Traffic Flow Theory

김영찬.
21세기관 524호
010.5317.2768
yckimm@uos.ac.kr

Text book: Traffic flow fundamentals, Adolf D. May, 1990

Ref: Transportation and traffic engineering handbook, 2nd ed., ITE, 1982

Traffic Engineering & Highway Engineering, 4th ed., Nicholas J. Garber, CENGAGE Learning, 2009

도철웅. 교통공학원론(상), 청문각, 2004

성적: 중간고사 (30), 기말고사 (40), 과제 (10), 출석 (10), 참여도 (10)

Contents

- traffic flow elements
  - flow, density, speed, headway, gap
  - statistical distributions, tests
- flow-density relationships – traffic stream models
  - macroscopic approach
  - microscopic approach
- shock waves in traffic stream
- gap and gap acceptance
- queuing theory

Model

- Physical model vs. mathematical model
- Static model vs. dynamic model
- Deterministic model vs. stochastic model (or probabilistic)
- Discrete model vs. continuous model
- Analytical model vs. numerical model
- Simulation (or evaluation) vs. optimization
- Microscopic model vs. macroscopic model

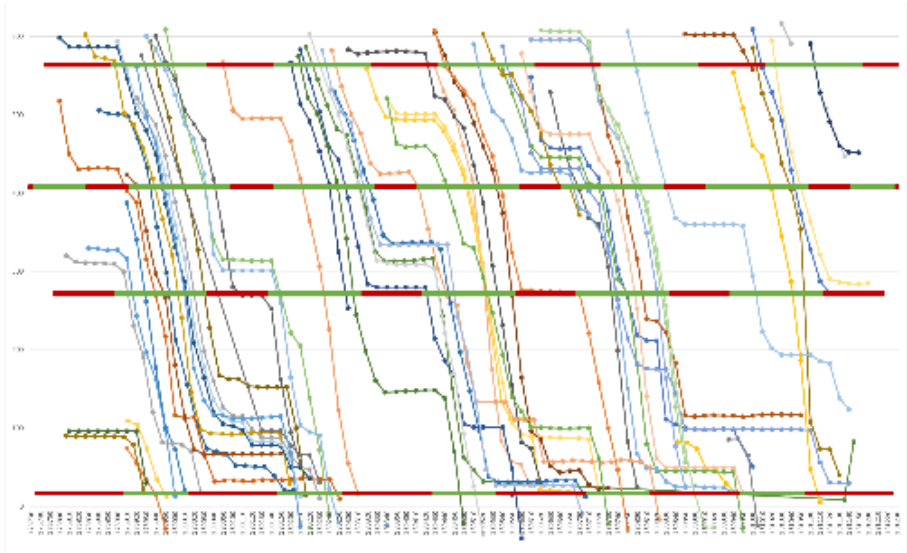
정수론
페르마의 마지막 정리
영화 Beautiful mind. 존 내쉬. 암호해독
영화 무한대를 본 남자. 라마누잔, 수의 분할
Taxicab number $1729=1^3+12^3=9^3+10^3$

직업인으로서 수학자
배고픈 직업인가?
제4차 산업혁명, 빅데이터, 소프트웨어 엔지니어

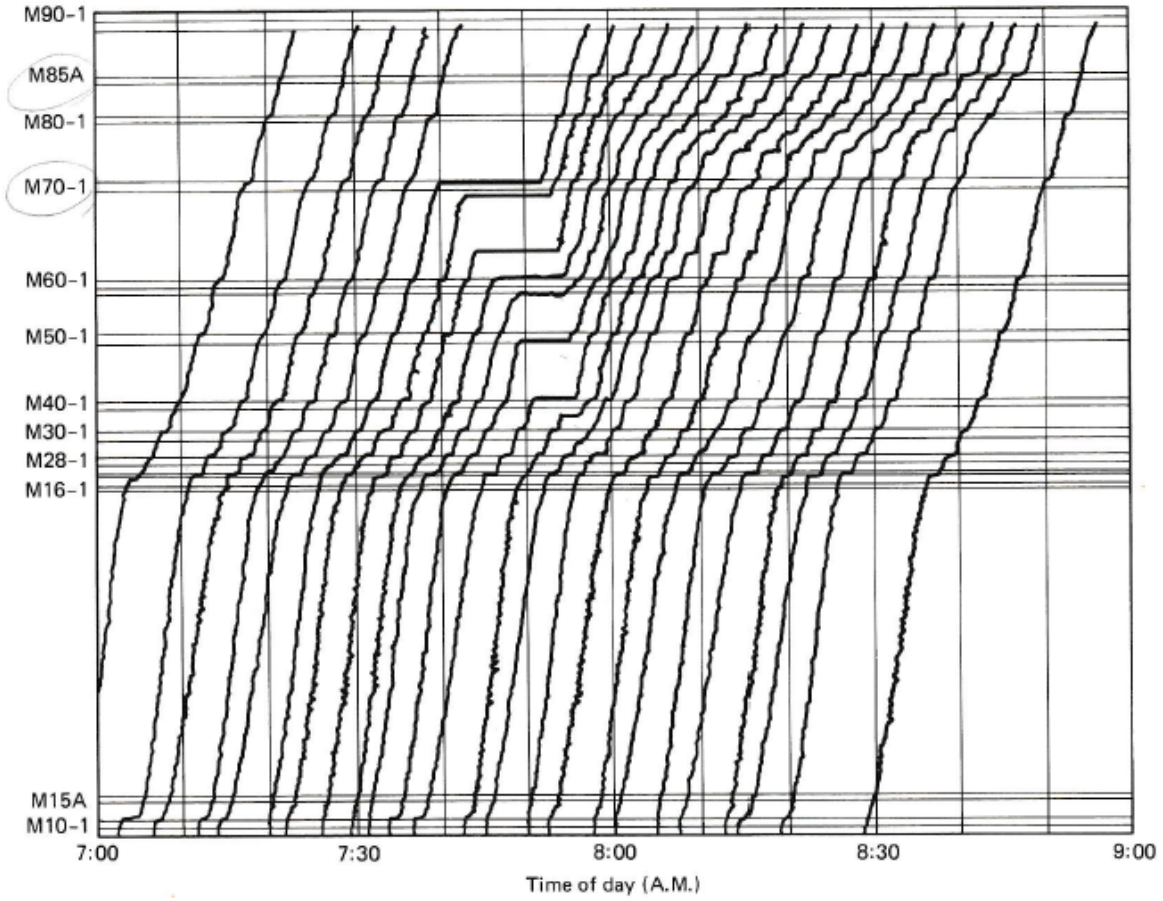
MIG 15

Phantom F-4

time-space diagram



Taxi DTG data

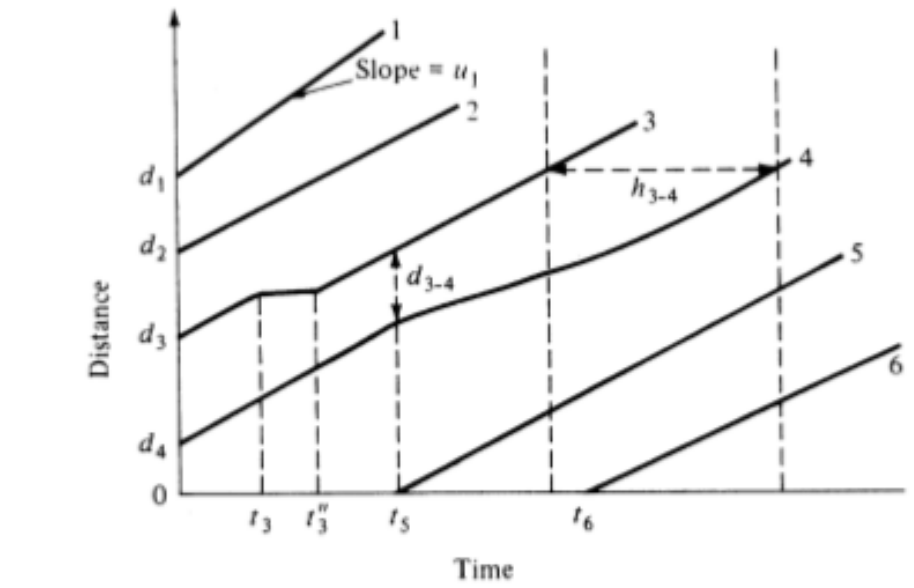


train trajectory

Variables

- Macroscopic -> microscopic
- Volume, flow, flux (veh/hour) -> time headway (sec/veh)
- Density, concentration (veh/km) -> space headway (m/veh)
- Average speed (km/hour) -> individual speed

  cf. pace (min/km)



Time-Space Diagram

- Volume = density * average speed
- [veh/hour] = [veh/km]*[km/hour]

Source: Transportation and traffic engineering handbook, 2nd ed., ITE, 1982

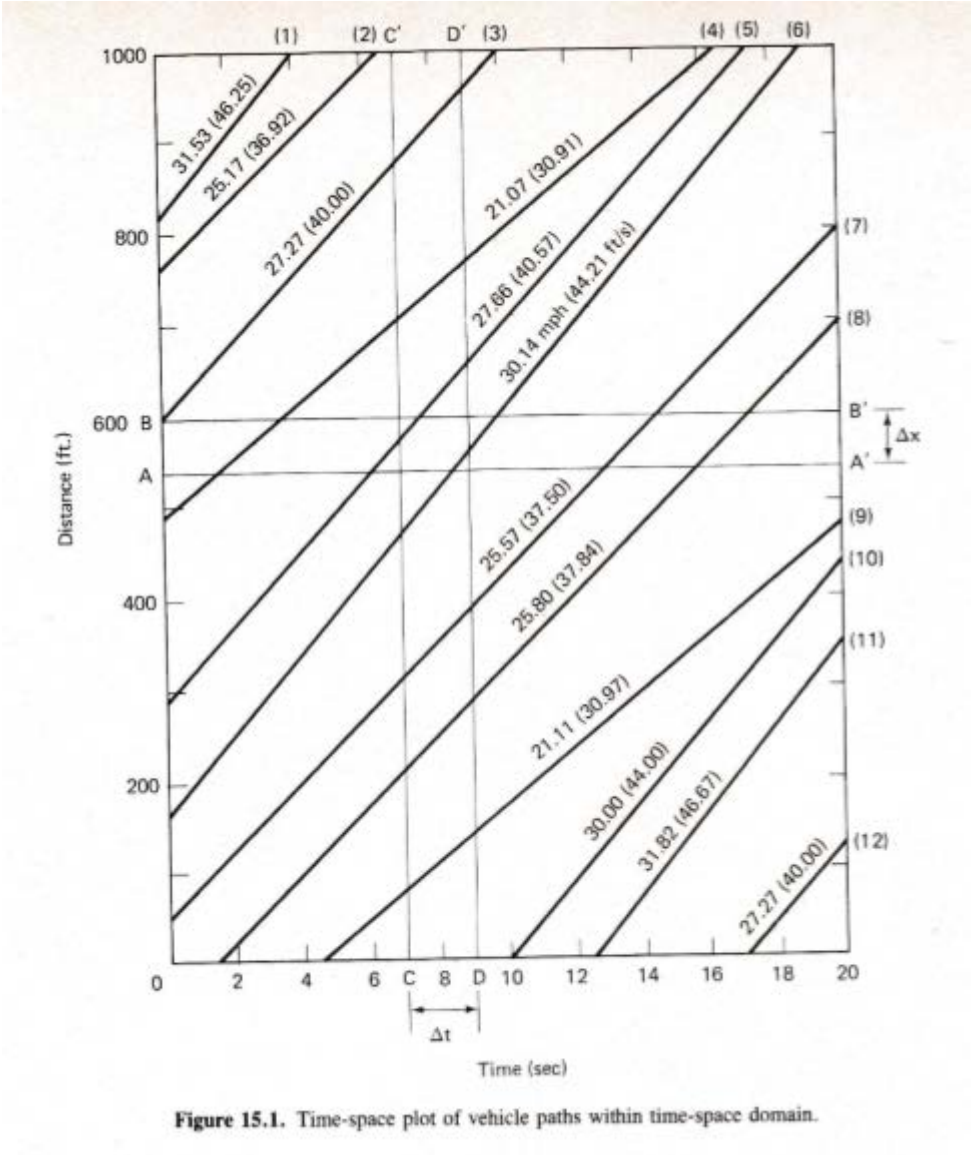


Figure 15.1. Time-space plot of vehicle paths within time-space domain.

Measurement at a point
Line A-A′ in Time T
- flow
q = N/T
= 5 veh/20 sec = .25veh/sec= 900veh/hr

flow (flow rate), volume

time headway h_t
(cf. gap)

veh no. / time of passing(sec)
4 1.62
5 6.16
6 8.60
7 13. 07
8 15.77

headways 4.54, 2.44, 4.47, 2.7
average headway 3.54
or

$$\bar{h_t} = \frac{\sum h_t}{N} = \frac{T}{N} = \frac{1}{q} = \frac{20.0\ sec}{5\ veh} = 4.0\ sec/veh$$

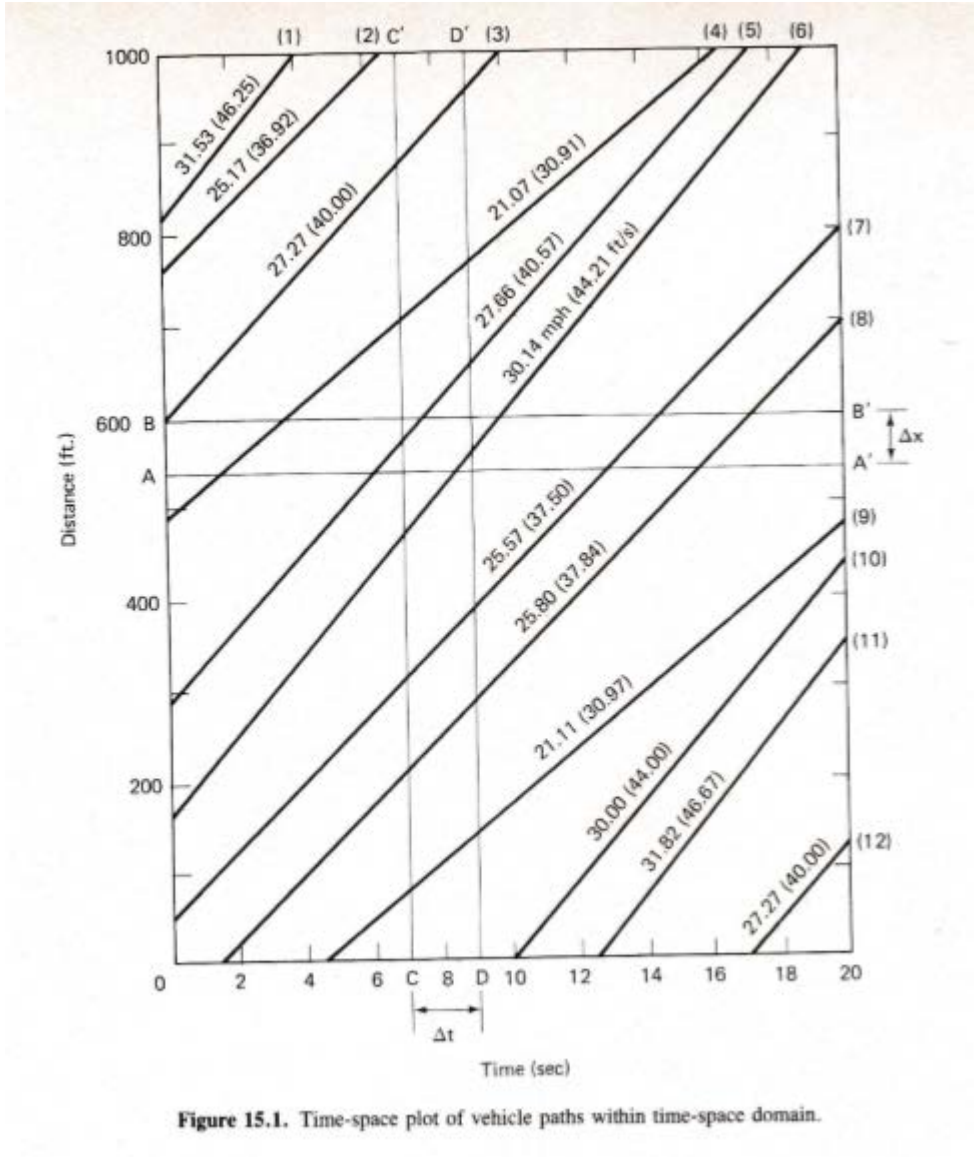


Figure 15.1. Time-space plot of vehicle paths within time-space domain.

- speed
- time mean speed: arithmetic mean of the spot speed, average
- $\bar{u}_t = \frac{1}{N}\sum_{i=1}^{N} u_i$
- = 21.07+27.66+30.14+25.57+25.80=26.05 mph
- space mean speed: harmonic mean of the speeds
- $\bar{u}_s = \frac{N}{\sum_{i=1}^{N}\frac{1}{u_i}}$= 5/(1/21.07+…..)=25.68 mph
- Wardrop
- $\bar{u}_t = \bar{u}_s + \frac{\sigma_s^2}{\bar{u}_s}$

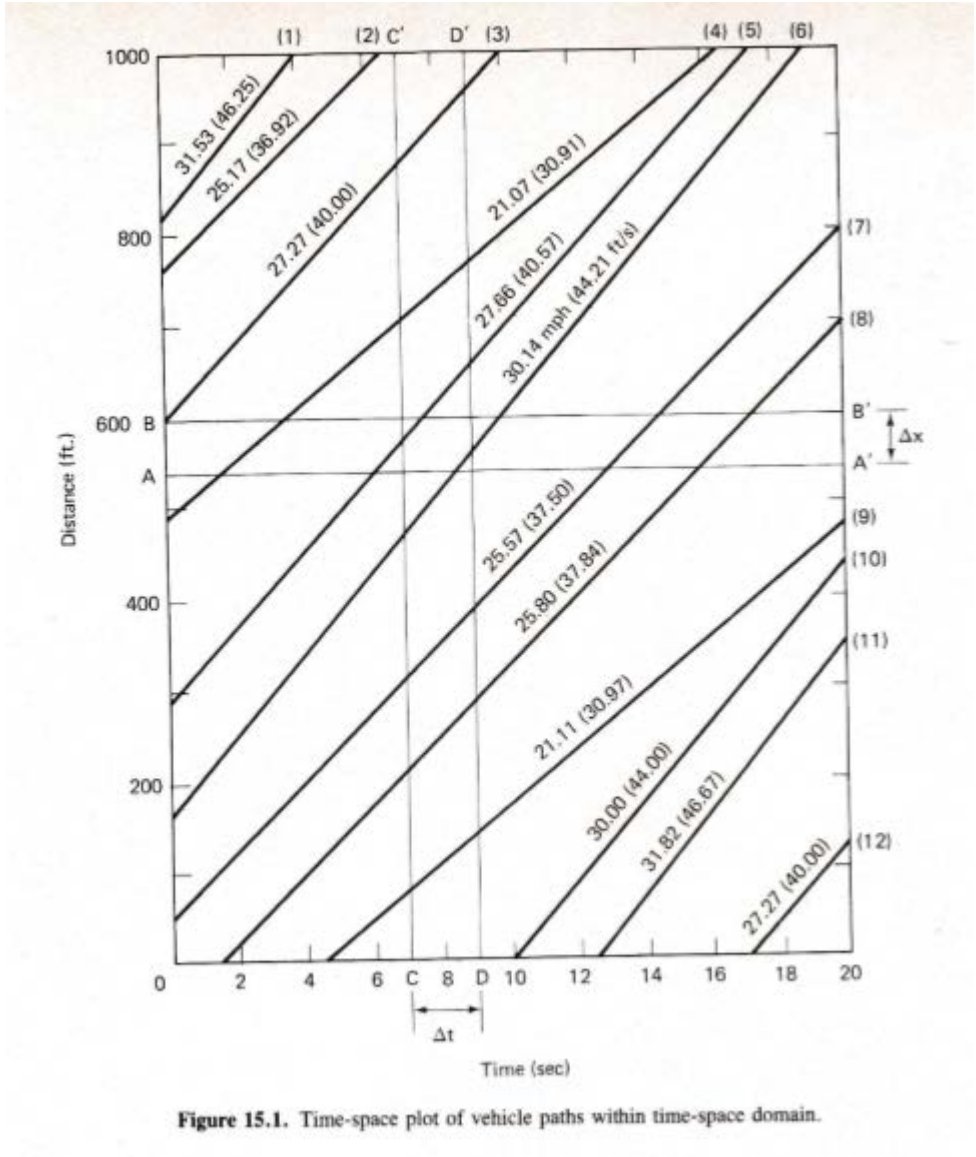


Figure 15.1. Time-space plot of vehicle paths within time-space domain.

- speed trap
- observation at A-A′ and B-B′, 60ft
- veh no/trap time(sec)/speed(mph)

  4/1.94/21.07

  5/1.48/27.66

  6/1.36/30.14

  7/1.60/25.57

  8/1.59/25.80
- time mean speed
- $\bar{u}_t = \frac{21.07+\cdots}{5} = 26.05mph$

- space mean speed
- $\bar{u}_s = \frac{\Delta x}{\overline{\Delta t_i}},\ where\ \overline{\Delta t_i} = \frac{\sum_{i=1}^{N} \Delta t_i}{N}$
- $\bar{u}_s = \frac{N\Delta x}{\sum_{i=1}^{N} \Delta t_i}$ = 5*60/7.97 = 37.64ft/sec
- general definition of space mean speed

$$= \frac{TT}{TTT} = \frac{Total\ Travel\ distance}{Total\ Travel\ Time}$$

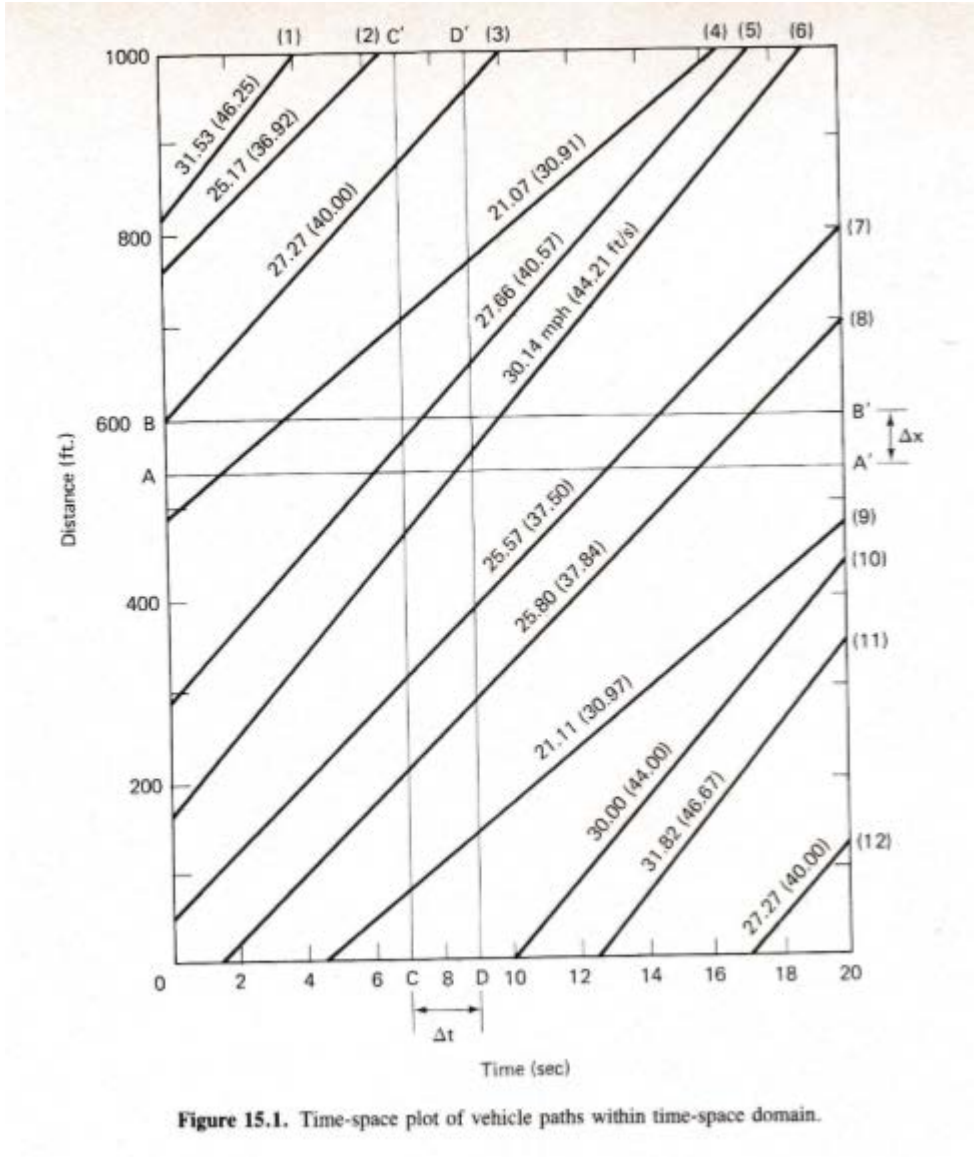


Figure 15.1. Time-space plot of vehicle paths within time-space domain.

- density: no. of veh's per length of roadway
- Assume substreams of k_i and u_i
- For each substream, k_i = q_i/u_i
- density-weighted average
- $\bar{u}_s = \frac{\sum k_i u_i}{\sum k_i} = \frac{\sum k_i u_i}{k}$
- Since k_i*u_i = q_i,
- $\bar{u}_s = \frac{\sum q_i}{k} = \frac{q}{k}$
- q = u_s*k
- flow = space_mean_speed * density
- k = (900veh/h)*(25.68mph)=35.05 vpm

- lane occupancy
- $R_1 = \frac{\sum vehicle\ lengths}{length\ of\ roadway\ section}$
- six vehicles, 18, 20, 45, 15, 18, 22 ft along 1000 ft long section
- R_1=138/1000=0.138
- ave_veh_length=23.0ft
- density=R_1/ave_veh_length=0.138/23.0*5280=31.7veh/mile
- Measuring veh length is not practical.
- Presence detector measures 'occupancy time'.
- $R_2 = \frac{\sum occupacy\ times}{total\ time\ of\ obervation\ period} = occupacy\ (ratio)$
- $k = R_2 \frac{5280}{L_e} = \frac{\sum t_o \cdot 5280}{L_e}$, where Le=effective length of vehicle in feet

- Assume det. length=20ft, veh. length=15ft
- L_e= 20+15=35ft
- occupancy times during a 60-sec period
- .38, .45, .35, .52, .55, .42, .30, .41, .60, .40 sec, sum=4.38
- k =(4.38/60)(5280/30)=12.85veh/mi
- From $\bar{u} = q/k$, $\bar{u}_s = \frac{NL_e}{\sum t_o} = \frac{10*30}{4.38} = 68.49 ftpsec = 46.70 mph$
- The mix of trucks and cars can lead to errors in the speed estimation.
- If 3 trucks with 45-ft length and 7 cars with 20-ft length,
- $k = \frac{3+7}{3*45+7*20}\left(\frac{4.38}{60}\right)5280 = 14.02\ veh/mi$

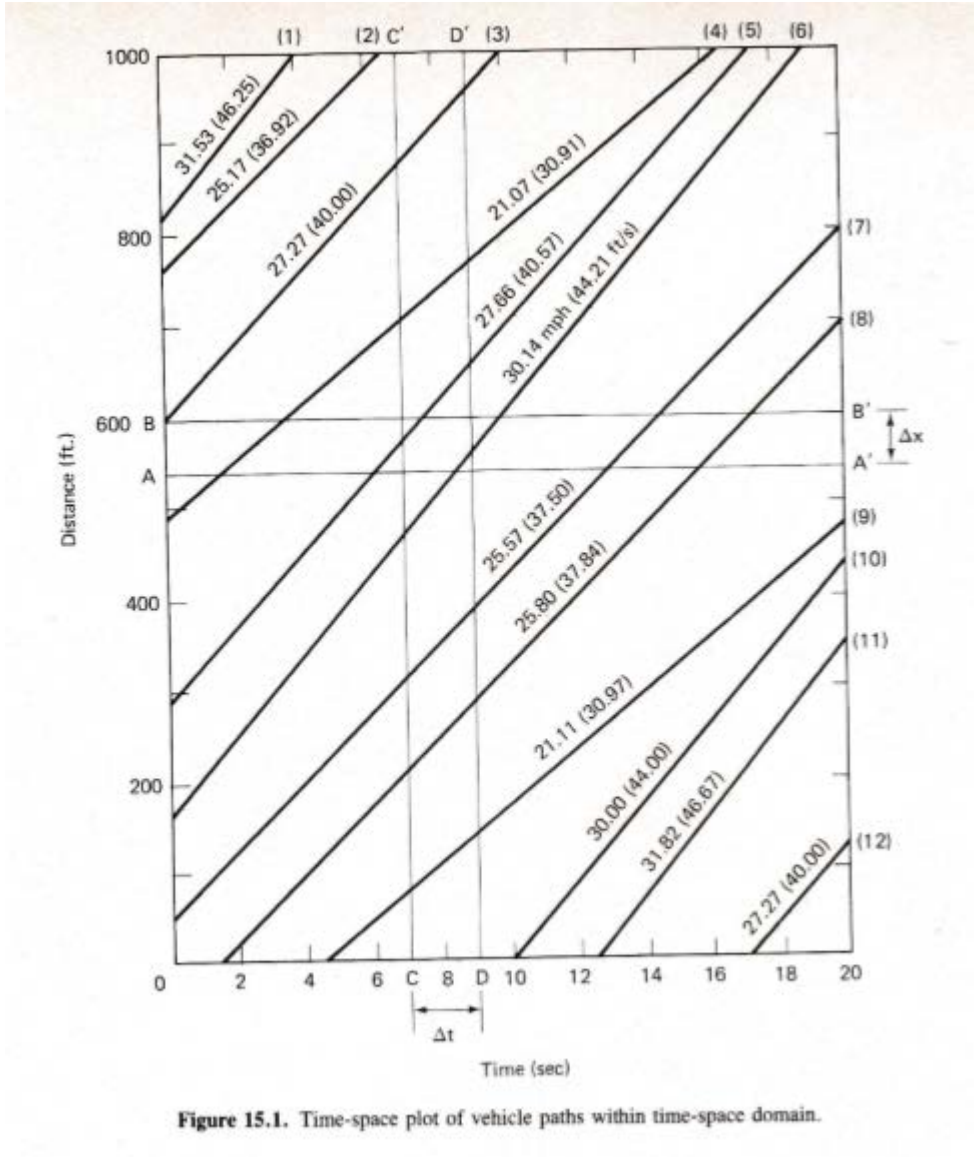


Figure 15.1. Time-space plot of vehicle paths within time-space domain.

- MEASUREMENT ALONG A LENGTH
- Line C-C′ and D-D′
- Density
- $k = \frac{N}{l} = \frac{7}{1000} 5280 = 36.96 vpm$
- Speed u is measured from two observations Δt apart
- $u_i = \frac{s_i}{\Delta t}$
- $\bar{u}_s = \frac{1}{N} \sum u_i = \frac{1}{N} \sum \frac{s_i}{\Delta t} = \frac{1}{N \Delta t} \sum s_i = \frac{TT}{TTT}$

Vehicle	Position 1	Position 2	s_i (ft)
3	880.0	960.0	80.0
4	706.4	768.2	61.8
5	574.0	655.1	81.1
6	469.5	557.9	88.4
7	312.5	387.5	75.0
8	208.1	283.8	75.7
9	77.4	139.4	62.0
			$\Sigma s_i = 524.0$

- $\bar{u}_s = \frac{524.0}{7*2.0} = 25.5mph$
- q = k*u
- q = 36.96*25.5=942vph

General definition of variables

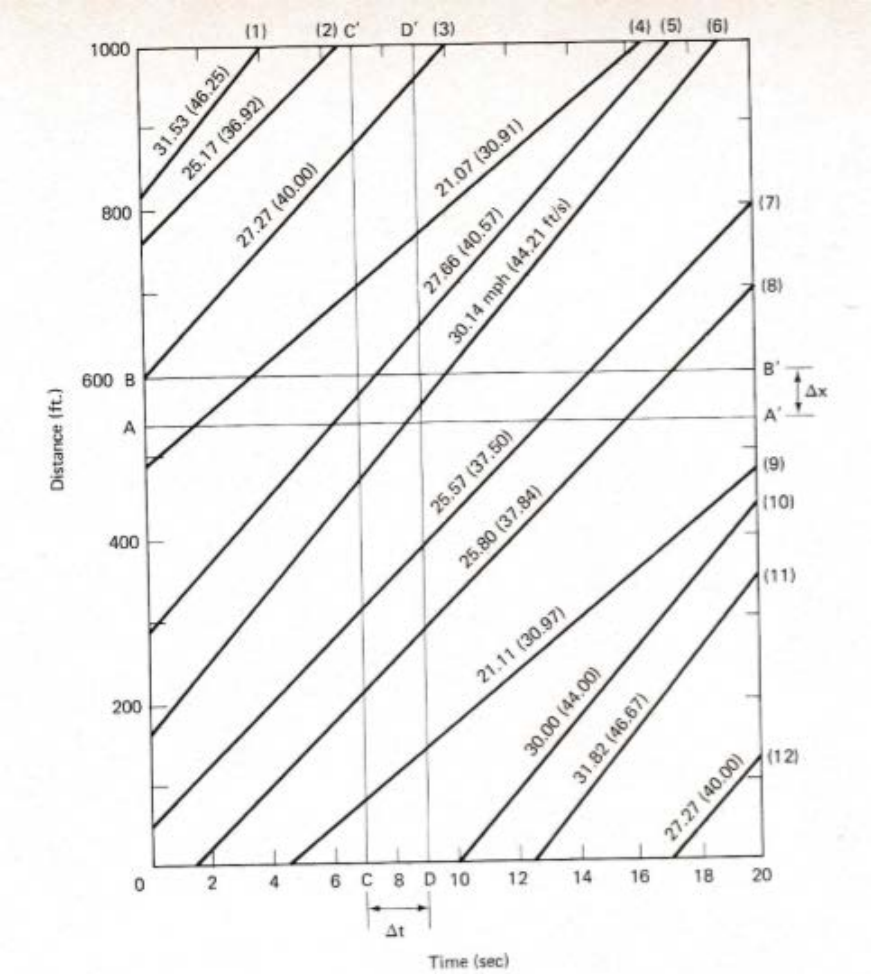


Figure 15.1. Time-space plot of vehicle paths within time-space domain.

$$q = \frac{\sum x_i}{A}$$

$$k = \frac{\sum t_i}{A}$$

$$\bar{u}_s = \frac{\sum x_i}{\sum t_i}$$

Σx_i = 5740 veh-ft
Σt_i = 148 veh-sec
A = 20,000 feet-sed
q = 5740/20000 = .29 veh/s = 1033.2 veh/s
k = 148/20000 = .0074 veh/ft = 39.07 veh/mi
u_s = 5740/148 = 38.78 ft/s = 26.44 mph