CIVL 2030: Introduction to Transportation Engineering

Rensselaer | SCHOOL OF ENGINEERING

Chapter 5: Fundamentals of Traffic Flow and Queuing Theory

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Today's Outline

- Introduction
- Traffic Stream Parameters
  - Traffic Flow, Speed, Density
- Basic Traffic Stream Models
  - Speed density model
  - Flow Density Model
  - Speed Flow Model
- Models of Traffic Flow
  - Poisson Model
  - Limitations of the Poisson Model

Today's Outline

- Queuing Theory and Traffic Flow Analysis
  - Dimensions of Queuing Models
  - D/D/1 Queuing
  - M/D/1 Queuing
  - M/M/1 Queuing
  - M/M/N Queuing
- Traffic Analysis at Highway Bottlenecks

Introduction

- Analysis of vehicle traffic provides the basis for measuring the operating performance of highways.
- Aspects that are addressed on traffic analysis:
  - Vehicles per unit of time
  - Vehicle type
  - Vehicle speed
  - Variation of traffic flow
- In light of this, analysis of traffic flow and queuing provides groundwork for quantifying measures of performance.

Traffic Stream Parameters

- Two types:
  - Uninterrupted Flow – traffic stream that operates free from the influence of such traffic control devices as signals and stop signs.
  - Interrupted Flow – traffic streams that operate under the influence of signals and stop signs.

- Environmental conditions can also affect the flow of traffic.

Night Driving

Fog

Traffic Flow, Speed, Density

- Traffic Flow: $$q = \frac{n}{t}$$ (5.1)

- Where:
  - q = traffic flow in vehicles per unit time
  - n = number of vehicles passing some designated roadway point during time t
  - t = duration of time interval

Units are Veh/h even though the analysis flow rate is usually based on the peak 15 minute flow.

Traffic Flow, Speed, Density

- Headway - time between the passage of the front bumpers of successive vehicles, at some highway point.
- Time headways are related to *t*, as defined in Eq. 5.1, by

$$t = \sum_{i=1}^{n} h_i \qquad (5.2)$$

- Where:

  t = duration of time interval

  h_i = time headway of the ith vehicle (the time that has transpired between the arrival of vehicle i and i-1)

  n = number of measured vehicle time headways at some designated roadway point.

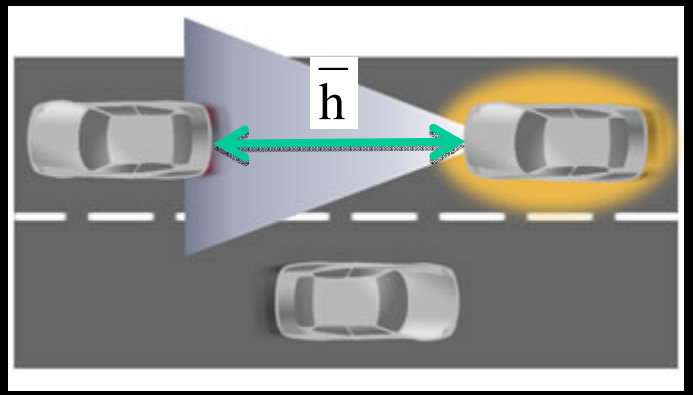
Traffic Flow, Speed, Density

Substituting Eq. 5.2 into Eq. 5.1 gives

$$q = \frac{n}{\sum_{i=1}^{n} h_i} \quad \text{or} \quad q = \frac{1}{\overline{h}} \qquad (5.3 \text{ and } 5.4)$$

- Where:

  $\overline{h}$ = is the average time headway, ($\sum h_i / n$), in unit time per vehicle.



Traffic Flow, Speed, Density

- Average traffic speed is defined in two ways"
  - **Time mean speed**

$$\overline{u}_t = \frac{\sum_{i=1}^{n} u_i}{n} \qquad (5.5)$$

- Where:

  $\overline{u}_t$ = time-mean speed in unit distance per unit time

  u_i = spot speed (the speed of the vehicle at the designated point on the highway) of the ith vehicle

  n = number of measured vehicle spot speeds

Traffic Flow, Speed, Density

- Space mean speed

$$\bar{u}_s = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1}{(l/t_i)}\right]} \qquad (5.9)$$

- Where

  $\bar{u}_s$ = space mean speed in unit distance per unit time

  l = length of roadway used for travel time measurements of vehicles

  t_i = time necessary for vehicle i to travel a roadway section of length l

  n = number of measured vehicle travel times

Traffic Flow, Speed, Density

Example

- You own two cars, they are both driven an equal distance and one gets 20 mpg, the other 50mpg. Is the average mpg 35 (50+20)/2?
  - No....say they are each driven 100 miles. The 50mpg car consumes 2 gallons the 20mpg car, 5 gallons. This gives 7 gallons for 200 miles or 28.75mpg (not 35 mpg).

$$\text{average mpg} = \frac{1}{\frac{1}{2}\left[\frac{1}{50} + \frac{1}{20}\right]} = 28.57\text{mpg}$$

Traffic Flow, Speed, Density

- Traffic Density

$$k = \frac{n}{l} \qquad (5.10)$$

- Where:
  - k = traffic density in vehicles per unit distance
  - n = number of vehicles occupying some length of roadway at some specified time
  - l = length of roadway
- Density can also be expressed as the inverse of the average spacing between vehicles.

Traffic Flow, Speed, Density

- The simple identity provides the basic relationship among traffic flow, speed (space-mean speed), and density is,

$$q = uk \qquad (5.14)$$

- Where:

  q = flow, typically in units of vehicles per hour (veh/h)

  u = speed (space mean speed), typically in units of mi/h (km/h)

  k = density, typically in units of veh/mi (veh/km)

Basic Traffic Stream Models

- Models that provide understanding of the interaction of the individual macroscopic measures in order to fully analyze the operational performance of traffic stream.

Speed Density Model