Traffic Engineering - Lecture 5: Queuing Analysis

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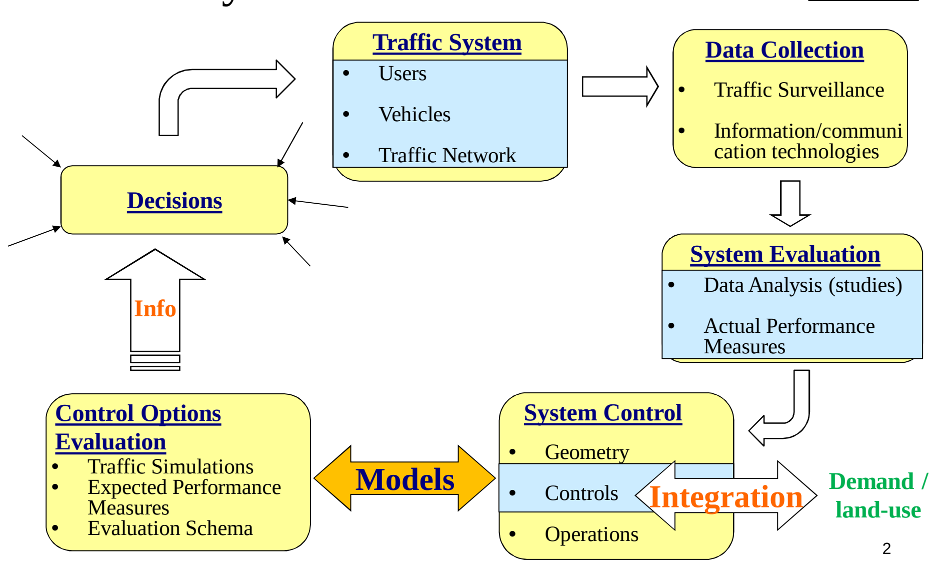
1

Course Syllabus

WHAT?
WHY?
HOW?



2

Traffic Congestion

- Recurrent Congestion:
  - Congestion that is repeatedly encountered (daily, weekly…etc), such as peak hour congestion.
- Non-Recurrent Congestion
  - Unusual congestion due to a temporary reduction in roadway capacity, such as accident-induced congestion.

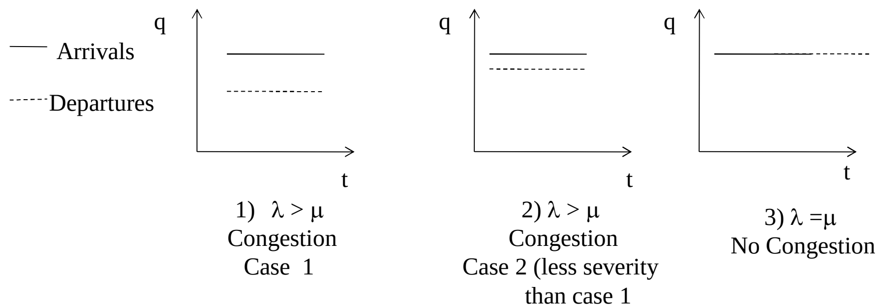
Queuing Analysis Classification Schema

- Arrivals and Departure characteristics
  - Deterministic (constant or time variant)
  - Probabilistic (such as Poisson distribution)
- Queuing Discipline
  - First-in-First-out (FIFO)
  - First-in-Last-out (FILO)
  - Served-in-Random-Order (SIRO)
- Number of Departure Channels

Queuing Analysis – D/D/1

(**D**eterministic Arrival/**D**eterministic Departure/ **1** channel)

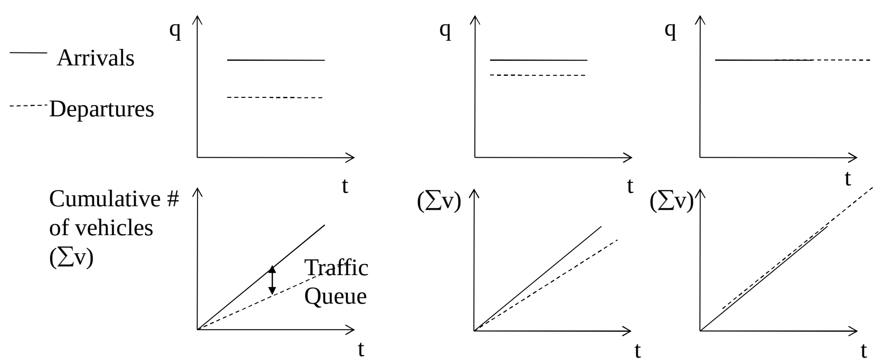
- Arrival (λ) Vs Departure (μ) Rates



Hoda Talaat 5

Queuing Analysis – D/D/1

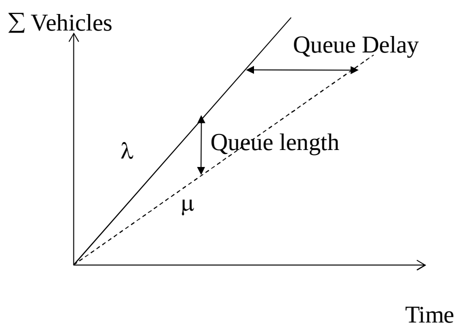
- Cumulative arrivals/departures



Hoda Talaat 6

Queuing Analysis – D/D/1

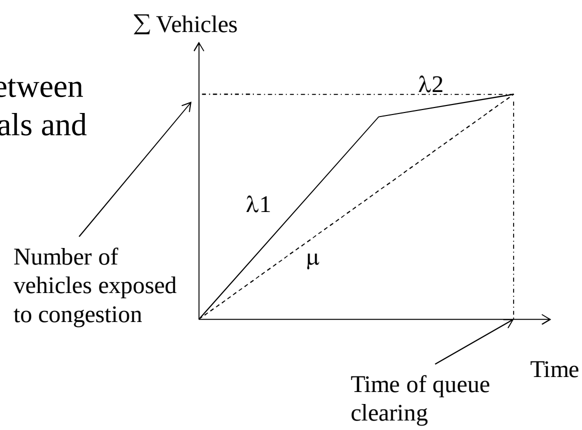
- Queue Length
  - Vertical Distance (# of vehicles in queue)
- Vehicles Delay
  - Horizontal Distances



Hoda Talaat 7

Queuing Analysis – D/D/1

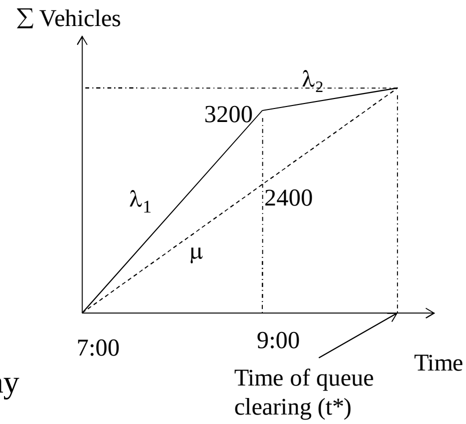
- Total Delay
  - Area enclosed between cumulative arrivals and departures



Hoda Talaat 8

D/D/1 - Example 1:
Constant Arrival rate per time interval

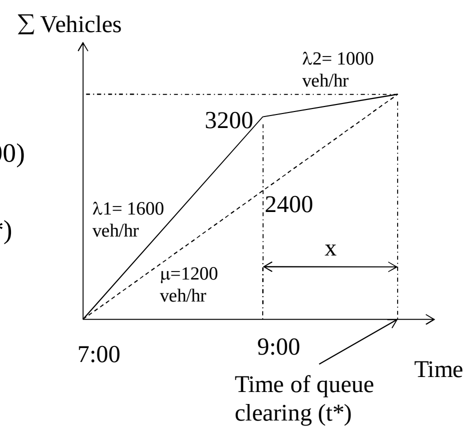
- 7:00 t0 9:00 am
  - Arrivals (λ_1)= 1600 veh/hr
  - Departures (μ) = 1200 veh/hr
- 9:00 an up
  - Arrivals (λ_2)= 1000 veh/hr
  - Departures (μ) = 1200 veh/hr
- Estimate max queue, time of queue clearing, and total delay



Hoda Talaat 9

D/D/1 - Example 1:
Constant Arrival rate per time interval

- Max Queue= 3200-2400
  = 800 vehicles
- <u>To get t*</u>
  - 3200+x*(1000)= 2400+x*(1200)
  - x= 4 hrs
  - Queue will clear at 1:00 pm (t*)
- Total Delay= area
  = 0.5*2*800+0.5*4*800
  = 2400 veh.hr

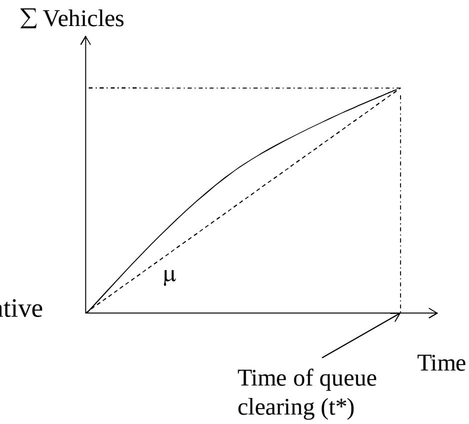


Hoda Talaat 10

D/D/1 - Example 2:

Arrival Rate as a function of time

- λ= 100-10t
  - Cumulative Arrivals= $\int \lambda \, dt$
    = $100t-5t^2$
- μ= 55
  - Cumulative Departures= μ t
    = 55t
- At t*
  - Cumulative Arrivals = Cumulative Departures
  - 100t-5t2=55t
  - t*= 9 hrs



Hoda Talaat 11

D/D/1 - Example 2:

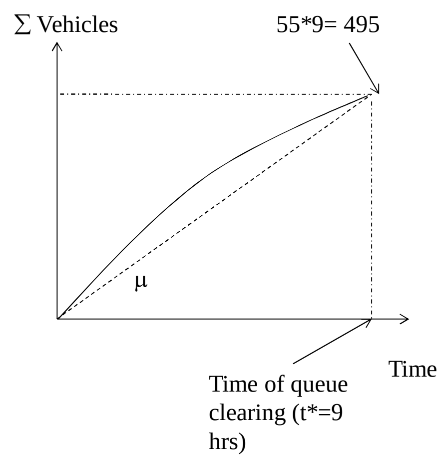
Arrival Rate as a function of time

- Total Delay= enclosed area

$$\int_0^9 (100t - 5t^2)dt - 0.5*9*495$$

$$= \left[50t^2 - \frac{5t^3}{3}\right]_0^9 - 2227.5$$

$$= 607.5 veh.hr$$



Hoda Talaat 12

D/D/1 - Example 2: Arrival Rate as a function of time

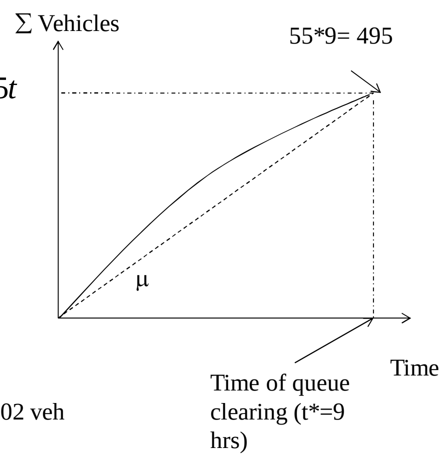
- Max Queue Length

$$queue-length(t) = 100t - 5t^2 - 55t$$

$$queue-length(t) = 45t - 5t^2$$

$$\frac{d(queue-length)}{dt} = 45 - 10t = 0$$

$t = 4.5hr$ ➔ Time of max queue



Max queue length=45(4.5)-5(4.5)^2= 101.25

➔ 102 veh

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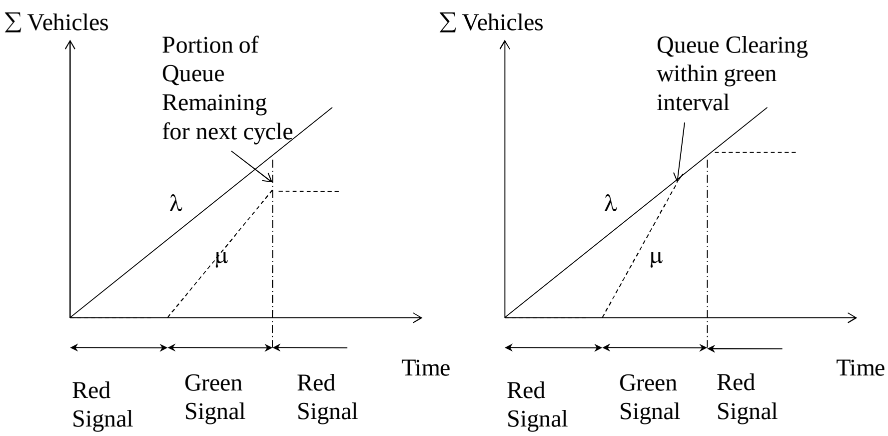
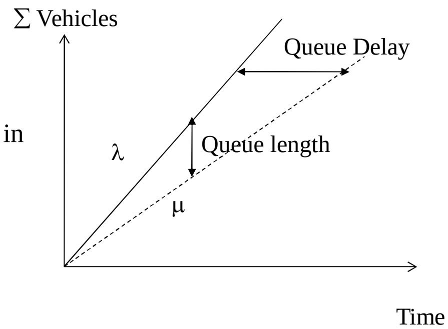
D/D/1 - Example 3: Constant Arrival Rates (signalized intersection)



Hoda Talaat 14

Applications of Queuing Analysis

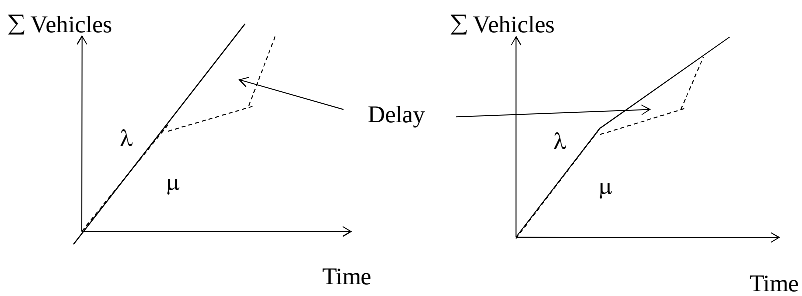
- How to Relief Recurrent Congestion
  - **Increase departure rate «**
    ➔ Increase Capacity (add lanes, eliminate operational reduction in capacity such as random stops, change in signal design…etc)
  - **Reduce arrival rate ª**
    ➔ Reduce demand (car pooling, flexible working hours, transit alternatives…etc)



Hoda Talaat 15

Applications of Queuing Analysis

- How to Relief Non-Recurrent Congestion
  - Reduce arrival rate λ
    ➔ Reduce demand by vehicles re-routing



Hoda Talaat 16