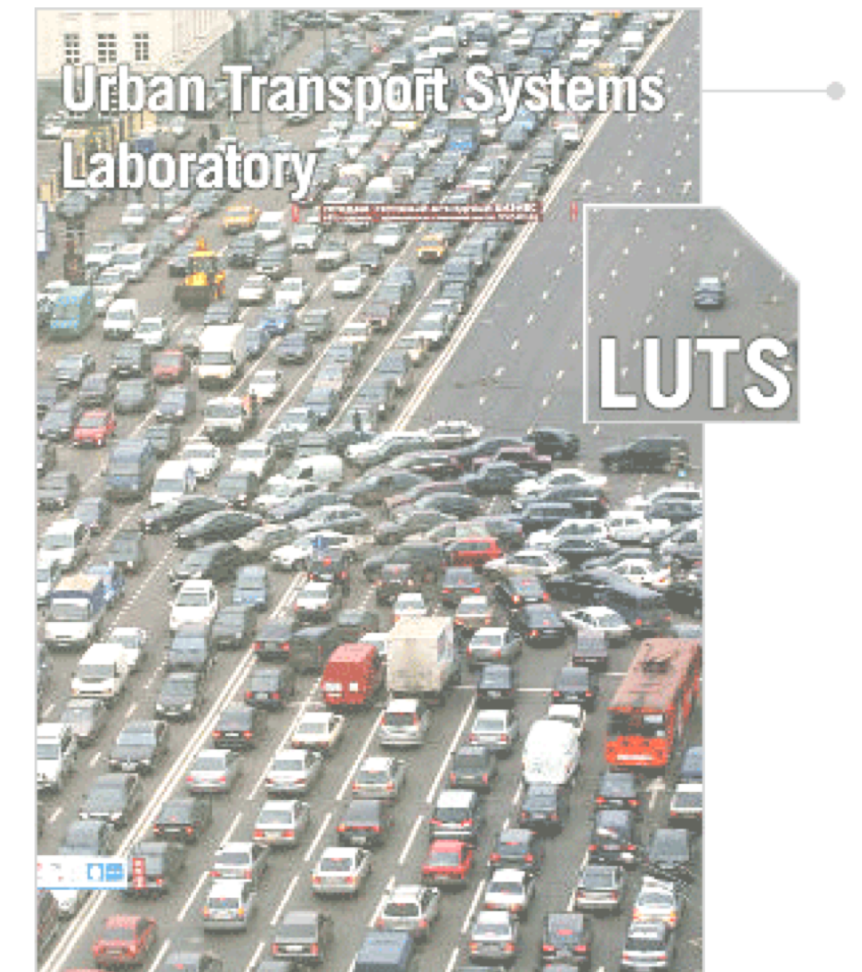


# Fundamental Diagram

**Intro to traffic flow modeling and ITS**

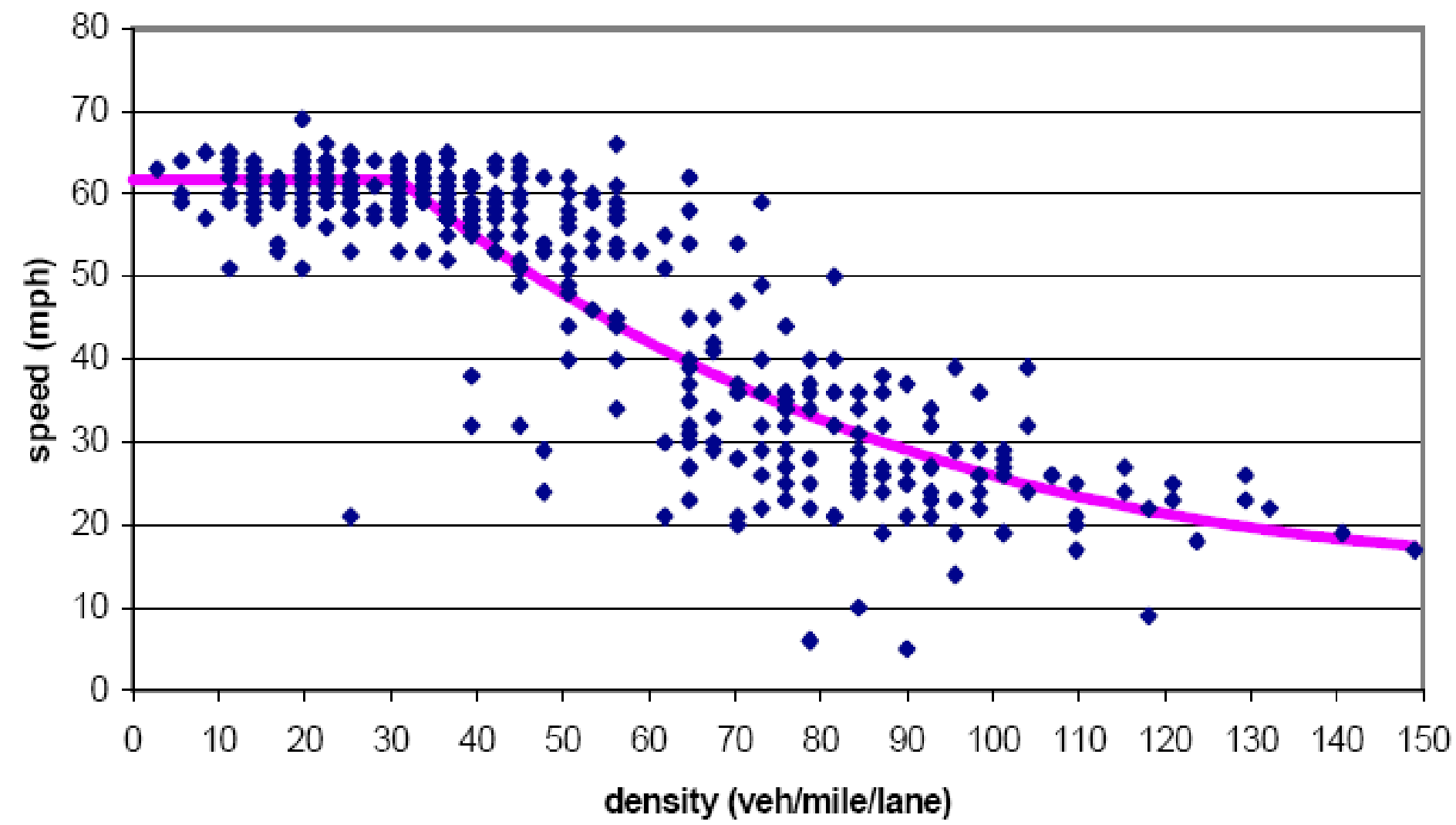
Prof. Nikolas Geroliminis



# Welcome



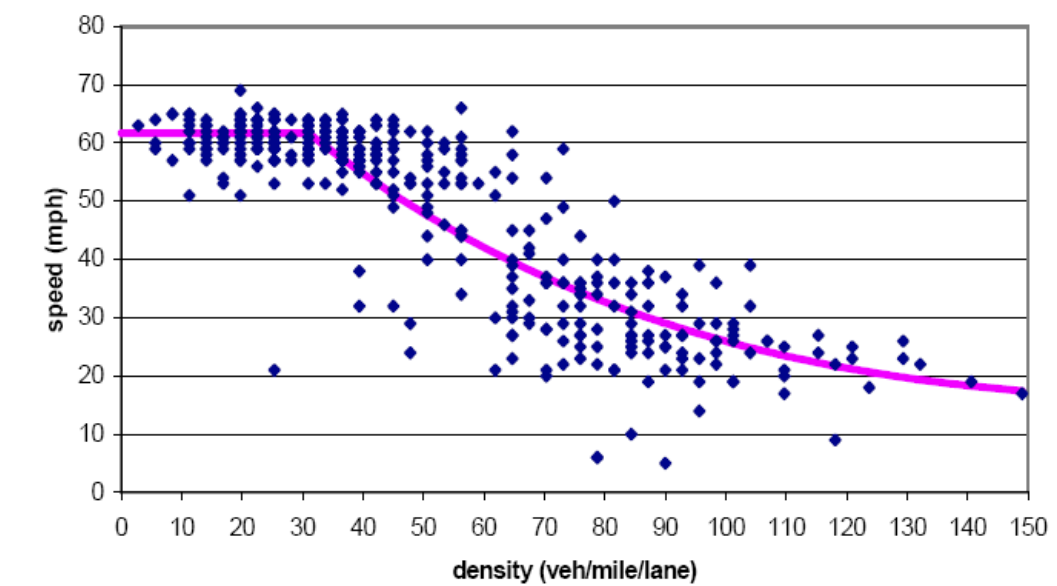
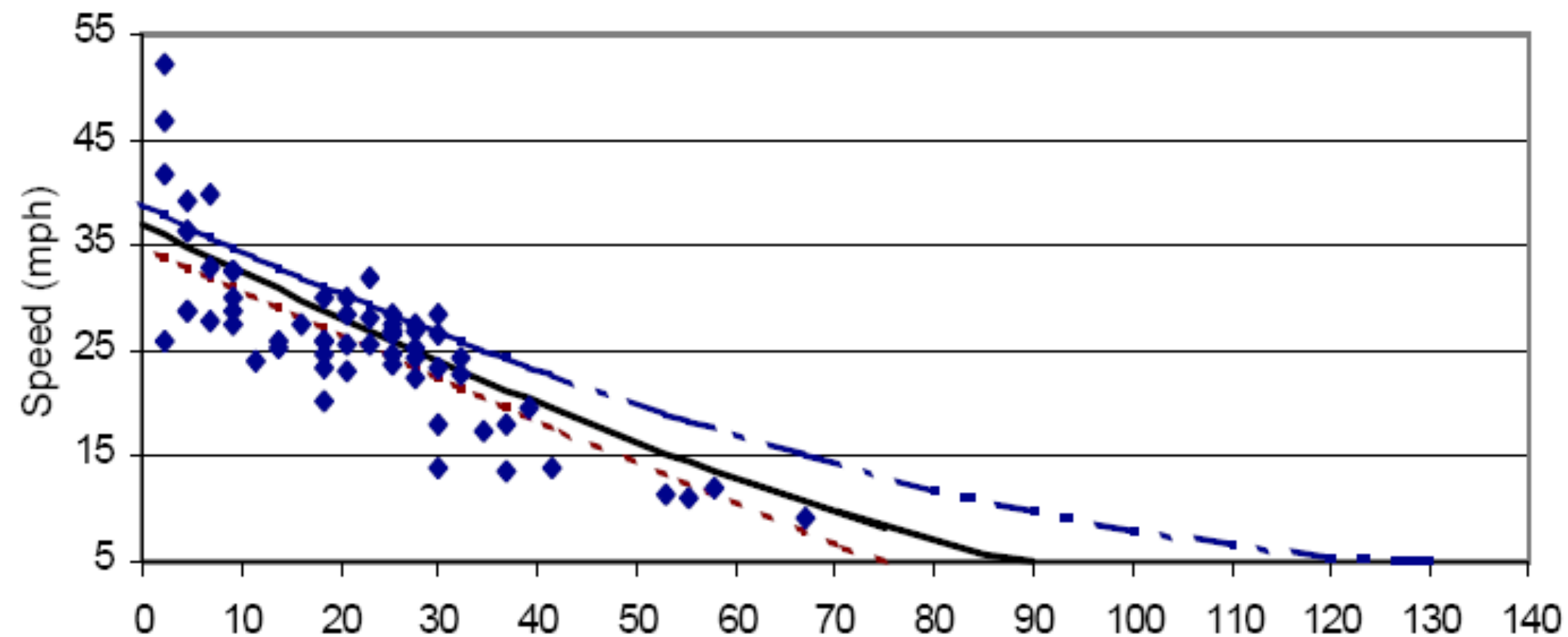
# Field observations (Freeways)



Scatter is due to:

- Heterogeneity of drivers
- Weather conditions
- Type of vehicles
- Non-stationary conditions

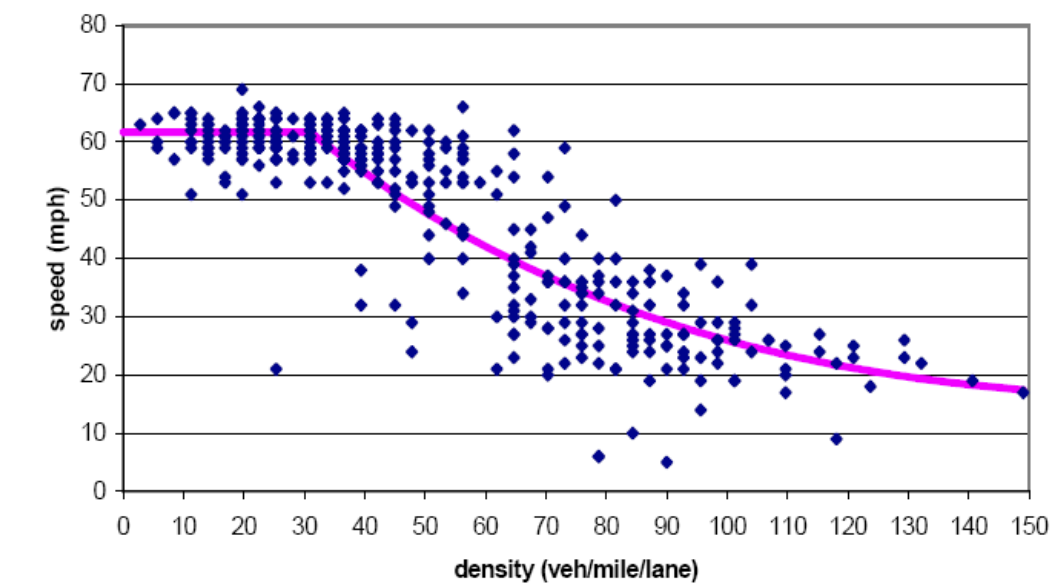
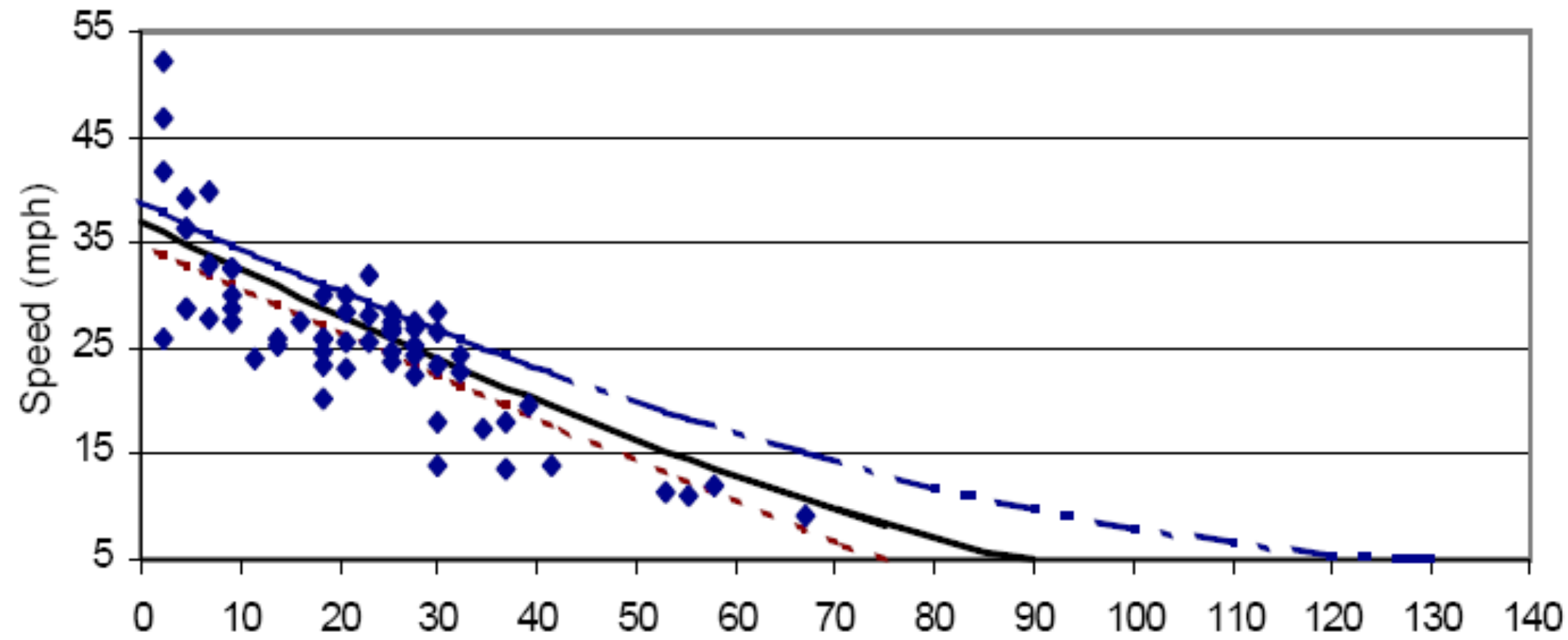
# Field observations (Arterials)



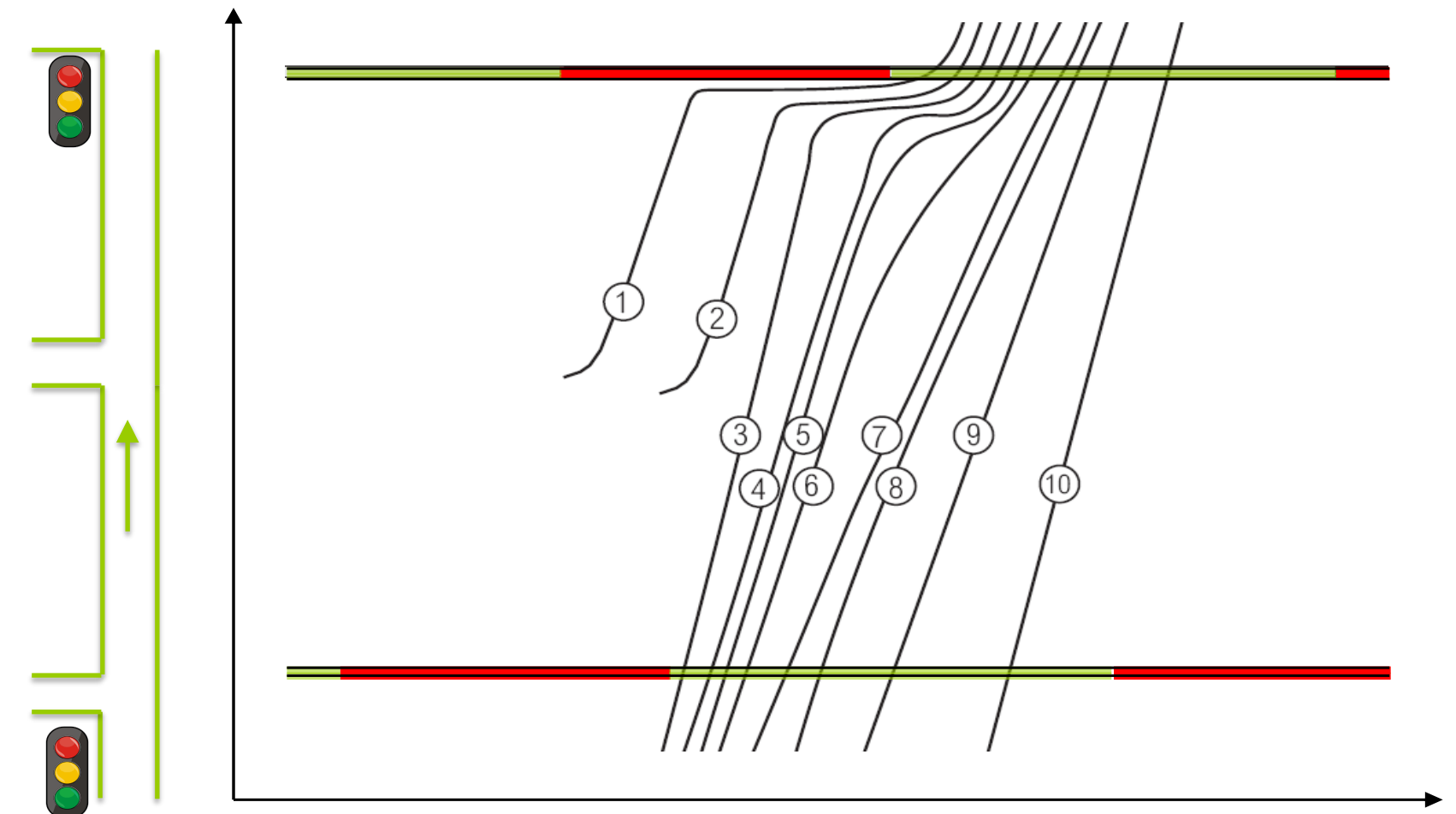
Observations:

- Arterial FD has more scatter for high speed
- Arterial FD is decreasing for low density

# Field observations (Arterials)



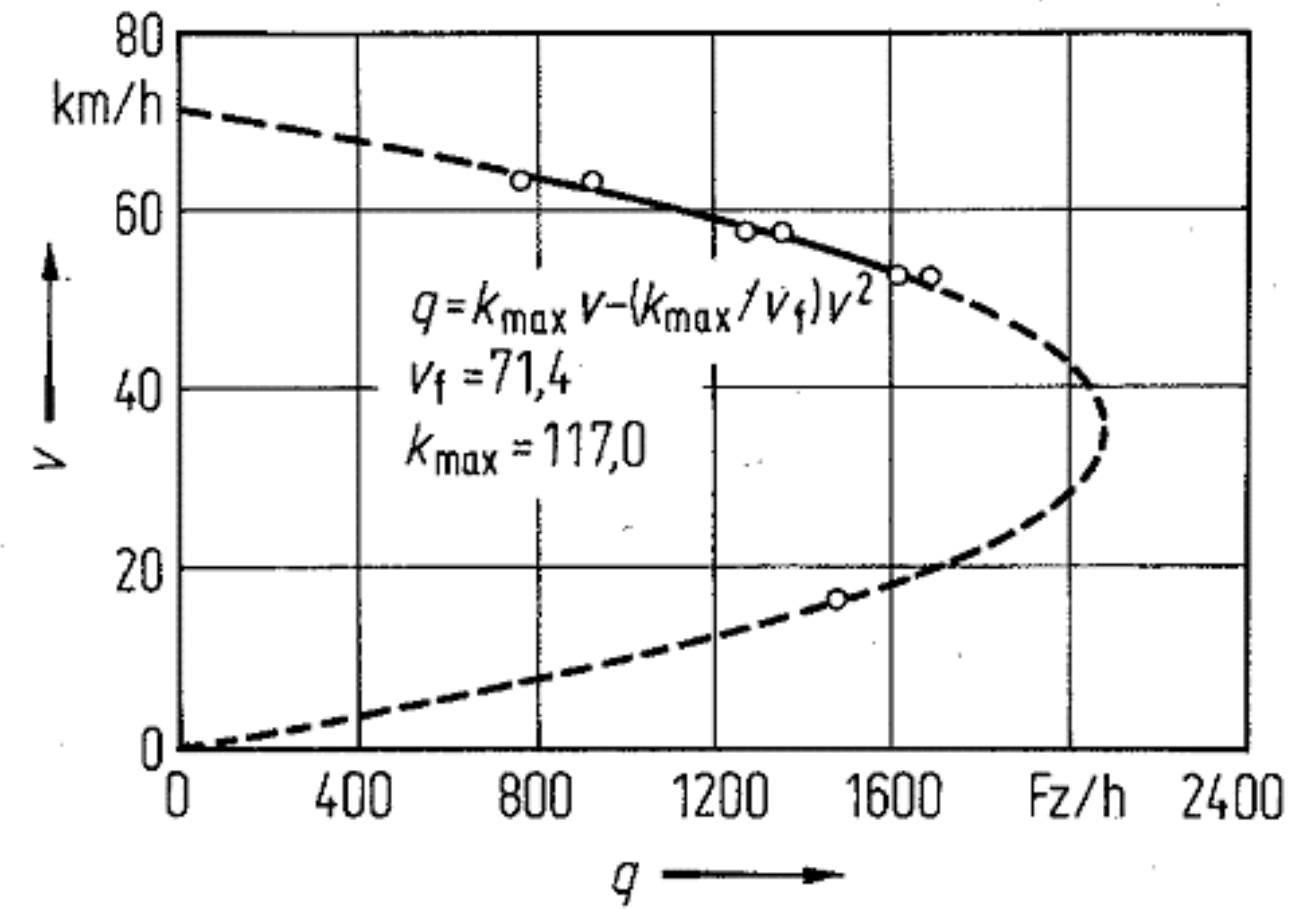
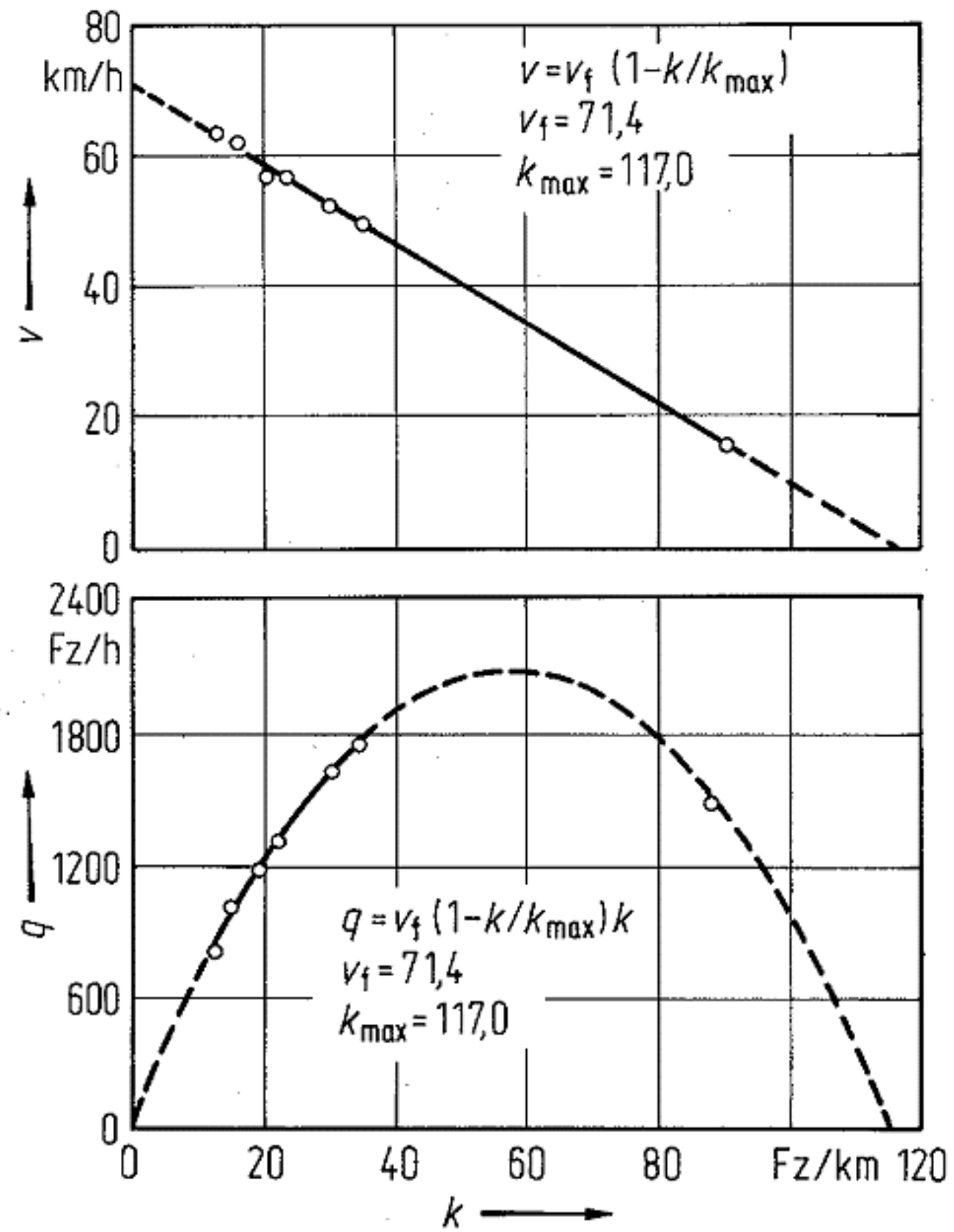
The effect of queues



# First Empirical observations (Greenshields, 1935)



# Greenshield's FD



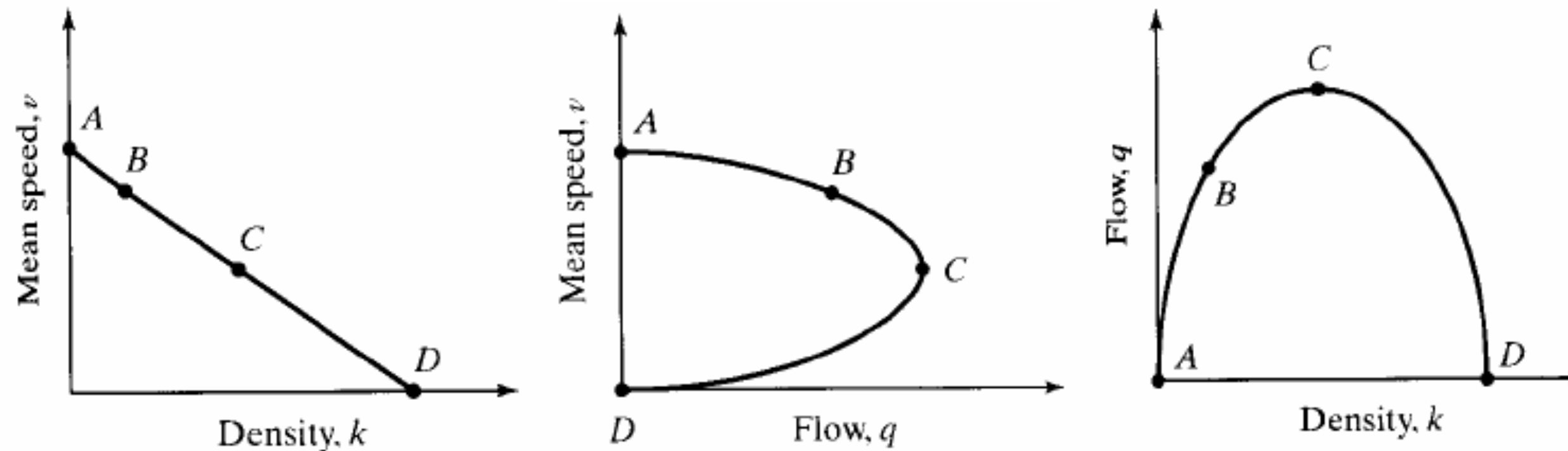
# Characteristics of relations among $v$ , $q$ , $k$

A: almost zero density, free flow speed, very low flow

B: higher density, reduced speed, higher flow

C: critical density, critical speed, max flow

D: jam density, min speed, very low flow

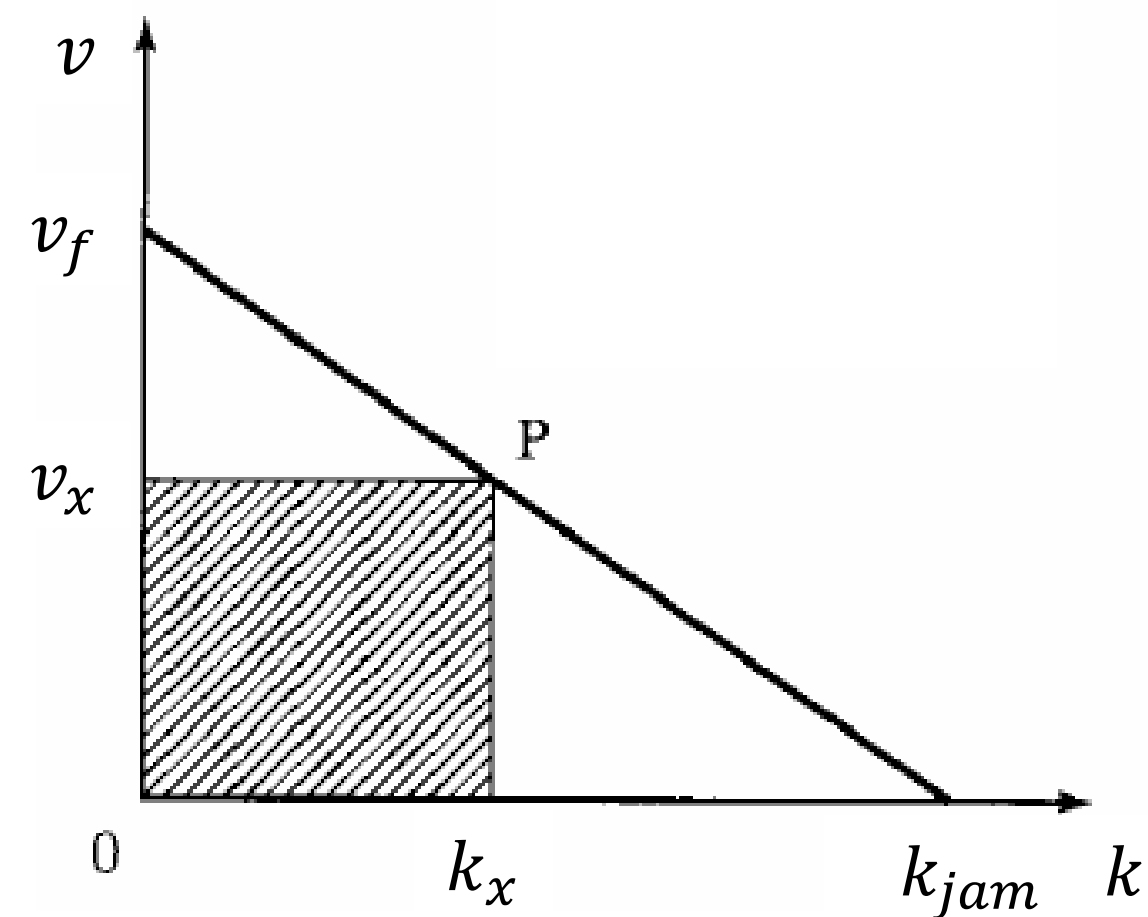


How one can estimate flow in the speed-density FD?

What is the speed that maximizes flow?

$$v = v_f \left(1 - \frac{k}{k_{jam}}\right)$$

$$q = v_f \left(k - \frac{k^2}{k_{jam}}\right)$$

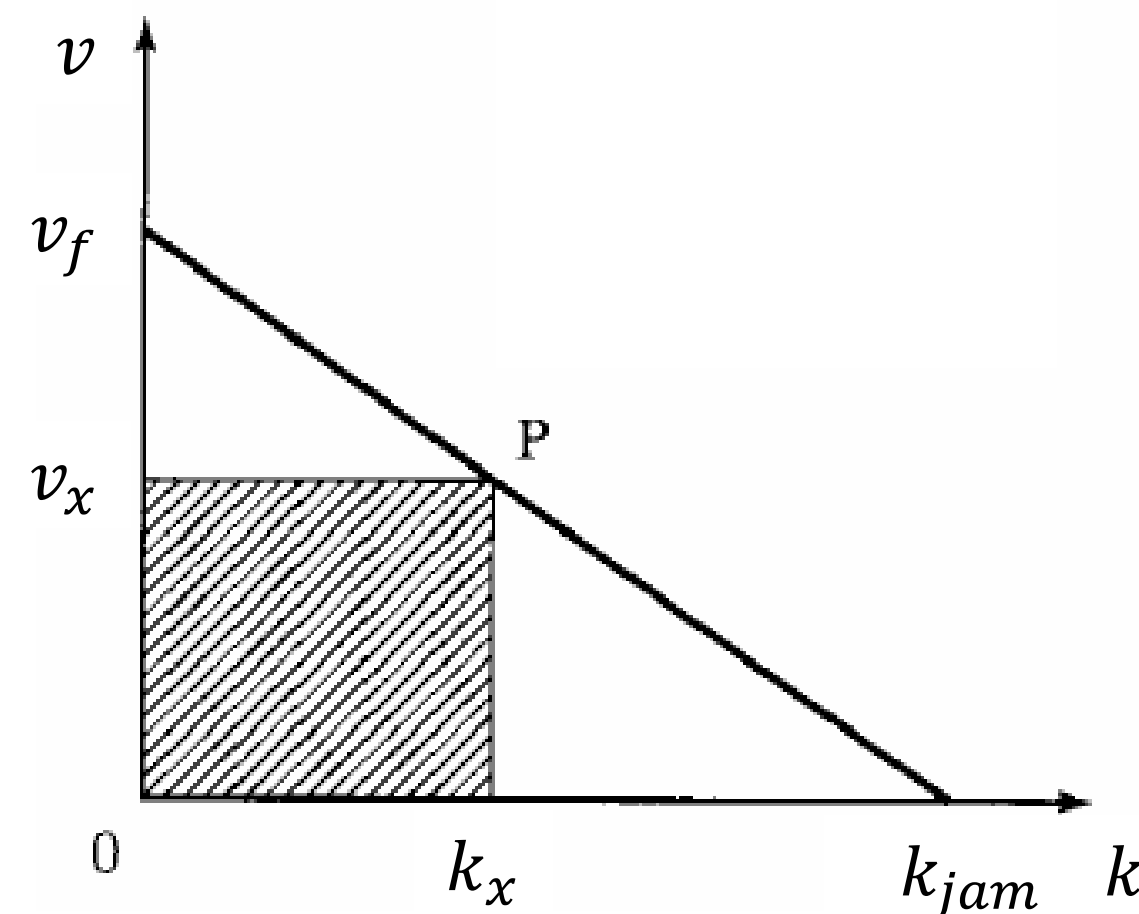


How one can estimate flow in the speed-density FD?

What is the speed that maximizes flow?

$$v = v_f \left(1 - \frac{k}{k_{jam}}\right)$$

$$q = v_f \left(k - \frac{k^2}{k_{jam}}\right)$$



$$\frac{dq}{dk} = v_f \left(1 - \frac{2k}{k_{jam}}\right) = 0$$

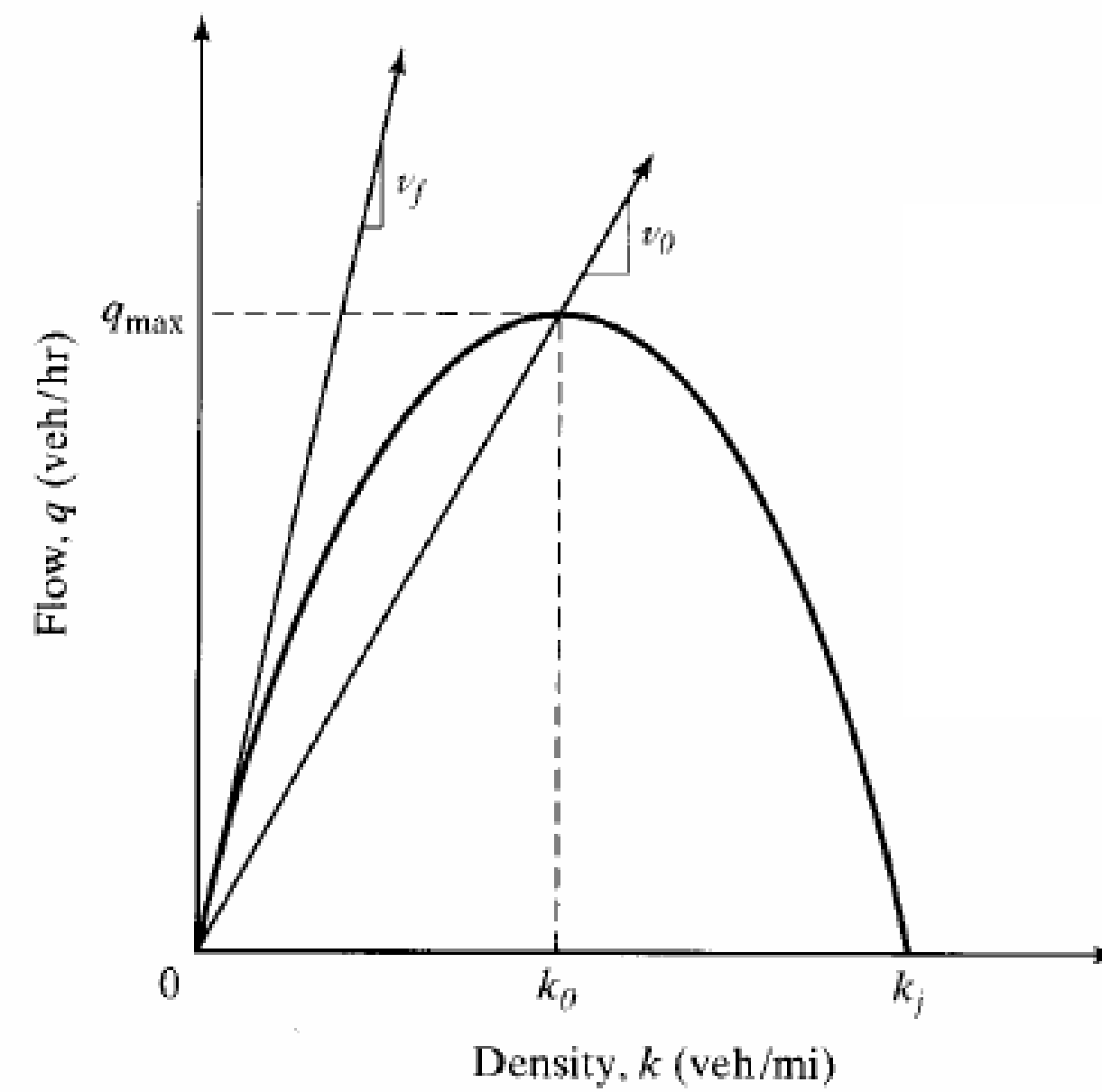
$$k_{cr} = \frac{k_{jam}}{2}$$

$$u_{cr} = 0.5u_f$$

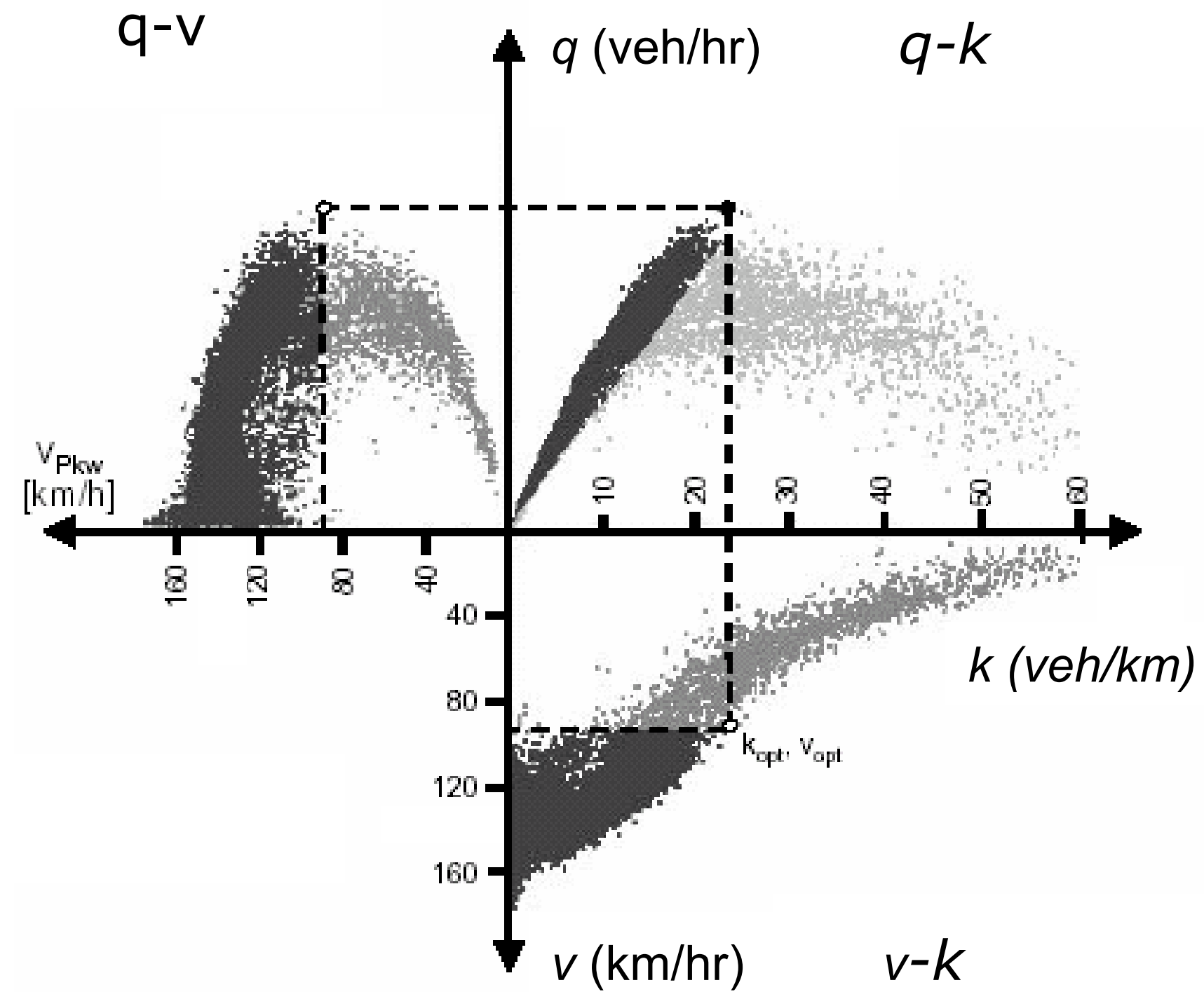
$$q_{max} = u_f k_{jam} / 4$$

# Flow - density FD

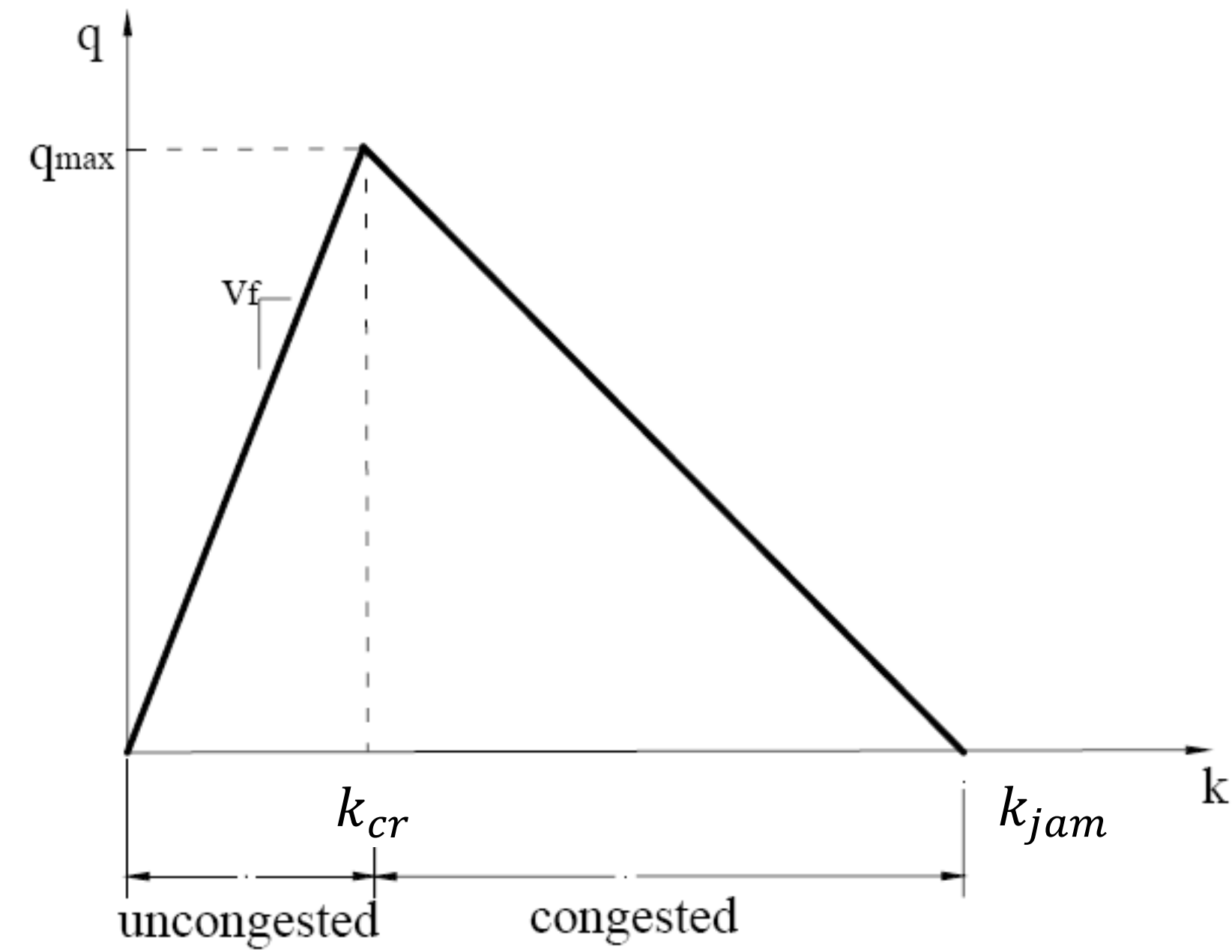
How one can estimate speed in the flow-density FD?



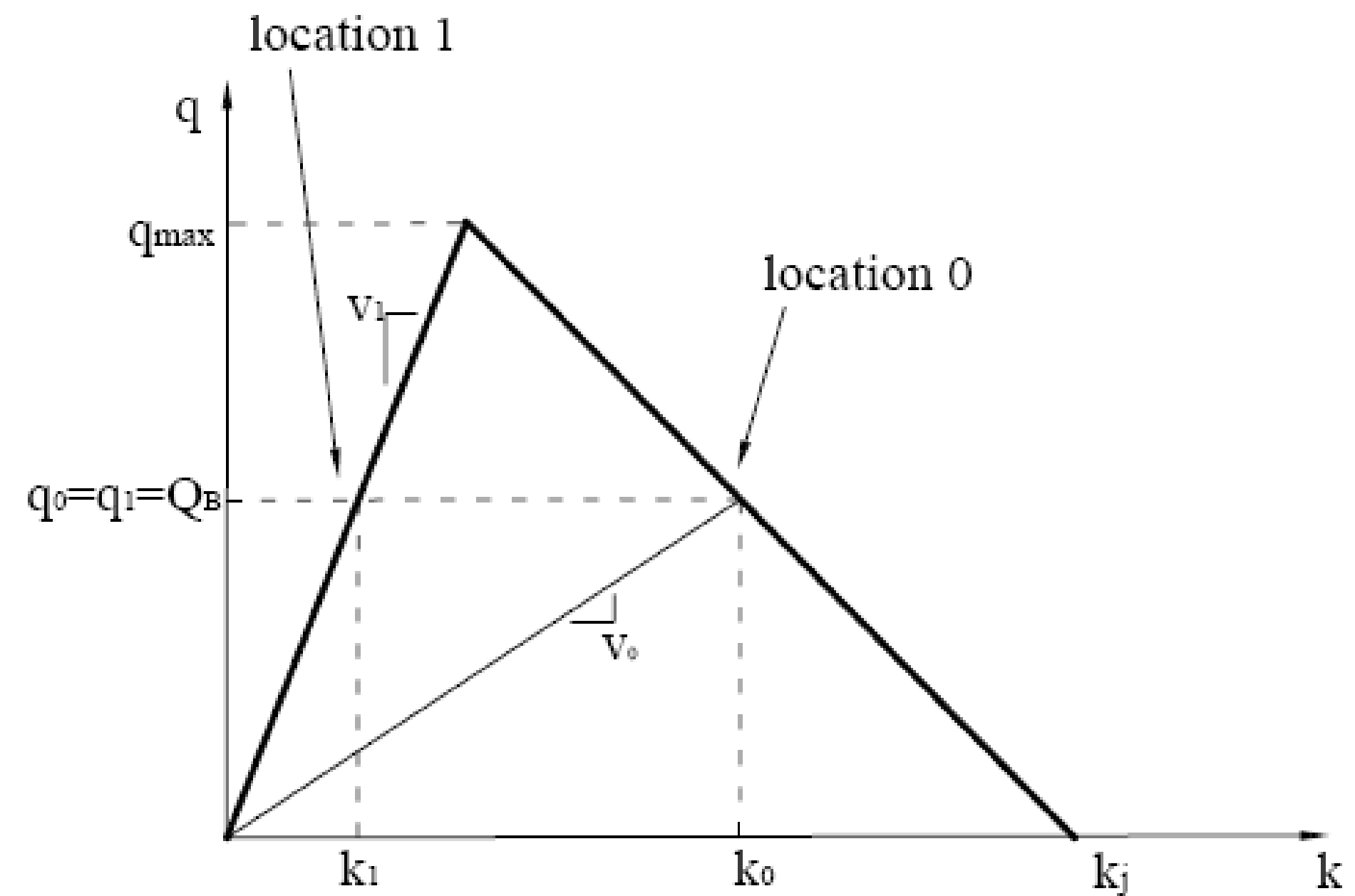
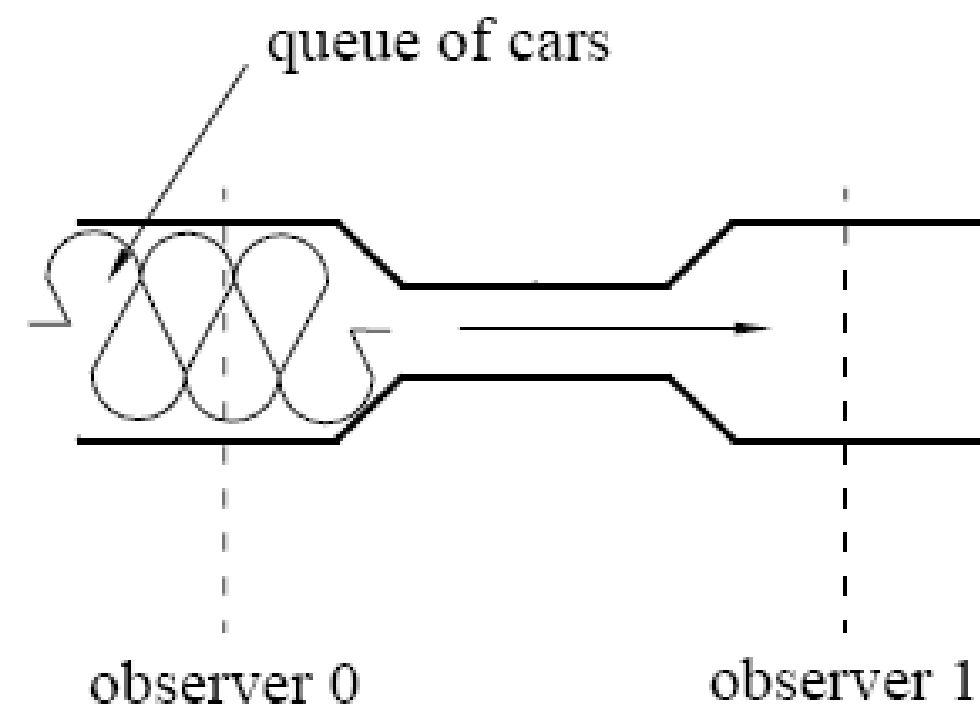
# Other empirical data



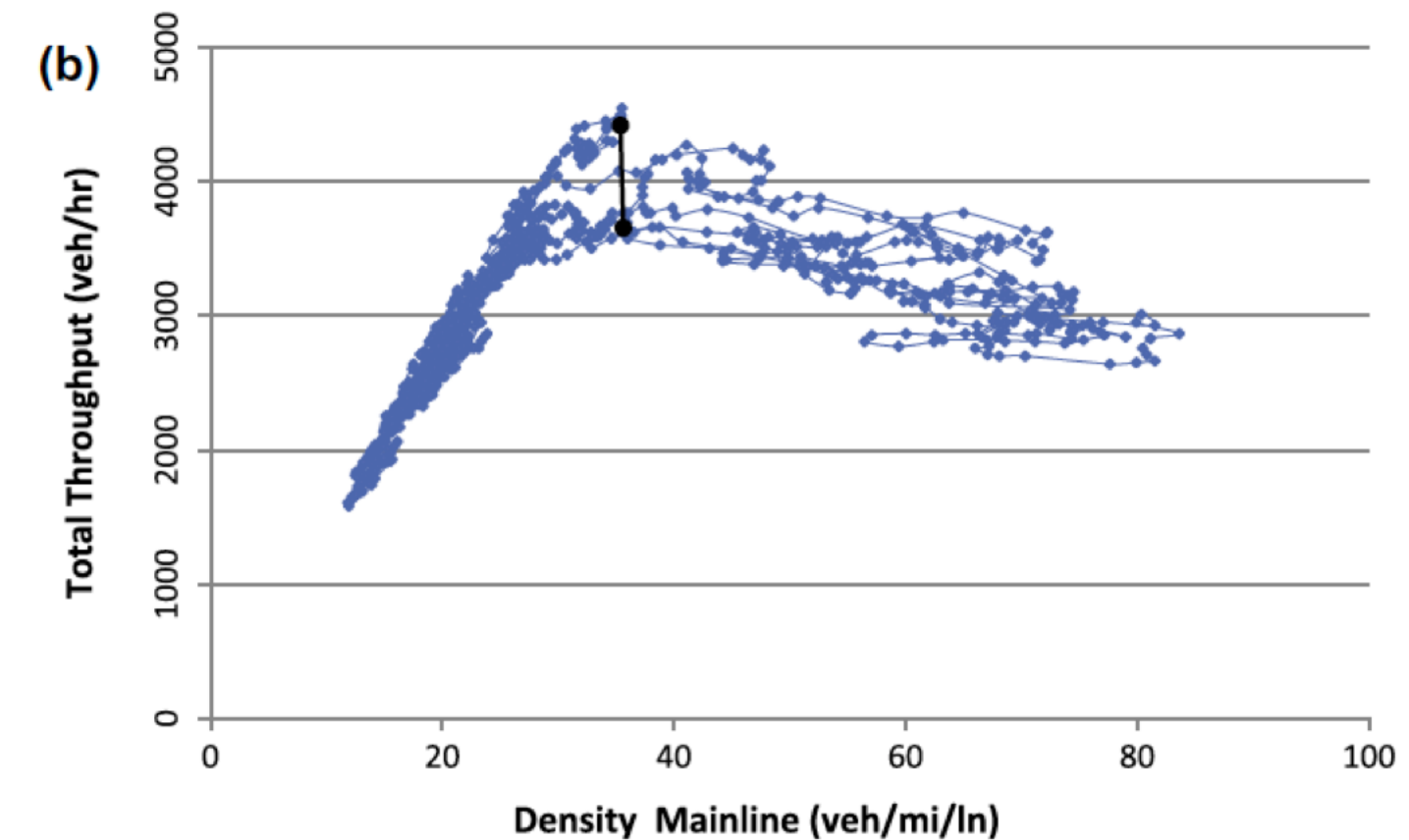
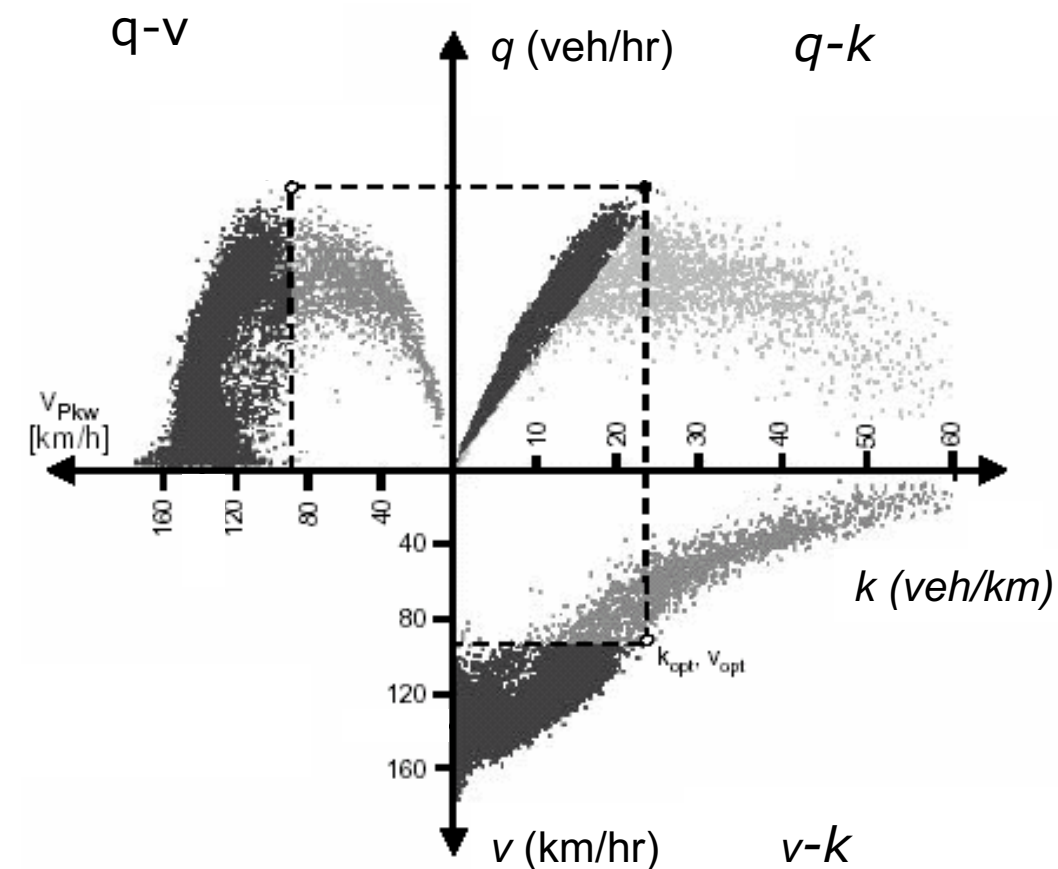
# A triangular FD



# The effect of bottlenecks on FDs



# Capacity drop phenomena



- Many studies have revealed that there is a stochastic nature of bottleneck capacities.
- [Banks \(1991\)](#) first suggested that discharge flow at bottlenecks diminishes once queues start forming upstream of the location.

# Summary