MOVES
Motor Vehicle Emission Simulator

Draft Tool to Model Ramps in Project Scale

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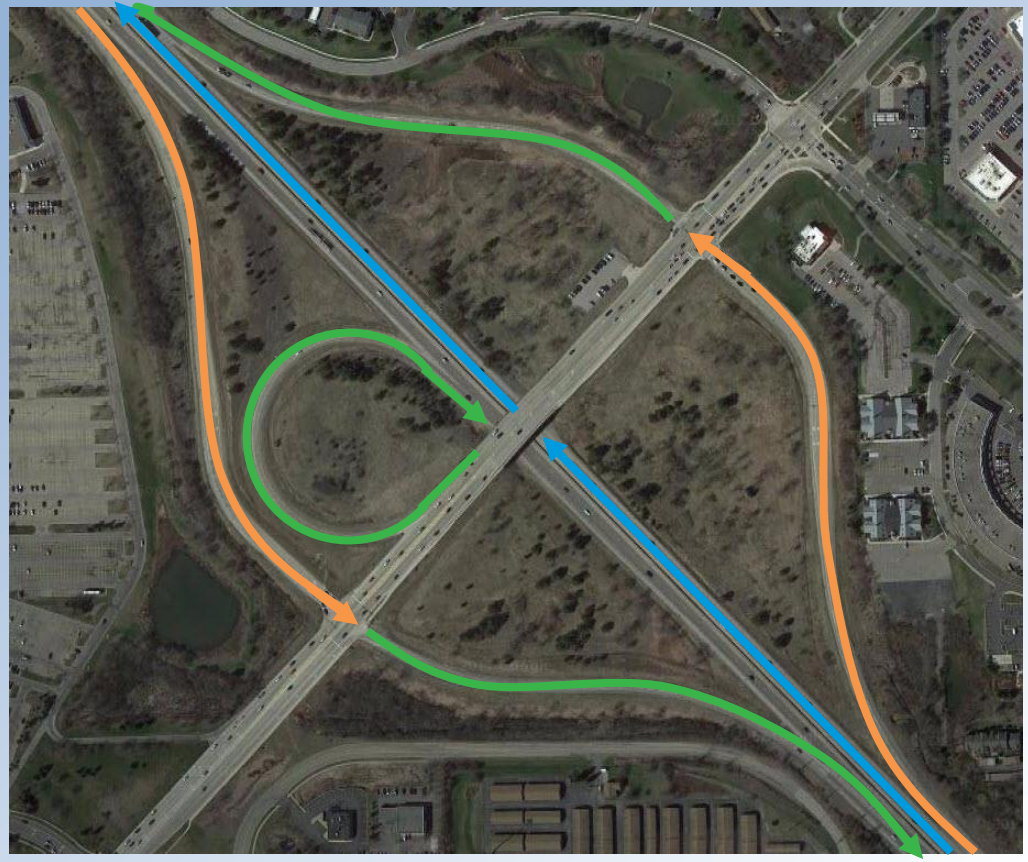
Outline

- Objective
  - To share development of the MOVES Ramp Tool
- Background
  - MOVES ramp modeling in project mode
- Ramp Tool Development
  - Data collection using PAMS
  - Summary of tool development
- Potential MOVES Ramp Tool Usage
  - Use cases

Background

- We are removing ramps as a separate emission calculation from National and County Scales
  - See September 2016 Workgroup presentation
- Ramps still need to be accounted for as separate links in Project Scale analyses
  - Project Scale allows users to define vehicle activity on individual links
  - Differences between individual ramps, especially between on-ramps, off-ramps, and highway links can be important at Project Scale

Background



- Activity on ramps differs from highway activity
  - More acceleration or deceleration depending on ramp type
  - Previous work showed on-ramps have higher exhaust emission rates than highway driving; off-ramps have less[1]

[1]Liu, H. et al. (2016). Operations and Emissions Characteristics of Light-Duty Vehicles on Ramps. *Transportation Research Record: Journal of the Transportation Research Board,* 2570, 1-11.

On Ramp (accelerating)

Off Ramp (braking)

Highway (constant speed)

Background

- In Project Scale, users have the option of defining vehicle activity on a link using:
  - Average speed on the link: *easiest but least precise*
  - A second-by-second drive schedule: *next best*
  - An operating mode distribution: *most precise, but data intensive*
- When using average speed approach, MOVES treats ramps the same as all other highway links
  - User enters average speed for ramp
  - MOVES calculates operating mode distribution for restricted road (highway) driving at that speed
  - Emission rates based on the same average speed would be the same for highway links and ramp links, but vehicle activity on ramps differs from highways

Background

- Using operating mode distributions that reflect real ramp activity would provide a more precise emissions estimate
  - We have ramp data collected as part of our Detroit ramp study
  - We have created a tool that provides operating mode distributions from this data, based on user inputs
- Objective of ramp tool: *Estimate operating mode distributions based on average speed on highway off- and on-ramps*

Data Used in the Draft Ramp Tool

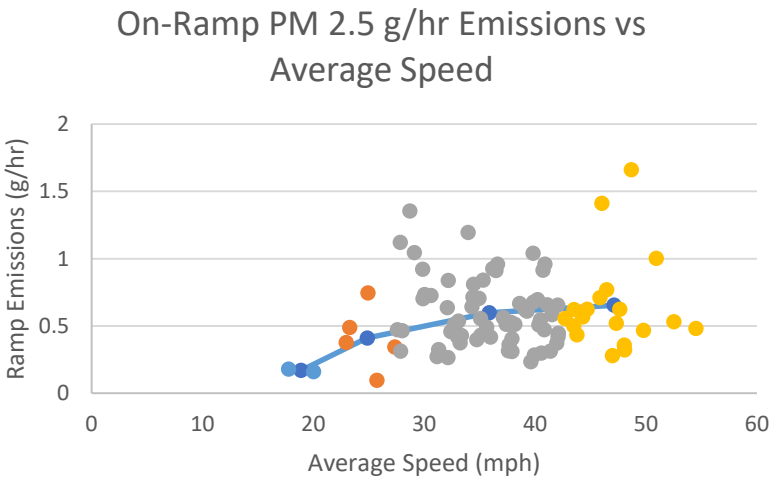
- PAMS - Portable Activity Monitoring System
  - Devices that collect second-by-second speed and position information
  - No emission data measured with PAMS
- Data collected on passenger cars driving in the Detroit, MI area during 2012[1]
- EPA isolated 270 instances of ramp driving using GPS data
  - Did not include interchange ramps where behavior would be more similar to highway driving
  - Mix of ramp type (on/off), ramp connection (free flow/stopped), ramp shape, and average speed

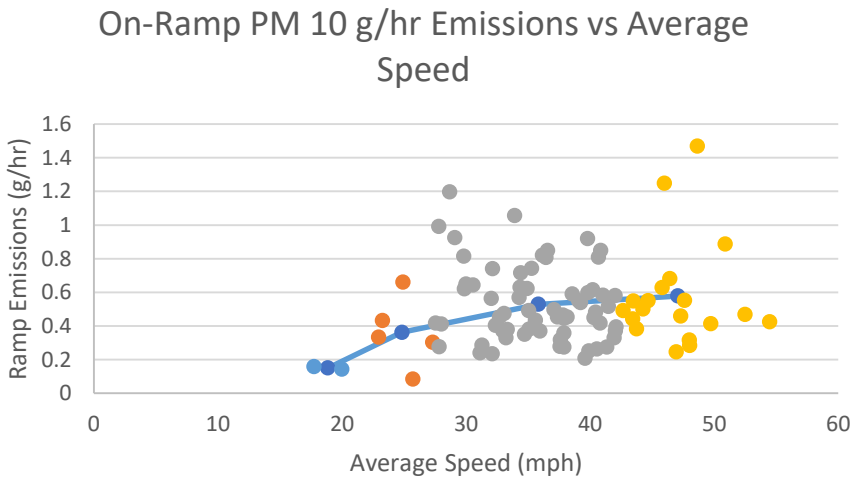
[1]Liu, H., D. Sonntag, D. Brzezinski, C. R. Fulper, D. Hawkins and J. E. Warila (2016). Operations and Emissions Characteristics of Light-Duty Vehicles on Ramps. *Transportation Research Record: Journal of the Transportation Research Board,* 2570, 1-11. DOI: doi:10.3141/2570-01.

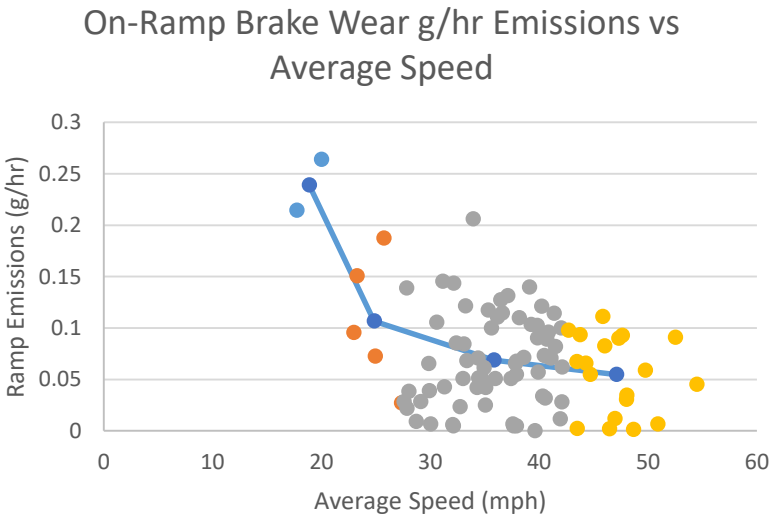
Development of the Draft Ramp Tool

- Trips grouped into bins by ramp type and average speed
- Bin speed ranges adjusted for consistent emission trends relative to average speed for all pollutants
  - Each second of data assigned an operating mode for three source types
    - Passenger car, passenger truck, and light commercial truck
    - Operating mode calculated using:
      - Vehicle specific power
      - MOVES default characteristics for source types
      - No grade data available; assumed grade of 0
  - MOVES emission rate for each trip calculated based on op modes
- Stored the average operating mode distribution for each ramp type, source type and speed bin

On-Ramp Speed Bins and Emission Rates

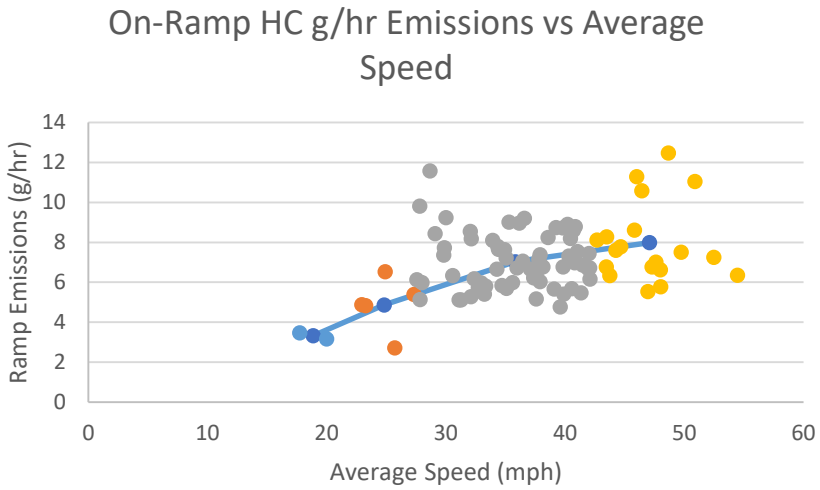


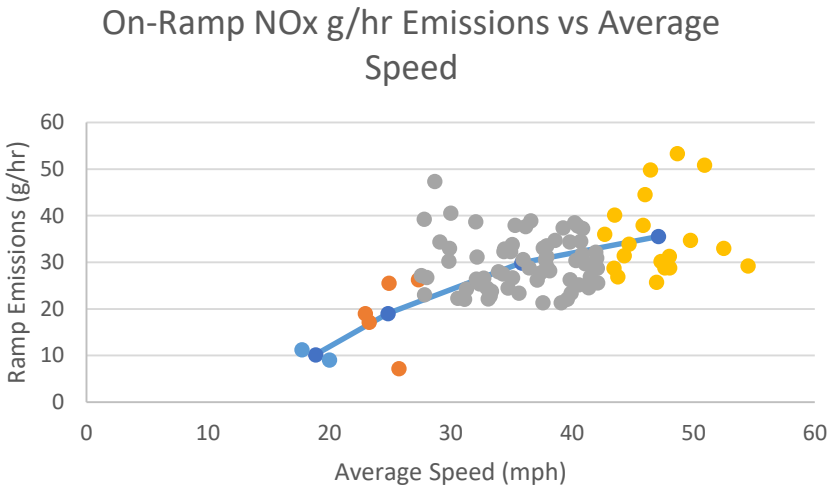


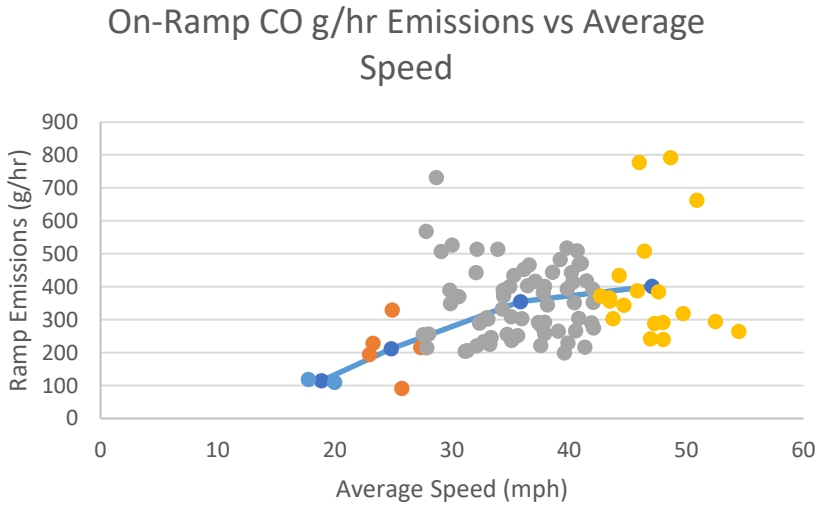


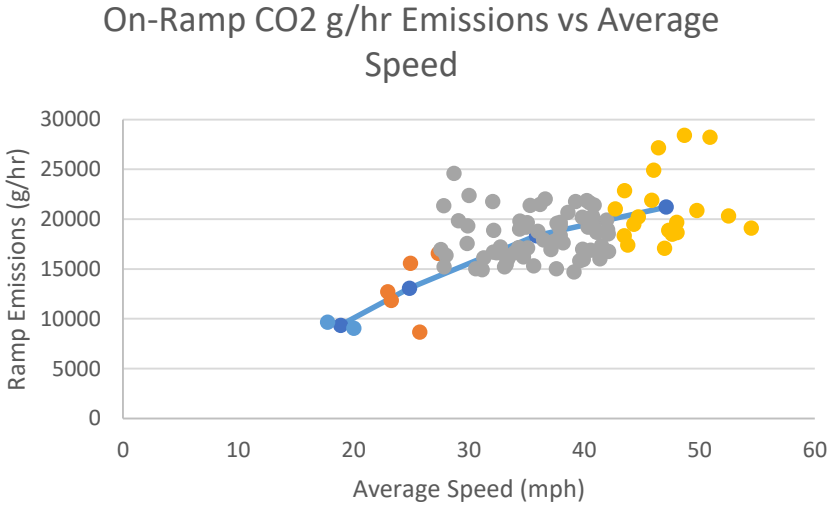
- Each point represents the average speed and emission rate for one trip
- Colors show grouped speed bins as discussed earlier
- Blue points (with trend line) are average speed and emission rate for each speed bin

On-Ramp Speed Bins and Emission Rates

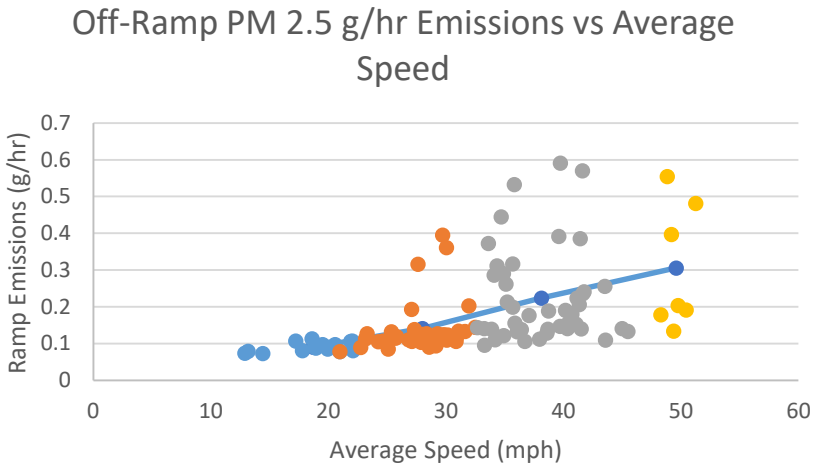


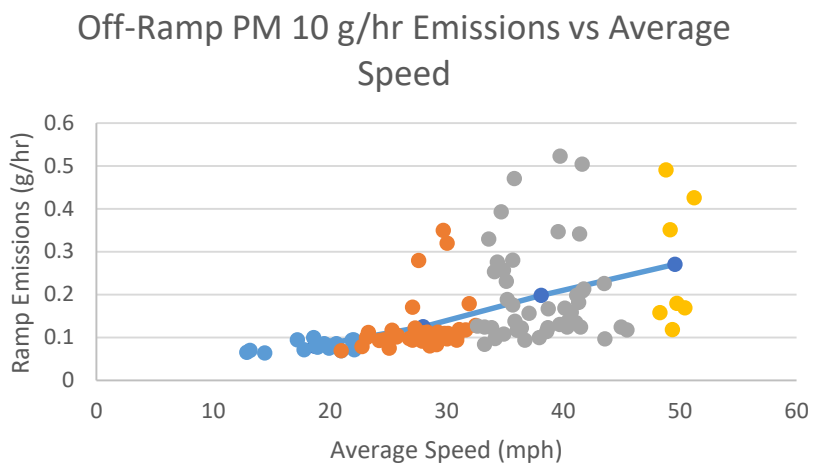


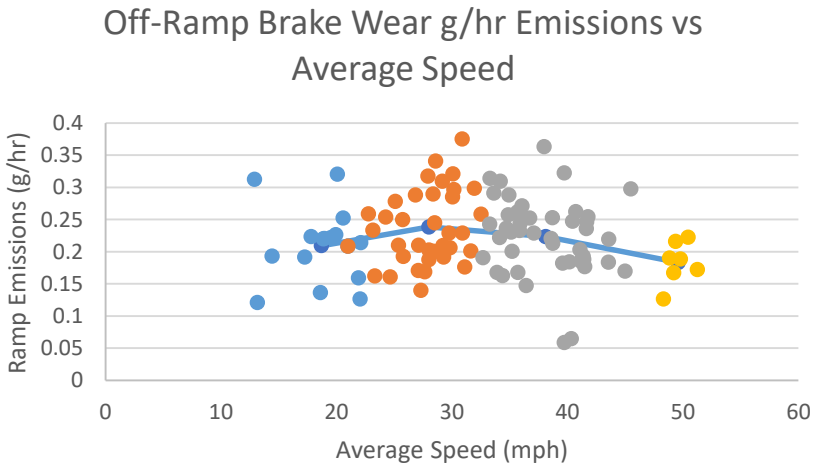




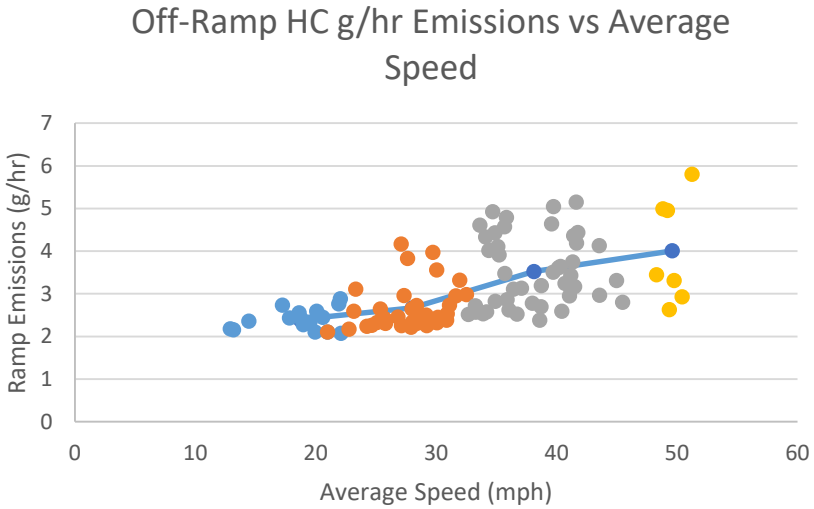
Off-Ramp Speed Bins and Emission Rates

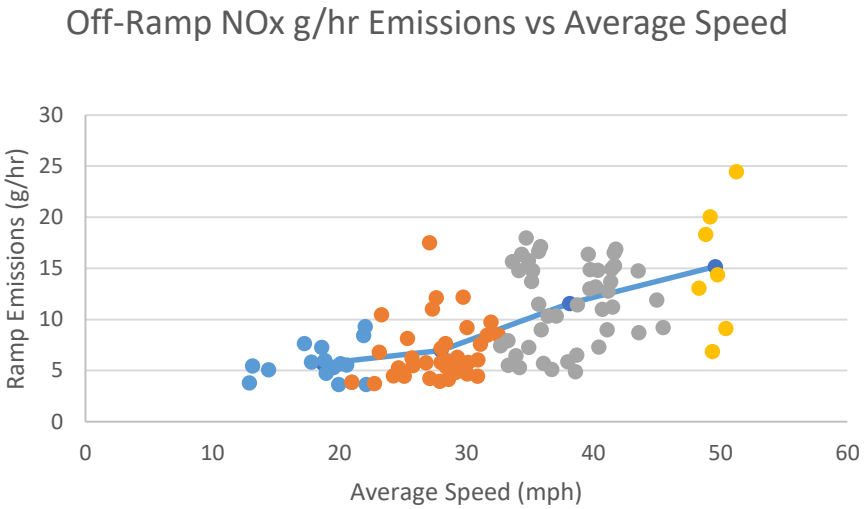


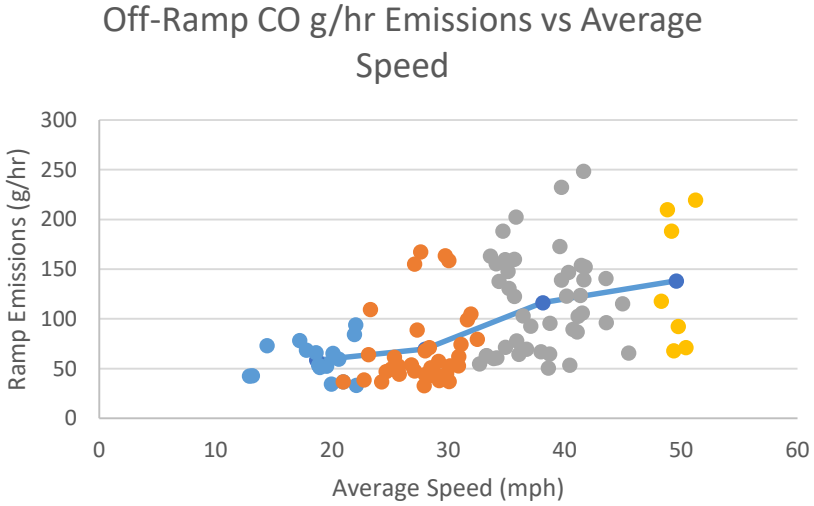


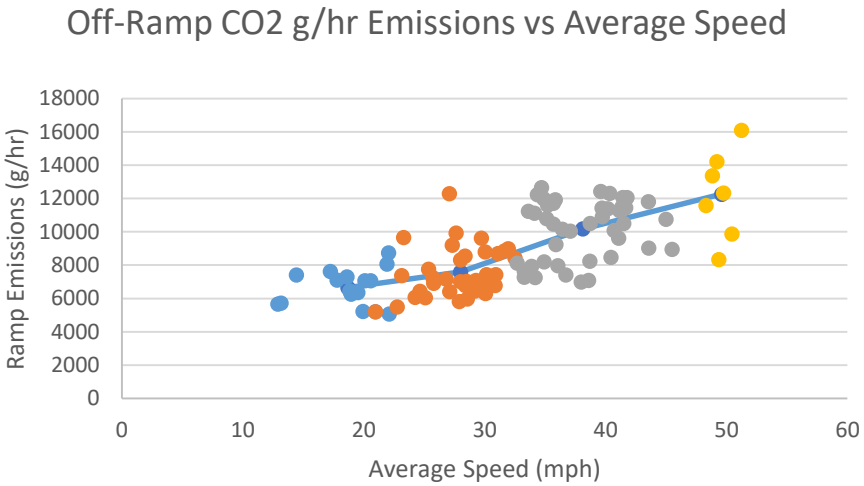


Off-Ramp Speed Bins and Emission Rates









Development of the Draft Ramp Tool

- Based on user-provided average speed, the Draft Ramp Tool interpolates between stored operating mode distributions

ON RAMPS			OFF RAMPS	
Average Speed in Data (mph)	Grouped Speed Bin	Speed Range (mph)	Grouped Speed Bin	Average Speed in Data (mph)
		12.5 - 17.5	1	18.92
20.39	1	17.5 - 22.5		
23.58	2	22.5 - 27.5	2	29.24
36.77	3	27.5 - 32.5		
		32.5 - 37.5	3	40.36
		37.5 - 42.5		
47.53	4	42.5 - 47.5		
		47.5 - 52.5	4	49.52
		52.5 - 57.5		

Vehicle Type	Average Speed	Op Mode 0	Op Mode 1	Op Mode 11	Op M 1
Passenger Cars	20.39306	0.10453	0.170732	0.139373	0.08
	23.5842	0.085202	0	0.174888	0.20
	36.7677	0.05781	0.164672	0.023942	0.03
	47.53046	0.05822	0.021235	0.01398	0.02
Passenger Trucks	20.39306	0.10453	0.170732	0.139373	0.08
	23.5842	0.085202	0	0.174888	0.20
	36.7677	0.05781	0.164672	0.023358	0.03
	47.53046	0.05822	0.021235	0.013272	0.02
Light Commercial Vehicles	20.39306	0.10453	0.170732	0.139373	0.08
	23.5842	0.085202	0	0.174888	0.20
	36.7677	0.05781	0.164672	0.02365	0.03
	47.53046	0.05822	0.021235	0.013272	0.02

Draft Ramp Tool Usage

- Potential applications:
  - Users need operating mode distributions for passenger cars, passenger trucks, or light commercial trucks on either on- or off-ramps
    - Tool not applicable to other source types
  - Average vehicle speed on ramp is between 18-50 mph
  - Traffic observation or simulation is not available
  - Users are not comparing emissions related to ramp geometry or grade

Next Steps

- Consider any comments from work group
- Additional details on development of the ramp tool and usage of the tool will be made available in the appendix of the report:
  - "Draft Population and Activity of On-road Vehicles in MOVES201X"
  - Will be made available with the MOVES peer-review materials
- Based on feedback, determine whether to make final version of tool publicly available on MOVES website in the future