IV, V, and VI are all related to ports and intermodal facilities. In these chapters, ports are used as a surrogate, but many of the conditions that apply to ports, such as the in-port operating mode including low speed driving and idling, as well as the types of trucks used and trips that occur at ports, also apply to intermodal facilities. Chapter IV presents an analysis of the activity at three sample ports. Chapter V explains how the VSP profiles developed for ports, as documented in Chapter II, can be applied to a MOVES analysis of emissions at a port. Chapter VI documents an evaluation of the potential control strategies that might be used at ports or intermodal facilities and the resulting emission reductions.

Finally, Chapter VII presents project conclusions. References used in this study are listed at the end of the report.

## CHAPTER II. DEVELOPMENT OF VSP PROFILES USING MICROSIMULATION MODELING

One of the objectives of this project was to develop a set of VSP profiles that simulate specific types of congestion conditions that can be input to the MOVES model and that are developed by transportation analysis techniques in order to improve MOVES inputs beyond average speed. The analytical methods used for planning applications are much simpler than microsimulation and as a result their outputs are of far lower resolution. In this study, microsimulation models were used to develop VSP profile inputs for MOVES under a variety of congestion levels and traffic conditions. This approach offers a level of refinement beyond using average speeds, which do not capture the details of how congestion forms and dissipates in practice. For example, vehicle activity is radically different under the different “regimes” of congestion, such as:

- Queue forming transitional flow, characterized by backward forming shock waves;
- Movement within the queue; and
- Recovery from queuing conditions.

In theory, using the analytical relationships derived from microsimulation allow more representative emissions estimates for project level analysis, because the driving cycles more closely match actual on-road conditions than simply using the MOVES default values. (However, the project did not test for any differences, but the data that was developed can be used for such a purpose.) Two sets of VSP profiles were developed under this project – one set of profiles simulates typical congested conditions (e.g., freeway ramps and interchange areas, freeway incidents, and signalized arterials) and the other set of VSP profiles simulates typical conditions at container ports and intermodal facilities. The development of each of these sets of profiles is discussed below followed by a discussion of the post-processing of the microsimulation outputs.

### A. MICROSIMULATION MODELING OF CONGESTED CONDITIONS

#### 1. Test Networks

For the development of the VSP profiles modeling congested roadway conditions, the Interstate 805 (I-805) corridor in San Diego, California was used to provide sample data for the simulations. The size of the test network used was determined through previous analysis conducted for FHWA as part of the Integrated Corridor Management (ICM) initiative. Cambridge Systematics, Inc. (CS) extracted this test network directly from the calibrated I-805 Transmodeler network being used for FHWA’s ICM modeling studies. CS has developed and calibrated this microsimulation model network using TransModeler Version 2.5 Build 980 with a base calibrated year of 2006. The I-805 corridor consists of the area between post mile 0 at the U.S./Mexican Border and mile 28.8 at the junction of I-5 and I-805. The Corridor includes 33 southbound and northbound interchanges. The Corridor also

includes additional arterials, Tier 1 (major) and Tier 2 (minor) arterials. This application was used because the model has already been calibrated to field conditions.

Four different types of congestion scenarios were modeled using this test network: 1) freeway on-ramps, 2) freeway-to-freeway interchanges, 3) freeway incidents with lane blockages, and 4) signalized arterials. Figure II-1 shows the test network used for the simple on-ramp condition – with and without ramp metering – as well as for the freeway incident scenarios. The “incident blockage locations” shows where incidents of different lane blockages and durations were coded in the incident scenarios. The ramp extracted was the on-ramp to I-805 southbound from Telegraph Canyon Road. At this location, I-805 southbound has four lanes and a speed limit of 65 miles per hour (mph), and the on-ramp is a single lane on-ramp. All roadways are modeled as level grades. Potential bottlenecks both upstream and downstream of the on-ramp were removed to ensure that the on-ramp functioned isolated from other system bottlenecks. Figure II-2 shows the network used for the freeway-to-freeway interchange scenarios. Figures II-3 and II-4 show the network used for the signalized arterial scenarios. This was extracted from the ICM network as the intersection of National City Boulevard (almost vertical links) and 8<sup>th</sup> Street (almost horizontal links). The location of this intersection is between I-5 and I-805 in Chula Vista.

**Figure II-1. Sub-Network Configuration for On-Ramp, Ramp Metering, and Incident Scenarios**

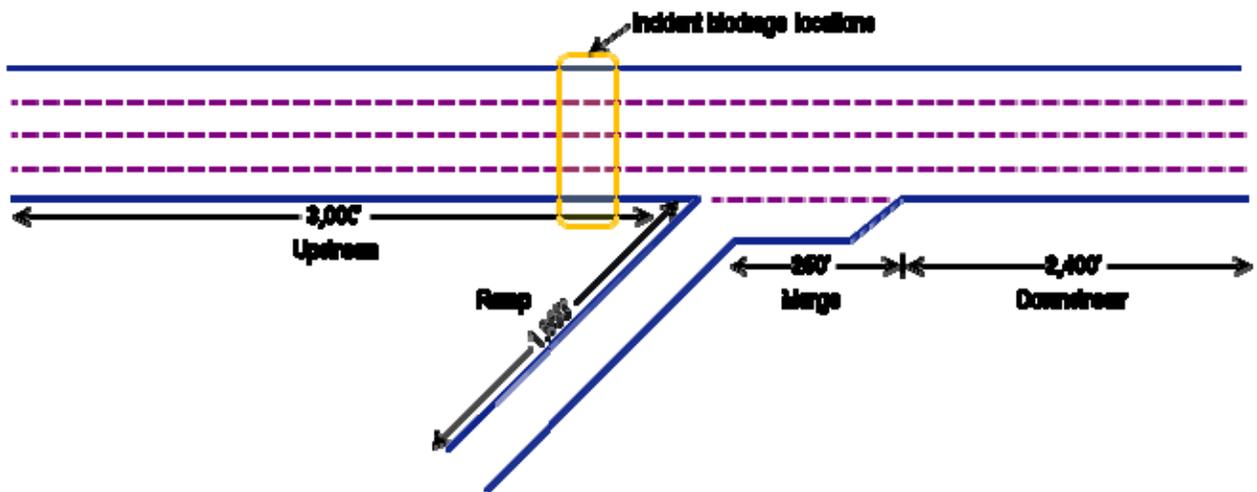
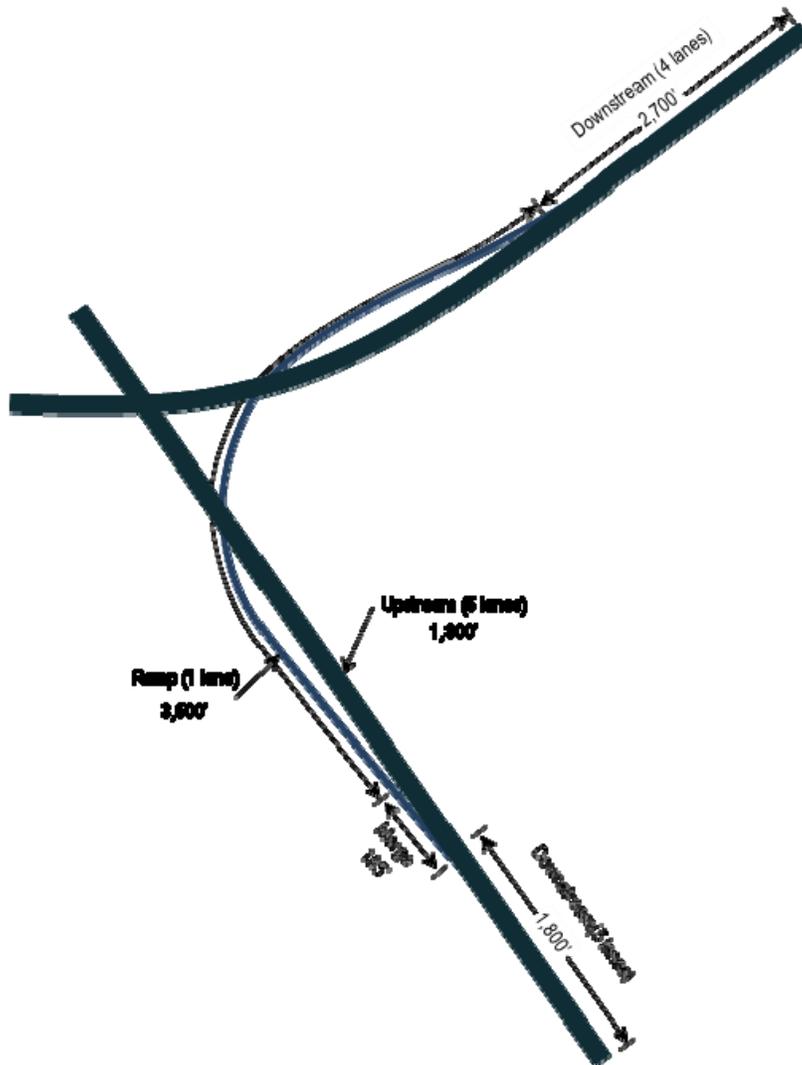


Figure II-2. Sub-Network Configuration for Freeway to Freeway Interchange



Note: This subnetwork is the interchange of I-805 and I-8. Vehicles are merging from I-8 westbound onto I-805 southbound.

Figure II-3. Sub-Network Configuration for Signalized Arterial

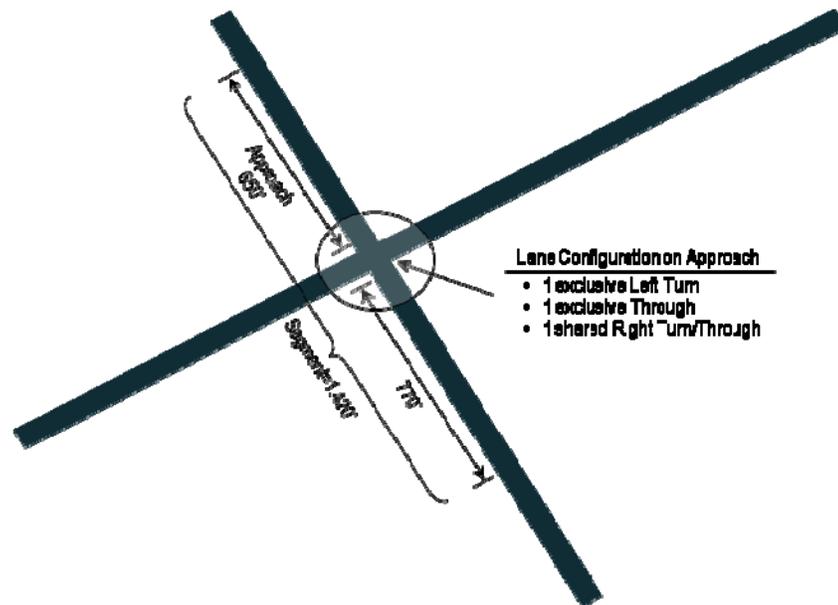
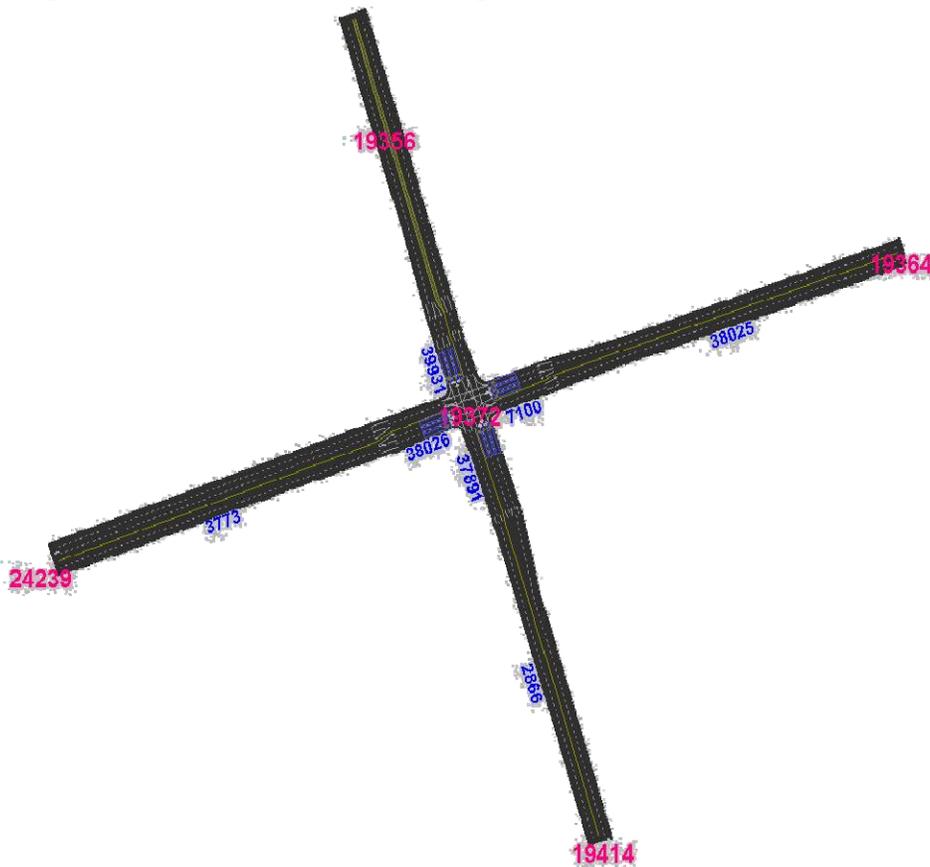


Figure II-4. Lane Detail for Signalized Arterial Sub-network



## 2. Roadway Capacity

As roadway capacity is not an input to the microsimulation software, several tests were conducted to estimate the capacity or maximum throughput of the simulated roadways. While keeping ramp volumes near zero, the mainline approach volumes were increased and the maximum throughput of the mainline roadway measured. Similarly, while keeping mainline ramp volumes low, ramp volumes were increased and the maximum ramp throughput measured.

During these tests, all parameters established during the calibration and validation of the larger simulation corridor model were kept constant, and only volumes were varied. A vehicle fleet mix of 100 percent passenger cars was used during the throughput tests, because the purpose was to estimate capacities which are expressed in passenger car-equivalents. Table II-1 shows the travel volume capacities for the mainline roadways and ramps that resulted from the simulation model compared with the capacities of the Highway Capacity Manual (HCM).

**Table II-1. Summary of Travel Volume Capacities**

<b>Approach</b>	<b>Number of Passenger Cars per Hour per Lane</b>	
	<b>Mainline</b>	<b>Ramp</b>
HCM Capacity	2,400	2,000
Maximum Throughput in Simulation Model	2,225	2,100

In order to test the operating conditions of the different congestion scenarios under specific volume-to-capacity (V/C) procedures, the maximum throughput observed in the simulation model, as shown in Table II-1, was used as the definition of capacity in place of the HCM procedures. The simulation procedures are based on a model calibrated to the conditions specific to San Diego, so we felt it was more appropriate to use values based on them.

## 3. Volume Procedures

For freeways, demand volumes were varied independently on the mainline and the ramp approaches into the merge area to meet the target V/C ratios during the peak hour of the simulation. The observed volume profile of demands across the peak period was kept constant and adjusted so that the peak hour volume (in passenger car equivalents) divided by capacity was equal to the V/C ratio being tested. A four-hour peak period was simulated, with the peak occurring in the second hour. This allows for the simulation to “warm-up.” The demand volumes for hours outside of the peak period were developed by applying factors from San Diego field data. Results are reported for the peak and the hour after the peak to capture the effect of queuing. Trucks are assumed to be a constant 8 percent of total volume. This truck percentage is believed to be a representative value for an urban freeway. (At the planning level, detailed future forecasts of truck types are almost never available, so using a representative value is reasonable. However, we expect that the emissions characteristics will change under assumptions of different truck distributions.) For comparison purposes (which indicate that the selected value of 8 percent is reasonable), the

default VMT percentage in MOVES, which is based on 1999 Highway Performance Monitoring System reporting, is 7.5 percent for trucks and 7.8 percent if trucks and buses are combined.

#### **4. Analysis Parameters**

As discussed above, microsimulation runs were performed for four different categories of scenarios: freeway on-ramps, freeway-to-freeway interchanges, freeway incidents, and signalized arterials. Each scenario was modeled under a range of V/C ratios. The specific V/C ratios and other scenario conditions run in the microsimulation model are as follows:

##### *Freeway On-Ramp*

- V/C levels: 0.9, 1.0, 1.10, 1.15, 1.20, 1.25, 1.40, and 1.50.
- With and without ramp metering (with ramp metering excludes the V/C ratio of 1.10).

##### *Freeway-to-Freeway Interchange*

- V/C levels: 0.90, 1.00, 1.10, 1.15, 1.20, 1.25, and 1.40.

##### *Freeway Incident*

- V/C levels: 0.9, 1.0, 1.15, 1.25, and 1.40.
- Blockage: 1 lane of 4, 2 lanes of 4, 3 lanes of 4.
- Duration: 30 minutes, 45 minutes, 60 minutes, 90 minutes.

##### *Signalized Arterial*

- V/C levels (total approach volume divided by total approach capacity): 0.7, 0.8, 0.9, 0.95, 1.0, 1.1, 1.2.
- Signal control: fixed time, actuated.

The application of these profiles is provided in Chapter III.

## **B. MICROSIMULATION MODELING OF PORT TRAVEL**

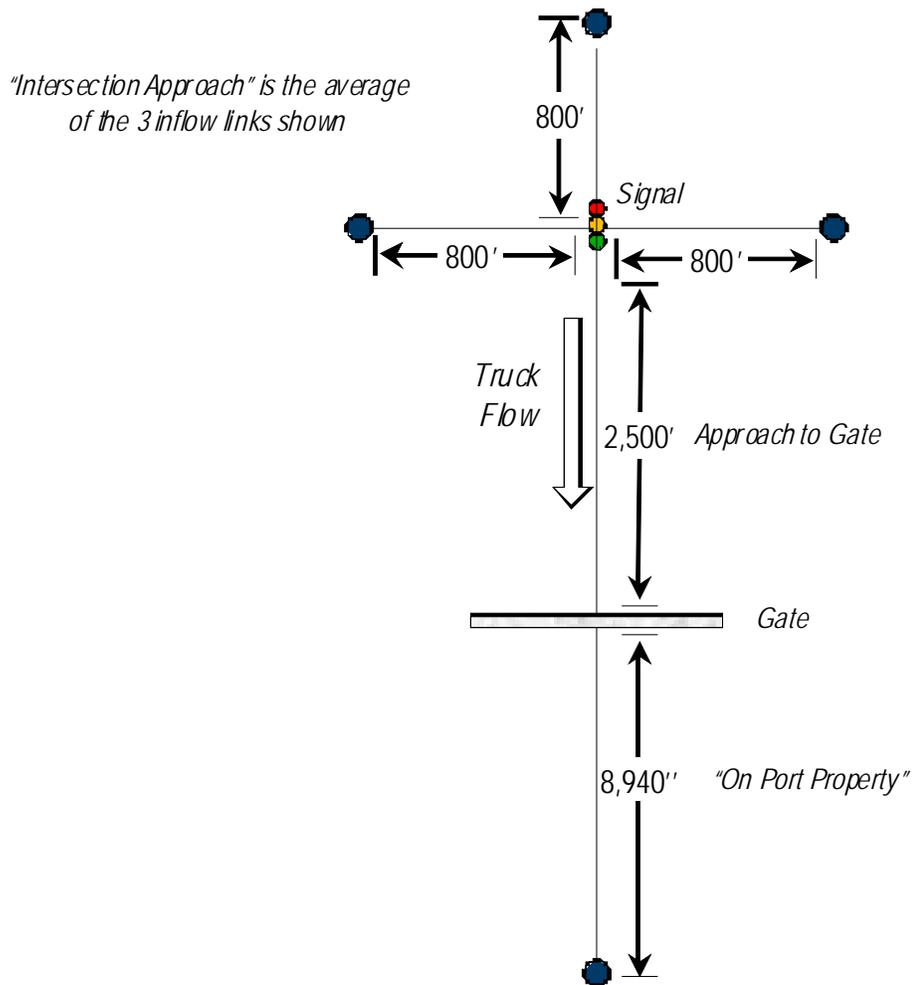
The second set of VSP profiles developed under this project to simulate travel at ports or intermodal facilities were developed using microsimulation models for a simple network to get an idea of the emission-producing activity of trucks operating on port grounds. The goal of these simulation tests was to capture the movement of trucks under three conditions: (1) on the local street network near the port, where they mix with autos, (2) approaching and stopping at the port gate, and (3) inside the port gate. Each of these conditions was modeled as a separate network link, as shown in Figure II-5.

For this simulation, the signalized arterial network, developed as described above for the congested condition simulations, was extended and adapted to model the intersection approach portion of this port simulation network. The V/C ratio of the signalized intersection was set at 0.80, based on the signalized arterial runs from the congested condition modeling. The trucks were evenly distributed on the approaches to the signalized intersection and only trucks (i.e., no cars) turned onto the approach to the gate. It was assumed that the entrance was solely for trucks and that employees would access the port via a different gate.

For the link simulating the approach to the gate, the only parameter that was varied was truck demand at the gate: 10, 20, 30, 40, 50, and 60 trucks per hour. The processing time at the gate was a constant four minutes per truck, consistent across the hours of simulation, for both entering and exiting vehicles. The value of four minutes per truck was based on observations by CS staff that had done previous work at port facilities.

Inside the gate, a simple, hypothetical configuration was developed. This was done because port property road networks are site-specific and it was felt that a simple network would be adequate to capture the low speed driving with frequent stop truck activity on port property. On this link inside the gate, trucks were restricted to a maximum speed of 20 mph. Trucks were also forced to idle for two 15-minute periods once on the port property. Total access and on-site times for trucks were not calculated, but in addition to the wait and idle times used, trucks are delayed by queues throughout the subnetwork.

**Figure II-5. Simulation Network for Port Gate Simulation**



## C. CALCULATION OF VSP FROM MICROSIMULATION OUTPUTS

The output of each simulation run is a vehicle trajectory file that, for every second of the simulation, indicates the speed and acceleration of every vehicle in the network, i.e., provides the instantaneous speed and acceleration. Such data is too finely grained for input to MOVES and required summarizing to the required MOVES input structure. Initially, the individual trajectories were summarized to develop second-by-second MOVES driving cycles by taking the average speed for all vehicles on each link for every second and assuming that this represented a realistic driving cycle. However, vehicle speeds will vary substantially over a link for a one-second snapshot, and the use of these driving cycles could lead to erroneous results when input to MOVES.

Instead, since both speed and acceleration are available in the microsimulation output for every vehicle for every second of simulation, MOVES *operating mode distributions* based on VSP were computed instead. According to EPA's recent draft particulate matter (PM) hot spot guidance (EPA, 2010), this is thought to be a much more accurate way of capturing driving cycle patterns when literally thousands of vehicles have their trajectories traced, as in simulation. The equation used to compute VSP, based on the most recently available information, was:<sup>2</sup>

$$VSP = \frac{Av + Bv^2 + Cv^3 + mav}{m_{fixed}}$$

where:

$m$	=	sourceMass (metric tons)
$A$	=	rolling Term A
$B$	=	rotating Term B
$C$	=	drag Term C
$v$	=	average vehicle velocity (m/s)
$a$	=	vehicle acceleration (m/s <sup>2</sup> )
$m_{fixed}$	=	fixedMassFactor (metric tons)

Since grade was set at 0 percent in the simulation, the term for it falls out of the equation and is not used.

Two vehicle types were present in the simulations – passenger cars and combination trucks – so they were treated separately. The reason for using only two vehicle types is that for planning applications, detailed truck distributions are not available, and we tried to match the simulations to data that planners have on hand. Velocity and acceleration values are as estimated by the microsimulation model. The following constant terms for the above equations were used. These values are the default data for these vehicle types contained in the SourceUseType table of the MOVES2010 default database.

<sup>2</sup>Based on an unpublished statement of work prepared by EPA, *Modification of OperatingModeDistributionGenerator java files and sourceUseType table to properly calculate VSP for changing sourceMass values*, June 25, 2009, provided to Pechan by EPA on August 16, 2010.

## Passenger Cars

$$A = 0.156461$$

$$B = 0.00200193$$

$$C = 0.000492646$$

$$m = 1.4788$$

$$m_{fixed} = 1.4788$$

## Combination Trucks

$$A = 2.08126$$

$$B = 0$$

$$C = 0.00418844$$

$$m = 31.4038$$

$$m_{fixed} = 17.1$$

**D. MOVES VSP DISTRIBUTION FILES**

Based on the vehicle speed and the calculated VSP, a MOVES operating mode ID was then assigned to each second. Then, the amount of time the vehicle was operating in each operating mode was calculated so that the final operating mode distributions could be prepared. Table II-2 shows the MOVES operating modes that were used in this project<sup>3</sup>. These are only some of the standard MOVES operating modes. A list of all the operating modes present in the MOVES default database<sup>4</sup> is provided in Appendix A. Operating mode distributions were then assigned for each applicable unique combination of pollutant and process ID. The operating mode distribution files were constructed for both the peak hour and the hour immediately following the peak.

**Table II-2. MOVES Operating Modes**

MOVES Operating Mode ID	Operating Mode
0	Braking
1	Idling
11	Low Speed Coasting; VSP < 0; 1 <= Speed < 25
12	Cruise/Acceleration; 0 <= VSP < 3; 1 <= Speed < 25
13	Cruise/Acceleration; 3 <= VSP < 6; 1 <= Speed < 25
14	Cruise/Acceleration; 6 <= VSP < 9; 1 <= Speed < 25
15	Cruise/Acceleration; 9 <= VSP < 12; 1 <= Speed < 25
16	Cruise/Acceleration; 12 <= VSP; 1 <= Speed < 25
21	Moderate Speed Coasting; VSP < 0; 25 <= Speed < 50
22	Cruise/Acceleration; 0 <= VSP < 3; 25 <= Speed < 50
23	Cruise/Acceleration; 3 <= VSP < 6; 25 <= Speed < 50
24	Cruise/Acceleration; 6 <= VSP < 9; 25 <= Speed < 50
25	Cruise/Acceleration; 9 <= VSP < 12; 25 <= Speed < 50
26	Cruise/Acceleration; 12 <= VSP; 25 <= Speed < 50
27	Cruise/Acceleration; 12 <= VSP < 18; 25 <= Speed < 50

<sup>3</sup>Operating modes 400 and 501 were added to the VSP profiles that were provided to FHWA. However, those operating modes were not used in the MOVES runs described in Chapter VI (the simulation runs had been performed prior to adding those operating modes).

<sup>4</sup>MOVES2010 default database is part of the MOVES2010 installation suite. Available at: <http://www.epa.gov/otaq/models/moves/index.htm#user>.

<b>MOVES Operating Mode ID</b>	<b>Operating Mode</b>
28	Cruise/Acceleration; $18 \leq \text{VSP} < 24$ ; $25 \leq \text{Speed} < 50$
29	Cruise/Acceleration; $24 \leq \text{VSP} < 30$ ; $25 \leq \text{Speed} < 50$
30	Cruise/Acceleration; $30 \leq \text{VSP}$ ; $25 \leq \text{Speed} < 50$
33	Cruise/Acceleration; $\text{VSP} < 6$ ; $50 \leq \text{Speed}$
35	Cruise/Acceleration; $6 \leq \text{VSP} < 12$ ; $50 \leq \text{Speed}$
36	Cruise/Acceleration; $12 \leq \text{VSP}$ ; $50 \leq \text{Speed}$
37	Cruise/Acceleration; $12 \leq \text{VSP} < 18$ ; $50 \leq \text{Speed}$
38	Cruise/Acceleration; $18 \leq \text{VSP} < 24$ ; $50 \leq \text{Speed}$
39	Cruise/Acceleration; $24 \leq \text{VSP} < 30$ ; $50 \leq \text{Speed}$
40	Cruise/Acceleration; $30 \leq \text{VSP}$ ; $50 \leq \text{Speed}$
400	Tire wear; idling
501	Brake wear; stopped

The links for which the data are presented depend on the test network, as indicated in Figures II-1 through II-5. For example, for the on-ramp scenarios, there are four links for which the traffic data are aggregated. These were all constructed from smaller segments in the microsimulation:

**DOWNSTREAM:** link downstream of the merge area (3,000 feet [ft.]).

**UPSTREAM:** link immediately upstream of the merge area (3,000 ft.).

**MERGE AREA:** link defined by the acceleration/merge lane from the on-ramp (275 ft.).

**RAMP:** the actual on-ramp, exclusive of the acceleration/merge lane (1,650 ft.).

The three links for which the operating mode distributions were developed for the port simulations are shown in Figure II-5 and described below:

**INTERSECTION APPROACH:** the average of the three 800-foot approach links at the signalized intersections; these are the source links for the trucks that will access the port.

**APPROACH TO GATE:** link immediately upstream the gate (2,500 ft.).

**ON PORT PROPERTY:** an aggregation of three links inside the gate (total: 8,940 ft.).

The MOVES operating mode profile files only contain a link identifier. Table II-3 provides a mapping of the link identifier included in the MOVES files for each scenario with a description of the link modeled.

**Table II-3. MOVES Operating Modes**

<b>Scenarios</b>	<b>Link Description</b>	<b>Link ID</b>
On-ramp with/without metering; incidents	Merge area	1
	On-Ramp	2
	Downstream from merge area	3
	Upstream from merge area	4
Freeway-to-freeway	Merge area	1
	On-Ramp	2
	Downstream from merge area	3
	Upstream from merge area	4
	Downstream from merge area #2	5
Signalized arterial (pre-timed/actuated)	Entire segment	8
	Intersection approach only	9

Scenarios	Link Description	Link ID
Port gate	Gate approach	21
	Intersection approach	23
	Inside gate	30

Tables II-4, II-5, and II-6 list the names of the resulting MOVES operating mode distribution files that correspond to each scenario.

**Table II-4. Resulting File Names for Signalized Arterial, Freeway On-Ramp, and Freeway-to-Freeway Interchange Scenarios**

Scenario	Condition	V/C Ratio	File Name
Signalized Arterial	Actuated	0.70	Arterial_Actuated_0.70_OP_MODE
		0.80	Arterial_Actuated_0.80_OP_MODE
		0.90	Arterial_Actuated_0.90_OP_MODE
		0.95	Arterial_Actuated_0.95_OP_MODE
		1.00	Arterial_Actuated_1.00_OP_MODE
		1.10	Arterial_Actuated_1.10_OP_MODE
		1.20	Arterial_Actuated_1.20_OP_MODE
	Pretimed	0.70	Arterial_Pretimed_0.70_OP_MODE
		0.80	Arterial_Pretimed_0.80_OP_MODE
		0.90	Arterial_Pretimed_0.90_OP_MODE
		0.95	Arterial_Pretimed_0.95_OP_MODE
		1.00	Arterial_Pretimed_1.00_OP_MODE
		1.10	Arterial_Pretimed_1.10_OP_MODE
		1.20	Arterial_Pretimed_1.20_OP_MODE
Freeway On-Ramp	Without ramp metering	0.90	VC_0.90_On_Ramp_OP_MODE
		1.00	VC_1.00_On_Ramp_OP_MODE
		1.10	VC_1.10_On_Ramp_OP_MODE
		1.15	VC_1.15_On_Ramp_OP_MODE
		1.20	VC_1.20_On_Ramp_OP_MODE
		1.25	VC_1.25_On_Ramp_OP_MODE
		1.40	VC_1.40_On_Ramp_OP_MODE
		1.50	VC_1.50_On_Ramp_OP_MODE
	With ramp metering	0.90	VC_0.90_On_Ramp_with_Metering_OP_MODE
		1.00	VC_1.00_On_Ramp_with_Metering_OP_MODE
		1.15	VC_1.15_On_Ramp_with_Metering_OP_MODE
		1.20	VC_1.20_On_Ramp_with_Metering_OP_MODE
		1.25	VC_1.25_On_Ramp_with_Metering_OP_MODE
		1.40	VC_1.40_On_Ramp_with_Metering_OP_MODE
Freeway to Freeway Interchange	0.90	VC_0.90_Fwy2Fwy_OP_MODE	
	1.00	VC_1.00_Fwy2Fwy_OP_MODE	
	1.10	VC_1.10_Fwy2Fwy_OP_MODE	
	1.15	VC_1.15_Fwy2Fwy_OP_MODE	
	1.20	VC_1.20_Fwy2Fwy_OP_MODE	
	1.25	VC_1.25_Fwy2Fwy_OP_MODE	
	1.40	VC_1.40_Fwy2Fwy_OP_MODE	
	1.50	VC_1.50_Fwy2Fwy_OP_MODE	

**Table II-5. Resulting File Names for Freeway Incident Scenarios**

Scenario	Condition	V/C Ratio	Duration (minutes)	File Name
Freeway Incident	Blockage 1 lane of 4	0.90	30	Inc_1Lane_30mins_0.90_OP_MODE
			45	Inc_1Lane_45mins_0.90_OP_MODE
			60	Inc_1Lane_60mins_0.90_OP_MODE
			90	Inc_1Lane_90mins_0.90_OP_MODE
		1.00	30	Inc_1Lane_30mins_1.00_OP_MODE
			45	Inc_1Lane_45mins_1.00_OP_MODE
			60	Inc_1Lane_60mins_1.00_OP_MODE
			90	Inc_1Lane_90mins_1.00_OP_MODE
		1.15	30	Inc_1Lane_30mins_1.15_OP_MODE
			45	Inc_1Lane_45mins_1.15_OP_MODE
			60	Inc_1Lane_60mins_1.15_OP_MODE
			90	Inc_1Lane_90mins_1.15_OP_MODE
		1.25	30	Inc_1Lane_30mins_1.25_OP_MODE
			45	Inc_1Lane_45mins_1.25_OP_MODE
			60	Inc_1Lane_60mins_1.25_OP_MODE
	90		Inc_1Lane_90mins_1.25_OP_MODE	
	1.40	30	Inc_1Lane_30mins_1.40_OP_MODE	
		45	Inc_1Lane_45mins_1.40_OP_MODE	
		60	Inc_1Lane_60mins_1.40_OP_MODE	
		90	Inc_1Lane_90mins_1.40_OP_MODE	
	Blockage 2 lane of 4	0.90	30	Inc_2LANES_30MINS_0.90_OP_MODE
			45	Inc_2LANES_45MINS_0.90_OP_MODE
			60	Inc_2LANES_60MINS_0.90_OP_MODE
			90	Inc_2LANES_90MINS_0.90_OP_MODE
1.00		30	Inc_2LANES_30MINS_1.00_OP_MODE	
		45	Inc_2LANES_45MINS_1.00_OP_MODE	
		60	Inc_2LANES_60MINS_1.00_OP_MODE	
		90	Inc_2LANES_90MINS_1.00_OP_MODE	
1.15		30	Inc_2LANES_30MINS_1.15_OP_MODE	
		45	Inc_2LANES_45MINS_1.15_OP_MODE	
		60	Inc_2LANES_60MINS_1.15_OP_MODE	
		90	Inc_2LANES_90MINS_1.15_OP_MODE	
1.25		30	Inc_2LANES_30MINS_1.25_OP_MODE	
		45	Inc_2LANES_45MINS_1.25_OP_MODE	
		60	Inc_2LANES_60MINS_1.25_OP_MODE	
	90	Inc_2LANES_90MINS_1.25_OP_MODE		
1.40	30	Inc_2LANES_30MINS_1.40_OP_MODE		
	45	Inc_2LANES_45MINS_1.40_OP_MODE		
	60	Inc_2LANES_60MINS_1.40_OP_MODE		
	90	Inc_2LANES_90MINS_1.40_OP_MODE		
Blockage 3 lane of 4	0.90	30	Inc_3LANES_30MINS_0.90_OP_MODE	
		45	Inc_3LANES_45MINS_0.90_OP_MODE	
		60	Inc_3LANES_60MINS_0.90_OP_MODE	
		90	Inc_3LANES_90MINS_0.90_OP_MODE	
	1.00	30	Inc_3LANES_30MINS_1.00_OP_MODE	
		45	Inc_3LANES_45MINS_1.00_OP_MODE	
		60	Inc_3LANES_60MINS_1.00_OP_MODE	
		90	Inc_3LANES_90MINS_1.00_OP_MODE	
	1.15	30	Inc_3LANES_30MINS_1.15_OP_MODE	
		45	Inc_3LANES_45MINS_1.15_OP_MODE	
60		Inc_3LANES_60MINS_1.15_OP_MODE		
90		Inc_3LANES_90MINS_1.15_OP_MODE		
1.25	30	Inc_3LANES_30MINS_1.25_OP_MODE		

Scenario	Condition	V/C Ratio	Duration (minutes)	File Name
			45	Inc_3LANES_45MINs_1.25_OP_MODE
			60	Inc_3LANES_60MINs_1.25_OP_MODE
			90	Inc_3LANES_90MINs_1.25_OP_MODE
		1.40	30	Inc_3LANES_30MINs_1.40_OP_MODE
		1.40	45	Inc_3LANES_45MINs_1.40_OP_MODE
		1.40	60	Inc_3LANES_60MINs_1.40_OP_MODE
		1.40	90	Inc_3LANES_90MINs_1.40_OP_MODE

**Table II-6. Resulting File Names for Port Operating Mode Distribution Files**

Scenario	Number of Trucks per Hour	File Name
Intersection and Approach to Port Gate	10	GATE_10TRUCKS_HR
	20	GATE_20TRUCKS_HR
	30	GATE_30TRUCKS_HR
	40	GATE_40TRUCKS_HR
	50	GATE_50TRUCKS_HR
	60	GATE_60TRUCKS_HR
Inside Port Gate	N/A	ON_PORT_PROPERTY

To visualize the resulting MOVES operating mode distributions, the operating mode fractions were grouped into the following more aggregate operating modes (instead of 25 actual modes) by source type, hour, and link. These distributions were then plotted for each link within a scenario.

- Braking;
- Idling;
- Low Speed Coasting;  $1 \leq \text{Speed} < 25$ ;
- Cruise/Acceleration  $1 \leq \text{Speed} < 25$ ;
- Moderate Speed Coasting;  $25 \leq \text{Speed} < 50$ ;
- Cruise/Acceleration;  $25 \leq \text{Speed} < 50$ ; and
- Cruise/Acceleration;  $50 \leq \text{Speed}$ .

Figures II-6 through II-9 show the operating mode distributions for the On-Ramp, Freeway to Freeway Interchange, Freeway Incident, and Signalized Arterial scenarios. Each of these figures illustrates the data simulating a V/C ratio of 1.00. Figure II-10 shows the operating mode distributions for the port simulation scenario with 60 trucks per hour. As illustrated by these figures, the distribution varies significantly not only between scenarios, but also among a scenario's links.

Figure II-6. Operating Mode Distribution – On Ramp – V/C Ratio 1.00

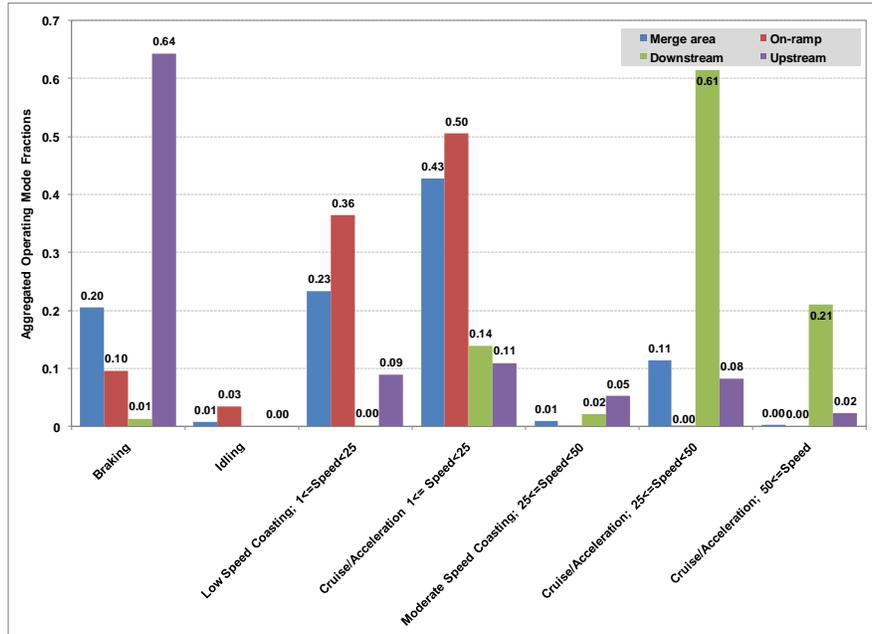
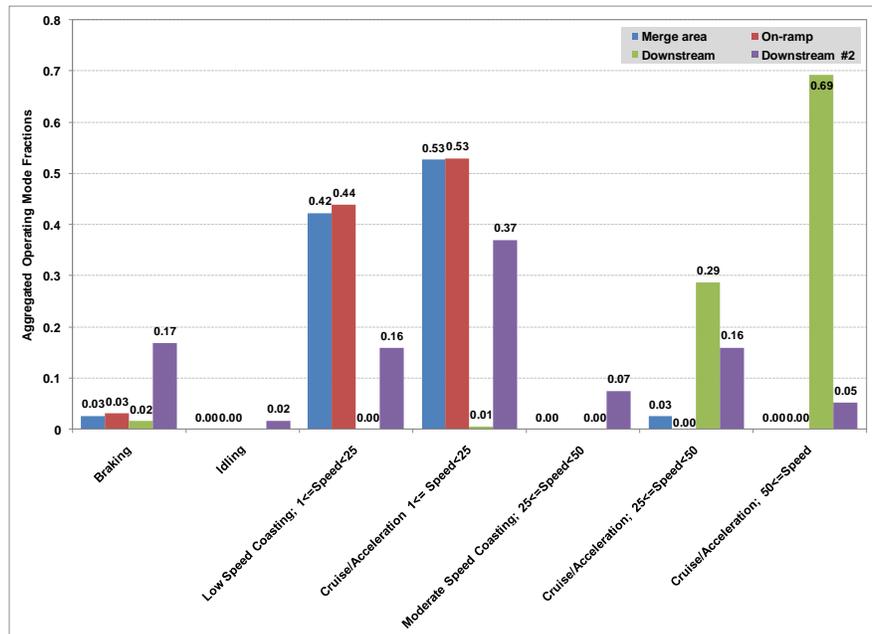
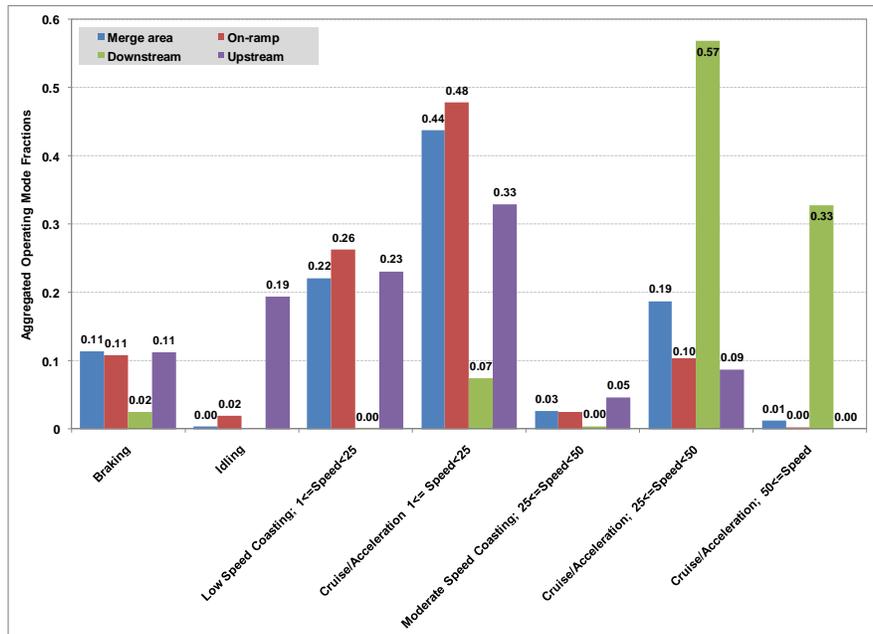


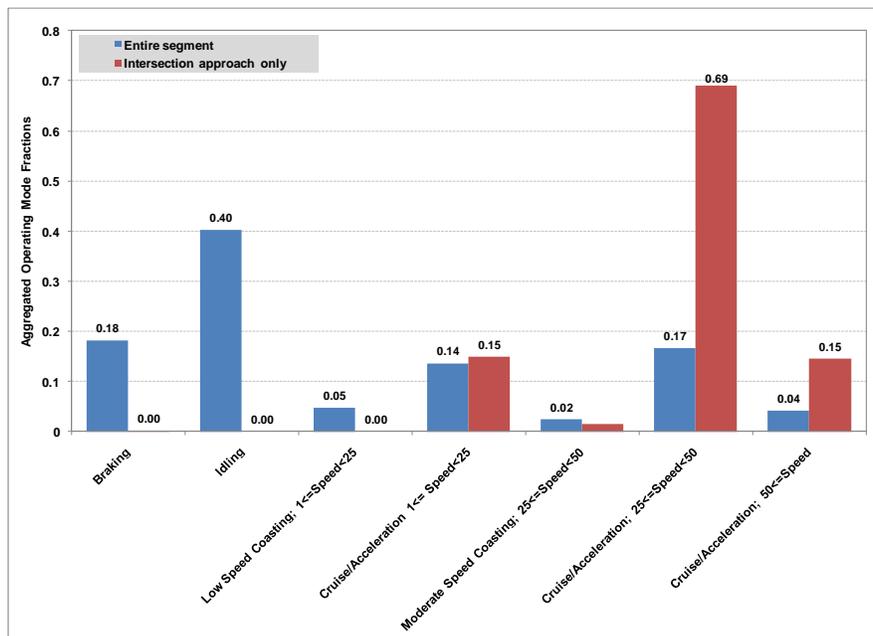
Figure II-7. Operating Mode Distribution – Freeway to Freeway Interchange – V/C Ratio 1.00



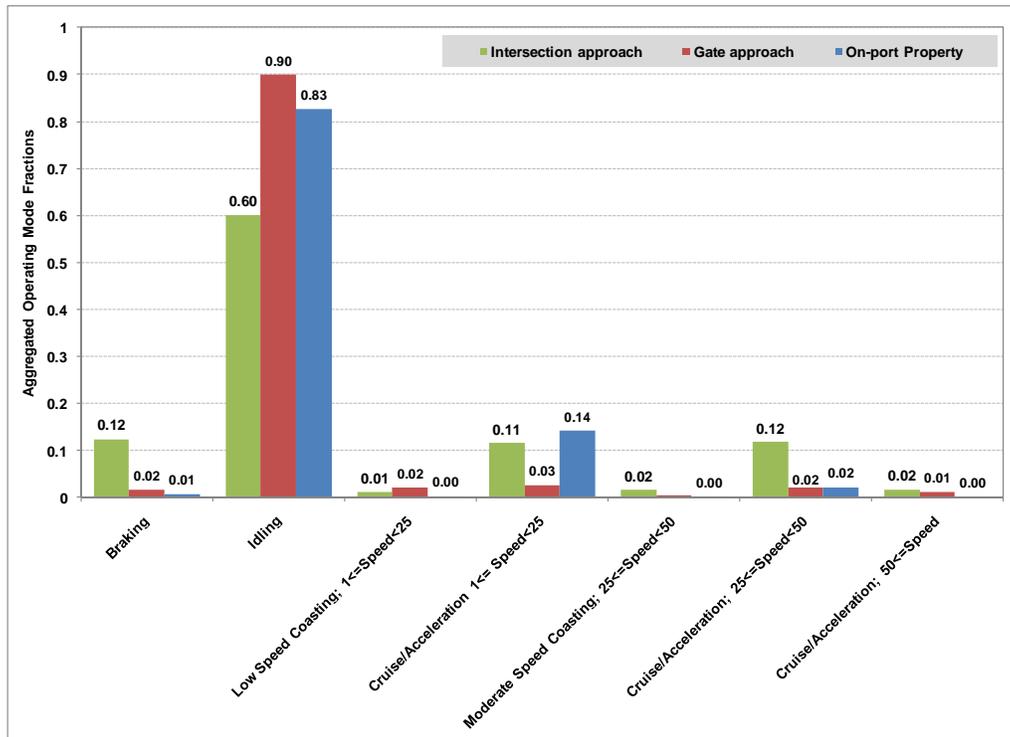
**Figure II-8. Operating Mode Distribution – Freeway to Freeway Incident – V/C Ratio 1.00 – 3 Lanes Blocked**



**Figure II-9. Operating Mode Distribution – Signalized Arterial – V/C Ratio 1.00**



**Figure II-10. Operating Mode Distribution – Intersection Approach and Approach to Port Gate (60 Trucks per Hour) and On-Port Property**



Figures II-11 and II-12 are presented here to illustrate the effect that the V/C ratio has on the resulting operating mode distributions. Both figures represent the on-ramp scenario, without metering. Figure II-11 represents a V/C ratio of 0.90 while Figure II-12 represents a V/C ratio of 1.50. In the more congested condition (higher V/C ratio), there is a significant increase in the low speed coasting and cruise/acceleration and a decrease in activity at the higher speeds. This is particularly true for the upstream, ramp, and merge links. The downstream link is less affected by the change in V/C ratio.

Figure II-11. Operating Mode Distribution – On Ramp – V/C Ratio 0.90

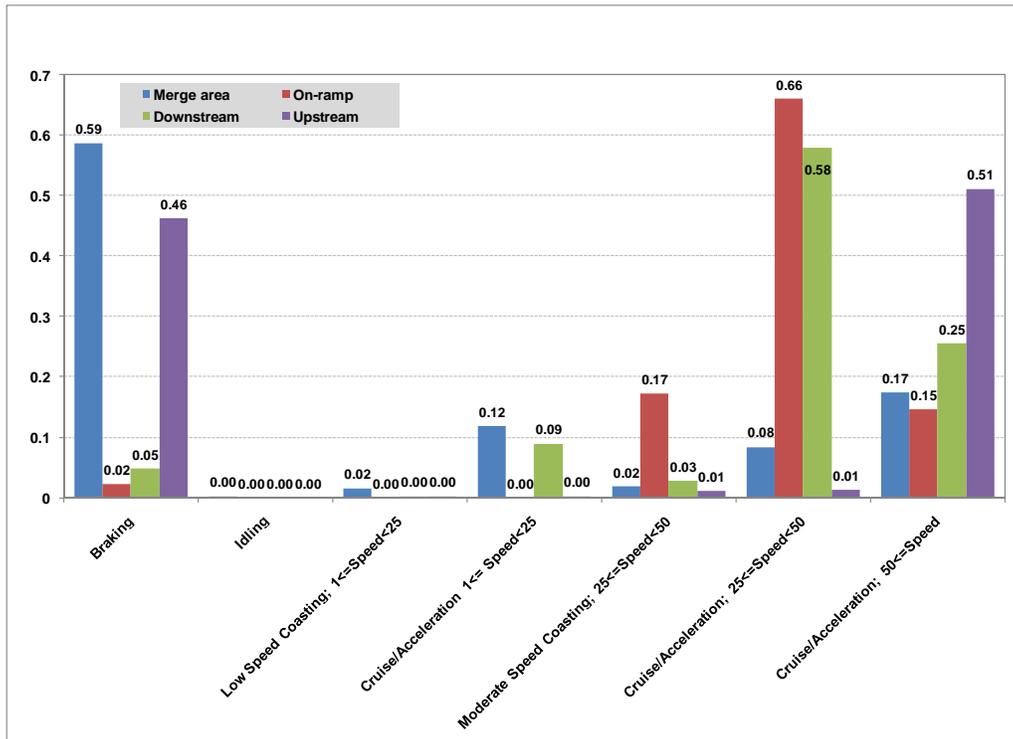
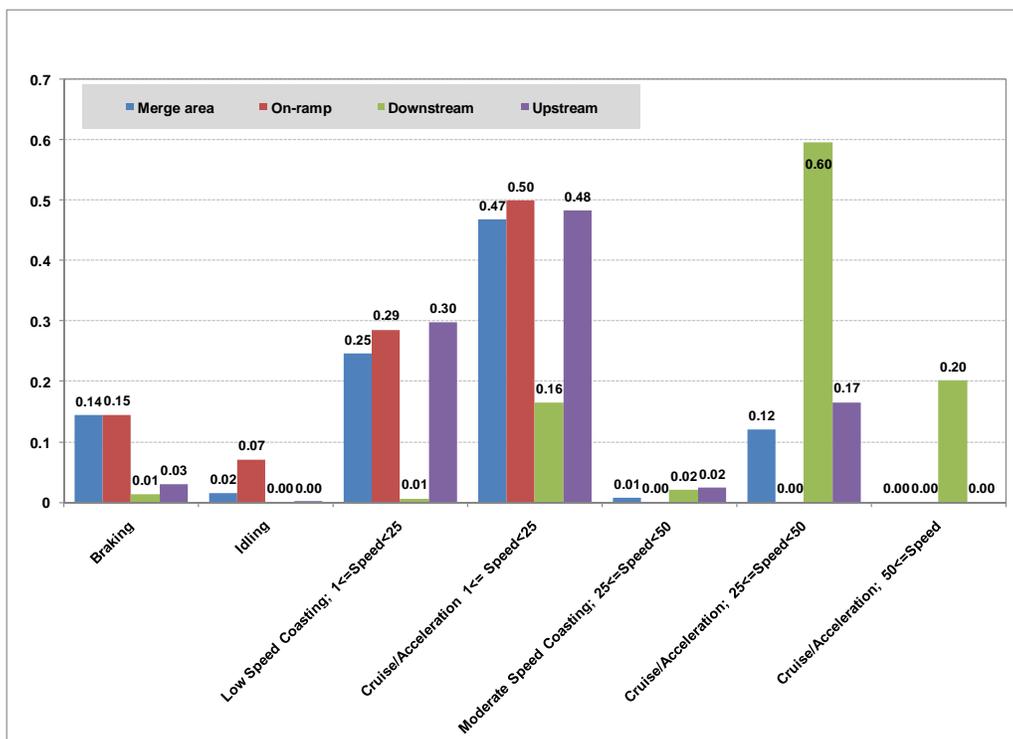


Figure II-12. Operating Mode Distribution – On Ramp – V/C Ratio 1.5



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## CHAPTER III. APPLICATION OF VSP PROFILES IN MOVES PROJECT LEVEL ANALYSES UNDER VARIOUS CONGESTION CONDITIONS

### A. USING MOVES FOR PROJECT LEVEL ANALYSES

Three modeling “scales” or “levels” are available in MOVES: national, county, and project levels. The national scale is the default selection in MOVES; when selected, data collected on a nation-wide level is apportioned or allocated to states or counties. This data will differ from data collected for a specific state or county. For a finer level of detail about a particular area, the user can choose the county scale. With this scale choice, the user must replace national default allocations with local user-supplied data. The county scale is intended to be used when doing SIP or regional conformity analyses.

The project scale, which is the focus of this study, is the finest level of modeling in MOVES. It allows the user to model the emission effects from a group of specific roadway links and/or a single off-network location. The definition of a roadway link is a section of any road where a vehicle is moving for more than three seconds. An off-network location is an area of activity that is not a roadway, for example a parking lot, where vehicle starts and extended idling emissions are produced. The use of the project scale requires the user to define the project (i.e., specify all individual roadway links and/or the off-network area). All of the required project level data can be input through the MOVES Project Domain Manager. At the project level scale, the VSP profiles developed as discussed above can be used as one of the inputs to the MOVES Project Domain Manager.

The inputs that need to be provided for use in a MOVES project level run are listed below. For detailed information on these inputs, consult EPA’s MOVES User’s Guide<sup>5</sup>.

Link-level files:

- **Operating Mode Distribution:** project-specific VSP profiles by link; allows the user to import operating mode fraction data for source types, hour/day combinations, roadway links and pollutant/process combinations. These are the VSP profiles developed through this project.
- **Links:** allows the user to define individual roadway links; average speeds by link in combination with link lengths, volumes, road types, and average grades.
- **Link Source Type:** allows the user to enter the fraction of the link traffic volume which is driven by each source type in a given hour.
- **Off Network:** provides information about vehicles which are not driving on the project links, but still contribute to the project emissions while idling or starting.
- **Link drive Schedule:** allows the user to define the precise speed and grade for each second on a particular roadway link. If provided by the user (as it was the case in this study), operating mode distributions input will take calculational precedence over

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<sup>5</sup>Motor Vehicle Emission Simulator (MOVES) User Guide for MOVES2010a, EPA-420-B-10-036, August 2010. <http://www.epa.gov/otaq/models/moves/MOVES2010a/420b10036.pdf>.

imported drive schedules (and over links average speed). Link drive schedules were therefore not provided for this project.

Other data:

- **Meteorology:** allows the user to import temperature and humidity data.
- **Age Distribution:** allows the user to enter data that provides the distribution of vehicle counts by age for each calendar year and vehicle type.
- **Fuel Formulation:** allows the user to select an existing fuel in the MOVES database and change its properties (default formulations were used).
- **Fuel Supply:** allows the user to assign existing fuels to counties, months, and years, and to assign the associated market share for each fuel (default data were used).
- **Inspection/Maintenance:** allows the user to import information describing inspection and maintenance programs (default data were used).

## **B. APPLYING THE VSP PROFILES FROM THE CONGESTED AND INCIDENT MICROSIMULATION TRAFFIC MODELING TO A MOVES SIMULATION**

### **1. Congested Scenarios Modeling**

For all the congested scenarios, except for the ones dealing with incidents, the selection of the appropriate operating mode distribution profile to best model a user's specific project-level congestion situation is as follows:

- Determine the V/C ratio of the bottleneck location: either the merge area for on-ramps and freeway-to-freeway junctions or traffic signals. The V/C ratio can be determined from travel demand forecasting model outputs, or from field data.
- Determine the type of active control – either ramp metering for freeways or pre-timed versus actuated control for signalized highways.
- Match the segments (links) for the project to the type of link from the summarized simulation output files, using Figures II-1 through II-4 as a guide.
- For each segment of the project, summarize the scenario (bottleneck) type, link type, V/C ratio, and type of active control that best describes that segment.

This boils down to essentially finding the test links and scenarios that best match with the application being studied and then applying the corresponding operation mode distribution file in a MOVES simulation.

### **2. Incident Scenarios Modeling**

Application of the incident scenarios requires more effort on the part of the analyst. The reason is that the simulations were run for very specific incident conditions, rather than for average recurring congestion conditions, so the results are only applicable to the incident characteristics for a given scenario. If the analyst is interested in the *overall* effect of incidents on a series of project links, independent estimates of the likelihood of incidents

with a given lane blockage and duration must be made, and the results weighted. So, for a given peak period, the analyst must determine the probability of each duration by blockage combination occurring; Table III-1 shows these combinations, where the cell entries are the probability of occurrence. Ideally, the probability data for doing this should be developed from locally archived incident management logs. (Many traffic management centers keep track of incident characteristics.) Consider a simplified example where all incidents that occur block 50 percent of the available lanes. The probabilities for these lane-blocking incidents are as follows:

- 30 minute duration – 0.40;
- 45 minute duration – 0.30;
- 60 minute duration – 0.20; and
- 90 minute duration – 0.10.

MOVES analyses should be run for each of these conditions. The resulting emissions are multiplied by the probabilities, and summed to get total emissions on each link. A more detailed analysis would involve estimating the percent of VMT represented by each cell, but this requires that incident management and continuous traffic data be fused. That is, a modeler would have to determine the VMT exposed to each condition in the cells of the matrix.

**Table III-1. Estimating the Probability of Incident Occurrence**

Duration	Percent of Lanes Blocked by Incident <sup>6</sup>			
	0%	25%	50%	75%
30 minutes	(recurring congestion only)			
45 minutes				
60 minutes				
90 minutes				

To apply this method with MOVES, for a given V/C ratio for a freeway bottleneck area, all of the incident duration/blockage operating mode distributions are input to MOVES as well as the recurring only condition (i.e., either the on-ramp or freeway-to-freeway interchange conditions). The resulting emission estimates from MOVES are then prorated by the probabilities in Table III-1.

### **C. DEVELOPING THE REMAINING MOVES LINK-LEVEL FILES**

After selecting the appropriate operating mode distribution file to apply in the user's situation, as discussed above, the remaining link-level files must be developed for input to MOVES. This includes the Links, Link Source Types, and Off Network files. Additional information about these inputs can be found in MOVES User's Guide<sup>7</sup>.

<sup>6</sup>Based on the conditions studied: 1 of 4, 2 of 4, and 3 of 4 lanes blocked.

<sup>7</sup>Motor Vehicle Emission Simulator (MOVES) User Guide for MOVES2010a, EPA-420-B-10-036, August 2010, <http://www.epa.gov/otaq/models/moves/MOVES2010a/420b10036.pdf>.

The Links file contains information about each link in the network to be modeled including a link ID, a county ID, a zone ID, the MOVES road type, the link length, the hourly link volume, the average link speed, the link description, and the average grade of the link. The user must provide data in the Links file for each unique link ID in the operating mode distribution file being used. The link ID should match that used in the operating mode distribution file and the link description can be obtained from Table II-3. The county ID should represent the county of the project being model. The MOVES road type for a signalized arterial scenario would typically be coded as 5, representing an urban unrestricted access road type while the remaining congestion scenarios would be coded as 4 to represent an urban restricted access road type. The link length (in miles) should represent the actual length of the link to be modeled and the link volume should represent the actual hourly volume on the link for the hour being modeled. Even if an operating mode distribution is provided (thus taking calculational precedence over average speeds), the link average speed entered on the Links tab is used in MOVES to compute source hours of operation. It thus needs to be consistent with the information entered in the operating mode distribution tab. The link average grade can be entered as 0.

The Link Source Type Hour file needs to contain a record for all source types driving on a given link, for all links in the network. The fraction of travel by all source types within the hour being modeled for each link needs to sum to 1.

The Off Network file also needs to be populated if there is an off-network link associated with the simulation (i.e., if the project contains vehicles starting or operating in the extended idle mode). This file provides information on the fraction of vehicles with starts, extended idling, and parking during the modeled hour on the links being studied. For each source type included in the network, the information needed is: the number of “off network” vehicles, and then, of this number, the fraction of the total number of vehicles of that source type with a start operation, an extended idle operation, or parked during the hour. For the cases of evaluating projects with congestion conditions, it can be assumed (though not required) that the number of vehicles off network is 0 and that the corresponding start, extended idle, and parked vehicle fractions are also 0.

The remaining required data files needed to perform MOVES runs for a project level analysis include meteorology, age distribution, fuel formulation and supply, and inspection/maintenance programs. These inputs are generally the same as the MOVES inputs that would be required for a county level run, such as for a SIP application, and are likely to have already been developed for the area being studied. However, users should verify each individual input as there may be exceptions (especially for age distribution and fuel formulation and supply). The user should refer to the MOVES users guide for further information on developing these inputs.

## CHAPTER IV. PORT ANALYSIS

One of the objectives of this study was to develop transportation data representative of the activity taking place at port and intermodal facilities that can be used to improve project-level emission estimates for like facilities in MOVES model applications. Vehicle activity at port and intermodal facilities have a unique combination of characteristics that is important to account for in an emissions analysis. This chapter presents information on travel-related data from three sample ports that can be used, in combination with the port specific VSP profiles discussed in Chapter II, to improve the quality of an emissions analysis by including inputs to represent these data in MOVES. Chapter VI provides a demonstration of how these data could then be applied in a MOVES emissions analysis for another port, in this case, the ports under the control of the Port Authority of New York and New Jersey.

### A. PORT ANALYSIS

A number of U.S. ports were surveyed for information about the truck travel patterns in and around those ports, with the objective of identifying ports that could serve as examples of expected travel patterns at other U.S. ports. This review identified three ports that the consulting team felt were able to provide recent, relevant data for others to use. These three ports were: Everglades, Florida; Savannah, Georgia; and Long Beach, California. This sample of ports provides information for a Gulf of Mexico port, an eastern seaboard port, and a west coast port.

The port analysis is a separate phase of the study and is not directly connected to the microsimulations described previously. The travel patterns identified in this chapter can serve as guidance to planners doing port analyses when no local data are available.

#### 1. Summary of Port Statistics for Three Selected Ports<sup>8</sup>

Table IV-1 summarizes key data from the three selected example ports for 2009. This data is provided so that analysts can compare the characteristics of their port with those that have been evaluated for this FHWA-sponsored study. These data provide a sense of scale on the activity present at each port.

**Table IV-1. Summary of 2009 Port Statistics for Three Selected Ports**

Activity	Everglades	Savannah	Long Beach
Total Containers (TEUs*)	796,160	2,404,965	5,067,597
Total Cargo Tonnage (Metric Tons)	5,204,103	20,531,261**	70,000,000
Total Vessels	4,251	2,073	4,746
Surface (Acres)	2,190	1,600	3,200
Employment	9,948***	Not Available	30,000
Operating Revenue (\$ Thousands)	109,669	227,796**	311,352

<sup>8</sup>Data sources:

- Savannah <http://www.gaports.com>
- Everglades <http://www.porteverglades.net>
- Long Beach <http://www.polb.com/>

Operating Income (\$ Thousands)	36,433	59,261**	127,614
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\*Twenty-foot Equivalent Units.

\*\*Georgia Ports Authority's total: Port of Savannah and Port of Brunswick.

\*\*\*Includes direct jobs only. Does not include induced, indirect, nor related user jobs.

## 2. Development of Truck Trip Distributions

### a. Trip Length Distribution To/From Port Facilities

To study the distance of trips to and from port facilities, three previous port gate surveys were used. The following describes each of the surveys:

**Everglades:** Port Everglades conducted a gate survey from June 21<sup>st</sup> to June 23<sup>rd</sup> of 2008. This survey captured a total of 121 trucks at the port's terminals.

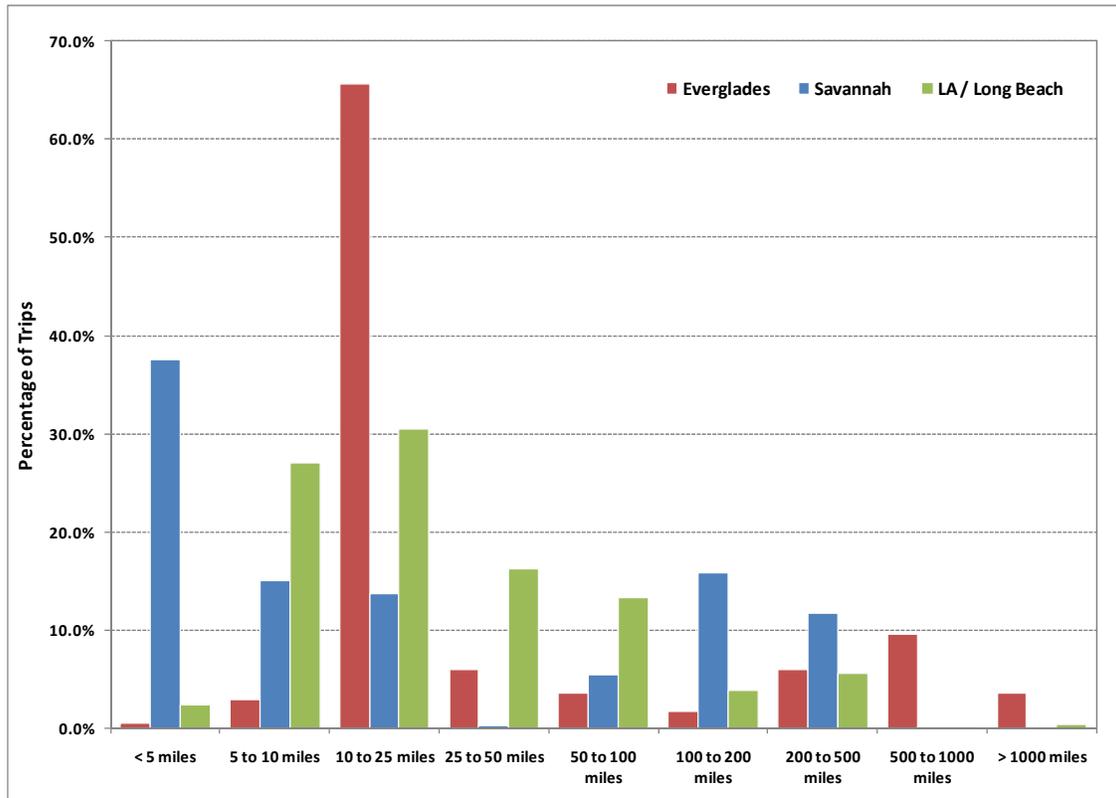
**Savannah:** The Port of Savannah conducted a gate survey on July 18<sup>th</sup> and July 19<sup>th</sup> in 2006. This survey captured a total of 887 trucks at the port's terminals.

**LA/Long Beach:** The Port of Long Beach conducted a gate survey in January of 2005. This survey captured a total of 2,723 trucks at the port's terminals. This is by far the highest volume of trucks surveyed of all of the locations analyzed in this report.

While each of the surveys asked a variety of different questions, the question that they all have in common is the last stop and next stop of the truck entering or leaving the port. This data was used to geocode the locations of these stops. Depending on the level of detail given in the response, one of several geocoding methods was used, which includes address matching, center of city, and center of state. The LA/Long Beach survey and the Savannah survey had many addresses available, especially for local trips. The Everglades survey was done completely by center of city. Center of state was only used in a few circumstances for long distance trips where no other information was available. Next, the route distance between these locations and the port were measured using routing software in TransCAD and the National Highway Planning Network (NHPN). It should be noted that these distances represent the actual driving distance of the truck on particular roadways, not the straight line distance between two points.

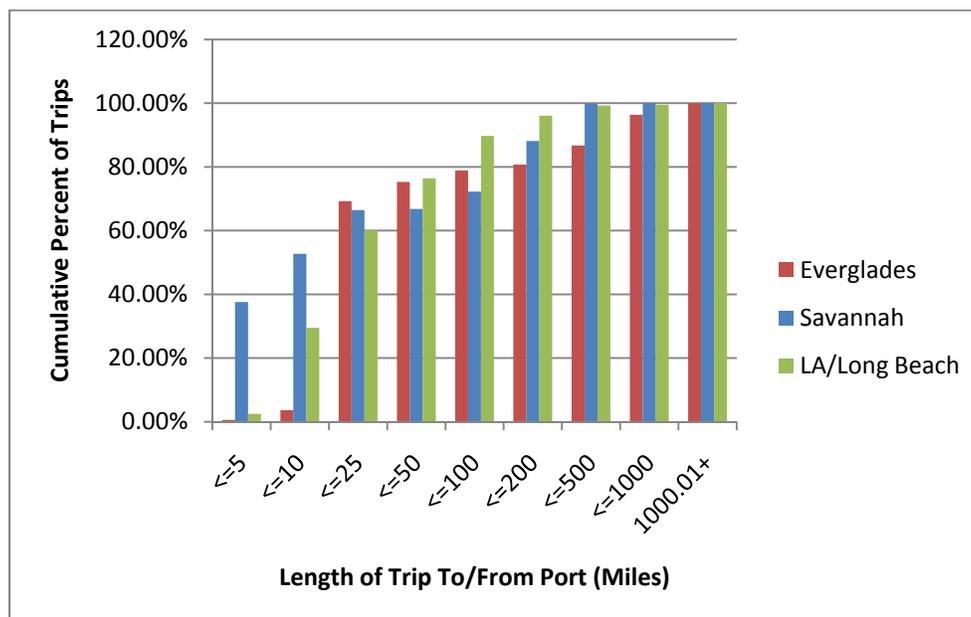
Figure IV-1 shows a graphical representation of the number of trips and their distance to/from the port for Everglades, Savannah, and LA/Long Beach, respectively. The distances were summarized into ranges. Figure IV-1 and Table IV-2 show the percentage of trips for each port that fall into various short distance and long distance ranges. Figure IV-2 and Table IV-3 show the same ranges, but with the cumulative percent of trips under certain thresholds. The results show that the trip distances vary greatly among the three ports studies, likely due to the different geography of cities around the ports. However, a general observation can be made that in all cases a large majority of trips (80-96 percent) are under 200 miles. This is an important distinction for air quality planning using the MOVES model because trucks traveling greater than 200 miles are considered long-haul and trucks traveling less than 200 miles are considered short-haul in MOVES.

**Figure IV-1. Percent of Port Terminal Truck Trips at Certain Distance Ranges**



**Table IV-2. Percentage of Port Terminal Truck Trips at Certain Distance Ranges**

Length of Trip (Miles)	Everglades	Savannah	LA/Long Beach
0-5	0.60%	37.62%	2.50%
5.01-10	3.01	15.11	27.02
10.01-25	65.66	13.75	30.56
25.01-50	6.02	0.31	16.32
50.01-100	3.61	5.46	13.33
100.01-200	1.81	15.90	3.90
200.01-500	6.02	11.80	5.62
500.01-1000	9.64	0.05	0.26
1000.01+	3.61	0.00	0.49

**Figure IV-2. Cumulative Percent of Trips at Certain Distance Ranges****Table IV-3. Cumulative Percent of Trips at Certain Distance Ranges**

Length of Trip (Miles)	Everglades	Savannah	LA/Long Beach
<=5	0.60%	37.62%	2.50%
<=10	3.61	52.73	29.52
<=25	69.28	66.47	60.08
<=50	75.30	66.79	76.40
<=100	78.92	72.25	89.73
<=200	80.72	88.14	96.10
<=500	86.75	99.95	99.25
<=1000	96.39	100.00	99.51
1000.01+	100.00	100.00	100.00

### ***b. Truck Type Distributions***

During the port gate surveys, information was also collected about the type of truck. While many of the surveys included detailed body types, such as container or flatbed, it is only important to differentiate between single unit trucks and combination trucks for the purpose of emissions modeling using MOVES.<sup>9</sup> In MOVES modeling, both single unit and combination trucks are further distinguished as either short haul or long haul trucks. Each of these different truck categories is assigned different driving cycles in MOVES, leading to differing emission factors for each truck category. Table IV-4 presents these summarized results, which shows almost all combination trucks for all three ports.

<sup>9</sup>Note that other factors such as age and fuel type (e.g., gasoline versus diesel) are also important considerations when calculating emissions. Age distributions are discussed elsewhere in this chapter. For the purposes of the emissions modeling performed for this project, only combination trucks were modeled, based on the data presented in Table IV-4, and almost all combination trucks are diesel-fueled.

**Table IV-4. Percent of Truck Types by Port Terminal**

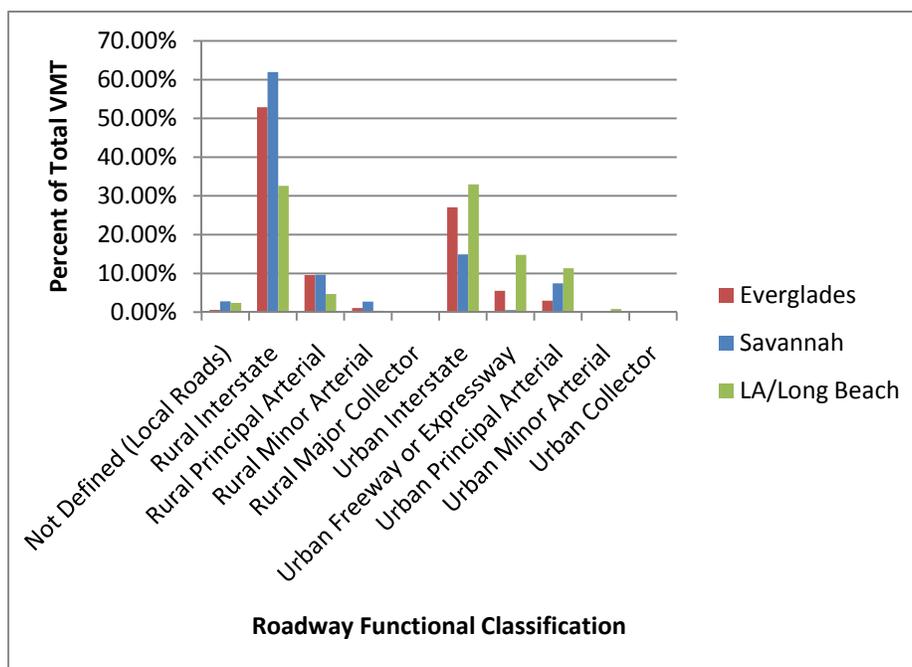
Truck Type	Everglades	Savannah	LA/Long Beach
Single Unit Truck	2.48%	0.23%	0.00%
Combination Truck	97.52	99.77	100.00
Total	100.00	100.00	100.00

**c. Road Type Distributions for Trips To/From Port Facilities**

During the routing of the trips to and from ports in the TransCAD software, information was kept on the functional classification of roadways taken. This functional classification information is available for each link in the network on the NHPN, which was used in the TransCAD analysis. The total VMT on each functional classification of roadways for all trips associated with each port was output by the software.

Figure IV-3 and Table IV-5 show the percent of VMT for all trips to and from each port that are spent on each roadway functional classification. It should be noted that the *not defined* category includes links in the NHPN that have no roadway classification and centroid connectors created by TransCAD to connect the origins/destination with the NHPN roadway network. In both cases, these represent local roads because the NHPN contains the higher classified roadways.

**Figure IV-3. Percent of Total VMT by Roadway Functional Classification for the Port Terminals**



**Table IV-5. Percent of Total VMT by Roadway Functional Classification for the Port Terminals**

Code	Functional Classification	Everglades	Savannah	LA/Long Beach
0	Not Defined (Local Roads)	0.59%	2.79%	2.39%
1	Rural Interstate	52.88	61.95	32.61
2	Rural Principal Arterial	9.59	9.64	4.70
6	Rural Minor Arterial	1.06	2.73	0.37
7	Rural Major Collector	0.10	0.01	0.00
11	Urban Interstate	27.07	14.91	32.98
12	Urban Freeway or Expressway	5.50	0.53	14.77
14	Urban Principal Arterial	2.97	7.42	11.35
16	Urban Minor Arterial	0.01	0.00	0.82
17	Urban Collector	0.23	0.01	0.00
Total		100.00	100.00	100.00

The TransCAD software is programmed to choose a route that takes the highest roadway classification for the longest period possible, much as a truck driver would choose such a route to minimize the total driving time. Therefore, it follows that interstates and urban freeways/expressways are the most traveled for trips from all three ports. In general, the percent of VMT spent on lower classified roads goes down with the lower roadway classifications. For example, principal arterials are generally the second most traveled and minor arterials are generally the third most traveled. Due to the availability of certain roadway types around each port and the rural/urban geography, the exact percentages from each port vary substantially. For example, Savannah has the highest percentage of VMT on rural interstates because the Savannah urban area is relatively small and Georgia in general has fewer urbanized areas than Florida or Southern California.

This VMT distribution by roadway functional classification is important to emissions modeling because it provides some indication of the speed that trucks drive traveling to and from ports. The speed is correlated with a particular emission rate, which is used to calculate total emissions. For example, rural interstates could be assumed to have a speed of 65 mph for which a particular emission rate could be looked up. For Savannah, that emission rate would be multiplied by 61.95 percent of the total VMT for the port to find the total emissions on rural interstates. A similar process would be followed for the other functional classifications, and emissions for all roadway functional classes would be summed to find the total emissions for trips to and from the port.

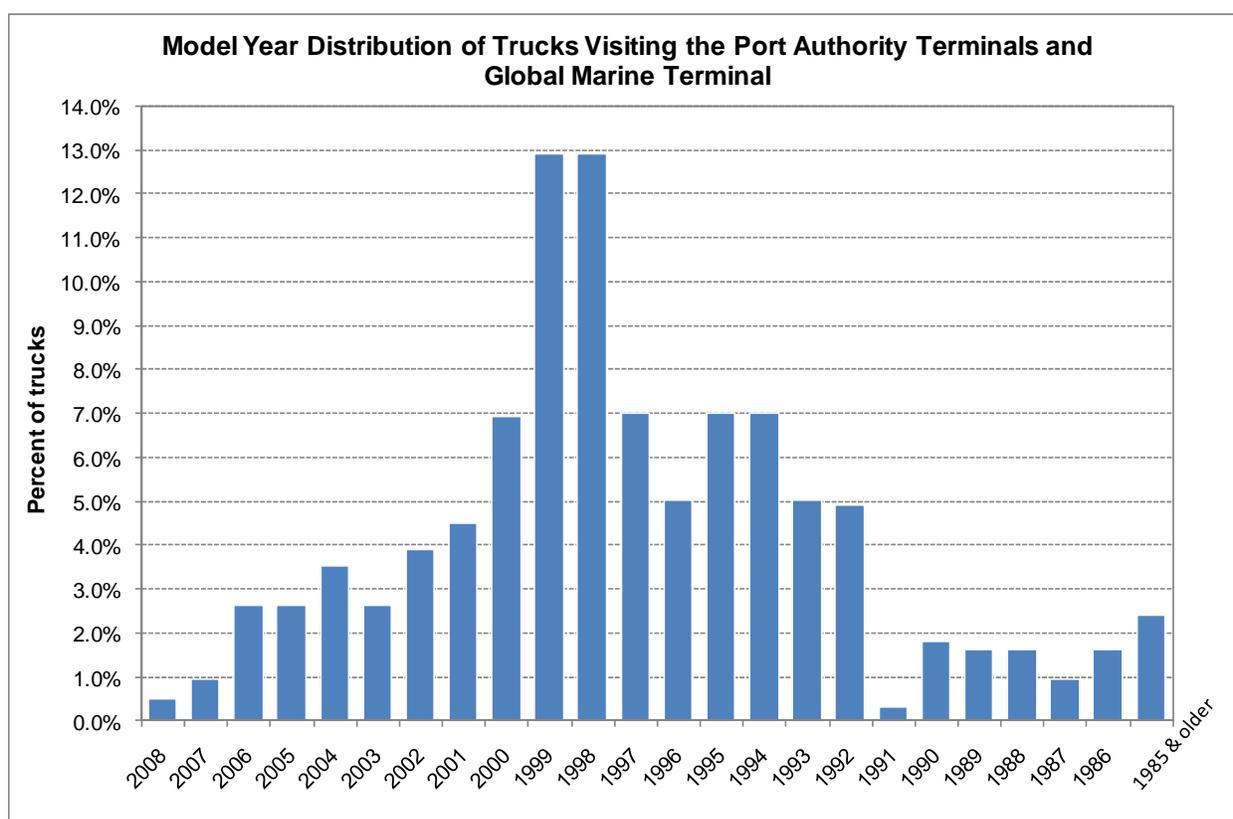
***d. Time of Day Distributions for Trips To/From Port Facilities***

No readily available information was found on the distribution of truck trips by time of day for the three ports analyzed. A reasonable assumption to make in the absence of survey data on time of day distributions is that the number of truck trips associated with the port terminal is relatively flat during the course of the port's normal operating hours.

*e. Truck Age Distributions*

No readily available information was found on the distribution of the age or model year of the trucks serving the three ports included in this port analysis. However, data on the age distribution of trucks serving the Port Authority of New York and New Jersey ports (the ports used for the emissions demonstration in Chapter VI) were available. That information is shown here since this is the sample port used to demonstrate the application of this port analysis in estimating port emissions. The truck age distribution for these New York/New Jersey ports was created based on data in “The Port Authority of New York and New Jersey Drayage Truck Characterization Survey at the Port Authority and the Global Marine Terminals.” The purpose of that survey was to collect information on the age of drayage trucks in six terminals within the Port Authority of New York and New Jersey. Figure IV-4, which was used to develop the truck age distribution, illustrates the percentage of trucks of each model year.

**Figure IV-4. Model Year Distribution of Trucks Visiting the Port Authority Terminals and Global Marine Terminal**



*The Port Authority of New York and New Jersey Drayage Truck Characterization Survey at the Port Authority and the Global Marine Terminal, December 2008, Page 3.*

The trucks surveyed were categorized as being owner-operated or owned by other than the driver. It is important to note that for the Port Authority of New York and New Jersey, the percentage of owner-operated trucks in each model year made up approximately two-thirds

of the sampled trucks. The survey results also indicated that a large percentage of trucks newer than 2003 are not owner-operated trucks, but rather, are fleet vehicles. Therefore, when analyzing emissions from ports with a relatively high proportion of fleet vehicles serving the port, the age distribution should be shifted to include a larger percentage of newer trucks.

Table IV-6 presents the MOVES age distribution input that was developed from the above data to perform calendar year 2008 emission modeling. The age fractions were selected as follows:

- Age ID 0: model year 2008 in the figure above (the newest model year fraction; this is 2008 in the MOVES input as this is the year being modeled) ~ 0.5 percent;
- Age ID 1: model year 2007 in the figure above ~ 0.95 percent; etc.;
- Age ID 22: model year 1986 in the figure above ~ 1.6 percent; and
- AgeID 23 through 30: the remaining fraction was evenly distributed between older trucks (the sum of the age fractions in the MOVES input file must be 1).

**Table IV-6. Age Distributions of Combination Short-Haul Trucks in Calendar Year 2008**

Age ID	Model Year	Vehicle Fraction NY / NJ Ports	Vehicle Fraction MOVES Default Base Year <sup>10</sup>	Vehicle Fraction MOVES Default Calculated <sup>11</sup>
0	2008	0.005	0.084252	0.054017
1	2007	0.0095	0.067209	0.054562
2	2006	0.026	0.057562	0.058045
3	2005	0.026	0.050628	0.057470
4	2004	0.035	0.069300	0.050350
5	2003	0.026	0.056228	0.037666
6	2002	0.039	0.048773	0.035425
7	2001	0.045	0.037878	0.037229
8	2000	0.069	0.045255	0.054716
9	1999	0.129	0.053548	0.065605
10	1998	0.129	0.056029	0.050240
11	1997	0.07	0.054994	0.041307
12	1996	0.05	0.059676	0.034515
13	1995	0.07	0.052840	0.045336
14	1994	0.07	0.048713	0.035658
15	1993	0.05	0.040034	0.029668

<sup>10</sup>The MOVES default age distribution provided here is a national age distribution for calendar year 1999 (no county default data are available). Default age distributions are only available for base years 1990 and 1999. When a simulation run is performed, MOVES uses age distributions for the base year (1990 or 1999) combined with sales information, migration factors, and survival rates to compute the age distribution in the calendar year selected for analysis. The primary default base year of 1999 was developed with data from the VIUS database (for trucks). The default base year of 1990 was developed with data from the TIUS92 database.

<sup>11</sup>The MOVES age distribution provided here is the age distribution calculated by MOVES for Hudson County (New Jersey) when a simulation run is performed for calendar year 2008 (calculation described above). This intermediate table is available in the "MOVESExecution" database right after the simulation run (the table is re-written after each run).

Age ID	Model Year	Vehicle Fraction NY / NJ Ports	Vehicle Fraction MOVES Default Base Year <sup>10</sup>	Vehicle Fraction MOVES Default Calculated <sup>11</sup>
16	1992	0.049	0.016687	0.022328
17	1991	0.0029	0.014696	0.025576
18	1990	0.018	0.013335	0.029016
19	1989	0.016	0.017959	0.029095
20	1988	0.016	0.011167	0.027367
21	1987	0.0095	0.009040	0.028760
22	1986	0.016	0.009914	0.024393
23	1985	0.0030125	0.003839	0.021541
24	1984	0.0030125	0.004789	0.017138
25	1983	0.0030125	0.004765	0.006840
26	1982	0.0030125	0.004000	0.005829
27	1981	0.0030125	0.003639	0.005119
28	1980	0.0030125	0.002622	0.006669
29	1979	0.0030125	0.000628	0.004012
30	1978	0.0030125	0.000000	0.004510

## B. ESTIMATING TRUCK TRIPS GENERATED AT INTERMODAL FACILITIES

For existing port facilities, the number of truck trips can be estimated using gate count data, if available, or conducting a manual count of trucks entering the facility over a specified period of time. For new or expanded port and intermodal facilities, estimates can be made based on estimates of the facility acreage or expected ship or rail car arrivals. A training session provided by FHWA entitled “Multimodal Freight Forecasting in Transportation Planning: Session 10, Facility and Site Planning Needs and Applications” related truck trips per day to total acreage, ship arrivals, and rail cars per year using Philadelphia, Pennsylvania data. The results for this are shown below.

All Facilities: Truck trips/day = 3.08 x Total Acreage  
 Ports: Truck trips/day = 1.90 x Ship Arrivals/year  
 Rail: Truck trips/day = (1.87 x Acreage) + (0.00517 x Rail Cars/year)

## C. POTENTIAL APPLICATION

The information and methodology presented above can provide ideas for how to derive some of the inputs necessary for an emissions analysis of truck trips to and from a port facility. This data could be considered if no local data is available. Averages from all three ports tend to be more reasonable when the categories are aggregated more as shown below.

**Total VMT** – To calculate total VMT generated by trucks traveling to and from a port, the total volume of trucks can be distributed into length of trip bins shown in Table IV-7 using the average column. Then these volumes can be multiplied by the appropriate distance for each bin located in the last column of Table IV-7. If the port of interest is known to be in the same area of the country as one of the three ports shown, or known to be in a geographic area with similar characteristics to one of the three ports shown, in terms of the distance to

likely origins and destinations, the distribution can be adjusted to be closer to or equal to the distribution for that port.

**Table IV-7. Distribution Among Trip Length Bins**

Length of Trip (Miles)	Everglades	Savannah	LA/Long Beach	Average	Distance for VMT Calculation (Miles)
0-25	69%	66%	60%	65%	12.5
25-200	11	22	34	22	112.5
200+	19	12	6	13	500
Total	100	100	100	100	

**Road Type Distribution** – As one of its inputs, MOVES requires a distribution of VMT among roadway types, which it defines as restricted and unrestricted access roadways in rural and urban areas. The percent distributions by FHWA functional classification presented above were grouped into these four MOVES roadway types as shown in Table IV-8. The averages may be used as a default, or the values from one of the three ports may be used if the area around the port of interest is known to be similar in terms of urban/rural split. It should be noted that the subtotals in the table show that while different ports have different urban/rural splits, the split between restricted and unrestricted access is similar among all three ports.

**Table IV-8. MOVES Road Type Distribution**

MOVES Road Type	Everglades	Savannah	LA/Long Beach	Average
Rural Restricted Access	53%	62%	33%	49%
Urban Restricted Access	33%	15%	48%	32%
<b>Restricted Access Subtotal</b>	<b>85%</b>	<b>77%</b>	<b>80%</b>	<b>81%</b>
Rural Unrestricted Access	11%	12%	5%	9%
Urban Unrestricted Access	4%	10%	15%	10%
<b>Unrestricted Access Subtotal</b>	<b>15%</b>	<b>23%</b>	<b>20%</b>	<b>19%</b>

**Vehicle Type Distribution** – MOVES requires VMT distributed by vehicle type as one of its inputs. While it is possible that single unit trucks could serve ports, Table IV-4 above shows that 97-100 percent of trucks traveling to and from ports are combination trucks. For this study, it can be assumed that all trucks are combination trucks. MOVES also defines trucks by short haul and long haul, which is defined respectively as trips below and above 200 miles. As shown in Table IV-5, on average 13 percent of trips are long haul and 87 percent of trips are short haul. Therefore, for this study, 0 percent single-unit short haul trucks, 0 percent single-unit long haul trucks, 87 percent combination short-haul trucks, and 13 percent combination long-haul trucks were used.

## CHAPTER V. APPLICATION OF THE PORT VSP PROFILES IN MOVES PROJECT LEVEL ANALYSES

This chapter describes how the VSP profiles developed for ports, as documented in Chapter II, could be applied by an analyst to estimate project-level emissions for a port facility.

In applying the operating mode profiles, described in Chapter II, to estimate emissions from truck trips at ports or intermodal facilities, the analyst should determine which of the three port link types modeled in the microsimulation modeling are applicable to their situation, make an estimate of the truck demand per hour, and select the corresponding operating mode profile or profiles. Note that the INSIDE GATE link is relevant only for uninterrupted travel (no stops) once trucks have entered the port facility. When accounting for emissions that occur during the truck trip to or from the facility that occur outside the port and beyond the signalized arterial leading to the facility, typical driving cycles that would normally occur on the types of roadways traveled would be appropriate, so the MOVES default driving cycles could be used to capture that portion of the trip emissions. When focusing on the portion of the trip specific to the port or intermodal facility, the user would need to set up a MOVES project level run where these operating mode distributions would be included as inputs.

The steps for applying these profiles to another port or intermodal facility are described below:

1. Estimate number of trucks per hour at the port gate. This can be done by dividing the estimate of the number of trucks entering the port gate per day per gate. Thus, if the port has 2,000 trucks entering per day and four gates, and operates from 6 a.m. to 4 p.m., an average of 50 trucks would enter per hour per gate.
2. Select the Port Gate Operating Mode Distribution file with the closest number of trucks per hour. In this case, the appropriate file for 50 trucks per hour would be GATE\_50TRUCKS\_HR. The file for 60 trucks per hour should be used in any cases where the truck volume per hour entering each gate is greater than 60.
3. Set up two MOVES project-level runs – one using the operating mode distribution associated with the links with the intersection and approach to the port gate, as selected in Step 2, and one with the operation mode distribution inside the port gate (the ON\_PORT\_PROPERTY file).
4. Develop other necessary MOVES project level files:
  - a. Age Distribution file – this can be developed based on similar survey information as discussed above for the New York ports, or if data are unavailable, the New York port age distribution can be used, adjusted as necessary to the calendar year being modeled.
  - b. Links – the user needs to define individual roadway links. The required user data are port county/zone (Federal information processing standard county code of the port location), the road types at the port (restricted/unrestricted rural/urban), each link's length and volume (units of vehicles per hour), and the average speed for each link. If using the provided operating mode distribution files, the links are as defined in the section above titled "Output

- Files,” so link volumes would be determined by the average hourly volume of trucks, and the link length should match the appropriate actual port link (e.g., if the average trip length within the port is 2 miles, this would be entered for the ON PORT PROPERTY link [link ID 30 in the ON\_PORT\_PROPERTY file]).
- c. Link Source Type – similarly, the user needs to provide the fraction of each link’s traffic volume that is driven by each source type.
  - d. Off network Link file – this file needs to be populated with the MOVES source types being considered in the analysis to account for project emissions from idling and starts. The required user data are the vehicle population, the start fraction (the fraction of this population that has a start operation in the given hour), extended idle fraction, and parked vehicle fraction.
  - e. Additional data files are needed for meteorology and fuel parameters, but these can be populated with the MOVES default for the county in which the project is located.
5. Run MOVES, selecting the pollutants, vehicles, and output of interest. Since the MOVES project level runs only include one hour of activity, the results should be scaled to the time period of interest (e.g., if the port operates for 10 hours per day, the hourly results would be multiplied by 10 to get daily results.

## CHAPTER VI. EMISSION CONTROL STRATEGY ANALYSIS AT SAMPLE PORT USING VSP PROFILES

This chapter describes a sample analysis of some emission reduction strategy options for the port terminals operated by the Port Authority of New York and New Jersey. This analysis was performed primarily using a recent origin-destination study which was performed during 2004 and 2005. Some relevant statistics from the Port Authority of New York and New Jersey Container Terminal Truck O-D survey are provided below, which may be useful for comparing with another port of interest.

Since some of the inputs required to perform the MOVES runs described in this section used data from the Port Authority of New York and New Jersey, it is important that users compare the data provided in Tables VI-1 and VI-2 below, to those of their port of interest in order to develop appropriate MOVES inputs.

Table VI-1 below summarizes key data from the Port Authority of New York and New Jersey for 2009. This data was taken from the Port Authority 2009 Annual Report<sup>12</sup>.

**Table VI-1. Summary of 2009 Statistics for the Port Authority of New York and New Jersey**

<b>Activity</b>	<b>Port Authority NY &amp; NJ</b>
Total Containers (TEUs - Twenty-foot Equivalent Units)	4,561,527
Total Cargo Tonnage (Metric Tons)	28,240,770
Surface (Acres)	1,340
Employment	6,977
Operating Revenue (\$ Thousands)	3,552,243
Operating Income (\$ Thousands)	529,603

Table VI-2 shows the daily gate movements in and out of all container terminals surveyed. Based on findings from the two-day surveys taken during December 2004 in New York and one-day surveys taken during May 2005 in New Jersey, approximately 9,600 trucks enter and exit the marine container terminals on a typical day. Truck volumes to and from the Port Newark and Elizabeth Port Authority Marine Terminal were approximately 78 percent of the regional total, with approximately 7,490 trucks entering and exiting. Truck volumes to and from the marine container terminals are dependent upon the shipping line schedules and, therefore, daily volumes of trucks are variable.

<sup>12</sup>“Annual Report 2009, Comprehensive Annual Financial Report for the Year Ended December 31, 2009,” Port Authority of New York and New Jersey, <http://www.panynj.gov/corporate-information/pdf/annual-report-2009.pdf>.

**Table VI-2. Typical Day Gate Movements – All Port Authority New York and New Jersey Container Terminals Surveyed**

		<b>Entering Terminal</b>	<b>Leaving Terminal</b>	<b>Total Activity</b>
Loaded Containers		2,324	5,410	7,734
	<i>Percent</i>	24%	56%	40%
Empty Containers		3,575	973	4,548
	<i>Percent</i>	37%	10%	24%
Bobtails & Chassis		3,733	3,249	6,982
	<i>Percent</i>	39%	34%	36%
<b>Total Daily Trucks</b>		<b>9,632</b>	<b>9,632</b>	<b>19,264</b>
	<i>Percent</i>	<b>100%</b>	<b>100%</b>	<b>100%</b>

For the Port Authority of New York and New Jersey port terminals, the general practice is to open the gates at 6:00 a.m. and close at 4:00 p.m.

Overall, 74 percent of the survey respondents said that they typically spend about 2 hours or less at the seven container terminals surveyed – which included queuing and processing time at the gates and the time spent inside the terminal for drop off or pick-up.

**Port Authority New York and New Jersey  
Time Spent at the Terminal – All Terminals Combined**

<b>Time Interval</b>	<b>Percentage</b>
½ hour or less	10%
About 1 hour	21
About 1.5 hours	17
About 2 hours	26
About 3 hours	15
About 4 hours	6
Over 4 hours	4
Do not know	1
<b>Total</b>	<b>100</b>

**A. OVERVIEW OF ANALYSIS AND CONTROL STRATEGIES ANALYZED**

Using the basic information shown above for the Port Authority of New York and New Jersey ports, several emission control strategies that could be used to reduce emissions at ports were analyzed. The strategies evaluated included idling reduction, diesel retrofits, truck replacements, and freight diversion to rail. These are not intended to be an all-inclusive list of control strategies for reducing emissions at ports, but rather to demonstrate how such analyses can be conducted at the project level using the VSP profiles developed as discussed in Chapter II. The primary reductions from the freight diversion to rail strategy come from significant reductions in truck VMT. Thus, this strategy was not evaluated at the project level, but was an evaluation comparing the reduced truck emissions to the corresponding increase in rail emissions.

## B. METHODOLOGY BY CONTROL STRATEGY

This section provides an overview of methodologies presented in Chapter VI.

### 1. Idling Reduction

Several states have laws that affect ports and marine terminals. They prohibit the idling of heavy-duty diesel trucks at marine terminals for more than 30 minutes (California, Illinois, Massachusetts, New Jersey, Texas, and Washington)<sup>13</sup>. A wide variety of idling reduction technologies exist; most of these are designed to provide services (e.g., heat, air conditioning, and/or electricity) to a vehicle that would otherwise require the operation of the main drive engine while the vehicle is temporarily parked or remains stationary. The following truck idling reduction technologies are verified by EPA<sup>14</sup>:

- **Electrified Parking Spaces:** an Electrified Parking Spaces system operates independently of the truck's engine and allows the truck engine to be turned off as the system supplies heating, cooling, and electrical power (provides off-board electrical power).
- **Auxiliary Power Units and Generator Sets:** these devices supply cooling, heating, and electrical power to Class 8 trucks and other applications.
- **Fuel Operated Heaters:** a Fuel Operated Heater provides heat (only) by combusting fuel drawn from the main engine or other fuel system.
- **Battery Air Conditioning Systems:** a Battery Air Conditioning System uses batteries to power an independent electric cooling system. Typically, these systems integrate a Fuel Operated Heater to supply heating.
- **Thermal Storage Systems:** a Thermal Storage System stores energy in cold storage as the truck is driven, and then provides air conditioning when the truck is turned off.
- **Automatic Shut-down/ Start-Up Systems:** automatic engine shut-down/start-up systems not only turn off the engine while idling but can re-start the engine when necessary<sup>15</sup>.

The impact of an idling reduction control strategy can be modeled in MOVES by adjusting the off-network link. As described in the MOVES user guide,<sup>16</sup> the off-network provides information about vehicles which are not driving on the project links, but still contribute to the project emissions (while idling or starting for instance). For each vehicle type, the off-network input includes:

- **The 'vehicle population':** average number of "off network" vehicles during the hour being modeled.
- **The 'start fraction':** a number which specifies the fraction of this population which has a "start" operation in the given hour.

<sup>13</sup>State Environmental Resource Center (SERC), <http://www.serconline.org/dieselPortPollution.html>.

<sup>14</sup>EPA SmartWay<sup>SM</sup>, Verified Idle Reduction Technologies, <http://www.epa.gov/otaq/smartway/transport/what-smartway/verified-technologies.htm#idle>.

<sup>15</sup>To date, SmartWay<sup>SM</sup> has only verified AESS systems for locomotives.

<sup>16</sup>Motor Vehicle Emission Simulator (MOVES), User Guide for MOVES2010a, EPA-420-B-10-036, August 2010, <http://www.epa.gov/otaq/models/moves/MOVES2010a/420b10036.pdf>.

- **The ‘extended idle fraction’:** a number which specifies the fraction of the population which has had an ‘extended idle’ operation in the given hour.
- **The ‘parked vehicle fraction’:** a number which specifies the fraction of the ‘vehicle population’ which have been parked in the given hour.

In order to model an idling reduction control strategy, the fraction of trucks idling (while waiting at the gate) was reduced; this fraction of trucks for which idling was reduced was added to the fraction of parked trucks and to the start fraction. For demonstration purposes, the case of an automatic shut-down system was selected; it was assumed that such a system does not have associated emissions. It is important to note that (when modeling other idling reduction technologies) emissions associated with the idling reduction control strategy need to be taken into account. Indeed, although overall emissions may decrease, emissions from the idling reduction technology itself need to be taken into account. The following section explains how the original off network link was created and how it was modified to model the idling reduction control strategy.

#### Original off-network link - no idling reduction

Source Type ID	Vehicle Population	Start Fraction	Extended Idle Fraction	Parked Vehicle Fraction
61	625	0.64	0.35	0.64

#### Modified off-network link - with idling reduction

Source Type ID	Vehicle Population	Start Fraction	Extended Idle Fraction	Parked Vehicle Fraction
61	625	0.9025	0.0875	0.9025

#### Original off-network link (no idling reduction):

- The total population of trucks for the hour modeled was assumed to be 625<sup>17</sup>.
- The fraction of trucks that were originally idling while at the gate was assumed to be 0.35<sup>18</sup>.
- The fraction of trucks that were originally parked while at the gate was assumed to be 0.64 (it was assumed that most trucks were either idling or parked while at the gate; a small fraction of 0.01 was left based on the “On-Port property” link trucks volume<sup>19</sup>).
- The fraction of trucks that start during the modeled hour was assumed to be 0.64. It was assumed that all the activity in the port occurs evenly during all (working) hours of the day; therefore, all the trucks that are parked must start. This is a simplification since during the early hours of the day, more trucks would be idling and stopped (very few

<sup>17</sup>Based on “The Port Authority of New York and New Jersey Drayage Truck Characterization Survey” (12/31/2008); a 12 hour-period of work per day and an even distribution of truck arrivals throughout the day were assumed.

<sup>18</sup>Based on “2006 Baseline Multi-Facility Emissions Inventory of Cargo Handling Equipment, Heavy-Duty Diesel Vehicles, Railroad Locomotives and Commercial Marine Vessels,” The Port Authority of New York and New Jersey, November 2008.

<sup>19</sup>To select this 0.01 fraction, Pechan used the ratio of volume of trucks in the “On-Port property” link to the volume of trucks in the “Driving” links developed by microsimulation (the volume of the “On-Port property” link simulated was 11-13, as compared to ~600-1800 for the other “Driving” links).

would actually start); in the late hours of the day, more trucks would be starting and less would be parked. To obtain more accurate results, this needs to be modified by users with port-specific data when modeling a particular hour.

- The average idling time for a truck that does idle was assumed to be 2 hours<sup>20</sup>.

Modified off-network link (with idling reduction):

As mentioned above, the case of an automatic shut-down system was selected. Engines were modeled to turn-off after 30 minutes of idling. This threshold was selected based on the state laws affecting ports described earlier. The fraction of trucks idling (while waiting at the gate) was reduced; this fraction of trucks for which idling was reduced was added to the fraction of parked trucks and to the start fraction.

- The total population of trucks for the hour modeled is still 625.
- The new fraction of trucks idling while at the gate is now 0.0875 (only a quarter of the original fraction, since trucks now idle for 30 minutes instead of 2 hours).
- The new fraction of trucks parked while at the gate is now 0.9025 (the fraction of trucks that were idling and were switched off is now integrated into the parked fraction).
- The new fraction of trucks that start during the modeled hour is now 0.9025 (again, we assumed that all trucks that stopped will start and that those starts are evenly distributed throughout the day).

## 2. Diesel Retrofits

Various retrofit technologies are available and verified by EPA. A list of the diesel retrofit technologies that EPA has approved for use in engine retrofit programs can be found on EPA's website, along with each system's expected efficiency<sup>21</sup>. The Continuously Regenerating Technology 3 (CRT3) Particulate Filter was selected in this example (it is one of the most efficient systems verified by EPA). The expected emissions reductions from the Diesel Particulate Filters (DPF) are listed in the table below:

Emissions Reductions (%)			
PM	Carbon Monoxide (CO)	Oxides of Nitrogen (NO <sub>x</sub> )	Hydrocarbon (HC)
90	72	n/a	93

MOVES has the capability to model on-road vehicle retrofit strategies for all exhaust pollutants for diesel trucks. A retrofit input file was created to model the impact of using the CRT3 Particulate Filter. This retrofit input file is provided in Appendix B. Some of the parameters in that input file include:

<sup>20</sup>Based on "2006 Baseline Multi-Facility Emissions Inventory of Cargo Handling Equipment, Heavy-Duty Diesel Vehicles, Railroad Locomotives and Commercial Marine Vessels," The Port Authority of New York and New Jersey, November 2008.

<sup>21</sup>Diesel Retrofit Technology Verification; <http://www.epa.gov/otaq/retrofit/verif-list.htm>.

- **Initial calendar year of retrofit implementation:** first calendar year the retrofit program is administered. Due to an error in the MOVES model (both MOVES2010 and MOVES2010a versions), retrofit can only be modeled as if it happened entirely during the year modeled (rather than over a several year period before the modeled year). Therefore, all of the retrofits were applied in 2008.
- **Final calendar year of the retrofit implementation:** last calendar year during which the retrofit program is administered. This was 2008, as noted above.
- **Initial model year that will be retrofitted:** first model year of coverage for a particular vehicle class/pollutant combination. This year was selected based on EPA's guidelines for verified technologies. The CRT3 DPF is verified for truck model years 1994 to 2006. Thus, the selected initial model year was 1994.
- **Final model year that will be retrofitted:** last model year of coverage for a particular vehicle class/pollutant combination. This year was selected based on EPA's guidelines for verified technologies and on EPA heavy-duty truck regulations. The 2004 Federal regulation focused mostly on NO<sub>x</sub>, with no new limit on PM; therefore, PM emissions for model years 2004 were likely high. However, the 2006 Federal regulation imposed a stringent PM limit, which probably required a DPF to be installed in new vehicles by the manufacturer. Therefore, a retrofit is relevant for model years until 2006.
- **Percentage of the fleet retrofit per year:** represents the percentage of VMT of a particular fleet of a particular vehicle class, retrofit calendar year group, model year group, and pollutant combination that is to be rebuilt in a given calendar year. As described above, all of the retrofits were in 2008 with retrofits occurring for 100 percent of the trucks. This scenario allows a user to scale down the impact of the retrofit by pro-rating the emissions reduction (x percent of the emissions reduction would be achieved if only x percent of the trucks were retrofitted).
- **Percentage effectiveness of the retrofit:** percent emission reduction achieved by a retrofit. It is computed from a non-retrofit emission baseline. The excepted emissions reductions from the CRT3 Particulate Filter were used for running exhaust and extended idling. For start emissions, the efficiency of HC/CO conversion was set to zero ("cold start" phenomenon).

### 3. Truck Replacements

The impact of a truck replacement control strategy can be modeled in MOVES by adjusting the vehicle age distribution input. E.H. Pechan & Associates, Inc. used the New York and New Jersey Regional Truck Replacement Program guidelines to develop the MOVES inputs (replacement of trucks that have engines model year 1993 or older with newer trucks model year 2004 to 2008). The original age distribution input was created based on data in "The Port Authority of New York and New Jersey Drayage Truck Characterization Survey." To model the truck replacement strategy, the fractions of trucks from 1993 and older were assumed to be zero and the original fractions were added to the newer truck fractions. The older trucks were modeled as being replaced with an even distribution of newer trucks that meet the New York and New Jersey Regional Truck Replacement Program criteria (20 percent of 2004, 20 percent of 2005, 20 percent of 2006, 20 percent of 2007, and 20 percent of 2008). With this method, it is possible to scale down the impact of the Truck Replacement Program by pro-rating the emissions reduction (x percent of the emissions

reduction would be achieved if only x percent of the trucks were replaced with an even distribution of newer trucks). The table below shows the original age distribution and how it was modified to model the truck replacement.

### Original Age Distribution

Source Type ID	Year ID	Age ID	Age Fraction
61	2008	0	0.005
61	2008	1	0.0095
61	2008	2	0.026
61	2008	3	0.026
61	2008	4	0.035
61	2008	5	0.026
61	2008	6	0.039
61	2008	7	0.045
61	2008	8	0.069
61	2008	9	0.129
61	2008	10	0.129
61	2008	11	0.07
61	2008	12	0.05
61	2008	13	0.07
61	2008	14	0.07
61	2008	15	0.05
61	2008	16	0.049
61	2008	17	0.0029
61	2008	18	0.018
61	2008	19	0.016
61	2008	20	0.016
61	2008	21	0.0095
61	2008	22	0.016
61	2008	23	0.0030125
61	2008	24	0.0030125
61	2008	25	0.0030125
61	2008	26	0.0030125
61	2008	27	0.0030125
61	2008	28	0.0030125
61	2008	29	0.0030125
61	2008	30	0.0030125

### Modified Age Distribution

Source Type ID	Year ID	Age ID	Age Fraction
61	2008	0	0.0453
61	2008	1	0.0498
61	2008	2	0.0663
61	2008	3	0.0663
61	2008	4	0.0753
61	2008	5	0.026
61	2008	6	0.039
61	2008	7	0.045
61	2008	8	0.069
61	2008	9	0.129
61	2008	10	0.129
61	2008	11	0.07
61	2008	12	0.05
61	2008	13	0.07
61	2008	14	0.07
61	2008	15	0
61	2008	16	0
61	2008	17	0
61	2008	18	0
61	2008	19	0
61	2008	20	0
61	2008	21	0
61	2008	22	0
61	2008	23	0
61	2008	24	0
61	2008	25	0
61	2008	26	0
61	2008	27	0
61	2008	28	0
61	2008	29	0
61	2008	30	0

Another option would be to replace an uneven distribution of trucks instead of replacing all trucks 1993 and older. For instance, another rule could be: the older the truck, the larger the proportion of trucks replaced. The table below shows how the age distribution can be modified to model such a program (it also lists the percentage of trucks replaced per model year). It was still assumed that trucks were replaced with 20 percent of 2004, 20 percent of 2005, 20 percent of 2006, 20 percent of 2007, and 20 percent of 2008. With this scenario, it is possible to scale down the impact of the program by pro-rating the emissions reduction (y percent of the emissions reduction would be achieved if instead of replacing 10 percent of 1993 trucks, 20 percent of 1992..., 100 percent of 1984, only (10\*y) percent 1993, (20\*y) percent of 1992..., (100\*y) percent of 1984 trucks were

replaced). Additional MOVES runs would be needed to evaluate the emission reduction, if the truck replacement followed a different pattern.

### Modified Age Distribution - The Older the Truck, the Larger the Percentage of Replacement

Source Type ID	Year ID	Age ID	Age Fraction	Model Year	% of Truck Replaced
61	2008	0	0.02174375	2008	0%
61	2008	1	0.02624375	2007	0%
61	2008	2	0.04274375	2006	0%
61	2008	3	0.04274375	2005	0%
61	2008	4	0.05174375	2004	0%
61	2008	5	0.026	2003	0%
61	2008	6	0.039	2002	0%
61	2008	7	0.045	2001	0%
61	2008	8	0.069	2000	0%
61	2008	9	0.129	1999	0%
61	2008	10	0.129	1998	0%
61	2008	11	0.07	1997	0%
61	2008	12	0.05	1996	0%
61	2008	13	0.07	1995	0%
61	2008	14	0.07	1994	0%
61	2008	15	0.045	1993	10%
61	2008	16	0.0392	1992	20%
61	2008	17	0.00203	1991	30%
61	2008	18	0.0108	1990	40%
61	2008	19	0.008	1989	50%
61	2008	20	0.0064	1988	60%
61	2008	21	0.00285	1987	70%
61	2008	22	0.0032	1986	80%
61	2008	23	0.00030125	1985	90%
61	2008	24	0	1984	100%
61	2008	25	0	1983	100%
61	2008	26	0	1982	100%
61	2008	27	0	1981	100%
61	2008	28	0	1980	100%
61	2008	29	0	1979	100%
61	2008	30	0	1978	100%

#### 4. Freight Diversion to Rail

Another strategy that can be employed to reduce port-related emissions is to divert freight from trucks to rail. Diversion of freight is an alternative that is currently being considered for the Port Authority of New York and New Jersey ports.<sup>22</sup> Based on this current study, the diversion of long-haul truck trips (defined as trips of 500 miles or more) could reduce

<sup>22</sup>Port Authority of New York and New Jersey, U.S. Department of Transportation, and Federal Highway Administration, "Cross-Harbor Freight Program, Alternatives Workshop, Development and Screening," March 24, 2010, <http://www.panynj.gov/about/pdf/Alternatives-Workshop.pdf>.

approximated 10 percent of the truck tonnage transported to or from these ports. When freight is diverted from trucks to rail over long distances, there is generally a significant emissions savings.

EPA has estimated the average emission factors for locomotives by calendar year, factoring in the emission standards applicable by model year and the populations of locomotives of each model year expected to be in place in a given calendar year.<sup>23</sup> EPA converted the emission factors in grams per brake horsepower-hour to grams per gallon by using a horsepower-hour per gallon conversion factor. These resulting emission factors in grams per gallon are shown in the table below. EPA has also noted that based on data collected by the Association of American Railroads, approximated one gallon of fuel is consumed when hauling 400 ton-miles of freight. Using this conversion factor, the table below shows the resulting emission factor by pollutant in grams per ton-mile of freight hauled by a large line-haul locomotive in 2008.

<b>Pollutant</b>	<b>Calendar Year 2008 Large Line Haul Average Emission Factor (grams per gallon)</b>	<b>Calendar Year 2008 Large Line Haul Average Emission Factor (grams per ton-mile)</b>	<b>2008 Emissions to Carry 25 Tons of Freight 500 Miles by Rail (grams)</b>
NO <sub>x</sub>	169	0.423	5,281
HC	9.0	0.023	281
PM <sub>10</sub>	5.1	0.013	159

While there is no standard weight of a container moved by rail or freight truck, for this analysis, we have assumed a weight of 50,000 pounds or 25 tons. The resulting rail emissions for hauling one 25 ton container 500 miles by rail are shown in the table above. These emissions were then compared to the emissions from one combination long-haul truck driving the same distance.

To estimate comparable truck emissions, MOVES was used to estimate the emission rate in grams per mile of a combination long-haul truck traveling through the New York area. This run was made at the county level of MOVES, using county-level defaults. This was done because the emissions from the 500-mile trip will greatly outweigh the emissions in the port area, so the operating mode profiles developed under this project were not relevant to this strategy. The table below shows the resulting truck emissions and the percentage reduction in emissions from one trip diverted from truck travel to rail.

<b>Pollutant</b>	<b>2008 Emissions to Carry 25 Tons of Freight 500 Miles by Rail (grams)</b>	<b>Calendar Year 2008 Emissions for a Long-Haul Truck Traveling 500 miles (grams)</b>	<b>Percentage Reduction in Emissions per Trip (%)</b>
NO <sub>x</sub>	5,281	10,632	50
Volatile Organic Compounds (VOCs)	281	400	30
PM <sub>10</sub>	159	506	68

<sup>23</sup>U.S. EPA, Office of Transportation and Air Quality, "Emission Factors for Locomotives," EPA-420-F-09-025, April 2009.

### C. RESULTS USING NEW VSP PROFILES

Three of the VSP profiles that were developed by microsimulation were tested in MOVES:

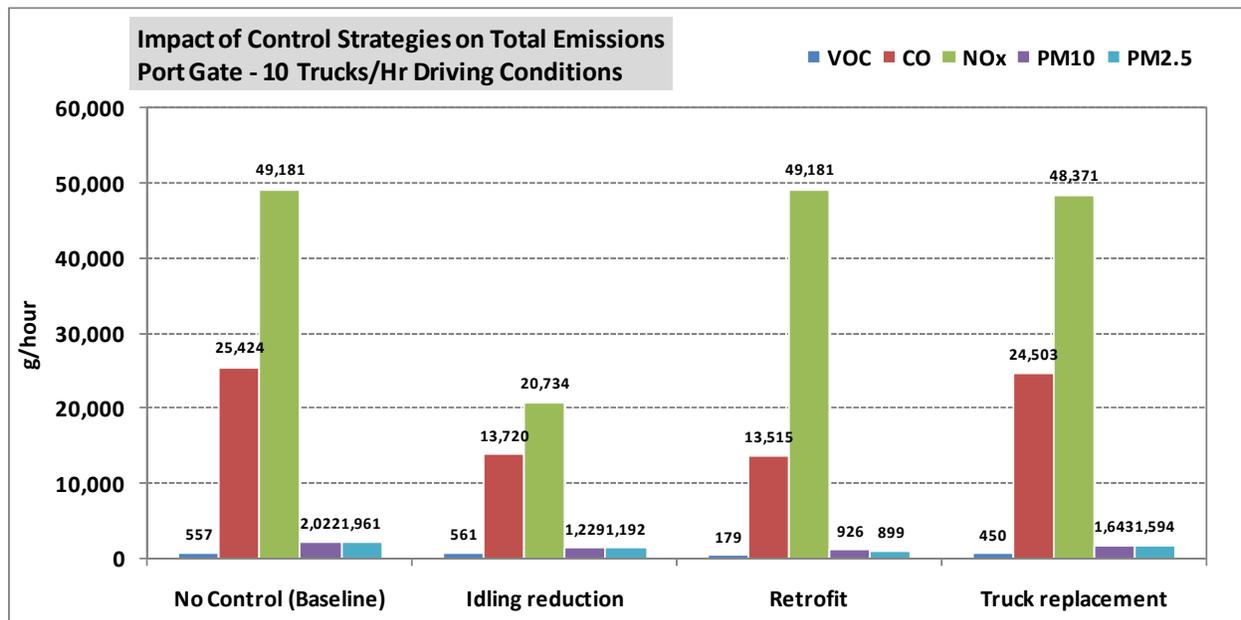
- Port Gate 10 trucks per hour;
- Port Gate 60 trucks per hour; and
- In-Port Property.

For each one of these VSP profiles, emissions<sup>24</sup> were estimated for four control strategies:

- No control strategy (baseline; modeled in MOVES);
- Idling reduction (modeled in MOVES);
- Diesel retrofit (modeled in MOVES); and
- Truck replacement (modeled in MOVES).

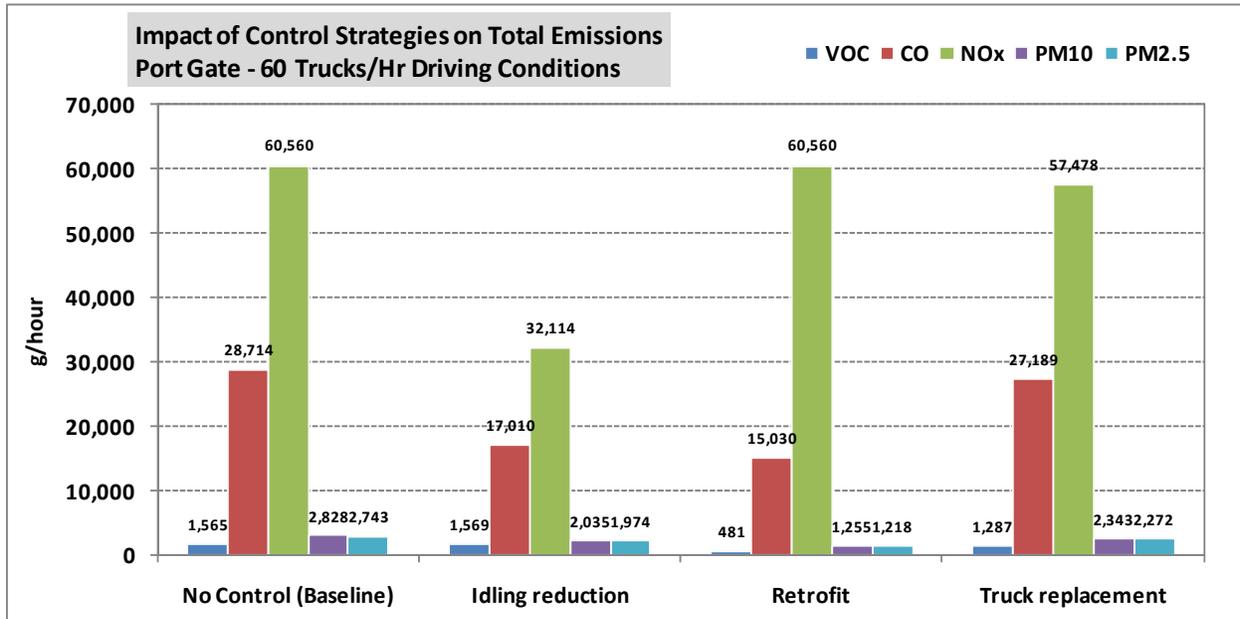
Figures VI-1, VI-2, and VI-3 present the results of the MOVES runs for the scenarios described above (total emissions). Figures VI-4, VI-5, and VI-6 illustrate the emissions reduction obtained from the idling reduction, diesel retrofits, and truck replacement strategies, compared to the baseline. Those results are shown numerically in Tables VI-3, VI-4, and VI-5.

**Figure VI-1. MOVES Emissions Output - Port Gate 10 Trucks per Hour Scenario**

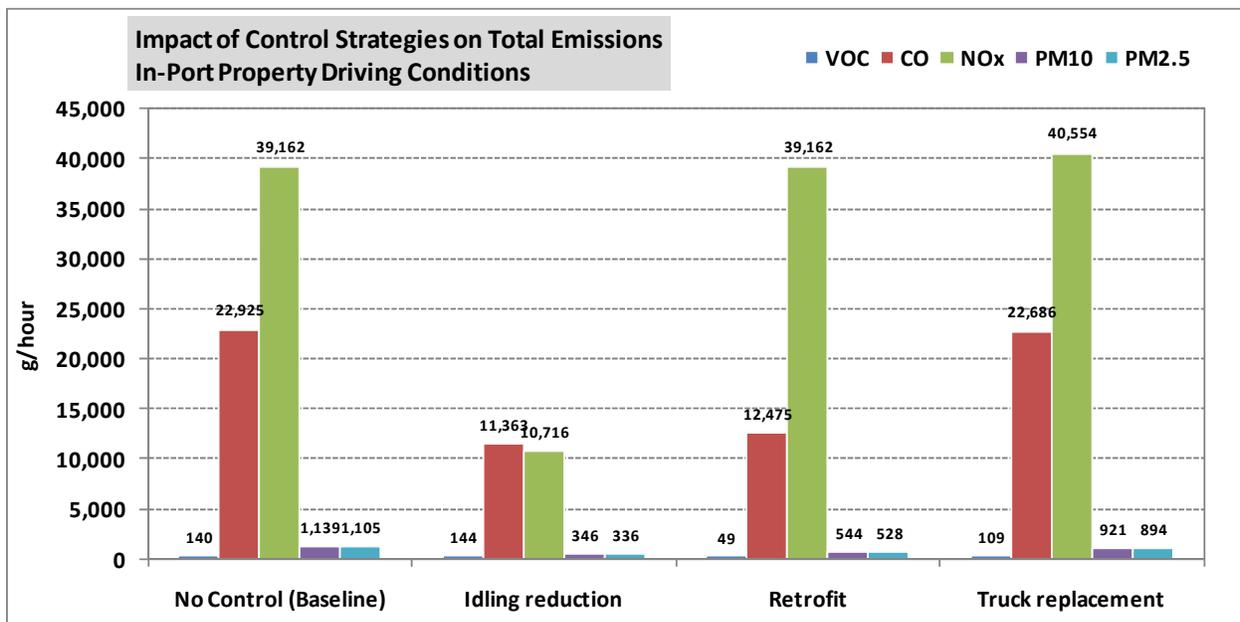


<sup>24</sup>Since only exhaust emissions will be affected by the selected control strategies, tire wear and brake wear PM emissions processes in MOVES output were disregarded.

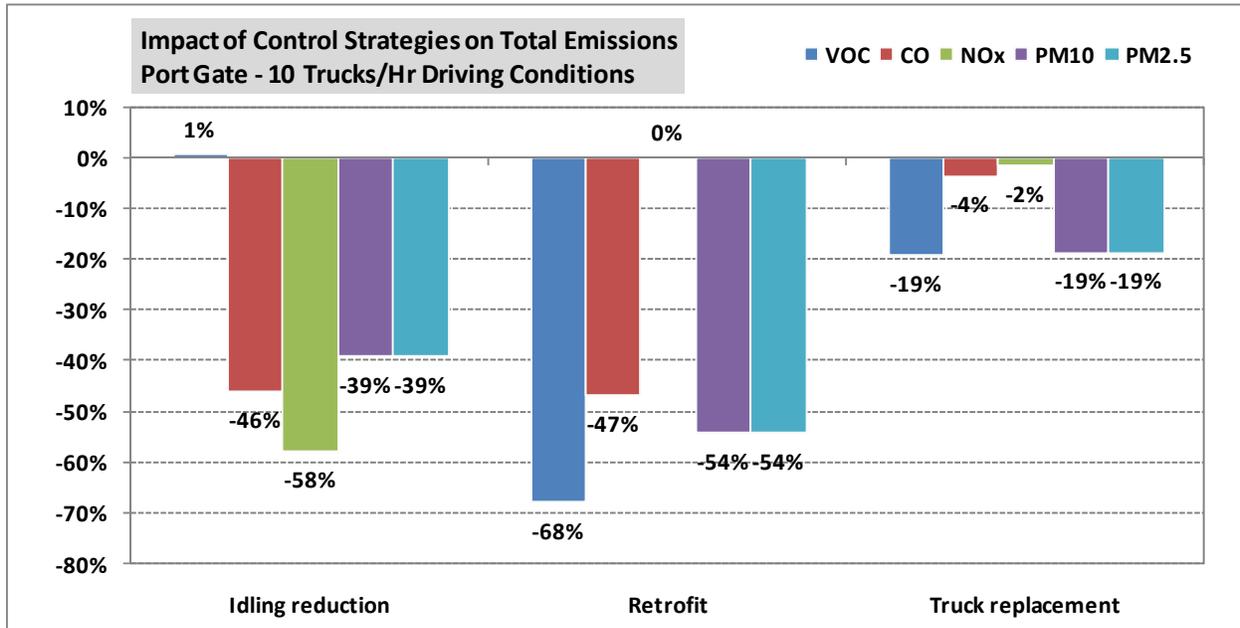
**Figure VI-2. MOVES Emissions Output - Port Gate 60 Trucks per Hour Scenario**



**Figure VI-3. MOVES Emissions Output - In Port Property Scenario**



**Figure VI-4. MOVES Emissions Reductions - Port Gate 10 Trucks per Hour Scenario**



**Figure VI-5. MOVES Emissions Reductions - Port Gate 60 Trucks per Hour Scenario**

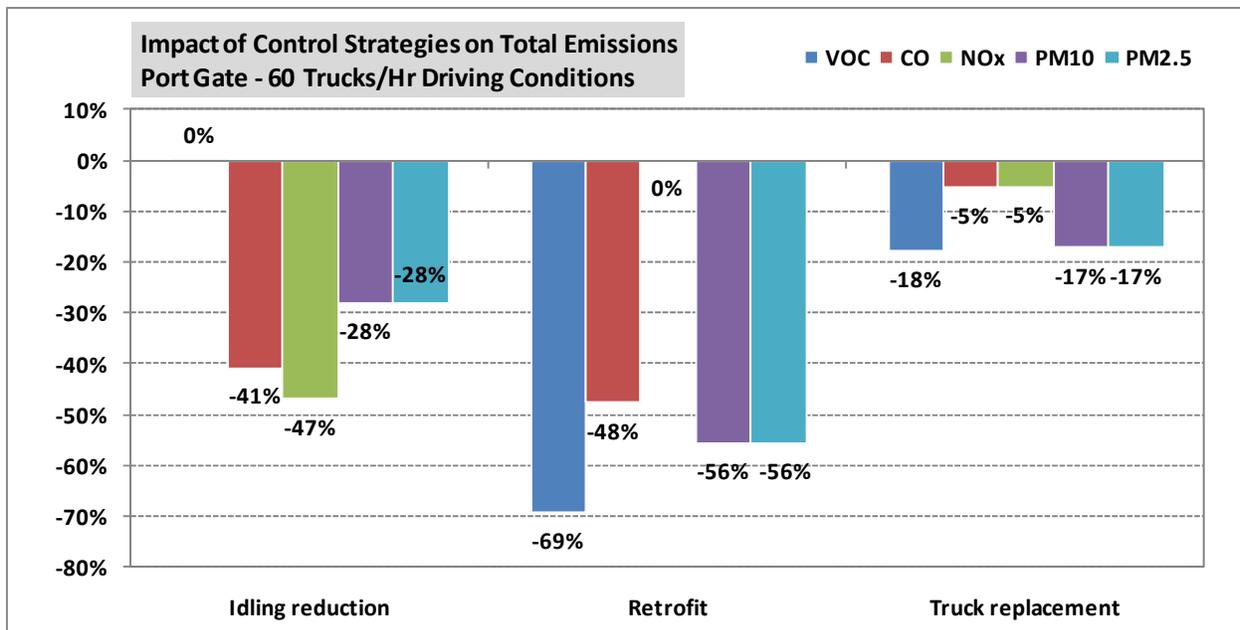


Figure VI-6. MOVES Emissions Reductions - In Port Property Scenario

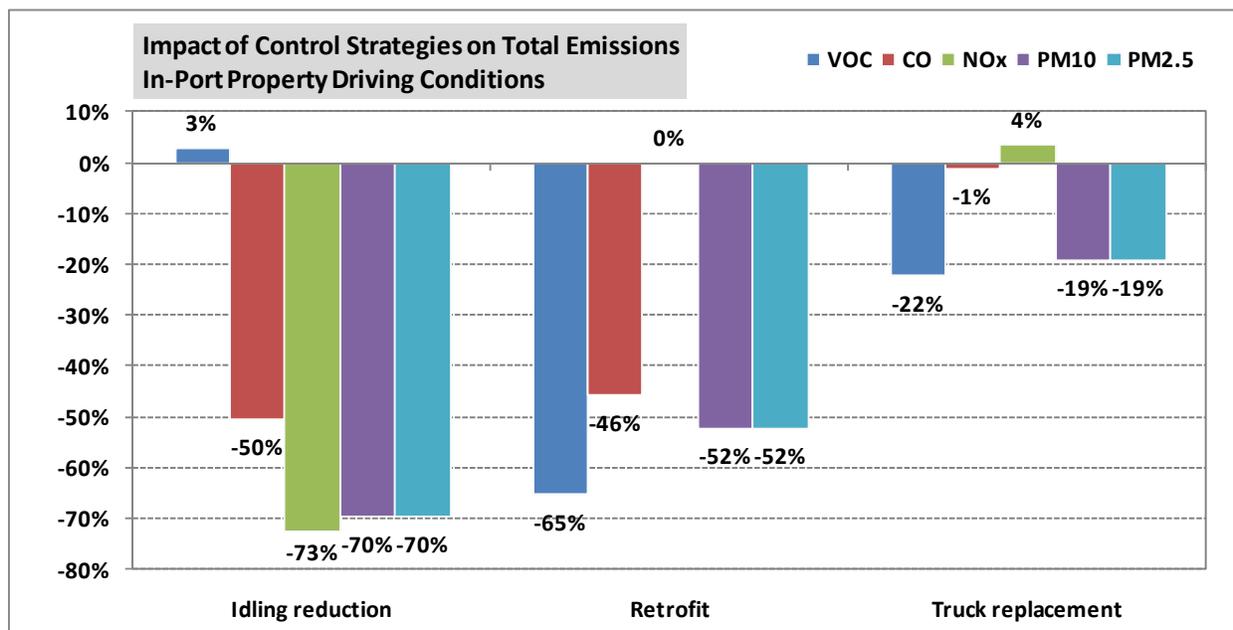


Table VI-3. MOVES Emissions Output - Port Gate 10 Trucks per Hour Scenario

Scenario	Control Strategy	VMT	# of Vehicles	# of Starts	Hours Idling Extended	Pollutant	Total Output (g)	Comparison with Baseline
Port Gate 10 Trucks/Hour	No Control (Baseline)	531	2,978	400	219	VOC	557	Baseline
						CO	25,424	
						NO <sub>x</sub>	49,181	
						PM <sub>10</sub>	2,022	
						PM <sub>2.5</sub>	1,961	
	Idling Reduction	531	2,978	564	55	VOC	561	1%
						CO	13,720	-46%
						NO <sub>x</sub>	20,734	-58%
						PM <sub>10</sub>	1,229	-39%
						PM <sub>2.5</sub>	1,192	-39%
	Retrofit	531	2,978	400	219	VOC	179	-68%
						CO	13,515	-47%
						NO <sub>x</sub>	49,181	0%
						PM <sub>10</sub>	926	-54%
						PM <sub>2.5</sub>	899	-54%
	Truck Replacement	531	2,978	400	219	VOC	450	-19%
CO						24,503	-4%	
NO <sub>x</sub>						48,371	-2%	
PM <sub>10</sub>						1,643	-19%	
PM <sub>2.5</sub>						1,594	-19%	

**Table VI-4. MOVES Emissions Output - Port Gate 60 Trucks per Hour Scenario**

Scenario	Control Strategy	VMT <sup>25</sup>	# of Vehicles <sup>26</sup>	# of Starts	Hours Idling Extended	Pollutant	Total Output <sup>27</sup> (g)	Comparison with Baseline
Port Gate 60 Trucks/Hour	No Control (Baseline)	574	3,075	400	219	VOC	1,565	Baseline
						CO	28,714	
						NO <sub>x</sub>	60,560	
						PM <sub>10</sub>	2,828	
						PM <sub>2.5</sub>	2,743	
	Idling Reduction	574	3,075	564	55	VOC	1,569	0%
						CO	17,010	-41%
						NO <sub>x</sub>	32,114	-47%
						PM <sub>10</sub>	2,035	-28%
						PM <sub>2.5</sub>	1,974	-28%
	Retrofit	574	3,075	400	219	VOC	481	-69%
						CO	15,030	-48%
						NO <sub>x</sub>	60,560	0%
						PM <sub>10</sub>	1,255	-56%
						PM <sub>2.5</sub>	1,218	-56%
	Truck Replacement	574	3,075	400	219	VOC	1,287	-18%
CO						27,189	-5%	
NO <sub>x</sub>						57,478	-5%	
PM <sub>10</sub>						2,343	-17%	
PM <sub>2.5</sub>						2,272	-17%	

**Table VI-5. MOVES Emissions Output - In Port Property Scenario**

Scenario	Control Strategy	VMT	# of Vehicles	# of Starts	Hours Idling Extended	Pollutant	Total Output (g)	Comparison with Baseline
In-Port Property	No Control (Baseline)	22	638	400	219	VOC	140	Baseline
						CO	22,925	
						NO <sub>x</sub>	39,162	
						PM <sub>10</sub>	1,139	
						PM <sub>2.5</sub>	1,105	
	Idling Reduction	22	638	564	55	VOC	144	3%
						CO	11,363	-50%
						NO <sub>x</sub>	10,716	-73%
						PM <sub>10</sub>	346	-70%
						PM <sub>2.5</sub>	336	-70%
	Retrofit	22	638	400	219	VOC	49	-65%
						CO	12,475	-46%
						NO <sub>x</sub>	39,162	0%
						PM <sub>10</sub>	544	-52%
						PM <sub>2.5</sub>	528	-52%
	Truck Replacement	22	638	400	219	VOC	109	-22%
CO						22,686	-1%	
NO <sub>x</sub>						40,554	4%	
PM <sub>10</sub>						921	-19%	
PM <sub>2.5</sub>						894	-19%	

<sup>25</sup>VMT = Vehicle Miles Traveled.<sup>26</sup>The # of vehicles includes the number of trucks simulated as part of the “driving links” + the trucks that are in the additional “off-network link” (trucks that are idling/parked).<sup>27</sup>The total output includes emissions from exhaust processes only (running, start, and extended idling).

Before discussing the findings for the three control strategies modeled, it is interesting to note that the percent reductions for PM<sub>2.5</sub> and PM<sub>10</sub> in the above tables are the same. This stems from the fact that the MOVES PM<sub>10</sub> emissions are a product of PM<sub>2.5</sub> emissions (for each emissions process) and a PM<sub>10</sub> emission ratio. This PM<sub>10</sub> emission ratio is a unitless factor for the amount of PM<sub>10</sub> created per unit of PM<sub>2.5</sub> (this factor varies by the output pollutant, the source type, and the fuel type)<sup>28</sup>.

The idling reduction strategy decreases CO, NO<sub>x</sub>, and PM emissions significantly. For instance, for the Port Gate 10 Trucks per Hour Scenario, emissions reductions are -56 percent, -58 percent, and -39 percent, respectively. It is important to note that in this particular example, idling emissions account for a large portion of the total baseline emissions (with no control strategy). This is due to the fact that driving distances are short (approach to gate only) and thus emissions from the “running” processes are comparatively low. Therefore, a drop in idling emissions translates into a drop in total emissions. VOC emissions are not affected by idling reduction because MOVES does not consider that any VOC emissions are generated during idling.

The retrofit control strategy has a significant impact on VOCs, CO, and PM. For the Port Gate 10 Trucks per Hour Scenario, the emissions reductions are -68 percent, -48 percent, and -56 percent, respectively. These reductions are directly correlated with the efficiency of the retrofit technology (in this case the CRT3 Particulate Filter); the chosen system does not have the capability of decreasing NO<sub>x</sub>, which is why those emissions remained constant.

Finally, the truck replacement strategy is the only one that leads to a change in the emissions of all pollutants. For the Port Gate 10 Trucks per Hour Scenario, those reductions were -19 percent for VOC, -19 percent for PM, -2 percent for NO<sub>x</sub>, and -4 percent for CO. The impact on emissions was not as significant as the one observed with other control strategies. The comment above about short driving distances (and thus low emissions from the “running” processes) is at the root of this phenomenon. If the emissions from the entire trip were to be taken into account, the drop in emissions would be more significant (the reductions in emissions from the “running” processes only range from -18 percent to -24 percent). One surprising result is the increase of NO<sub>x</sub> emissions with the truck replacement strategy for the In Port Property Scenario. Below is a possible explanation for this phenomenon:

- First, the distribution of heavy duty diesel/gasoline trucks in MOVES is as follows: 100 percent diesel after 1988 and 92-99 percent of diesel from 1978 to 1988 (1978 is the oldest model year in our analysis). Therefore, when a truck replacement strategy is modeled, an increase in the proportion of diesel trucks is applied.
- Then, according to EPA, NO<sub>x</sub> emissions from idling diesel trucks are about 5 times as high as NO<sub>x</sub> emissions from idling gasoline trucks<sup>29</sup>. Therefore, when a truck replacement strategy is modeled, as the proportion of diesel trucks is increased, NO<sub>x</sub> idling emissions are also increased.

<sup>28</sup>Software Design and Reference Manual, Draft Motor Vehicle Emission Simulator (MOVES) 2009, EPA-420-B-09-007, March 2009, available at: <http://www.epa.gov/otaq/models/moves/420b09007.pdf>.

<sup>29</sup>Emission Facts, Idling Vehicle Emissions, EPA420-F-98-014, April 1998.

- One could also question why this phenomenon (*global* NO<sub>x</sub> emissions increase) is only observed for the in-port property scenario. It is likely that all driving scenarios follow the trend described above for *idling emissions*. However, the other driving scenarios have a larger number of trucks and longer links than the in-port property scenario. Therefore, running emissions are higher for other driving scenarios. Since running emissions significantly decrease with the truck replacement, this leads to a decrease of the *global* NO<sub>x</sub> emissions. For the in-port property, running emissions are small compared to idling emissions. Thus, the NO<sub>x</sub> *idling* emissions increase leads to an increase of the *global* NO<sub>x</sub> emissions.

#### **D. RESULTS USING MOVES-GENERATED DEFAULT VSP PROFILES**

In order to assess if the impact of control strategies varies depending on the driving conditions, a MOVES-generated “Default” VSP profile was modeled in MOVES<sup>30</sup>. Emissions from this “Default” VSP profile were estimated for the same four control strategies:

- No control strategy (baseline; modeled in MOVES);
- Idling reduction (modeled in MOVES);
- Diesel retrofit (modeled in MOVES); and
- Truck replacement (modeled in MOVES).

Figure VI-7 presents the results of the MOVES run for the scenarios described above (total emissions). Figure VI-8 illustrates the emissions reduction obtained from the idling reduction, diesel retrofit, and truck replacement strategies, compared to the baseline. Those results are shown numerically in Table VII-6.

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<sup>30</sup>For the “Default” VSP profile, no operating mode was included in MOVES inputs (only an average speed which was taken from the “Port Gate 10 TPH” scenario). When only an average speed is specified for each link in the “Links” table, MOVES selects two default driving schedules and uses the average speed input to interpolate between the two cycles to create a new default cycle for that average speed.

Figure VI-7. MOVES Emissions Output - "Default" VSP Profile

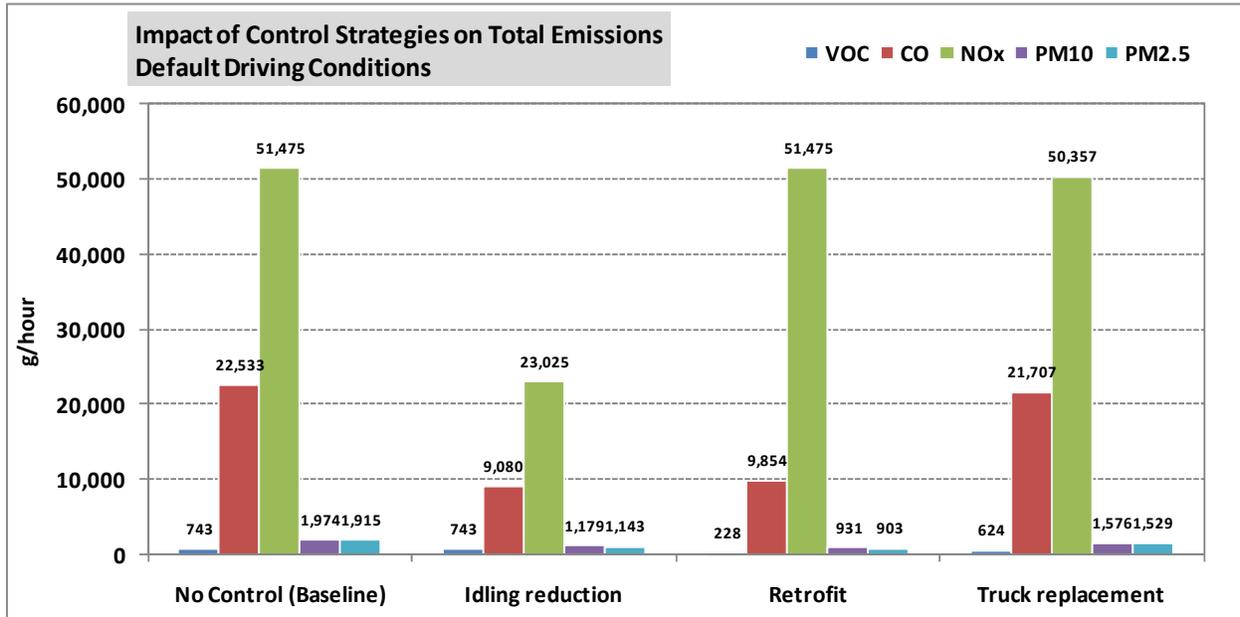
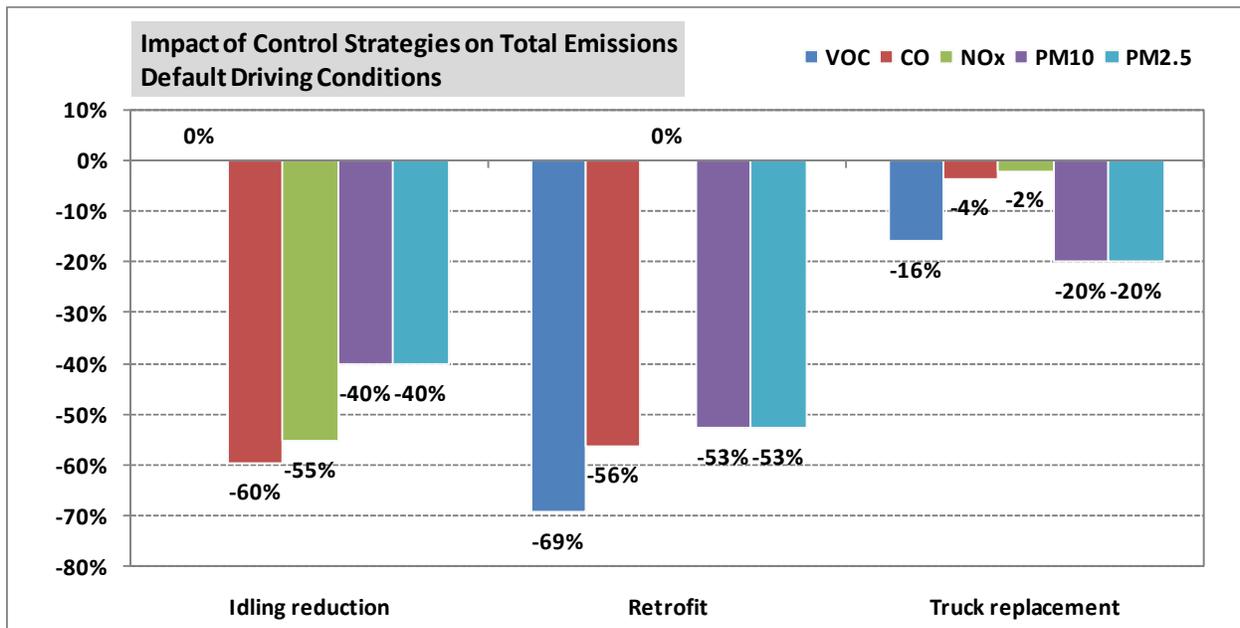


Figure VI-8. MOVES Emissions Reductions - "Default" VSP Profile



**Table VI-6. MOVES Emissions Output - “Default” VSP Profile**

Scenario	Control Strategy	VMT <sup>31</sup>	# of Vehicles <sup>32</sup>	# of Starts	Hours Idling Extended	Pollutant	Total Output <sup>33</sup> (g)	Comparison with Baseline
Default Driving Conditions	No Control (Baseline)	531	2,978	400	219	VOC	743	Baseline
						CO	22,533	
						NO <sub>x</sub>	51,475	
						PM <sub>10</sub>	1,974	
						PM <sub>2.5</sub>	1,915	
	Idling Reduction	531	2,978	564	55	VOC	743	0%
						CO	9,080	-60%
						NO <sub>x</sub>	23,025	-55%
						PM <sub>10</sub>	1,179	-40%
						PM <sub>2.5</sub>	1,143	-40%
	Retrofit	531	2,978	400	219	VOC	228	-69%
						CO	9,854	-56%
						NO <sub>x</sub>	51,475	0%
						PM <sub>10</sub>	931	-53%
						PM <sub>2.5</sub>	903	-53%
	Truck Replacement	531	2,978	400	219	VOC	624	-16%
CO						21,707	-4%	
NO <sub>x</sub>						50,357	-2%	
PM <sub>10</sub>						1,576	-20%	
PM <sub>2.5</sub>						1,529	-20%	

## E. COMPARISON OF RESULTS

Table VI-7 summarized the results from the control strategy analyses when using the MOVES default operating mode profiles with the comparable results when using the operating mode profiles developed based on port conditions. This table shows that the results differ most significantly for the idling reduction strategy. For the retrofit control strategy, CO showed fairly significant differences in emission reduction percentages when the port-specific profiles were used compared to the MOVES defaults. However, for VOC and PM, the results were relatively similar. The truck replacement strategy showed only minor differences in emission reduction percentages for all pollutants when the default operating modes were used as opposed to the port-specific profiles.

Overall, the differences between default drive cycles and VSP profiles are rather small. One reason is that whether a VSP profile is provided or not, “extended” idling emissions are the same (because the off network input which is applied in both cases, does not change). However, as described earlier (in Chapter VI section C), idling emissions account for a large portion of the total baseline emissions in this particular example (because driving distances are short and thus emissions from the “running” processes are low comparing to idling emissions). Therefore, a significant portion of the baseline emissions are exactly the same for default drive cycles and input VSP profiles. This can explain limited differences among the scenarios, even if VSP profiles are different. If only running emissions were modeled

<sup>31</sup>VMT = Vehicle Miles Traveled.

<sup>32</sup>The number of vehicles includes the number of trucks simulated as part of the “driving links” + the trucks that are in the additional “off-network link” (trucks that are idling/parked).

<sup>33</sup>The total output includes emissions from exhaust processes only (running, start, and extended idling).

(and/or if different off network inputs were developed), then larger differences between VSP profiles would likely be observed. Another possible reason is that while no operating mode was input for the default drive cycles, the links average speed was provided. This average speed was the same as the one used in the Port Gate 10 trucks per hour scenario.

**Table VI-7. Comparison of Emission Reduction Percentages from Port Control Strategies using MOVES Default Operating Conditions and Port-Specific Operating Mode**

Control Strategy	Pollutant	Emissions Reductions of 3 Control Strategies for 4 Different Scenarios			
		Default Driving Conditions	Port Gate 10 Trucks/Hour	Port Gate 60 Trucks/Hour	In-Port Property
No Control (Baseline)	VOC	<i>Baseline</i>			
	CO				
	NO <sub>x</sub>				
	PM <sub>10</sub>				
	PM <sub>2.5</sub>				
Idling Reduction	VOC	0%	1%	0%	3%
	CO	-60%	-46%	-41%	-50%
	NO <sub>x</sub>	-55%	-58%	-47%	-73%
	PM <sub>10</sub>	-40%	-39%	-28%	-70%
	PM <sub>2.5</sub>	-40%	-39%	-28%	-70%
Retrofit	VOC	-69%	-68%	-69%	-65%
	CO	-56%	-47%	-48%	-46%
	NO <sub>x</sub>	0%	0%	0%	0%
	PM <sub>10</sub>	-53%	-54%	-56%	-52%
	PM <sub>2.5</sub>	-53%	-54%	-56%	-52%
Truck Replacement	VOC	-16%	-19%	-18%	-22%
	CO	-4%	-4%	-5%	-1%
	NO <sub>x</sub>	-2%	-2%	-5%	4%
	PM <sub>10</sub>	-20%	-19%	-17%	-19%
	PM <sub>2.5</sub>	-20%	-19%	-17%	-19%

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## CHAPTER VII. CONCLUSIONS

Now that MOVES2010 has been released, many transportation and air quality researchers are working to take advantage of MOVES's capability and flexibility using available local data, experiments measuring driving patterns, and by linking MOVES with models that simulate vehicle behavior. This project uses the capabilities of traffic microsimulation models to develop VSP profiles for some of the situations that project-level analyses are likely to be interested in using MOVES to evaluate. Profiles are available from this study for freeway on-ramps, freeway-to-freeway interchanges, freeway incidents, and signalized arterials as an alternative to using standard MOVES defaults. Expected users of these VSP profiles would be analysts who are interested in improving upon the standard MOVES defaults, but who do not have the means to use microsimulation models to develop such profiles themselves. The research work provides practitioners who are interested in using microsimulation output as input to MOVES with some case study examples of potential processes and associated challenges.

The study demonstrated that microsimulation can provide inputs in a form that can be used by the new generation of emissions models, in this case, the MOVES model. The linkage was made by producing operating mode distributions for network links with different geometric and operating characteristics from the detailed vehicle activity produced by microsimulation models. The study limited the number of links used in each geometric/operating scenario. However, the links were concentrated in and around bottleneck locations, which should be the focus of more intensive scrutiny because these are the locations where vehicle activity is the most variable due to traffic flow turbulence and queuing.

Under very severe congestion levels, the link limitation probably did not capture the full extent of queuing – it most likely extended past the most upstream of the test links. To compensate for this, analysts can make an off-line determination of expected queue length and then assign the extra links the same operating mode distribution as links with queuing from the scenario tests.

Microsimulation models produce a file that has a speed and acceleration estimate for every vehicle in the network. This provides too many values for most modelers needs. In this study, since both speed and acceleration are available in the microsimulation output for every vehicle for every second of simulation, MOVES operating mode distributions based on VSP were computed instead. According to EPA's recent draft PM hot spot guidance, this is thought to be a much more accurate way of capturing driving cycle patterns where literally thousands of vehicles have their trajectories traced, as in simulations.

In modeling external truck trips to ports, the VMT distribution by roadway functional classification is important to pinpoint, because it provides an indication of the speed that trucks drive traveling to and from these ports. Emission rates vary by speed.

Using information from an example port, a number of emission control strategies that could be used to reduce emissions at ports were analyzed. The strategies evaluated included

idling reduction, diesel retrofits, truck replacements, and freight diversion to rail. From these analyses it was found that:

1. The idling reduction strategy provides significant CO, NO<sub>x</sub>, and PM emission reductions.
2. MOVES passes through whatever the estimates of emission reductions are for a retrofit control technology and the penetration rate of that technology into the fleet.
3. The estimated emission reductions for a truck replacement strategy were not as pronounced as for the other strategies, in part due to the short driving distances used in the evaluations.
4. Emission differences between using default drive cycles and VSP profiles for the example emission control strategy analyses were small. This appears to be the result of extended idling emissions being a large portion of total port emissions and these off network sources are not affected by VSP profiles.

Similarly, this report also describes another set of MOVES files that can be used to model the unique conditions that occur at intermodal facilities and ports, capturing important activities such as idling, for the specific types of vehicles (trucks) used at these types of facilities.

Because MOVES2010 has been released less than one year, it is expected that considerable effort will be undertaken to develop MOVES inputs that take full advantage of MOVES abilities to estimate emissions by driving mode. Therefore, analysts that use the profiles provided as one of the products of this project should be aware of new opportunities to improve the information that they are using in project-level analysis.

Prior studies of port terminal attracted travel have focused mainly on truck origins and destinations. There is little or no information in the literature that provides measurements of trucks speed profiles as they travel to and from ports, or inside the port terminals. However, at least one research study is making such measurements, so transportation practitioners should be aware of, and make use of, the information available from such studies to improve their own emissions modeling work.

For example, there is ongoing research on truck travel nearby and inside port terminals at the Port of Houston. Preliminary information from this Port of Houston study contains speed and brake-horsepower by sequence profiles from portable emission measurement systems installed on trucks that traverse the Houston freeways that provide truck access to the Port of Houston. These profiles – or similar ones developed for other areas – can be matched with the VSP profiles provided in this study to determine the appropriate VSP profile for use in MOVES.

The Port of Houston profiles for inside-the-gate port activity are particularly useful for modeling truck behavior given the lack of information on such activity in the literature. The inside-the-port portable emission measurement systems measurements indicate that 69 percent of the time that trucks are at the port, they are idling. Preliminary information from

this study was presented at the September 2010 EPA Emission Inventory Conference and can be found at [www.epa.gov/ttn/chief](http://www.epa.gov/ttn/chief).

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## APPENDIX A: MOVES OPERATING MODES (opModeID)

opModeID	opModeName
0	Braking
1	Idling
11	Low Speed Coasting; VSP< 0; 1<=Speed<25
12	Cruise/Acceleration; 0<=VSP< 3; 1<= Speed<25
13	Cruise/Acceleration; 3<=VSP< 6; 1<=Speed<25
14	Cruise/Acceleration; 6<=VSP< 9; 1<=Speed<25
15	Cruise/Acceleration; 9<=VSP<12; 1<=Speed<25
16	Cruise/Acceleration; 12<=VSP; 1<=Speed<25
21	Moderate Speed Coasting; VSP< 0; 25<=Speed<50
22	Cruise/Acceleration; 0<=VSP< 3; 25<=Speed<50
23	Cruise/Acceleration; 3<=VSP< 6; 25<=Speed<50
24	Cruise/Acceleration; 6<=VSP< 9; 25<=Speed<50
25	Cruise/Acceleration; 9<=VSP<12; 25<=Speed<50
26	Cruise/Acceleration; 12<=VSP; 25<=Speed<50
33	Cruise/Acceleration; VSP< 6; 50<=Speed
35	Cruise/Acceleration; 6<=VSP<12; 50<=Speed
36	Cruise/Acceleration; 12 <= VSP; 50<=Speed
100	Starting (Used for all starts)
200	Extended Idling
300	All Running
101	Soak Time < 6 minutes
102	6 minutes <= Soak Time < 30 minutes
103	30 minutes <= Soak Time < 60 minutes
104	60 minutes <= Soak Time < 90 minutes
105	90 minutes <= Soak Time < 120 minutes
106	120 minutes <= Soak Time < 360 minutes
107	360 minutes <= Soak Time < 720 minutes
108	720 minutes <= Soak Time
27	Cruise/Acceleration; 12<=VSP<18; 25<=Speed<50
28	Cruise/Acceleration; 18<=VSP<24; 25<=Speed<50
29	Cruise/Acceleration; 24<=VSP<30; 25<=Speed<50
30	Cruise/Acceleration; 30<=VSP; 25<=Speed<50
37	Cruise/Acceleration; 12<=VSP<18; 50<=Speed
38	Cruise/Acceleration; 18<=VSP<24; 50<=Speed
39	Cruise/Acceleration; 24<=VSP<30; 50<=Speed
40	Cruise/Acceleration; 30<=VSP; 50<=Speed
150	Hot Soaking
151	Cold Soaking
500	Existing
401	tirewear;speed < 2.5mph
402	tirewear;2.5mph <= speed < 7.5mph
403	tirewear;7.5mph <= speed < 12.5mph
404	tirewear;12.5mph <= speed < 17.5mph
405	tirewear;17.5mph <= speed <22.5mph
406	tirewear;22.5mph <= speed < 27.5mph
407	tirewear;27.5mph <= speed < 32.5mph
408	tirewear;32.5mph <= speed < 37.5mph
409	tirewear;37.5mph <= speed < 42.5mph

opModeID	opModeName
410	tirewear;42.5mph <= speed < 47.5mph
411	tirewear;47.5mph <= speed < 52.5mph
412	tirewear;52.5mph <= speed < 57.5mph
413	tirewear;57.5mph <= speed < 62.5mph
414	tirewear;62.5mph <= speed < 67.5mph
415	tirewear;67.5mph <= speed < 72.5mph
416	tirewear;72.5mph <= speed
301	running;speed < 2.5mph
302	running;2.5mph <= speed < 7.5mph
303	running;7.5mph <= speed < 12.5mph
304	running;12.5mph <= speed < 17.5mph
305	running;17.5mph <= speed < 22.5mph
306	running;22.5mph <= speed < 27.5mph
307	running;27.5mph <= speed < 32.5mph
308	running;32.5mph <= speed < 37.5mph
309	running;37.5mph <= speed < 42.5mph
310	running;42.5mph <= speed < 47.5mph
311	running;47.5mph <= speed < 52.5mph
312	running;52.5mph <= speed < 57.5mph
313	running;57.5mph <= speed < 62.5mph
314	running;62.5mph <= speed < 67.5mph
315	running;67.5mph <= speed < 72.5mph
316	running;72.5mph <= speed
400	Tire wear; idling
501	Brake wear; stopped

## APPENDIX B: RETROFIT INPUT FILE - CRT3 PARTICULATE FILTER

Pollutant	Process	Fuel	Source	Initial Calendar Year	Final Calendar Year	Initial Model Year	Final Model Year	Fraction Year	Fraction Effective
Total Gaseous Hydrocarbons	Running Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	93%
Carbon Monoxide (CO)	Running Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	72%
Oxides of Nitrogen	Running Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	0%
Primary PM10 - Organic Carbon	Running Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM10 - Elemental Carbon	Running Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM10 - Sulfate Particulate	Running Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM2.5 - Organic Carbon	Running Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM2.5 - Elemental Carbon	Running Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM2.5 - Sulfate Particulate	Running Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Total Gaseous Hydrocarbons	Start Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	0%
Carbon Monoxide (CO)	Start Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	0%
Oxides of Nitrogen	Start Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	0%
Primary PM10 - Organic Carbon	Start Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM10 - Elemental Carbon	Start Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM10 - Sulfate Particulate	Start Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM2.5 - Organic Carbon	Start Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM2.5 - Elemental Carbon	Start Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM2.5 - Sulfate Particulate	Start Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Total Gaseous Hydrocarbons	Extended Idle Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	93%
Carbon Monoxide (CO)	Extended Idle Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	72%
Oxides of Nitrogen	Extended Idle Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	0%
Primary PM10 - Organic Carbon	Extended Idle Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM10 - Elemental Carbon	Extended Idle Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM10 - Sulfate Particulate	Extended Idle Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM2.5 - Organic Carbon	Extended Idle Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM2.5 - Elemental Carbon	Extended Idle Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%
Primary PM2.5 - Sulfate Particulate	Extended Idle Exhaust	Diesel Fuel	Combination Short-Haul Truck	2008	2008	1994	2006	100%	90%