



Integrating Traffic Operation with Emission Impact using Dual-loop Data

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Outline

- Introduction
- Study Methodology
- Analysis of Results
- Conclusions

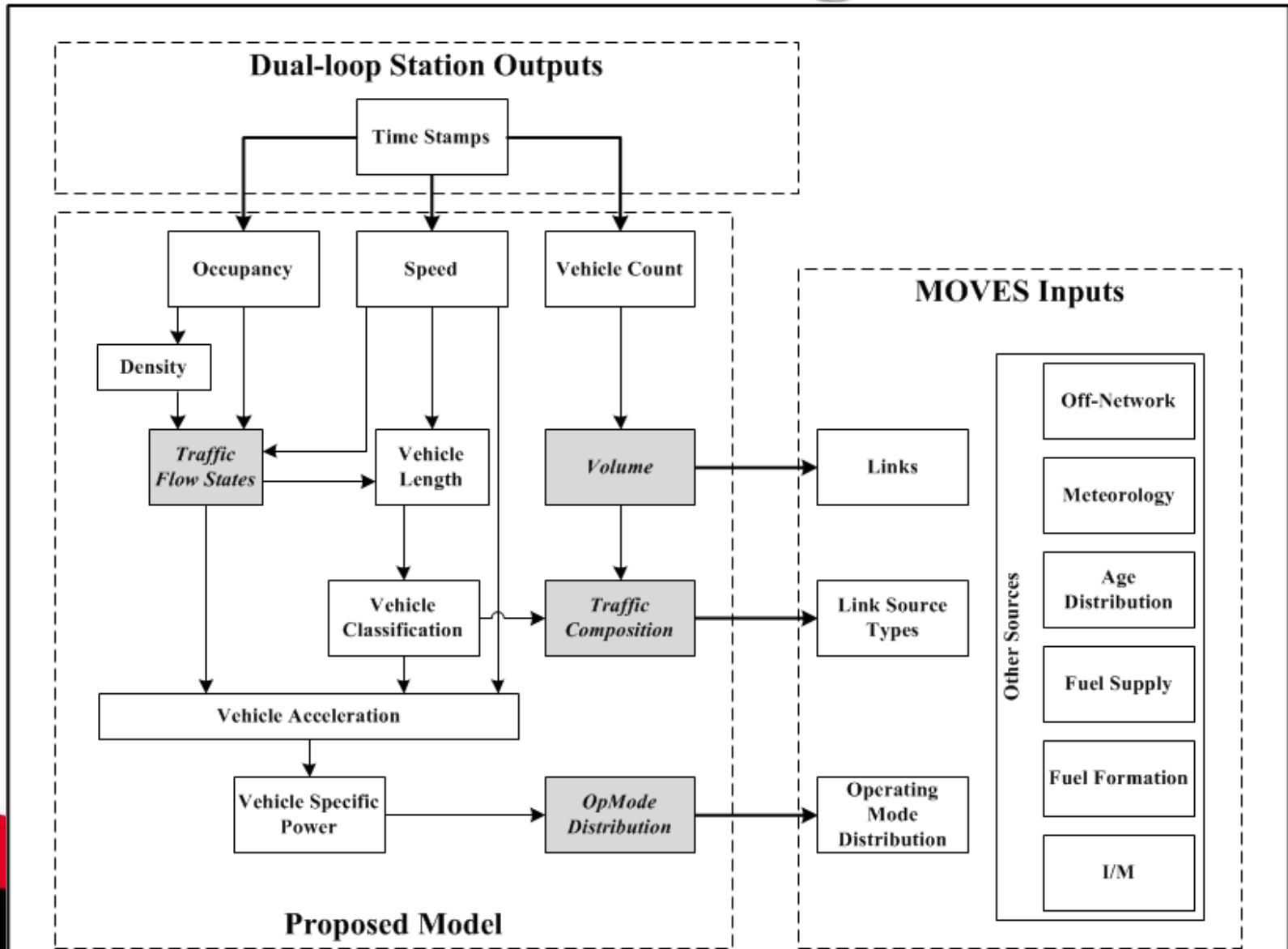
Introduction

- Dual-loop data: describe operating characteristics of traffic flow at spots.
- MOVES (Motor Vehicle Emission Simulator) needs traffic inputs:
 - Operating mode (OpMode) distribution;
 - Traffic volume;
 - Traffic composition.
- Challenges:
 - Vehicle classification : inaccurate when congested;
 - Volume and vehicle composition: not accurately estimated when congested;
 - No method available for OpMode distribution from dual-loop data.

Study Methodology

- Extracting traffic inputs to MOVES from dual-loop data ;
- Integrating operation situation and mobile source emission impact analysis.
- Data:
 - Dual-loop data: from I-71 section in Columbus, 7/14 -7/16, 2009;
 - Video data: model validation;
 - Video data: collected at the same location during the same time period.

Schematic Diagram



Three Data Processing Algorithms

Dual-loop Data Screening Algorithm

- Eliminating erroneous data from raw dual-loop data.

Traffic Flow States Identification Algorithm

- Identifying free flow, synchronized flow and traffic jam from dual-loop data.

MOVES Inputs Calculation Algorithm

- Calculating traffic volume, vehicle composition and operating mode distribution from dual-loop data.

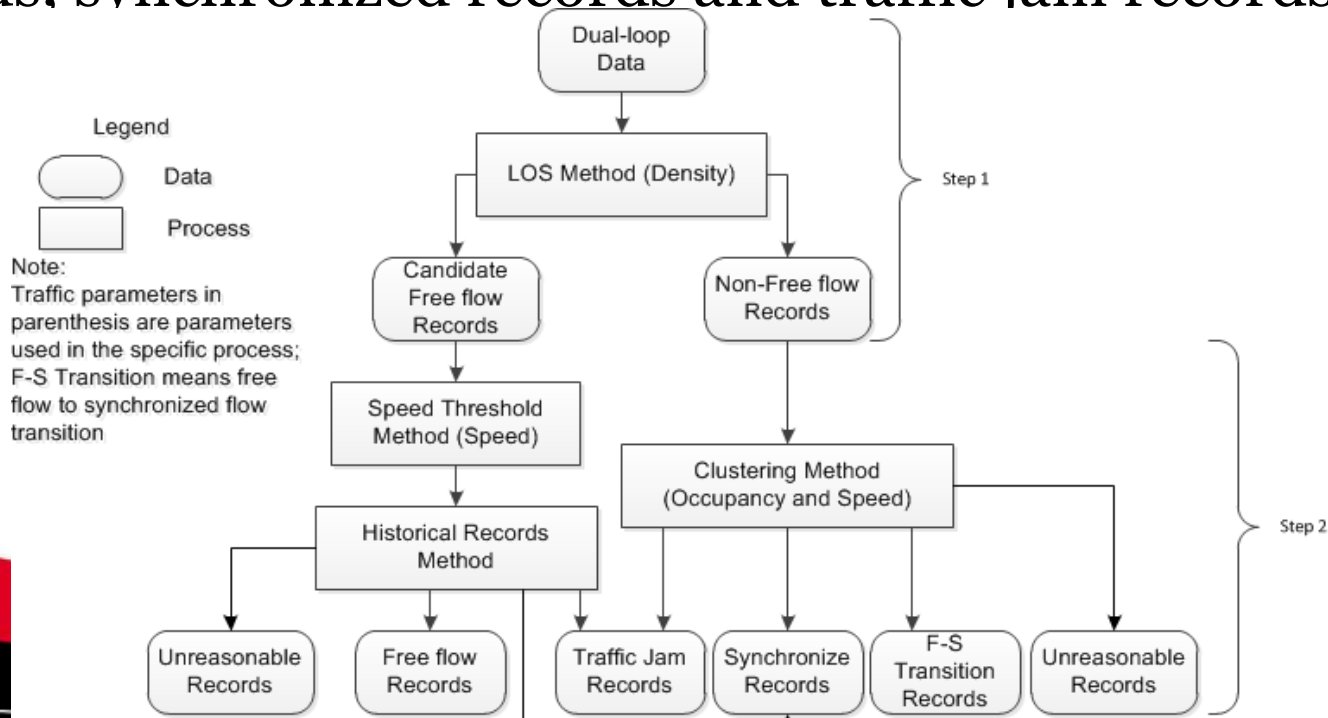
Traffic flow states identification algorithm:

- Why traffic flow state is needed:
 - Indicator of traffic operation situations;
 - Basis for vehicle classification and vehicle composition.
- Speed, occupancy and density:
 - Flow state identification parameters.

Traffic flow states identification algorithm

A hybrid algorithm.

- LOS: preliminarily determine free flow and non-free flow records;
- Speed threshold and historical records methods: determine real free flow records;
- Clustering method: categorize free-synchronized transition records, synchronized records and traffic jam records.



MOVES inputs calculation algorithm:

- Vehicle length: from vehicle length models for different traffic flow states;
- Vehicle composition: from vehicle length;
- Vehicle acceleration: from vehicle length and on-times from M and S loops;
- Vehicle Specific Power (VSP): from vehicle type, speed and acceleration;
- Operating mode: from individual vehicle's VSP and speed;
- Operating mode distribution: from vehicle fleet's operating mode information. Volume is extracted as well.

MOVES inputs calculation algorithm: Acceleration Calculation

- Aggregation method to improve precision;
- Based on the idea that under same traffic flow conditions, acceleration for same type of vehicles is similar;
- 10 vehicles' average speed and on-times are used to calculate acceleration:

$$\text{acceleration} = \frac{\text{Mean}(\text{speed}_S) - \text{Mean}(\text{speed}_M)}{\text{Mean}(\text{time vehicles traveling from } M \text{ to } S)}$$

MOVES inputs calculation algorithm: VSP Calculation

- Following equations are used to estimate VSP:

$$\begin{aligned} VSP(\text{light - duty vehicle}) \\ = v(1.1a + 9.81\text{grade}(\%) + 0.132) + 3.02 \times 10^{-4}(v + v_w)^2v \end{aligned}$$

$$VSP(\text{truck}) = v(a + 9.81\sin(\text{grade}) + 0.092) + 0.00021v^3$$

Where:

v = speed;

a = acceleration;

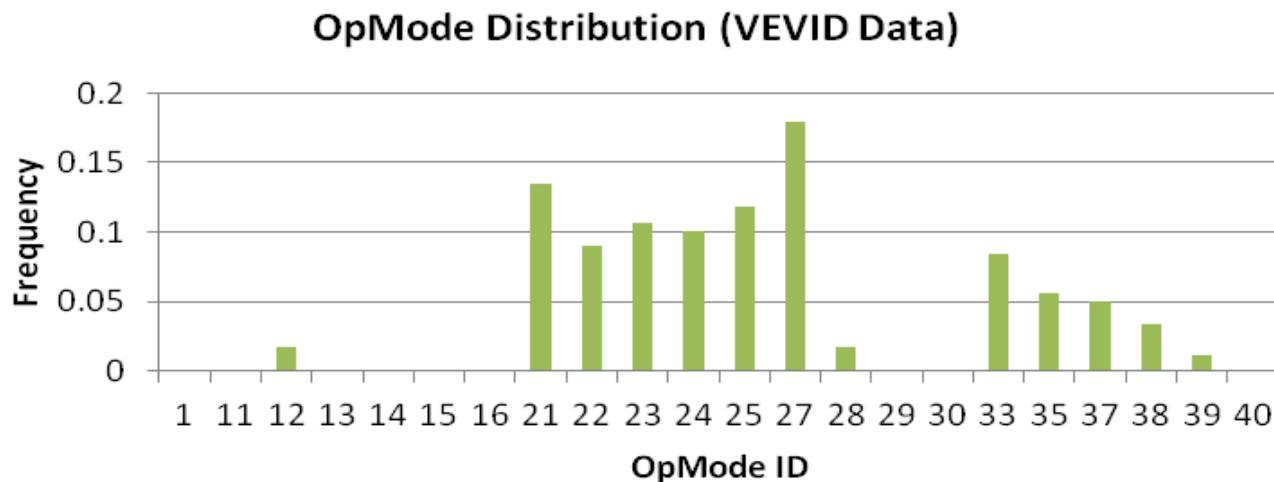
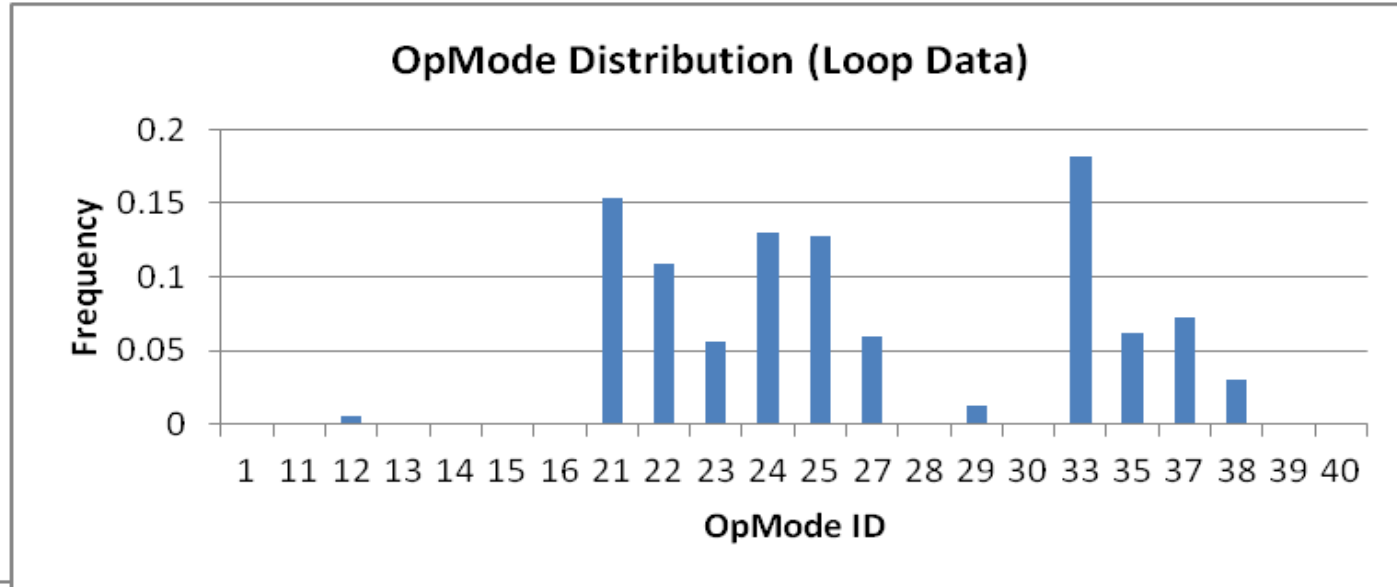
v_w = headwind into the vehicle.

**Operating
Mode
Table
(Recommended
by EPA)**

VSP	Instantaneous Speed		
	0-25 mph	15-50	>50
<0 KW/ton	Bin 11	Bin 21	N/A
0-3	Bin 12	Bin 22	N/A
3-6	Bin 13	Bin 23	N/A
<6	N/A	N/A	Bin 33
6-9	Bin 14	Bin 24	N/A
6-12	N/A	N/A	Bin 35
9-12	Bin 15	Bin 25	N/A
≥12	Bin 16	N/A	N/A
12-18	N/A	Bin 27	Bin 37
18-24	N/A	Bin 28	Bin 38
24-30	N/A	Bin 29	Bin 39
≥30	N/A	Bin 30	Bin 40

Model Validation

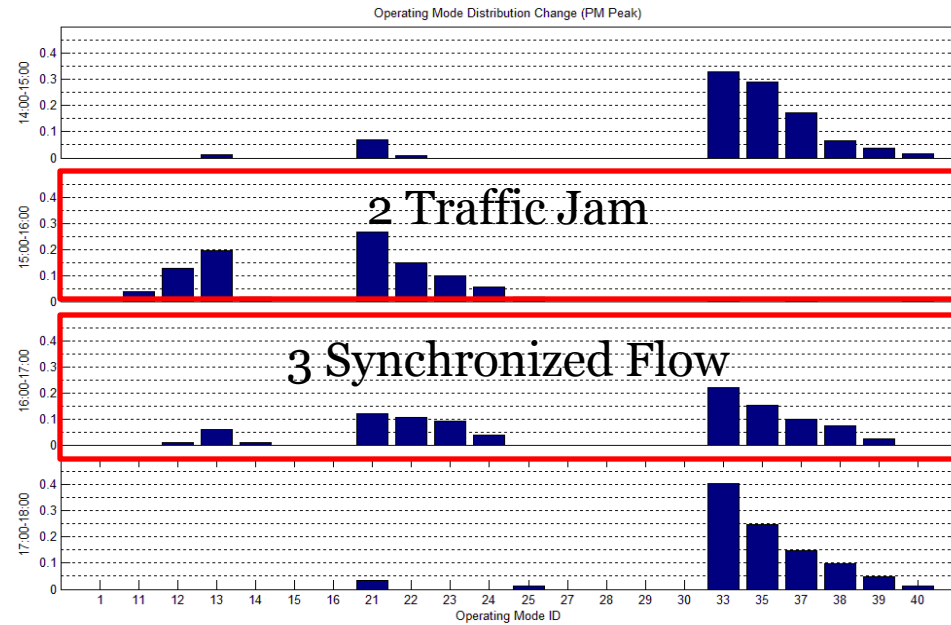
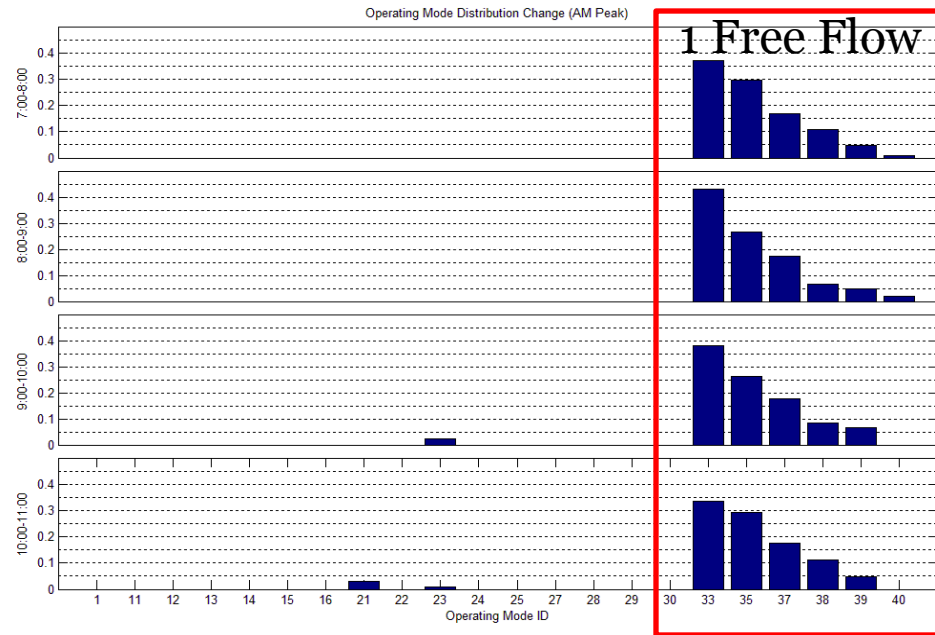
✓ Video ground-truth vehicle trajectory data validates the results of the presented mode.



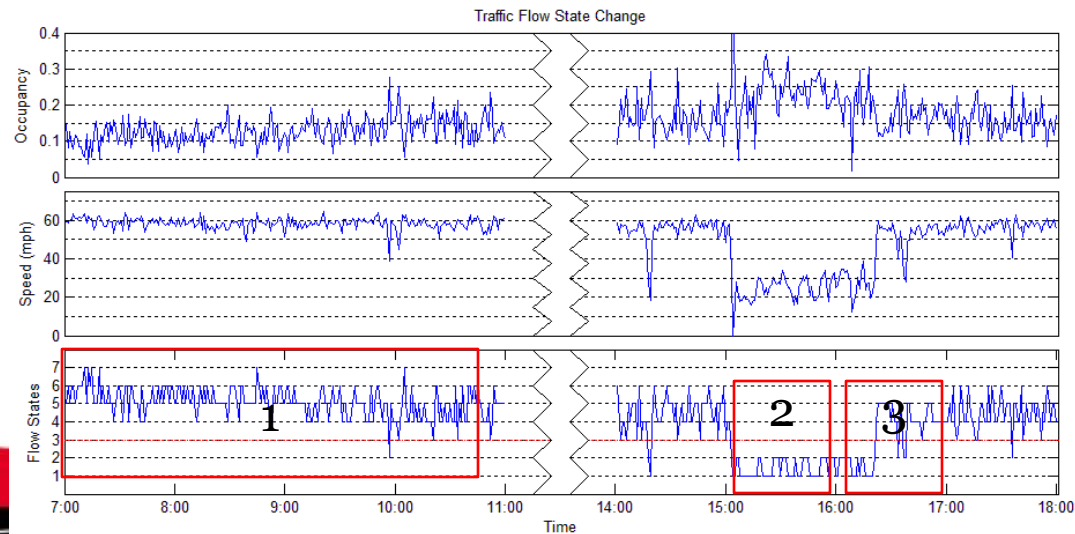
Analysis of Data

- The procedure of using dual-loop data for mobile source emission impact study is performed.
 - Three days' AM (7:00 to 11:00) and PM (14:00 to 18:00) data is used for the purpose.
 - The relationship between operating mode distribution and traffic flow states is examined first.

OpMode Distribution and Traffic Flow States

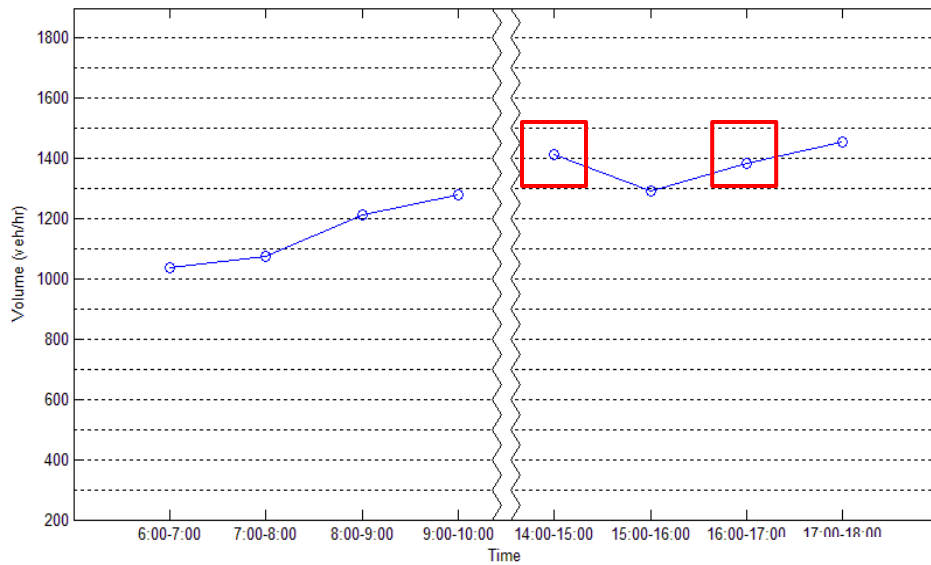


- Strong relationship between OpMode distribution and traffic flow states.

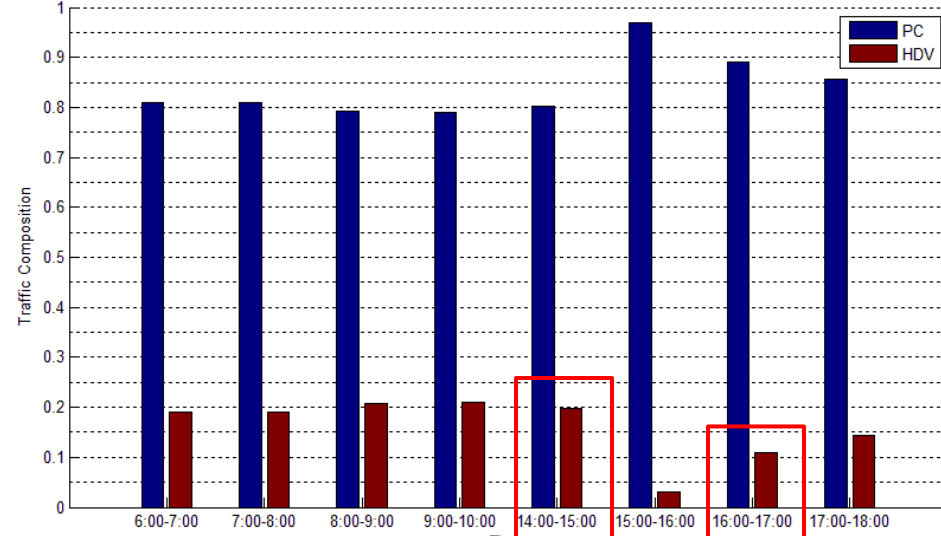


Studying Particulate Matters (PM) with Dual-loop Data

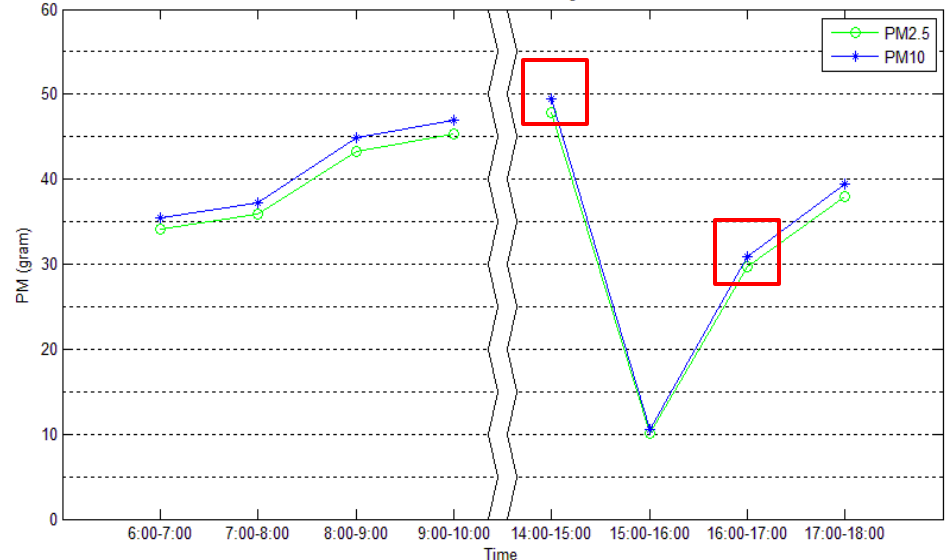
Volume Change



Traffic Composition Change

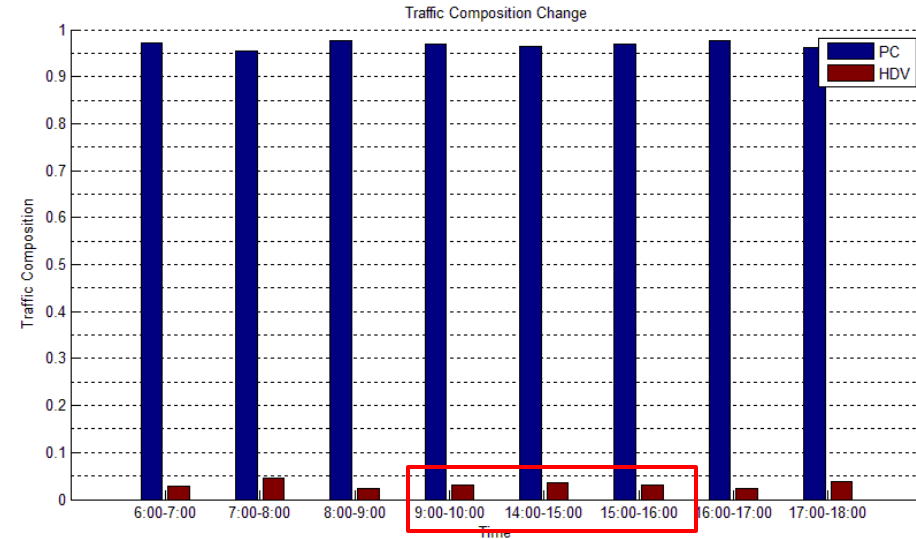
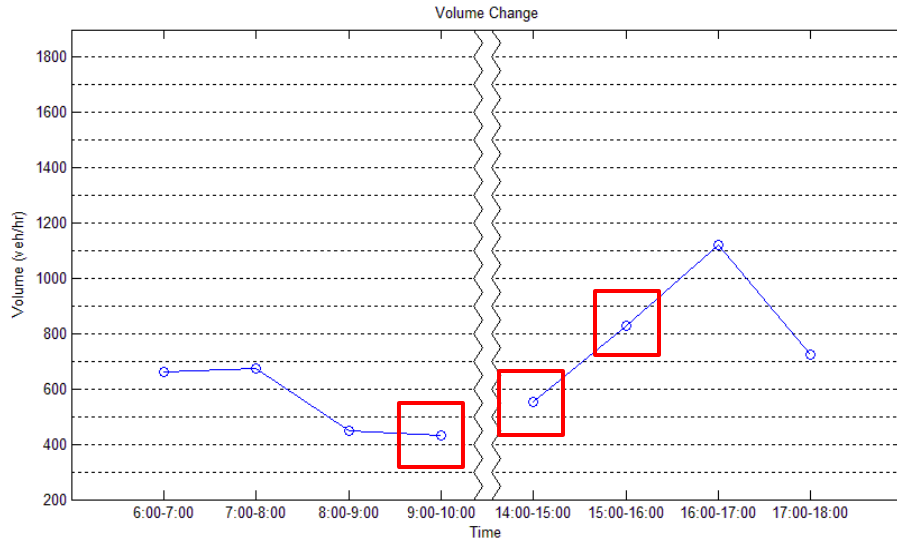


Particulate Matters Change

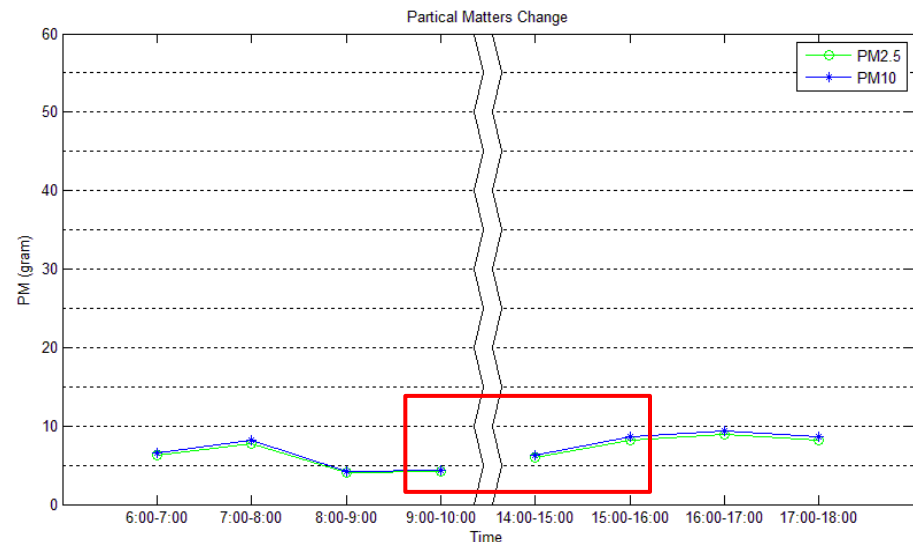


- The magnitude of PM is determined primarily by the number of trucks

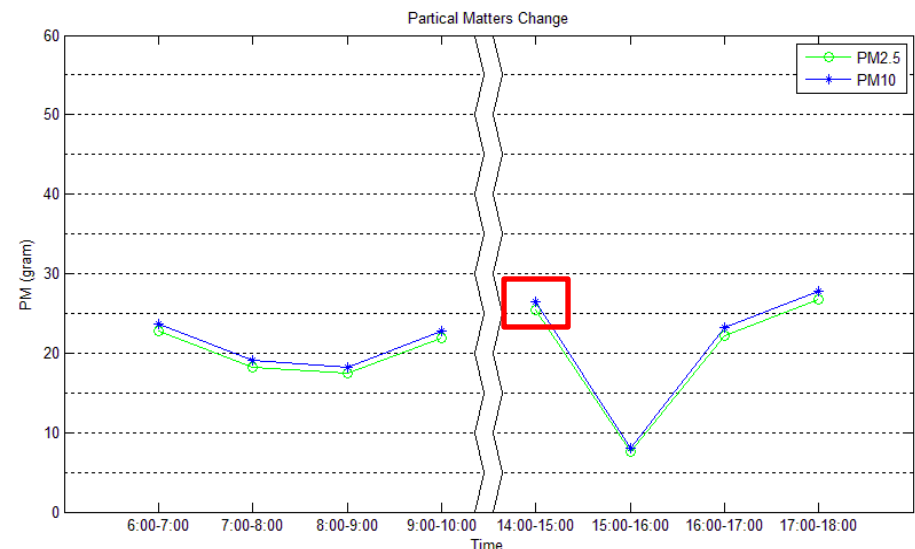
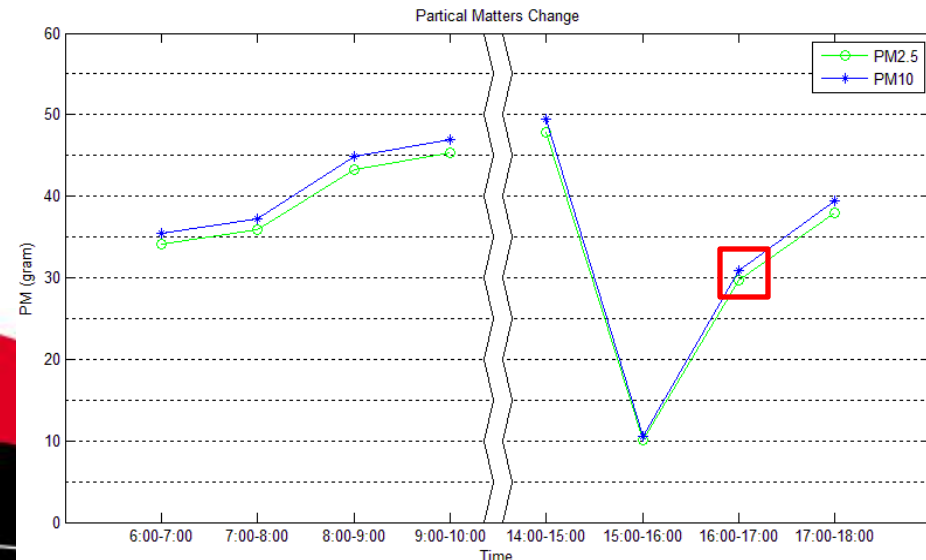
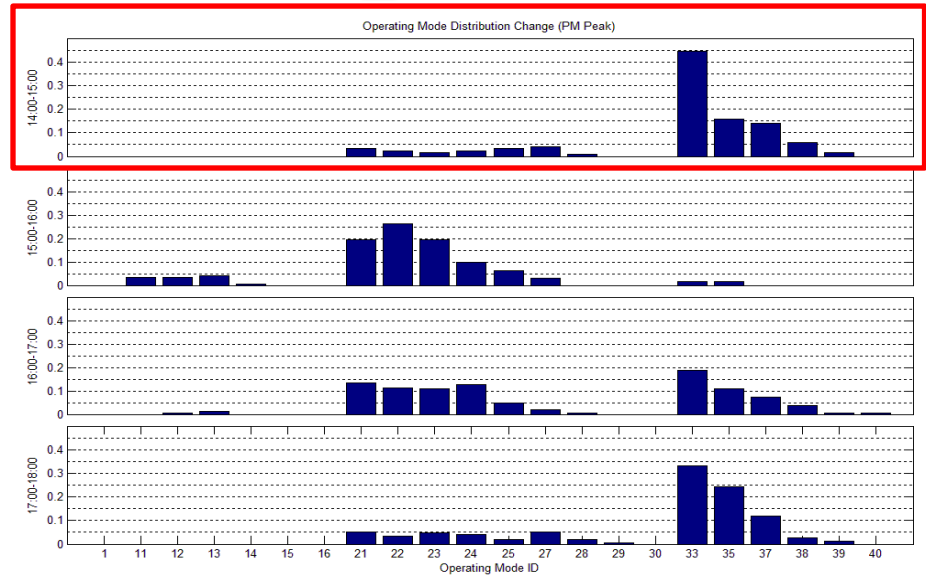
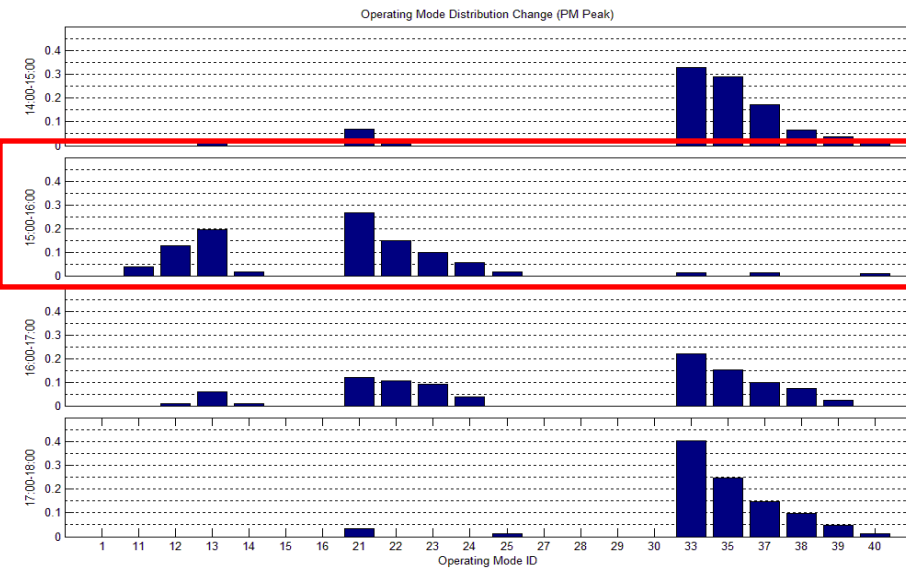
Studying Particulate Matters (PM) with Dual-loop Data



- The traffic volume also has significant impact on PM magnitude



Studying Particulate Matters (PM) with Dual-loop Data



Conclusions

- The impact of traffic flow operation on vehicle emission along a specific roadway section could be associated with three quantified traffic flow variables, i.e., operating mode distribution, volume, and traffic fleet composition.
- In application of MOVES, those three variables are key traffic related inputs to MOVES.
- Those three variables can be quantitatively extracted from dual-loop data source.
- Those three variables vary consistently with changes in traffic flow states (traffic flow state is an indicator of traffic operational situation);
- The results of the study are validated by the ground-truth video trajectory data.
- Larger amount of sample data is needed in the future research.

Acknowledgement

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The results and ideas presented in the presentation represent the authors' point of views only

Questions

