

HCM 2010: BASIC CONCEPTS



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OUTLINE

- ◆ **Capacity**
- ◆ **Auto mode concepts – demand, speed, flow, density**
- ◆ **Microscopic characteristics – spacing, headway**
- ◆ **Fundamental traffic relationship**
- ◆ **Interrupted flow – signalized, unsignalized (Stop, Yield)**
- ◆ **Delay and queuing at signals**



CAPACITY

- ◆ **Capacity** *“represents the maximum sustainable hourly flow rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, environmental, traffic, and control conditions.”*
- ◆ Reasonable expectancy is key
 - ◆ The stated capacity must be achieved repeatedly for peak periods
 - ◆ Not the maximum flow rate ever to be observed



AUTOMOBILE MODE CONCEPTS

◆ Volume

- ◆ Number of vehicles that pass over a given point or section of a lane or roadway during a given time interval
- ◆ Typically expressed in terms of annual, daily, hourly, or subhourly periods

◆ Flow rate

- ◆ The equivalent hourly rate at which vehicles pass over a given point or section of a lane or roadway during a given time interval of less than 1 h, usually 15 min.

◆ Demand

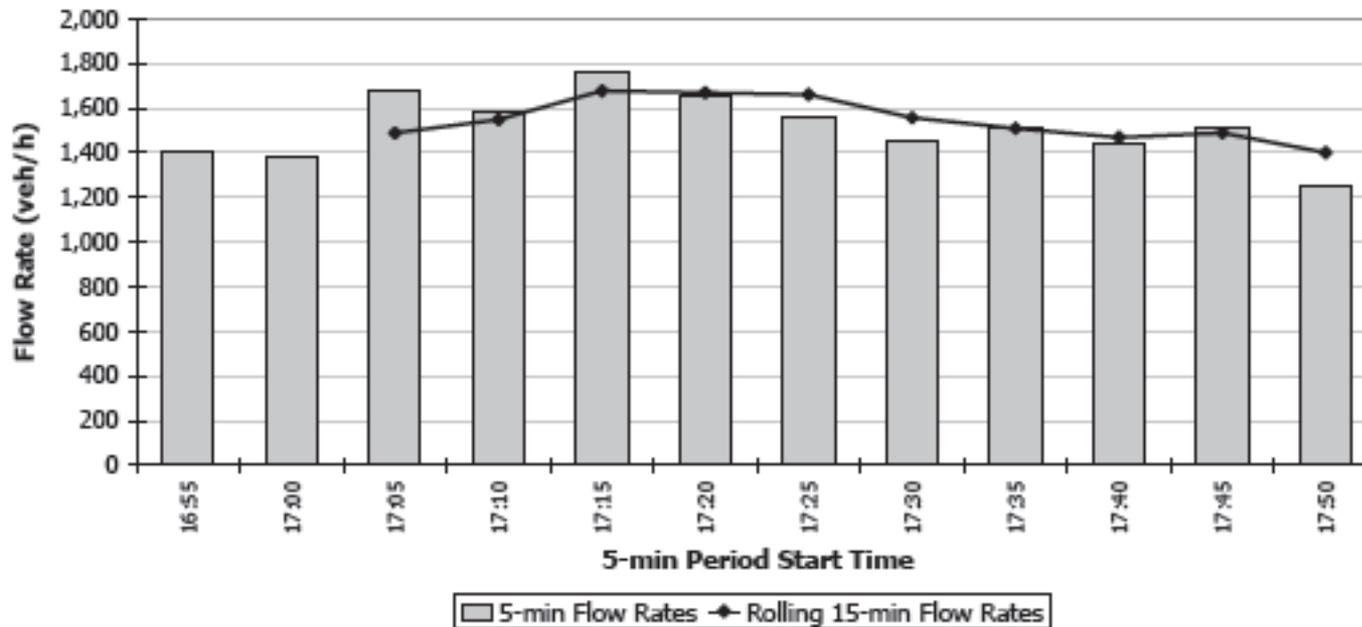
- ◆ Number of vehicles that desire to use a given system element during a specific time period, typically 1 h or 15 min.

DEMAND VOLUMES

- ◆ Observed volumes at a system element (e.g., point) may differ from demand volumes
 - ◆ Due to an upstream bottleneck
 - ◆ HCM uses demand volumes
 - ◆ If a bottleneck is present upstream of the system element use arrival volume than departure volume at the bottleneck
- ◆ Demand patterns may change after removing a bottleneck
- ◆ Ignoring the effect of upstream bottleneck and treating observed volumes as demand volumes
 - ◆ Inaccurate HCM analysis
 - ◆ Underestimate the extent of congestion and overestimate LOS

PEAK HOUR FACTOR

◆ Subhourly variations in flow rate



◆ Peak hour factor (PHF) = hourly volume/peak flow rate (within the hour)



SPEED

◆ Speed

- ◆ Quality of traffic service provided to motorist
 - ◆ Determines LOS for two-lane highways and urban streets
- ## ◆ Different speed parameters for a traffic stream
- ◆ Average travel speed
 - ◆ Space mean speed
 - ◆ Time mean speed
 - ◆ Free-flow speed
 - ◆ Average running speed

SPEED PARAMETERS

- ◆ Average travel speed
 - ◆ Length of segment divided by the average travel time
 - ◆ Includes stopped delay times
 - ◆ Same as the space mean speed
- ◆ Time mean speed
 - ◆ Arithmetic average of speeds of vehicles observed passing a point on a highway
 - ◆ Also referred to as the average spot speed
 - ◆ Greater than or equal to space mean speed



SPEED PARAMETERS

- ◆ Free-flow speed
 - ◆ Average speed measured under low-volume conditions
 - ◆ Drivers free to drive at their desired speeds not constrained by traffic control or geometrics

- ◆ Average running speed
 - ◆ Length of segment divided by the average running time
 - ◆ Includes only time during which vehicles are in motion
 - ◆ Does not include stopped delay

DENSITY

- ◆ Density
 - ◆ Number of vehicles occupying a given length of a lane or roadway at a particular instant
 - ◆ Usually expressed as vehicles per mile (veh/mi) or passenger cars per mile (pc/mi)
- ◆ Field measurements are difficult
- ◆ Thus, computed using fundamental relationship $q = ku$
 - ◆ u and q can be easily measured
- ◆ Density is key parameter for uninterrupted flow facilities
 - ◆ Denotes quality of traffic operations
 - ◆ Proximity of vehicles to one another, maneuverability inside traffic stream



MICROSCOPIC CHARACTERISTICS

◆ Spacing

- ◆ Distance between successive vehicles in a traffic stream
- ◆ Measured from the same point on each vehicle (e.g., front bumper)

◆ Headway

- ◆ Time between successive vehicles as they pass a point on a lane or roadway,
- ◆ Also measured from the same point on each vehicle

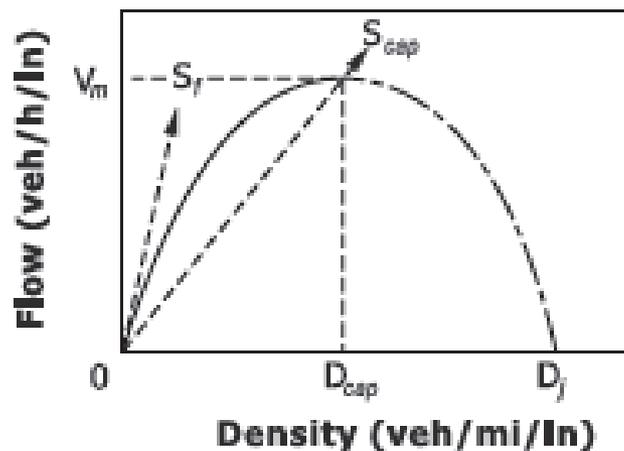
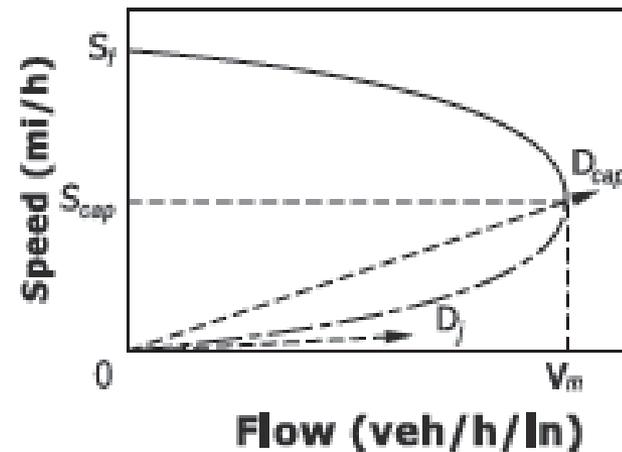
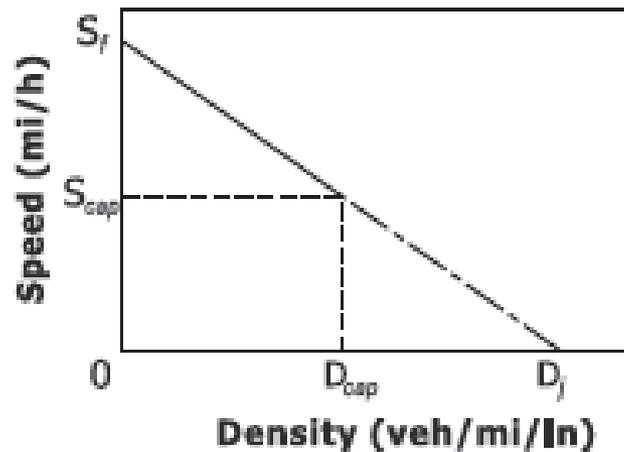
◆ Related to macroscopic variables density and flow rate

- ◆ Average spacing = $5280/\text{density}$
- ◆ Average headway = $3600/\text{flow rate}$

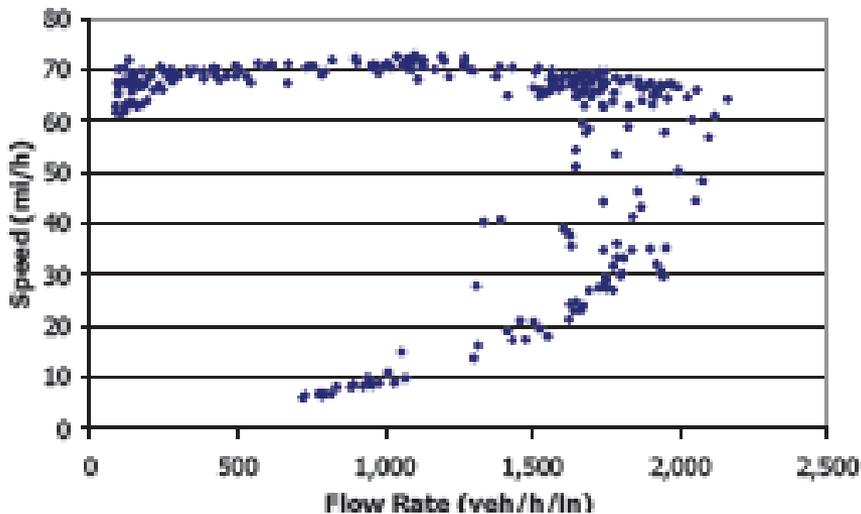
OCCUPANCY

- ◆ Occupancy
 - ◆ Proportion of roadway length covered by vehicles or,
 - ◆ Proportion of time a roadway cross section is occupied by vehicles
- ◆ Roadway occupancy as a surrogate for density
- ◆ Easier to measure (say using loop detectors)
- ◆ Precise length of vehicles is needed to convert occupancy to density, else errors occur

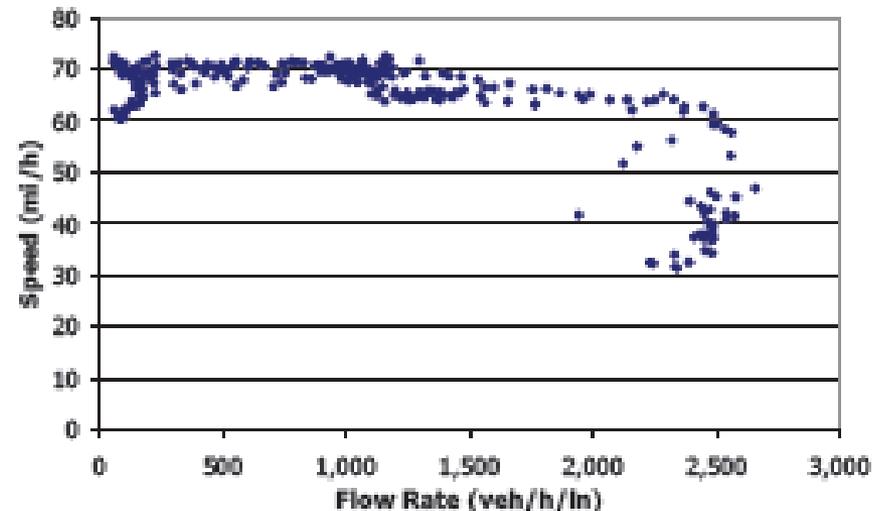
FUNDAMENTAL RELATIONSHIP OF TRAFFIC



FUNDAMENTAL RELATIONSHIP OF TRAFFIC



(a) I-405, Los Angeles, California



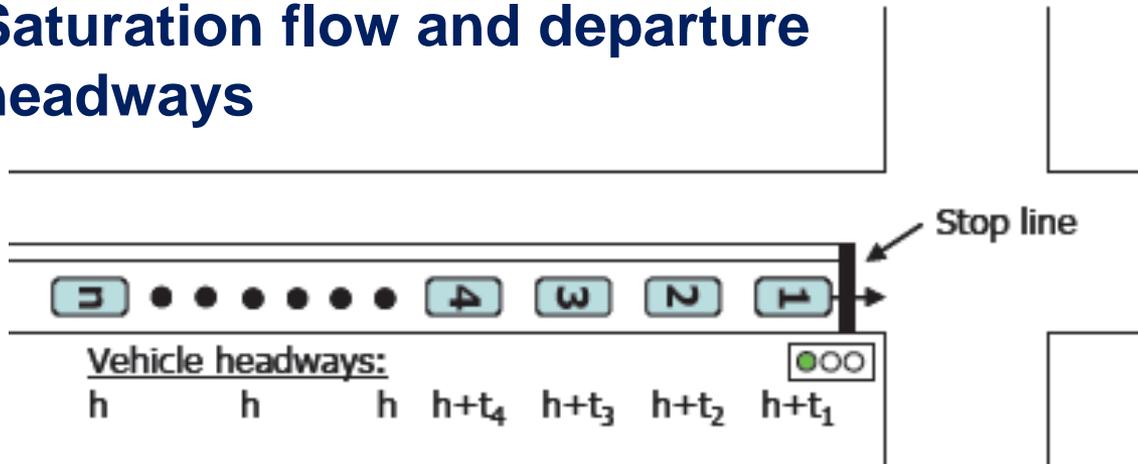
(b) I-805, San Diego, California

INTERRUPTED FLOW PARAMETERS

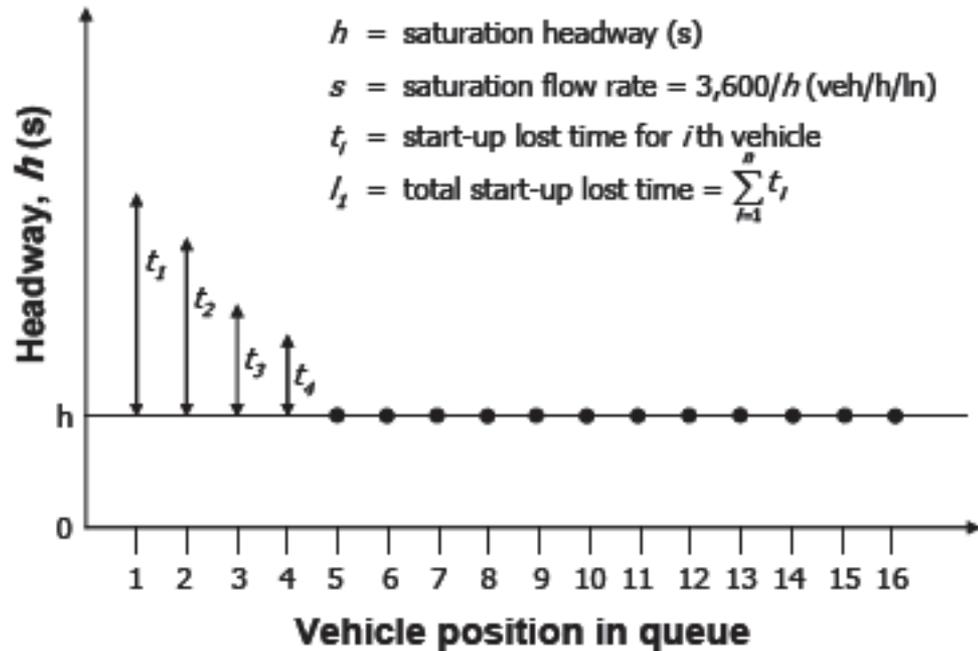
- ◆ Volume and flow rate (same as previously defined)
- ◆ Saturation flow and departure headways
- ◆ Control variables (STOP or signal control)
- ◆ Gaps available in the conflicting traffic streams
- ◆ Control delay

SIGNALIZED INTERSECTION FLOW

Saturation flow and departure headways

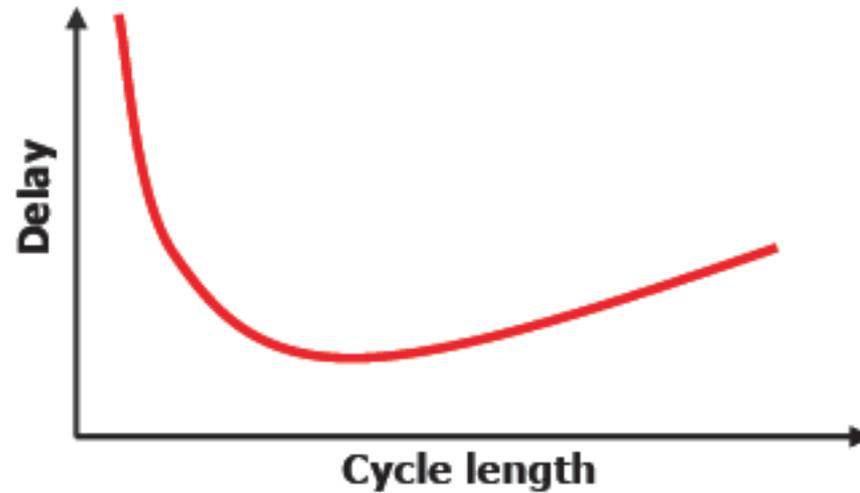


$$s = \frac{3,600}{h}$$



SIGNAL: DELAY VS CYCLE LENGTH

Optimal cycle length exists that minimizes the total intersection delay





STOP AND YIELD CONTROL

- ◆ Time Gap and Space Gap between major road vehicles entering an unsignalized intersection
 - ◆ Measured from rear bumper to front bumper
- ◆ Gap acceptance – completion of a vehicle's movement into a gap
- ◆ Capacity of minor road depends on
 - ◆ Distribution of available gaps in major road traffic stream
 - ◆ Gap sizes acceptable to drivers
- ◆ Headways (front bumper to front bumper) used in lieu of gaps due to ease of data collection

STOP AND YIELD CONTROL

◆ Critical headway

- ◆ Minimum time headway in the major traffic stream that will allow entry of one minor road vehicle

◆ Follow-up headway

- ◆ When more than one minor road vehicle merge into one major road gap, the headway between minor road vehicles is follow-up headway



INTERRUPTED FLOW MEASURES - DELAY

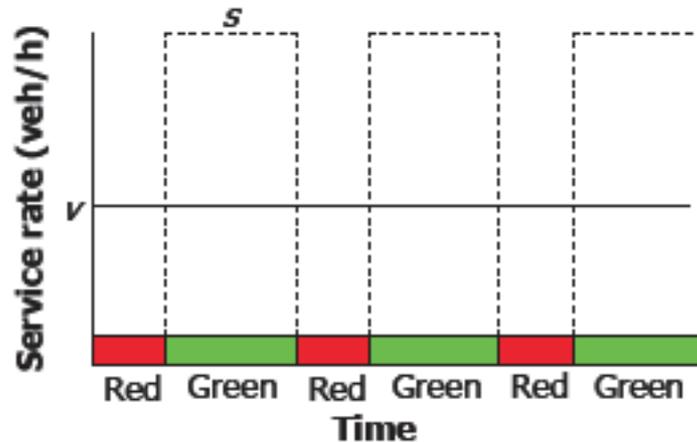
- ◆ Types of delay
 - ◆ Control delay (principal service measure for LOS)
 - ◆ Geometric delay
 - ◆ Incident delay
 - ◆ Traffic delay
 - ◆ Total delay
- ◆ Control delay – delay due to the presence of a traffic control device and it includes
 - ◆ Delays associated with vehicles slow down in advance of an intersection
 - ◆ Time spent stopped on an intersection approach
 - ◆ Time spent as vehicles move up in the queue
 - ◆ Time needed for vehicles to accelerate to their desired speed

INTERRUPTED FLOW MEASURES – STOPS, QUEUING

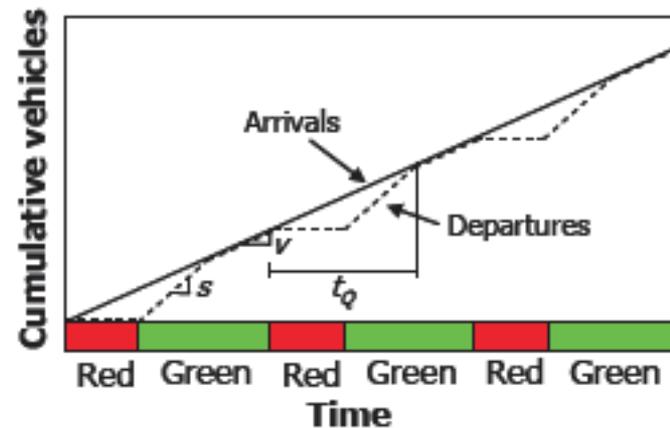
- ◆ Stops – cause delay and cost in terms of fuel consumption and wear on vehicle (operating cost)
- ◆ Stop rate – count of stops divided by number of vehicles served (units - stops/vehicle)
- ◆ Queuing – operational and design measure
 - ◆ Average queue length
 - ◆ Maximum back of queue
 - ◆ Maximum probable queue (e.g., a 95th percentile queue)

QUEUING AT SIGNALS

- ◆ Idealized undersaturated queue at a signalized intersection



(a) Arrival and Service Rates



(b) Queue Lengths

$$vt_Q = s(t_Q - r) \quad \text{or} \quad t_Q = \frac{sr}{s - v}$$