Traffic Stream Models

Vehicular Following: \[ s = v\delta + \frac{v^2}{2d_l} + \frac{v^2}{2d_f} + L + x_o \]

- \( v \): initial speed of the two vehicles
- \( d_l \): deceleration of the leading vehicle
- \( d_f \): deceleration of the following vehicle
- \( \delta \): perception-reaction time
- \( x_o \): safety margin after stop
- \( L \): length of vehicle

Safety Consideration:

- \( d_n \): Comfortable (normal) deceleration
- \( d_e \): Emergency deceleration
- \( \infty \): Instantaneous or “stone wall” stop

Stream Variables

- Spacing and Concentration: \( s = \frac{1}{k} \)
- Headway and Flow: \( h = \frac{1}{k} \)
- Average Mean Speed
The Fundamental Equation of a Vehicular Stream

\[ Q = VK \]

The three variables (Q, V, and K) vary simultaneously.

The case of Uniform flow:

\[ k = \frac{1}{v} \]

\[ k = f(v) = \frac{1}{v \delta + \frac{v^2}{2a} + L + x_q} \]

\[ q = f(v) = \frac{v}{v \delta + \frac{v^2}{2a} + L + x_q} \]

Car-following Models:
- Describes the relationship between the driver’s desired speed (acceleration) and the distance headway from a preceding vehicle
- Describe steady-state flow
- Microscopic in nature

Traffic Stream Models

Individual Models
1. Single-Regime Models (Same model for uncongested and congested)
2. Multiregime Models (Different model for uncongested and congested)

Family of Models
1. Single-Regime Models
2. Multiregime Models

Traffic Stream Models

Traffic Stream Models
**Single-Regime Models**

1. Greenshields
2. Greenberg
3. Underwood
4. Northwestern
5. Pipes
6. Van Aerde

**Greenshields Single-Regime Models**

Based on GM-3 car Following Model
Assume Linear Density/Speed Relationship

\[ d = \frac{C_s}{v_f - v} \]

where \( C_s = \frac{v_f}{k_f} \) ->

\[ v = v_f - \left( \frac{v_f}{k_f} \right) k \]

**Greenberg Single-Regime Models**

Non-linear model based on equation of motion and continuity for one-dimensional compressible flow

\[ v = v_f \left( \frac{k_f}{k} \right) \]

\( v_o \) = optimal speed

**Underwood Single-Regime Models**

\[ v = v_f \left( \frac{k'}{k_o} \right) \]

\( k_o \) = Optimal Density
Traffic Stream Models

**Northwestern Single-Regime Models**

\[ v = \frac{V}{k_o} e^{-0.5 \left( \frac{k_o}{k} \right)^2} \]

\( k_o \) = Optimal Density

**Pipes Single-Regime Models**

The car-length for each 10 mph rule

Assume Linear Density/Speed Relationship

\[ d = C_1 + C_2 v \quad \Rightarrow \quad v = \frac{1}{C_1} \left( \frac{1}{k} \frac{1}{k_f} \right) \]

**Multi-Regime Models**

More than one model to cover different density regions [Driver behavior might be different in the two regions]

*Edie proposed:

\[ k \leq 50 \quad v = 54.9 e^{-k/169.9} \]

\[ k > 50 \quad v = 28.6 \ln \left( \frac{162.5}{k} \right) \]

**Van Aerde Single-Regime Models**

Introduced new parameter that can be calibrated using filed data

\[ d = C_1 + C_2 v + \frac{C_3}{v_f - v} \quad \Rightarrow \quad k = \frac{1}{C_1 + \frac{C_2}{v_f - v} + C_3 v} \]
**Traffic Stream Models**

**Proposed family of Models**

\[ v^{\infty} = v_f^{\infty} \left[ 1 - \left( \frac{k_f}{k_r} \right)^{\frac{1}{r-1}} \right] \]

**Shock Waves**

**Shock Wave Speed**

\[ v_{AB} = \frac{Q_f - Q_s}{k_f - k_s} = \frac{\Delta Q}{\Delta k} \]

Positive Shock Wave \((v_{AB} > 0)\):  
Shock Wave Moving **IN** the direction of traffic

Negative Shock Wave \((v_{AB} < 0)\):  
Shock Wave Moving **AGAINST** the direction of traffic

**Traffic Stream Models Applications: Shock Waves**

**Classification:**

- **Frontal**
  - Stationary \((v_{AB} = 0)\)
  - Forming
  - Recovery

- **Backward**
  - Stationary \((v_{AB} = 0)\)
  - Forming
  - Recovery
A vehicular stream at point "A" has the following characteristics: $Q = 1200$ vph and $k = 100$ vpm is interrupted by a flag-person for 5 min beginning at time $t = t_0$. At time $t = t_0 + 5$ min vehicles at the front of the stationary platoon begin to be released at $Q = 1600$ vph and $v = 20$ mph.

Assuming that $kj = 240$ vpm, a) plot the location of the front of the platoon versus time and the location of the rear of the platoon versus time and (b) plot the length of the growing platoon versus time.