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Fundamentals of Traffic Operations and Control

Lab 2: Traffic Data from Drones and Vehicle Emission Models

Required Material:
Matlab and/or Python
Data files: *lab2_data.csv* (provided)

Introduction:

In this second lab we will do an environmental analysis of traffic data in urban networks. The provided data was collected using drones and advanced computer vision techniques to identify and track the vehicles. We will focus on the estimation of CO_2 emissions generated by the vehicles. For that, we will use three different methods introduced in the lectures. We will also compute some driving behavior characteristics for each vehicle (average speed, time spent in acceleration, deceleration, idling, cruising, and the average values for each state). Through the analysis of the emissions estimated by the models, one can infer the impact of the driving behavior on the level of emissions and discuss some policy implications.

Data description

The data file contains the data of one drone during a 20-minute time interval, collected in the city of Athens. For each vehicle, the data describe the vehicle type and trajectory (i.e., the distance travelled over time).

Vehicle_ID	Vehicle_type	Time	Cumulative_distance
1	Car	0	0
…..	…..	0.4	0.6
…..	…..	0.8	1.5
…..	…..	1.2	3
…..	…..	1.6	5
…..	…..	…..	…..
…..	…..	…..	…..
…..	…..	…..	…..
…..	…..	40	200
…..	…..	40.4	205

Vehicle_ID: identifier of each vehicle.
Vehicle_type: either Car, Motorcycle or Heavy Vehicle.
Time: time stamp. [Unit: seconds]
Cumulative_distance: cumulative distance travelled, for each vehicle. [Unit: meters]

Step 1:

Compute for each vehicle: average speed, and time spent in each operating mode (acceleration, deceleration, idling, cruising). Summarize the results by type of vehicle: average speed, and % of time spent in each operating mode. Briefly explain the differences among vehicles types (e.g., heavy vehicles spend a higher/lower share of their driving time in cruising mode compared to cars and motorcycles).

For each time interval, we consider that a vehicle's operating mode is *accelerating* if the acceleration is higher than $0.5 m/s^2$, and *decelerating* if the acceleration is lower than $-0.5 m/s^2$. Otherwise (absolute value of the acceleration smaller or equal than $0.5 m/s^2$), the vehicle is *cruising* if the average speed during the time interval is higher than 0.28 m/s (circa 1km/h), and *idling* if the average speed is smaller.

Step 2:

Model: average speed based. Use the U-curve from EMFAC2007 to estimate the total CO_2 emissions. Such curve is representative of the whole fleet of vehicles. The model has been adjusted to account for the modernization of the fleet of vehicles, which resulted in a reduction of the emission rates.

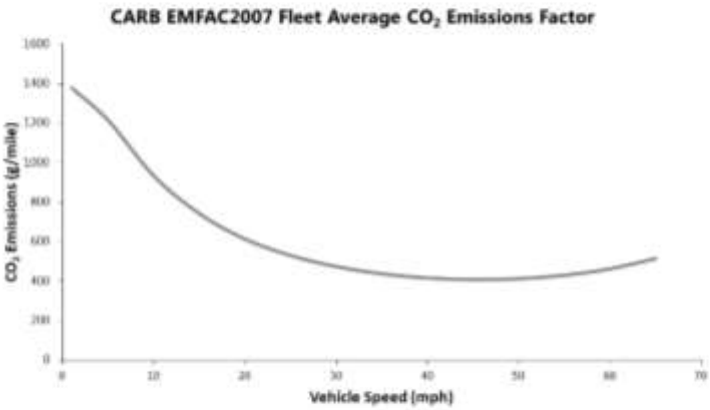

Figure 1. EMFAC2007 U-curve before adjusting

To model the relationship between vehicle speed and emissions, use the adjusted curve: $y = C*[891 - 22.1360x + 0.2346x^2 - 0.0007x^3]$, where y is the CO_2 emission rate in *g/km* and x is the average speed in *km/h*. C=0.55 (correction factor).

Output: total CO_2 emitted. As a sanity check, also include the total km travelled and the resulting average CO_2 g/km emitted.

Step 3:

Model: modal emissions based. Emissions are related to the operating mode of a vehicle. Use the following table for an average car, adapted from Frey (2003):

Operating mode	CO_2 (g/s)
Idle	0.7
Acceleration	2.8
Deceleration	1.4
Cruise	1.8

However, bear in mind that motorcycle emissions can be quite different from car emissions. To use this table for other types of vehicles, instead of cars, apply the following conversion factors: 0.5x for motorcycles, and 5x for heavy vehicles.

Output: total CO_2 emitted. As a sanity check, also include the total travel time and the resulting average CO_2 g/s emitted, for each vehicle type.

Step 4:

Model: modal emissions based. The last model can be classified as a modal emissions-based model of type 2 (“engine power and speed map”). It considers both the values of speed and acceleration over time, as well as the road slope, to estimate the power demand. The vehicle specific power factor (VSP) greatly determines the emission rate. (Frey et al, 2008)

$$VSP = 0.278v[0.305a + 0.132] + 0.0000065v^3$$

where: v = speed [km/h], a = acceleration [km/h/s], and VSP [kw/ton].

* The VSP formula has been simplified by assuming no slope.

In the modal approach, the emissions are stratified into 14 VSP modes for a standard car:

VSP mode	definition	NO (mg/sec)	HC (mg/sec)	CO (mg/sec)	CO_2 (g/sec)	fuel (g/sec)
1	$VSP < -2$	0.12	0.076	1.83	1.30	0.41
2	$-2 \le VSP < 0$	0.092	0.083	1.86	1.43	0.45
3	$0 \le VSP < 1$	0.026	0.056	0.90	0.97	0.31
4	$1 \le VSP < 4$	0.14	0.12	2.59	2.03	0.64
5	$4 \le VSP < 7$	0.21	0.16	3.68	2.74	0.87
6	$7 \le VSP < 10$	0.23	0.20	4.74	3.42	1.08
7	$10 \le VSP < 13$	0.29	0.24	5.73	4.02	1.27
8	$13 \le VSP < 16$	0.32	0.28	6.18	4.56	1.44
9	$16 \le VSP < 19$	0.37	0.31	7.09	5.08	1.61
10	$19 \le VSP < 23$	0.47	0.35	7.81	5.61	1.77
11	$23 \le VSP < 28$	0.59	0.38	8.36	6.05	1.91
12	$28 \le VSP < 33$	0.68	0.42	9.01	6.41	2.03
13	$33 \le VSP < 39$	0.79	0.46	10.5	6.86	2.17
14	$39 \le VSP$	0.97	0.48	10.9	7.41	2.34

[a] The average 95% confidence intervals for these VSP modes in % are ±5, ±2, ±3, ±1, and ±1 for NO, HC, CO, CO_2, and fuel, respectively. The unit for VSP is kw/ton.

Again, apply the conversion factor (0.5x for motorcycles and 5x for heavy vehicles) to the emissions obtained, when applicable.

Output: total CO_2 emitted. As a sanity check, also include the total travel time and the resulting average CO_2 g/s emitted, for each vehicle type.

Compare the results obtained with the three methods.

Step 5:

Influence of driver aggressiveness on the emissions. Compute the % of time *being aggressive* for each driver (that is, the % of time of her trip in which the driver has an aggressive driving style). Aggressiveness is characterized by sudden changes in the speed, consider that a driver is being aggressive when her acceleration is greater or equal than $0.5 m/s^2$ (in absolute value, sharp decelerations also count). Then, classify the drivers according to their time being aggressive as follows:

Type of driver	% of time being aggressive
Aggressive	> 60
Smooth	< 30
Standard	Otherwise

For the sake of simplicity, in this analysis, consider only cars and the 2nd model (step 3). Compute the shares of each type of driver and their average emissions of CO_2/km. Comment on the differences among the average emissions per km depending on the type of driver and evaluate the potential savings.

References:

Frey et al (2003) On-Road Measurement of Vehicle Tailpipe Emissions Using a Portable Instrument, Journal of the Air & Waste Management Association, 53:8, 992-1002

Frey et al. (2008). Fuel use and emissions comparisons for alternative routes, time of day, road grade, and vehicles based on in-use measurements. Environmental Science & Technology 42, 2483-2489