Characterization of On-Road Bus Emissions of NOx, CO, and HCs

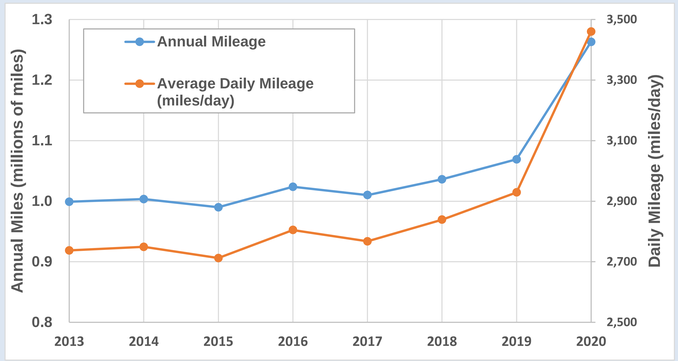
Randal S. Martin, Daniela Barrera Zarco, Motasem Abualqumboz

Utah State University, Dept. of Civil & Environmental Engineering, Utah Water Research Laboratory

Introduction

- Since 1992, the Cache Valley Transit District (CVTD) provides fare-free bus service to the population of Cache Valley, UT
- CTVD's vehicle miles traveled (VMT's) have grown from around 2,750 mi/day (1million miles annually) in the mid-2010's to nearly 3,500 mi/day (1.3 million miles annually), in 2020 (see Figure 1)

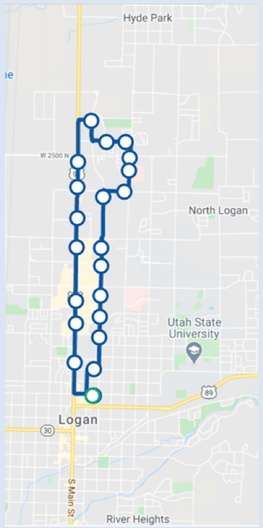
Figure 1. CVTD Daily and Annual Mileage (2013-2020)



- In cooperation with researchers at USU, CVTD has previously (2007, 2010) tested on-road emissions of oxides of nitrogen (NOx), carbon monoxide (CO), and hydrocarbons (HCs – also known as volatile organic compounds, VOCs) from a sampling of their bus types and routes.
  - The historical objectives were:
    - assess CVTD's actual contribution to Cache Valley's air pollutant burden
    - estimate the relative number of passenger car drivers required to switch to mass transit to see a net decrease in emissions
- 2020 Study Plan/Objectives
  - Update previous studies (on-road NOx, CO, HCs emissions and relative comparison with area vehicle fleet
    - 3 different buses (age/engine type)
      - 2008 diesel; 431,800 miles
      - 2011 diesel/hybrid; 251,432 miles
      - 2019 diesel; 61,869 miles

Methodology

Figure 2. CVTD Route 5

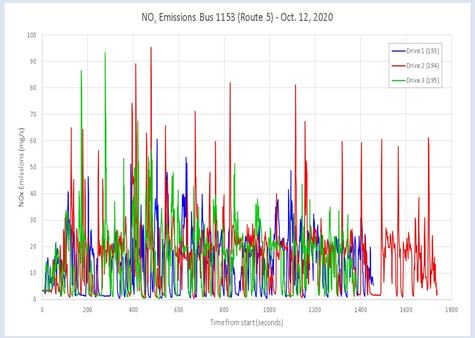


- Each bus emissions tested in triplicate
- All buses drove the same transect
  - CVTD Route 5 (see Figure 2)
    - Main St. north to 2700 N, then return via 200 E (mostly) to Transit Center
    - residential to highway speeds (variable engine loading)
- Insitu tailpipe NOx, CO, HCs measured using an Applus 5-Gas Analyzer
  - 1 second frequency data collection
  - O_2 and CO_2 coincidently measured
  - calibrated daily with a commercial gas mixture
- Ammonia (NH_3) emissions also monitored
  - Not required per project objectives
  - ECM mini-PEMS instrument
- Supporting measurements (OBD, GPS)
  - Location, exhaust flowrate, temperature, pressure, vehicle speed, engine RPMs

Results

- Tailpipe concentrations (ppm or %) converted to mass fluxes (g/mi) using exhaust flowrate and vehicle speed
- Figure 3 shows an example of the typical temporal variability of the pollutant emissions (NOx) across the triplicate transects
  - In the case of NOx, the spikes represent greater engine loading (e.g. acceleration, uphill, etc.)

Figure 3. Temporal NOx flux (g/s)for the 2008 diesel bus



- As shown in Table 1:
  - newest diesel bus showed lowest NOx emissions
    - 65.5x lower than hybrid, 100x lower than older diesel
  - CO and HCs emissions similar for newest diesel and hybrid
    - both around ½ of older diesel
  - NH_3 lower than other species
    - hybrid "cleanest" then older diesel (10x), then newer diesel (35x)

Table 1. 2020 average pollutant emissions (g/mi) the observed CVTD buses

Study	Bus	NOx (g/mi)	CO (g/mi)	HCs (g/mi)	CO_2 (g/mi)	NH_3 (g/mi)
2020	2008 Diesel	2.9	0.49	0.91	1,452	0.0021
	2011 Hybrid	1.8	0.14	0.40	1,470	0.0002
	2019 Diesel	0.029	0.21	0.48	1,164	0.0069

Conclusions

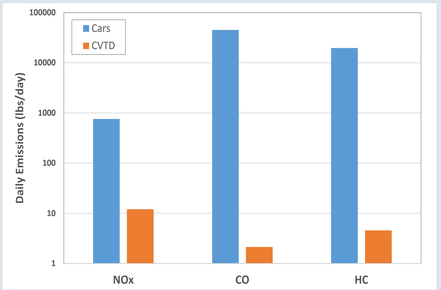
- Concurrent study measured similar emissions from 47 gasoline vehicles representative of the Wasatch Front fleet (Table 2)

Table 2. Average pollutant emissions (g/mi) for representative Wasatch gasoline vehicle fleet.

USU Wasatch Front Tier 0 – Tier 3 gasoline vehicles	NOx (g/mi)	CO (g/mi)	HCs (g/mi)	CO_2 (g/mi)	NH_3 (g/mi)
	0.12	3.1	7.1	357	0.061

- Using average emissions across the three bus types, the number of resident drivers required to achieve emissions "parity" would be:
  - 13.2 for NOx, 0.04 for CO, and 0.2 for HCs
- Factoring in total fleet vehicle miles traveled (VMTs), Cache Valley's gasoline vehicles account for nearly two orders of magnitude more emissions each for NOx, CO, and HCs than the average of the CVTD bus fleet (Figure 4)

Figure 4. CV total CVTD and gasoline emissions



Acknowledgements

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