Utilizing MOVES' Link Drive Schedule for Estimating Project-Level Emissions

Robert Chamberlin, PE/PTOE
Ben Swanson
Eric Talbot, EIT
Jeff Dumont
Steve Pesci, Univ. of New Hampshire

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TRB Workshop on Integrating MOVES with Transportation Microsimulation Models

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Overview

- Motivation – Develop an Analytical Approach that Practitioners Can Use
- What is a Project-Level Analysis?
- A Spectrum of Tools -- Microsimulation-Air Emissions Models
- Points of Connection
- The Analysis Testbed – An Intersection Control Change
  - Signalized Intersection – Roundabout – All Way Stop
- Connecting the Microsimulation Model to MOVES
  - Developing a Link Drive Schedule
- Results and Recommendations for Future Research

Motivation

- Why Connect a Traffic Microsimulation Model to MOVES?
- Regulatory requirement: EPA May 2010 guidance for performing "project-level" transportation conformity analysis
  - "Hot Spots" analysis, PM and CO
- Increasing Need from Other Quarters of Society for Tools to Estimate Emissions Impacts of Traffic Operational Changes
  - CMAQ requirement of the emissions benefits of a proposed project
  - City of Portland, OR – CO2 offsets from signal optimization
  - State regulations (e.g. Massachusetts Environmental Policy Act)
  - Sustainability initiatives (e.g. University of New Hampshire)
- **An Approach that Practicing Traffic Engineers Can Use**

What is a "Project Level" Analysis?

- MOVES Project-Level Analysis
  - Projects of Local Air Quality Concern:
    - Within PM10 Non-Attainment or Maintenance Areas
    - Include High % of Diesel Trucks
- Examples:
  - High volume highways (>125,000 AADT) with >8% diesel trucks
  - New highway facilities connecting to a major intermodal terminal
  - Highway expansion affecting an existing congested intersection (LOS D-F) with an increase in diesel trucks
  - A "regionally significant project" defined in 40 CFR 93.101
- What Are Our Options for Performing this Type of Analysis?

A Spectrum of Tools – Microsimulation/Emission Model Pairings

Microsimulation Software	Emissions Software
AIMSUN	Versit+micro
INTEGRATION	VT-Micro
Paramics	CMEM
VISSIM	Versit
VISSIM	PHEM
TRANSIMS	MOVES
CORSIM	VeTESS
Synchro/SimTraffic	TREMOVE
	COPERT (EEA)
	ModEM

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VISSIM	VISSIM	⟷ Versit	Versit
VISSIM	VISSIM	⟷ PHEM	PHEM
TRANSIMS	TRANSIMS	⟷ MOVES	MOVES
CORSIM			VeTESS
Synchro/SimTraffic			TREMOVE
			COPERT (EEA)
			ModEM

- Points of connection:
  - Vehicle characteristics (fleet age mix, power/weight)
  - Environmental characteristics (meteorological)
  - Network characteristics (functional class, grade)
  - Vehicle trajectories (speed/accel profiles)

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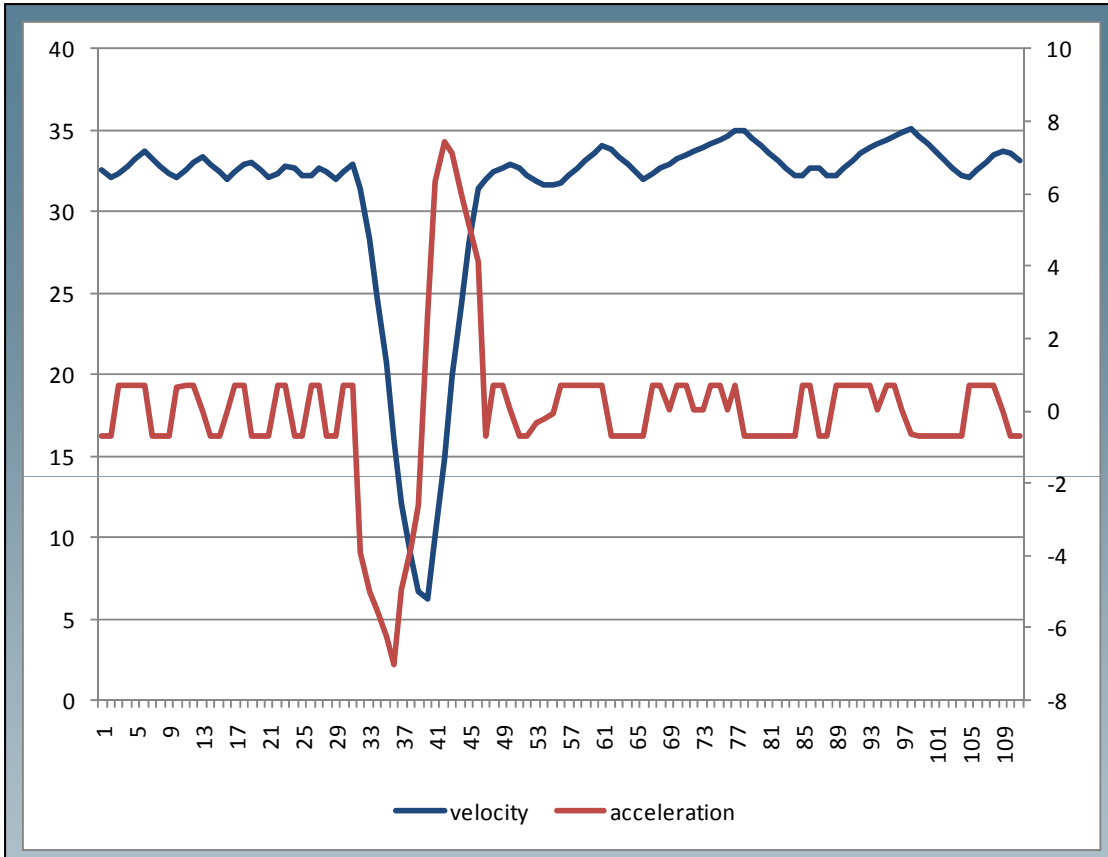
Points of Connection-- Vehicle Trajectory Files

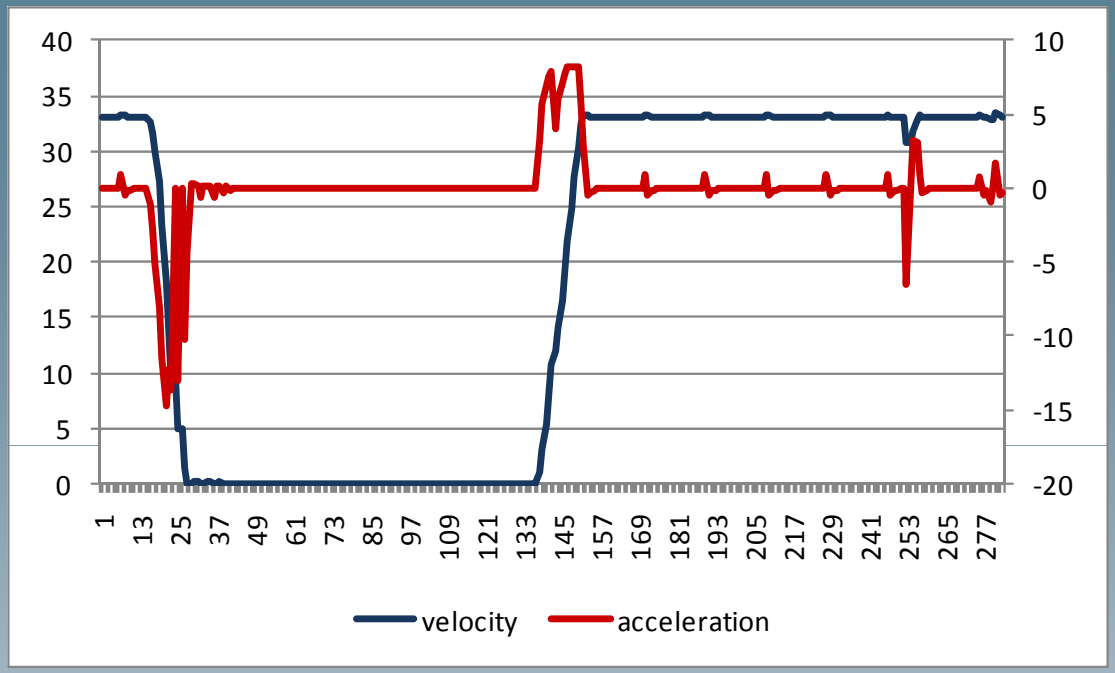


Sample vehicle trajectory from VISSIM

VISSIM
Vehicle Record File
(.fzp)

t	VehNr	DistX	a	v
3600	846	496	-0.58	29.87
3600	841	3020	0.51	31.73
3600	833	3654	-0.72	31.6
3600	829	3734	0.77	32.6
3600	824	3822	0.3	32.48
3600	819	3987	0.77	30.91
3600	832	4500	-0.76	31.68
3600	831	4792	0.53	29.57
3600	827	5354	-0.04	30.46
3600	826	5429	0.7	30.94
3600	825	5517	-0.63	31.41
3600	822	6127	0.89	31.5
3600	818	6195	0.81	31.78
3600	814	6274	0.41	32.21
3600	813	6527	-0.48	32.71
3600	848	359	0.65	28.94

Points of Connection -- Vehicle Trajectory Files



Sample vehicle trajectory from Paramics

Paramics

vehicle-trajectory.csv

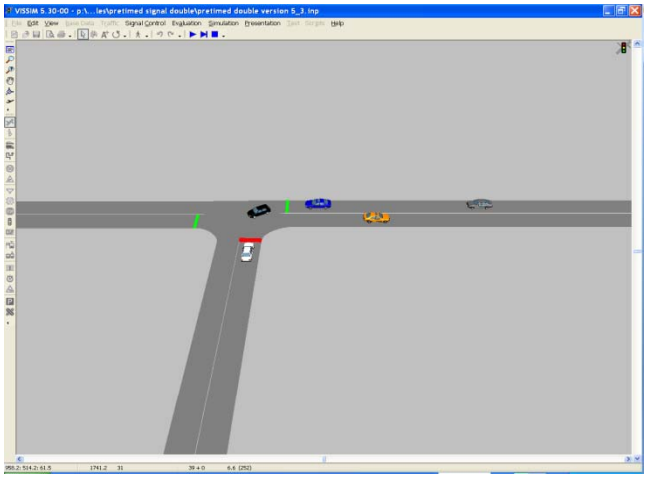
time	ID	x	y	v	a
3600.5	848	-68.27	1634.37	0.52	0.32
3600.5	856	-1286.25	1634.37	34.38	0
3600.5	861	-2306.02	1634.37	33.09	0
3600.5	862	-2435.31	1634.37	33.46	0
3600.5	863	-2615.37	1634.37	33.64	0
3600.5	842	19.68	1646.47	0	0
3600.5	843	40.97	1646.47	0.21	0.18
3600.5	844	71.3	1646.47	2.66	-0.84
3600.5	847	111.63	1646.47	3.64	-0.63
3600.5	849	150.51	1646.47	3.35	-0.59
3600.5	850	195.95	1646.47	10.75	-3.85
3600.5	851	352.91	1646.47	22.15	-5.17
3600.5	853	681.48	1646.47	32.73	-2.15
3600.5	855	1297.49	1646.47	32.91	0
3600.5	858	1843.25	1646.47	31.63	0
3600.5	860	2144.19	1646.47	32.91	0

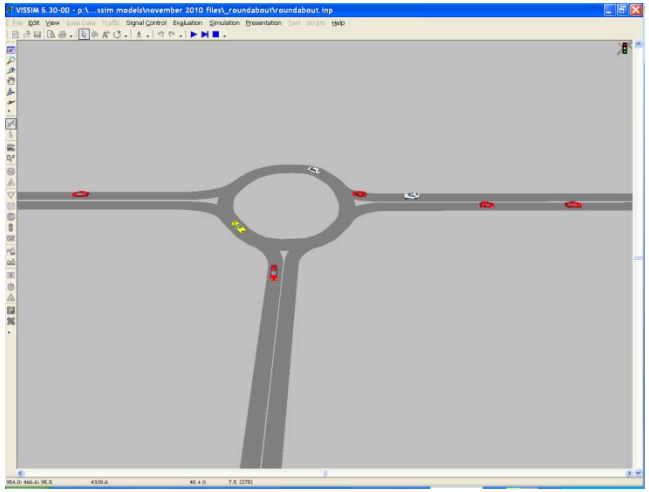
Three Options for Modeling Project-Level Emissions in MOVES

- Average Speed
  - Widespread recognition that the "average speed approach" is insufficient to capture the environmental impacts of vehicle travel.
  - "Two "trips" that have the same average speed can have drastically different emissions results depending on whether the trip was made on free flowing arterials or on a congested freeway." *Barth, et al NCHRP 25-11*
  - "…for the same average speed, one can observe widely different instantaneous speed and acceleration profiles, each resulting in very different fuel consumption and emission levels." *Rakha and Ahn*
- Operating Mode Distributions
- Link Drive Schedules….a "How To"

The Analysis Testbed

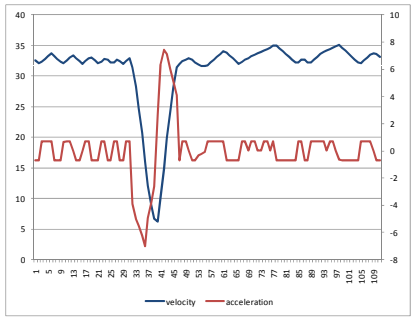
- 3-Leg Intersection Modeled as Pretimed Signal, Roundabout, and All Way Stop
- 0.5 mile approach link, 30 mph
- Two sets of traffic volumes
  - 850 vehicles/hour (LOS B, 11 seconds/vehicle)
  - 1700 vehicles/hour (LOS D, 35 seconds/vehicle)
- One vehicle type – Passenger Car (ID=21)

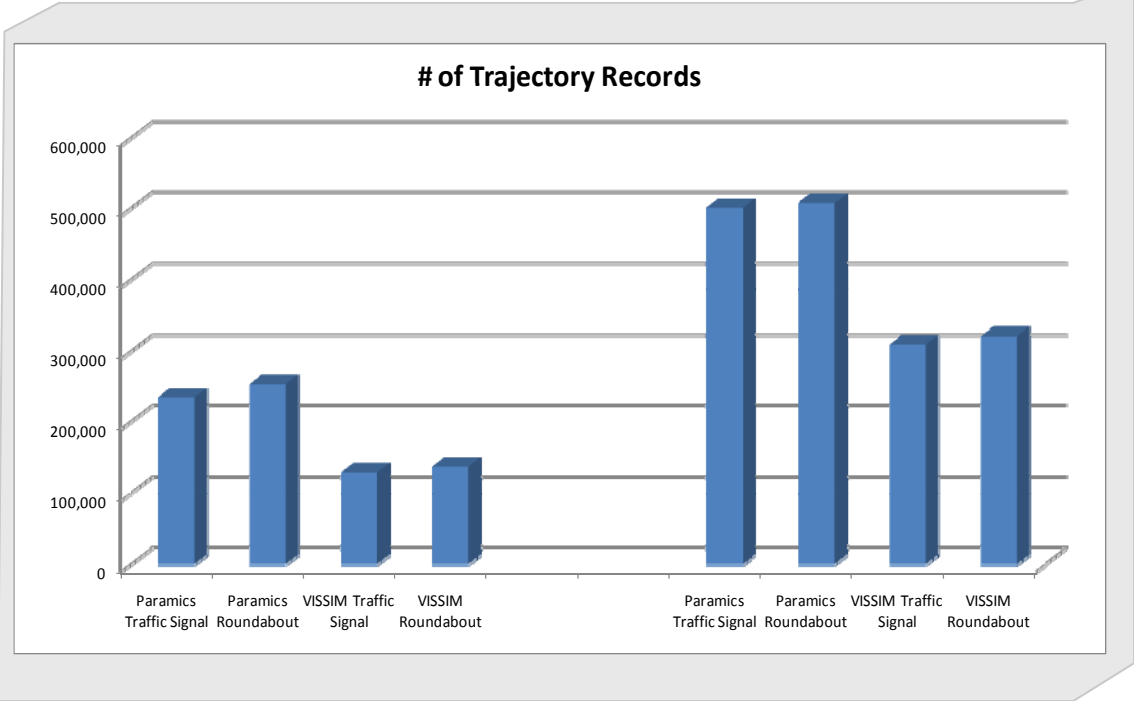




A Practical Matter on Data Production and Run Time

- Low volume runs - 850 vehicles/hour
- High volume runs - 1700 vehicles/hour
- 150-300 records per vehicle
- 120,000 – 500,000 records – either…
  - A VERY long MOVES run, or
  - Too much for the MOVES LDS?





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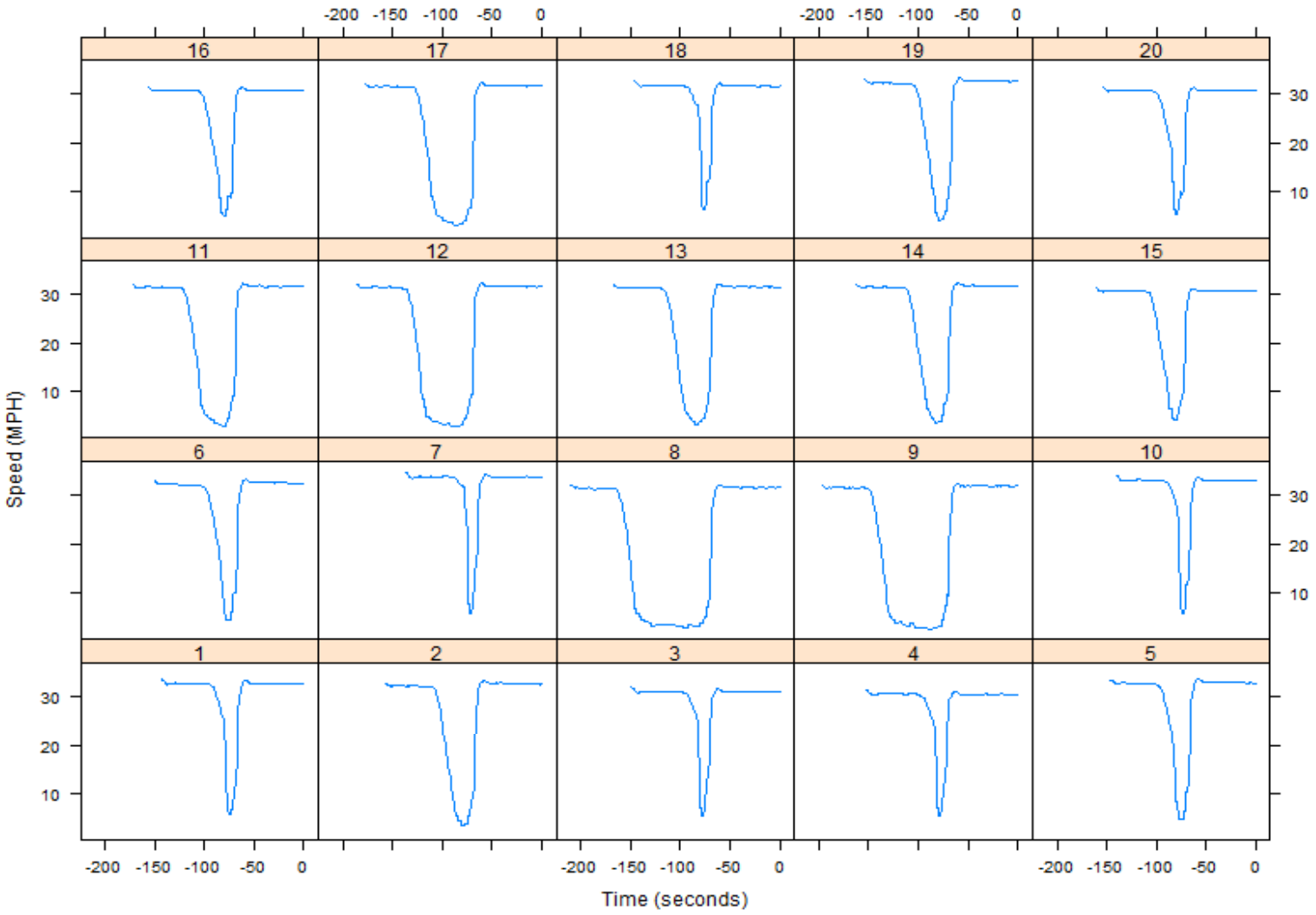
How to Process the Traffic Model Output for Input to MOVES?

- How to manage thousands of records? Two steps:
- Step 1: K-Means Algorithm to Cluster "Like" Trajectories
  - Minimizes the Least Squared Differences Among a Set of X Observations into K clusters…

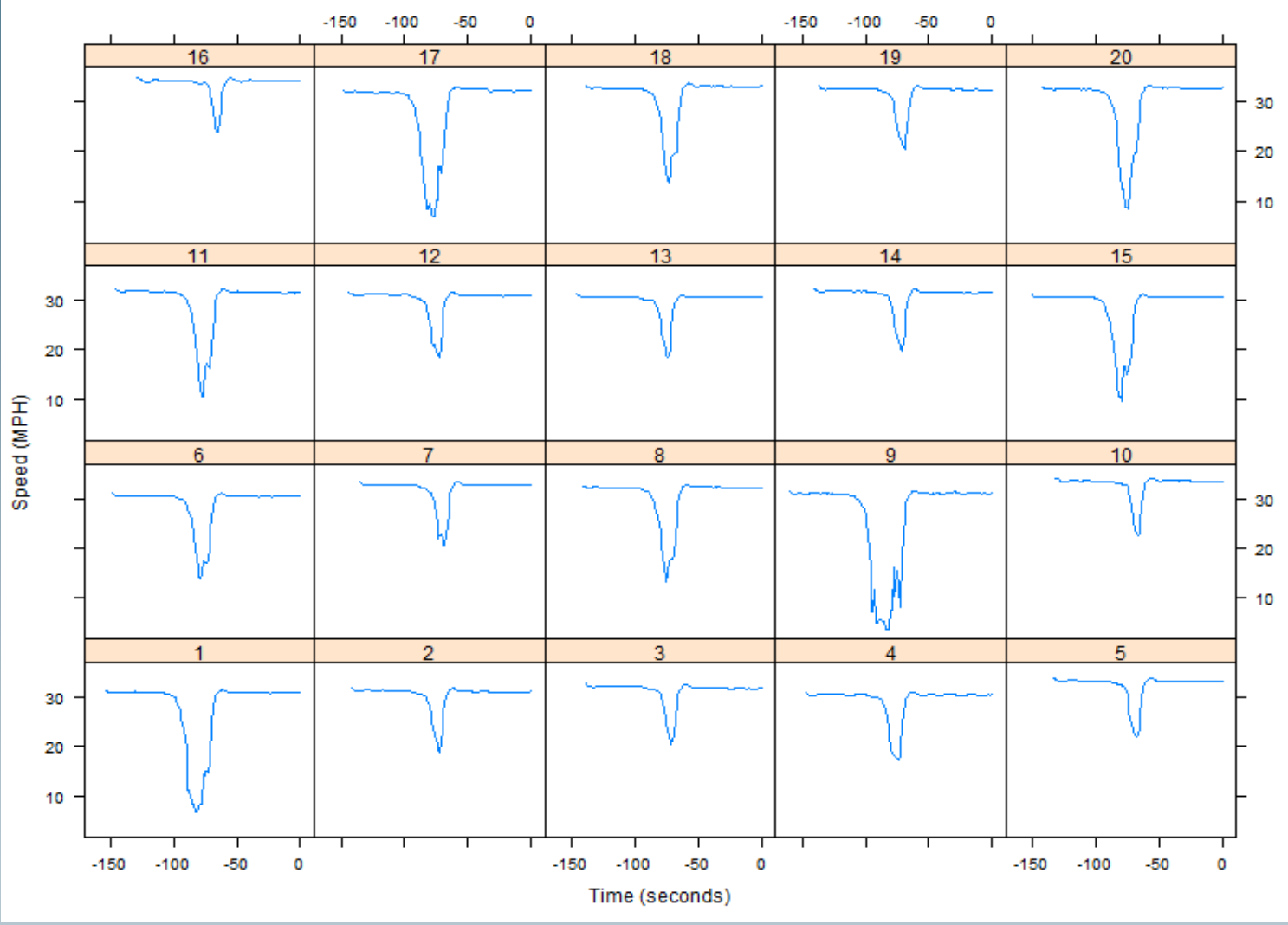
$$\arg\min_{s} \sum_{1=i}^{k} \sum_{x_j \in S_i} \left\| x_j - \mu_i \right\|^2$$

What the K-Means Algorithm Produces



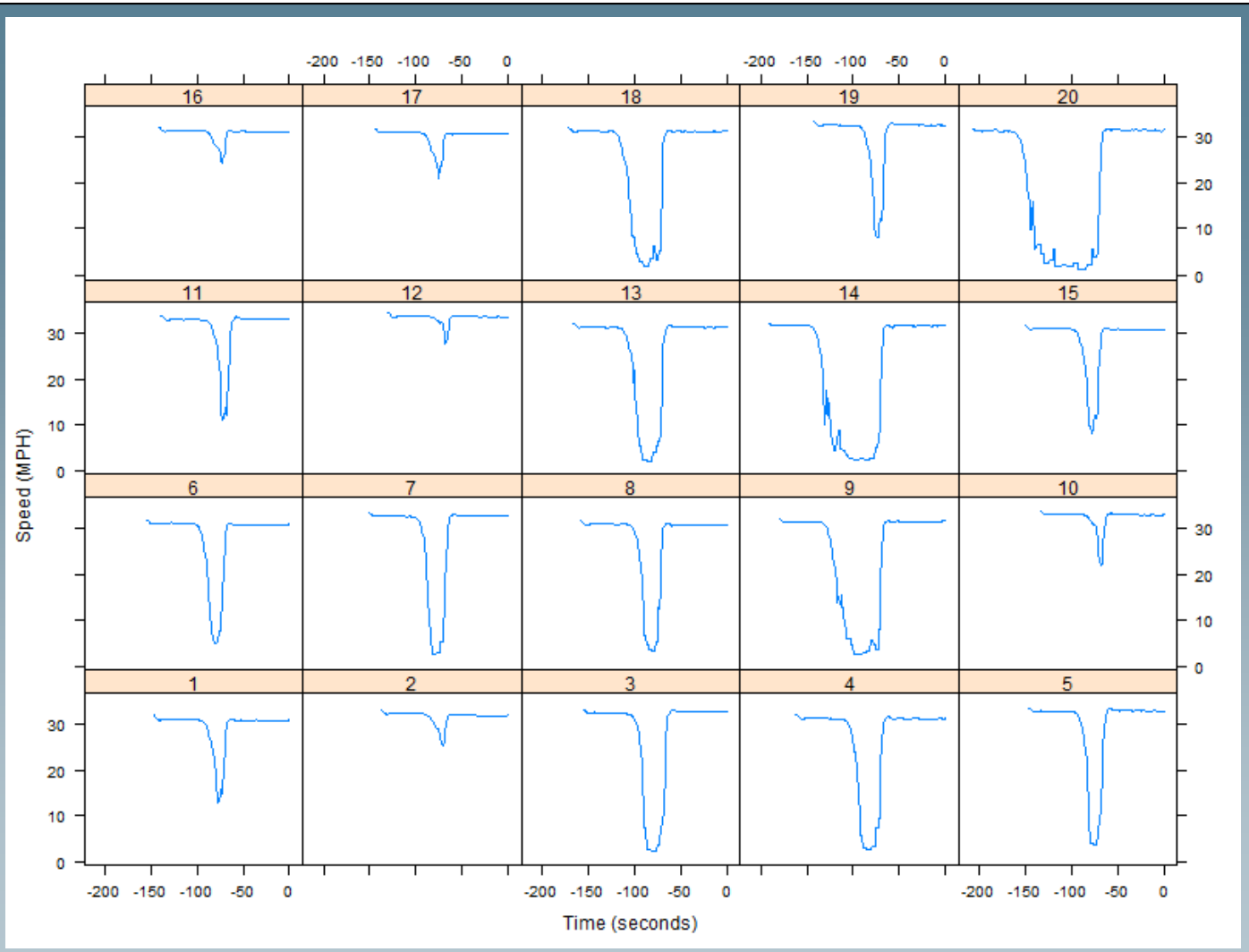
All Way Stop

What the K-Means Algorithm Produces



Roundabout

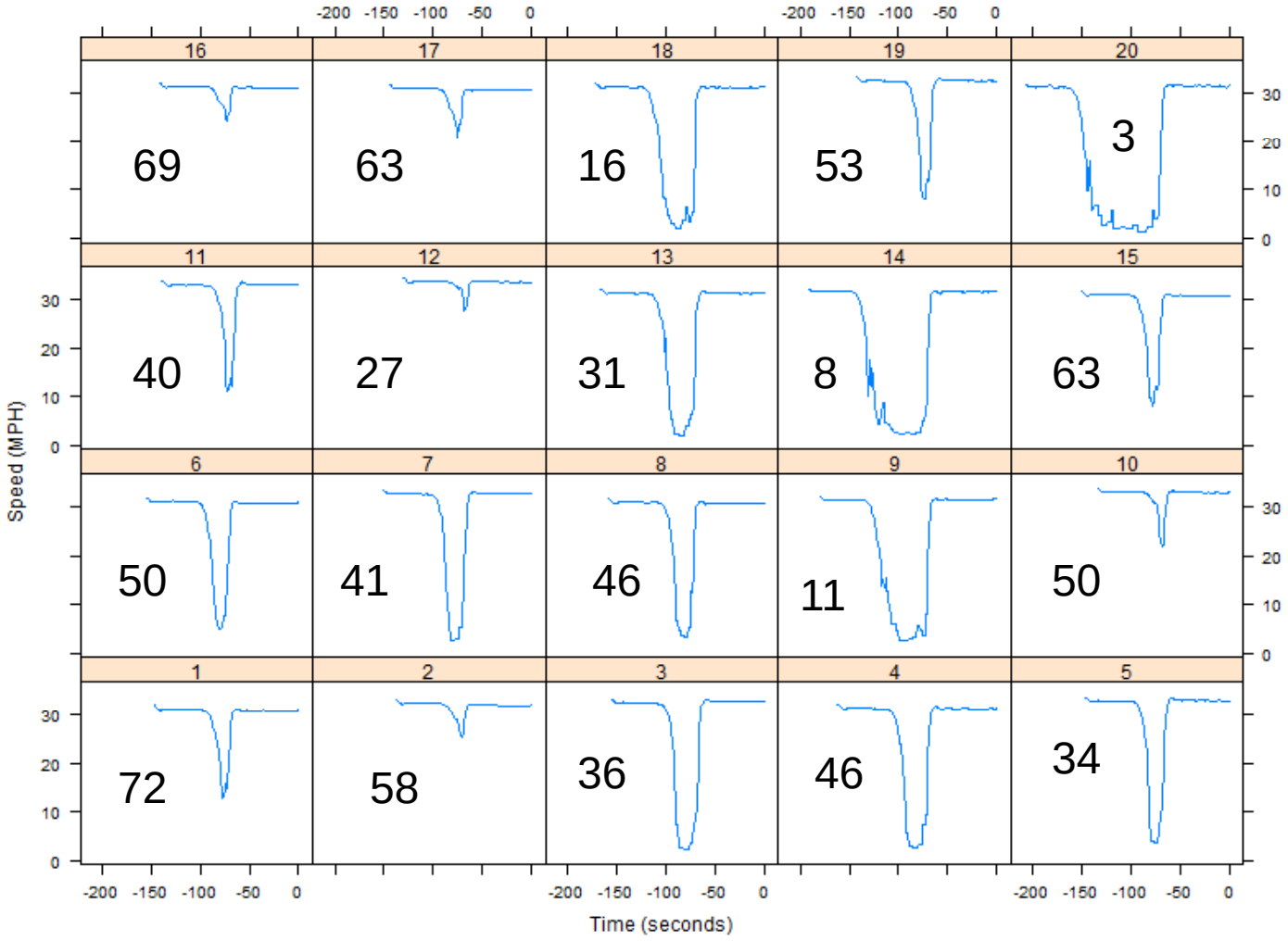
What the K-Means Algorithm Produces



Pretimed Signal

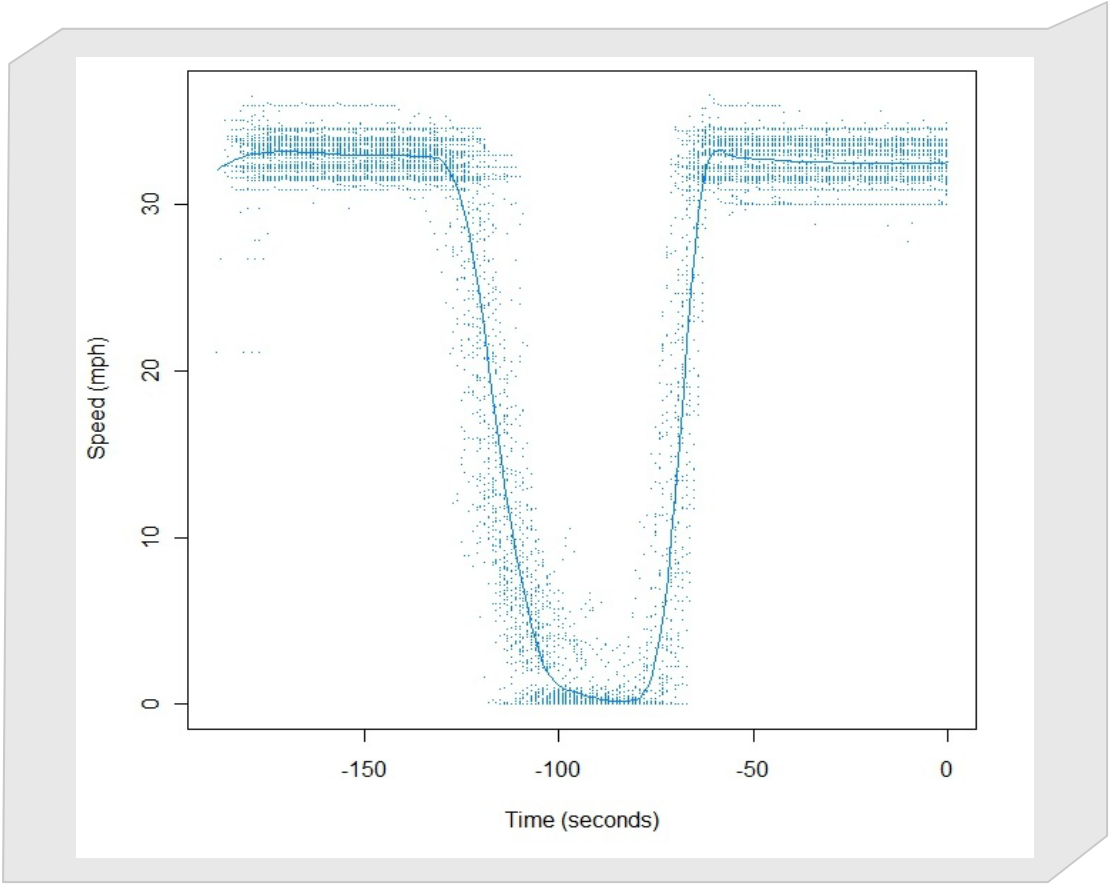
Every Bin is a MOVES Drive Schedule

What Else You Need -- # of Vehicles per Bin and Average Speed of Bin



The Link Drive Schedule

- Step 2: LOESS (Locally Weighted Scatterplot Smoothing)
  - Creates one drive schedule representing many "like" trajectories
  - The Link Drive Schedule is a Key Input into the MOVES Run Specification File for Project-Level Analysis



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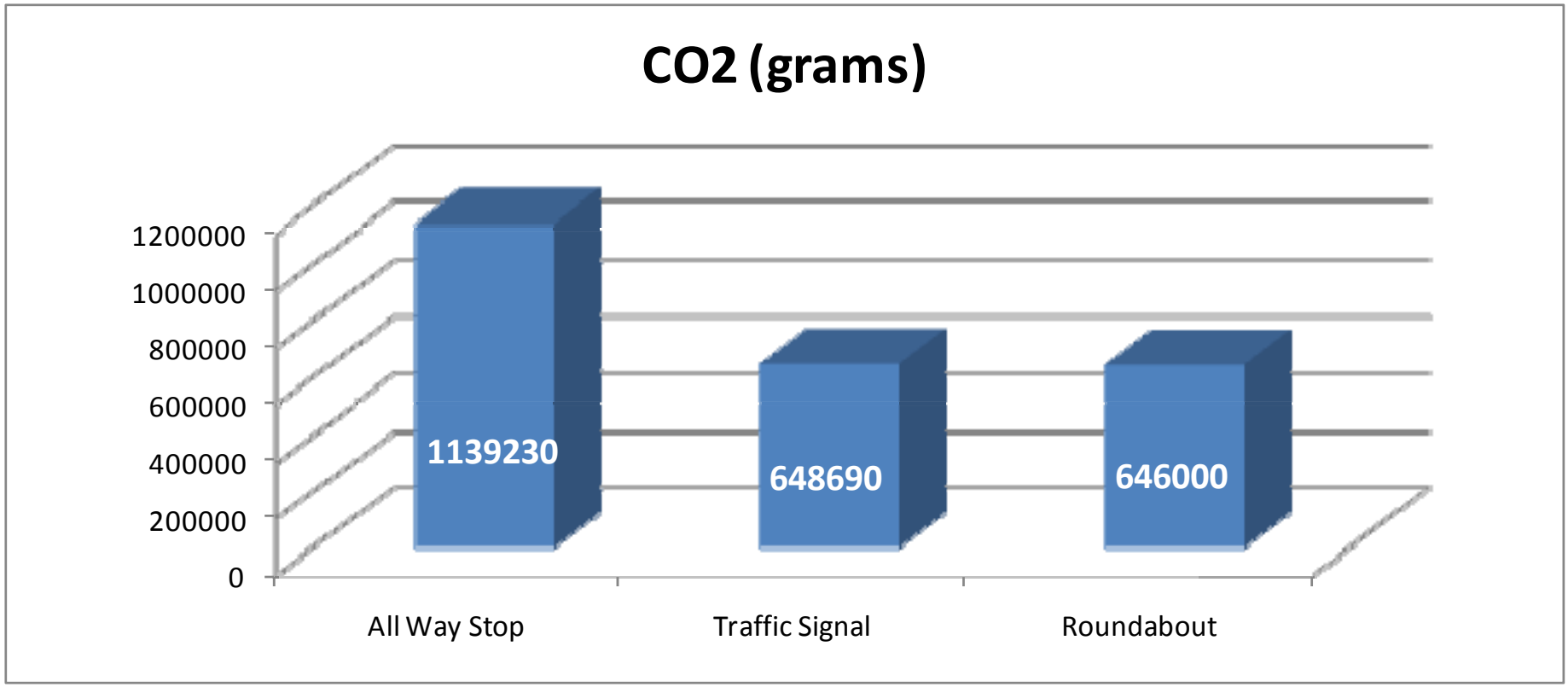
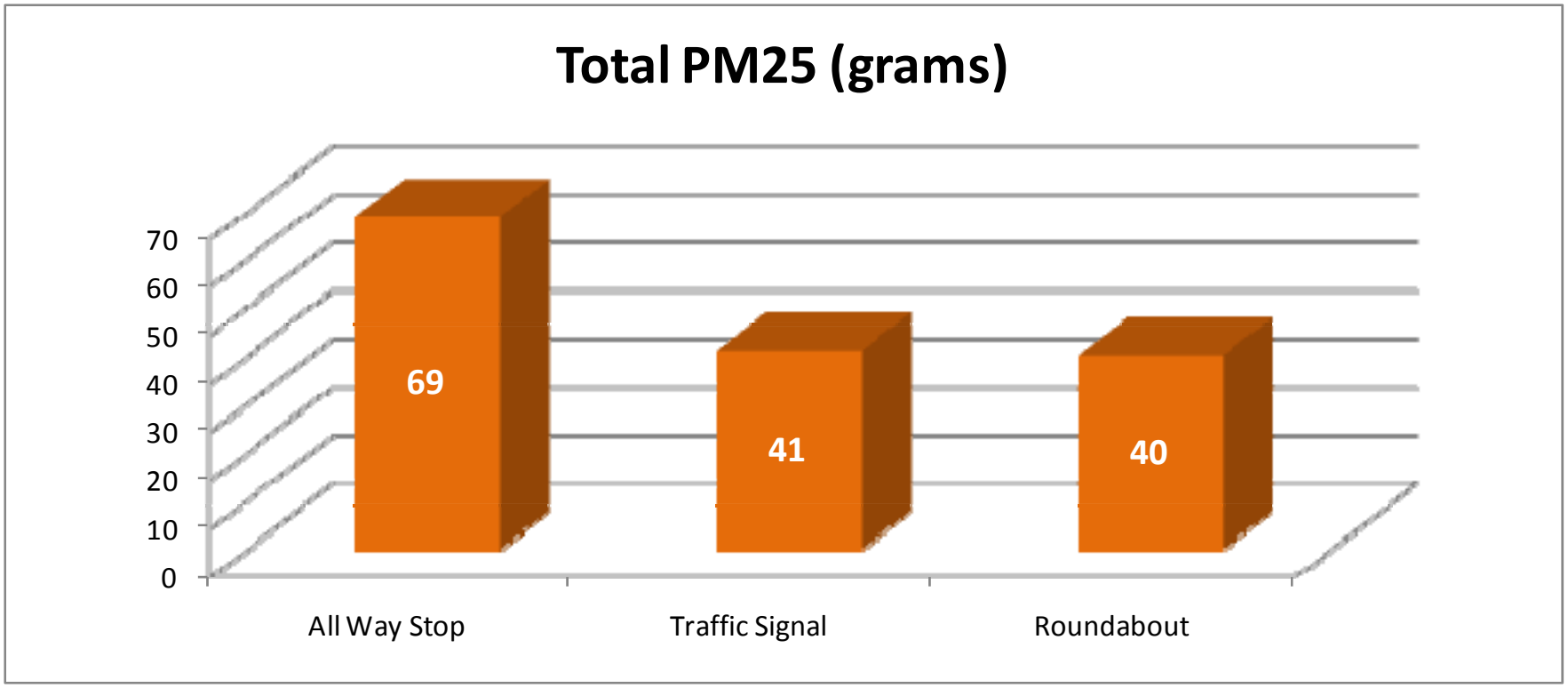
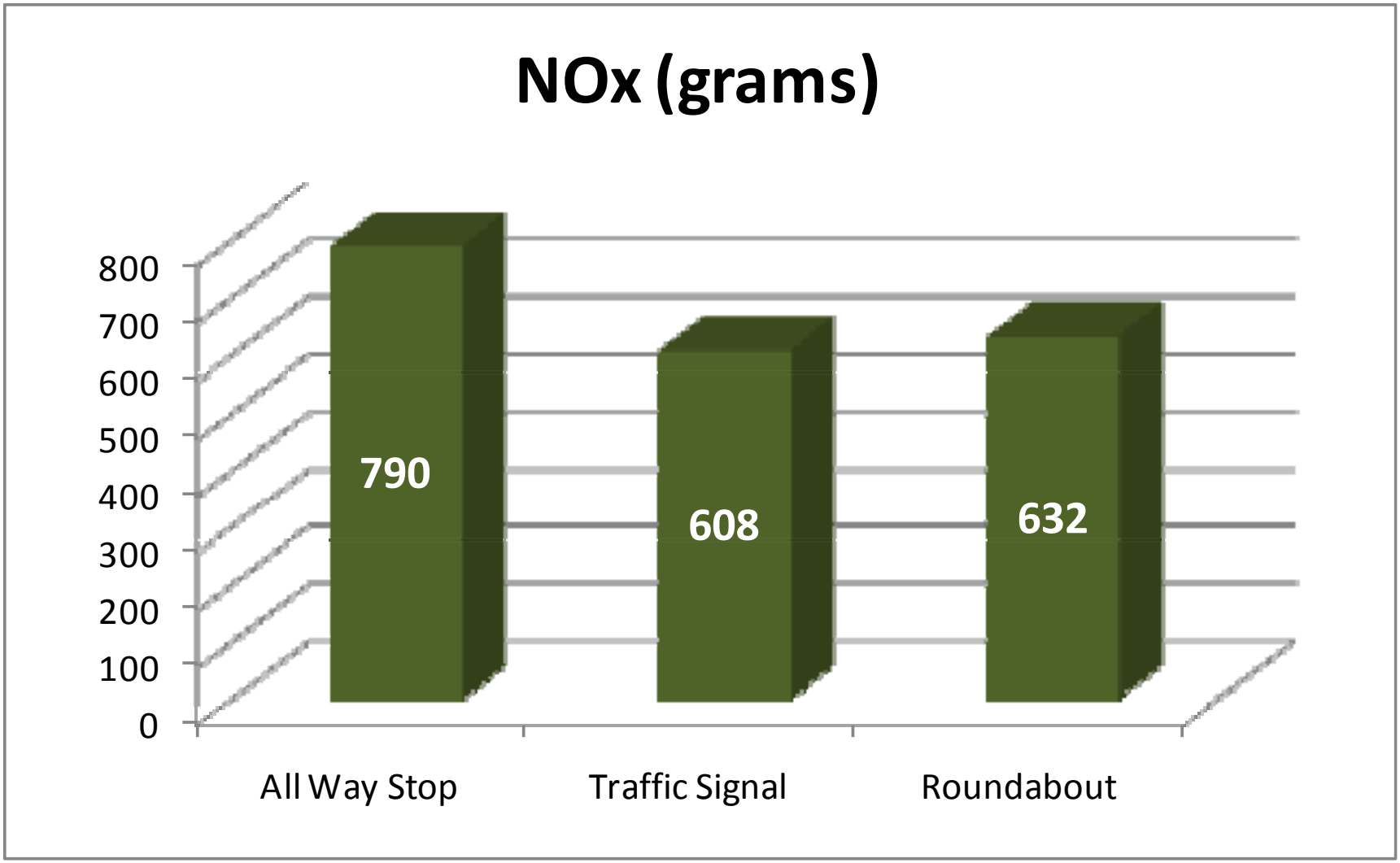
Results – VISSIM High Volume (1700 vph) – CO2



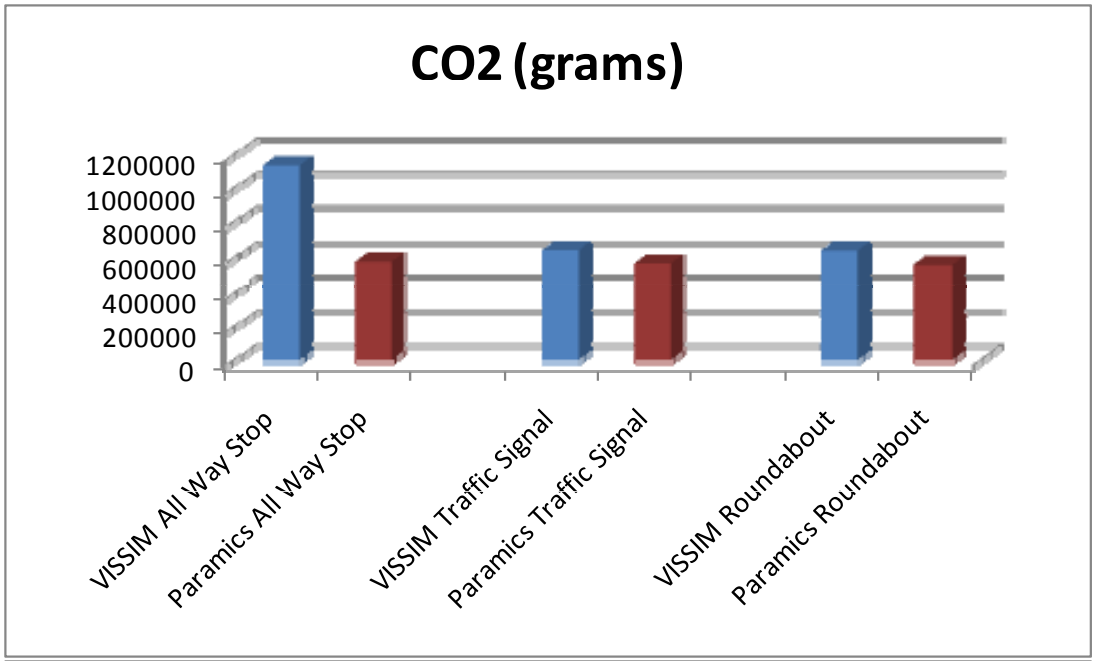
Results – VISSIM High Volume (1700 vph) – PM2.5

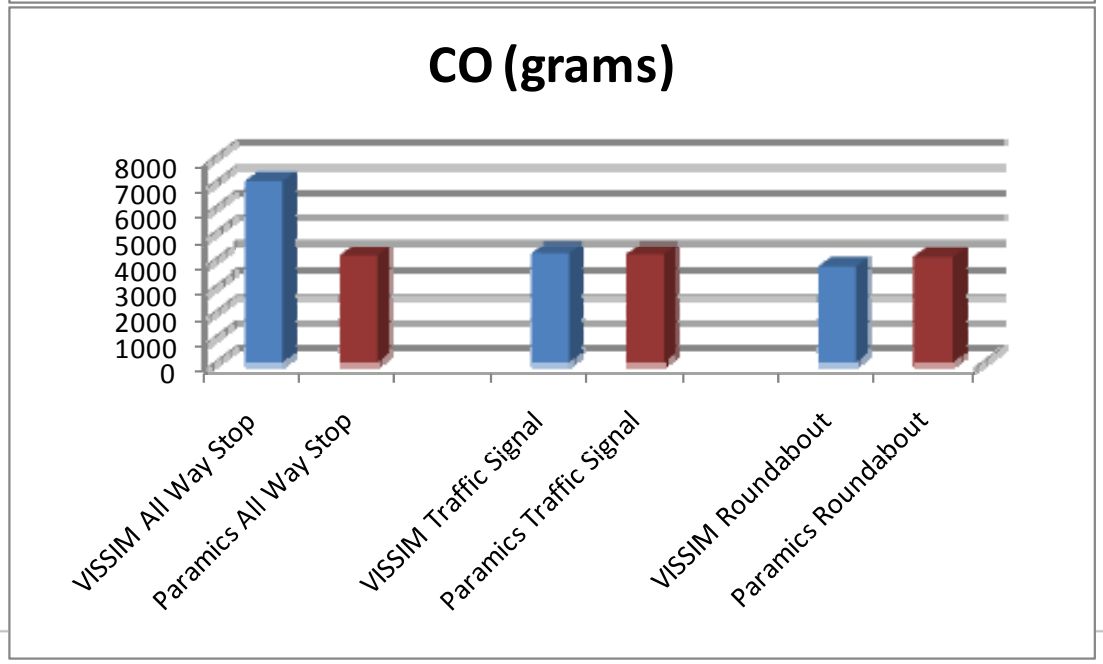


Results – VISSIM High Volume (1700 vph) - NOx



Results – Comparison Across Different Microsimulators





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Findings and Future Work

- **Findings**
  - In Using the Link Drive Schedule Approach:
    - Utilize a k-means algorithm to classify vehicle trajectories into MOVES "links"
    - Utilize Locally Weighted Scatterplot Smoothing (LOESS) to reduce a bin of similarly-classified trajectories into a characteristic Drive Schedule
    - Uses Normal MOVES Run Specification File Executed as a Project-Level Scenario
- **Methodological Questions**
  - How to appropriately define the geographic bounds of the "project area"?
  - If the "project area" is a small portion of a larger microsimulation model, how to manage the emissions from the rest of the network, sequester the vehicles that traverse the "project area"?
  - How to best manage the many "degrees of freedom"? i.e. differences in traffic simu**lation packages?**
  - What is the correct number of bins to minimize sampling error? Latent cluster analysis.
- **Research Begets Research**
  - What is the practical limit of modeling vehicle trajectories? How many unique trajectories can MOVES handle?
  - Are there significant differences in vehicle trajectory files produced by different microsimulation packages that affect their pre-processing into Link Drive Schedules?

For More Information…

- **Session 479 – Current Environmental Issues in Transportation**
  - Poster Session (Paper 11-0673)
  - Tuesday 25 January, 9:30-12:30
  - Hilton International Center