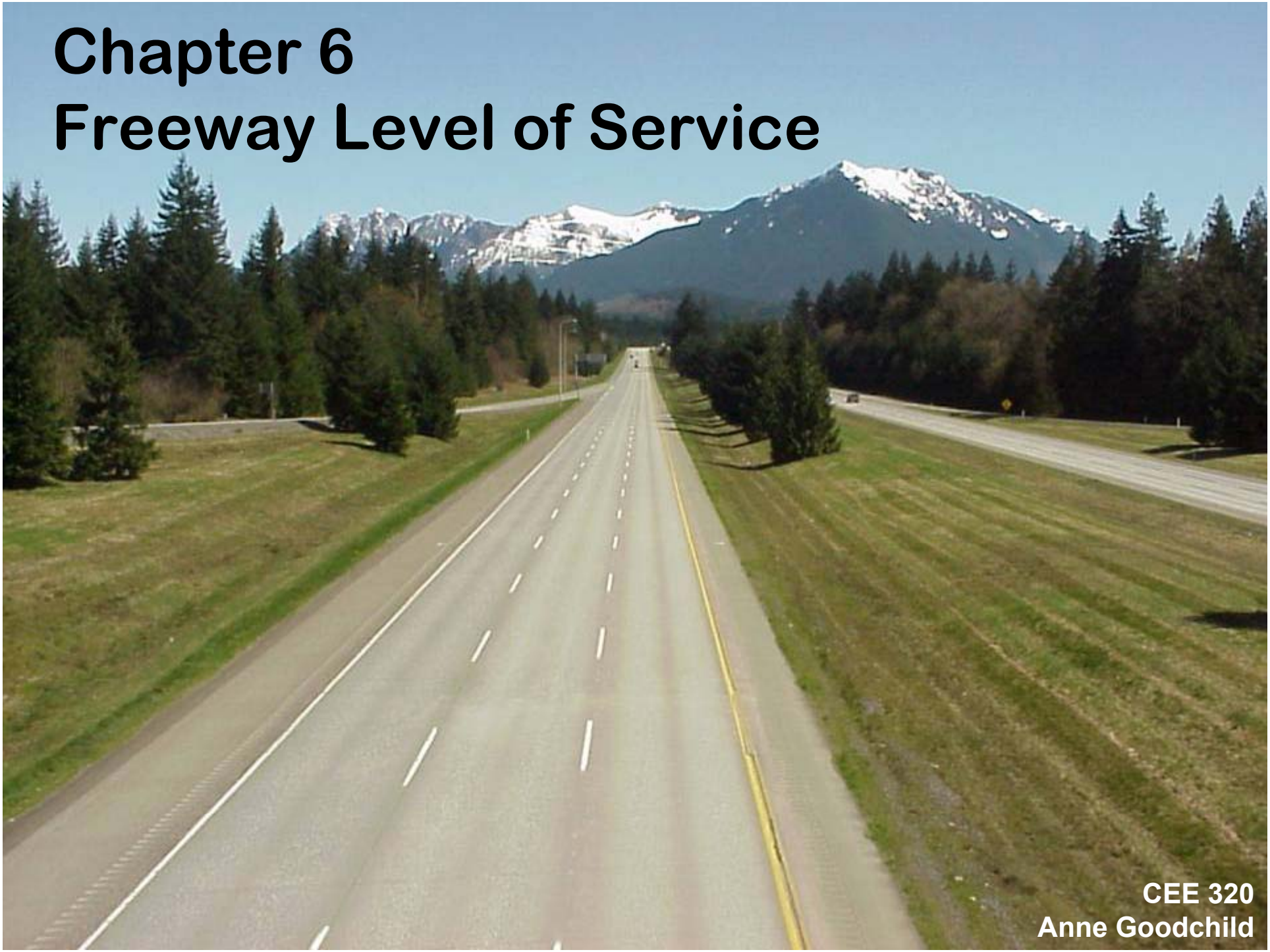
Chapter 6
Freeway Level of Service



CEE 320
Anne Goodchild

Definitions – Level of Service (LOS)

- **Chief measure of "quality of service"**
  - Describes operational conditions within a traffic stream.
  - Does not include safety
  - Different measures for different facilities
- **Six measures (A through F)**
- **Freeway LOS**
  - **Based on traffic density**

Levels of Service

- **LOS A**
  - Free-flow operation

- **LOS B**
  - Reasonably free flow
  - Ability to maneuver is only slightly restricted
  - Effects of minor incidents still easily absorbed

From *Highway Capacity Manual*, 2000

Levels of Service

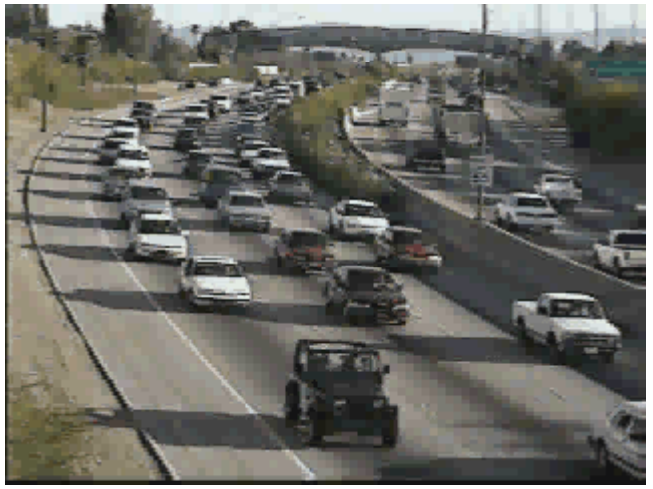
- **LOS C**
  - Speeds at or near FFS
  - Freedom to maneuver is noticeably restricted
  - Queues may form behind any significant blockage.

- **LOS D**
  - Speeds decline slightly with increasing flows
  - Density increases more quickly
  - Freedom to maneuver is more noticeably limited
  - Minor incidents create queuing

From *Highway Capacity Manual*, 2000

Levels of Service

- **LOS E**
  - Operation near or at capacity
  - No usable gaps in the traffic stream
  - Operations extremely volatile
  - Any disruption causes queuing



- **LOS F**
  - Breakdown in flow
  - Queues form behind breakdown points
  - Demand > capacity

From *Highway Capacity Manual*, 2000

Definitions

- **Freeway:**
  - A divided highway with full control of access and two or more lanes for the exclusive use of traffic in each direction.
- **Freeway Capacity:**
  - The maximum sustained 15-min flow rate, expressed in passenger cars per hour per lane, that can be accommodated by a uniform freeway segment under prevailing traffic and roadway conditions in one direction of flow.

Definitions – Flow Characteristics

- **Undersaturated**
  - Traffic flow that is unaffected by upstream or downstream conditions.
- **Queue discharge**
  - Traffic flow that has just passed through a bottleneck.
- **Oversaturated**
  - Traffic flow that is influenced by the effects of a downstream bottleneck.

From *Highway Capacity Manual*, 2000

Definitions – Free-Flow Speed

- **Free-Flow Speed (FFS)**
  - The mean speed of passenger cars that can be accommodated under low to moderate flow rates on a uniform freeway segment under prevailing roadway and traffic conditions.
- **Factors affecting free-flow speed**
  - Lane width
  - Lateral clearance
  - Number of lanes
  - Interchange density
  - Geometric design

Definitions

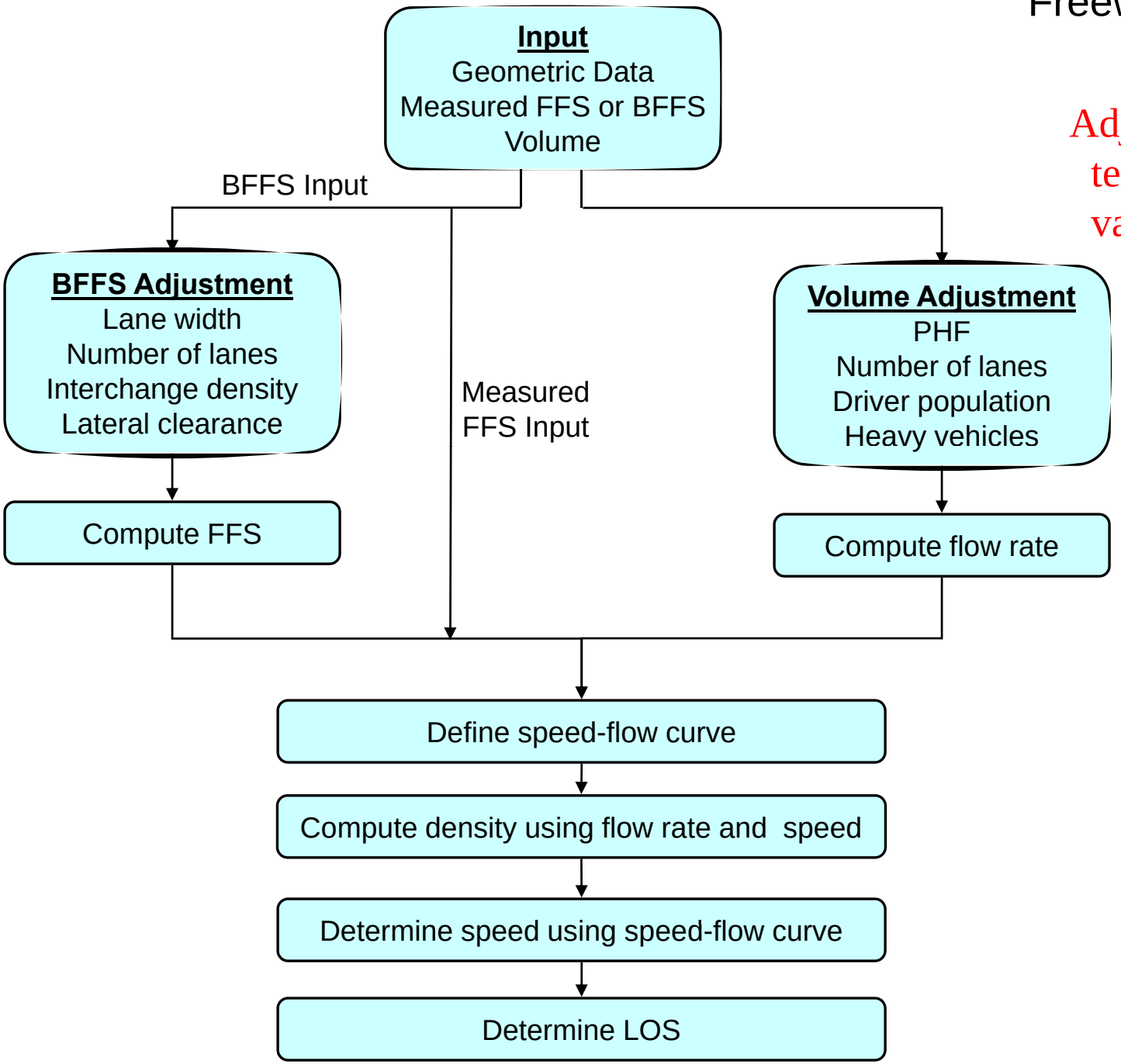
- **Passenger car equivalents**
  - Trucks and RVs behave differently
  - Baseline is a freeway with all passenger cars
  - Traffic is expressed in passenger cars per lane per hour (pc/ln/hr or pcplph)
- **Driver population**
  - Non-commuters suck more at driving
  - They may affect capacity
- **Capacity**
  - Corresponds to LOS E and v/c = 1.0

Freeway LOS

LOS Calculation

- **Does not consider**
  - **Special lanes reserved for a particular type of vehicle (HOV, truck, climbing, etc.)**
  - **Extended bridge and tunnel segments**
  - **Segments near a toll plaza**
  - **Facilities with FFS < 55 mi/h or > 75 mi/h**
  - **Demand conditions greatly in excess of capacity**
  - **Influence of downstream blockages or queuing**
  - **Posted speed limit**
  - **Extent of police enforcement**
  - **Intelligent transportation system features**
  - **Capacity-enhancing effects of ramp metering**

Freeway LOS



Adjust for temporal variation

Freeway LOS

LOS Criteria for Basic Freeway Segments

Criteria	LOS A	LOS B	LOS C	LOS D	LOS E
FFS = 75 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	75.0	74.8	70.6	62.2	53.3
Maximum v/c	0.34	0.56	0.76	0.90	1.00
Maximum service flow rate (pc/h/ln)	820	1350	1830	2170	2400
FFS = 70 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
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FFS = 65 mi/h					
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FFS = 60 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
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Note:
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From *Highway Capacity Manual*, 2000

Determining FFS

- **Measure FFS in the field**
  - **Low to moderate traffic conditions**
- **Use a baseline and adjust it (BFFS)**

$$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID}$$

FFS	=	free-flow speed (mph)
BFFS	=	base free-flow speed, 70 mph (urban), 75 mph (rural)
f_{LW}	=	adjustment for lane width (mph)
f_{LC}	=	adjustment for right-shoulder lateral clearance (mph)
f_N	=	adjustment for number of lanes (mph)
f_{ID}	=	adjustment for interchange density (mph)

Lane Width Adjustment (f_{LW})

- **Base condition (f_{LW} = 0)**
  - **Average width of 12 ft. or wider across all lanes**

EXHIBIT 23-4. ADJUSTMENTS FOR LANE WIDTH

Lane Width (ft)	Reduction in Free-Flow Speed, f_{LW} (mi/h)
12	0.0
11	1.9
10	6.6

From *Highway Capacity Manual*, 2000

Lateral Clearance Adjustment (f_{LC})

- **Base condition (f_{LC} = 0)**
  - **6 ft. or greater on right side**
  - **2 ft. or greater on the median or left side**

EXHIBIT 23-5. ADJUSTMENTS FOR RIGHT-SHOULDER LATERAL CLEARANCE

Right-Shoulder Lateral Clearance (ft)	Reduction in Free-Flow Speed, f_{LC} (mi/h)			
	Lanes in One Direction			
	2	3	4	≥ 5
≥ 6	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
4	1.2	0.8	0.4	0.2
3	1.8	1.2	0.6	0.3
2	2.4	1.6	0.8	0.4
1	3.0	2.0	1.0	0.5
0	3.6	2.4	1.2	0.6

From *Highway Capacity Manual*, 2000

Number of Lanes Adjustment (f_N)

- **Base condition (f_N = 0)**
  - **5 or more lanes in one direction**
  - **Do not include HOV lanes**
  - **f_N = 0 for all rural freeway segments**

EXHIBIT 23-6. ADJUSTMENTS FOR NUMBER OF LANES

Number of Lanes (One Direction)	Reduction in Free-Flow Speed, f_N (mi/h)
≥ 5	0.0
4	1.5
3	3.0
2	4.5

Note: For all rural freeway segments, f_N is 0.0.

From *Highway Capacity Manual*, 2000

Interchange Density Adjustment (f_{IC})

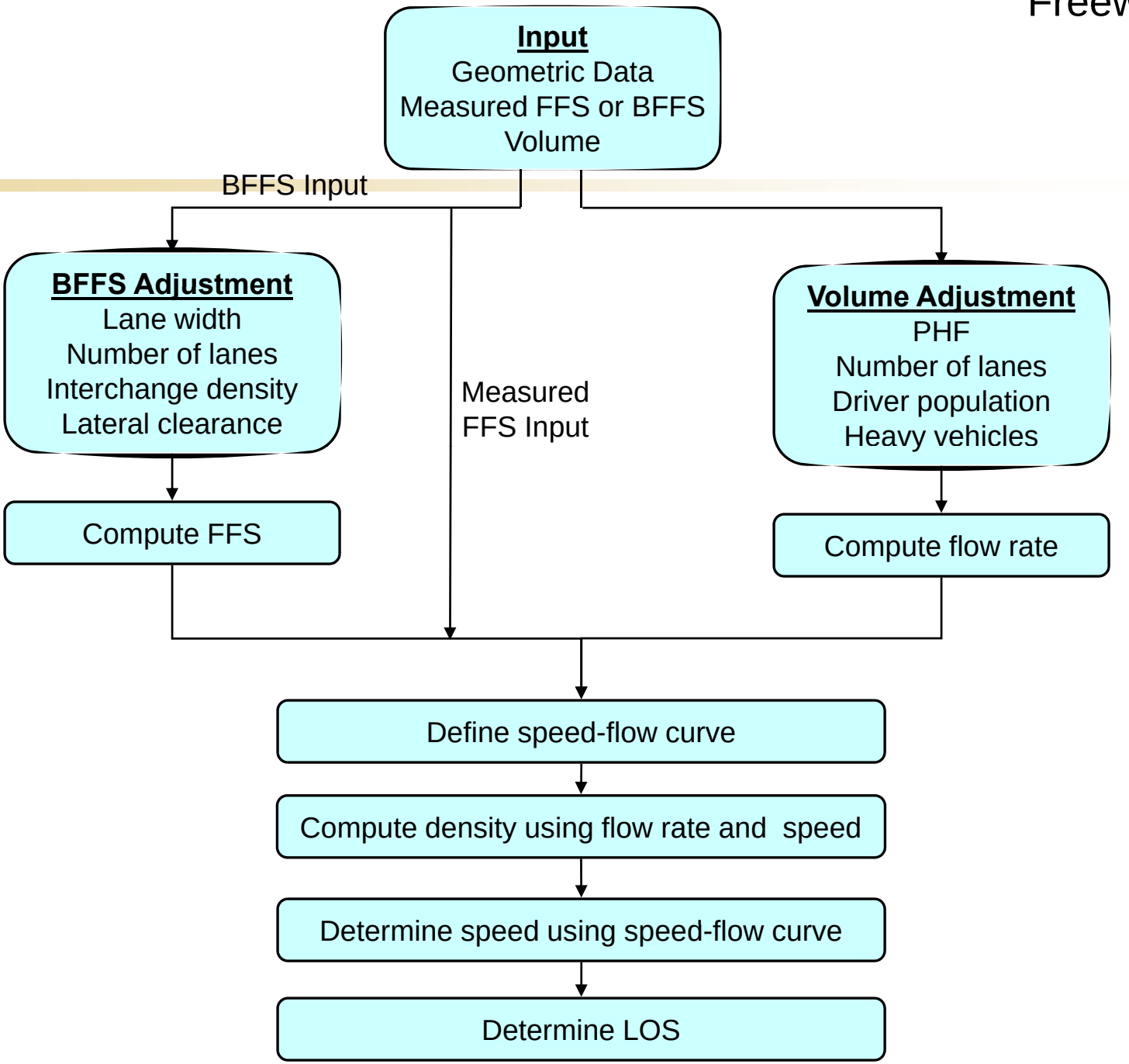
- **Base condition (f_{IC} = 0)**
  - **0.5 interchanges per mile (2-mile spacing)**
  - **Interchange defined as having at least one on-ramp**
  - **Determined over 6-mile segment**

EXHIBIT 23-7. ADJUSTMENTS FOR INTERCHANGE DENSITY

Interchanges per Mile	Reduction in Free-Flow Speed, f_{ID} (mi/h)
0.50	0.0
0.75	1.3
1.00	2.5
1.25	3.7
1.50	5.0
1.75	6.3
2.00	7.5

From *Highway Capacity Manual*, 2000

Freeway LOS


Input
Geometric Data
Measured FFS or BFFS
Volume
BFFS Input
BFFS Adjustment
Lane width
Number of lanes
Interchange density
Lateral clearance
Measured
FFS Input
Volume Adjustment
PHF
Number of lanes
Driver population
Heavy vehicles
Compute FFS
Compute flow rate
Define speed-flow curve
Compute density using flow rate and speed
Determine speed using speed-flow curve
Determine LOS

Determining Flow Rate

- **Adjust hourly volumes to get pc/ln/hr**

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

v_p = 15-minute passenger-car equivalent flow rate (pcphpl)

V = hourly volume (veh/hr), highest total one direction

PHF = peak hour factor

N = number of lanes in one direction

f_{HV} = heavy-vehicle adjustment factor

f_P = driver population adjustment factor

Peak Hour Factor (PHF)

- **Typical values**
  - **0.80 to 0.95**

$$PHF = \frac{V}{V_{15} \times 4}$$

V = hourly volume (veh/hr) for hour of analysis

V_{15} = maxiumum 15-min. flow rate within hour of analysis

4 = Number of 15-min. periods per hour

Heavy Vehicle Adjustment (f_{HV})

- **Base condition (f_{HV} = 1.0)**
  - **No heavy vehicles**
  - **Heavy vehicle = trucks, buses, RVs**
- **Otherwise: Two-step process**
  - **Determine passenger-car equivalents (E_T)**
  - **Determine f_{HV}**

Passenger-Car Equivalents (E_T)

- **Extended segments method**
  - **Determine the type of terrain and select E_T**
  - **No one grade of 3% or more is longer than 0.25 miles**

    OR
  - **No one grade of less than 3% is longer than 0.5 miles**

EXHIBIT 23-8. PASSENGER-CAR EQUIVALENTS ON EXTENDED FREEWAY SEGMENTS

Factor	Type of Terrain		
	Level	Rolling	Mountainous
E_T (trucks and buses)	1.5	2.5	4.5
E_R (RVs)	1.2	2.0	4.0

From *Highway Capacity Manual*, 2000

Passenger-Car Equivalents (E_T)

- **Specific grades method**
  - **Any grade of 3% or more that is longer than 0.25 miles**

    OR
  - **Any grade of less than 3% that is longer than 0.5 miles**

EXHIBIT 23-11. PASSENGER-CAR EQUIVALENTS FOR TRUCKS AND BUSES ON DOWNGRADES

Downgrade (%)	Length (mi)	E_T Percentage of Trucks			
		5	10	15	20
< 4	All	1.5	1.5	1.5	1.5
4–5	≤ 4	1.5	1.5	1.5	1.5
4–5	> 4	2.0	2.0	2.0	1.5
> 5–6	≤ 4	1.5	1.5	1.5	1.5
> 5–6	> 4	5.5	4.0	4.0	3.0
> 6	≤ 4	1.5	1.5	1.5	1.5
> 6	> 4	7.5	6.0	5.5	4.5

From *Highway Capacity Manual*, 2000

EXHIBIT 23-9. PASSENGER-CAR EQUIVALENTS FOR TRUCKS AND BUSES ON UPGRADES

Upgrade (%)	Length (mi)	E_T Percentage of Trucks and Buses								
		2	4	5	6	8	10	15	20	25
< 2	All	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
≥ 2–3	0.00–0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.25–0.50	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.50–0.75	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.75–1.00	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5
	> 1.00–1.50	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	> 1.50	3.0	3.0	2.5	2.5	2.0	2.0	2.0	2.0	2.0
> 3–4	0.00–0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.25–0.50	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5
	> 0.50–0.75	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	> 0.75–1.00	3.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0
	> 1.00–1.50	3.5	3.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
	> 1.50	4.0	3.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
> 4–5	0.00–0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.25–0.50	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	> 0.50–0.75	3.5	3.0	3.0	3.0	2.5	2.5	2.5	2.5	2.5
	> 0.75–1.00	4.0	3.5	3.5	3.5	3.0	3.0	3.0	3.0	3.0
	> 1.00	5.0	4.0	4.0	4.0	3.5	3.5	3.0	3.0	3.0
> 5–6	0.00–0.25	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.25–0.30	4.0	3.0	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	> 0.30–0.50	4.5	4.0	3.5	3.0	2.5	2.5	2.5	2.5	2.5
	> 0.50–0.75	5.0	4.5	4.0	3.5	3.0	3.0	3.0	3.0	3.0
	> 0.75–1.00	5.5	5.0	4.5	4.0	3.0	3.0	3.0	3.0	3.0
	> 1.00	6.0	5.0	5.0	4.5	3.5	3.5	3.5	3.5	3.5
> 6	0.00–0.25	4.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0
	> 0.25–0.30	4.5	4.0	3.5	3.5	3.5	3.0	2.5	2.5	2.5
	> 0.30–0.50	5.0	4.5	4.0	4.0	3.5	3.0	2.5	2.5	2.5
	> 0.50–0.75	5.5	5.0	4.5	4.5	4.0	3.5	3.0	3.0	3.0
	> 0.75–1.00	6.0	5.5	5.0	5.0	4.5	4.0	3.5	3.5	3.5
	> 1.00	7.0	6.0	5.5	5.5	5.0	4.5	4.0	4.0	4.0

Equivalent tables for RVs

From *Highway Capacity Manual*, 2000

Determine f_{HV}

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

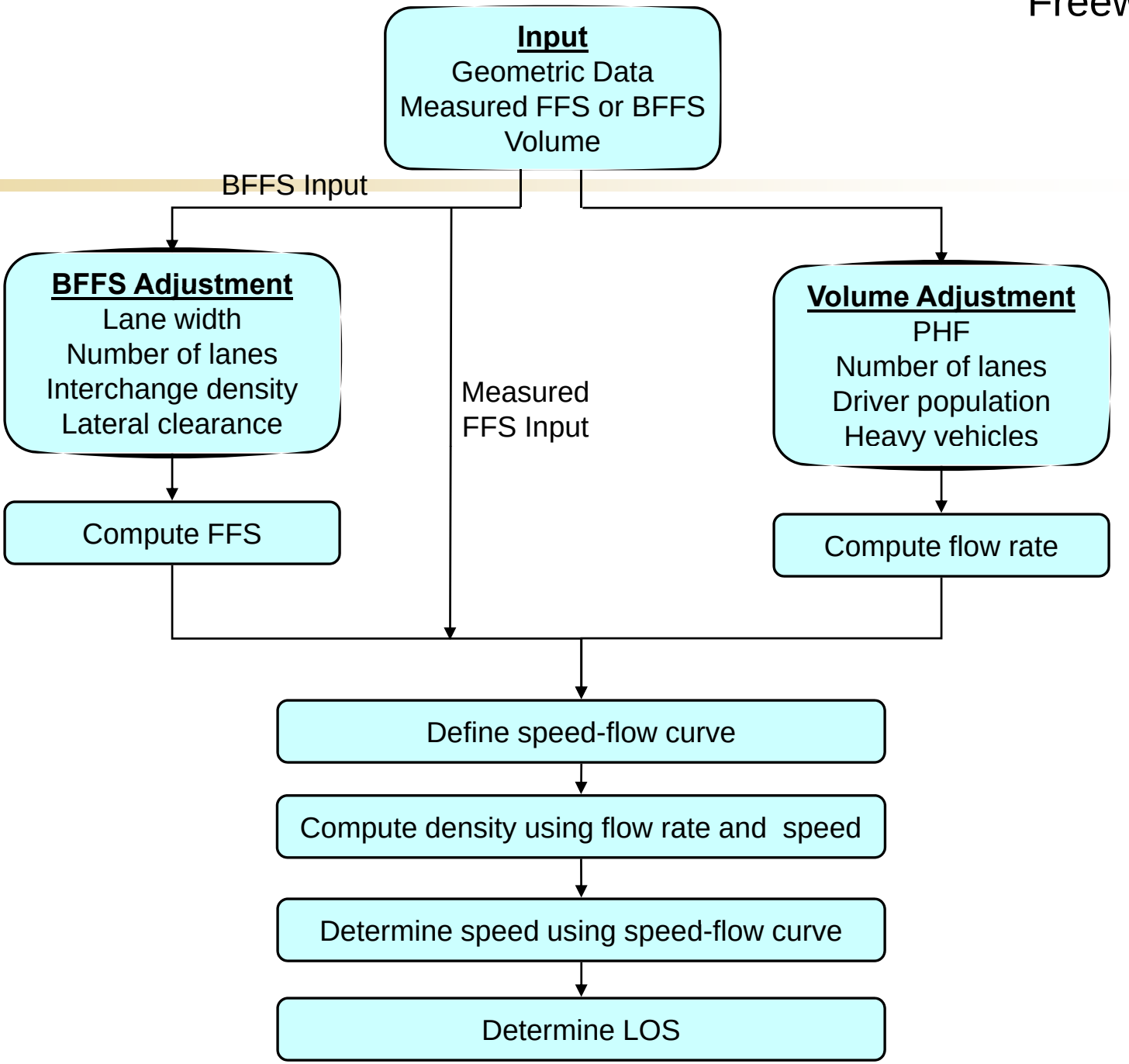
f_{HV}	=	Heavy vehicle adjustment factor
E_T, E_R	=	Passenger-car equivalents for trucks/buses and RVs
P_T, P_R	=	Proportion of trucks/buses and RVs in traffic stream
E_t		Greater than 1.5

Driver Population Adjustment (f_P)

- **Base condition (f_P = 1.0)**
  - **Most drivers are familiar with the route**
    - **Commuter drivers**
  - **Typical values between 0.85 and 1.00**

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

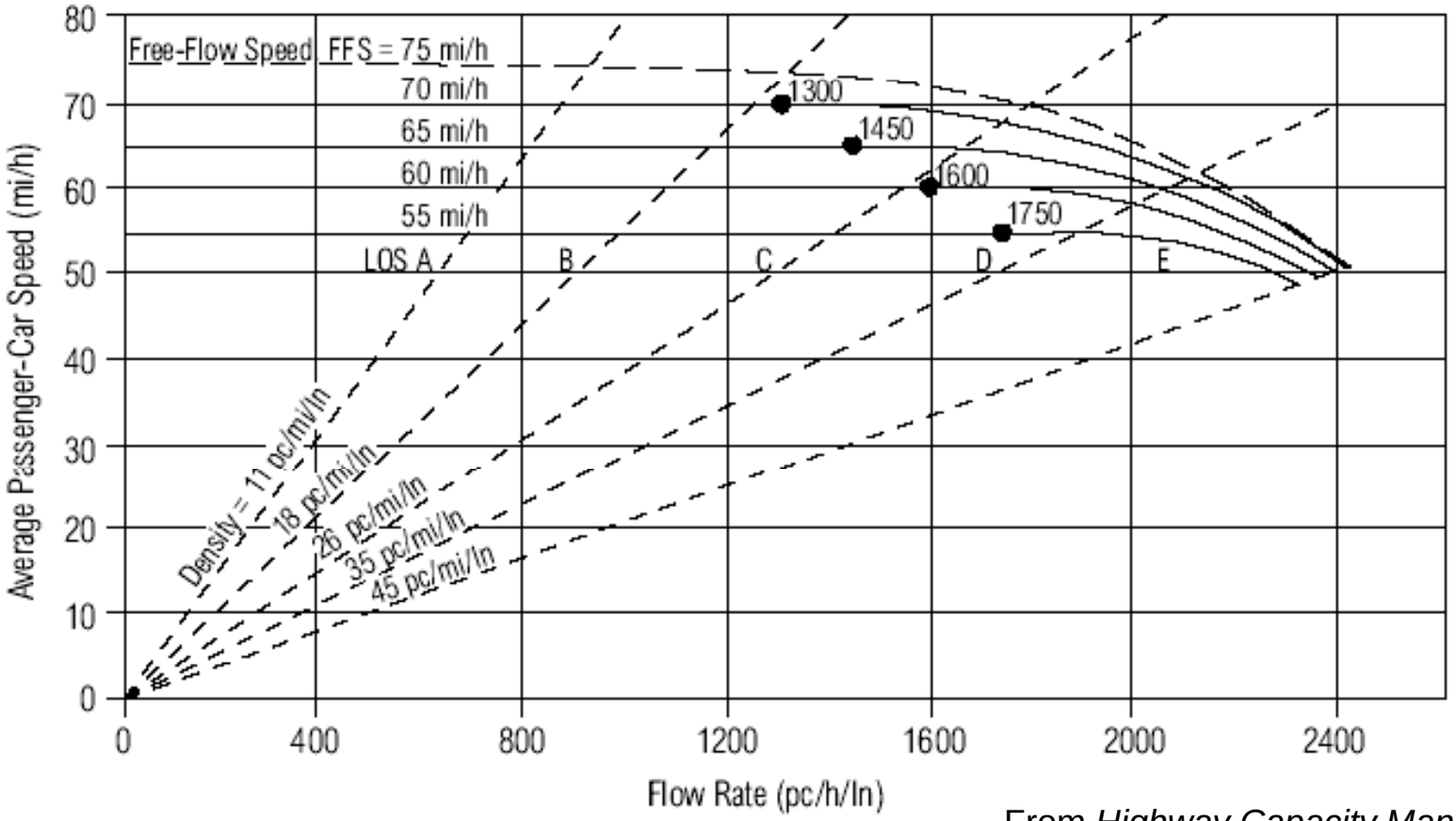
Freeway LOS


Input
Geometric Data
Measured FFS or BFFS
Volume
BFFS Input
BFFS Adjustment
Lane width
Number of lanes
Interchange density
Lateral clearance
Measured
FFS Input
Volume Adjustment
PHF
Number of lanes
Driver population
Heavy vehicles
Compute FFS
Compute flow rate
Define speed-flow curve
Compute density using flow rate and speed
Determine speed using speed-flow curve
Determine LOS

Define Speed-Flow Curve

Select a Speed-Flow curve based on FFS

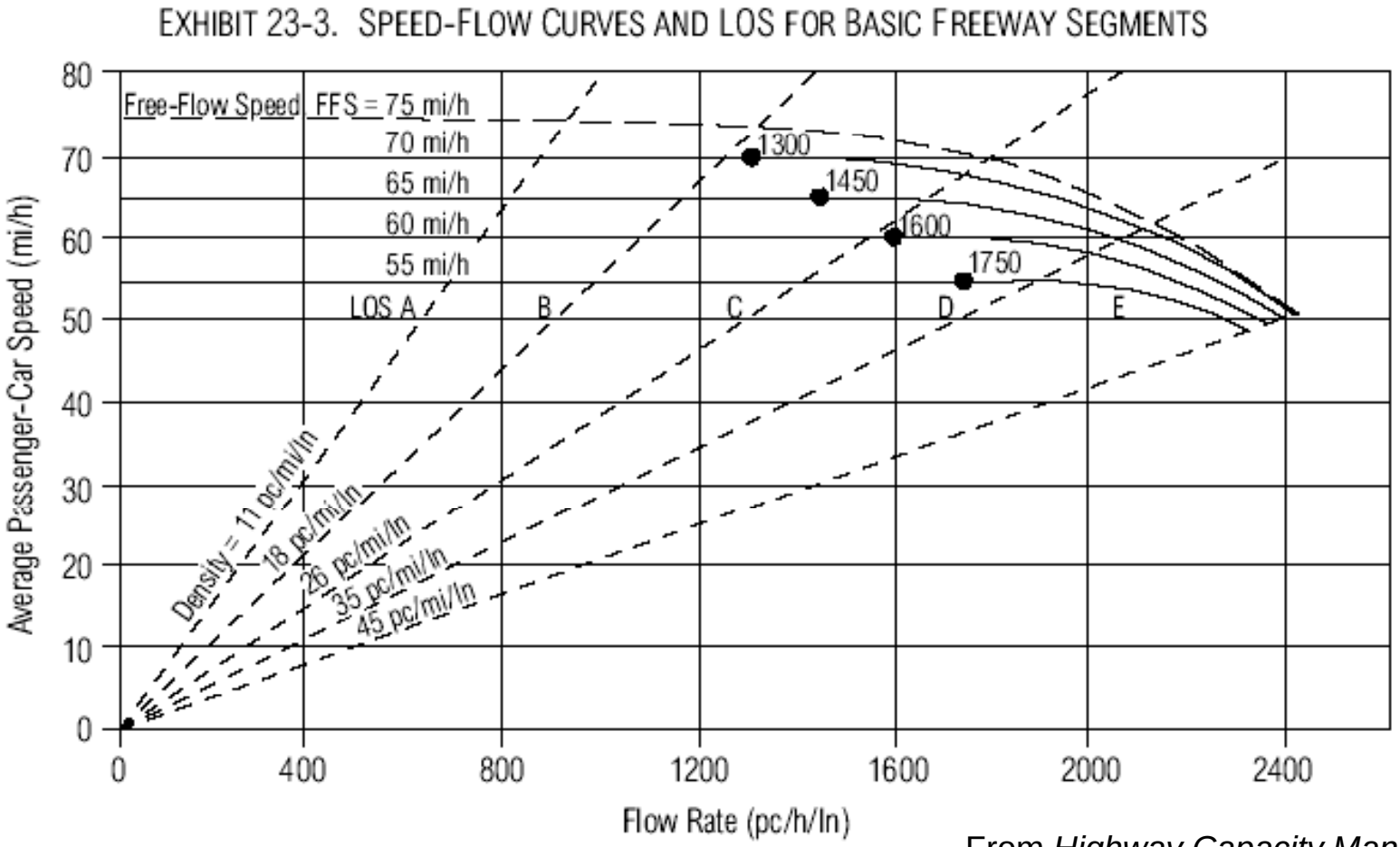
EXHIBIT 23-3. SPEED-FLOW CURVES AND LOS FOR BASIC FREEWAY SEGMENTS



From *Highway Capacity Manual*, 2000

Determine Average PC Speed (S)

Use v_p and FFS curve to find average passenger car speed (S)



From *Highway Capacity Manual*, 2000

Determine Average PC Speed (S)

For 70 < FFS ≤ 75 mph AND (3400 – 30FFS) < v_p ≤ 2400

$$S = FFS - \left[\left(FFS - \frac{160}{3}\right)\left(\frac{v_p + 30FFS - 3400}{30FFS - 1000}\right)^{2.6}\right]$$

For 55 < FFS ≤ 70 mph AND (3400 – 30FFS) < v_p ≤ (1700 + 10FFS)

$$S = FFS - \left[\frac{1}{9}(7FFS - 340)\left(\frac{v_p + 30FFS - 3400}{40FFS - 1700}\right)^{2.6}\right]$$

For 55 < FFS ≤ 75 mph AND v_p < (3400 – 30FFS)

$$S = FFS$$

Use equation instead of curve

Determine Density

- **Calculate density using:**

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

D = density (pc/mi/ln)

v_p = flow rate (pc/hr/ln)

S = average passenger-car speed (mph)

Use equation instead of curve

Freeway LOS

Determine LOS

LOS Criteria for Basic Freeway Segments

Criteria	LOS A	B	C	D	E
FFS = 75 mi/h					
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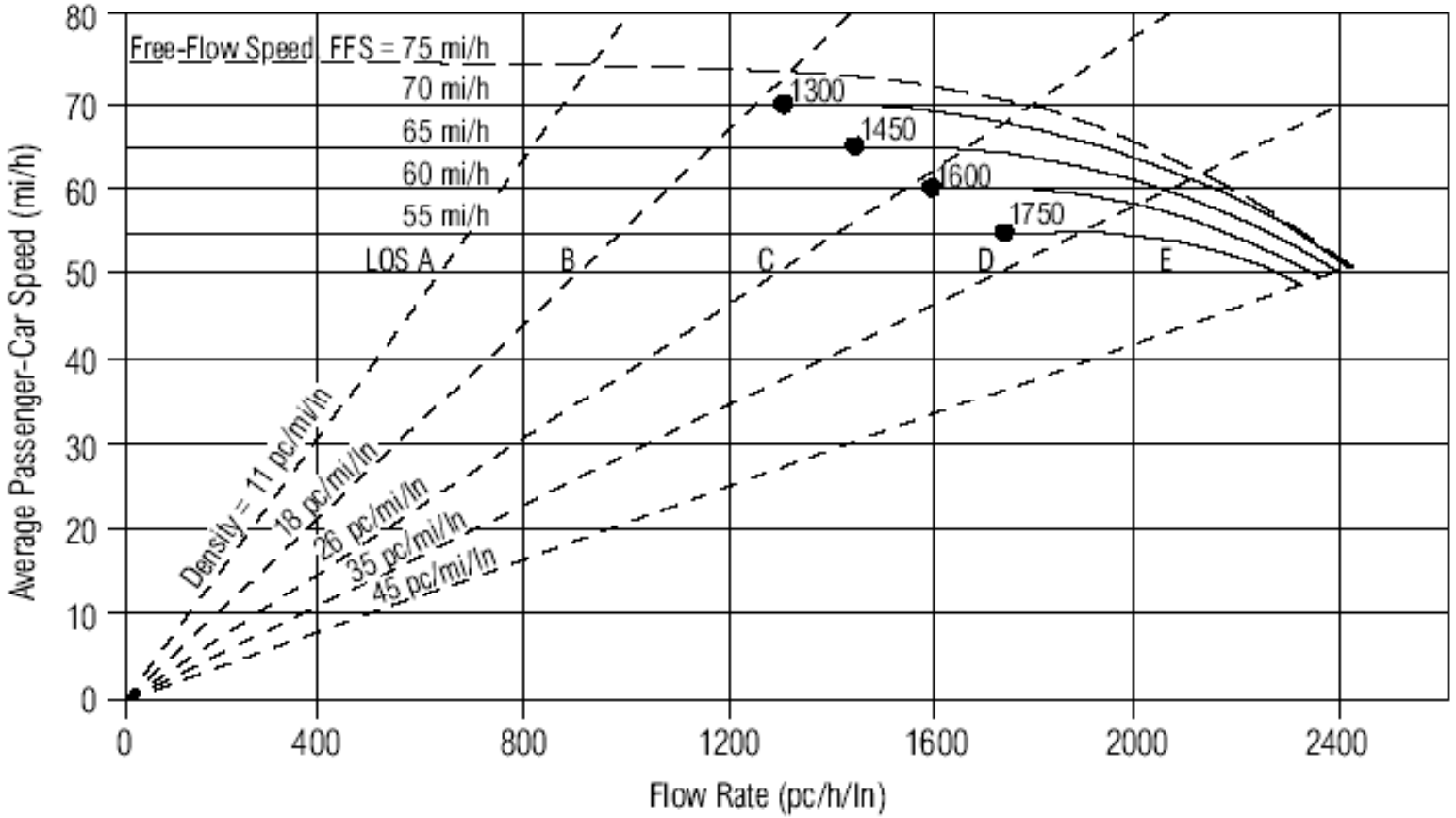
Use table instead of curve

From *Highway Capacity Manual*, 2000

Determine LOS

EXHIBIT 23-3. SPEED-FLOW CURVES AND LOS FOR BASIC FREEWAY SEGMENTS



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