Understanding Transit Bus Emissions: Effects of Road Network and Trip Characteristics

Ahsan Alam and Marianne Hatzopoulou, McGill University, Canada

In this study, a total of 10 corridors in Montreal were chosen spanning a wide range of land-uses and road geometries as shown in Figure 1.

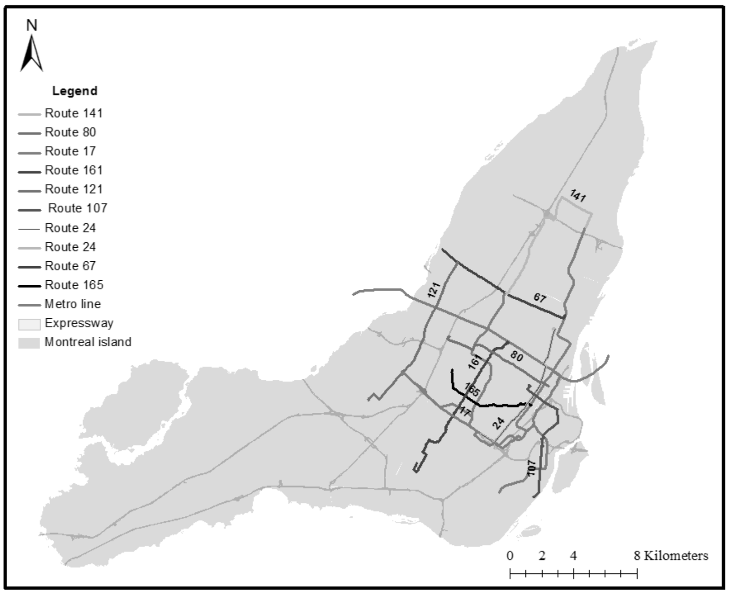

Figure 1: Selected bus routes for on-board data collection

For each corridor data was collected for both morning and afternoon peak periods as well as for both directions. Also to account for the variability in traffic flow, for each combination data was collected three times. The data collection campaign mainly includes: (1)

instantaneous bus speeds of a sample buses using GPS devices, and (2) manual count of passenger ridership at each bus stop.

The second-by-second speed profile for each corridor was disaggregated at link level whereas each link is defined as the segment between successive bus stops. Using the link-level speed profile, for each link the vehicle specific power (VSP) and operational mode (*opmode*) distribution were calculated using the following equations and Table 1 (USEPA, 2010).

$$\mathrm{VSP} = \left(\frac{A}{M}\right) * v + \left(\frac{B}{M}\right) * v^2 + \left(\frac{C}{M}\right) * v^3 + (a + \mathrm{Sin}\theta) * v \quad \ldots\ldots (1)$$

$$A = (\text{bus wt. in metric ton}) * 0.0643 \quad \ldots\ldots (2)$$

$$B = 0 \quad \ldots\ldots (3)$$

$$C = (\text{bus wt. in metric ton}) * \left(\frac{3.22}{\text{bus wt. in kg}} + 5.06 * 10^{-5}\right) \quad \ldots\ldots (4)$$

Where A, B, and C are the road load coefficients in units of (kiloWatt second)/(meter), (kilowatt second^2)/(meter^2), and (kiloWatt second^3)/(meter^3), respectively. The denominator term, ‘M’, is the fixed mass factor (for transit M=17.1 metric tons), ‘g’ is the acceleration due to gravity (9.8 meter/ second^2), ‘v’ is the vehicle speed in meter/second, ‘a’ is the vehicle acceleration in meter/second^2, and Sinθ is the (fractional) road grade.

In the next step, a link typology was conducted to identify similar links by considering average speed, link location, direction of the trip, road characteristics etc. Then an average *opmode* distribution was calculated for each category of links.

To understand the *opmode* distribution differences between local data and traditional emission estimator package, we chose Motor Vehicle Emissions Simulator (MOVES) which is developed by the United State Environmental Protection Agency (USEPA). In North America, MOVES has been widely used for its capability of conducting multi-scale analyses. It can estimate macroscale inventories for nation/sate-wide inventory reports, mesoscale inventories for regional scale, and microscale inventories for hot spot identification at the project level. The first two emission methods use average link speeds where

Table 1 *Opmode* identification under different speed category

Speed (mph)	**Operational mode ID**	**Vehicle Specific Power (VSP)**
	0	Braking
	1	Idling
1<=Speed<25	11	Low Speed Coasting; VSP<0
	12	0<=VSP< 3
	13	3<=VSP< 6
	14	6<=VSP< 9
	15	9<=VSP<12
	16	12<=VSP
25<=Speed<50	21	VSP< 0
	22	0<=VSP< 3
	23	3<=VSP< 6
	24	6<=VSP< 9
	25	9<=VSP<12
	27	12<=VSP<18
	28	18<=VSP<24
	29	24<=VSP<30
	30	30<=VSP
50<=Speed	33	VSP< 6
	35	6<=VSP<12
	37	12<=VSP<18
	38	18<=VSP<24
	39	24<=VSP<30
	40	30<=VSP

emissions are estimated based on the average speed of the link and corresponding emissions rate (in g/VMT). These models do not consider the instantaneous behavior of the vehicles rather it assumes a default speed profile for a particular average speed. Hence, emissions estimated by these average speed methods do not represent the actual emissions and it is important to understand how much estimated emissions could be different than the actual when average speed based method is used.

Therefore, an average-speed specific *opmode* distribution was extracted from the MOVES database so that it can be compared with GPS data based o*pmode* distribution. The comparison could be useful to give a clear understanding of how the default MOVES distribution is different from the local distribution. Later using the corresponding *opmode* distribution, emissions are estimated for both MOVES default and GPS data for each average speed category. Comparison of *opmode* distribution and emissions were conducted across a wide combination of roadway type, grade, and passenger load. The comparison could be useful to identify the cases where the differences are minimum and maximum.

In order to understand the impact of different variables on transit bus emissions, a link-level regression analysis is conducted to estimate emissions more accurately as a function of two main types of variables: 1) road network characteristics, and 2) trip characteristics. Road network variables includes link length, number of lanes, roadway grade, roadway type, presence of exclusive bus lane, average speed etc; whereas trip characteristics includes number of onboard passenger, number of passenger activity at bus stops, bus stop spacing, distance to the nearest metro, land-use type, bus type, time and direction of the trip etc. The regression results could be useful to transit planners before improving existing routes or implementing new routes with a aim to reduce transit bus emissions.

References:

USEPA. (2010). MOVES2010 highway vehicle: population and activity data. EPA-420-R-10-026, Assessment and Standards Division Office of Transportation and Air Quality U.S. Environmental Protection Agency.