PROFESSIONAL TRAFFIC OPERATIONS ENGINEER CERTIFICATION PROGRAM REFRESHER COURSE

Module 2:Traffic Operations

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Meet Your Instructor

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Presentation Overview

- Traffic Flow Concepts
- Highway Capacity Analysis
- Transportation System Management Tools
- Site Traffic Impact Analysis
- Travel Demand Management
- Intelligent Transportation Systems

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Traffic Flows Concepts

- *Uninterrupted Flow:* Vehicles are not interrupted by external factors. Occurs on freeways and some rural roads.
- *Interrupted Flow:* Vehicle flow on interrupted flow facilities is influenced by external factors such as traffic signals, stop or yield signs, or frequent uncontrolled intersections or high volume driveways.

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Uninterrupted Flow

Traffic Stream Parameters

Parameter	Symbol	Typical Units	Reciprocal	Symbol	Typical Units
Flow	*v*	veh/hr	Headway	*h*	sec/veh
Speed	*S*	mi/h (km/h)	Travel Time	*t*	sec/mi (sec/km)
Density	*D*	veh/mi (veh/km)	Spacing	*s*	ft/veh (m/veh)

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Volume

The number of vehicles that pass a point on a roadway, a lane or a direction of a roadway per unit of time

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Flow Rate

Convert volume into flow rate by dividing by peak hour factor

For 15 minute periods

$$PHF = \frac{\text{Hourly Volume}}{4 \times \text{Peak 15 Min. Volume}}$$

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Speed

Distance Traveled Per Unit of Time

- *Time Mean Speed (TMS):* Time mean speed is defined as the average speed of all vehicles passing a point over a specified time period.
- *Space Mean Speed (SMS):* Space mean speed is defined as the average speed of all vehicles occupying a given section of roadway over a specific time period

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Density

Density is the number of vehicles in a given length of roadway or a lane. It is usually expressed in vehicles/mi (vehicles/km).

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Uninterrupted Flow – Basic Relationship

$$D = \frac{v}{S}$$

v = flow (veh/h)

S = space mean speed (mi/h or km/h)

D = density (veh/mi or veh/km)

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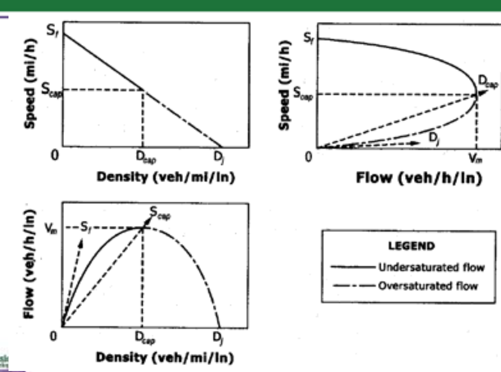

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Key Points

v_m = maximum flow or capacity

S_f = free flow speed when flows approach zero

S_{cap} = optimum speed under maximum flow conditions (capacity)

D_j = jam density when both flow and speed approach zero, and

D_{cap} = optimum density under maximum flow conditions (capacity)

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Freeway Operations

- Considered “uninterrupted flow”
- Capacity defined as the “maximum sustainable hourly flow rate at which vehicles reasonably can be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway and traffic conditions.”
- Levels of Service - A to F
  - A - Best operating conditions
  - F - Worst operating conditions

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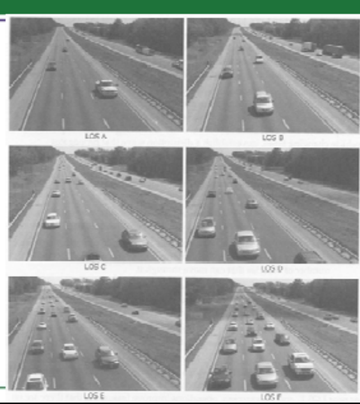
Level of Service



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Flow Rates Under Base Conditions

- 12 ft (3.6 m) lane width
- No obstructions within 6 ft (1.8 m) of the right edge of traveled way
- Minimum median lateral clearance of 2 ft (0.6 m)
- Only passenger cars in the traffic stream
- Driver population principally regular users

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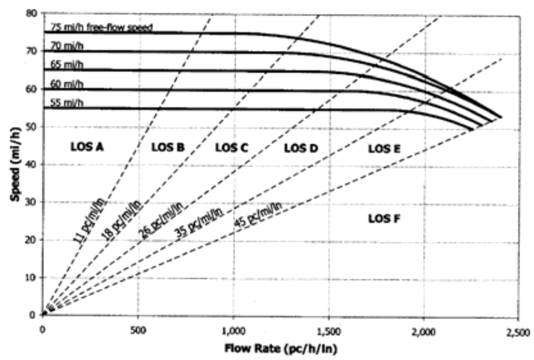
Capacity and Level of Service



Basic Freeway Section Capacity

Calculation Procedures

Flow Rates
Free Flow Speed
Density
Level of Service

Flow Rate

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

v_P = Demand flow rate under equivalent base conditions (pc/h/ln)
V = Demand volume (veh/h)
PHF = peak-hour factor
N = number of lanes in analysis direction
f_{HV} = heavy-vehicle adjustment factor
f_P = unfamiliar driver population factor

Free Flow Speed

- Measure in field under low flow rate conditions
- Estimate:

$$FFS = 75.4 - f_{LW} - f_{LC} - 3.22TRD^{0.84}$$

Where: FFS = Free flow speed (mph)
f_{LW} = adjustment for lane width (mph)
f_{LC} = adjustment for right-side lateral clearance (mi/h)
TRD = total ramp density (ramps/mi)

Level of Service

$$v = S \times D$$

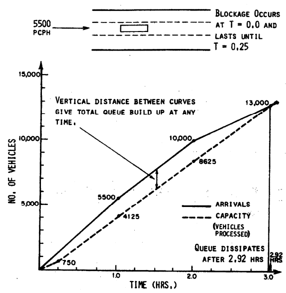
$$D = \frac{v}{S}$$

v = flow (veh/h)

S = space mean speed (mi/h or km/h)

D = density (veh/mi or veh/km)

Input-Output Analysis of Freeway Bottleneck



Time	Input Rate	Output Rate
0-0.25	5500/hr	3000/hr
0.25-1.0	5500/hr	4500/hr
1.0-2.0	4500/hr	4500/hr
2.0-3.0	3000/hr	4500/hr

Queuing Analysis

- Used to evaluate facilities where average arrival headways are less than average service times
- Examples: toll booth, drive-up window at fast food restaurant, etc.

Queuing Analysis

$$E_m = \frac{\lambda^2}{\mu(\mu - \lambda)}$$

$$E_w = \frac{\lambda}{\mu(\mu - \lambda)}$$

$$P(n > N) = (\lambda / \mu)^{N+1}$$

E_m = Mean queue length (veh)

E_w = Mean waiting time in queue (min.)

P(n>N) = Probability of more than N vehicles in the queue

λ = Arrival flow rate (veh/min.)

μ = Departure flow rate (veh/min.)

Freeway Operational Deficiencies

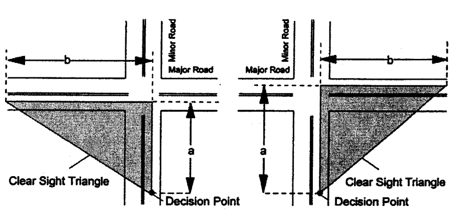
- Freeway Surveillance
- Ramp Metering and Control
- Motorist Information Systems
- Emergency Motorist Call Boxes
- Service Patrols
- High Occupancy Vehicle (HOV) Lanes
- Reversible or Contra-flow Lanes

Interrupted Flow: Intersections

- At-grade intersections are some of the most complex locations within the transportation system
- Levels of traffic control:
  - ✓Uncontrolled
  - ✓Yield controlled
  - ✓2-way Stop controlled
  - ✓All-way Stop controlled
  - ✓Traffic signals

Approach Clear Sight Triangles

Uncontrolled and Yield-controlled Intersections

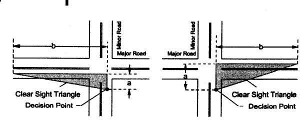


Clear Sight Triangle for Viewing Traffic Approaching from the Left

Clear Sight Triangle for Viewing Traffic Approaching from the Right

Departure Clear Sight Triangles

2-Way Stop-controlled Intersections



Clear Sight Triangle for Viewing Traffic Approaching from the Left

Clear Sight Triangle for Viewing Traffic Approaching from the Right

ISD = 1.47 V x t_g (U.S. units)

ISD = 0.278 V x t_g (metric)

ISD = intersection sight distance (ft or m)

V = major street traffic speed (mph or km/h)

t_g = time gap (sec)

Stop-Controlled Intersection Capacity

- Two-way Stop:
  - Based on model that estimates number of adequate gaps in “conflicting traffic flow”
- All-way Stop:
  - Entering headways on one approach depend on whether there is traffic present on any of the other approaches
  - Capacity is determined by iteratively increasing volume on subject approach (while keeping volumes on conflicting approaches constant) until a “degree of utilization” of 1.0 is reached

Signalized Intersection Capacity

- Movement Groups and Lane Groups
- Movement Group Flow Rates
- Lane Group Flow Rates
- Adjusted Saturation Flow Rate
- Proportion Arriving During Green
- Signal Phase Duration
- Capacity and v/c
- Delay
- LOS
- Queue Storage Ratio

Signalized Intersection Capacity

Movement Groups and Lane Groups

Number of Lanes	Movements by Lanes	Movement Groups (MG)	Lane Groups (LG)
1	Left, thru., & right:	MG 1:	LG 1:
2	Exclusive left: Thru. & right:	MG 1: MG 2:	LG 1: LG 2:
2	Left & thru.: Thru. & right:	MG 1:	LG 1: LG 2:
3	Exclusive left: Exclusive left: Through: Through: Thru. & right:	MG 1: MG 2:	LG 1: LG 2: LG 3:

Signalized Intersection Capacity

Determine Movement Group Flow Rate

- Movement flow rate for each movement group in veh/h during analysis period (divide hourly volume by PHF)
- Subtract RTOR flow rate from right-turn flow rate based on field observation

Signalized Intersection Capacity

Determine Lane Group Flow Rate

- Same as movement group flow rate for exclusive turn lanes and approaches with only one lane
- If approach has shared lane(s) and non-shared through lanes, lane group flow rates determined based on driver desire to minimize service time

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Signalized Intersection Capacity

Determine Adjusted Saturation Flow Rate

- Base Saturation Flow Rate
- Adjustment Factors

$s = s_o\, f_W f_{HV}\, f_g\, f_p\, f_{bb}\, f_a\, f_{LU}\, f_{LT}\, f_{RT}\, f_{Lpb}\, f_{Rpb}$

Default s_o = 1,900 pc/h/ln if population ≥ 250,000; otherwise s_o = 1,750 pc/h/ln

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Signalized Intersection Capacity

Determine Proportion Arriving on Green

- Control delay and queue size are highly dependent on proportion of vehicles that arrive on green or red signal indication
- Proportion calculated for each lane group based on signal timing and quality of progression

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Signalized Intersection Capacity

Determine Signal Phase Duration

- If signal is pre-timed, phase duration is an input, and this step is skipped
- If signal is actuated, average duration of phase is calculated

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Signalized Intersection Capacity

Determine Capacity and v/c

- Compute Lane Group Capacities

  c = N x s x (g/C)
- Compute Lane Group v/c Ratios

Signalized Intersection Capacity

Determine Delay

$$d = d_1 + d_2 + d_3$$

Where d = control delay (s/veh)

d_1 = uniform delay

d_2 = incremental delay

d_3 = initial queue delay

Signalized Intersection Capacity

Determine LOS

LOS determined for each lane group, each approach, and intersection as a whole

Control Delay (s/veh)	LOS by Volume-to-Capacity Ratio[a]	
	≤1.0	>1.0
≤10	A	F
>10–20	B	F
>20–35	C	F
>35–55	D	F
>55–80	E	F
>80	F	F

Note: [a] For approach-based and intersectionwide assessments, LOS is defined solely by control delay.

Signalized Intersection Capacity

Determine Queue Storage Ratio

- Position of last vehicle stopped farthest from stop line during a cycle
- Depends on arrival pattern and number of vehicles that do not clear on previous cycle
- If queue exceeds storage space, queue will overflow and block other vehicles

Transportation System Management

TSM Techniques

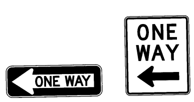
- One-way streets
- Reversible lanes
- Turn controls
- High occupancy vehicle lanes
- Curb lane use control and parking management
- Bus stop locations
- Access management
- Signal system operation

One-Way Street Applications

- Large volumes of left turns
- Closely spaced traffic signals
- One-way couples in corridor
- Grid pattern of CBD streets
- Continuous frontage roads along freeway

One-Way Streets

- Advantages
  - Crashes reduced 10 to 50%
  - Intersection capacity increased
  - Improved gaps at midblock and minor crossing streets
  - Reduced travel time
- Disadvantages
  - Longer trip distances
  - Lack of pedestrian refuge
  - No emergency vehicle bypass
  - Opposition from business owners
  - Lane change crashes increase



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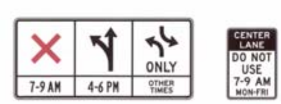
Reversible Lanes

Balance roadway capacity with directional distribution of traffic



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Turn Controls

Factors to consider:

- Degree of congestion and delay
- Crashes
- Alternative routes
- Impact of diverted traffic

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High-Occupancy Vehicle (HOV) Lanes

- Concurrent flow HOV lanes
  - Adjacent to through lanes
- Contra-flow HOV lanes
  - Usually on one-way streets
- Operation may interfere with non-HOV's
- Must be well-signed and marked
- Plan must be flexible to respond to changing patterns
- Enforcement and public education critical

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Curb Lane Use Control

- Movement of traffic is the highest priority use of curb lane
- Loading of delivery and transit vehicles is second priority
- Time limit parking is third priority
- Long term parking only if higher priorities are satisfied

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Bus Stop Locations

- Locate to minimize impact on through traffic flow
- Provide turn-out bays
- Mid-block and far-side locations minimize impact on intersection operations

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Access Management Tools

- Limiting the location and number of driveways
- Driveway design - channelization, provision of acceleration and deceleration lanes, and other geometric improvements
- Driveway control - prohibit movements
- Medians - prohibit or limit access and/or store left turning vehicles
- Two-way left turn lanes
- Limit the number and spacing of traffic signals, and
- Providing frontage roads

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Signal System Considerations

- Performance of arterial streets is significantly influenced by traffic signal system operation
- Desirable signal spacing:
  - ½ mile (800 m) for principal arterials
  - Minimum of ¼ mile (400 m) for low speed operation
  - Space at regular intervals

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Site Traffic Impact Analysis

Purpose: To determine the needs for any improvements to the adjacent and nearby road system to maintain a satisfactory level of service, safety, and access to a proposed development.

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When is a Study Needed

- When the development will generate a specific number of peak hour trips
- When the development will generate a specific number of daily trips
- When development size exceeds a specified limit
- At the government agency's discretion
- When development occurs in a sensitive area
- When financial assessments are required
- Suggested rule of thumb – 100 added peak hour trips in the peak direction

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Study Area Limits

- All site access drives
- Adjacent roadways and major intersections
- First signalized intersection in each direction from the site based on local policy
- Additional areas as specified by local policy

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Study Horizon

- Anticipated opening day of major phases
- Anticipated date of full build-out
- Five years after full build-out

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Steps in the Process

- Site Traffic Generation
- Site Traffic Assignment and Distribution
- Non-site Traffic Forecast
- Analysis of Level of Service at Signalized and Non-signalized Locations
- Site Access Improvements
- Internal Site Circulation and Parking Analysis

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Potential Site Access Improvements

- Provide additional through or turning lanes
- Increase turning lane storage
- Curb return radii at intersections
- Signal timing –individual intersections and systems
- Provide acceleration and/or deceleration lanes
- Limit access to right-in and right-out only

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Internal Site Circulation and Parking

- Location of access points with respect to traffic generators within the site.
- Internal parking layout and roadway circulation pattern
- Provisions for service and delivery vehicles
- Available storage space (queuing space) at exits from the site

Professional development

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Transportation Demand Management

Transportation Demand Management (TDM) is any action or set of actions aimed at influencing people's travel behavior in such a way that alternative mobility options are presented and/or traffic congestion is reduced.

Professional development

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Measures to Reduce Congestion

- Supply Side – Increase Capacity
- Demand Side – Decrease Demand

Professional development

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Site Specific TDM Strategies

- Alternative modes of transportation
  - Carpools, vanpools
  - Public transit
  - Bicycle, pedestrian modes
- Alternative work hours
  - Flextime, staggered hours, compressed work week, or other strategies to promote alternative work hours.
- Telecommuting to eliminate trips.

Professional development

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Complementary Support Services

- Financial Incentives
- Assistance programs like rideshare matching, marketing, and parking management
- Flexible work schedules
- Award programs to participants
- Other services such as child care or auto services

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Areawide TDM Strategies

- Growth management through urban design or legislation.
- Congestion pricing, charging more for travel during peak commuting periods.
- Parking management
- Auto restricted zones
- Legislation to promote trip reduction

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Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) are defined as a collection of a broad range of diverse technologies including information processing, communications, control, and electronics applied to the solution of transportation problems.

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Representative ITS Services

- Collect and transmit information on traffic conditions and transit schedules for travelers before and during their trips.
- Decrease congestion by reducing the number of traffic incidents.
- Improve the productivity of commercial, transit, and public safety fleets.
- Assist drivers in reaching a desired destination with navigation systems.

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Traveler Information Systems

- Pre-Trip Planning
  - Commercial radio/TV
  - Telephone call-in service
  - Information kiosks
  - Personal communications devices (PDA's)
- En-Route Information
  - Variable message signs/variable speed limits
  - Highway advisory radio (HAR)
  - Warnings of anticipated weather warnings of congestion, lane closures, crashes, etc.
  - In-vehicle navigation
  - Transit stop displays

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Commercial Vehicle Operations

- Electronic clearance
- Roadside inspection
- On-board safety monitoring

Intelligent Vehicle Systems

- Rear-end collision avoidance
- Longitudinal and lateral control
- Road departure/lane change collision avoidance

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Sample Study Question

What is the average number of vehicles in line at an exit booth where the total volume is 425 vph and the service rate is 625 vph?

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Sample Study Question

The average number of vehicles at the exit booth is:

$$E_m = \frac{\lambda^2}{\mu(\mu - \lambda)}$$

Where λ = arrival flow rate = 425 vph/60 min/hr = 7.08 veh/min

μ = departure flow rate = 625 vph/60 min/hr = 10.42 veh/min

$$E_m = \frac{(7.08)^2}{(10.42)(10.42 - 7.08)} = 1.4\, veh.$$

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Sample Study Question

Which of the following is **NOT** considered an ITS strategy?

a. Electronic toll collection
b. Variable speed limits
c. Service patrol vehicles
d. GPS locating systems for transit vehicles

Sample Study Question

The following 15-minute volumes were recorded in a traffic count:

300 veh
400 veh
500 veh
300 veh

What is the peak hour factor?

Sample Study Question

The peak hour factor is:

$$\text{PHF} = \frac{\text{Hourly Volume}}{4 \times \text{Peak 15minute Volume}}$$

$$PHF = \frac{300 + 400 + 500 + 300}{4 \times 500} = 0.75$$

Sample Study Question

A traffic engineer conducted a study on an uninterrupted section of freeway. The average space mean speed was 30 mi/h. The flow rate was 1,800 veh/h. What was the density of flow?

Sample Study Question

The basic equation for uninterrupted flow is:

$$v = S \times D$$

Where v = flow rate = 1,800 vph
S = space mean speed = 30 mi/h

Then $D = v/S$ = 1,800/30 = 60 veh/mi

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Questions

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Thank you

Questions/Comments
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