Macroscopic Traffic Variables

CIVE.5490, UMass Lowell

Zhengbing He, Ph.D.
https://www.GoTrafficGo.com

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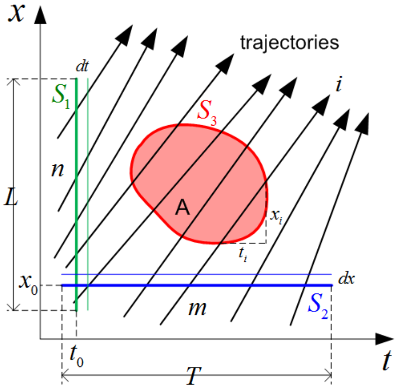
Measurement intervals

Three types of t-x intervals for the measurement:

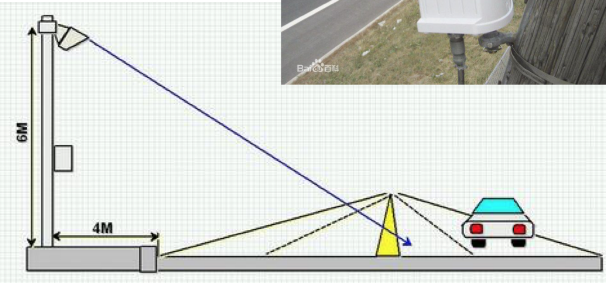
- **S1**-such as aerial photograph
- **S2**-such as loop detectors
- **S3**-such as drones.

When trajectory data is available, **S3** are the most appropriate.

Edie's generalized definitions



Remote traffic monitor sensor (RTMS)



Video surveillance

Drone

Germany: HighD

https://levelxdata.com/highd-dataset/

IEEE 21st International Conference on Intelligent Transportation Systems (ITSC), Maui, Hawaii, USA, November 2018

The highD Dataset: A Drone Dataset of Naturalistic Vehicle Trajectories on German Highways for Validation of Highly Automated Driving Systems

Robert Krajewski, Julian Bock, Laurent Kloeker and Lutz Eckstein

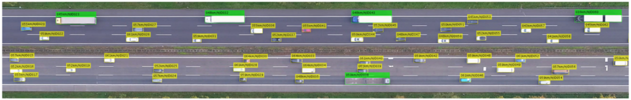
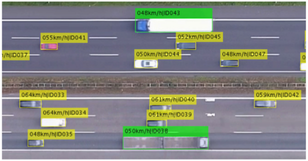


Figure 1. Example of a recorded highway including bounding boxes and labels of detected vehicles. The color of the bounding boxes indicates the class of the detected object (car: yellow, truck: green). Every vehicle is assigned a unique id for tracking and its speed is estimated over time.



Switzerland: pNEUMA

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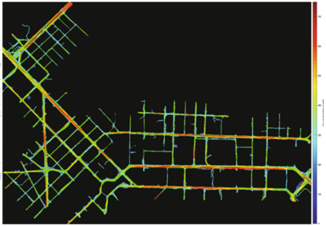
On the new era of urban traffic monitoring with massive drone data: The *pNEUMA* large-scale field experiment

Emmanouil Barmpounakis, Nikolas Geroliminis*

École Polytechnique Fédérale de Lausanne (EPFL), Station 18, CH-1015 Lausanne, Switzerland



Macroscopic Variables

Three main macroscopic variables:

- Density, k (veh/km)
- Flow, q (veh/h)
- Speed, v (km/h)

Unit is the key

Density, k (veh/km)

Definition: vehicle number per distance unit at a time slice.

- **S1**: $k(x, t_0, L) = \frac{n}{L}$

  from the definition

- **S3**: $k(x, t, A) = \frac{n}{L} = \frac{ndt}{Ldt} \approx \frac{total\ \ time\ \ spent\ \ by\ \ all\ \ vehicles\ \ in\ \ A}{Area\ \ A}$

  we write as $\boldsymbol{k(A) = \frac{t(A)}{|A|}}$

  expand the definition to an area

- **S2**: $k(x_0, t, T) = \frac{\sum_m \frac{dx}{v_i}}{Tdx} = \frac{\sum_m \frac{1}{v_i}}{T}$

  apply $\frac{total\ \ time\ \ spent\ \ by\ \ all\ \ vehicles\ \ in\ \ A}{Area\ \ A}$ in S3 to S2 area

Flow (rate), q (veh/h)

Definition: vehicle number passing a cross-section per time unit.
We call the *maximum possible flow* as **capacity**.
Capacity of a highway lies between 1800 $\sim$ 2400 veh/h per lane.

- **S2**: $q(x_0, t, T) = \frac{m}{T}$

  from the definition

- **S3**: $q(x, t, A) = \frac{mdx}{Tdx} \approx \frac{Total\ \ distance\ \ covered\ \ by\ \ vehicles\ \ in\ \ A}{Area\ \ A}$

  we write as $\boldsymbol{q(A) = \frac{d(A)}{|A|}}$

  expand the definition to an area

- **S1**: $q(x, t_0, L) = \frac{\sum_n v_i dt}{Ldt} = \frac{\sum_n v_i}{L}$

  apply $\frac{total\ \ distance\ \ covered\ \ by\ \ vehicles\ \ in\ \ A}{Area\ \ A}$ in S3 to S1 area

Speed, v (km/h)

Definition: the mean speed v as the quotient of the flow rate and the density; i.e., $v = q/k$

Two types:

- Space-mean speed: $v = q/k$
- Time-mean speed: $v_t = \frac{1}{m}\sum_m v_i$

Note: time-mean speed does NOT comply with $v = q/k$ (the fundamental diagram)

Speed, v (km/h)

- **S1**: using the flow and density equations in S1

$$v(x, t_0, L) = \frac{\sum_n v_i}{L} / \frac{n}{L} = \frac{1}{n} \sum_n v_i$$

Note: space-mean speed=time-mean speed. We thus define the space-mean speed for a location interval (S1) as: $\frac{1}{n} \sum_n v_i$

- **S2**: using the flow and density equations in S2

$$v(x_0, t, T) = \frac{m}{T} / \frac{\sum_m \frac{1}{v_i}}{T} = \frac{m}{\sum_m \frac{1}{v_i}}$$

- **S3**: Using definition:

$$v(x, t, A) = \frac{q(x,t,A)}{k(x,t,A)} \approx \frac{Total\ distance\ covered\ by\ vehicles\ in\ A}{Total\ time\ spent\ by\ vehicles\ in\ A}$$

we write as $\boldsymbol{v(A) = \frac{d(A)}{t(A)}}$

the measurement area A no longer appears

Distinguishing space-mean and time-mean speed

Example problem: in a two-lane road, vehicles travel at 60km/h on the left lane and at 120km/h on the right lane. Assume that 1200 veh/h pass on each lane. What are the density, the flow, the (space-mean) speed and the time-mean speed on this road?

The solution is:

- $q = 1200 * 2 = 2400 veh/h$
- $k = 1200/60 + 1200/120 = 30 veh/km$
- $v = q/k = 80 km/h$
- $v_t = (120 + 60)/2 = 90 km/h$

Relative occupancy (no unit)

Definition: The ratio of [the time that vehicles spend on passing a cross-section] to [the detection period T]

- The occupancy o of a vehicle is easy to obtain in **S2**; i.e., loop detectors in practice.

  The relative occupancy b in **S2** is given by:

  $$b(x_0, t, T) = \frac{1}{T} \sum_m o_i$$

- If assume all vehicles have the same length L, we can get:

  $$b(x, t_0, L) = Lk(x, t_0, T)$$ – How to derive it

  $$b(x, t_0, L) = \frac{1}{T} \sum_m o_i = \frac{1}{T} \sum_m \frac{L}{v_i}$$
  $$= L \frac{\sum_m \frac{1}{v_i}}{T} = Lk(x, t_0, T) \leftarrow k \text{ in } \mathbf{S2}$$

  Recall the definition of occupancy: L/v_i

Note: this formula is not appropriate in practical situations because inhomogeneity of the real traffic flow. If want to find density by using detectors, it is relatively better to use $k = q/v$.

Homogeneous and stationary traffic

- Homogeneous traffic: the vehicles are identical;
- Stationary traffic: the traffic state (described by the macroscopic variables) does not change over time

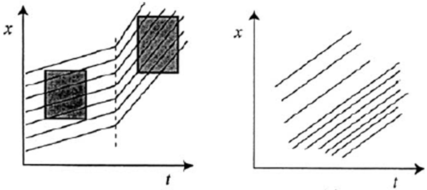
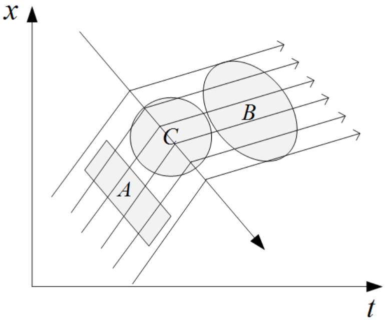


Figure: Examples of non-stationary traffic

Summary about Edie's definitions

Edie's definitions are important because it allows one to compare the behavior of two traffic streams even if they have been observed in different ways, such as the comparison of A and B.

One should try to avoid the non-stationary area, such as C, because one value of the macroscopic variable only corresponds to one traffic state.



Summary about macroscopic traffic variables

The discrete nature of traffic requires time intervals of at least half a minute if we want to achieve meaningful macroscopic information. When the time intervals exceed a duration of five minutes, certain dynamic characteristics are lost.

Thank you!