

Interchange Design

CE 453 Lecture 31

Objectives

1. Relate possible interchange design actions to flexibility concepts
 - a) Overlapping routes
 - b) Lane balance
 - c) Weaving area
2. Define benefits of uniformity and flexibility concepts

Operational Flexibility – Overlapping Routes

1. Avoid overlapping routes – especially within interchanges (two plus routes using same alignment)
2. Why? They can:
 - a) Concentrate volumes because of two route demand in same place
 - b) Weaving is typical
 - c) Usually results in complicated geometry when trying to comply with basic design principles
 - d) Have complicated signing
 - e) All results in high workload (result?)

Operational Flexibility – Overlapping Routes (contd.)

3. Treatments for overlapping routes:
 - a) Give preference to higher class route
 - b) Position routes so they don't cross, although they may share alignment
 - c) Use CD roads for major/minor overlap (Exhibit 10-47)
 - d) Fully separate routes

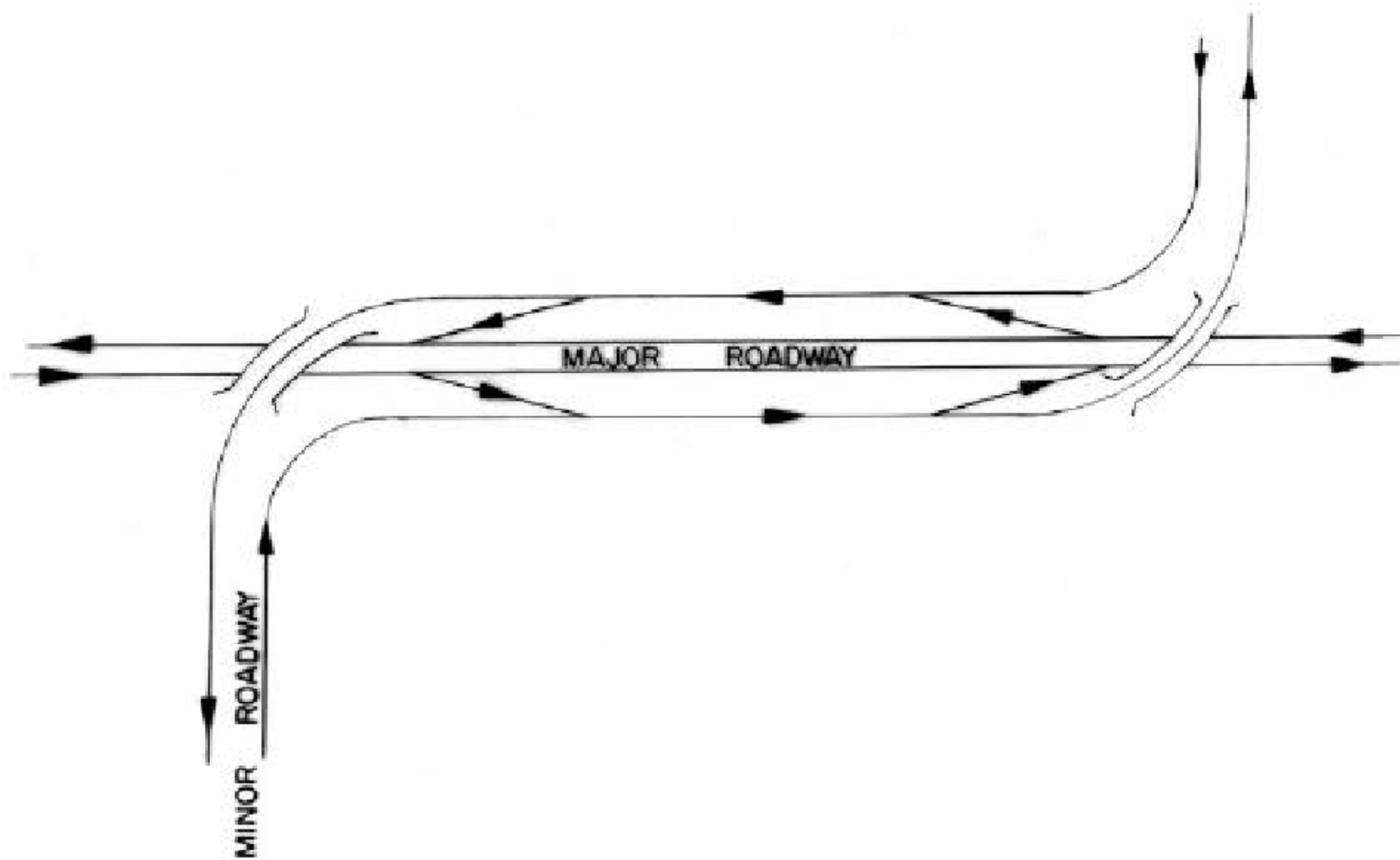
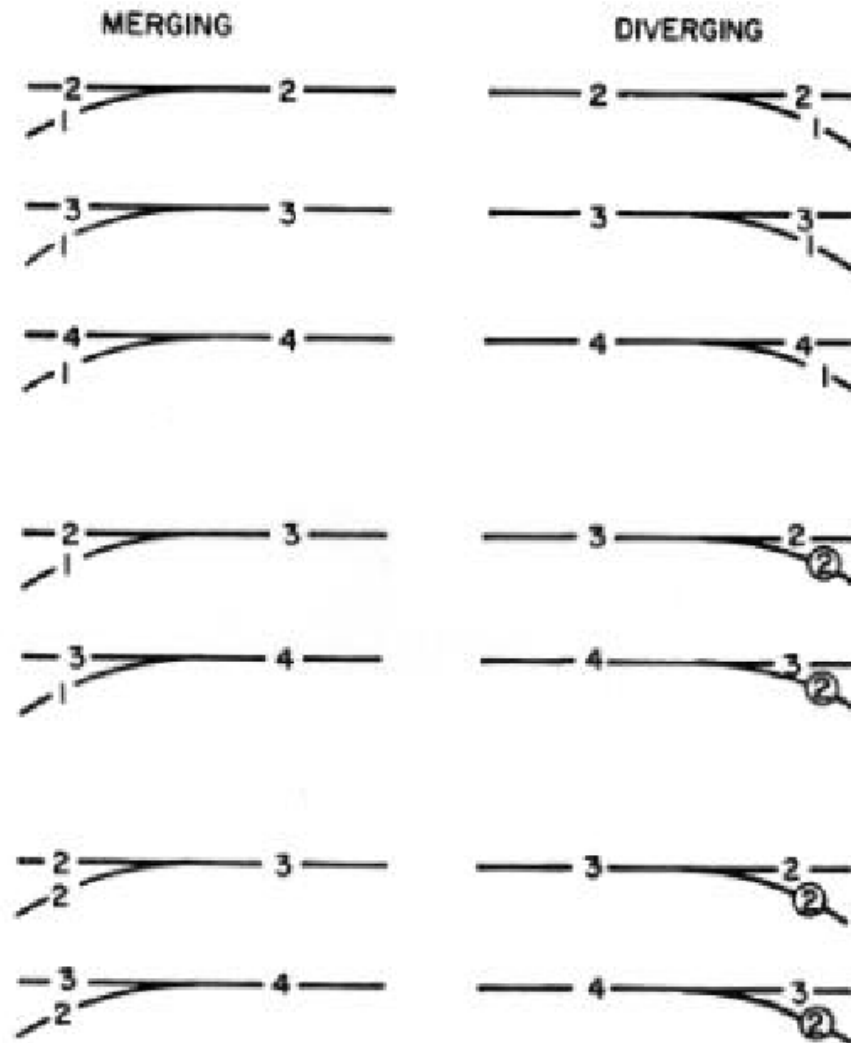


Exhibit 10-47. Collector-Distributor Road on Major-Minor Roadway Overlap

Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

Operational Flexibility – Lane Balance

1. Provide lane balance (i.e., an operationally balanced arrangement of traffic lanes on mainline lanes and ramps) (Exhibit 10-49)
 - a) Entrance Ramps: number of lanes downstream should be the same or one less than upstream $N_c = N_f + N_e - 1$ or $N_c = N_f + N_e$ (N_f = # of freeway lanes, N_e = # of entrance lanes, and N_c = number of combined lanes downstream)



② ONE LANE UNDER SPECIAL CONDITIONS OF PRINCIPLE 2 UNDER THE SECTION "COORDINATION OF LANE BALANCE AND BASIC NUMBER OF LANES"

Exhibit 10-49. Typical Examples of Lane Balance

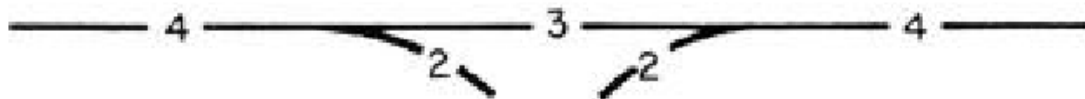
Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

Operational Flexibility – Lane Balance

- b) Exit Ramps: number of lanes on exit and mainline should be one more than mainline upstream of exit (e.g., 2 ML and 2ML and 1 EL) – exception cloverleaf or auxiliary lane 450 m or less – then before and after lanes are equal
- c) Reduce basic number of lane by only one at a time, this can be done:
 - Beyond point lane is needed (e.g., beyond major fork or series of exits)
 - At 2-lane exit
 - Between interchanges (on right, following the exit, 2,000 to 3,000 feet downstream of interchange (avoid expectancy problems), where DSD is provided)

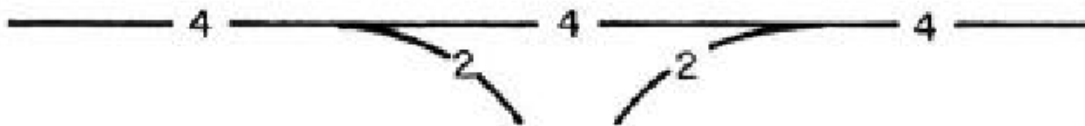
Operational Flexibility – Auxiliary Lanes

1. Definition: “...portion of roadway adjoining the traveled way for parking, speed change, turning, storage for turning, weaving, truck climbing, and other purposes supplementary to through-traffic movement.”
2. Role: mitigate ramp impacts by
 1. complying with lane balance and basic number of lane rules (Exhibit 10-50 and 10-52)
 2. accommodating speed changes for exiting/entering vehicles
 3. providing same LOS as freeway in ramp and weaving areas



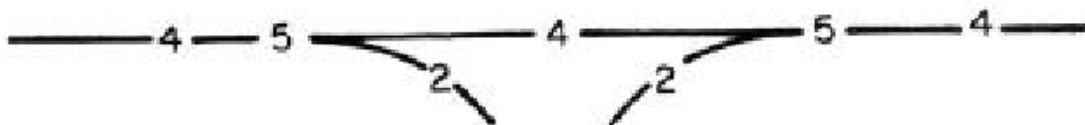
LANE BALANCE BUT NO COMPLIANCE WITH BASIC NUMBER OF LANES

- A -



NO LANE BALANCE BUT COMPLIANCE WITH BASIC NUMBER OF LANES

- B -

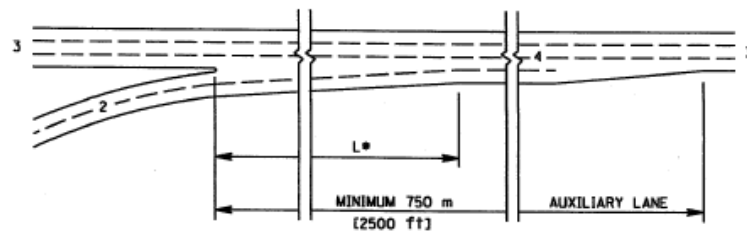


COMPLIANCE WITH BOTH LANE BALANCE AND BASIC NUMBER OF LANES

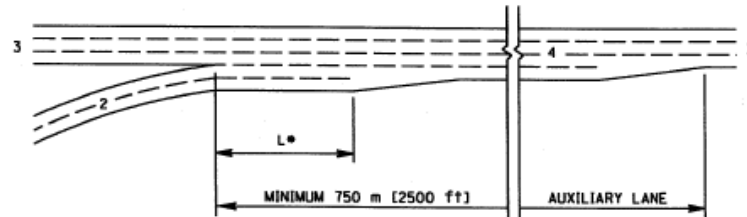
- C -

Exhibit 10-50. Coordination of Lane Balance and Basic Number of Lanes

Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

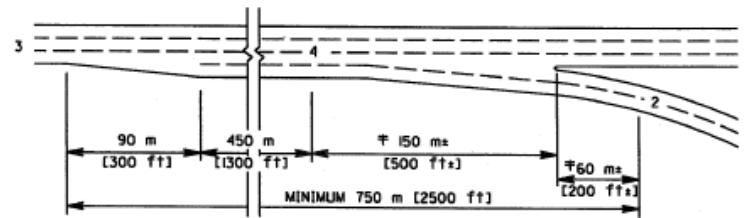


-A1- TAPERED DESIGN

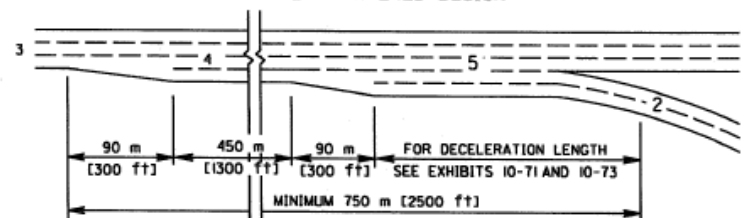


-A2- PARALLEL DESIGN (PREFERRED)

AUXILIARY LANE EXTENDED FOR EFFECTIVE DISTANCE BEYOND ENTRANCE
 * Refer to Exhibit 10-76 for minimum length criteria.



-B1- TAPERED DESIGN



-B2- PARALLEL DESIGN (PREFERRED)

AUXILIARY LANE INTRODUCED FOR EFFECTIVE DISTANCE IN ADVANCE OF EXIT

* Varies with angle of divergence

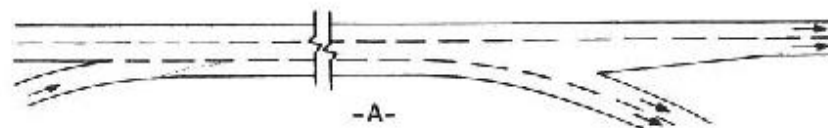
(A) Point controlling speed on ramp

Exhibit 10-52. Coordination of Lane Balance and Basic Number of Lanes Through Application of Auxiliary Lanes

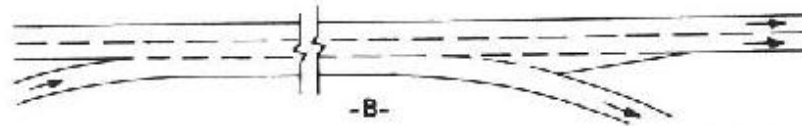
Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

Operational Flexibility – Auxiliary Lanes

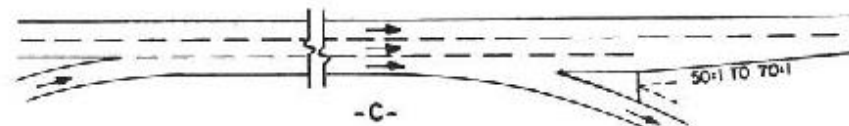
3. Introduce Auxiliary lanes 2500 feet upstream of 2 lane exits, distance upstream of 1 lane exits that accommodates reasonable accel/decel from freeway D.S. to ramp proper D.S.
4. Drop Auxiliary lanes (Exhibit 10-51) as part of isolated 2-lane entrance, at closely spaced interchanges – at 2 lane exit, at single lane cloverleaf exit, beyond physical nose of single lane exit, 500-1000 feet beyond single lane exit.



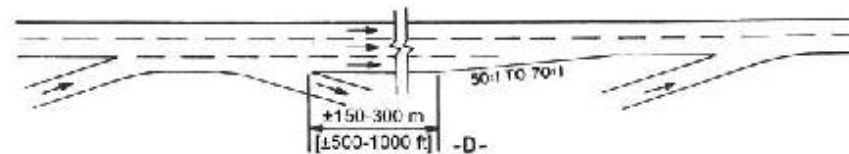
-A-
AUXILIARY LANE DROPPED ON EXIT RAMP



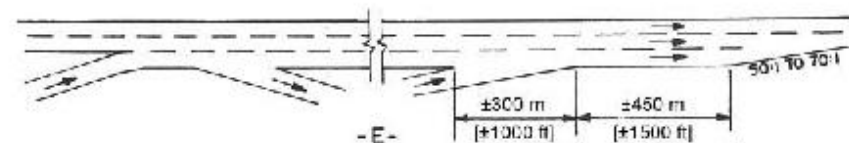
-B-
AUXILIARY LANE BETWEEN CLOVERLEAF LOOPS OR CLOSELY SPACED INTERCHANGES DROPPED ON SINGLE EXIT LANE.



-C-
AUXILIARY LANE DROPPED AT PHYSICAL NOSE



-D-
AUXILIARY LANE DROPPED WITHIN AN INTERCHANGE



-E-
AUXILIARY LANE DROPPED BEYOND AN INTERCHANGE

Exhibit 10-51. Alternative Methods of Dropping Auxiliary Lanes

Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

Operational Flexibility – Avoid Weaving Areas

1. Definition: section of freeway with 2 or more traffic streams crossing paths
2. See HCM for weaving area definition (A, B, and C)
3. Problems: turbulence reduces efficiency, increased driver workload, and higher number of vehicle conflicts
4. Design parameters: configuration, length, and weaving/non-weaving volumes
5. Solutions: avoid designs with inherent weaving, or introduce CD roads to remove weaving on mainline

Operational Uniformity/Flexibility Benefits

1. Reduced number of lane changes (improved operations and fewer vehicle conflicts)
2. Signing simplified
3. Reduced navigation workload
4. Ramp traffic impact reduced
5. Provide flexibility to serve different traffic patterns

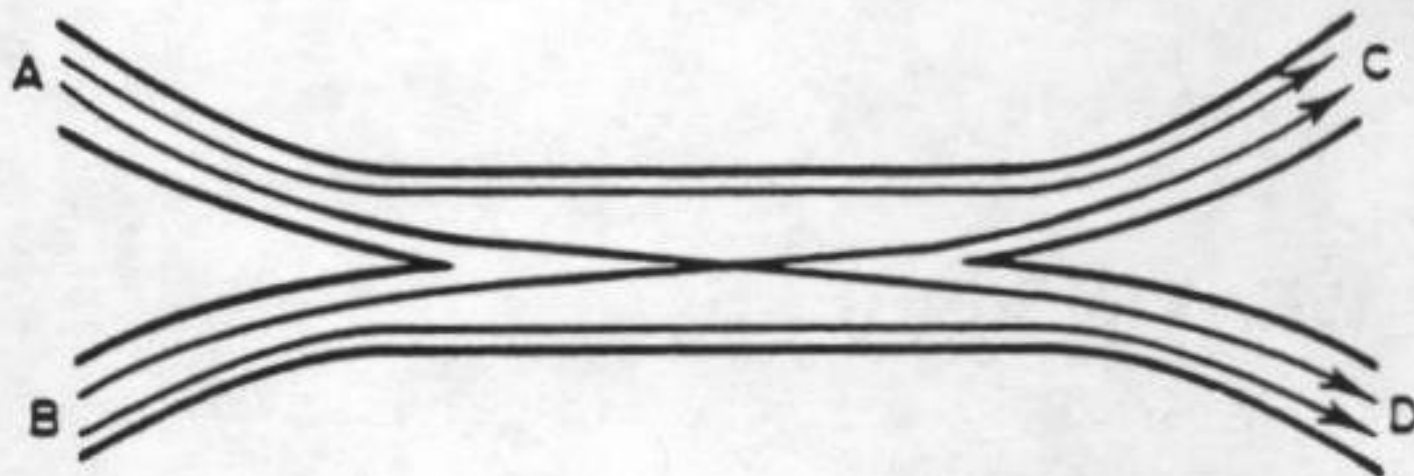


Figure 4-1. Formation of a weaving section.

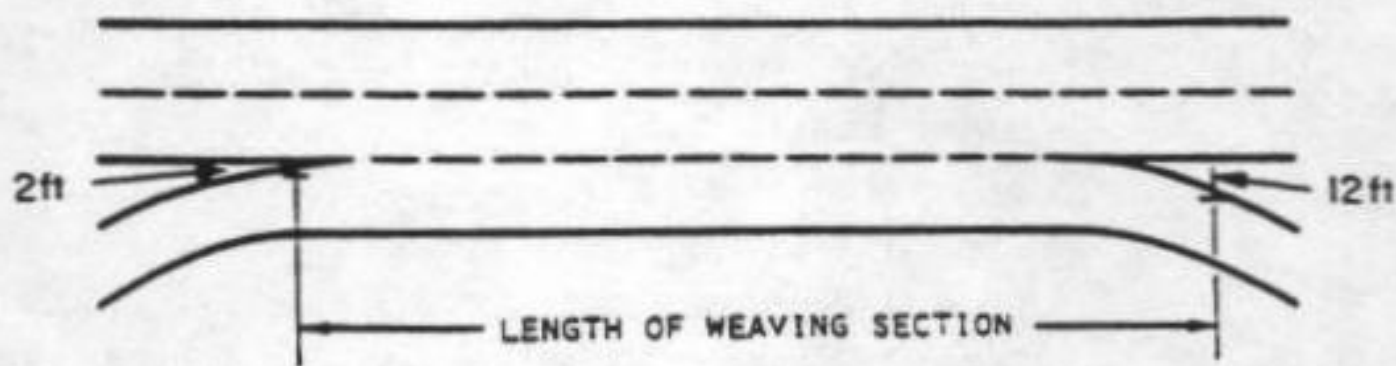


Figure 4-2. Measuring length of a weaving section.

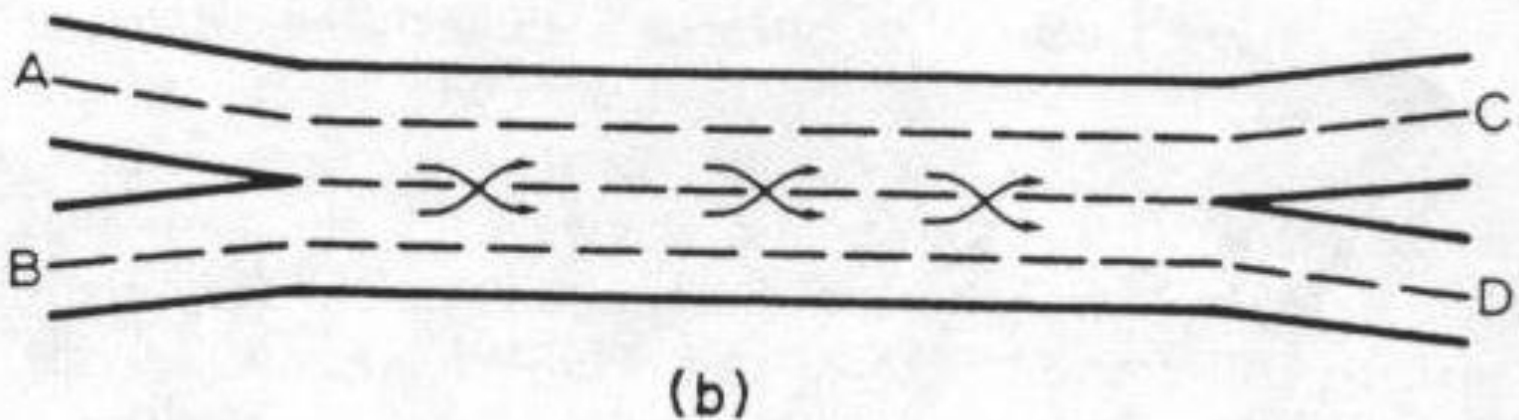
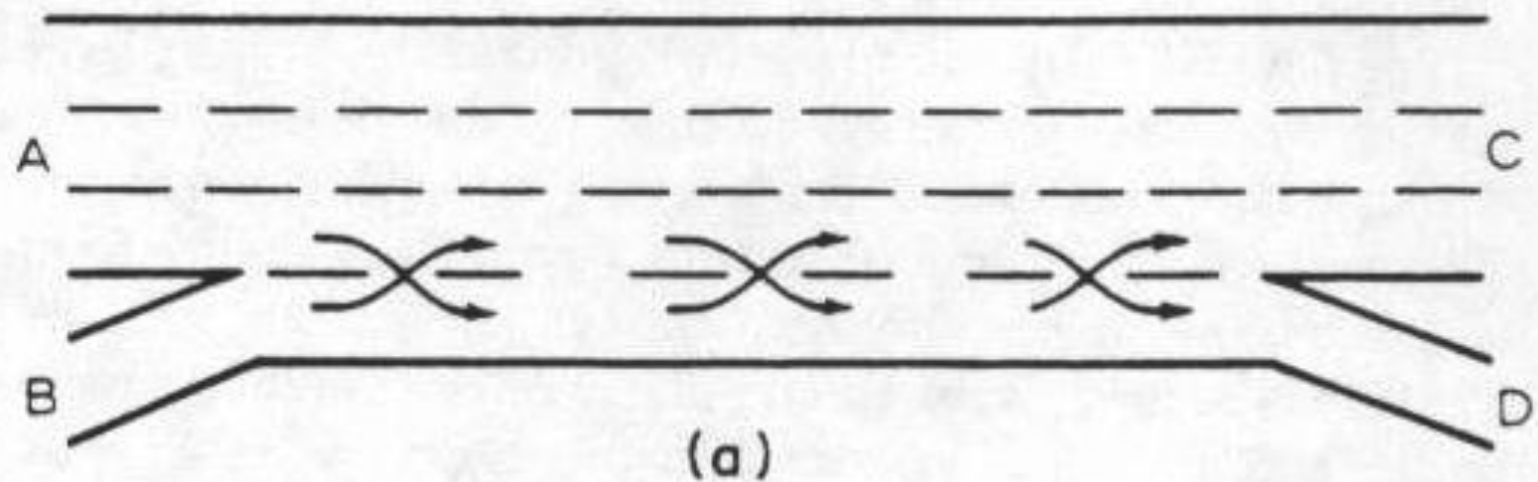


Figure 4-3. Type A weaving areas: (a) ramp-weave/one-sided weave, and (b) major weave with crown line.

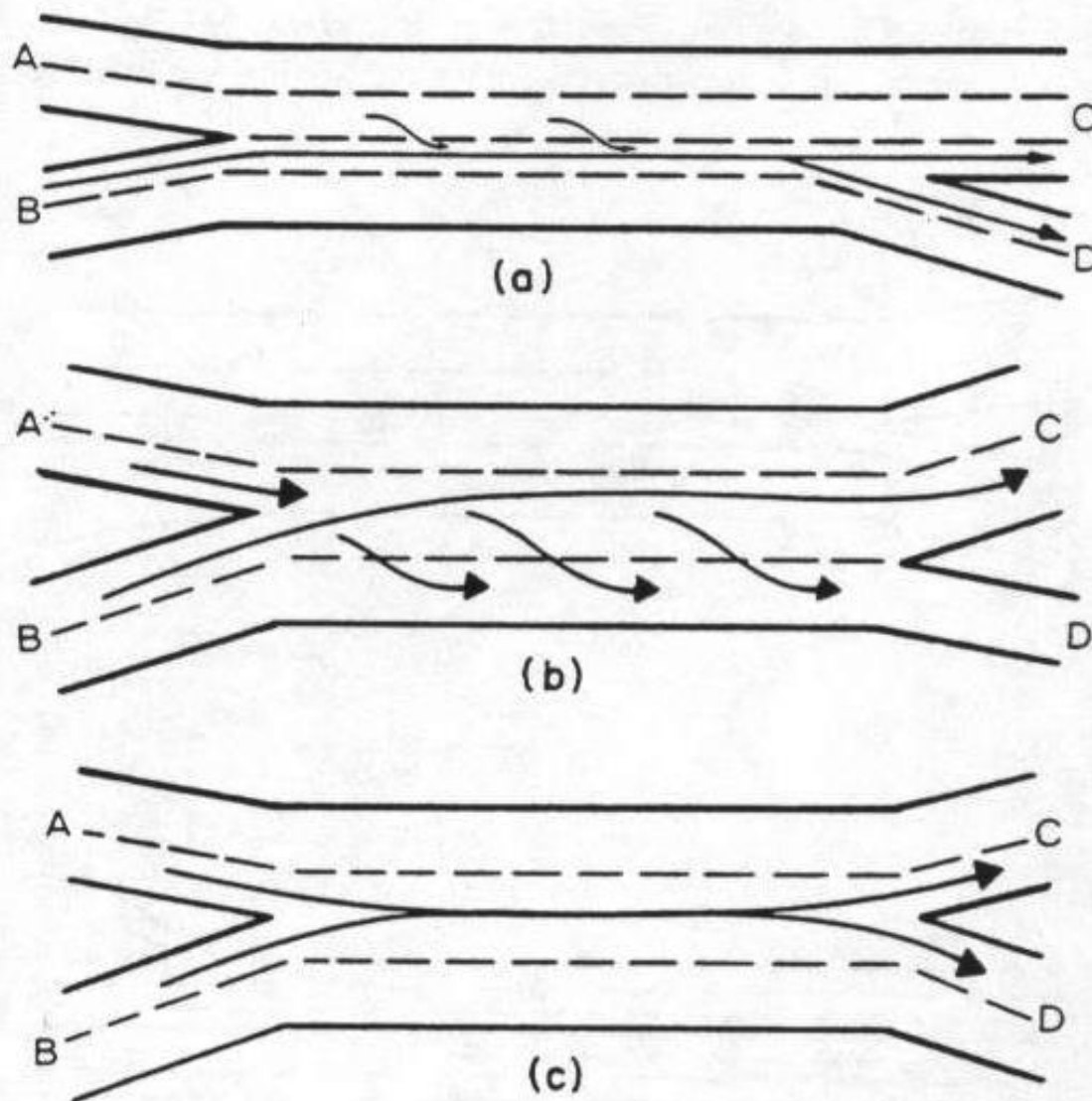


Figure 4-4. Type B weaving areas: (a) major weave with lane balance at exit gore, (b) major weave with merging at entrance gore, and (c) major weave with merging at entrance gore and lane balance at exit gore.

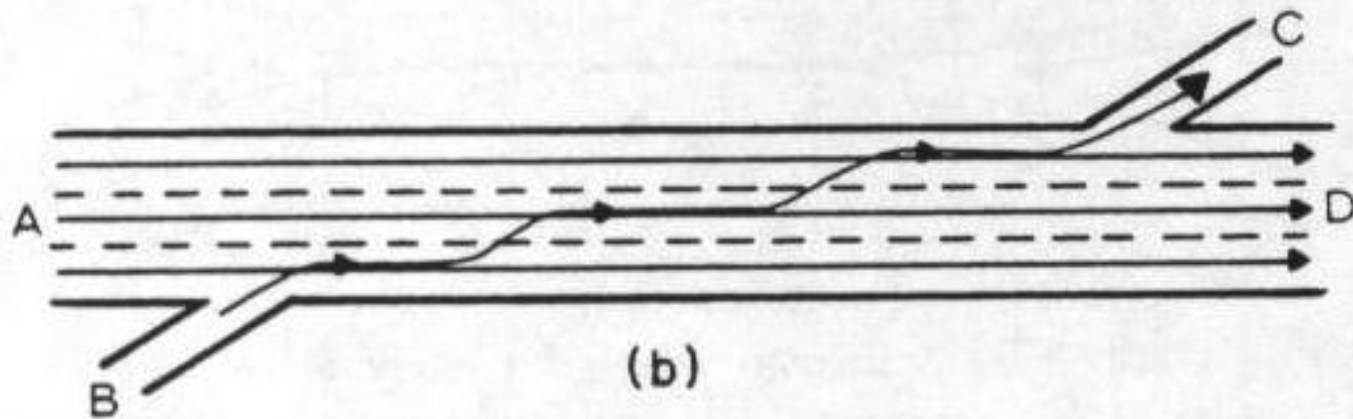
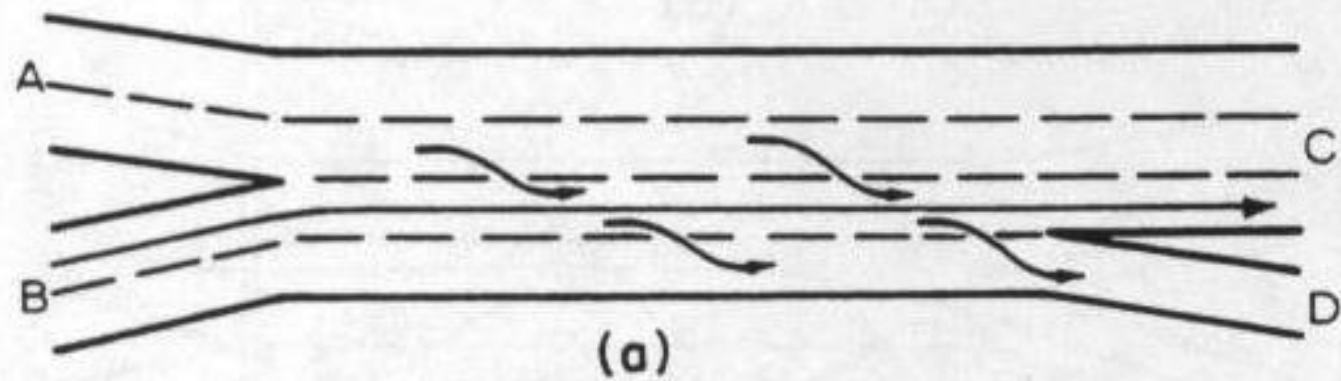
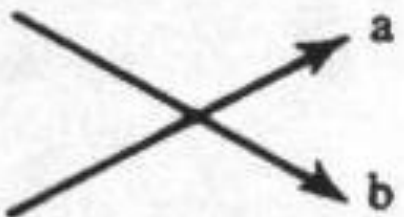


Figure 4-5. Type C weaving areas: (a) major weave without lane balance or merging, and (b) two-sided weave.

TABLE 4-1. CONFIGURATION TYPE VS. MINIMUM NUMBER OF REQUIRED LANE CHANGES

			
MINIMUM NUMBER OF REQ'D LANE CHANGES FOR WEAVING MVT. a	MINIMUM NUMBER OF REQ'D LANE CHANGES FOR WEAVING MVT. b		
	0	1	≥ 2
0	Type B	Type B	Type C
1	Type B	Type A	—
≥ 2	Type C	—	—

DEFINITION

- L . . . Length of weaving area, in ft.
- L_H . . Length of weaving area, in hundreds of ft.
- N . . . Total number of lanes in the weaving area.
- N_w . . . Number of lanes used by weaving vehicles in the weaving area.
- N_{nw} . . Number of lanes used by nonweaving vehicles in the weaving area.
- v . . . Total flow rate in the weaving area, in passenger car equivalents, in pcph.
- v_w . . . Total weaving flow rate in the weaving area, in passenger car equivalents, in pcph.
- v_{w1} . . Weaving flow rate for the larger of the two weaving flows, in passenger car equivalents, in pcph.
- v_{w2} . . Weaving flow rate for the smaller of the two weaving flows, in passenger car equivalents, in pcph.
- v_{nw} . . . Total nonweaving flow rate in the weaving area, in passenger car equivalents, in pcph.
- VR . . . Volume ratio v_w/v .
- R . . . Weaving ratio v_{w2}/v_w .
- S_w . . . Average running speed of weaving vehicles in the weaving area, in mph.
- S_{nw} . . . Average running speed of nonweaving vehicles in the weaving area, in mph.

TABLE 4-3. CONSTANTS FOR PREDICTION OF WEAVING AND NONWEAVING SPEEDS IN WEAVING AREAS

GENERAL FORM:

$$S_w \text{ or } S_{nw} = 15 + \frac{50}{1 + a(1 + VR)^b (v/N)^c / L^d}$$

TYPE OF CONFIGURATION	CONSTANTS FOR WEAVING SPEED, S_w				CONSTANTS FOR NONWEAVING SPEED, S_{nw}			
	a	b	c	d	a	b	c	d
TYPE A								
Unconstrained	0.226	2.2	1.00	0.90	0.020	4.0	1.30	1.00
Constrained	0.280	2.2	1.00	0.90	0.020	4.0	0.88	0.60
TYPE B								
Unconstrained	0.100	1.2	0.77	0.50	0.020	2.0	1.42	0.95
Constrained	0.160	1.2	0.77	0.50	0.015	2.0	1.30	0.90
TYPE C								
Unconstrained	0.100	1.8	0.80	0.50	0.015	1.8	1.10	0.50
Constrained	0.100	2.0	0.85	0.50	0.013	1.6	1.00	0.50

TABLE 4-4. CRITERIA FOR UNCONSTRAINED VS. CONSTRAINED OPERATION OF WEAVING AREAS^a

TYPE OF CONFIGURATION	NO. OF LANES REQ'D FOR UNCONSTRAINED OPERATION, N_w	MAX. NO. OF WEAVING LANES, N_w (max)
Type A	$2.19 N VR^{0.571} L_H^{0.234} / S_w^{0.438}$	1.4
Type B	$N \{0.085 + 0.703 VR + (234.8/L) - 0.018(S_{nw} - S_w)\}$	3.5
Type C	$N \{0.761 - 0.011 L_H - 0.005(S_{nw} - S_w) + 0.047 VR\}$	3.0 ^b

^a All variables are as defined in Table 4-2.

^b For 2-sided weaving areas, *all* freeway lanes may be used as weaving lanes.

NOTE: When $N_w \leq N_w$ (max), operation is unconstrained.

When $N_w > N_w$ (max), operation is constrained.

N_w = the number of lanes that must be used by weaving vehicles in order to achieve balanced or unconstrained operation; and

N_w (max) = the maximum number of lanes that may be used by weaving vehicles for a given configuration.

TABLE 4-5. LIMITATIONS ON WEAVING AREA EQUATIONS

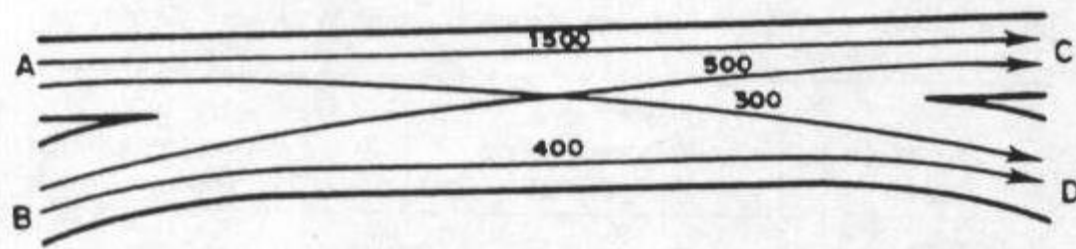
TYPE OF CONFIGURATION	WEAVING CAPACITY, MAXIMUM v_w	MAXIMUM v/N	MAXIMUM VOL. RATIO, V/R		MAXIMUM WEAVING RATIO, R	MAXIMUM WEAVING LENGTH, L
Type A	1,800 pcph	1,900 pcphpl	N	V/R	0.50	2,000 ft
			2	1.00		
			3	0.45		
			4	0.35		
			5	0.22		
Type B	3,000 pcph	1,900 pcphpl	0.80		0.50	2,500 ft
Type C	3,000 pcph	1,900 pcphpl	0.50		0.40	2,500 ft

NOTE: Type C limitations do not apply to two-sided weaving areas.

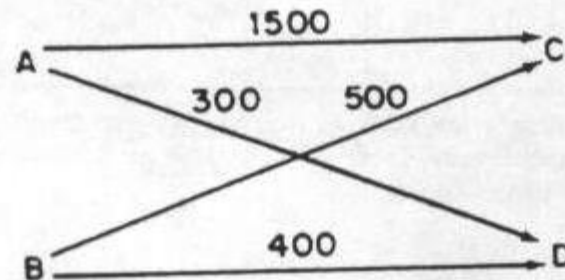
TABLE 4-6. LEVEL-OF-SERVICE CRITERIA FOR WEAVING SECTIONS

LEVEL OF SERVICE	MIN. AVG. WEAVING SPEED, S_w (MPH)	MIN. AVG. NON-WEAVING SPEED, S_{nw} (MPH)
A	55	60
B	50	54
C	45	48
D	40	42
E	35/30 ^a	35/30 ^a
F	< 35/30 ^a	< 35/30 ^a

^a The 35-mph boundary for LOS E/F is used when comparing to computed speeds using the equations of Table 4-3. The 30-mph boundary is used for comparison to field-measured speeds.



SECTION AND FLOWS



WEAVING DIAGRAM

THEN:

v_{w1} = WEAVING FLOW WITH THE HIGHEST NUMERIC VALUE (500)

v_{w2} = WEAVING FLOW WITH THE SMALLEST NUMERIC VALUE (300)

v_w = TOTAL WEAVING FLOW (500 + 300 = 800)

v = TOTAL FLOW IN THE WEAVING AREA (500+300+1500+400 = 2700)

VR = VOLUME RATIO = v_w/v (800/2700 = 0.296)

R = WEAVING RATIO = v_{w2}/v_w (300/800 = 0.375)

L = WEAVING LENGTH = 1,200 FT

N = NUMBER OF LANES = 4

Figure 4-6. Construction and use of weaving diagrams.

$$v = \frac{V}{\text{PHF} \times f_{HV} \times f_w \times f_p} \quad (4-2)$$

where:

v = flow rate for peak 15 min, in pcph under ideal conditions;

V = hourly volume, in vph, under prevailing conditions;

PHF = peak-hour factor;

f_{HV} = heavy vehicle adjustment factor, determined using the procedures of Chapter 3;

f_w = lane width and lateral clearance adjustment factor, determined using the procedures of Chapter 3; and

f_p = driver population adjustment factor, determined using the procedures of Chapter 3.