Utilizing Traffic Simulation Tools with MOVES and AERMOD

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Overview

- Quantify the emissions and fuel consumption associated with traffic congestion from Commercial Motor Vehicle (CMV) crashes
- Project Description
- Traffic Simulation
- Emissions Analysis
- Future Use with Dispersion Analysis

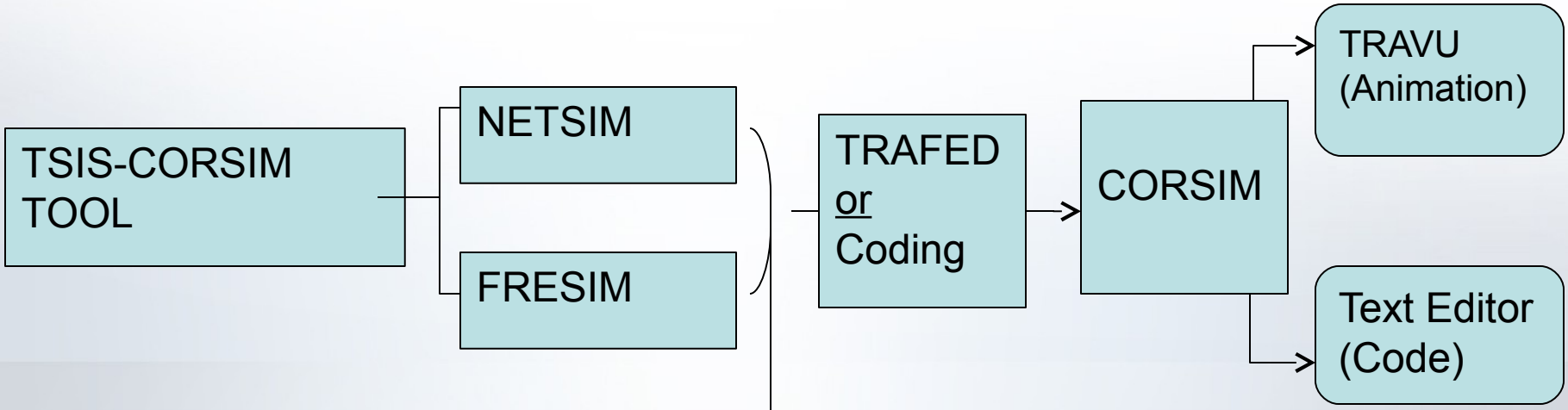
Field CMV Crash Delay Data

- All States contacted for crash data – Kentucky and Pennsylvania contributed statewide CMV crash closure duration and location data

Attribute	Kentucky	Pennsylvania
Location	Road mile marker	Latitude/longitude
Duration	Discreet value of lane closure	7 range values for incident (e.g. 0-30 min.)
Severity	Fatal, Injury, Property Damage Only (PDO)	Fatal, Injury, PDO
Truck type	No data	Yes
Urban/rural distinction	As defined by Kentucky State Highway Patrol	As defined by PennDOT
Vehicle configuration	4 truck types, 2 bus types	7 truck types, 2 bus types
Other relevant data	Hazmat presence, other involved vehicles	# injuries/fatalities, Hazmat presence

CMV Crash Delay TSIS-CORSIM Tool

- **TSIS** (Traffic Software Integrated System) **CORSIM** (CORridor-microscopic SIMulation program) version **6.2** (Feb. 2010)
  - **Components**
    - NETSIM for urban streets (or rural non-freeway)
    - FREESIM for freeways
  - **Investigation Sequence**
    - Simulation Design → Translation → Processing → Outputs

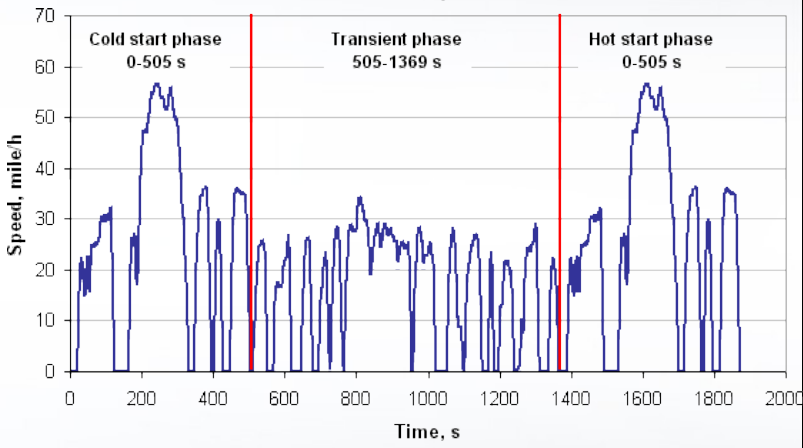


Problem: Emissions Traffic Modeling Did Not Directly Align with Emissions Modeling

- Emissions estimations relied on simplistic vehicle performance (MOBILE)
  - Constant velocities
  - Non-validated idling times
  - Limited set of pre-defined drive cycles

- What happened with emissions values?
  - Non-alignment with traffic simulations
  - Low fuel burn estimates (paradoxical results)
  - Low nitrous oxides (NOx) estimates

Vehicle Drive Cycle Example



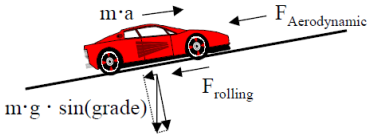
From: http://www.daham.org/basil/leedswww/emissions/drivecycles.htm

Solution: Traffic Simulation Animation Files to Provide Vehicle Specific Power

Inquiries to subject matter experts revealed possible solution

1. Obtain animation file vehicle time-step data from traffic simulation
2. Translate vehicle performance (in binary code) to database via Volpe Center developed parser tool. Actual performance factors:
   - Vehicle aerodynamic drag
   - Road surface friction
   - Inertia forces
3. Utilize vehicle specific power equation to calculate more accurate engine performance
4. Run US EPA MOVES model on project level to obtain associated emissions estimates

Vehicle Specific Power (VSP)



$$VSP = \frac{\text{Power}}{\text{Mass}} = \frac{\frac{d}{dt}(E_{Kinetic} + E_{Potential}) + F_{Rolling} \cdot v + F_{Aerodynamic} \cdot v + F_{int\ ernal\ friction} \cdot v}{m} =$$

$$\approx v \cdot a \cdot (1 + \varepsilon_i) + g \cdot grade \cdot v + g \cdot C_R \cdot v + \frac{1}{2} \rho_a C_D \frac{A}{m} (v + v_w)^2 \cdot v + C_{if} \cdot v$$

Previous Work:

• Specific Power	$= 2 \cdot v \cdot a$	(EPA, 1993)
• Positive Kinetic Energy	$= \Sigma\ pos(SP_i) / \Sigma$ distance	(Watson et al., 1983)
• DPWRSUM	$= \Sigma\ \lvert SP_i - SP_{i-1} \rvert$	(Webster and Shih, 1996)

From: Jimenez, J et .al. "Vehicle Specific Power: A Useful Parameter for Remote Sensing and Emission Studies" 1999

Traffic Simulations Overview

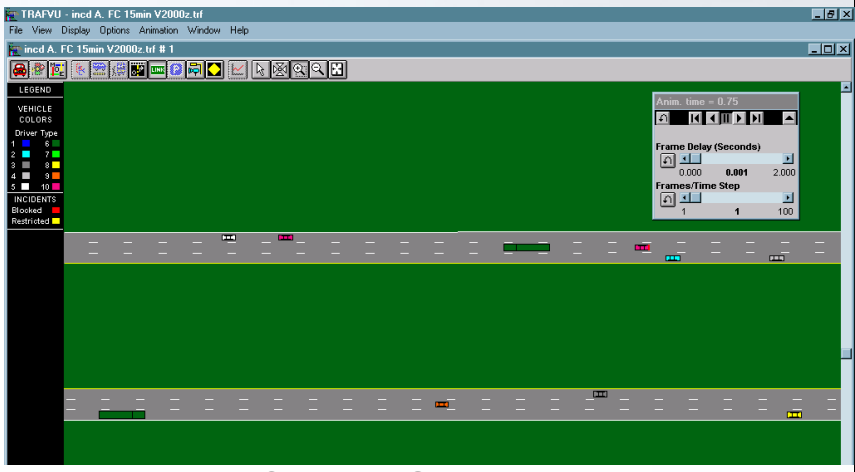
- **Traffic Simulation runs (TSIS CORSIM tool – version 6.2)**
  - Baseline cases (without crashes) Monte Carlo 10 runs each
  - Crash scenarios, Monte Carlo 40 runs each
    - Full closures (15 minutes; 1½ hour; 4 hr) *diversions for longer 2 runs*
    - Partial closures (same durations as full closure)
  - Network configurations
    - Expressway, urban & rural (without surface network)
    - Arterial, urban only (with connected expressway)
    - Other, urban & rural local/collector/minor arterial (with connected expressways)

Traffic Simulation Details

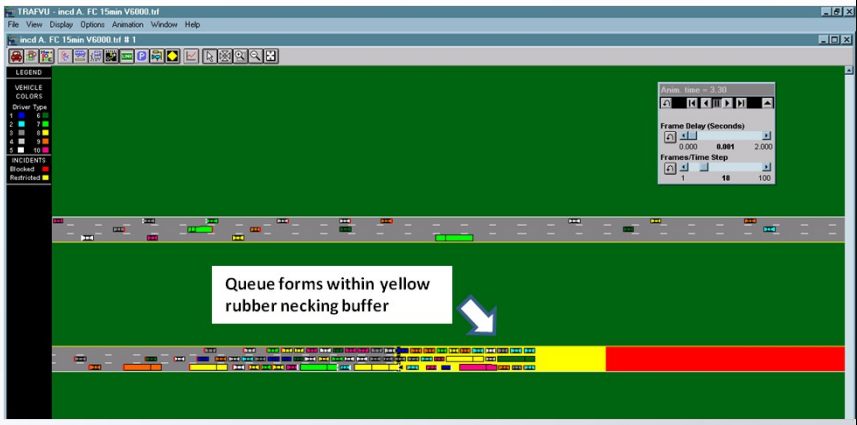
- **Baseline Scenario Runs**
  - Facilities 5 representational categories
  - Volumes (50-6,000 vehicles per hour)
  - Lane Number range (2-6 bi-directional) HPMS data
  - Fleet Composition
  - Speeds Freeflow (HPMS data)

- **Crash Scenario Runs**
  - Baseline Facility, Volume, Freeflow, Volumes, Fleets, and Speeds
  - Land closure durations (Kentucky and Pennsylvania

Baseline Scenario

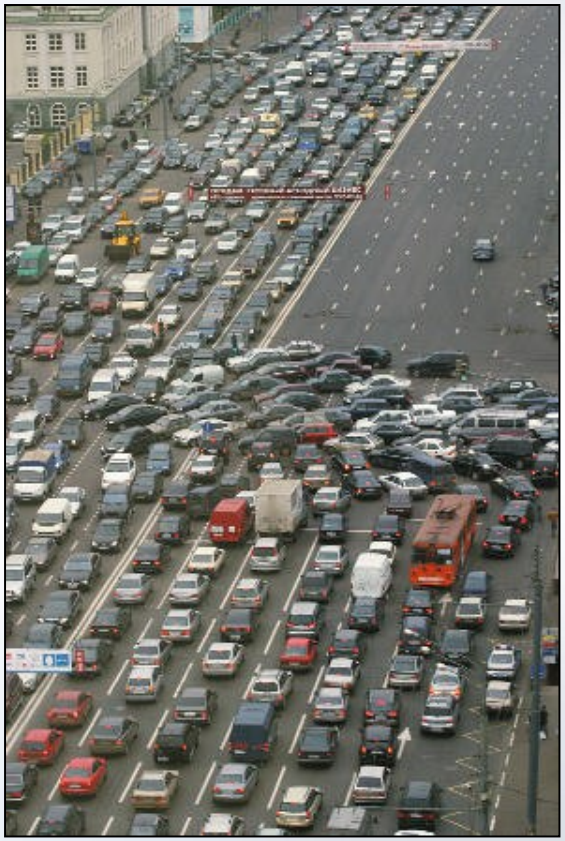


Crash Scenario



Traffic Simulation Details

- **Scenario Observed Requirements**
  - Roadway length sufficient to contain traffic queues
  - Extended duration road and lane closures
    - Freeway utilizes TSIS-CORSIM incident feature
    - Non-freeway necessitated alternative introduced measures (e.g. dummy traffic controls, etc.)
  - Deterministic vehicle/driver performance for diverted traffic
- **Traffic Simulations Output**
  - Delay distributions (median value selected) baseline delay subtracted

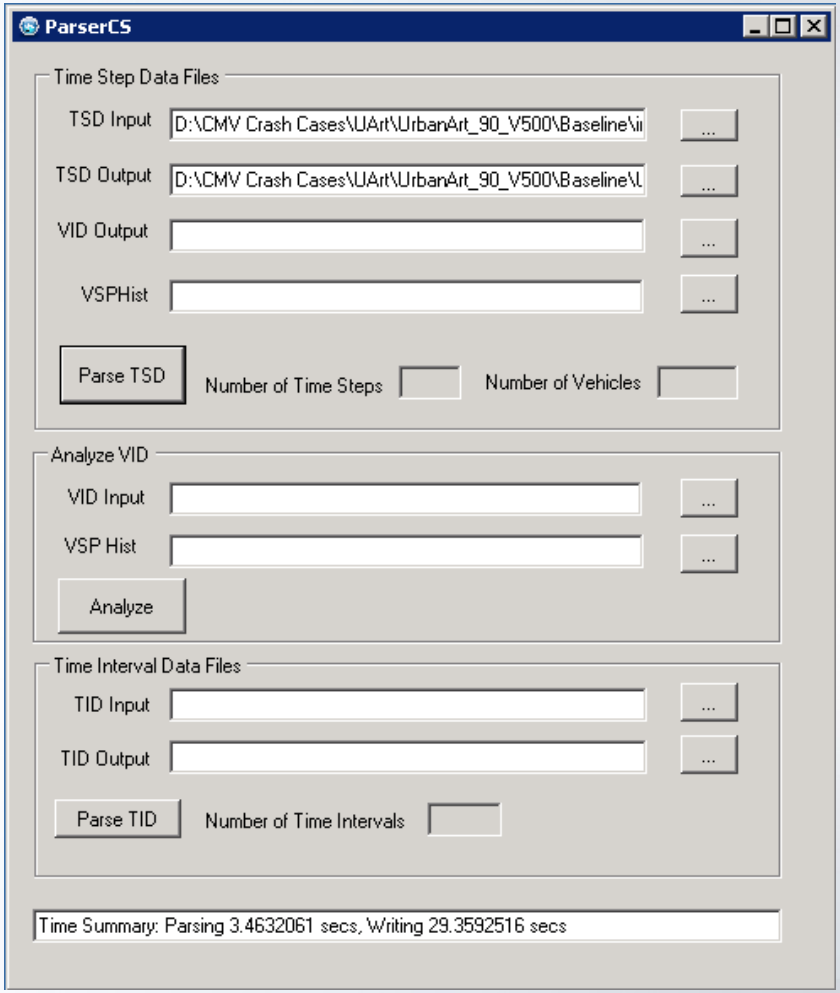


Emissions Analysis

- **Emissions Analysis Methodology**
  - Parsing of TSIS-CORSIM Binary Files
    - Utilize Parser Application developed by Volpe
    - Parser reads second by second CORSIM animation file data and calculates VSP
    - VSP is calculated for each Link and separated by vehicle type
  - Motor Vehicle Emission Simulator (MOVES) 2010a
    - Parser Application creates an output table that utilizes MOVES Operating Mode Distribution feature
    - Operating Mode Distribution determines drive cycle across each link for each vehicle type by hour
  - Emissions Analysis
    - Incident minus Baseline to estimate the emissions impacts

Parsing of TSIS-CORSIM Binary Files

- **TSIS-CORSIM Binary Files**
  - Utilized for the TRAFVU component for visualizing the simulation
  - Contains information for each vehicle at a 1 second resolution
  - Contains aggregated information for each time interval assigned by the user
- **Parsing Application Developed to Translate Binary Output**
  - Time Step Data Files (TSD) - Individual Vehicle data



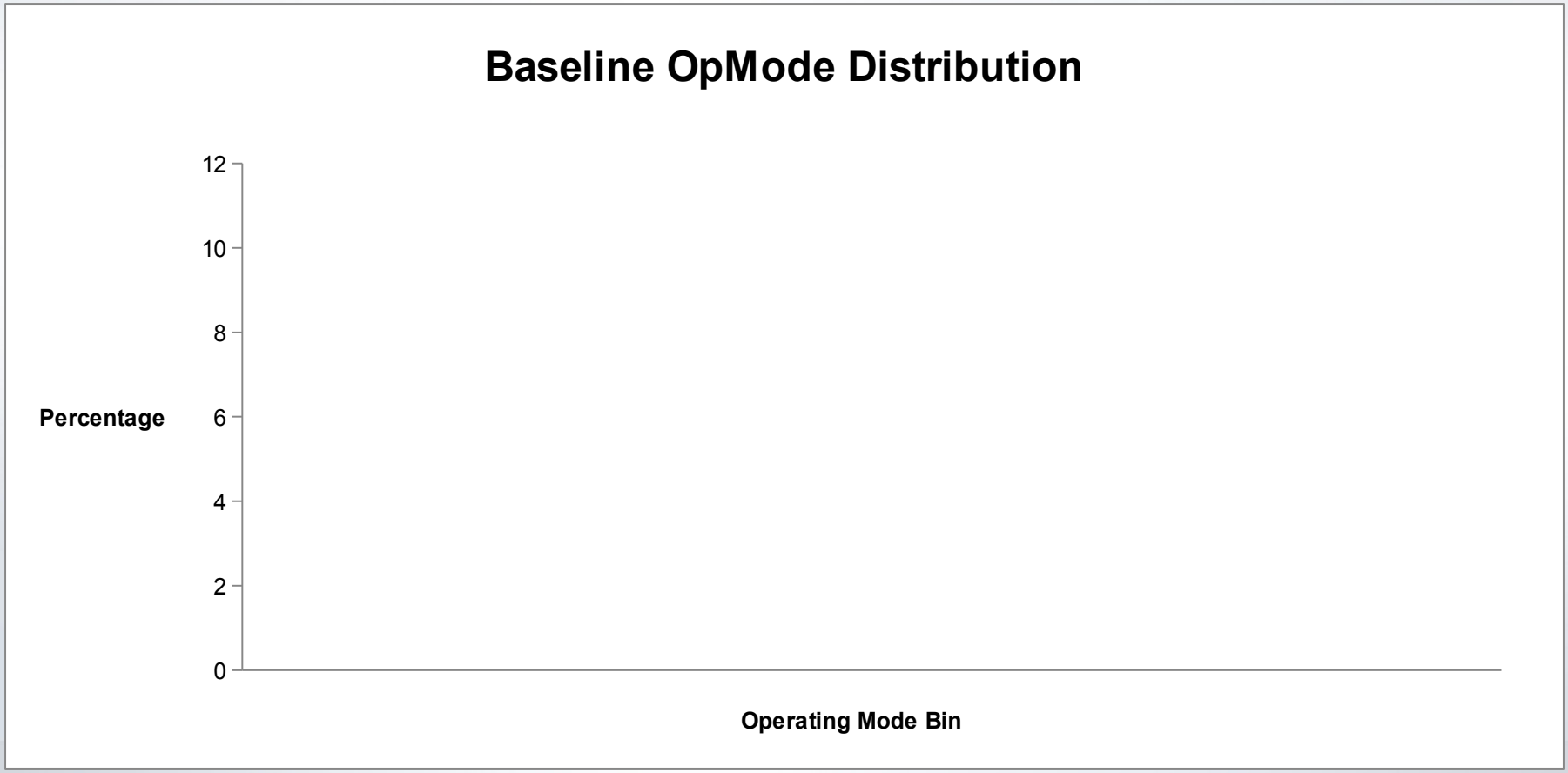
CORSIM to MOVES Mapping

CORSIM	MOVES						
Vehcile_Type	sourcetypeID	rollingTermA	rotatingTermB	dragTermC	sourceMass	fixedMassFactor	sourceTypeName
1	21	0.156461	0.00200193	0.000492646	1.4788	1.4788	Passenger Car
2	21	0.156461	0.00200193	0.000492646	1.4788	1.4788	Passenger Car
3	52	0.561933	0	0.00160302	7.64159	17.1	Single Unit Short-haul Truck
4	52	0.561933	0	0.00160302	7.64159	17.1	Single Unit Short-haul Truck
5	52	0.561933	0	0.00160302	7.64159	17.1	Single Unit Short-haul Truck
6	62	2.08126	0	0.00418844	31.4038	17.1	Combination Long-haul Truck
8	21	0.156461	0.00200193	0.000492646	1.4788	1.4788	Passenger Car
9	21	0.156461	0.00200193	0.000492646	1.4788	1.4788	Passenger Car

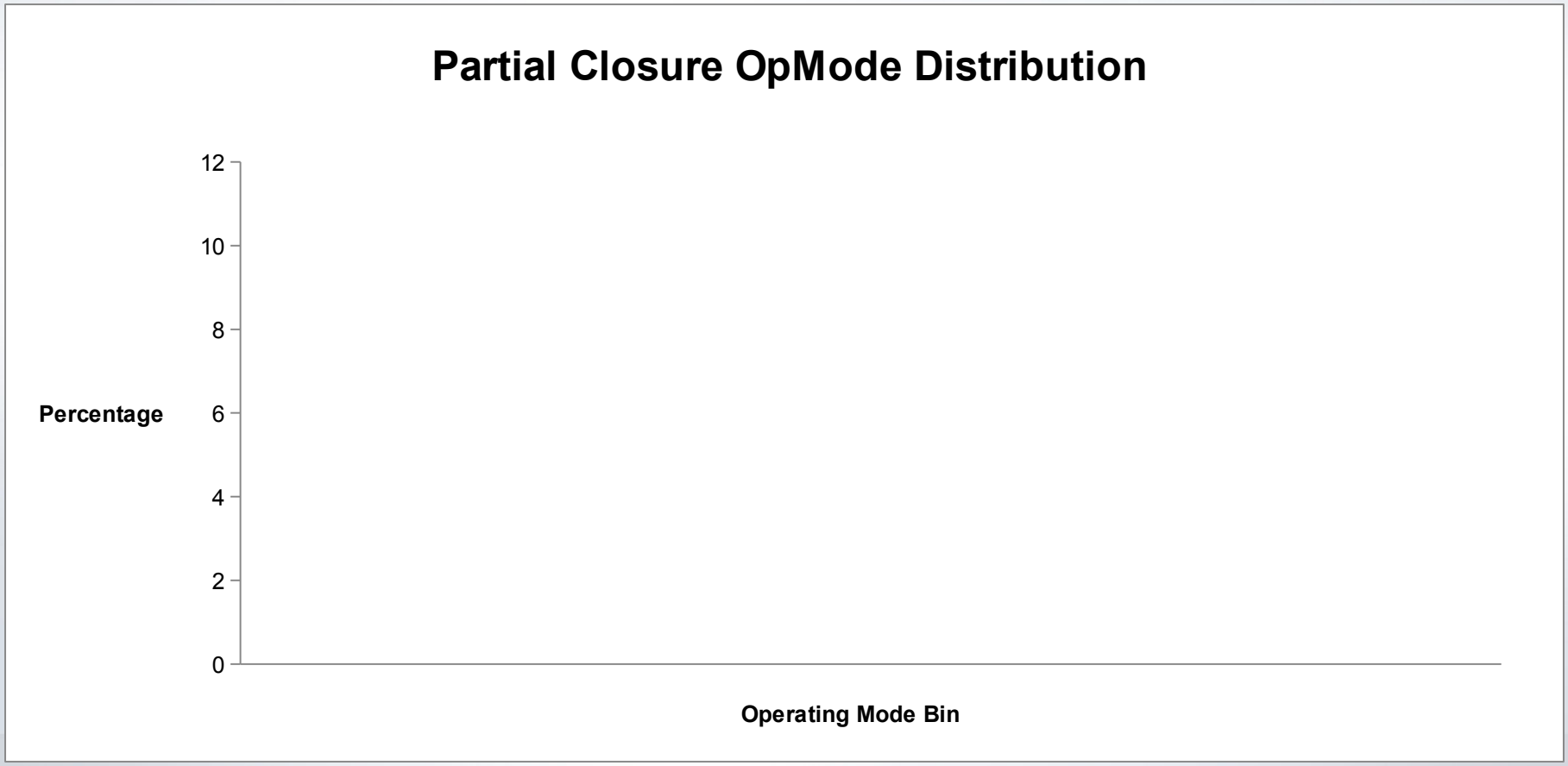
VSP Parameters

Link	SourceType	OpMode	Desc	Count
810082	21	0	Braking	0.00
810082	21	1	Idling	0.00
810082	21	11	Low Speed Coasting; VSP< 0;1<=Speed<25	0.00
810082	21	12	Cruise/Acceleration; 0<=VSP< 3; 1<=Speed<25	0.00
810082	21	13	Cruise/Acceleration; 3<=VSP< 6; 1<=Speed<25	0.00
810082	21	14	Cruise/Acceleration; 6<=VSP< 9; 1<=Speed<25	0.00
810082	21	15	Cruise/Acceleration; 9<=VSP<12; 1<=Speed<25	0.00
810082	21	16	Cruise/Acceleration; 12<=VSP;1<=Speed<25	0.00
810082	21	21	Moderate Speed Coasting; VSP< 0; 25<=Speed<50	0.00
810082	21	22	Cruise/Acceleration; 0<=VSP< 3; 25<=Speed<50	0.00
810082	21	23	Cruise/Acceleration; 3<=VSP< 6; 25<=Speed<50	0.00
810082	21	24	Cruise/Acceleration; 6<=VSP< 9; 25<=Speed<50	0.00
810082	21	25	Cruise/Acceleration; 9<=VSP<12; 25<=Speed<50	0.00
810082	21	27	Cruise/Acceleration; 12<=VSP; 25<=Speed<50	0.00
810082	21	28	Cruise/Acceleration; 18<=VSP<24; 25<=Speed<50	0.00
810082	21	29	Cruise/Acceleration; 24<=VSP<30; 25<=Speed<50	0.00
810082	21	30	Cruise/Acceleration; 30<=VSP; 25<=Speed<50	0.00
810082	21	33	Cruise/Acceleration; VSP< 6; 50<=Speed	0.04
810082	21	35	Cruise/Acceleration; 6<=VSP<12; 50<=Speed	0.49
810082	21	37	Cruise/Acceleration; 12<=VSP<18; 50<=Speed	0.43
810082	21	38	Cruise/Acceleration; 18<=VSP<24; 50<=Speed	0.03
810082	21	39	Cruise/Acceleration; 24<=VSP<30; 50<=Speed	0.01
810082	21	40	Cruise/Acceleration; 30<=VSP; 50<=Speed	0.00

Operating Mode Distribution – Free Flow



Operating Mode Distribution – Congestion



Emissions Results

Urban Interstate

Duration = 90 min Partial and Full Closure

Closure	Volume	CO2 (grams)	CO (grams)	NOx (grams)	Energy (MMBtu)	PM10 (grams)	PM25 (grams)	SO2 (grams)	HC (grams)	VOC (grams)
Partial	1000	43296	1452	-19	0	8	7	2	29	27
Full	1000	2555818	15339	4877	30	305	293	46	1691	1657
Partial	2000	6631950	49575	17125	83	911	876	114	3163	3090
Full	2000	18126560	121890	38918	225	2360	2270	320	11087	10846
Partial	3000	21131530	150437	54987	265	2862	2753	361	10016	9790
Full	3000	38901130	266171	84789	488	5175	4973	689	23796	23272

Dispersion Considerations

- **Nomenclature problem**
  - Traffic links
  - Emission links
  - Dispersion links

- **Emission allocation into AERMOD is not as straight forward as the MOBILE to CAL3QHCR input**

Dispersion Considerations (cont)

- **Specific Emission Problems**
  - When area sources are used, there is not a direct connect with MOVES and AERMOD (units of mass/time-area vs. mass/time)
  - Determination of traffic link output to emission link input/output and dispersion link input requires considerable pre-planning by analyst (e.g., idle contribution at an intersection; where, how much, vehicle mode)

Dispersion Considerations (cont)

- **Dispersion Specific Issues**
  - Best way to approximate the line source using either volume or area sources
  - Methodologies for input of initial plume parameters into AERMOD needs to be improved
  - Chemistry (e.g., NO2/NOX ratio, HAPS)
  - Consistent input between among users to meet the needs of reviewers
  - Inconsistencies at near field receptor locations
  - Need for verification

Acknowledgments

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