

Unit 2: Traffic Behaviour and Traffic Theory Fundamentals

Module 2-2

Fundamental Speed-Flow-Density Relationships



Traffic Management Training Module



Today's presenter



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Outline of this Module

- Basic Traffic Variables
- Relationship Between Basic Traffic Variables
- Fundamental Diagram (FD)

Section 2.1 – 2.4 of Guide to Traffic Management Part 2: Traffic Theory Concepts Austroads (2020)



Basic Traffic Variables



Introduction



- Streams of traffic are comprised of individual vehicles, driven by individual drivers, interacting with each other and the roadway environment.
- Because each driver behaves in a unique way, it is not possible to describe traffic flow as theoretically concisely as other purely physical phenomena.
- But we still need quantitative techniques to assess operational measures.



Introduction

- **Uninterrupted Flow**

a traffic stream which is not delayed or interfered with elements external to the traffic stream itself (such as intersections, pedestrian crossings, etc.) but only by its own internal traffic interactions (e.g. highways, rural roads, etc.)

- **Interrupted Flow**

a traffic stream which is affected significantly by external elements (e.g. urban links)



Basic Traffic Variables

- The three main descriptors of traffic flow are:
 - Volume (q)
 - Density (k)
 - Speed (v)

- Traffic volume (aka flow), density, and (average) speed describe the traffic stream as a whole, and are referred to as **macroscopic** states.



Basic Traffic Variables

1. Volume (q)

Volume (flow) is the number of vehicles per unit time passing a given point on a road.

$$q = \frac{n}{T}$$

q : volume [veh/unit time]

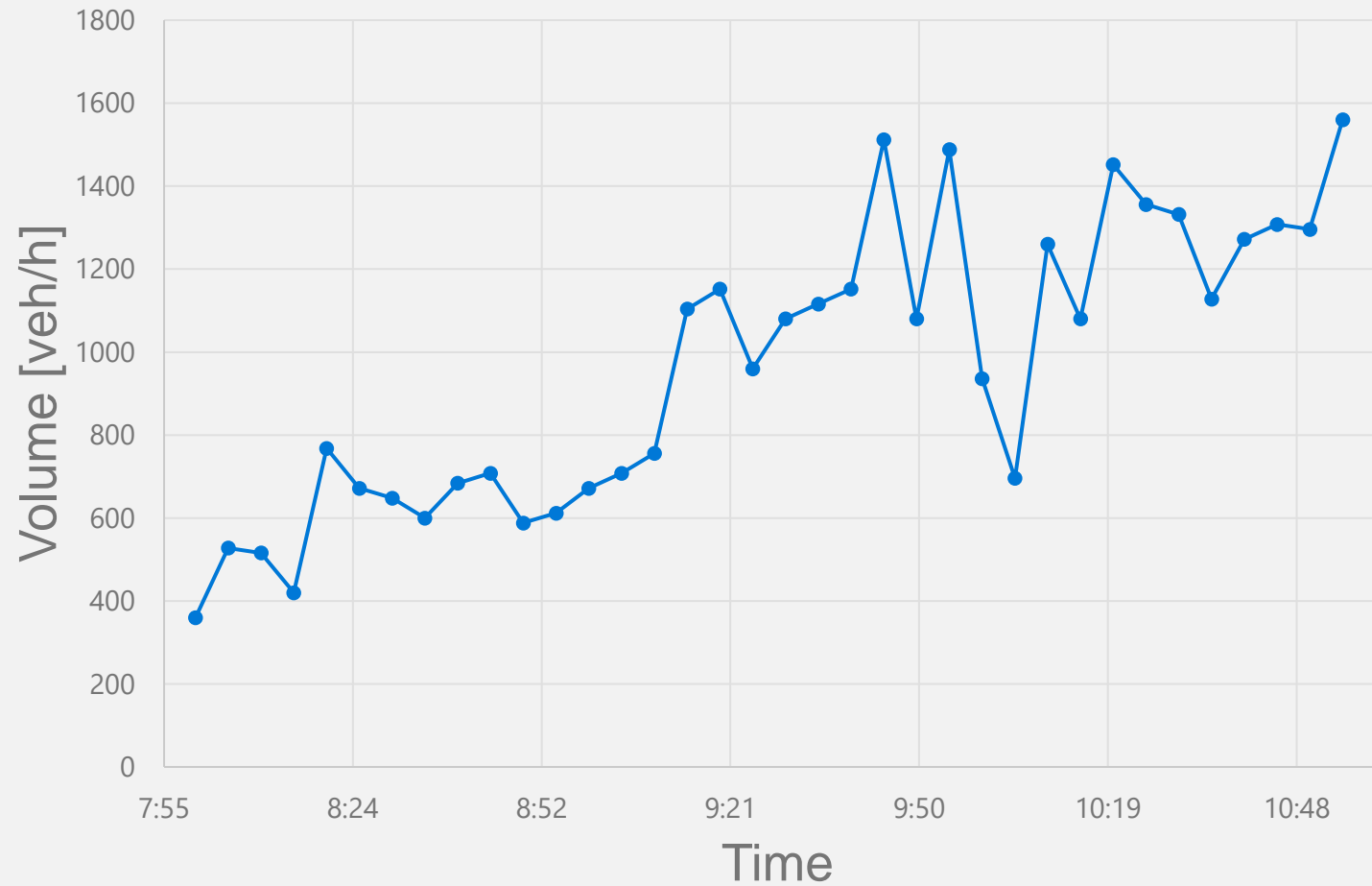
n : number of vehicles passing a designated roadway point during time T

T : duration of time interval



Basic Traffic Variables

- Example



Basic Traffic Variables

2. Headway (h)

A (time) headway is the time interval separating the passing of a fixed point by two consecutive vehicles in a traffic stream.

Relationship between volume and average headway

$$q = \frac{1}{h}$$



Basic Traffic Variables

3. Density (k)

Density (aka concentration) is the number of vehicles present within a unit length of lane, carriageway or road at a given instant of time.

$$k = \frac{n}{L}$$

k : traffic density [veh/unit distance]

n : number of vehicles on a part of roadway (section) at a specified time

L : length of the section



Basic Traffic Variables

4. Spacing (s)

A spacing is the distance between the fronts of two consecutive vehicles in a traffic stream at a given instant of time.

Relationship between density and average spacing

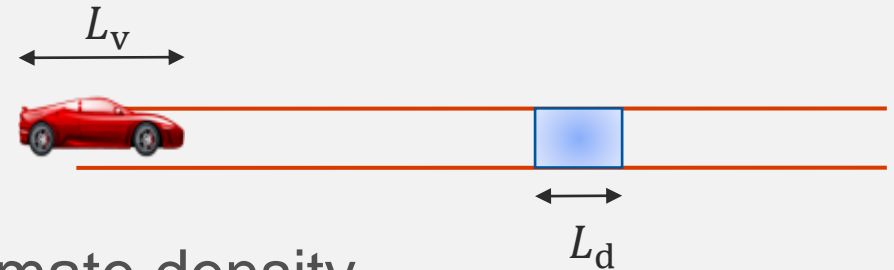
$$k = \frac{1}{s}$$



Basic Traffic Variables

Occupancy (o)

The proportion of time, over a given time interval, that there is a vehicle present at a specified point in the lane.



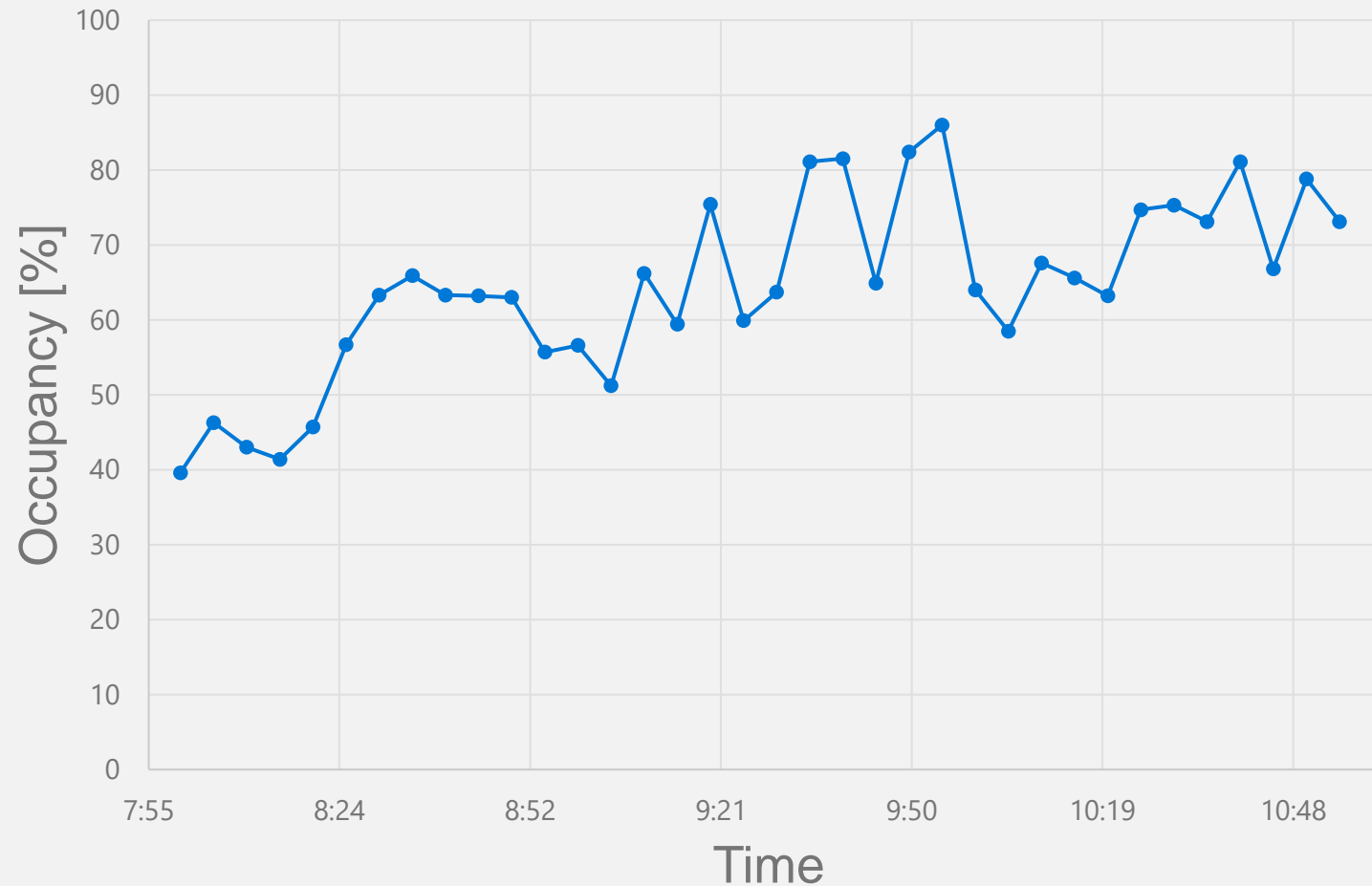
- Surrogate measure from loop detectors to estimate density

$$k = \frac{o}{L_d + L_v}$$



Basic Traffic Variables

- Example



Basic Traffic Variables

5. Speed (v)

- Time mean speed (v_t)
the arithmetic mean of the measured speeds of all vehicles passing a given point during a given time interval

- Space mean speed (v_s)
the arithmetic mean of the measured speeds of all vehicles within a given length of lane or carriageway, at a given instant of time



Basic Traffic Variables

5. Speed (v)

$$v_t = \frac{\sum_{i=1}^n v_i}{n}$$

$$v_s = \frac{n}{\sum_{i=1}^n \left(\frac{1}{v_i}\right)}$$

Space mean speed is the accurate average speed to be used for travel time analysis.

v_t : time mean speed [unit distance/unit time]

v_s : space mean speed [unit distance/unit time]

v_i : the speed of the i^{th} vehicle passing the fixed point on the road

n : number of measured vehicle spot speeds



Relationship Between Basic Traffic Variables



Relationship Between Basic Traffic Variables

Relationship between volume and average headway

$$q = \frac{1}{h}$$

Relationship between density and average spacing

$$k = \frac{1}{s}$$

Continuity equation:

$$q = kv$$

q : volume [veh/h]

v : speed (space mean speed) [km/h]

k : density [veh/km]

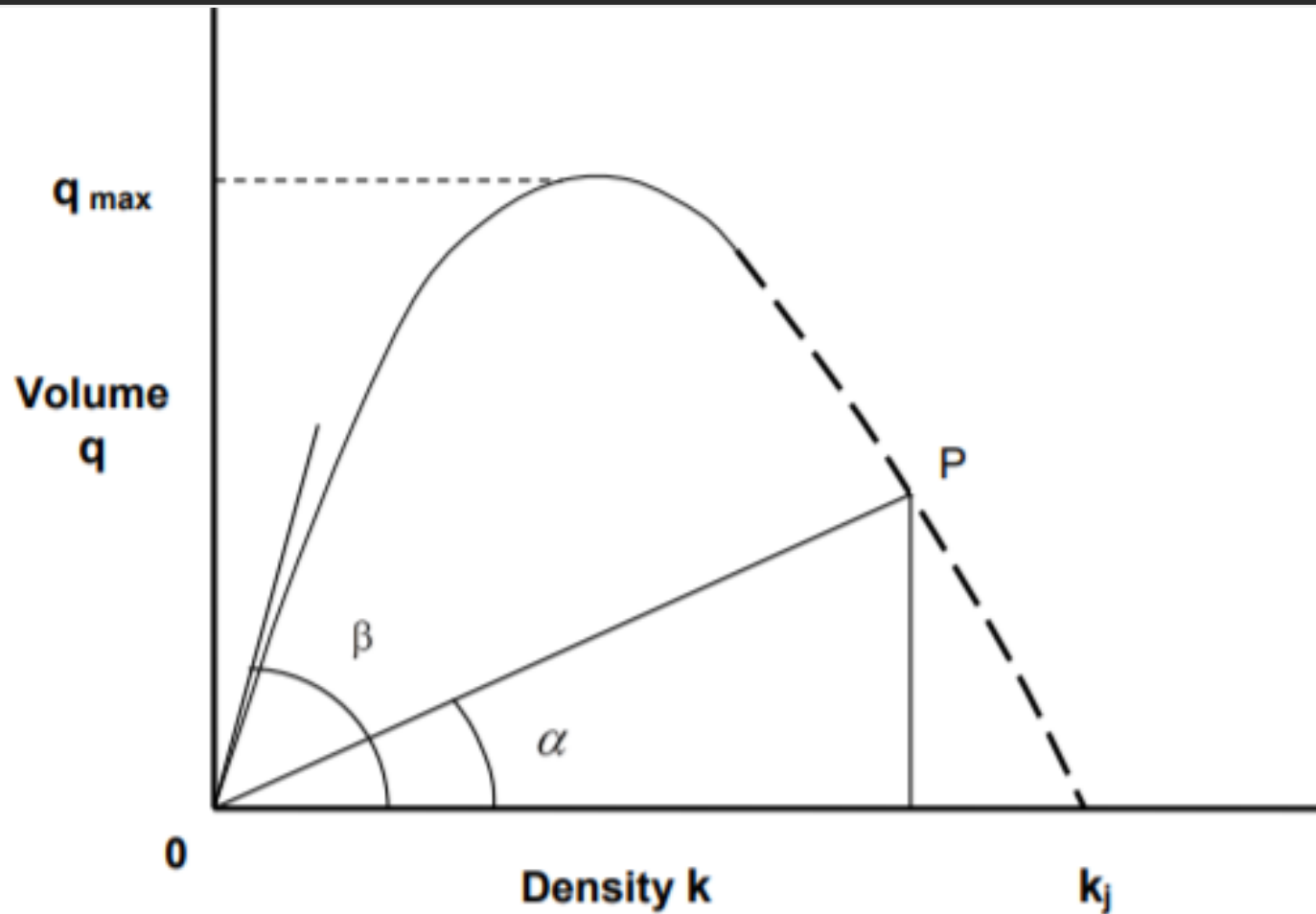


Fundamental Diagrams (FD)



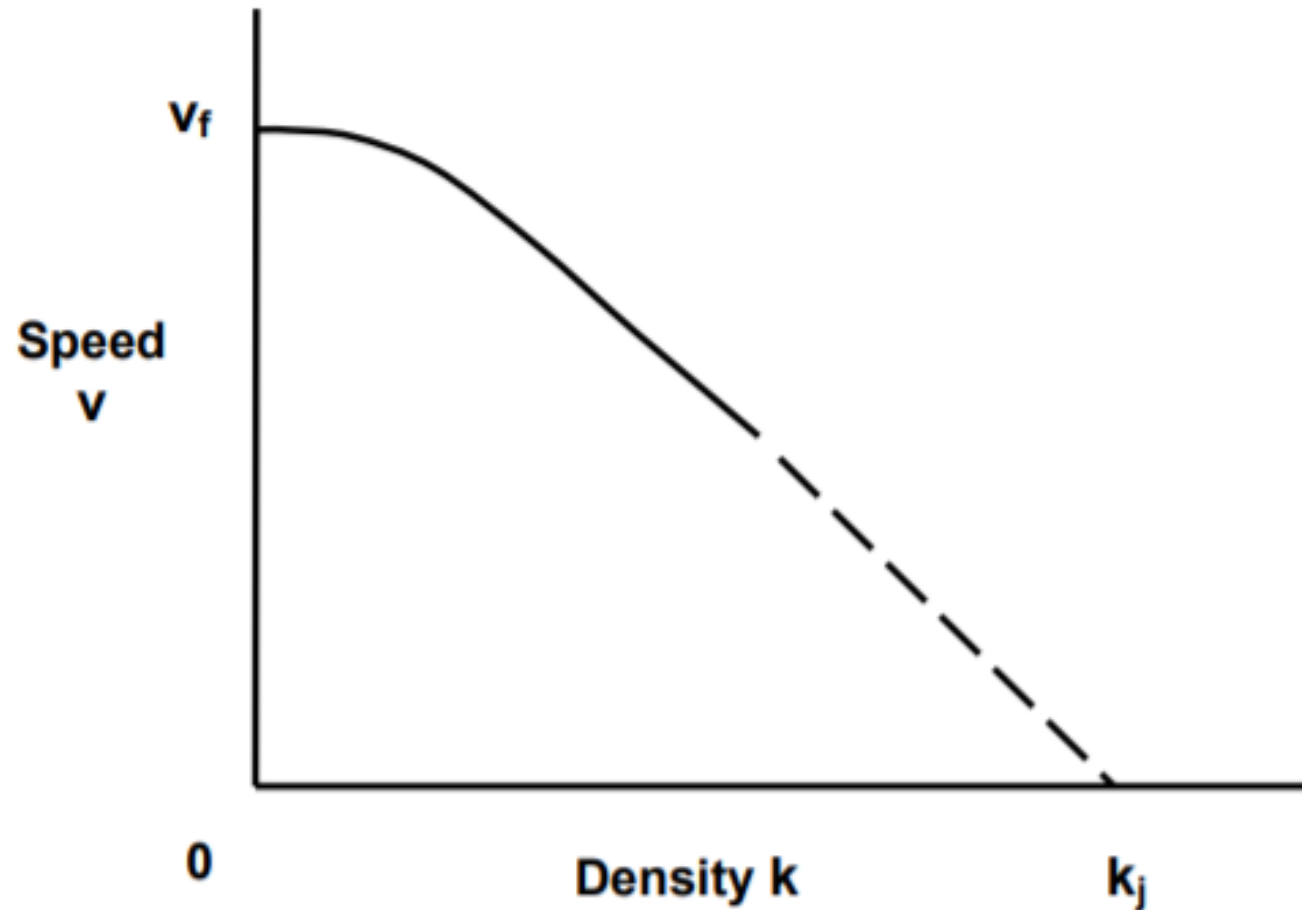
Fundamental Diagram

Volume-density FD



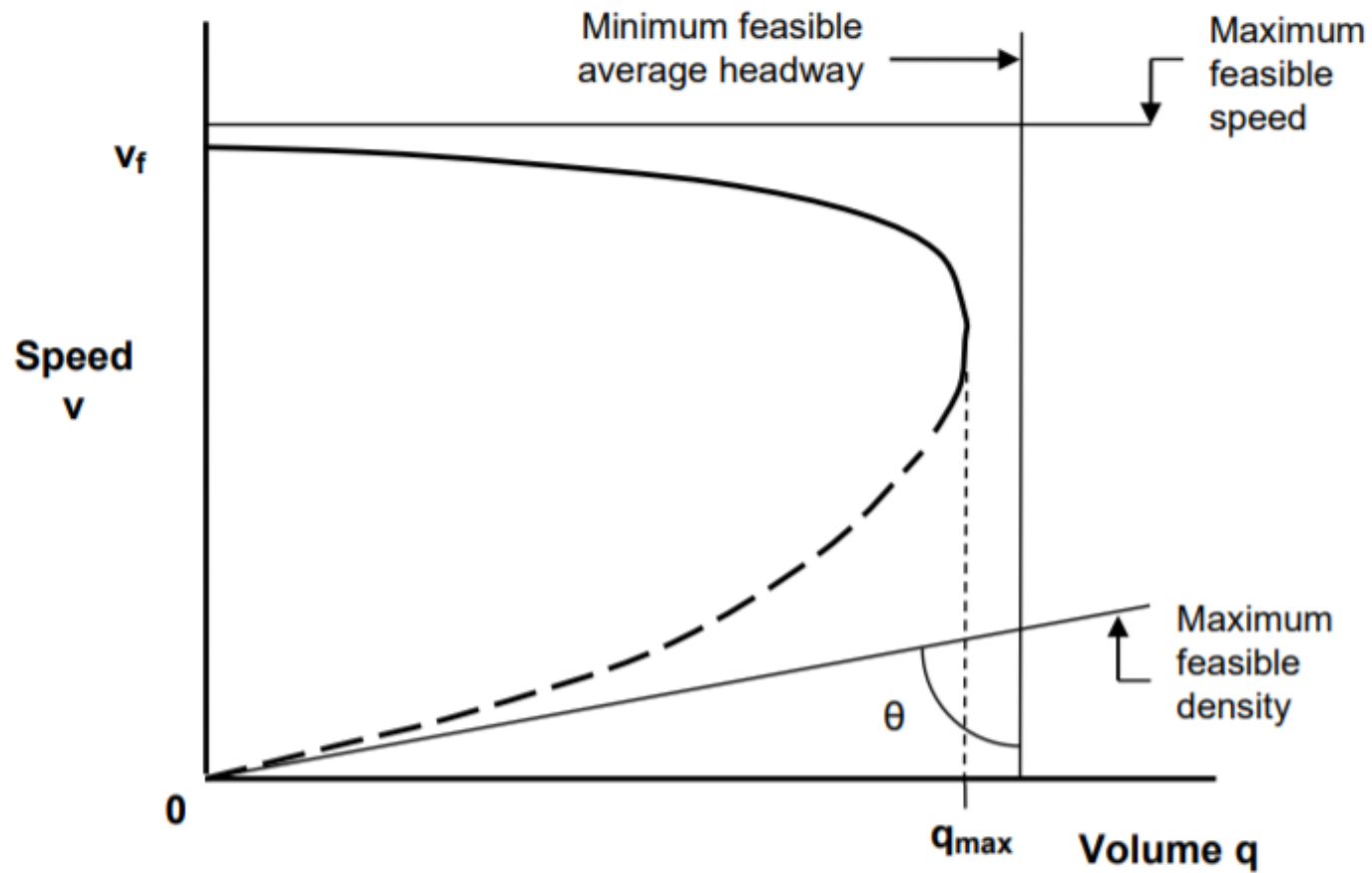
Fundamental Diagram

Speed-density FD



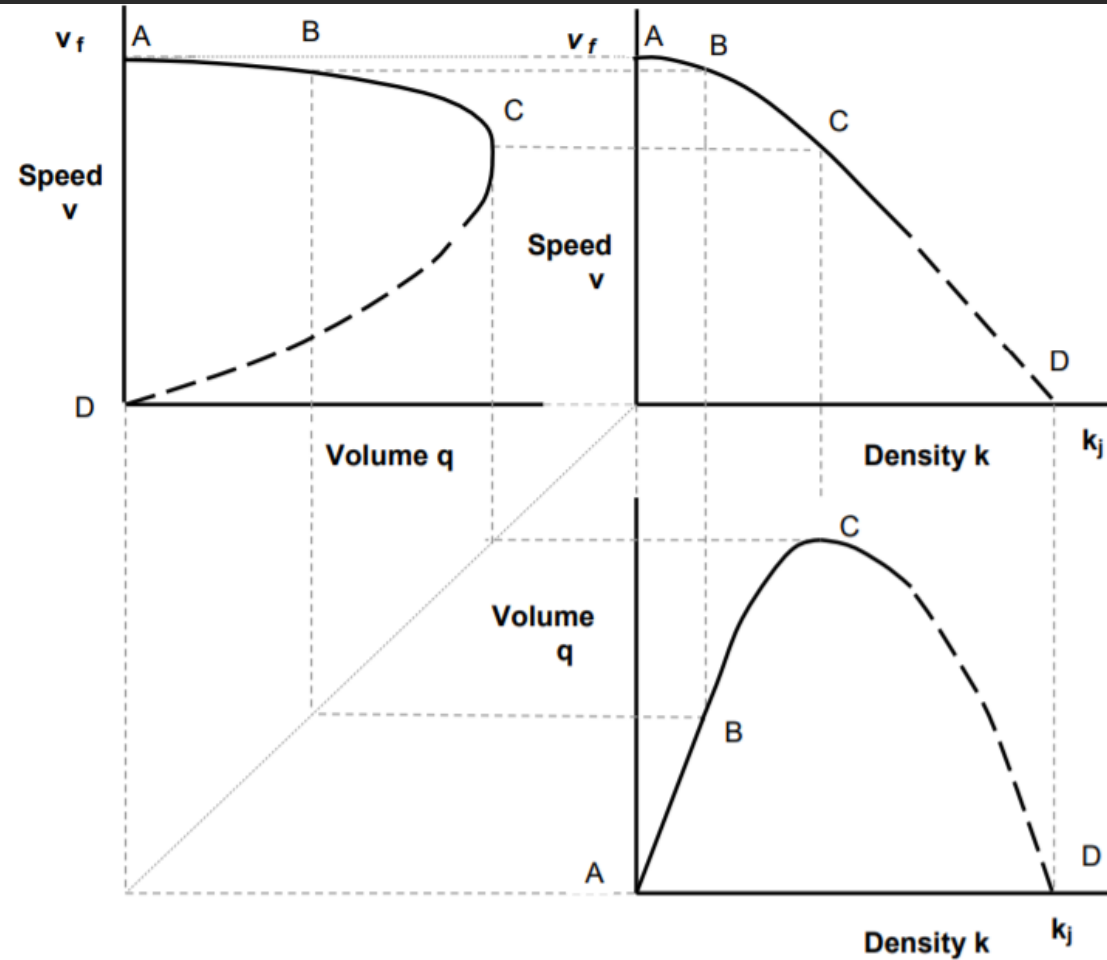
Fundamental Diagram

Speed-volume FD



Fundamental Diagrams

All FDs



Time to Reflect



Q1. The speeds of five vehicles were measured by a loop detector as 70, 90, 80, 85, and 75 [km/h]. What are the time mean and space mean speed?

- A. 80 - 80
- B. 80 – 75
- C. 80 – 77.8



Time to Reflect

Q1. The speeds of five vehicles were measured by a loop detector as 60, 100, 80, 85, and 75 [km/h]. What are the time mean and space mean speed?

- A. 80 - 80
- B. 80 – 75
- C. 80 – 77.8

Explanation:

Answer C is correct!

$$v_t = \frac{\sum_{i=1}^n v_i}{n} = \frac{60+100+80+85+75}{5} = \frac{400}{5} = 80 \text{ [km/h]}$$

$$v_s = \frac{1}{\frac{1}{n} \sum_{i=1}^n (v_i)^{-1}} = \frac{5}{\frac{1}{60} + \frac{1}{100} + \frac{1}{80} + \frac{1}{85} + \frac{1}{75}} = \frac{5}{0.0652} = 77.8 \text{ [km/h]}$$



References



Austroads (2020). Guide to Traffic Management Part 2: Traffic Theory Concepts. AGTM02-20, Austroads, Sydney, NSW.
<https://austroads.com.au/publications/traffic-management/agtm02/media/AGTM02-20-Part-2-Traffic-Theory-Concepts.pdf>



Thank you for participating

