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Toolbox Tuesdays
Multimodal Level of Service Applications

Matthew Ridgway
Principal
Fehr & Peers
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COMPASS BLUEPRINT
building partnerships. serving communities.

SOUTHERN CALIFORNIA ASSOCIATION of GOVERNMENTS

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Agenda

- Introduction
- Highway Capacity Manual 2000
- Highway Capacity Manual 2010 – coming soon!
- NCHRP 3-70
- Other MMLOS strategies:
  - Simulation – Person-Delay
  - Built environment factors
  - Layered networks
  - Managed speeds

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Introduction

- What are the consequences of maintaining LOS C vs. LOS E?

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Introduction

- Multimodal Level of Service – what are we getting at?
  - Is this a nice place to walk?
  - Is this a nice place to bike?
  - Is transit convenient?
- Older methodologies: pedestrian density, delay
- Newer methodologies: comfort
- Alternative methodologies:
  - Built environment factors
  - Person-delay
  - Layered networks
  - Speed management

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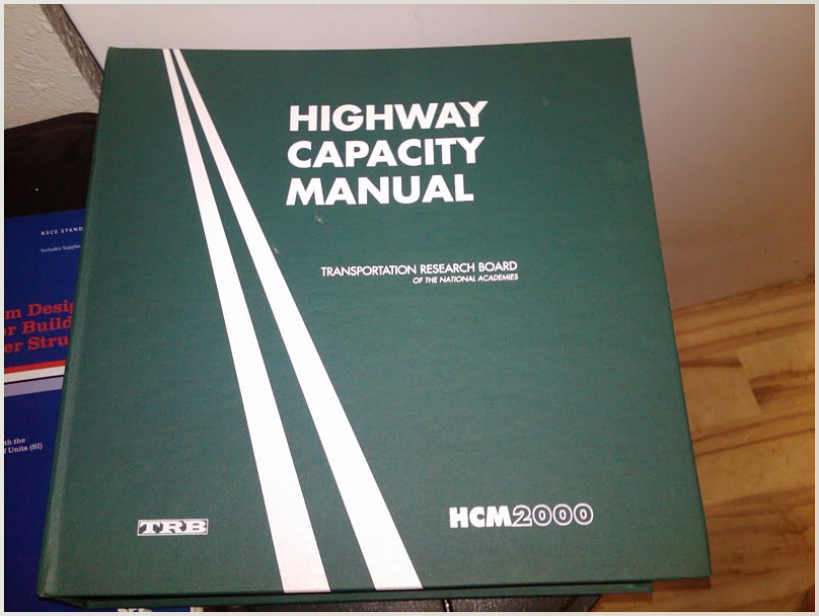
Highway Capacity Manual 2000

- Methodologies based on FHWA research
- Chapter 18: Pedestrians
  - Research dates back to 1975
  - LOS based on density and delay
- Chapter 19: Bicycles
  - Research dates back to 1975
  - LOS based on density and delay
- Chapter 27: Transit
  - Research dates back to 1962



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Highway Capacity Manual 2000

- Chapter 18: Pedestrians
- LOS for:
  - Walkways and sidewalks
  - Queuing areas
  - Shared off-street paths
  - Pedestrian crosswalks
  - Pedestrian facilities along urban streets

PEDESTRIANS WORKSHEET

General Information		***Site Information***	
Analyst		Facility	
Agency or Company		Jurisdiction	
Date Performed		Analysis Year	
Analysis Time Period			

☐ Operational (LOS) ☐ Design (W_E) ☐ Planning (LOS) ☐ Planning (W_E)

Walkways and Sidewalk Pedestrian Facilities

	1	2
Total width of crosswalks, W_T (ft)		
Sum of obstructions width and/or shy distances,[1] W_o (ft)		
Effective crosswalk width, W_E (ft), $W_E = W_T - W_o$		
Peak 15-min flow rate (both directions), v_{15} (p/15-min)		
Pedestrian unit flow rate, v_p (p/min/ft), $v_p = \frac{v_{15}}{15 * W_E}$		
LOS (Exhibits 18-3, 18-4, 18-5, 18-6, or 18-7)		

Shared Pedestrian-Bicycle Facilities

Mean pedestrian speed, S_p (ft/s)		
Mean bicycle speed, S_b (ft/s)		
Same-direction bicycle flow rate, Q_{sb} (bicycles/h)		
Opposing-direction bicycle flow rate, Q_{ob} (bicycles/h)		
Passing events, F_p (events/h), $F_p = Q_{sb}\left(1 - \frac{S_p}{S_b}\right)$		
Opposing events, F_m (events/h), $F_m = Q_{ob}\left(1 + \frac{S_p}{S_b}\right)$		
Total events, F (events/h), $F = F_p + 0.5F_m$		
LOS (Exhibit 18-8)		

Crossings at Signalized Intersections, Unsignalized Intersections, and Urban Street Facilities

Pedestrian Delay at Signalized Intersections	1	2	3	4	5	6	7	8
Cycle length, C (s)								
Effective green time for pedestrians, g (s)								
Average delay, d_p (s), $d_p = \frac{0.5(C-g)^2}{C}$								
LOS at signalized intersections (Exhibit 18-9)								
Pedestrian Delay at TWSC Intersections								
Pedestrian walking speed, S_p (ft/s)								
Pedestrian start-up time, t_s (s)								
Length of crosswalk, L (ft)								
Single pedestrian critical gap, t_c (s), $t_c = \frac{L}{S_p} + t_s$								
Typical pedestrian number in crossing platoon, N_p								
Spatial pedestrian distribution,[2] N_p (p), $N_p = \text{INT}\left[\frac{8.0(N_p - 1)}{W_E}\right] + 1$								
Group critical gap, t_G (s), $t_G = t_c + 2(N_p - 1)$								
Vehicular flow rate, v (veh/s)								
Average pedestrian delay, d_p (s), $d_p = \frac{1}{v}(e^{vt_G} - vt_G - 1)$								
LOS at unsignalized intersections (Exhibit 18-13)								
Average Pedestrian Travel Speeds Over Several Links								
Length of link,[3] L_i (ft)								
Average travel speed, S_A (ft/s), $S_A = \frac{L_i}{\Sigma \frac{L_i}{S_i} + \Sigma A_i}$								
LOS urban street pedestrian facility (Exhibit 18-14)								

Notes

1. Includes curb width, street furniture, window shops, building protrusions, inside clearance, and all other field-observed obstructions.
2. If there is no platoon crossing, assume $N_p = 1$.
3. Link length includes segment length of sidewalk and upstream signal crosswalk length.

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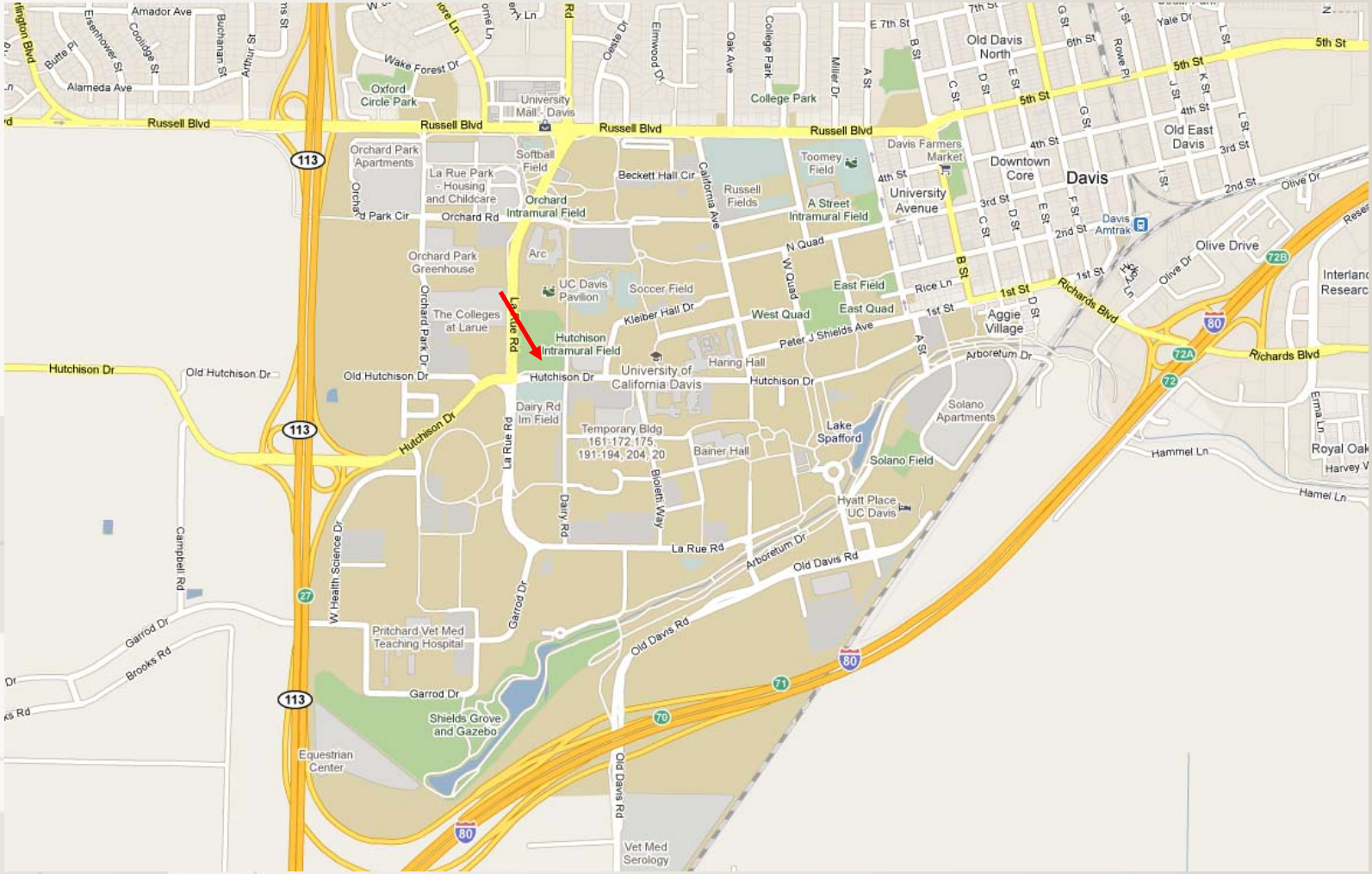
The study segment: Hutchison Drive



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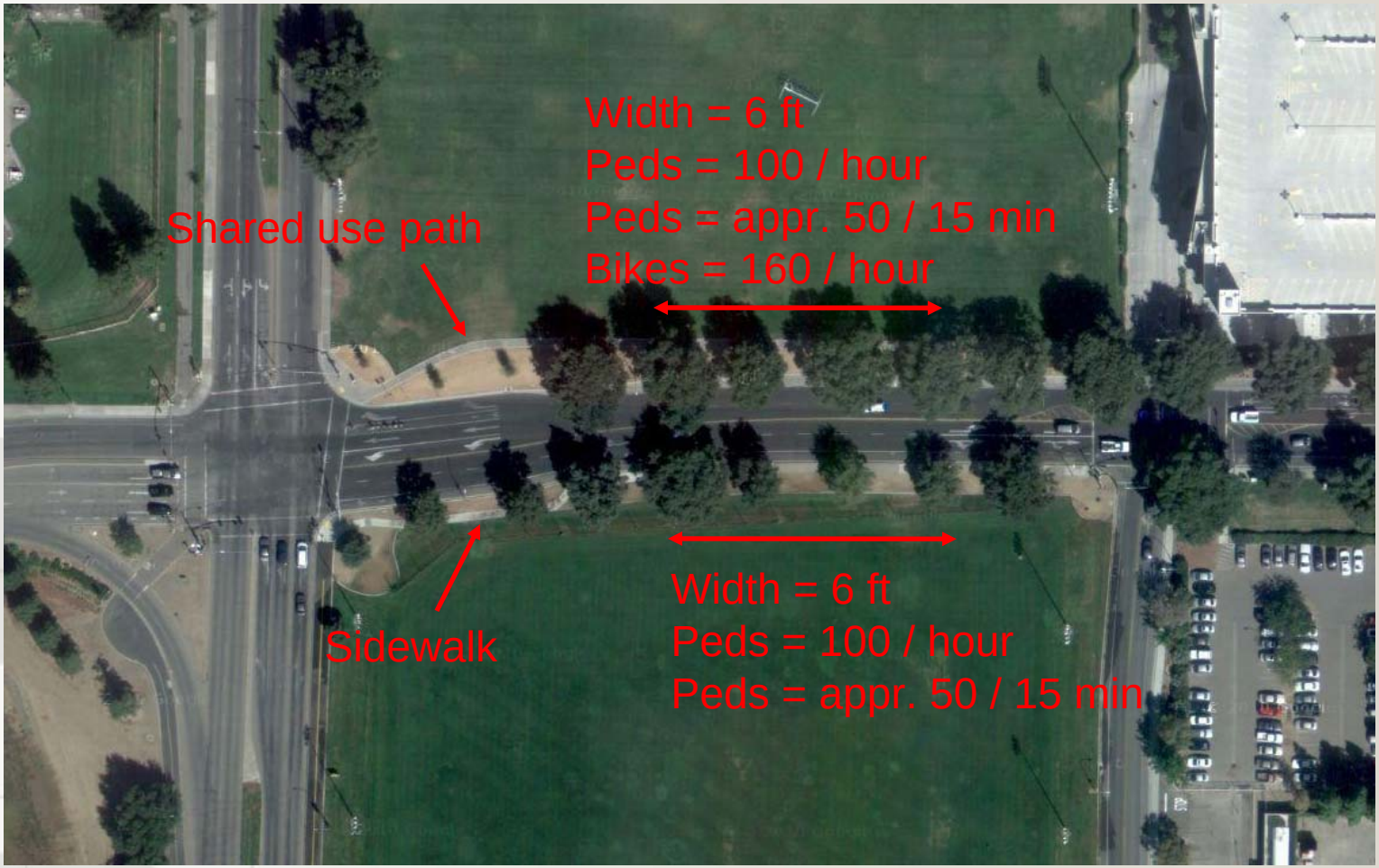
The study segment: Hutchison Drive



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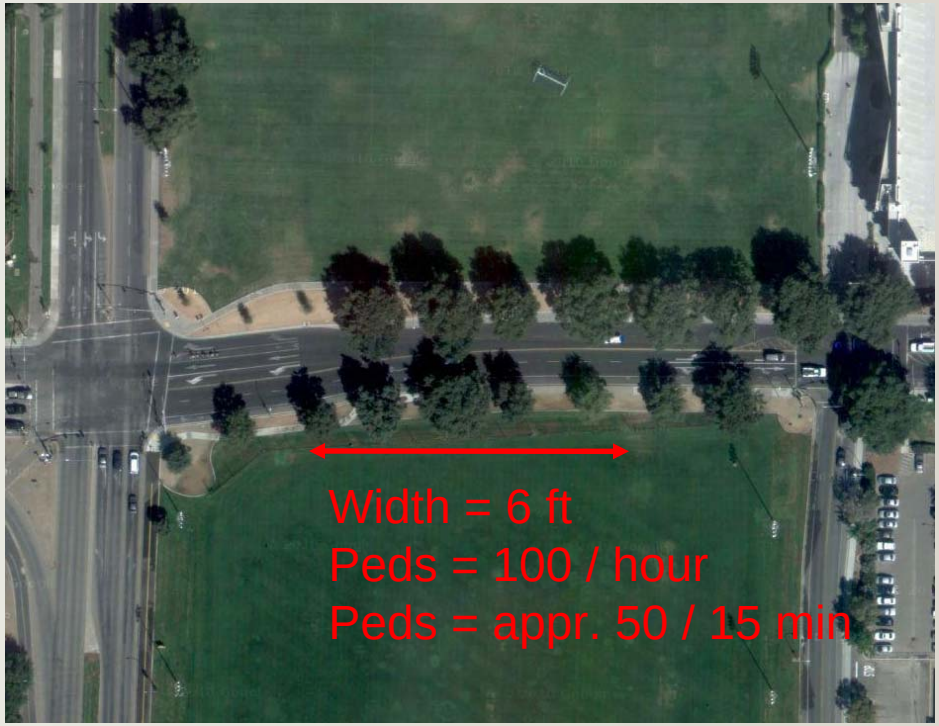
Highway Capacity Manual 2000

Walkways and sidewalks

- LOS depends on *density*:
  - Walkway width
  - Pedestrian flow rate
- LOS determined for
  - Average flow
  - Platoon flow
- South sidewalk:
  - LOS A – average flow
  - LOS B – platoon flow
- To improve LOS, increase width



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Highway Capacity Manual 2000

Walkways and sidewalks

- LOS depends on *density*:
- South sidewalk:
  - LOS A – average flow
  - LOS B – platoon flow

EXHIBIT 18-3. AVERAGE FLOW LOS CRITERIA FOR WALKWAYS AND SIDEWALKS

LOS	Space (ft^2/p)	Flow Rate (p/min/ft)	Speed (ft/s)	v/c Ratio
A	> 60	≤ 5	> 4.25	≤ 0.21
B	> 40–60	> 5–7	> 4.17–4.25	> 0.21–0.31
C	> 24–40	> 7–10	> 4.00–4.17	> 0.31–0.44
D	> 15–24	> 10–15	> 3.75–4.00	> 0.44–0.65
E	> 8–15	> 15–23	> 2.50–3.75	> 0.65–1.0
F	≤ 8	variable	≤ 2.50	variable

EXHIBIT 18-4. PLATOON-ADJUSTED LOS CRITERIA FOR WALKWAYS AND SIDEWALKS

LOS	Space (ft^2/p)	Flow Rate[a] (p/min/ft)
A	> 530	≤ 0.5
B	> 90–530	> 0.5–3
C	> 40–90	> 3–6
D	> 23–40	> 6–11
E	> 11–23	> 11–18
F	≤ 11	> 18

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Highway Capacity Manual 2000

Shared off-street path

- LOS depends on *passing events*:
  - Speed
  - Flow rate
- LOS determined for pedestrians
- North off-street path:
  - LOS D for pedestrians
- Cannot improve LOS, but can provide separate facility

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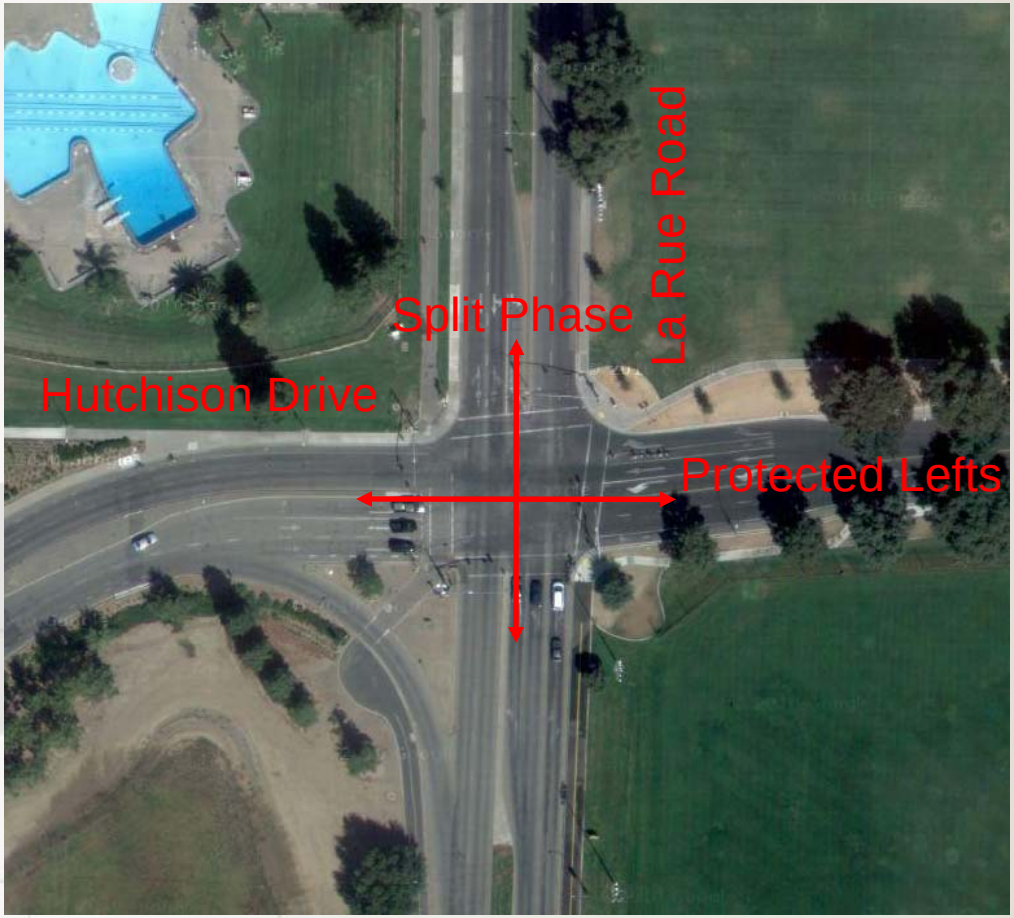
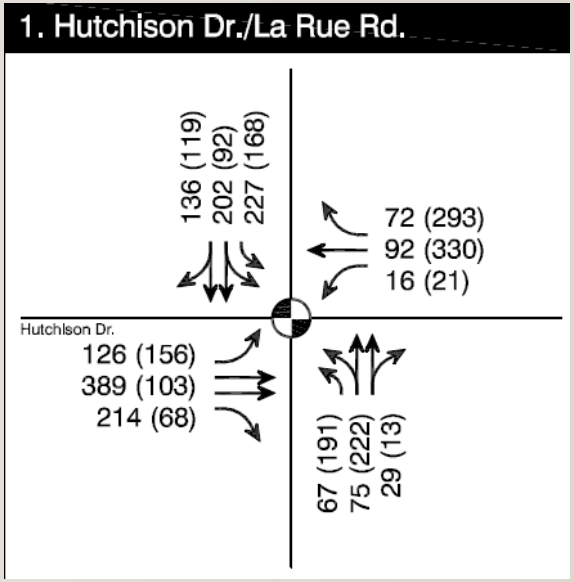
The study intersection: Hutchison Drive and La Rue Road



- Cycle length: 95s
- Northbound green: 30s
- East/west green: 26s



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The study intersection: Hutchison Drive and La Rue Road

PM peak hour:

Intersection Summary			
HCM Average Control Delay	33.9	HCM Level of Service	C
HCM Volume to Capacity ratio	0.61		
Actuated Cycle Length (s)	65.7	Sum of lost time (s)	20.0
Intersection Capacity Utilization	64.7%	ICU Level of Service	C
Analysis Period (min)	15		
c Critical Lane Group			

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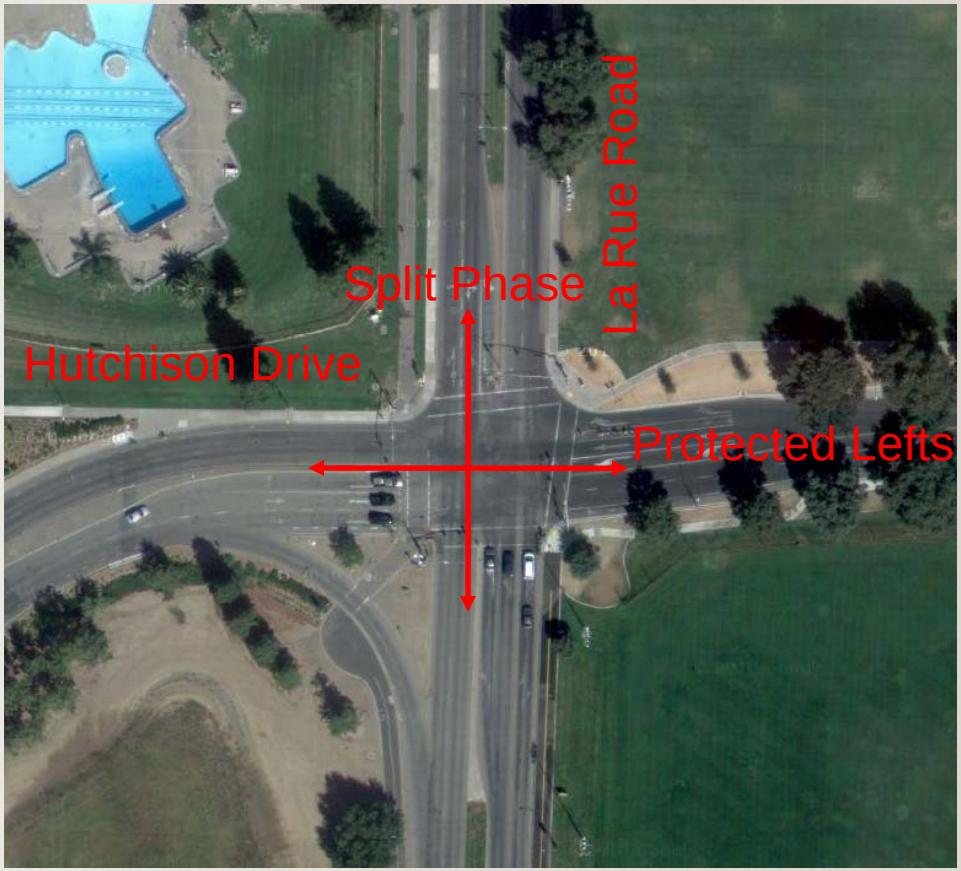
At signalized intersections

- LOS depends on *pedestrian delay*:
  - Cycle length
  - Phase green time
- Crossing major street:
  - LOS C
- Crossing minor street
  - LOS C
- Can improve LOS with shorter cycle length



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At signalized intersections, ctnd.

- LOS E-F: easy to achieve
- What about vehicle LOS?
- What about minimum green splits (based on FDW)?

Average pedestrian delay, d_p:

$$D_p = \frac{0.5\,(C-g)^2}{C}$$

Where:

C = cycle length

g = effective green time for peds

EXHIBIT 18-9. LOS CRITERIA FOR PEDESTRIANS AT SIGNALIZED INTERSECTIONS

LOS	Pedestrian Delay (s/p)	Likelihood of Noncompliance
A	< 10	Low
B	≥ 10–20	
C	> 20–30	Moderate
D	> 30–40	
E	> 40–60	High
F	> 60	Very High

EXHIBIT 16-2. LOS CRITERIA FOR SIGNALIZED INTERSECTIONS

LOS	Control Delay per Vehicle (s/veh)
A	≤ 10
B	> 10–20
C	> 20–35
D	> 35–55
E	> 55–80
F	> 80

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At signalized intersections

- LOS depends on *space (ft² per pedestrian)*:
  - Pedestrian volume
  - Area of crosswalk or corner
- At corner:
  - LOS A
- In crosswalk:
  - LOS A
- Can improve LOS with more area
- Only relevant to areas with high pedestrian volumes

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At signalized intersections

- LOS depends on *space (ft² per pedestrian)*:
- At corner:
  - LOS A
- In crosswalk:
  - LOS A

EXHIBIT 18-3. AVERAGE FLOW LOS CRITERIA FOR WALKWAYS AND SIDEWALKS

LOS	Space (ft^2/p)	Flow Rate (p/min/ft)	Speed (ft/s)	v/c Ratio
A	> 60	≤ 5	> 4.25	≤ 0.21
B	> 40–60	> 5–7	> 4.17–4.25	> 0.21–0.31
C	> 24–40	> 7–10	> 4.00–4.17	> 0.31–0.44
D	> 15–24	> 10–15	> 3.75–4.00	> 0.44–0.65
E	> 8–15	> 15–23	> 2.50–3.75	> 0.65–1.0
F	≤ 8	variable	≤ 2.50	variable

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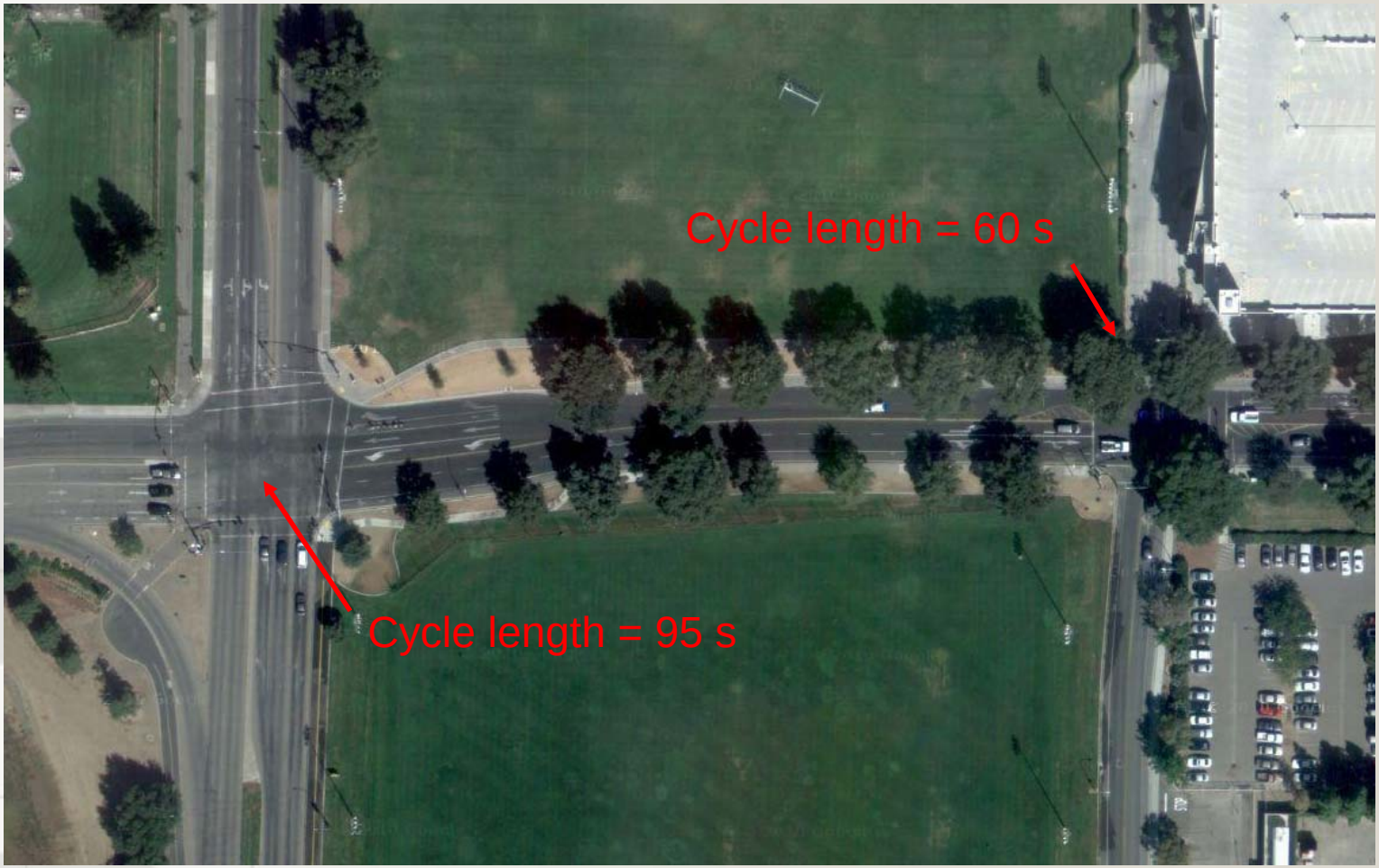
The study segment: Hutchison Drive



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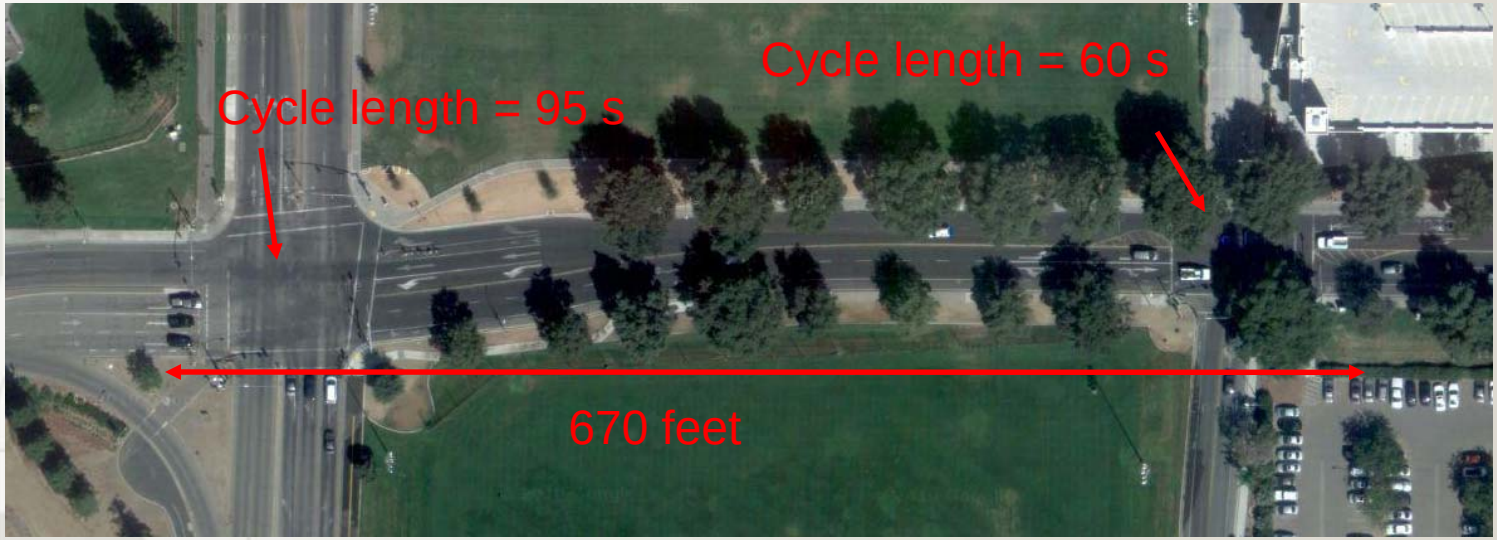
On urban streets

- LOS depends on *travel speed*
  - Intersection delay
- Between La Rue Road and Dairy Road: 3.1 ft/s LOS D



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On urban streets

- LOS depends on *travel speed*
  - Intersection delay
- Can improve LOS by decreasing cycle lengths

LOS A unlikely

EXHIBIT 18-14. LOS CRITERIA FOR PEDESTRIAN SIDEWALKS ON URBAN STREETS

LOS	Travel Speed (ft/s)
A	> 4.36
B	> 3.84–4.36
C	> 3.28–3.84
D	> 2.72–3.28
E	≥ 1.90–2.72
F	< 1.90

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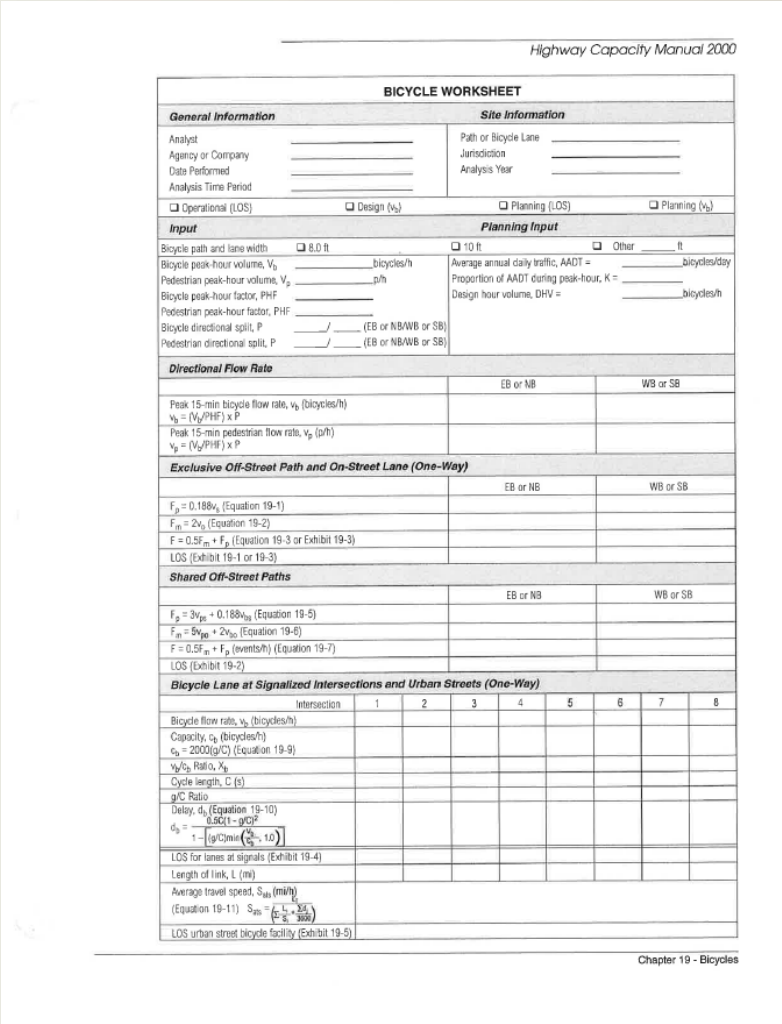
Highway Capacity Manual 2000

- Chapter 19: Bicycles
- LOS for:
  - Off-street paths (Class I)
    - Shared
    - Exclusive
  - Bike lanes
    - Interrupted
    - Uninterrupted
    - Both ("on urban streets"



Highway Capacity Manual 2000

BICYCLE WORKSHEET

General Information		***Site Information***	
Analyst	_____	Path or Bicycle Lane	_____
Agency or Company	_____	Jurisdiction	_____
Date Performed	_____	Analysis Year	_____
Analysis Time Period	_____		

❑ Operational (LOS) ❑ Design (v_b) ❑ Planning (LOS) ❑ Planning (v_p)

Input		***Planning Input***	
Bicycle path and lane width	❑ 8.0 ft	❑ 10 ft ❑ Other _____ ft	
Bicycle peak-hour volume, V_b	_____bicycles/h	Average annual daily traffic, AADT =	_____bicycles/day
Pedestrian peak-hour volume, V_p	_____p/h	Proportion of AADT during peak-hour, K =	_____
Bicycle peak-hour factor, PHF	_____	Design hour volume, DHV =	_____bicycles/h
Pedestrian peak-hour factor, PHF	_____		
Bicycle directional split, P	_____/ _____ (EB or NB/WB or SB)		
Pedestrian directional split, P	_____/ _____ (EB or NB/WB or SB)		

Directional Flow Rate

	EB or NB	WB or SB
Peak 15-min bicycle flow rate, v_b (bicycles/h) $v_b = (V_b/PHF) \times P$		
Peak 15-min pedestrian flow rate, v_p (p/h) $v_p = (V_p/PHF) \times P$		

Exclusive Off-Street Path and On-Street Lane (One-Way)

	EB or NB	WB or SB
$F_p = 0.188v_b$ (Equation 19-1)		
$F_m = 2v_b$ (Equation 19-2)		
$F = 0.5F_m + F_p$ (Equation 19-3 or Exhibit 19-3)		
LOS (Exhibit 19-1 or 19-3)		

Shared Off-Street Paths

	EB or NB	WB or SB
$F_p = 3v_{pc} + 0.188v_{bs}$ (Equation 19-5)		
$F_m = 5v_{pp} + 2v_{bo}$ (Equation 19-6)		
$F = 0.5F_m + F_p$ (events/h) (Equation 19-7)		
LOS (Exhibit 19-2)		

Bicycle Lane at Signalized Intersections and Urban Streets (One-Way)

Intersection	1	2	3	4	5	6	7	8
Bicycle flow rate, v_b (bicycles/h)								
Capacity, c_b (bicycles/h) $c_b = 2000(g/C)$ (Equation 19-9)								
v_b/c_b Ratio, X_b								
Cycle length, C (s)								
g/C Ratio								
Delay, d_b (Equation 19-10) $d_b = \frac{0.5C(1-g/C)^2}{1-[(g/C)\min(X_b, 1.0)]}$								
LOS for lanes at signals (Exhibit 19-4)								
Length of link, L (mi)								
Average travel speed, S_{ab} (mi/h) (Equation 19-11) $S_{ab} = \left(\frac{L}{\frac{L}{S_b} + \frac{\Sigma d_b}{3600}}\right)$								
LOS urban street bicycle facility (Exhibit 19-5)								

Chapter 19 - Bicycles

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Highway Capacity Manual 2000

Shared off-street path

- LOS depends on *passing events*:
  - Pedestrian flow rate
  - Bicycle flow rate
- LOS determined for bicyclists
- North off-street path:
  - LOS F for bicyclists
- Cannot improve LOS, but can provide separate facility

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Shared off-street path

- Limited path width / types
- How would wider (12 ft) path affect LOS?

EXHIBIT 19-2. LOS CRITERIA FOR SHARED OFF-STREET PATHS

LOS	Frequency of Events, 2-Way, 2-Lane Paths[a] (events/h)	Frequency of Events, 2-Way, 3-Lane Paths[b] (events/h)
A	≤ 40	≤ 90
B	> 40–60	> 90–140
C	> 60–100	> 140–210
D	> 100–150	> 210–300
E	> 150–195	> 300–375
F	> 195	> 375

Notes:
a. 8.0-ft-wide paths.
b. 10-ft-wide paths.

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On-street bike lane

- LOS depends on *passing events*:
  - Bicycle flow rate
- LOS does not depend on:
  - Lane width
  - Speed limit
  - Traffic volume
- LOS D for bicyclists
- Cannot improve LOS, but can provide separate facility

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On-street bike lane

- LOS depends on *passing events*:
- LOS D for bicyclists

EXHIBIT 19-1. LOS CRITERIA FOR EXCLUSIVE BICYCLE PATHS

LOS	Frequency of Events, 2-Way, 2-Lane Paths[a] (events/h)	Frequency of Events, 2-Way, 3-Lane Paths[b] (events/h)
A	≤ 40	≤ 90
B	> 40–60	> 90–140
C	> 60–100	> 140–210
D	> 100–150	> 210–300
E	> 150–195	> 300–375
F	> 195	> 375

Notes:
a. 8.0-ft-wide paths. Also used for on-street bicycle lanes.
b. 10-ft-wide paths.

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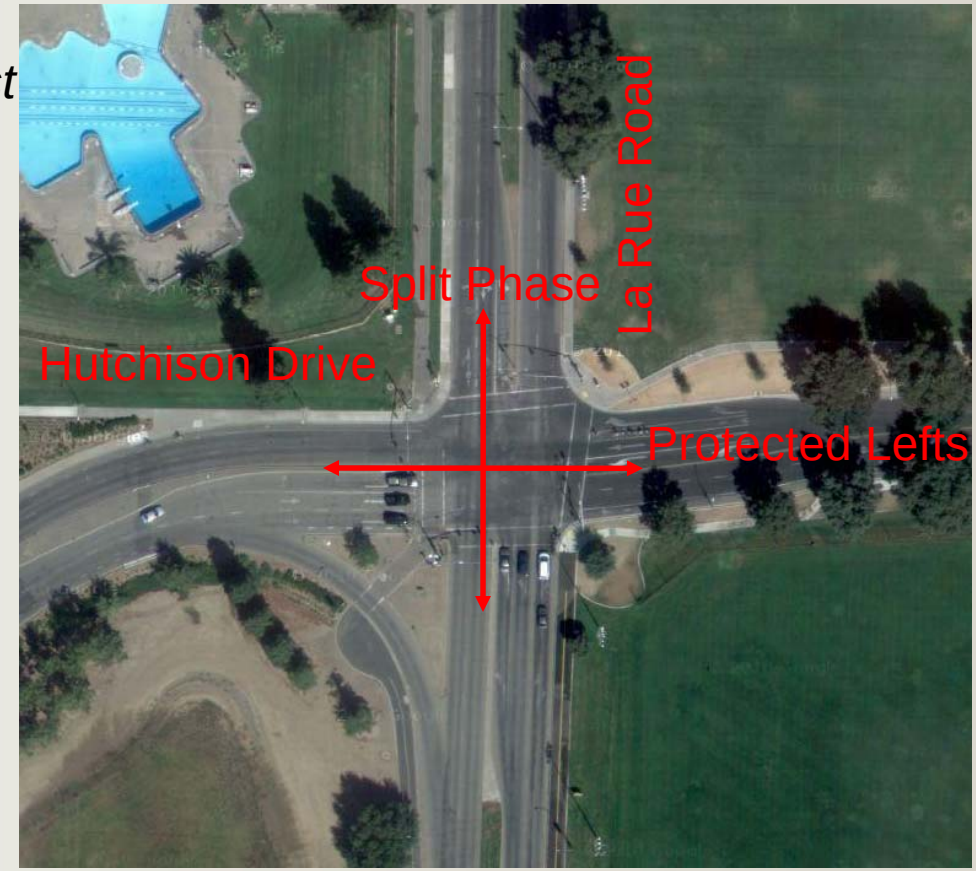
At signalized intersections

- LOS depends on *bicyclist delay*:
  - Cycle length
  - Phase green time
  - Bicycle flow rate
- Crossing major street:
  - LOS C
- Can improve LOS with shorter cycle length



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Highway Capacity Manual 2000

At signalized intersections

- LOS depends on *bicyclist delay*:
- Crossing major street:
  - LOS C

EXHIBIT 19-4. LOS FOR BICYCLES AT SIGNALIZED INTERSECTIONS

LOS	Control Delay (s/bicycle)
A	< 10
B	≥ 10–20
C	> 20–30
D	> 30–40
E	> 40–60
F	> 60

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Highway Capacity Manual 2000

- Chapter 27: Transit
- Focuses on *service*, not the roadway

EXHIBIT 27-1. SERVICE FREQUENCY LOS FOR URBAN SCHEDULED TRANSIT SERVICE

LOS	Headway (min)	Veh/h	Comments
A	< 10	> 6	Passengers don't need schedules
B	≥ 10–14	5–6	Frequent service; passengers consult schedules
C	> 14–20	3–4	Maximum desirable time to wait if bus/train missed
D	> 20–30	2	Service unattractive to choice riders
E	> 30–60	1	Service available during hour
F	> 60	< 1	Service unattractive to all riders

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Highway Capacity Manual 2000

- Chapter 27: Transit, ctnd.

EXHIBIT 27-4. HOURS-OF-SERVICE LOS

LOS	Hours per Day	Comments
A	> 18–24	Night or owl service provided
B	> 16–18	Late evening service provided
C	> 13–16	Early evening service provided
D	> 11–13	Daytime service provided
E	> 3–11	Peak-hour service/limited midday service
F	0–3	Very limited or no service

EXHIBIT 27-5. PASSENGER LOAD LOS

LOS	Bus		Rail		Comments
	ft^2/p	p/seat[a]	ft^2/p	p/seat[a]	
A	> 12.90	0.00–0.50	< 19.90	0.00–0.50	No passenger need sit next to another
B	8.60–12.89	0.51–0.75	14.00–19.90	0.51–0.75	Passengers can choose where to sit
C	6.50–8.59	0.76–1.00	10.20–13.99	0.76–1.00	All passengers can sit
D	5.40–6.49	1.01–1.25	5.40–10.19	1.01–2.00	Comfortable loading for standees
E	4.30–5.39	1.26–1.50	3.20–5.39	2.01–3.00	Maximum schedule load
F	< 4.30	> 1.50	< 3.20	> 3.00	Crush loads

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Highway Capacity Manual 2000

- Chapter 27: Transit, ctnd.

EXHIBIT 27-7. RELIABILITY LOS FOR ON-TIME PERFORMANCE

LOS	On-Time Percentage	Comments[a]
A	97.5–100.0	1 late bus per month
B	95.0–97.4	2 late buses per month
C	90.0–94.9	1 late bus per week
D	85.0–89.9	
E	80.0–84.9	1 late bus per direction per week
F	< 80.0	

EXHIBIT 27-8. RELIABILITY LOS FOR HEADWAY ADHERENCE

LOS	Coefficient of Variation
A	0.00–0.10
B	0.11–0.20
C	0.21–0.30
D	0.31–0.40
E	0.41–0.50
F	> 0.50

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Shared-Use Path Level of Service

- FHWA
- Highway Capacity Manual 2010
- LOS based on:
  - Maintaining optimum speed (for bicycles)
  - Freedom to maneuver
  - "SUPLOS"

Table 5. SUPLOS scale.

LOS Score	LOS Grade	
$X \geq 4.0$	A	Best
$3.5 \leq X < 4.0$	B	↓
$3.0 \leq X < 3.5$	C	
$2.5 \leq X < 3.0$	D	
$2.0 \leq X < 2.5$	E	
$X < 2.0$	F	Worst

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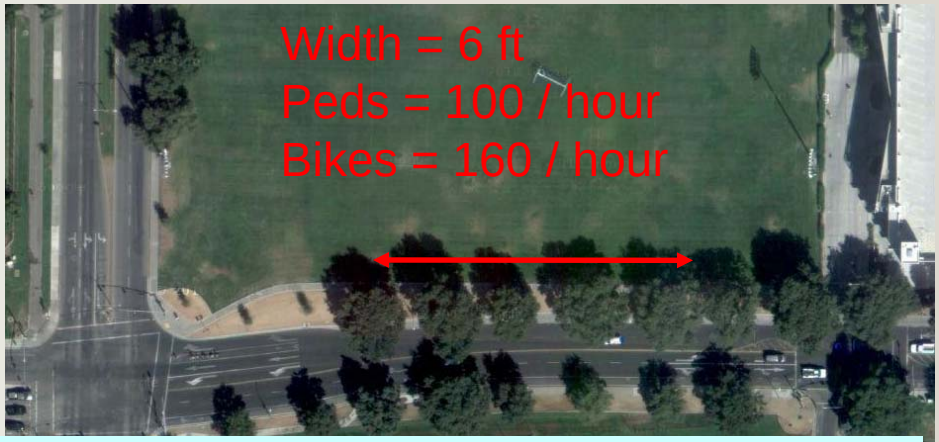
Shared-Use Path Level of Service

Share-use path

- North off-street path:
  - LOS D for bicyclists
- Cannot improve LOS, but can provide separate facility



Shared Use Path Flow Analysis Tool

Trail Level of Service (LOS) Calculator

Draft Spreadsheet Based on Federal Highway Administration Shared Use Path Study

North Carolina State University and Toole Design Group

ROW #1

Segment Name	Path Width	Centerline	Volume (users per hour in 1 direction) and Mode Split							User Perception	
	Closest 0.5 ft.	0=No Centerline	*Volume*	*Mode Split (%)**							
Name	Width (ft)	1=Centerline	One-Way (per hour)	Adult Bicyclists	Pedestrians	Runners	In-Line Skaters	Child Bicyclists	All Modes	Score	Grade
UC Davis	6.0	0	130.0	61.0%	39.0%	0.0%	0.0%	0.0%	100.0%	2.51	D

*Default mode split is 55% adult bicyclists, 20% pedestrians, 10% runners, 10% in-line skaters, and 5% child bicylists.

Click Here for Default Mode Split

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NCHRP 3-70: comfort-based LOS

- *Multimodal Level-of-Service Analysis for Urban Streets*
- Highway Capacity Manual 2010
- LOS based on:
  - Autos: quality of service
  - Transit: quality of service
  - Bikes: *comfort*
  - Pedestrians: *comfort*

- Accounts for:
  - Street cross-section
    - Travel lanes
    - Bike lanes
    - Parking
    - Buffer
    - Sidewalk
  - Auto volume (ADT)
  - Transit frequency
  - Pedestrian volumes

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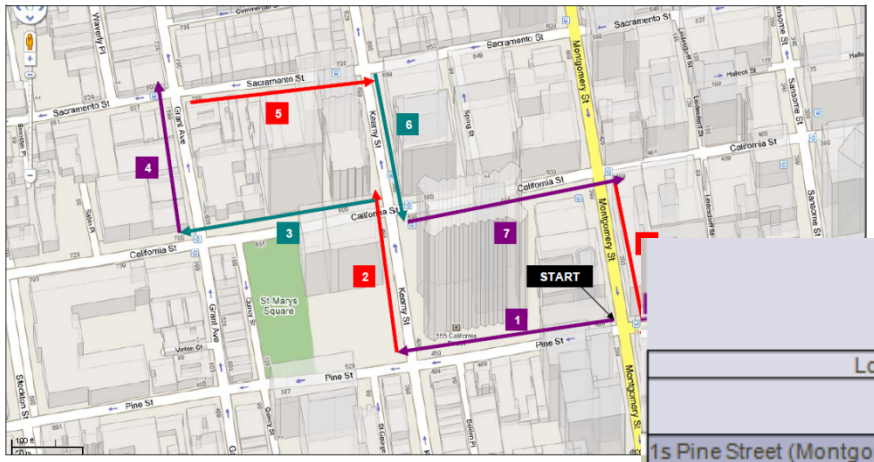
NCHRP 3-70: comfort-based LOS

MULTI-MODAL LOS SURVEY
DIRECTION # 1

April 20, 2009
San Francisco, CA

Plan to be back in the office by 12:30pm



Segment & Xing Separate

Location	Type	NCHRP	Survey		
			Satisfaction All Forms	Facility Service	Environment
1s Pine Street (Montgomery/Kearny)	Segment	D	B	C	C
2s Kearny Street (Pine/California)	Segment	C	C	C	C
3s California (Kearny/Grant)	Segment	B	B	B	A
4s Grant (California/Sacramento)	Segment	B	B	C	B
5s Sacramento (Grant/Kearny)	Segment	C	C	D	C
6s Kearny (Sacramento/California)	Segment	C	C	B	C
7s California (Kearny/Montgomery)	Segment	C	A	B	A
8s Montgomery (California/Pine)	Segment	C	B	B	B
1i Pine Street (Montgomery/Kearny)	Xing	C	C	B	C
2i Kearny Street (Pine/California)	Xing	B	C	C	C
3i California (Kearny/Grant)	Xing	B	B	B	B
4i Grant (California/Sacramento)	Xing	B	A	C	C
5i Sacramento (Grant/Kearny)	Xing	B	C	C	C
6i Kearny (Sacramento/California)	Xing	B	C	C	C
7i California (Kearny/Montgomery)	Xing	C	B	B	B
8i Montgomery (California/Pine)	Xing	C	B	B	B
		same LOS	44%	19%	38%
		within 1 LOS	88%	100%	94%

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NCHRP 3-70: comfort-based LOS

Segment & Xing Separate

Location	Type	NCHRP	Survey		
			Satisfaction All Forms	Facility Service	Environment
1s Pine Street (Montgomery/Kearny)	Segment	D	B	C	C
2s Kearny Street (Pine/California)	Segment	C	C	C	C
3s California (Kearny/Grant)	Segment	B	B	B	A
4s Grant (California/Sacramento)	Segment	B	B	C	B
5s Sacramento (Grant/Kearny)	Segment	C	C	D	C
6s Kearny (Sacramento/California)	Segment	C	C	B	C
7s California (Kearny/Montgomery)	Segment	C	A	B	A
8s Montgomery (California/Pine)	Segment	C	B	B	B
1i Pine Street (Montgomery/Kearny)	Xing	C	C	B	C
2i Kearny Street (Pine/California)	Xing	B	C	C	C
3i California (Kearny/Grant)	Xing	B	B	B	B
4i Grant (California/Sacramento)	Xing	B	A	C	C
5i Sacramento (Grant/Kearny)	Xing	B	C	C	C
6i Kearny (Sacramento/California)	Xing	B	C	C	C
7i California (Kearny/Montgomery)	Xing	C	B	B	B
8i Montgomery (California/Pine)	Xing	C	B	B	B
		same LOS	44%	19%	38%
		within 1 LOS	88%	100%	94%

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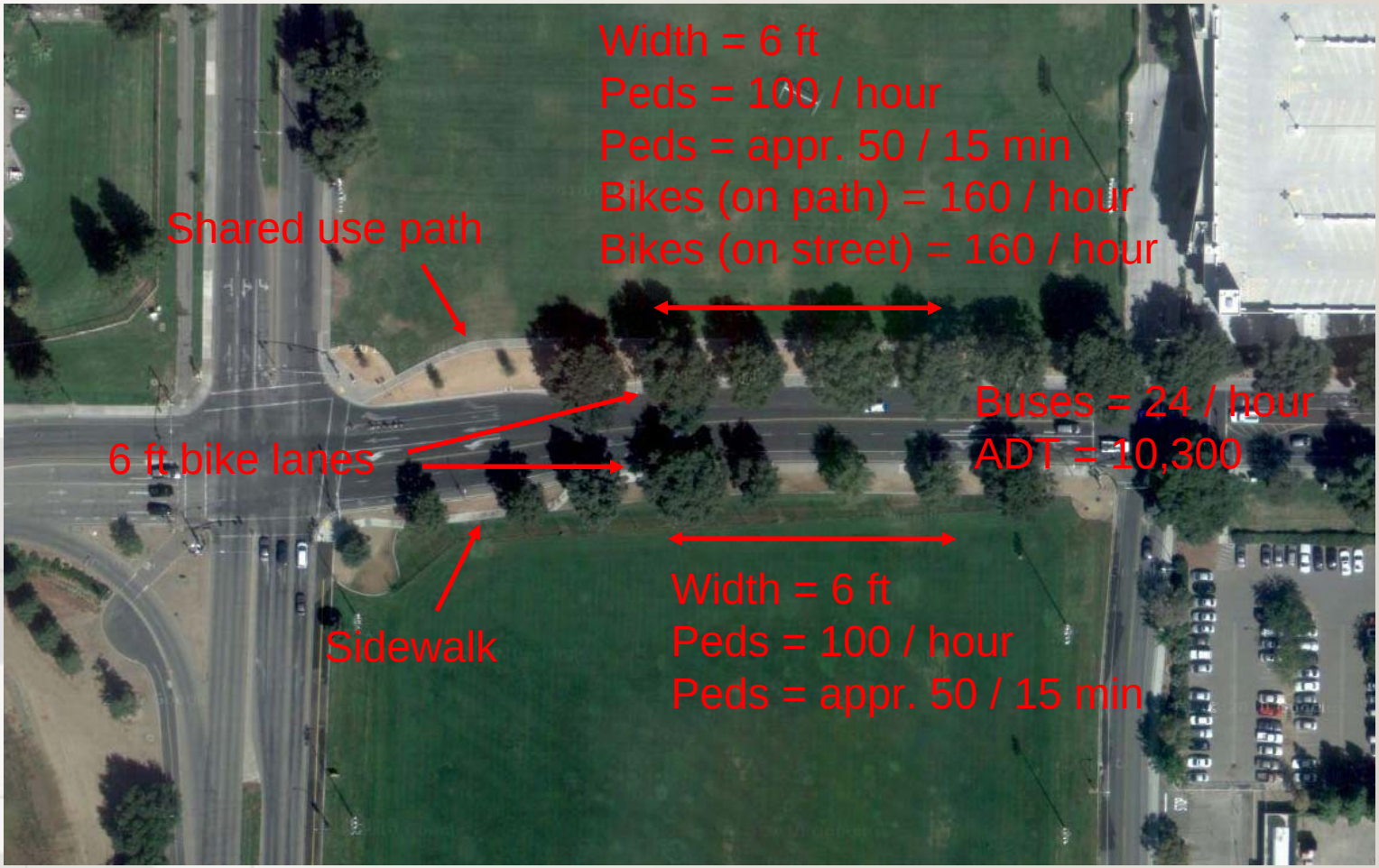
The study segment: Hutchison Drive



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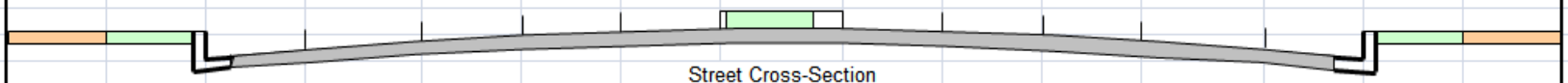
NCHRP 3-70 Multimodal LOS

			Range Check	
ADT	10,310	(>=0 vpd)	OK	Yes
% HV	2%	(0-100%)	OK	No
Buses/hr	24	(>=0 bph)	OK	No
Peds/hr	200	(>=0 pph)	OK	If Very High

Ped LOS	LOS	LOS #
Pseg	B	2.04
Pint	C	3.01
Model 1	C	3.50
Model 2	D	3.74
RCDF 1	A	1.20
RCDF 2	A	1.20

Mode	LOS	LOS #	v/c
Auto	C	3.40	0.4447
Transit	A	1.69	
Bicycle	D	3.21	
Pedestrian	C	3.50	

ROW
89 ft



Street Cross-Section

Sidewalk	Buffer	Parking	Bike Ln	Trav. Lane	Trav. Lane	Trav. Lane	Median	Trav. Lane	Trav. Lane	Trav. Lane	Bike Ln	Parking	Buffer	Sidewalk
6	0	0	6	0	12	12	0	12	12	0	8	0	15	6

(all entries in feet, enter zero for non-existant lanes)

Street :	Hutchison Drive		
Limits:	b/t LaRue Road and Dairy Road		
Key:	Data Entry	Draft, for internal evaluation only	
Spreadsheet by: R. Dowling, Dowling Associates, Inc., July 5, 2007, Updated 02/12/08.			

Important?	Key Parameters		
Yes	Signal Spacing:	575	(200-10,560 ft.)
slight	Progression Quality:	3	(1=poor, 6=excellent)
slight	Speed Limit	25	(15-70 mph)
no	Bus Stops w. Shelter:	50%	(0-100%)
no	Pavement Quality:	4	(1=poor, 5=excellent)

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- Auto LOS depends on:
  - ADT
  - Number of lanes
  - Signal spacing
  - Signal progression
  - Operating speed
- ADT = 10,300
  - LOS C

- To improve LOS:
  - Reduce volume
  - Add lanes
  - Improve signal progression

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- Transit LOS depends on:
  - Number of lanes
  - Vehicle ADT
  - Bus frequency
  - Stop amenities (shelters)
- Bus frequency = 24 / hour
  - LOS A

- To improve LOS:
  - Add service
  - Add stop amenities (shelters)

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- Bike LOS depends on:
  - Number of lanes
  - Travel lane width
  - ADT
  - On-street parking
  - Speed limit
  - Provision of bike lane
- Bike lanes = 8 feet
  - LOS D

- To improve LOS:
  - Reduce ADT
  - Widen curb lane
  - Reduce speed limit
  - Reconfigure on-street parking
  - Widen bike lane

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- Pedestrian LOS depends on:
  - Number of lanes
  - ADT
  - Speed limit
  - On-street parking
  - Landscaped buffer
- Sidewalks = 6 feet
  - LOS C

- To improve LOS:
  - Reduce ADT
  - Traffic calming
  - Widen buffer
  - Widen sidewalk

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Comfort-based LOS: what about crosswalks?

Table 1. Recommendations for installing marked crosswalks and other needed pedestrian improvements at uncontrolled locations.*

Roadway Type (Number of Travel Lanes and Median Type)	Vehicle ADT ≤ 9,000			Vehicle ADT >9000 to 12,000			Vehicle ADT >12,000 - 15,000			Vehicle ADT > 15,000		
	Speed Limit**											
	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h
2 Lanes	C	C	P	C	C	P	C	C	N	C	P	N
3 Lanes	C	C	P	C	P	P	P	P	N	P	N	N
Multi-Lane (4 or More Lanes) With Raised Median***	C	C	P	C	P	N	P	P	N	N	N	N
Multi-Lane (4 or More Lanes) Without Raised Median	C	P	N	P	P	N	N	N	N	N	N	N

Key: C = Candidate sites for marked crosswalks; P = Possible increase in pedestrian crashes may occur if crosswalks are marked without other pedestrian enhancements; N = Marked crosswalks alone are insufficient.

- LOS A-B
- LOS C-D
- LOS E-F

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Crosswalk Tool

FIELD	CATEGORY	INPUT	UNITS	DESCRIPTION/ NOTES
1	Speed Limit	35	mph	Posted or statutory speed limit or the 85th percentile speed on the major street
2	Peak Hour Pedestrian Volume	25	ped/h	Number of pedestirans crossing the major roadway in a peak hour
3	Major Road Peak Hour Volume (Total)	1500	veh/h	Total number of vehicles and bicylists on both approaches during the peak hour
4	Major Road Peak Hour Volume Direction 1	700	veh/h	Include only if a painted or raised median is present (min of 6 feet wide)
5	Major Road Peak Hour Volume Direction 2	800	veh/h	Include only if a painted or raised median is present (min of 6 feet wide)
6	Average Pedestrian Walking Speed	3.5	ft/s	Average pedestrian walking speed, default speet = 3.5 feet/second
7	15th Percentile Crossing Speed	3	ft/s	Speed for the slowest 15% of pedestrians; default speed = 3 feet/second
8	Pedestrian start-up time and end clearance time*	3	s	The *Highway Capacity Manual* suggests 3 seconds
9	Pedestrian Crossing Distance (curb to curb)	86	ft	Distance between the near and far curbs
10	First Half Crossing Distance	38	ft	Distance between the near curb and a painted or raised median refuge island
11	Second Half Crossing Distance	38	ft	Distance between a painted or raised median refuge island and the far curb
12	Number of Lanes (total both directions)	6	Lanes	Number of lanes on major roadway
13	Expected Motorist Compliance	Low		Typical motorist compliance, default = Low
14	Is frequent at-grade transit present?	No		Does frequent surface transit run along major or minor road at the intersection?
15	Are bicycle lanes present?	No		
16	Is there heavy bicycle traffic?	No		
17	Is there a clear major and minor road?	No		Is there a clear differentiation in the traffic volume between the two roads?
18	Is this a midblock location or off-set intersection?	Yes		
19	Is there heavy truck traffic?	No		
20	Does existing infrastructure limit potential treatments?	No		Are there storm drains, poles, or other permanent structures at any corner of the intersection?
21	Is there on-street parking at the location?	Yes		
22	Is the location in a downtown area?	No		
23	Is a median refuge island present?	No		Does the refuge island have a width of at least 6 feet to accommodate pedestrian queues?
24	Is there sufficient width to accommodate a median?	No		At least 4 feet (with lane widths reduced to 10 or 11 feet)
25	Actual Total Pedestrian Delay		s	Optional (if calcuated at the site)

OUTPUTS	
Signalized Crossing or Unsignalized Crossing?	Unsignalized Crossing
Pedestrian LOS	F
Candidate Pedestrian Treatment Identified:	Stutter Flash*
Candidate for Median Refuge Island?	NO
Candidate for Road Diet?	YES
Other Treatments for Consideration**:	Hawk*, Stuttter Flash*
Paired Treatments for Consideration	Curb Extensions, Bus Bulb, Reduced Curb Radii, Staggered Pedestrian Refuge, High Visibility Crosswalk Markings, Advance Yield Lines, Advance signage

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Comfort-based LOS – not quite there yet

- What about …?

Supportive land uses

Urban design factors

ADA Features

Identifying mitigations

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Built Environment Factors

- To what extent does a roadway feature bike- and ped-friendly design elements?
- Key features:
  - Reduced travel lanes
  - Reduced crossing widths
  - Reduced vehicle speeds / volumes
- Enhancement features:
  - Median islands
  - Bulbouts
  - Improved crosswalks

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Built Environment Factors

Divisadero Street, Fresno, CA: before and after a road diet

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Built Environment Factors for Pedestrians

Median island

Bulbout

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Built Environment Factors for Pedestrians

Advanced yield lines

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Built Environment Factors for Pedestrians

Textured crosswalks

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Built Environment Factors for Pedestrians

Advanced stop bars

Crosswalks on all legs

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Built Environment Factors for Pedestrians

Colored crosswalks

High visibility crosswalks

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Built Environment Factors for Pedestrians

Removal of obstacles

Pedestrian busy buttons

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Built Environment Factors for Pedestrians

Pedestrian scramble phase

Braille wayfinding

Built Environment Factors for Bikes

Bicycle detection

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Built Environment Factors for Bikes

Bicycle push-buttons

Bike boxes

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Built Environment Factors

- Of 20 factors:
  - 18-20: LOS A
  - 14-17: LOS B
  - 10-13: LOS C
  - 7-9: LOS D
  - 3-6: LOS E
  - 0-2: LOS F
- Would it work?

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Person-Delay via Simulation

- Measure person delay across all modes
- Accounts for vehicle and transit occupancy
- How will certain improvements benefit different modes (or not!)
- Example: Hutchison Drive / La Rue Road intersection

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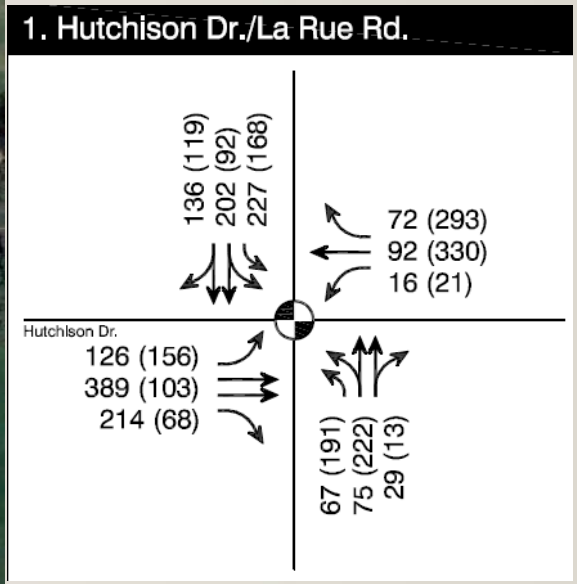
Person-Delay: Hutchison Drive and La Rue Road



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Person-Delay

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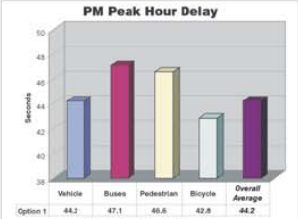
USING TRAFFIC SIMULATION TO EVALUATE AUTOMOBILE, TRANSIT, BICYCLE, AND PEDESTRIAN DELAYS IN DESIGNING AN INTERSECTION - A CASE STUDY FROM THE UNIVERSITY OF CALIFORNIA AT DAVIS

Option 1: Hutchison Drive/La Rue Road with All Bicycle/Pedestrian Phase

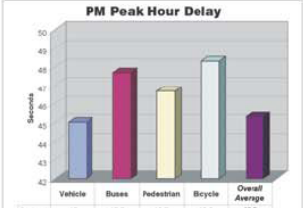
Under Option 1, the Hutchison Drive/La Rue Road intersection would have an exclusive bicycle/pedestrian phase. During this phase, all vehicles would stop and only bicyclists would travel through the intersection. The intersection would operate with a 120 second cycle length. Due to the California vehicle code, on-street bicyclists must use the exclusive bicycle/pedestrian phase and cannot use vehicle phases.



HCM Intersection = D

Option 2: Hutchison Drive/La Rue Road with Exclusive Bicycle Path Phase

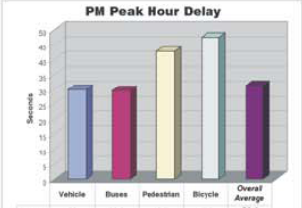
Under Option 2, the Hutchison Drive/La Rue Road intersection would have an exclusive bicycle/pedestrian phase only on the north side of Hutchison Drive or for the bicycle path on the west side of La Rue Road.



HCM Intersection = D

Option 3: Hutchison Drive/La Rue Road with Traditional Design (No Bike/Ped Phase)

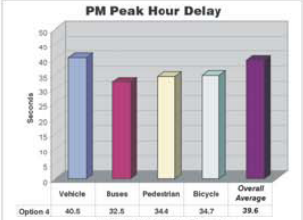
Under Option 3, bicyclists and pedestrians would travel with the flow of vehicles through the intersection as occurs at typical signalized intersections (e.g., current configuration). This option causes conflicts between east-west bicycle movements and the heavy westbound right-turn vehicle movement



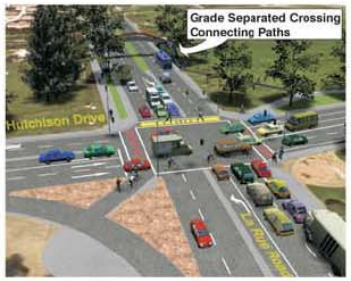
HCM Intersection = C

Option 4: Hutchison Drive/La Rue Road with Head Start for Bicyclists/Pedestrians

Option 4 is similar to Option 3, but would give bicyclists and pedestrians traveling on the southbound and westbound bicycle path approaches a five second head start before eastbound and westbound through vehicles receive a green light. This option would minimize right-turn conflicts during the start of the green phase when the highest vehicle flows occur.

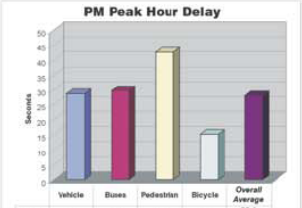


HCM Intersection = D



Option 5: Hutchison Drive/La Rue Road with Grade Separated Bicycle Crossing

Under Option 5, a grade separated crossing would be provided for bicyclists and pedestrians traveling between the path on the north side of Hutchison Drive and the path on the west side of La Rue Road. This improvement has the lowest total delay and the least number of potential conflicts between modes.



HCM Intersection = C

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Person-Delay

[redacted]

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Person-Delay

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Person-Delay via Simulation

TABLE 2
INTERSECTION –
YEAR 2005 PM PEAK HOUR DELAY FOR ALL TRAVEL MODES

Option	Travel Mode (1)				Overall
	Vehicles	Buses	Pedestrians	Bicycles	
	Average Delay – LOS	Average Delay – LOS	Average Delay	Average Delay	Average Delay
1 - Bike/Pedestrian Phase	44.2 – D	47.1 – D	46.6	42.8	44.2
2 - Bike/Pedestrian Phase for Path Only	45.0 – D	47.7 – D	46.7	48.3	45.3
3 - Traditional Design (Current Configuration)	30.0 – C	29.6 – C	42.7	47.5	31.4
4 – Head Start Phase for Bike Path	40.5 – D	32.5 – C	24.4	34.7	39.6
5 – Grade Separated Crossing	28.7 – C	29.8 – C	64.2	15.1	28.1

Notes:
(1) The *Highway Capacity Manual* does not assign an LOS for pedestrians and bicyclists based on average delays. Delays were reported for comparison purposes only.
(2) The increase in pedestrian delay is associated with a reduction in pedestrians that are now using the grade separated crossing resulting in a higher average delay per pedestrian for remaining crossings on other approaches.

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Person-Delay via Simulation

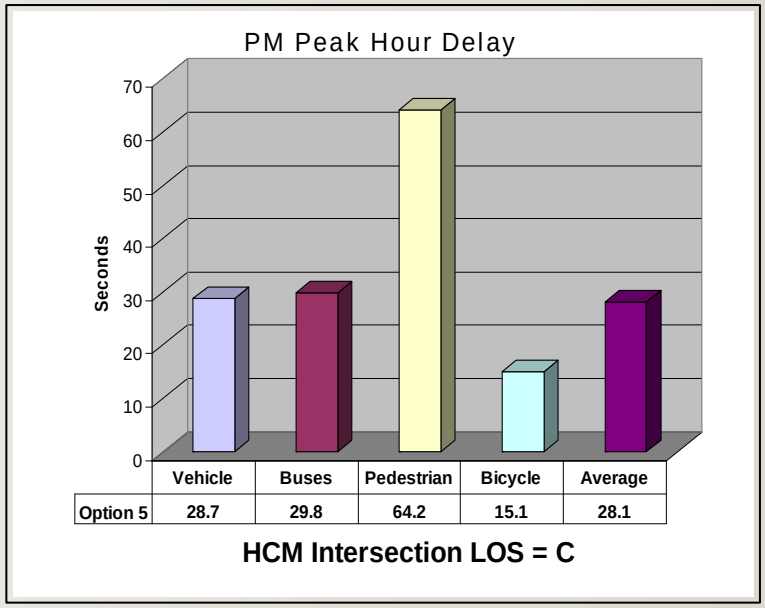

Illustration of Alternative 5 (bicycle/pedestrian bridge) and analysis by mode

Source: *Conventional Level of Service Analysis, Thresholds, and Policies Get a Failing Grade*, Milam and Mitchell, 2007

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Layered Network

- Street classification system: designate priority modes to specific streets
- Each mode has its own set of design and operational features and performance standards
- Use to prioritize improvements or evaluate trade-offs for mitigation

Transit Priority Streets, Alameda, CA

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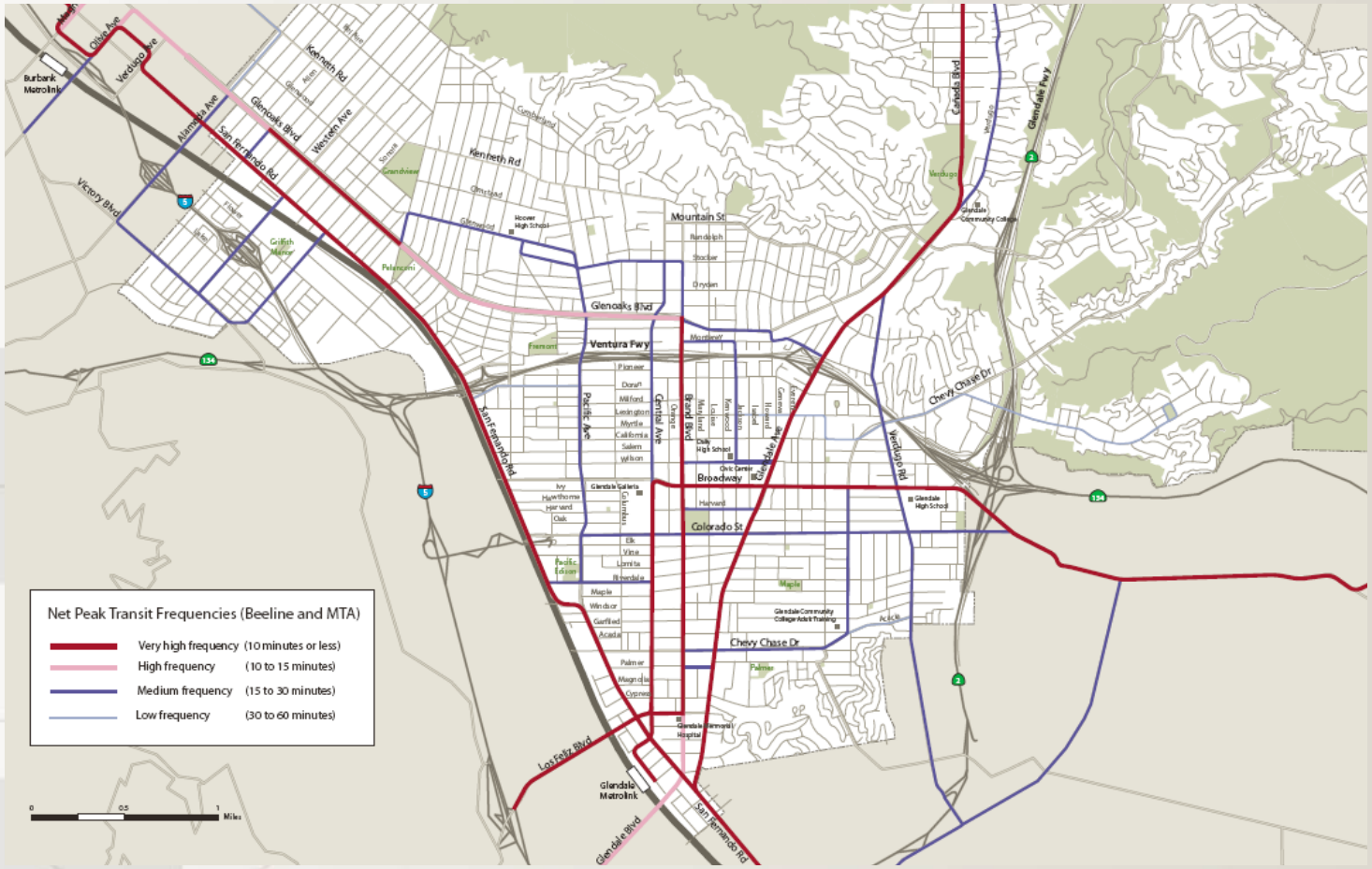
Layered Network

- Glendale, CA: Downtown Glendale Mobility Plan


Net Peak Transit Frequencies (Beeline and MTA)
Very high frequency (10 minutes or less)
High frequency (10 to 15 minutes)
Medium frequency (15 to 30 minutes)
Low frequency (30 to 60 minutes)
Burbank Metrolink
Glendale Metrolink
Glenoaks Blvd
Ventura Fwy
Mountain St
Broadway
Colorado St
Chevy Chase Dr
Verdugo Rd
Central Ave
Brand Blvd
Pacific Ave
San Fernando Rd
Los Feliz Blvd
Glendale Fwy
Cayuda Blvd
Victory Blvd
Olive Ave
Verdugo Ave
Alameda Ave
Kenneth Rd
Western Ave
Glenoaks Blvd
Glendale Community College
Glendale High School
Hoover High School
Griffith Manor
Pelanconi
Grandview
Fremont
Pacific Edison
Maple
Palmer
Glendale Memorial Hospital
Glendale Community College Adult Training
Civic Center
Dunsmuir
Mountain
Randolph
Stocker
Dryden
Doran
Milford
Lexington
Myrtle
California
Salem
Wilson
Ivy
Hawthorne
Harvard
Oak
Elk
Vine
Lomita
Broadale
Windsor
Garfield
Acadia
Cypress
Columbus
Orange
Maryland
Louise
Kenwood
Jackson
Ireland
Isabel
Geneva
Jeanette
Acacia
Verdugo
Cumberland
Glenwood
Glenoak
Glenland
Glenfield
Elm
Pine
Fairview
Flower
Mariposa
Kenneth
Western
Victory
Olive
Verdugo
Alameda
San Fernando
Glenoaks
Kenneth
Western
Cayuda
Glendale
Central
Brand
Pacific
Verdugo
Chevy Chase
Colorado
Broadway
Mountain
Glenoaks
Ventura
Los Feliz
Glendale
San Fernando
Victory
Olive
Verdugo
Alameda
Kenneth
Western
Glenoaks

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Layered Network

- Seattle, WA Transit Priority Corridors

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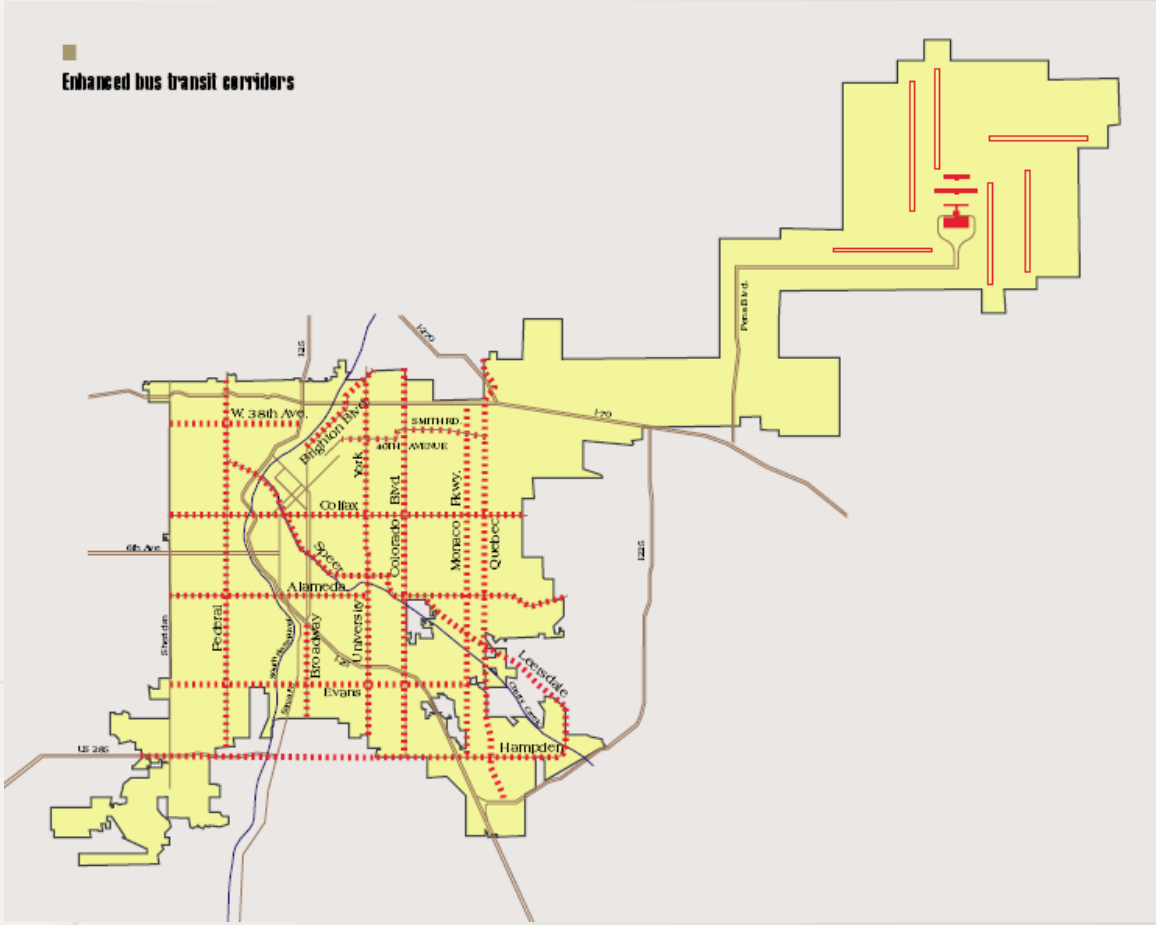
Layered Network

- Denver, CO: Blueprint Denver



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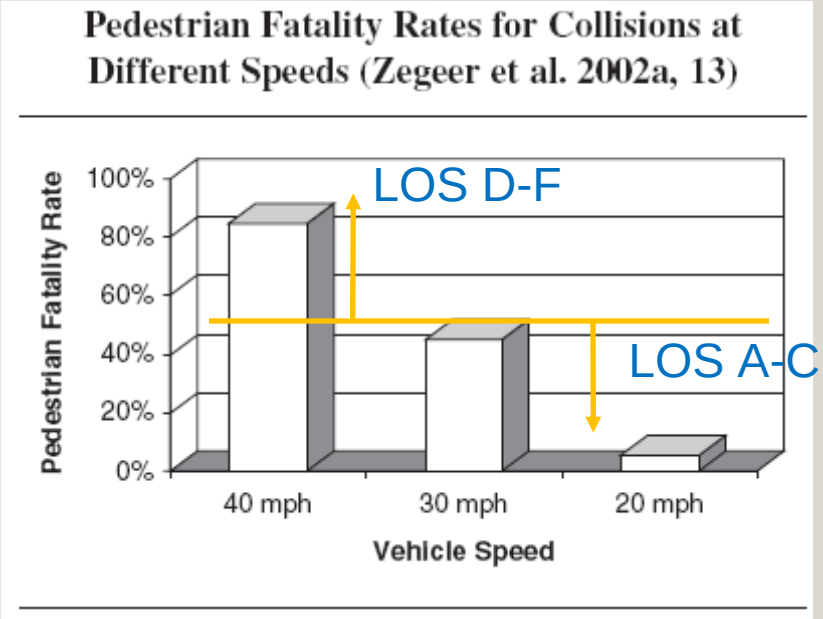
Manage Speeds

- Correlate vehicle speed to safety
- Goal of stable flow (minimize GHG emissions)
- Can estimate speed for all modes
- Can provide different "weights" for different exposure levels (e.g. crossing a street counts as more time than walking along a path)
- Supports shorter cycle lengths, more comprehensive multimodal network, and a grid system



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Toolbox Tuesdays
Multimodal Level of Service Applications

Questions?

COMPASS BLUEPRINT
building partnerships. serving communities.

SOUTHERN CALIFORNIA ASSOCIATION of GOVERNMENTS