EXAMPLE PROBLEM1

The Freeway Existing four-lane freeway, rural area, rolling terrain, 110-km/h speed limit.

The Question What is the LOS during the peak hour?

The Facts

√ Two lanes in each direction
√ 3.3-m lane width,
√ 0.6-m lateral clearance
√ Commuter traffic,
√ 2,000-veh/h peak-hour volume , (one direction),
√ 5 percent trucks,
√ 0.92 PHF
√ 0.6 interchanges per kilometer, and
√ Rolling terrain.,

Comments

√ Assume 0 percent buses and RVs since none are indicated.

√ Assume BFFS of 120 km/h for rural areas.
√ Assume that the number of lanes does not affect free-flow speed.
freeway is in a rural area.
√ Assume fp = 1.00 for commuter traffic.

الجداول المستخدمة لحساب العوامل الداخلة في المعادلات الخاصة بالطرق الحرة

الجدول التالي يعطي قيم المعاملات ET و ER

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

الجدول التالي يوضح المعاملات Flw لعرض كل حارة مرور

Lane Width (m)	Reduction in Free-Flow Speed, f_{LW} (km/h)
3.6	0.0
3.5	1.0
3.4	2.1
3.3	3.1
3.2	5.6
3.1	8.1
3.0	10.6

الجدول التالي يوضح قيمة المعامل Flc

Right-Shoulder Lateral Clearance (m)	Reduction in Free-Flow Speed, f_{LC} (km/h)			
	Lanes in One Direction			
	2	3	4	≥ 5
≥ 1.8	0.0	0.0	0.0	0.0
1.5	1.0	0.7	0.3	0.2
1.2	1.9	1.3	0.7	0.4
0.9	2.9	1.9	1.0	0.6
0.6	3.9	2.6	1.3	0.8
0.3	4.8	3.2	1.6	1.1
0.0	5.8	3.9	1.9	1.3

معامل عدد الحارات FN

Number of Lanes (One Direction)	Reduction in Free-Flow Speed, f_N (km/h)
≥ 5	0.0
4	2.4
3	4.8
2	7.3

معامل كثافة التبادل FID

Interchanges per Kilometer	Reduction in Free-Flow Speed, f_{ID} (km/h)
≤ 0.3	0.0
0.4	1.1
0.5	2.1
0.6	3.9
0.7	5.0
0.8	6.0
0.9	8.1
1.0	9.2
1.1	10.2
1.2	12.1

يتم تحديد مستوى الخدمة LOS لقطاع الطريق الحر الأساسي من مقارنة الكثافة المحسوبة مع مجال الكثافة في الجدول التالي

Criteria	LOS				
	A	B	C	D	E
FFS = 120 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	120.0	120.0	114.6	99.6	85.7
Maximum v/c	0.35	0.55	0.77	0.92	1.00
Maximum service flow rate (pc/h/ln)	840	1320	1840	2200	2400
FFS = 110 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	110.0	110.0	108.5	97.2	83.9
Maximum v/c	0.33	0.51	0.74	0.91	1.00
Maximum service flow rate (pc/h/ln)	770	1210	1740	2135	2350
FFS = 100 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	100.0	100.0	100.0	93.8	82.1
Maximum v/c	0.30	0.48	0.70	0.90	1.00
Maximum service flow rate (pc/h/ln)	700	1100	1600	2065	2300
FFS = 90 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	90.0	90.0	90.0	89.1	80.4
Maximum v/c	0.28	0.44	0.64	0.87	1.00
Maximum service flow rate (pc/h/ln)	630	990	1440	1955	2250

Steps:

1. Convert volume (veh/h) to flow rate (pc/h/ln) (use Equation 23-2).	$v_p = \frac{V}{(PHF)(N)(f_{HV})(f_p)}$ $v_p = \frac{2,000}{(0.92)(2)(f_{HV})(1.00)}$
2. Find f_{HV} (use Exhibit 23-8 and Equation 23-3).	$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$ $f_{HV} = \frac{1}{1 + 0.05(2.5 - 1) + 0}$ $f_{HV} = 0.930$
3. Find v_p (use Equation 23-2).	$v_p = \frac{2,000}{(0.92)(2)(0.930)(1.00)} = 1,169$ pc/h/ln
4. Compute free-flow speed (use Exhibits 23-4, 23-5, 23-6, 23-7, and Equation 23-1).	$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID}$ $FFS = 120 - 3.1 - 3.9 - 0.0 - 3.9$ FFS = 109.1 km/h
5. Determine level of service (use Exhibit 23-2).	LOS B

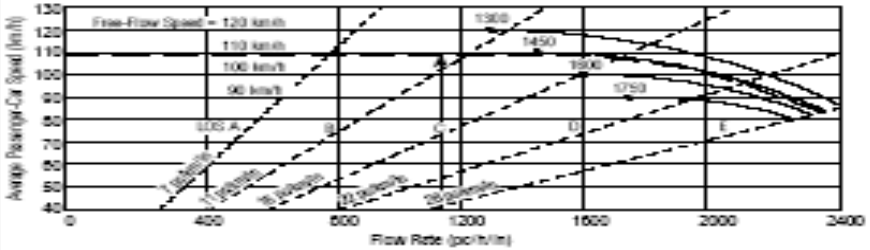
The Results:

LOS = B,

Speed = 109 km/h, and

Density = 11 pc/km/ln.

BASIC FREEWAY SEGMENTS WORKSHEET



Application	Input	Output
Operational (LOS)	FFS, N, v_p	LOS, S, D
Design (N)	FFS, LOS, v_p	N, S, D
Design (v_p)	FFS, LOS, N	v_p, S, D
Planning (LOS)	FFS, N, AADT	LOS, S, D
Planning (N)	FFS, LOS, AADT	N, S, D
Planning (v_p)	FFS, LOS, N	v_p, S, D

General Information

Analyst: WLL
Agency or Company: CEI
Date Performed: 4/12/99
Analysis Time Period:

Site Information

Highway/Direction of Travel:
From/To:
Jurisdiction:
Analysis Year: 1999

☒ Operational (LOS) ☐ Design (N) ☐ Design (v_p) ☐ Planning (LOS) ☐ Planning (N) ☐ Planning (v_p)

Flow Inputs

Volume, V: 2000 veh/h
Annual avg. daily traffic, AADT: veh/day
Peak-hour proportion of AADT, K:
Peak-hour direction proportion, D:
DDHV = AADT * K * D: veh/h
Driver type: ☒ Commuter/Weekday ☐ Recreational/Weekend

Peak-hour factor, PHF: 0.92
% Trucks and buses, P_T: 5
% RVs, P_R: 0
General terrain: ☐ Level ☒ Rolling ☐ Mountainous
Grade Length: km Up/Down: %

Calculate Flow Adjustments

f_p: 1.00
E_T: 2.5

E_R: 2.0
$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$: 0.960

Speed Inputs

Lane width: 3.5 m
Rt.-shoulder lateral clearance: 0.6 m
Interchange density: 0.6 I/km
Number of lanes, N: 2
FFS (measured): km/h
Base free-flow speed, BFFS: 120 km/h

Calculate Speed Adjustments and FFS

f_{LW}: 3.1 km/h
f_{LC}: 5.9 km/h
f_D: 5.9 km/h
f_N: 0.0 km/h
FFS = BFFS − f_{LW} − f_{LC} − f_D − f_N: 109.1 km/h

LOS and Performance Measures

Operational (LOS) or Planning (LOS)

$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: 1169 pc/h/ln
S: 109.1 km/h
D = v_p /S: 10.7 pc/km/ln
LOS: B

Design (v_p) or Planning (v_p)

LOS:
v_p: pc/h/ln
V = v_p * PHF * N * f_{HV} * f_p: veh/h
S: km/h
D = v_p /S: pc/km/ln

Design (N) or Planning (N) 1st Iteration

N: assumed
$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: pc/h/ln
LOS:

Design (N) or Planning (N) 2nd Iteration

N: assumed
$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: pc/h/ln
S: km/h
D = v_p /S: pc/km/ln
LOS:

Glossary

N – Number of lanes
V – Hourly volume
v_p – Flow rate
LOS – Level of service
DDHV – Directional design-hour volume
S – Speed
D – Density
FFS – Free-flow speed
BFFS – Base free-flow speed

Factor Location

E_R – Exhibits 23-8, 23-10
E_T – Exhibits 23-8, 23-9, 23-11
f_p – Page 23-12
LOS, S, FFS, v_p – Exhibits 23-2, 23-3
f_{LW} – Exhibit 23-4
f_{LC} – Exhibit 23-5
f_N – Exhibit 23-6
f_D – Exhibit 23-7

EXAMPLE PROBLEM 2

The Freeway New suburban freeway is being designed.

The Question How many lanes are needed to provide LOS D during the peak hour?

The Facts

√ 4,000 veh/h (one direction), √ 0.85 PHF,
√ Level terrain, √ 0.9 interchanges per kilometer,
√ 15 percent trucks, √ 3 percent RVs, and
√ 3.6-m lane width, √ 1.8-m lateral clearance.

Comments

√ Assume commuter traffic. Thus, fp = 1.00.
√ Assume BFFS of 120 km/h.

√ Assume that the number of lanes affects free-flow speed, since the freeway is being designed in a suburban area.

Outline of Solution

All input parameters are known. Flow rate, speed, density, and
LOS are calculated starting with a four-lane freeway and then increasing the number of
lanes to six, eight, and so forth until LOS D is achieved.
The calculation of speed is based
on the equation found in Exhibit 23-3.

Steps:

1.	Convert volume (veh/h) to flow rate (pc/h/ln) (use Equation 23-2).	$v_p = \frac{V}{(PHF)(N)(f_{HV})(f_p)}$
2.	Find f_{HV} (use Exhibit 23-8 and Equation 23-3).	$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$ $f_{HV} = \frac{1}{1 + (0.15)(1.5 - 1) + 0.03(1.2 - 1)}$ $f_{HV} = 0.925$
3.	For four-lane option (use Equation 23-2).	$v_p = \frac{4,000}{(0.85)(2)(0.925)(1.00)} = 2,544$ pc/h/ln
4.	The four-lane option is not acceptable since 2544 pc/h/ln exceeds capacity of 2400 pc/h/ln.	
5.	For six-lane option (use Equation 23-2).	$v_p = \frac{4,000}{(0.85)(3)(0.925)(1.00)} = 1,696$ pc/h/ln
6.	Compute free-flow speed for a six-lane freeway (use Exhibits 23-4, 23-5, 23-6, 23-7, and Equation 23-1).	$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID}$ $FFS = 120 - 0.0 - 0.0 - 4.8 - 8.1$ $FFS = 107.1$ km/h
7.	Determine level of service (use Exhibit 23-2).	LOS C

The Results:

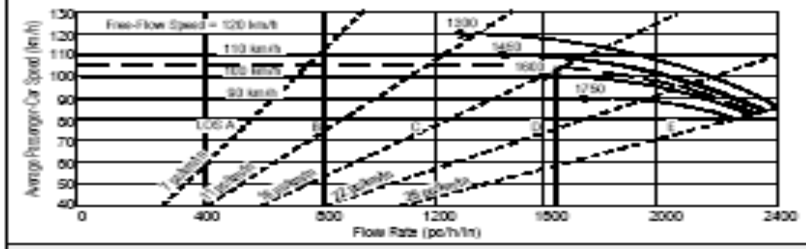
Six lanes are needed,

LOS = C,

Speed = 107 km/h, and

Density = 16 pc/km/ln.

BASIC FREEWAY SEGMENTS WORKSHEET



Application	Input	Output
Operational (LOS)	FFS, N, v_p	LOS, S, D
Design (N)	FFS, LOS, v_p	N, S, D
Design (v_p)	FFS, LOS, N	v_p, S, D
Planning (LOS)	FFS, N, AADT	LOS, S, D
Planning (N)	FFS, LOS, AADT	N, S, D
Planning (v_p)	FFS, LOS, N	v_p, S, D

General Information

Analyst: JMYE
Agency or Company: CEI
Date Performed: 4/14/99
Analysis Time Period:

Site Information

Highway/Direction of Travel:
From/To:
Jurisdiction:
Analysis Year: 1999

☐ Operational (LOS) ☒ Design (N) ☐ Design (v_p) ☐ Planning (LOS) ☐ Planning (N) ☐ Planning (v_p)

Flow Inputs

Volume, V: 4000 veh/h
Annual avg. daily traffic, AADT: veh/day
Peak-hour proportion of AADT, K:
Peak-hour direction proportion, D:
DDHV = AADT * K * D: veh/h
Driver type ☒ Commuter/Weekday ☐ Recreational/Weekend

Peak-hour factor, PHF: 0.85
% Trucks and buses, P_T: 15
% RVs, P_R: 5
General terrain
☒ Level ☐ Rolling ☐ Mountainous
Grade Length: km Up/Down: %

Calculate Flow Adjustments

f_p: 1.00
E_T: 1.5

E_R: 1.2
$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$: 0.925

Speed Inputs

Lane width: 3.6 m
Rt.-shoulder lateral clearance: 1.8 m
Interchange density: 0.9 /km
Number of lanes, N: 2/3
FFS (measured): km/h
Base free-flow speed, BFFS: 120 km/h

Calculate Speed Adjustments and FFS

f_{LW}: 0.0 km/h
f_{LC}: 0.0 km/h
f_D: 8.1 km/h
f_N: 7.5/4.8 km/h
FFS = BFFS − f_{LW} − f_{LC} − f_D − f_N: 104.6/107.1 km/h

LOS and Performance Measures

Operational (LOS) or Planning (LOS)

$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: pc/h/ln
S: km/h
D = v_p /S: pc/km/ln
LOS:

Design (v_p) or Planning (v_p)

LOS:
v_p: pc/h/ln
V = v_p * PHF * N * f_{HV} * f_p: veh/h
S: km/h
D = v_p /S: pc/km/ln

Design (N) or Planning (N) 1st Iteration

N: 2 assumed
$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: 2544 pc/h/ln
LOS: oversaturated

Design (N) or Planning (N) 2nd Iteration

N: 3 assumed
$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: 1696 pc/h/ln
S: 106.5 km/h
D = v_p /S: 15.9 pc/km/ln
LOS: C

Glossary

N - Number of lanes
V - Hourly volume
v_p - Flow rate
LOS - Level of service
DDHV - Directional design-hour volume
S - Speed
D - Density
FFS - Free-flow speed
BFFS - Base free-flow speed

Factor Location

E_R - Exhibits 23-8, 23-10
E_T - Exhibits 23-8, 23-9, 23-11
f_p - Page 23-12
LOS, S, FFS, v_p - Exhibits 23-2, 23-3
f_{LW} - Exhibit 23-4
f_{LC} - Exhibit 23-5
f_N - Exhibit 23-6
f_D - Exhibit 23-7

EXAMPLE PROBLEM 3

The Freeway Existing six-lane freeway in a growing urban area.

The Question What is the current LOS during the peak hour? What LOS will occur in 3 years? When should a fourth lane be added in each direction to avoid an excess of demand over capacity?

The Facts

√ 5,000 veh/h (one direction, existing);
√ 6 lanes;
√ Level terrain;
√ 10 percent trucks;
√ 5,600 veh/h (one direction, in 3 years);
√ 0.95 PHF; and
√ Beyond 3 years, traffic grows at 4 percent per year;
√ FFS = 110 km/h (measured in field).

Comments

√ Since no information is given on possible changes over time, assume that 10percent trucks, PHF, and FFS remain constant.

√ This problem deals with a variety of demand levels and can most easily be solved by computing the maximum volume that can be accommodated for each level of service.

√ Assume 0 percent buses and RVs.

√ Assume commuter traffic.

Outline of Solution The maximum volume (veh/h) for each LOS is computed, the demand volumes are compared, and a level of service is estimated.

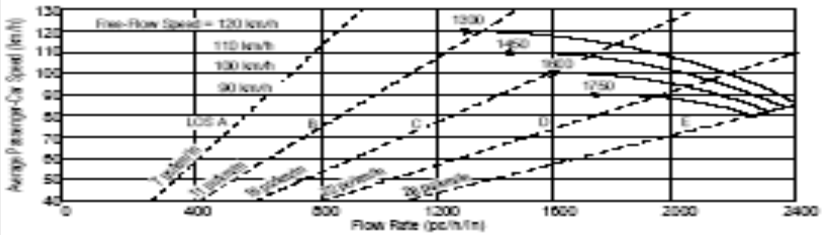
Steps:

1.	Convert the maximum service flow rate (pc/h/ln) for each LOS to veh/h (use Equation 23-2).	$v_p = \frac{V}{(PHF)(N)(f_{HV})(f_p)}$ $V = v_p(PHF)(N)(f_{HV})(f_p)$
2.	Find f_{HV} (use Equation 23-3 and Exhibit 23-8).	$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$ $f_{HV} = \frac{1}{1 + 0.10(1.5 - 1) + 0}$ $f_{HV} = 0.952$
3.	Find maximum v_p for each LOS (use Exhibit 23-2).	LOS A, v_p = 770 pc/h/ln LOS B, v_p = 1,210 LOS C, v_p = 1,740 LOS D, v_p = 2,135 LOS E, v_p = 2,350
4.	Compute V (veh/h) (use equation from Step 1 with $f_p = 1.00$).	LOS A, V = 2,089 veh/h LOS B, V = 3,283 LOS C, V = 4,721 LOS D, V = 5,793 LOS E, V = 6,376
5.	Compare 5,000 veh/h and 5,600 veh/h with above, determine LOS.	
6.	When traffic exceeds 6,376 veh/h, a fourth lane in each direction will be needed. A compounding equation is used.	$5{,}600(1.04^n) = 6{,}376$ $n = 3.3$ years

The Results:

LOS D (existing),LOS D (in 3 years), and a fourth lane will be needed in 3.3 years beyond the end of the first 3 years.

BASIC FREEWAY SEGMENTS WORKSHEET



Application	Input	Output
Operational (LOS)	FFS, N, v_p	LOS, S, D
Design (N)	FFS, LOS, v_p	N, S, D
Design (v_p)	FFS, LOS, N	v_p, S, D
Planning (LOS)	FFS, N, AADT	LOS, S, D
Planning (N)	FFS, LOS, AADT	N, S, D
Planning (v_p)	FFS, LOS, N	v_p, S, D

General Information

Analyst: JMYE
Agency or Company: CD
Date Performed: 4/15/99
Analysis Time Period:

Site Information

Highway/Direction of Travel:
From/To:
Jurisdiction:
Analysis Year: 1999/2002

☒ Operational (LOS) ☐ Design (N) ☐ Design (v_p) ☒ Planning (LOS) ☐ Planning (N) ☐ Planning (v_p)

Flow Inputs

Volume, V: 5000/5600 veh/h
Annual avg. daily traffic, AADT: veh/day
Peak-hour proportion of AADT, K:
Peak-hour direction proportion, D:
DDHV = AADT * K * D: veh/h
Driver type ☒ Commuter/Weekday ☐ Recreational/Weekend

Peak-hour factor, PHF: 0.95
% Trucks and buses, P_T: 10
% RVs, P_R: 0
General terrain
☒ Level ☐ Rolling ☐ Mountainous
Grade Length: km Up/Down: %

Calculate Flow Adjustments

f_p: 1.00
E_T: 1.5

E_R:
$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$: 0.952

Speed Inputs

Lane width: m
Rt.-shoulder lateral clearance: m
Interchange density: I/km
Number of lanes, N: 3
FFS (measured): 110 km/h
Base free-flow speed, BFFS: km/h

Calculate Speed Adjustments and FFS

f_{LW}: km/h
f_{LC}: km/h
f_D: km/h
f_N: km/h
FFS = BFFS − f_{LW} − f_{LC} − f_D − f_N: km/h

LOS and Performance Measures

Operational (LOS) or Planning (LOS)

$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: pc/h/ln
S: km/h
D = v_p /S: pc/km/ln
LOS: D (existing)/D (in 5 years)

Design (v_p) or Planning (v_p)

LOS: C/D/E
v_p: 1740/2135/2550 pc/h/ln
V = v_p * PHF * N * f_{HV} * f_p: 472/579/693/876 veh/h
S: km/h
D = v_p /S: pc/km/ln

Design (N) or Planning (N) 1st Iteration

N: assumed
$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: pc/h/ln
LOS:

Design (N) or Planning (N) 2nd Iteration

N: assumed
$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: pc/h/ln
S: km/h
D = v_p /S: pc/km/ln
LOS:

Glossary

N – Number of lanes
V – Hourly volume
v_p – Flow rate
LOS – Level of service
DDHV – Directional design-hour volume
S – Speed
D – Density
FFS – Free-flow speed
BFFS – Base free-flow speed

Factor Location

E_R – Exhibits 23-8, 23-10
E_T – Exhibits 23-8, 23-9, 23-11
f_p – Page 23-12
LOS, S, FFS, v_p – Exhibits 23-2, 23-3
f_{LW} – Exhibit 23-4
f_{LC} – Exhibit 23-5
f_N – Exhibit 23-6
f_D – Exhibit 23-7

EXAMPLE PROBLEM 4

The Freeway Existing four-lane freeway in a rural area.

The Question What is the LOS for both the upgrade and the downgrade directions
during the peak hour?

The Facts

√ 2 lanes in each direction, √ 2,300 veh/h peak-volume(one direction),
√ 15 percent trucks,
√ 0.90 PHF, √ Segment 1, 900 m at 3 percent grade,
√ Segment 2, 800 m at 5 percent grade, and
√ FFS = 115 km/h (measured in field, upgrade direction) √ FFS = 120 km/h (measured in field, downgrade direction).

Comments

√ Assume 0 percent buses and RVs since none are indicated.

√ The precise procedure for composite grades is used because there is a segment steeper than 4 percent and the total length is greater than 1200 m.

√ Assume fp = 0.95 because drivers are generally unfamiliar with the area.

Outline of Solution The truck performance curves in Appendix A are used to develop
an equivalent grade (i.e., a constant grade that has the same effect on heavy vehicles as does the composite grade) .
Demand is computed in terms of passenger cars per hour per lane, and LOS is determined from the speed-flow graph. The calculation of speed isbased on the equation found in Exhibit 23-3.

Steps:

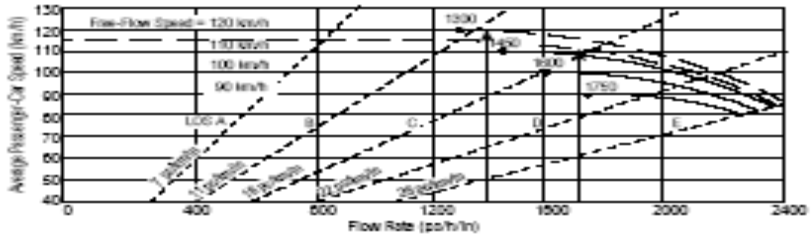
1. Determine equivalent constant grade (use Exhibit A23-2).	Using Appendix A, enter 900 m. Speed at top of 3 percent grade is 68 km/h. Intersection of horizontal at 68 km/h and 5 percent curve implies trucks have been on 5 percent for 375 m. A vertical is drawn at 1175 m to the 5 percent deceleration curve, and a horizontal shows a final truck speed of 42 km/h. A horizontal line at a speed of 42 km/h and a vertical line at 1700 m intersect at a composite grade of 5 percent. Similarly, the composite grade for the downgrade is computed as –1 percent.
2. Convert volume (veh/h) to flow rate (pc/h/ln) (use Equation 23-2).	$v_p = \frac{V}{(PHF)(N)(f_{HV})(f_p)}$
3. Find f_{HV} (upgrade) (Exhibit 23-9 and Equation 23-3).	$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$ $f_{HV} = \frac{1}{1 + 0.15(3.0 - 1) + 0} = 0.769$
4. Find f_{HV} (downgrade) (use Exhibit 23-11 and Equation 23-3).	$f_{HV} = \frac{1}{1 + 0.15(1.5 - 1) + 0} = 0.930$
5. Find v_p (upgrade) (use Equation 23-2).	$v_p = \frac{2{,}300}{(0.90)(2)(0.769)(0.95)} = 1{,}749$ pc/h/ln
6. Find v_p (downgrade) (use Equation 23-2).	$v_p = \frac{2{,}300}{(0.90)(2)(0.930)(0.95)} = 1{,}446$ pc/h/ln
7. Determine LOS (use Exhibit 23-2).	LOS C (upgrade and downgrade)

The Results:

Upgrade
LOS C,
Speed = 113 km/h, and
Density = 15 pc/km/ln.

Downgrade
LOS C,
Speed = 120 km/h, and
Density = 12 pc/km/ln.

BASIC FREEWAY SEGMENTS WORKSHEET



Application	Input	Output
Operational (LOS)	FFS, N, v_p	LOS, S, D
Design (N)	FFS, LOS, v_p	N, S, D
Design (v_p)	FFS, LOS, N	v_p, S, D
Planning (LOS)	FFS, N, AADT	LOS, S, D
Planning (N)	FFS, LOS, AADT	N, S, D
Planning (v_p)	FFS, LOS, N	v_p, S, D

General Information

Analyst: JMYE
Agency or Company: CE
Date Performed: 5/16/99
Analysis Time Period:

Site Information

Highway/Direction of Travel:
From/To:
Jurisdiction:
Analysis Year: 1999

☒ Operational (LOS) ☐ Design (N) ☐ Design (v_p) ☐ Planning (LOS) ☐ Planning (N) ☐ Planning (v_p)

Flow Inputs

Volume, V: 2500 veh/h
Annual avg. daily traffic, AADT: veh/day
Peak-hour proportion of AADT, K:
Peak-hour direction proportion, D:
DDHV = AADT * K * D: veh/h
Driver type ☐ Commuter/Weekday ☐ Recreational/Weekend

Peak-hour factor, PHF: 0.90
% Trucks and buses, P_T: 15
% RVs, P_R: 0
General terrain
☐ Level ☐ Rolling ☐ Mountainous
Grade Length: 1.7 km Up/Down: 5/-1 %

Calculate Flow Adjustments

f_p: 0.95
E_T: 3.0/1.5

E_R:
$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$: 0.769/0.980

Speed Inputs

Lane width: m
Rt.-shoulder lateral clearance: m
Interchange density: /km
Number of lanes, N: 2
FFS (measured): 115/120 km/h
Base free-flow speed, BFFS: km/h

Calculate Speed Adjustments and FFS

f_{LW}: km/h
f_{LC}: km/h
f_D: km/h
f_N: km/h
FFS = BFFS − f_{LW} − f_{LC} − f_D − f_N: km/h

LOS and Performance Measures

Operational (LOS) or Planning (LOS)

$v_p = \frac{V \text{ or DDHV}}{PHF * N * f_{HV} * f_p}$: 174.9/144.6 pc/h/ln
S: 112.7/119.8 km/h
D = v_p/S: 15.5/12.1 pc/km/ln
LOS: C/C

Design (v_p) or Planning (v_p)

LOS:
v_p: pc/h/ln
V = v_p * PHF * N * f_{HV} * f_p: veh/h
S: km/h
D = v_p/S: pc/km/ln

Design (N) or Planning (N) 1st Iteration

N: assumed
$v_p = \frac{V \text{ or DDHV}}{PHF * N * f_{HV} * f_p}$: pc/h/ln
LOS:

Design (N) or Planning (N) 2nd Iteration

N: assumed
$v_p = \frac{V \text{ or DDHV}}{PHF * N * f_{HV} * f_p}$: pc/h/ln
S: km/h
D = v_p/S: pc/km/ln
LOS:

Glossary

N - Number of lanes
V - Hourly volume
v_p - Flow rate
LOS - Level of service
DDHV - Directional design-hour volume
S - Speed
D - Density
FFS - Free-flow speed
BFFS - Base free-flow speed

Factor Location

E_R - Exhibits 23-8, 23-10
E_T - Exhibits 23-8, 23-9, 23-11
f_p - Page 23-12
LOS, S, FFS, v_p - Exhibits 23-2, 23-3
f_{LW} - Exhibit 23-4
f_{LC} - Exhibit 23-5
f_N - Exhibit 23-6
f_D - Exhibit 23-7

EXAMPLE PROBLEM 5

The Freeway New urban facility being planned with a forecast opening-day AADT of 75,000 veh/day.

The Question What is the minimum number of lanes needed to provide at least LOS D during the peak hour on opening day? What are the speed and density of traffic for the proposed number of lanes?

The Facts

√ 75,000 veh/day,

√ K = 0.090,

√ Directional split = 55/45, and

√ Rolling terrain.

Comments

√ Several input variables (FFS, PHF, percent trucks) are not given. Reasonable default values are selected as FFS = 110 km/h (in lieu of field measurement), PHF = 0.90, 10 percent trucks, and 0 percent RVs.

√ Assume commuter traffic (fp = 1.00).

Outline of Solution Flow rate, speed, density, and LOS are calculated starting with a four-lane freeway and then increasing the number of lanes to six, eight, and so forth until LOS D is achieved. The calculation of speed is based on the equation found in Exhibit 23-3.

Steps:

1.	Convert AADT to design-hour volume.	DDHV = AADT * K * D DDHV = 75,000 * 0.090 * 0.55 DDHV = 3,713 veh/h
2.	Find f_{HV} (use Exhibit 23-8 and Equation 23-3).	$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$ $f_{HV} = \frac{1}{1 + 0.10(2.5 - 1) + 0}$ $f_{HV} = 0.870$
3.	For four-lane option (use Equation 23-2).	$v_p = \frac{3,713}{(0.90)(2)(0.870)(1.00)} = 2,371$ pc/h/ln
4.	Determine level of service (use Exhibit 23-2).	LOS F
5.	For six-lane option (use Equation 23-2).	$v_p = \frac{3,713}{(0.90)(3)(0.870)(1.00)}$ $v_p = 1,581$ pc/h/ln
6.	Determine level of service (use Exhibit 23-2).	LOS C
7.	Calculate speed and density	S = 109.8 km/h D = 14.4 pc/km/ln

The Results:

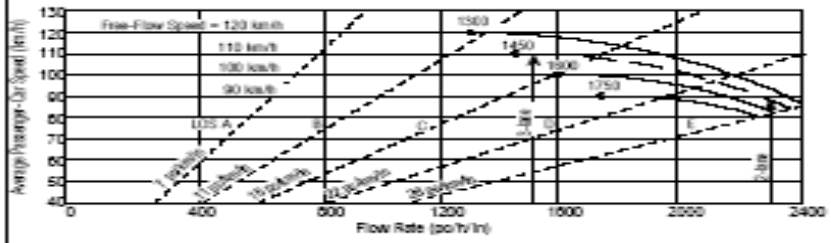
Six lanes are needed,

LOS = C,

Speed = 110 km/h, and

Density = 14 pc/km/ln.

BASIC FREEWAY SEGMENTS WORKSHEET



Application	Input	Output
Operational (LOS)	FFS, N, v_p	LOS, S, D
Design (N)	FFS, LOS, v_p	N, S, D
Design (v_p)	FFS, LOS, N	v_p, S, D
Planning (LOS)	FFS, N, AADT	LOS, S, D
Planning (N)	FFS, LOS, AADT	N, S, D
Planning (v_p)	FFS, LOS, N	v_p, S, D

General Information

Analyst: JMYE
Agency or Company: CEI
Date Performed: 4/15/99
Analysis Time Period:

Site Information

Highway/Direction of Travel:
From/To:
Jurisdiction:
Analysis Year: 1999

☐ Operational (LOS) ☐ Design (N) ☐ Design (v_p) ☐ Planning (LOS) ☒ Planning (N) ☐ Planning (v_p)

Flow Inputs

Volume, V: ____ veh/h
Annual avg. daily traffic, AADT: 75,000 veh/day
Peak-hour proportion of AADT, K: 0.090
Peak-hour direction proportion, D: 0.55
DDHV = AADT * K * D: 3712 veh/h
Driver type: ☒ Commuter/Weekday ☐ Recreational/Weekend

Peak-hour factor, PHF: 0.90
% Trucks and buses, P_T: 10
% RVs, P_R: 0
General terrain
☐ Level ☒ Rolling ☐ Mountainous
Grade Length: ____ km Up/Down: ____ %

Calculate Flow Adjustments

f_p: 1.00
E_T: 2.5

E_R:
$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$: 0.870

Speed Inputs

Lane width: ____ m
Rt.-shoulder lateral clearance: ____ m
Interchange density: ____ I/km
Number of lanes, N:
FFS (measured): 110 km/h
Base free-flow speed, BFFS: ____ km/h

Calculate Speed Adjustments and FFS

f_{LW}: ____ km/h
f_{LC}: ____ km/h
f_D: ____ km/h
f_N: ____ km/h
FFS = BFFS − f_{LW} − f_{LC} − f_D − f_N: ____ km/h

LOS and Performance Measures

Operational (LOS) or Planning (LOS)

$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: ____ pc/h/ln
S: ____ km/h
D = v_p / S: ____ pc/km/ln
LOS:

Design (v_p) or Planning (v_p)

LOS:
v_p: ____ pc/h/ln
V = v_p * PHF * N * f_{HV} * f_p: ____ veh/h
S: ____ km/h
D = v_p / S: ____ pc/km/ln

Design (N) or Planning (N) 1st Iteration

N: 2 assumed
$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: 2371 pc/h/ln
LOS: F

Design (N) or Planning (N) 2nd Iteration

N: 3 assumed
$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: 1581 pc/h/ln
S: 109.8 km/h
D = v_p / S: 14.4 pc/km/ln
LOS: C

Glossary

N – Number of lanes
V – Hourly volume
v_p – Flow rate
LOS – Level of service
DDHV – Directional design-hour volume
S – Speed
D – Density
FFS – Free-flow speed
BFFS – Base free-flow speed

Factor Location

E_R – Exhibits 23-8, 23-10
E_T – Exhibits 23-8, 23-9, 23-11
f_p – Page 23-12
LOS, S, FFS, v_p – Exhibits 23-2, 23-3
f_{LW} – Exhibit 23-4
f_{LC} – Exhibit 23-5
f_N – Exhibit 23-6
f_D – Exhibit 23-7