Fundamentals of Traffic Operations and Control

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EPFL

LUTS

Course Information (4 credits)

- **Format**: 2 hrs of lecture per week + 2 hrs of exercise-laboratory per week (on average)

Instructor in Charge Nikolas Geroliminis

- Office: GC C2 389 phone: [021 69] 32481

Grading

- Homeworks 0% Labs (2) 30%
- Mid-term 30% Final Exam 40%

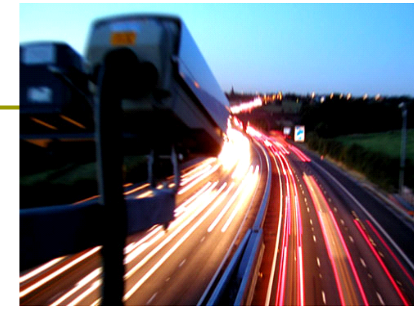
Textbook

- Lecture notes, book chapters and handouts will be distributed throughout the semester, or posted on web.

The team

- *Pengbo Zhu, Yura Tak, Anne-Valérie Preto*

Smart and Complex Mobility



Educational Goals

- High level of technical expertise to succeed in positions in transportation engineering practice/research in CH and worldwide
- Produce engineering designs that are based on sound principles and consider functionality, safety, cost effectiveness and sustainability
- Fundamental knowledge to pursue lifelong learning such as graduate work

Course OBJECTIVES

- Introduce the major elements of transportation and create awareness of the broader context
- Develop basic skills in applying the fundamentals of the transportation field
- Be prepared for further study in this field

Transportation Infrastructure

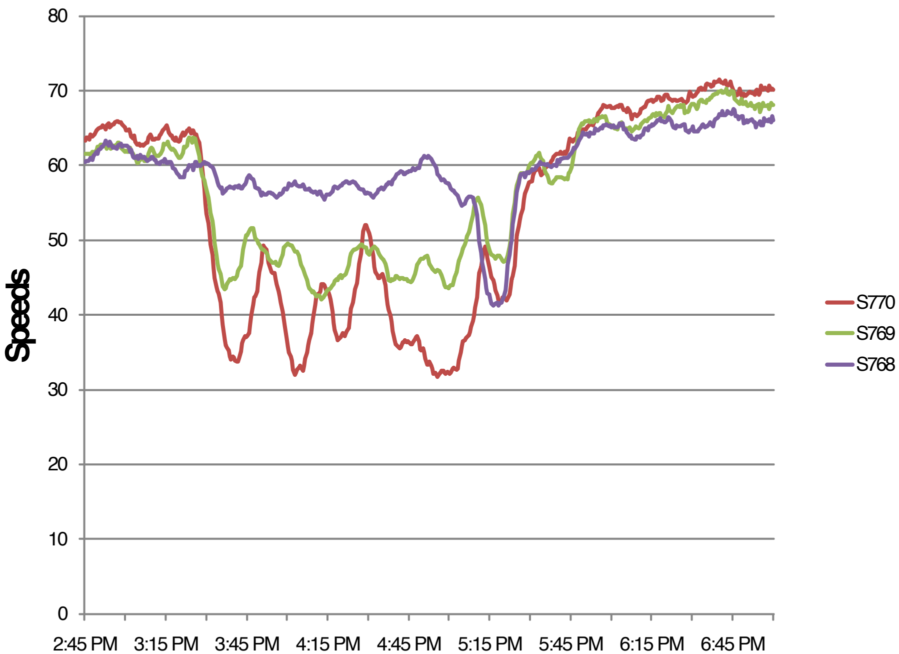
- Critical Components of Transportation Infrastructure System
  - Drivers
  - Vehicles
  - Roads and highways
    - Freeway system
    - Rural highway system
    - Arterial and street systems
  - General environment
  - Traffic control devices
  - ITS infrastructures

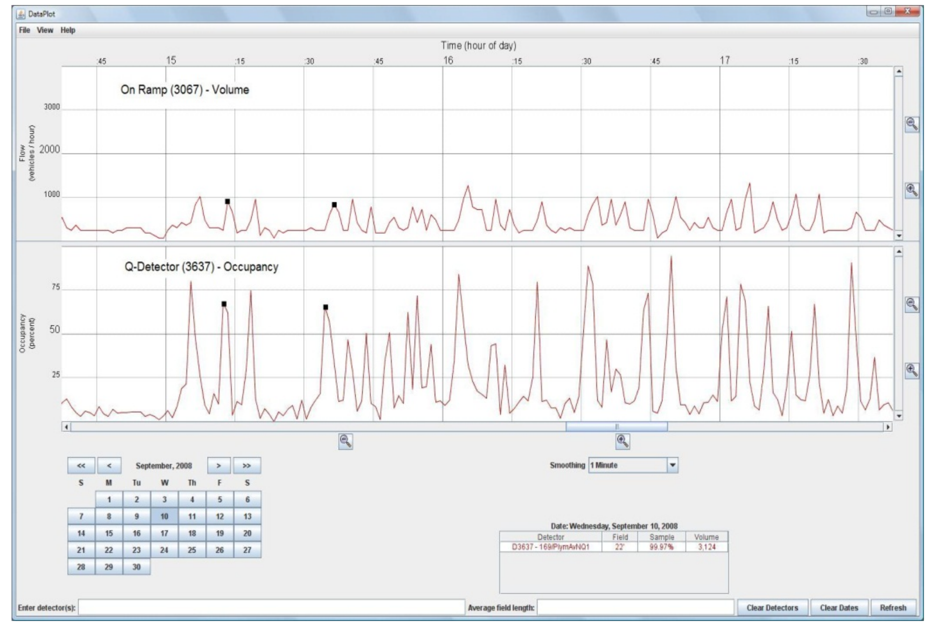
- Need tools to design, evaluate, and operate such complex systems.

Course description

- **Traffic Modeling**
  Relations between properties of traffic streams and models describing how congestion changes over time and space at different levels of scale.
  Micro- (Car following), Meso- (Cell Transmission Model), Macro- (city level)
- **Control of Traffic Signals**
  Schemes to affect traffic stream properties in some desirable way(s); e.g. coordinating green times at neighboring highway traffic signals to reduce driver delay. Adaptive control, Coordination, Ramp metering
- **Scheduled Transportation Systems**
  Basic principles in operating fleets, Allocation of urban space, Design, Instabilities, Bus Bunching. Car Sharing. On-demand transportation. Logistics. Preparation for more advanced study.

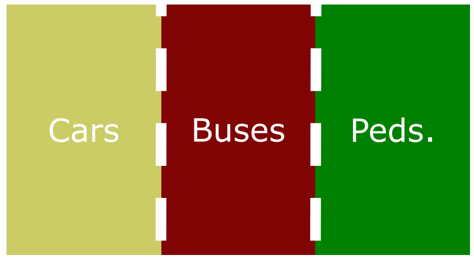
Data analysis

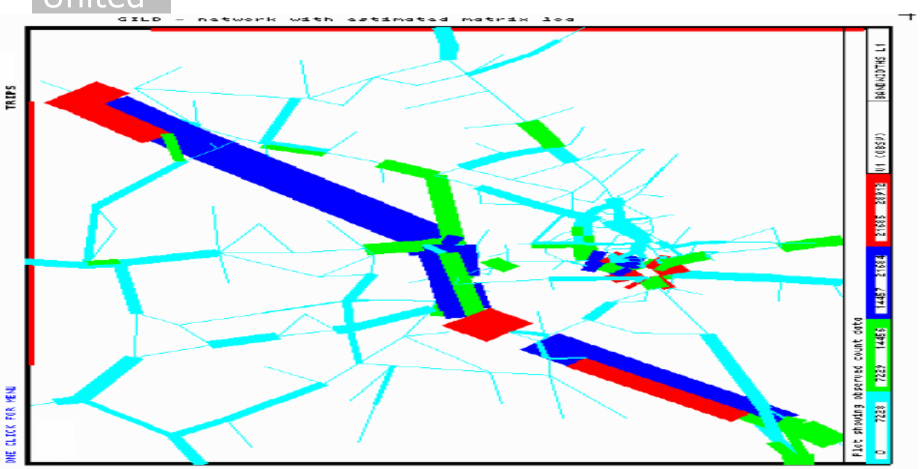


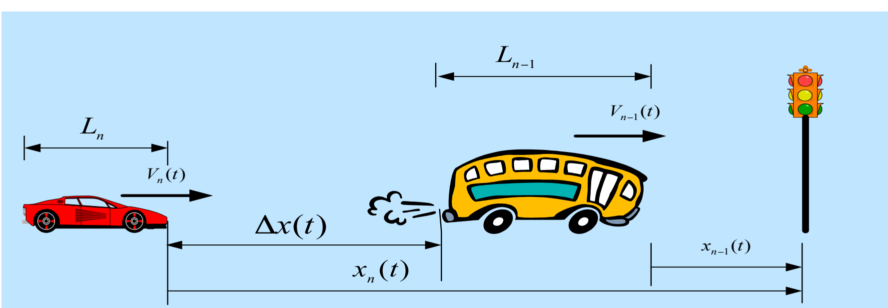


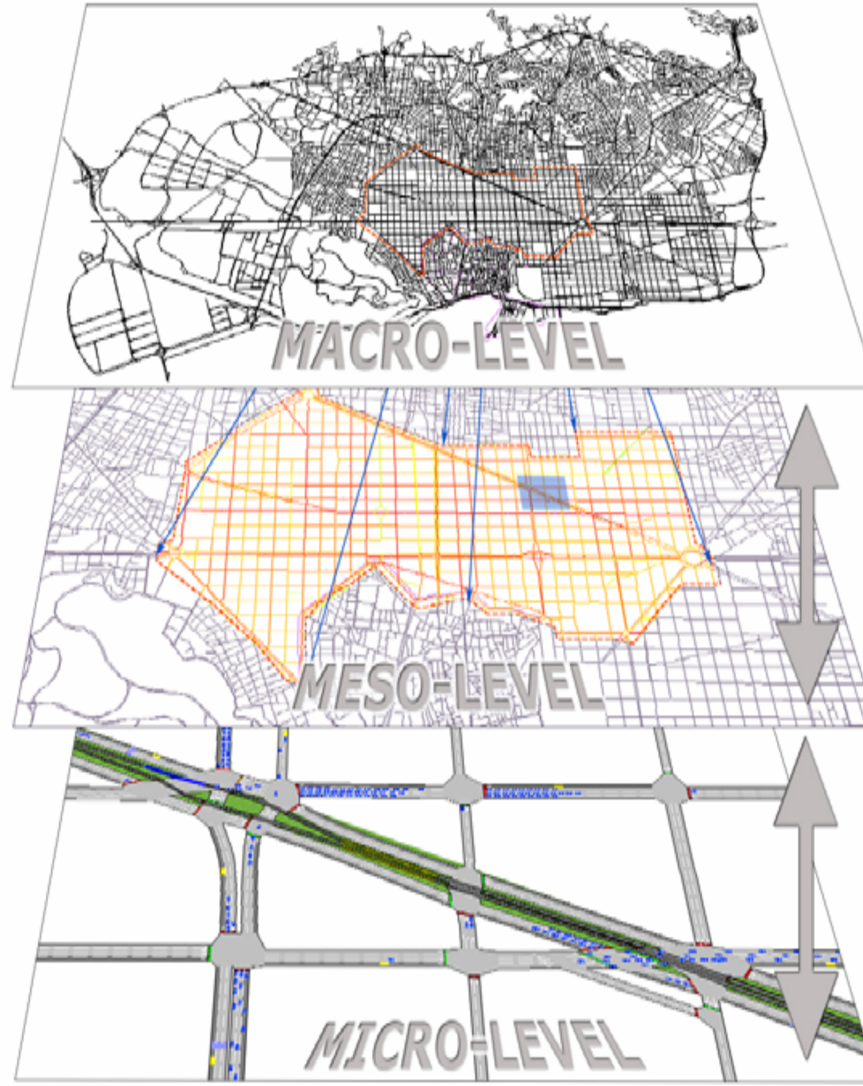
Date	5 min	L1 Flow (Vh/5 min)	L1 Occ	L2 Flow (Vh/5 min)	…..	Flow (Vh/5 min)	Occ	# Lane Points	% Observed
11/10/2007	0:00	24	0.0154	33	…..	95	0.0178	4	100
11/10/2007	0:05	27	0.0193	47	…..	124	0.0223	4	100
11/10/2007	0:10	25	0.0159	43	…..	121	0.0206	4	100
11/10/2007	0:15	27	0.0188	51	…..	126	0.0228	4	100
11/10/2007	0:20	15	0.0103	43	…..	109	0.0215	4	100
…..	…..	…..	…..	…..	…..	…..	…..	…..	…..
…..	…..	…..	…..	…..	…..	…..	…..	…..	…..
…..	…..	…..	…..	…..	…..	…..	…..	…..	…..
11/10/2007	1:30	16	0.0103	34	…..	87	0.0153	4	100
11/10/2007	1:35	20	0.0128	38	…..	101	0.0187	4	100
11/10/2007	1:40	10	0.0061	27	…..	77	0.0137	4	100

Different scales of traffic modeling









Intro to Traffic Management

Traffic Signal Control

Urban Space Allocation

Bus Priority

Parking

Transport systems management

Traffic Control

Ramp metering

Optimal timing design for signal lights

Coordination of signalized intersections

Design of Facilities

Road-geometric design (lane addition, removing bottlenecks)

Improvement in car technologies

Demand management

Demand reallocation

Flexible work hours and telecommuting, Different work schedule, Vehicle use restrictions

Decreasing demand

work from home, decrease of week workload, change home place, change land use

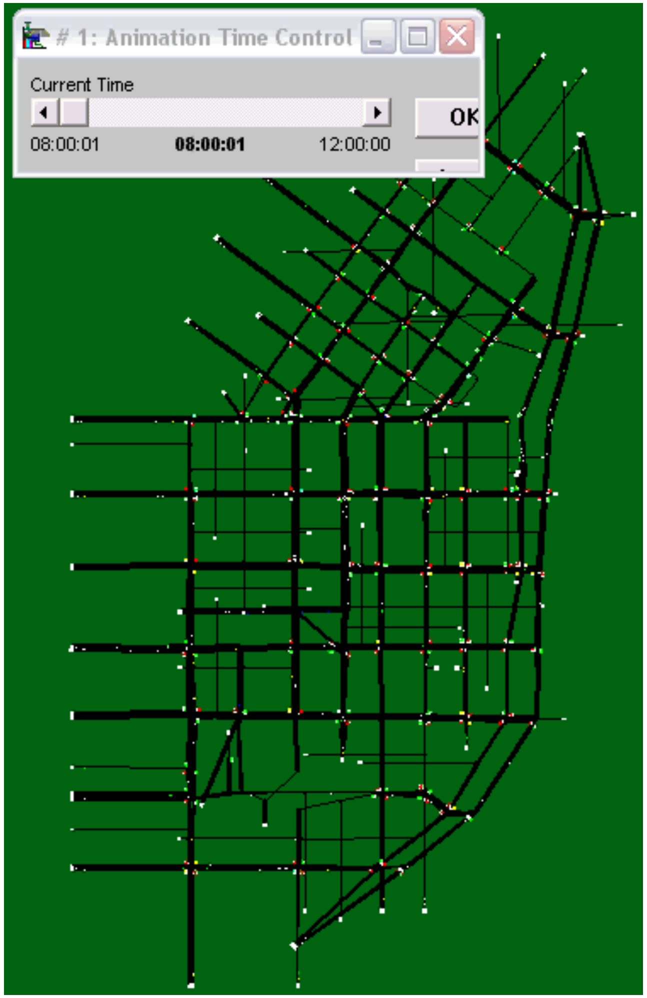
Demand “compression”

car pooling, minibus, transit

Pricing

Road/Congestion pricing, Parking policies

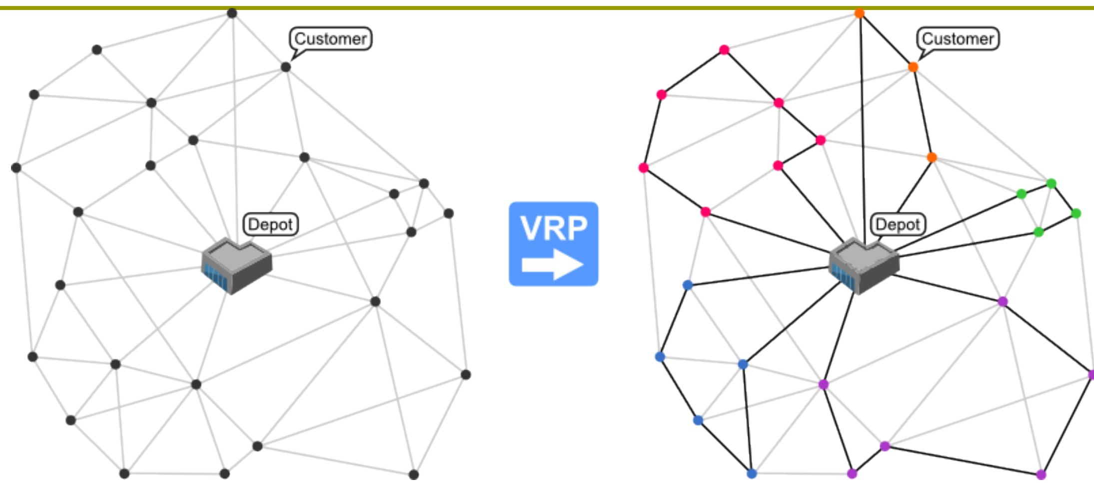
Performance evaluation



Scheduled Transportation Systems

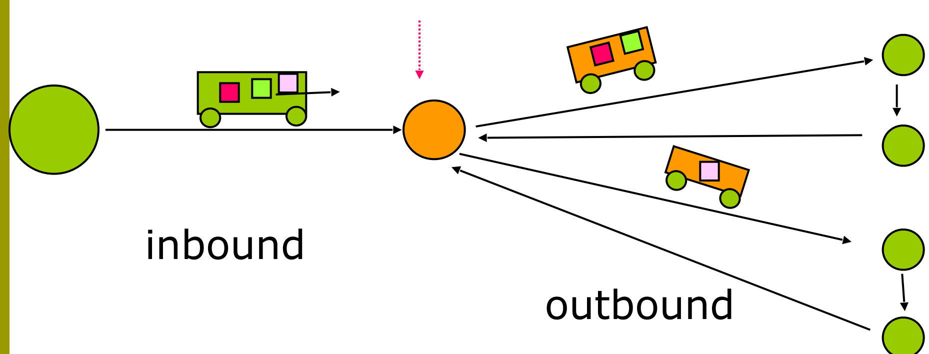
Vietnam

Design of logistics systems

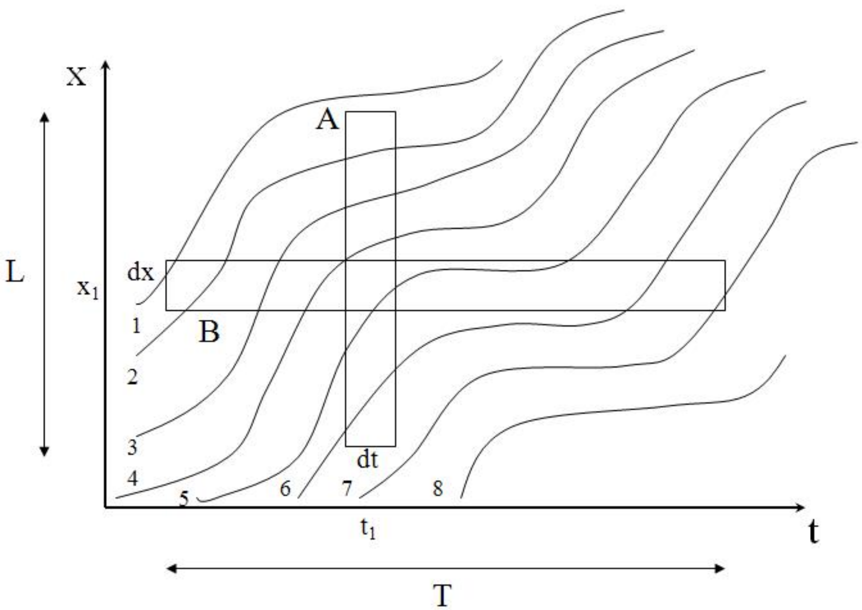


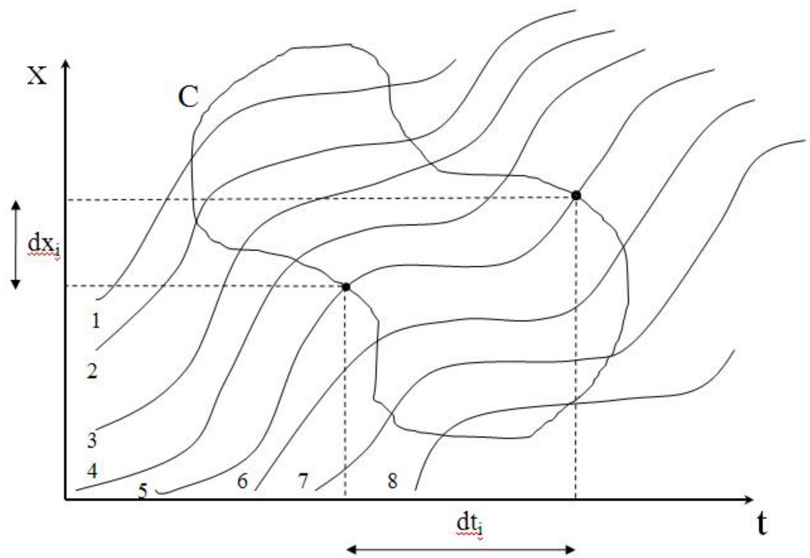
- Vehicle Routing Problem
- One-to-Many
- Many-to-Many

- Sorting
- Storage
- Handling



Generalized definitions of *q* and *k*





$$Q = \frac{d(A)}{|A|} = \frac{VKT}{Area}$$

$$K = \frac{t(A)}{|A|} = \frac{VHT}{Area}$$

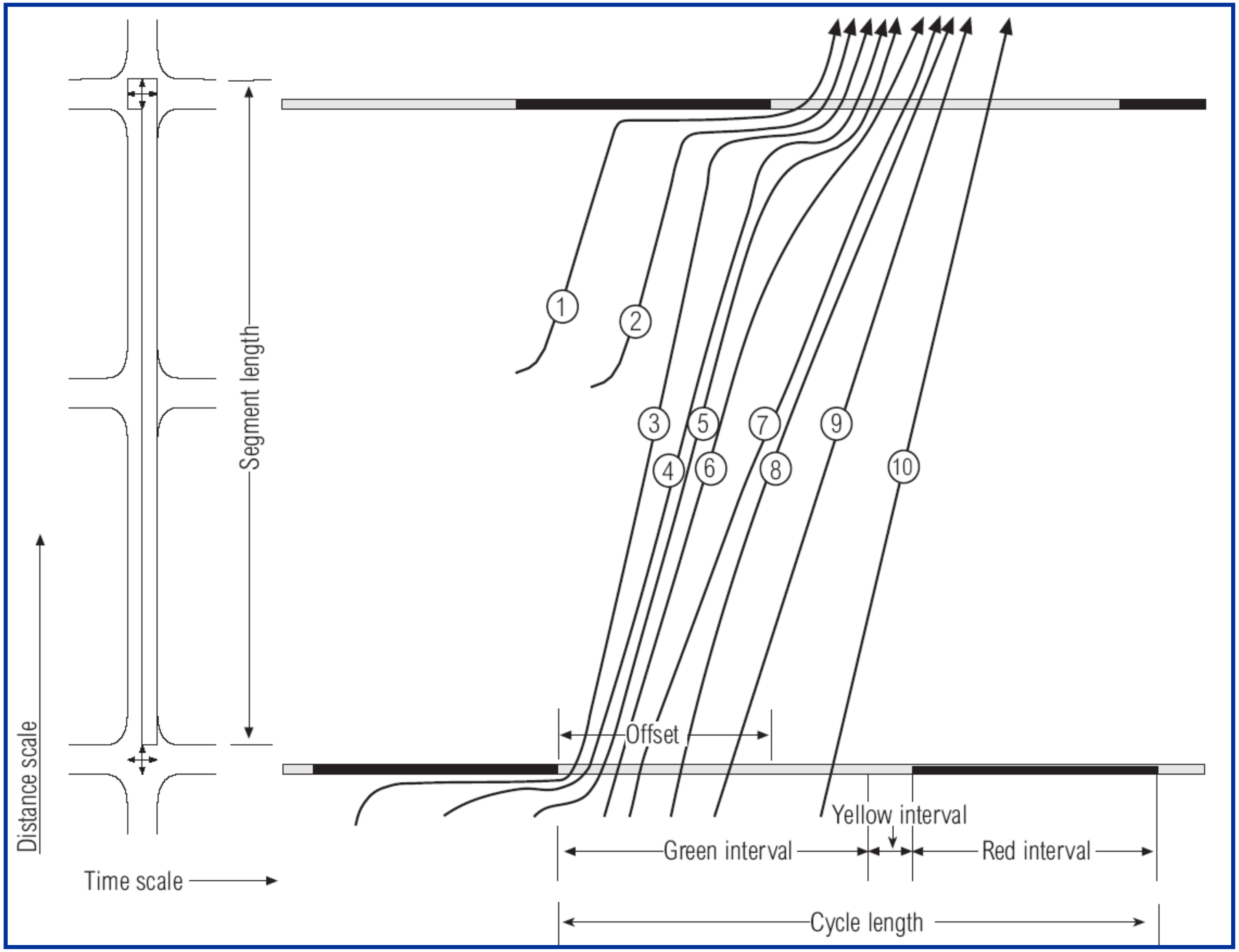
$$V_{SMS} = \frac{d(A)}{t(A)} = \frac{VKT}{VHT}$$

Review of traffic engineering class

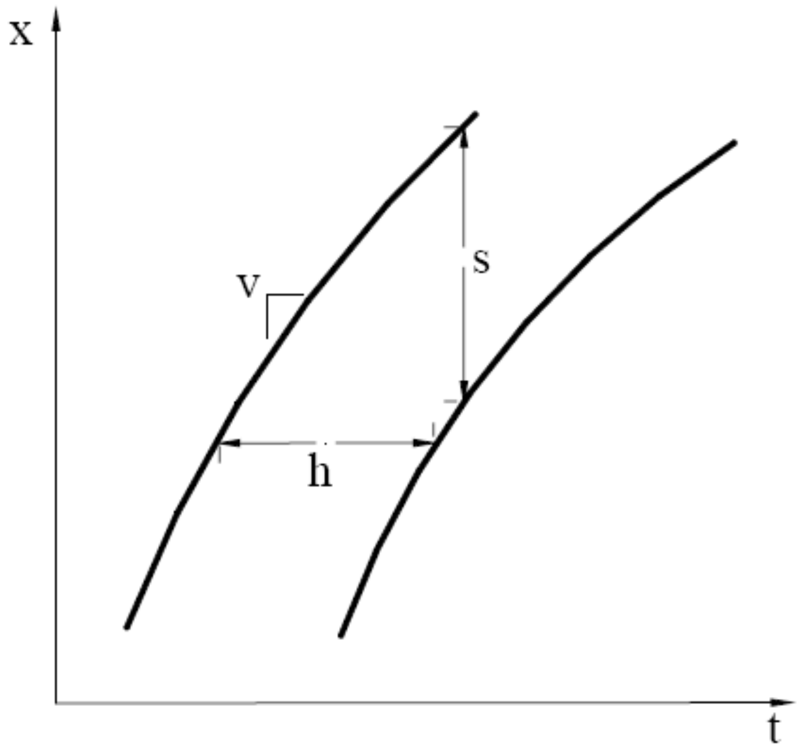
- Traffic Stream Characteristics

- See Notes (Please review and come back with questions next week)

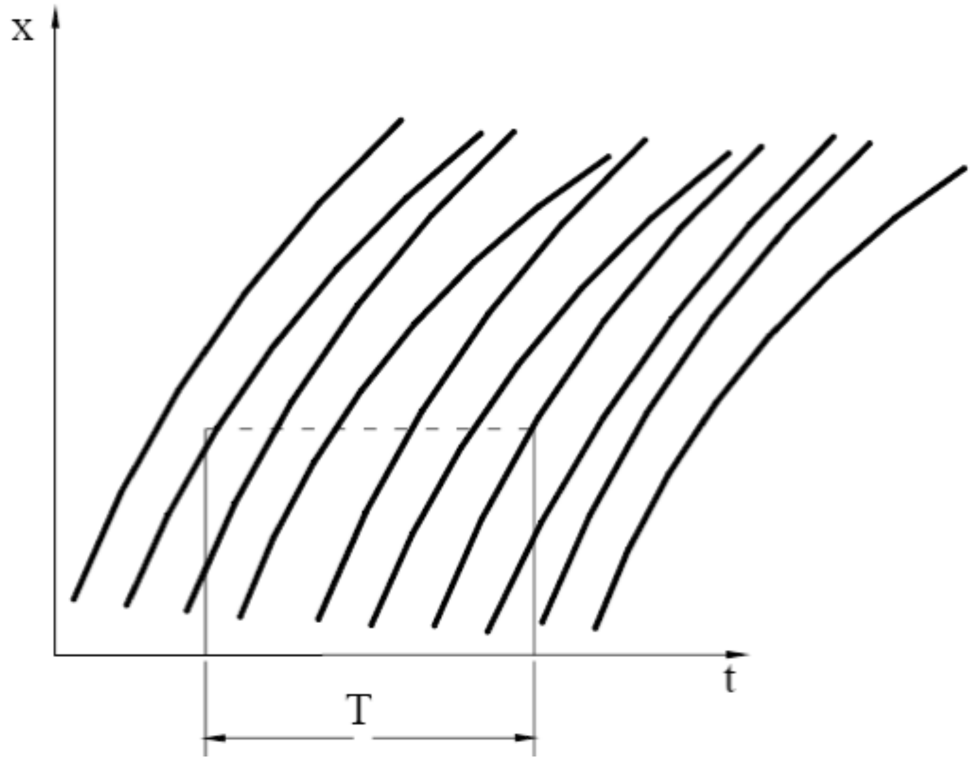
Urban Streets: Vehicle Trajectories



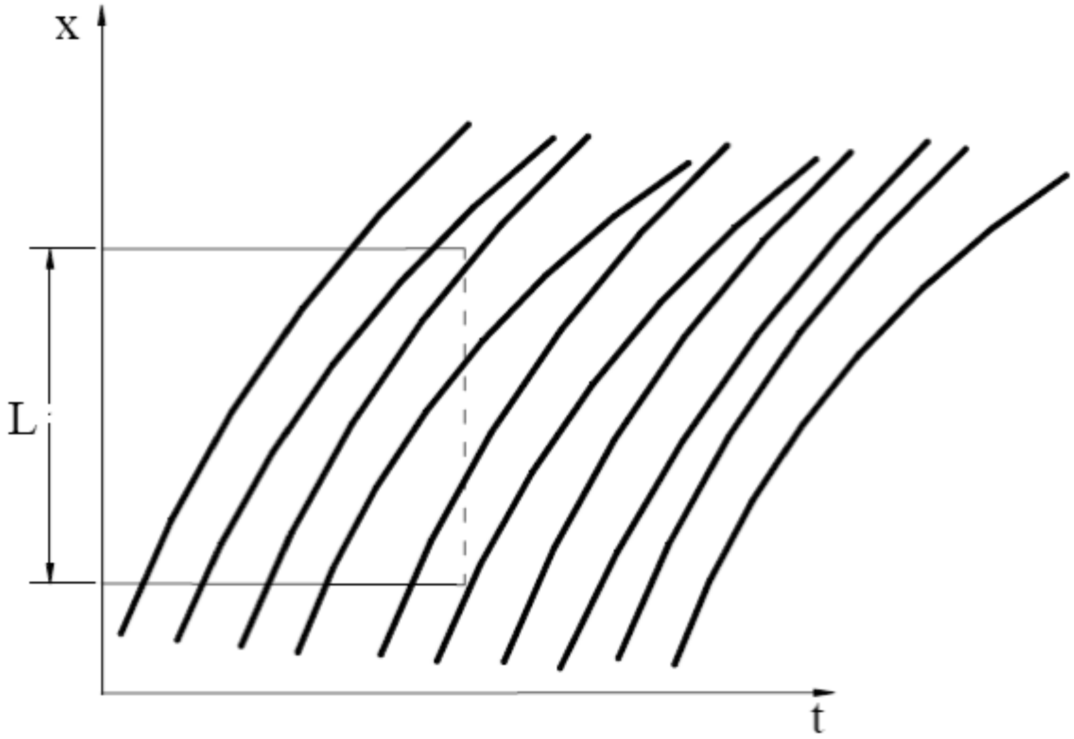
Headway and Spacing Definitions



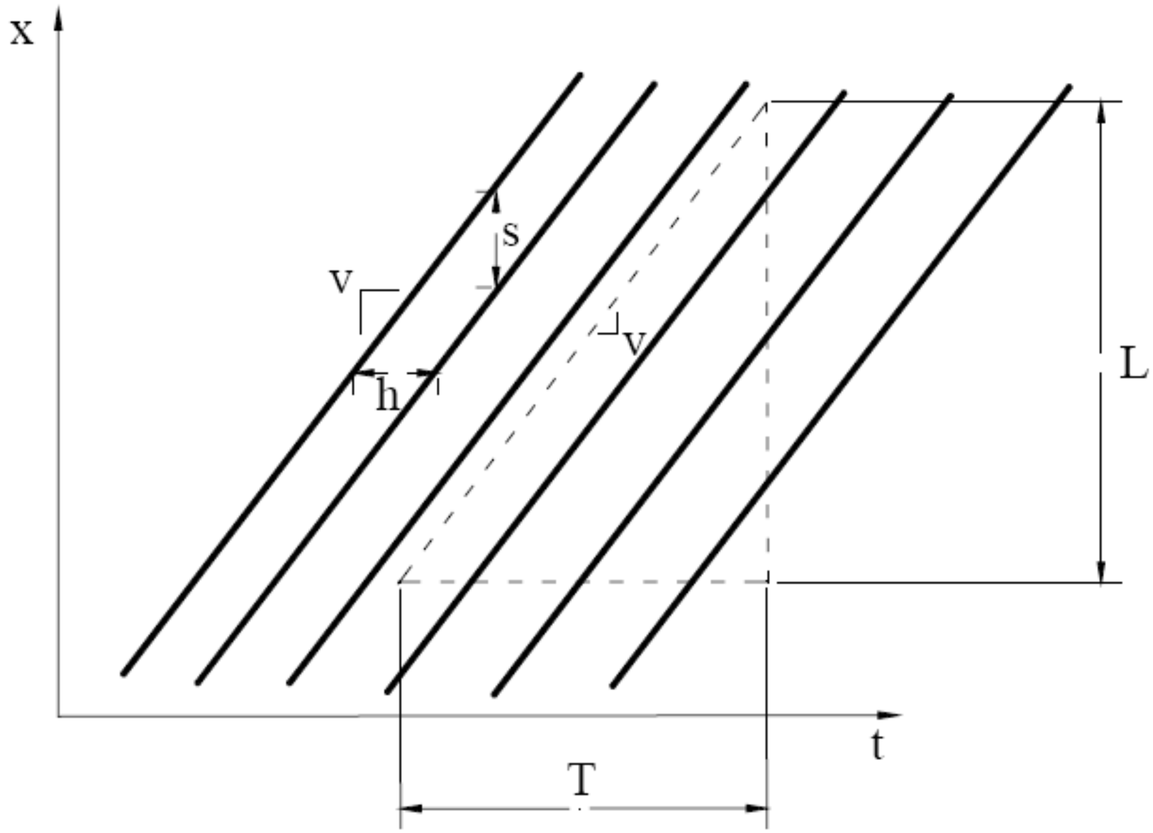
Flow definition



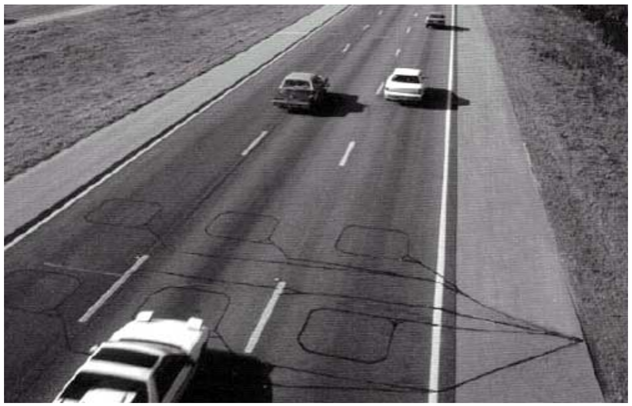
Density Definition

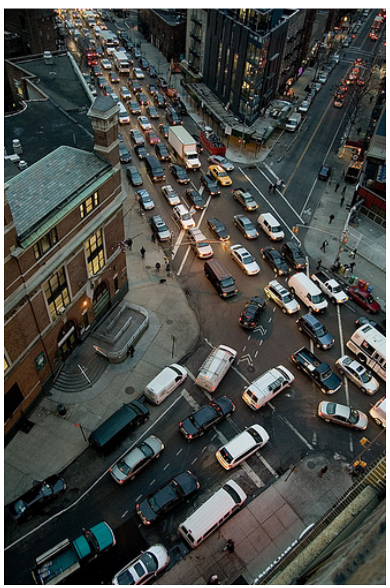


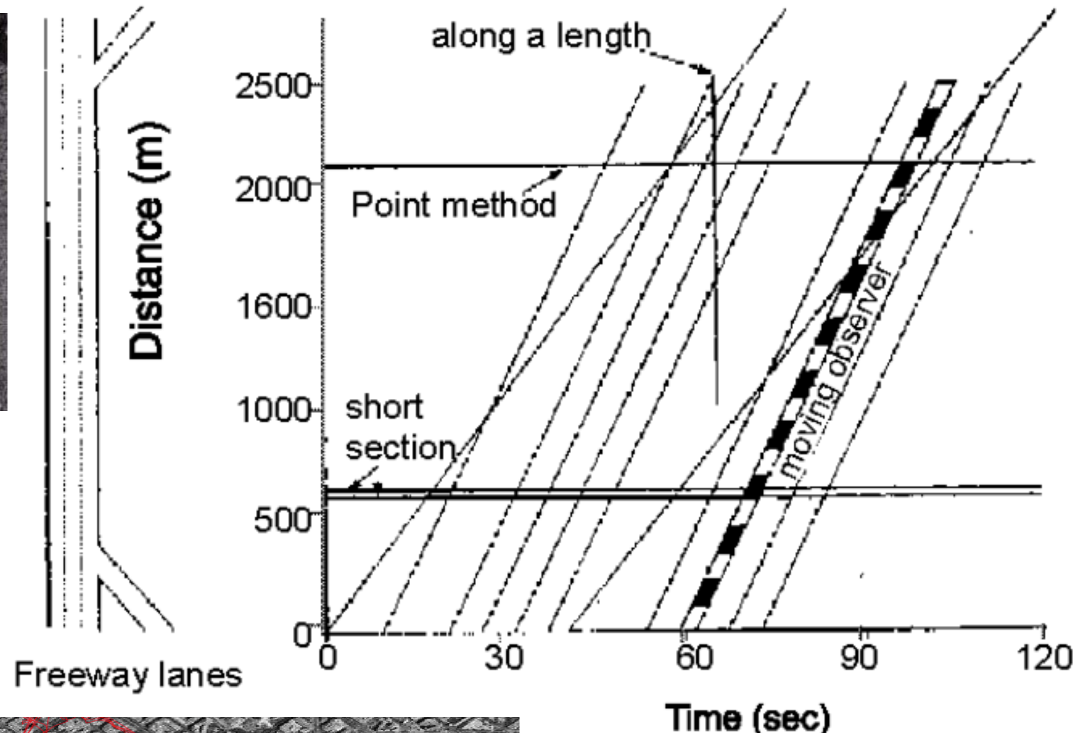
Flow = density *+/- speed

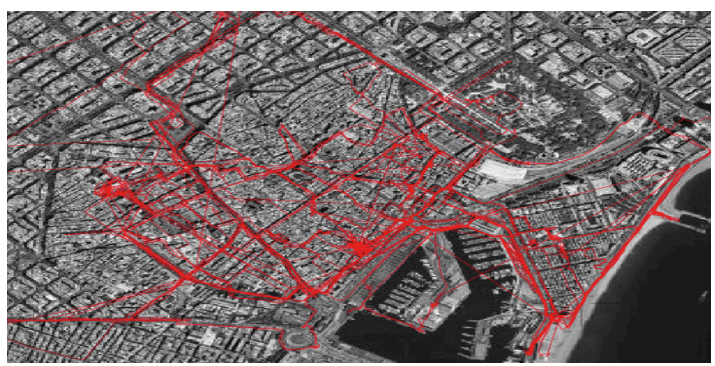


Methods of Observation



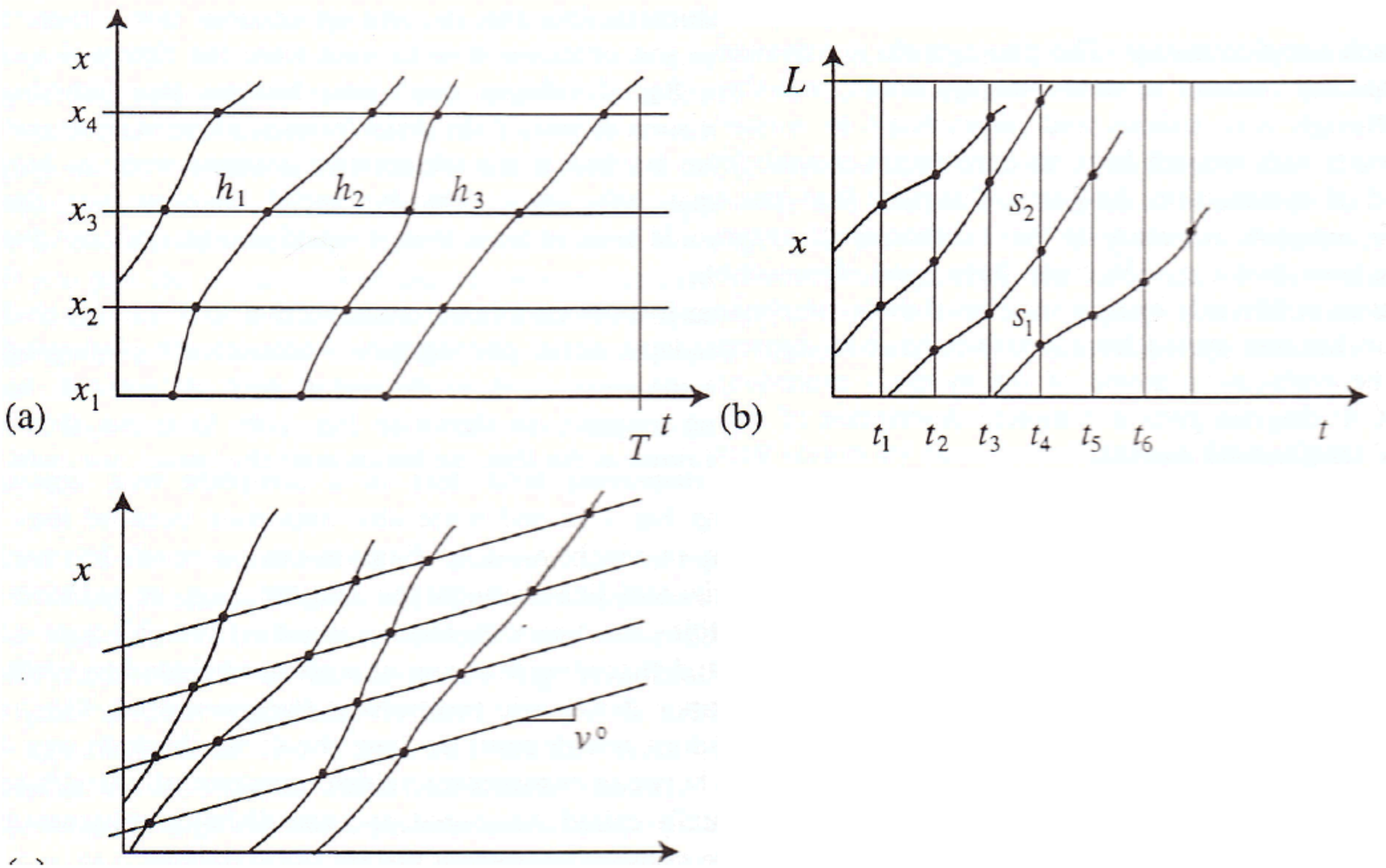






Construction of x-t diagram from data

(a) Roadside observers at various locations.
(b) aerial photographs at different instants.
(c) moving observers.



TMS (v_t) and SMS (v_s)

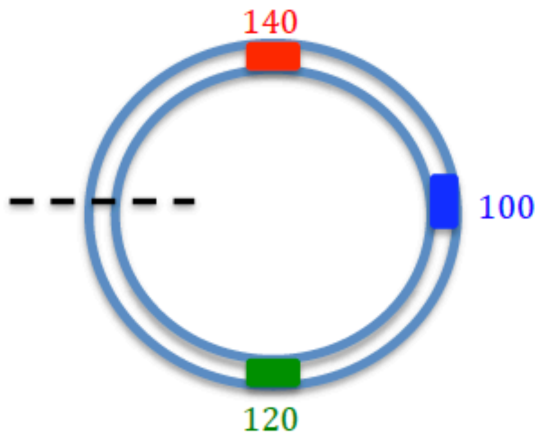
space mean speed:

$$\bar{u}_s = \frac{120 + 140 + 100}{3} = 120[\mathrm{km/h}]$$

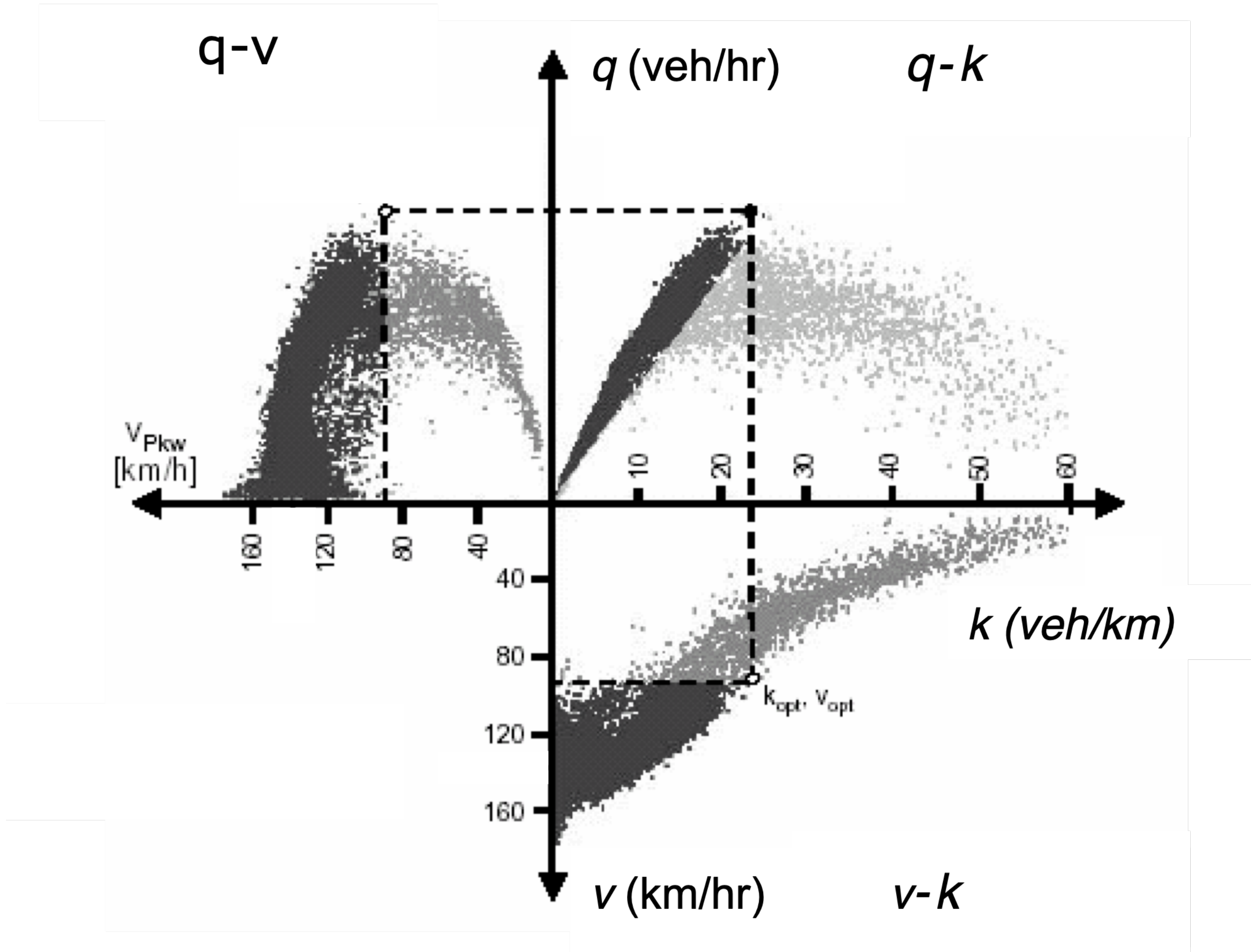
time mean speed:

during one hour:
vehicle travels at 100 (km/h) completes 50 laps
vehicle travels at 120 (km/h) completes 60 laps
vehicle travels at 140 (km/h) completes 70 laps

$$\bar{u}_t = \frac{50(100) + 60(120) + 70(140)}{180} = 122[\mathrm{km/h}]$$

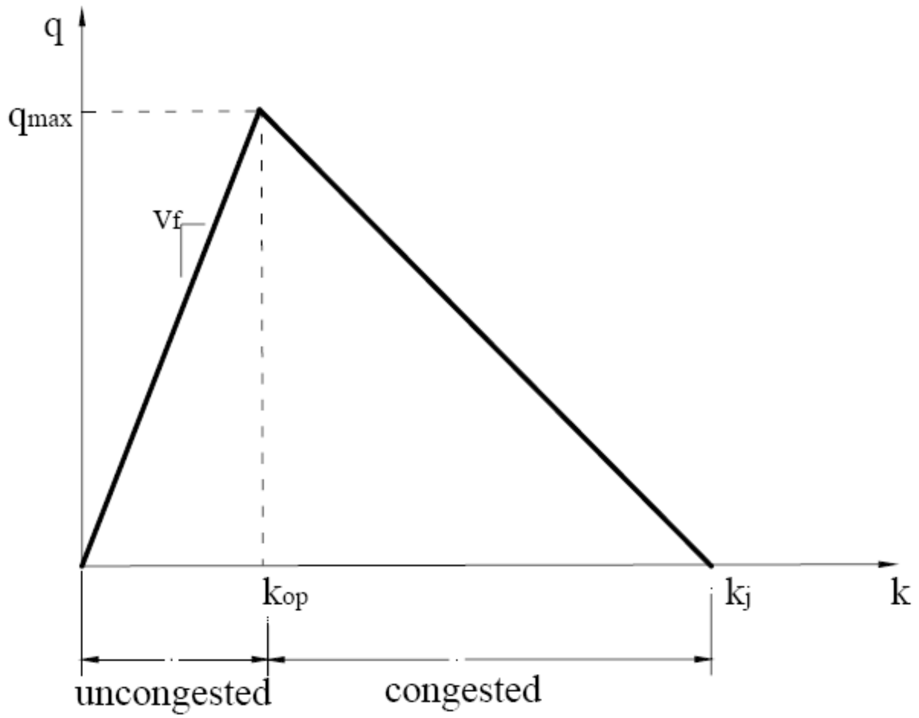


Real freeway data

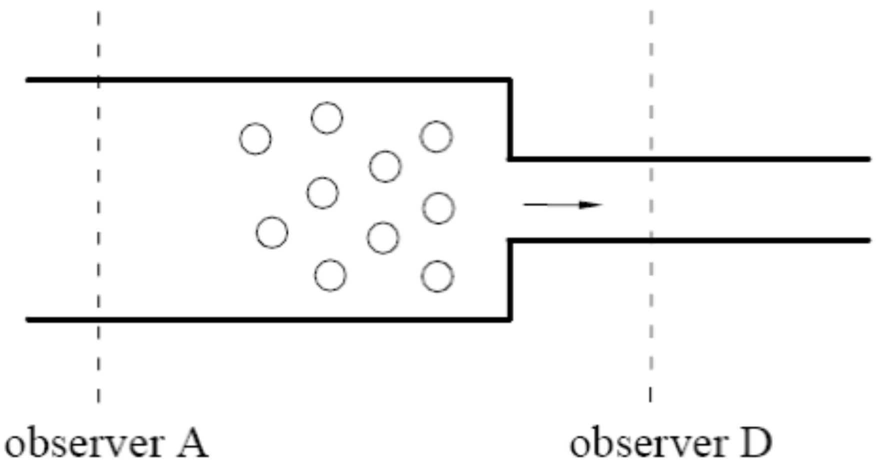


A triangular FD

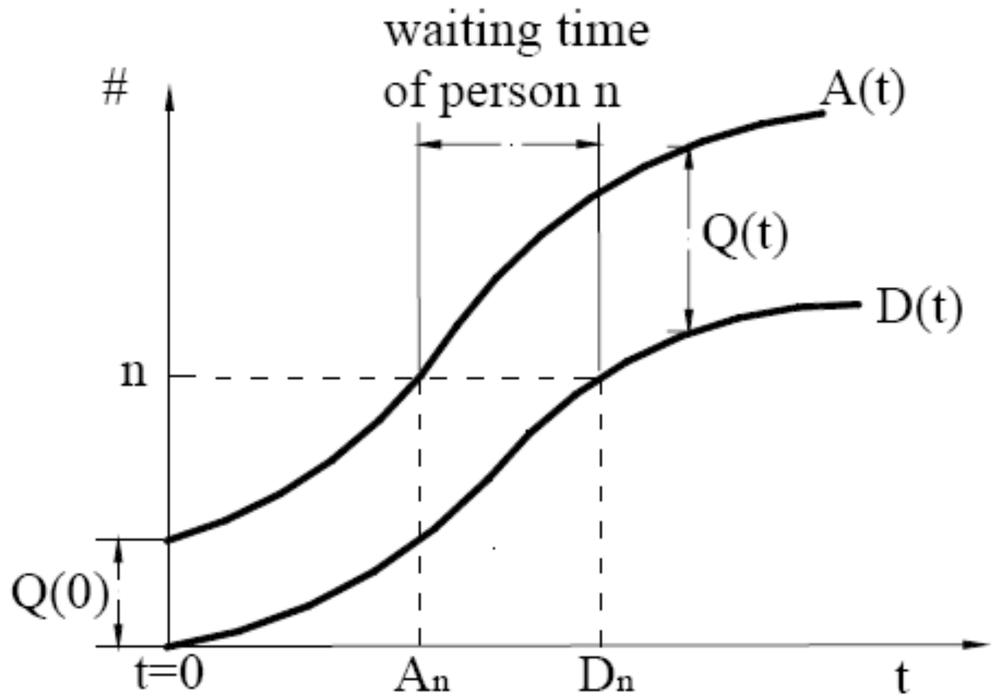
- However, these diagrams are not very realistic. Researchers now know that the flow-density relation is better described by a triangle than by a parabola.
- The following graph shows the Fundamental Diagram as we use it today. It contains enough information to find any of the 5 descriptors, if one is given *k*.

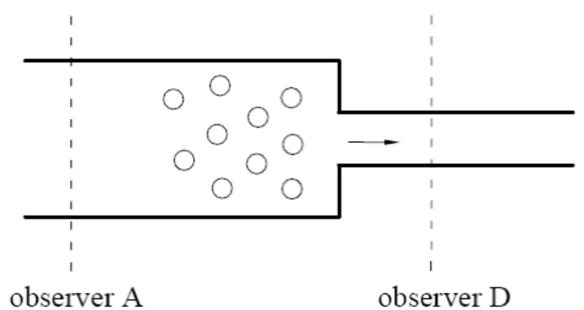


Input-Output Diagrams



Input-Output Diagrams

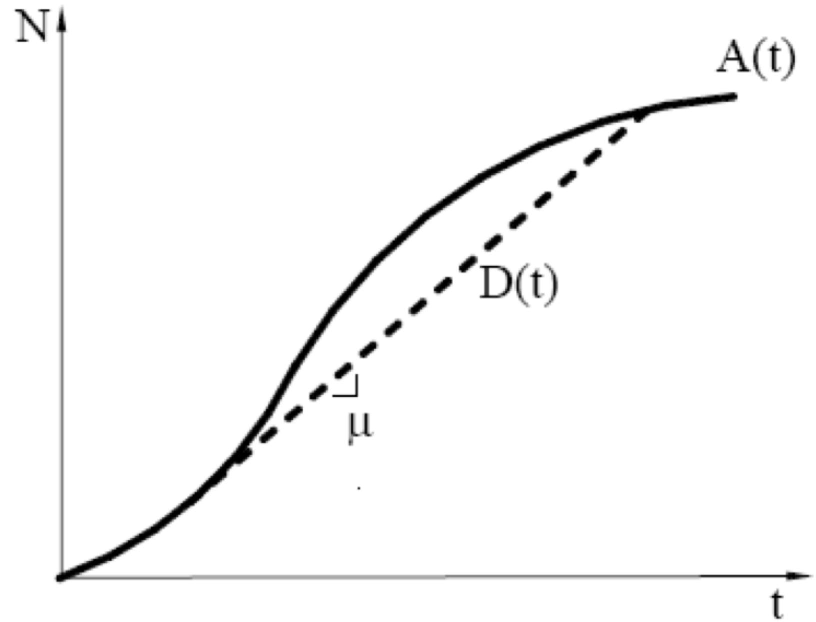




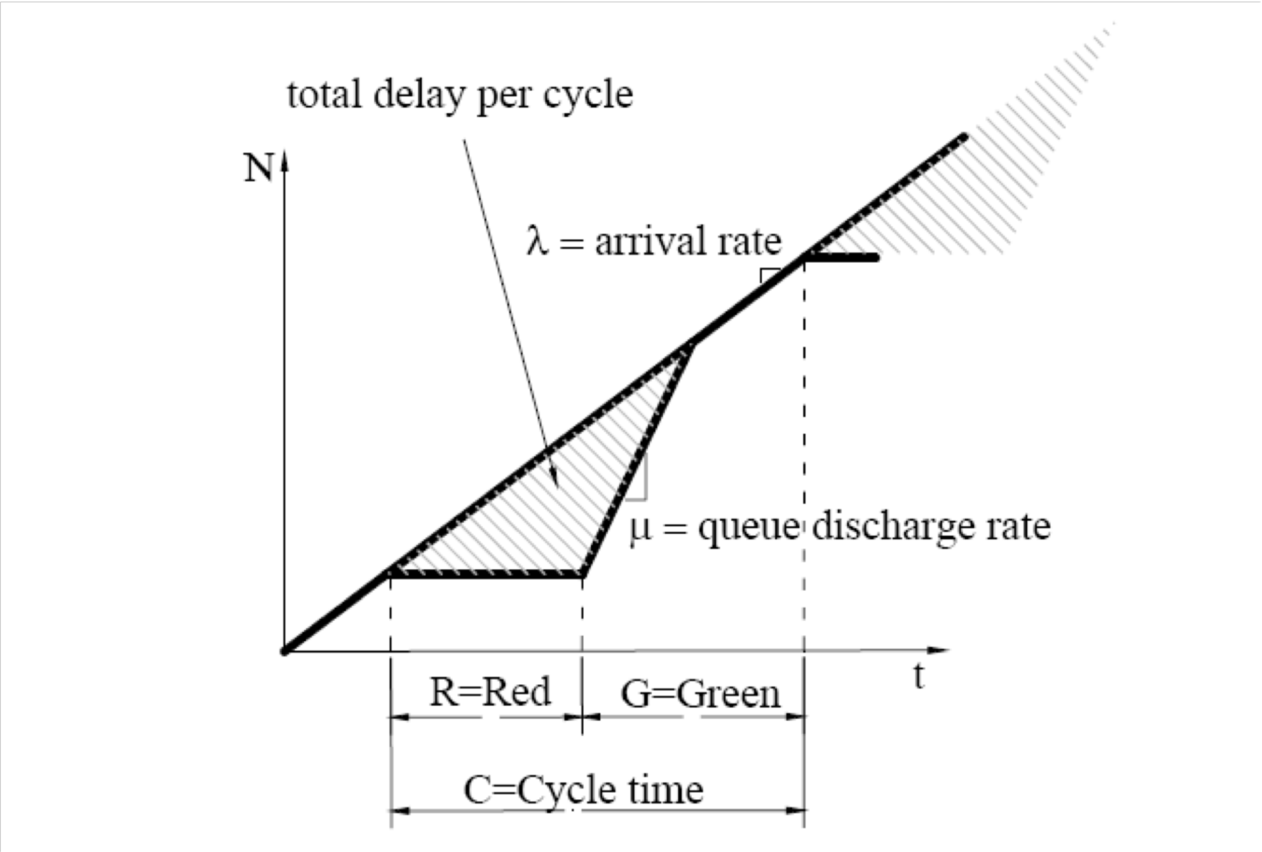
- $Q(0)$ = number of customers in queue at time 0
- $Q(t)$ = number of customers in queue at time t
- A_n = time of arrival of the n[th] customer
- D_n = time of departure of the n[th] customer

Construct I-O curves

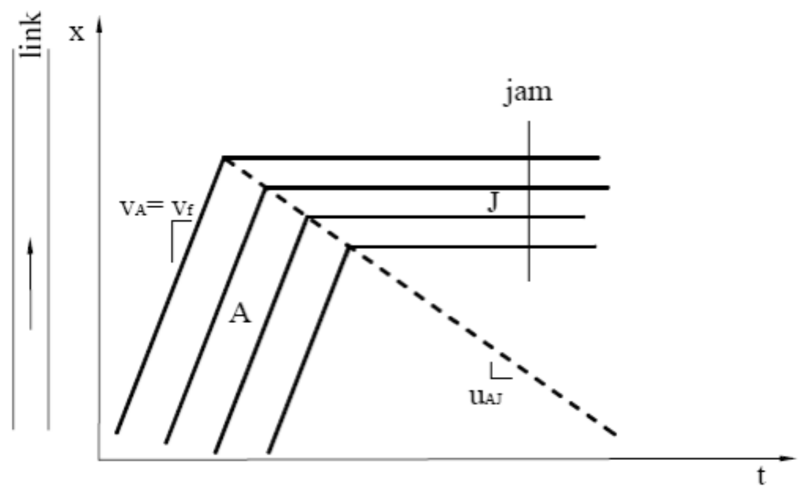
- Given $A(t)$, L, v_f and μ (service rate)

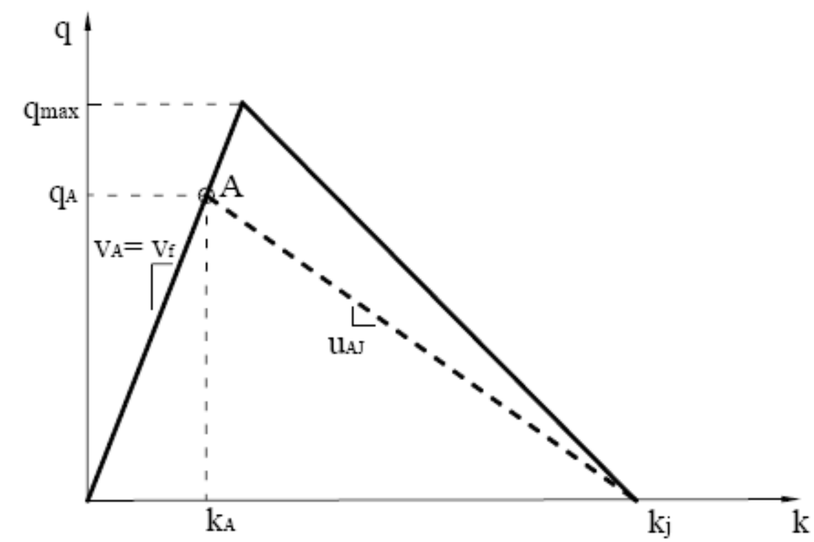


I-O curves (Example of a traffic signal)

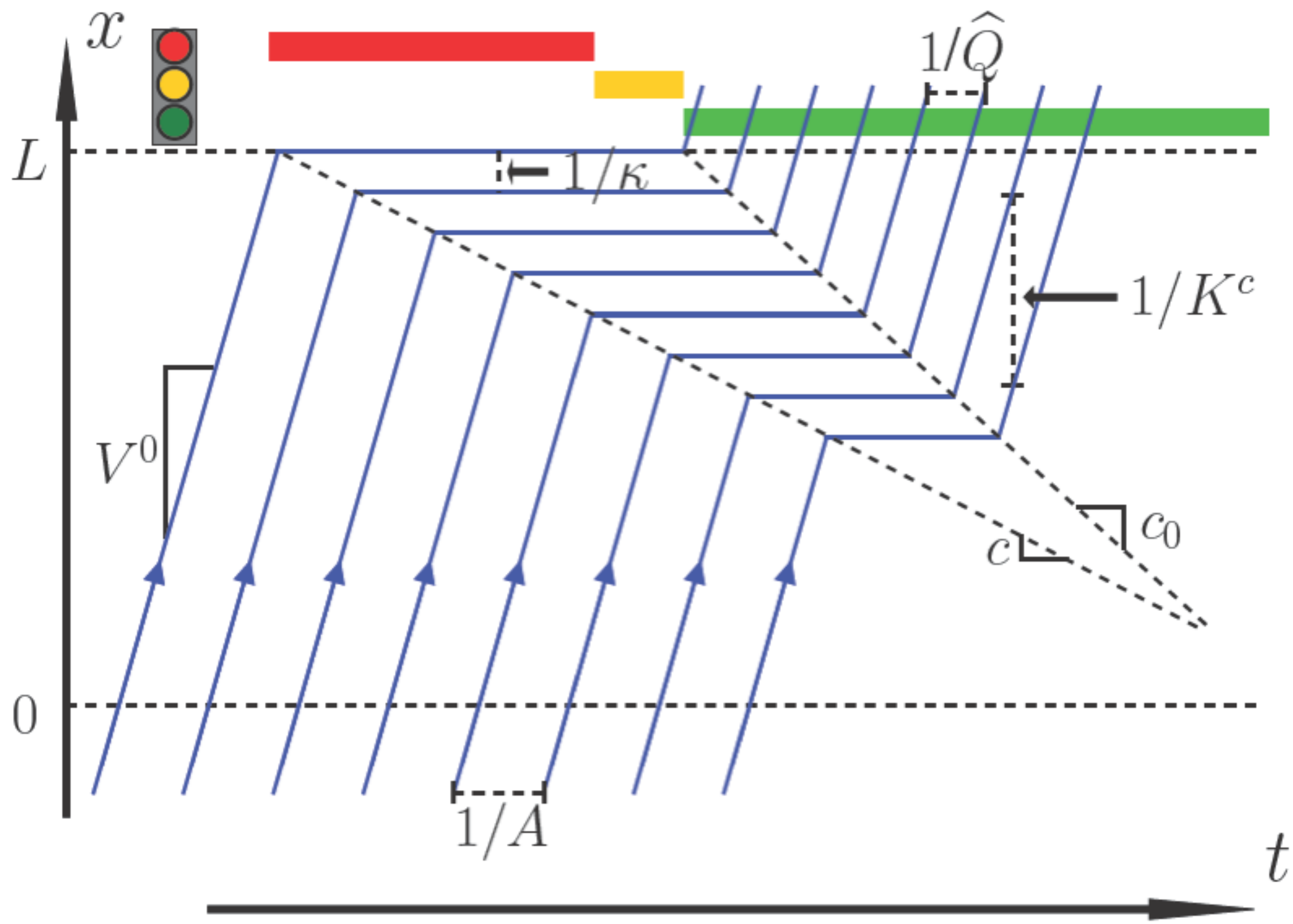


Kinematic wave theory (Example 1)

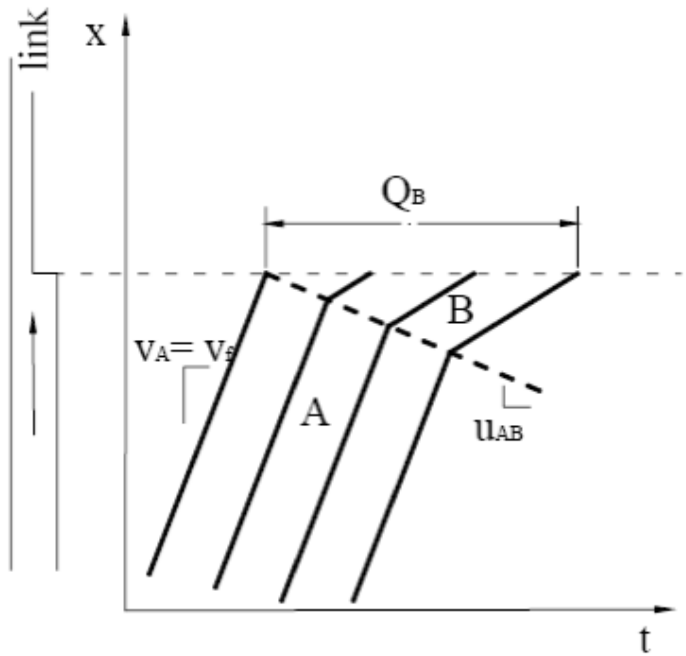


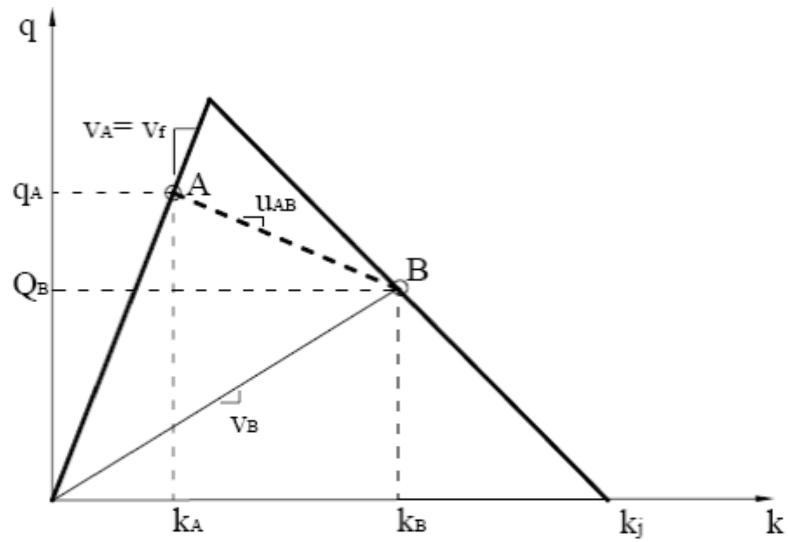


Traffic signal example



Kinematic wave theory (Example 2)





Exercise 1

- Consider a single-lane road of length L=300m with a traffic signal at each end. Estimate the average link flow and density according to the generalized definitions for the following values:
- Green=30sec, Red=30sec
- Demand q=600veh/hr
- Triangular FD with capacity=1800vh/hr, jam density=150vh/km, critical density=30vh/km

Problem 2: Passing rate formula

- A vehicle travelling at speed v, overpasses a traffic stream travelling at speed v′ and density k′. Identify the passing rate (vehicles passing per unit time).