The National Academies of
SCIENCES · ENGINEERING · MEDICINE

TRANSPORTATION RESEARCH BOARD

Moving Beyond "Accommodating" – Integrated Multi-Modal Analysis in the HCM6

Wednesday, October 23, 2019
2:00-3:30 PM ET

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

RCEP

REGISTERED CONTINUING EDUCATION PROGRAM

Purpose

To discuss the multi-modal analysis methods incorporated into the Highway Capacity Manual (HCM), Sixth Edition: A Guide for Multimodal Mobility Analysis.

Learning Objectives

At the end of this webinar, you will be able to:

- Describe the range of potential multi-modal urban street analyses by urban street element (link, intersection, segment, facility) and by level of analysis detail (planning, operations, design)
- Identify the range of multi-modal urban street performance measures that the HCM can estimate
- Identify potential applications of the HCM's multimodal urban streets method to actual projects

PDH Certificate Information

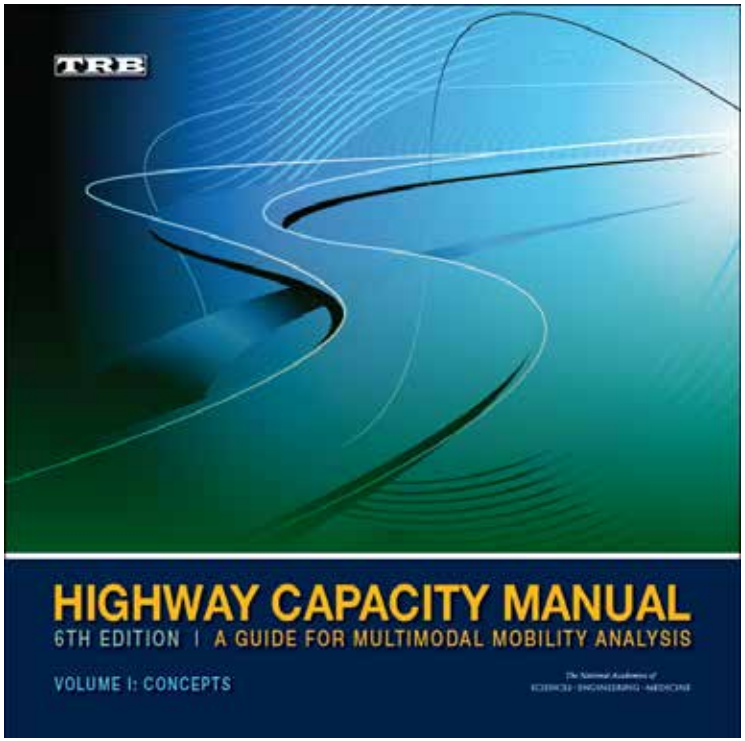
- This webinar is valued at 1.5 Professional Development Hours (PDH)
- Instructions on retrieving your certificate will be found in your webinar reminder and follow-up emails
- You must register and attend as an individual to receive a PDH certificate
- Certificates of Completion will be issued only to individuals who register for and attend the entire webinar session – this includes Q&A
- TRB will report your hours within one week
- Questions? Contact Reggie Gillum at RGillum@nas.edu

HCM – 6th Edition

Moving Beyond “Accommodating”: Integrated Multimodal Analysis in HCM6

October 23, 2019

HCM Webinar Series



- Using the HCM for planning
- Freeway facility analysis
- Travel time reliability analysis
- Multimodal analysis
- Intersection control evaluation (ICE)
- Alternative intersection and corridor analysis

Instructors

- Paul Ryus, PE
  - Principal Engineer, Kittelson & Associates, Inc.
  - Former member, TRB Highway Capacity & QOS Committee

- Aaron Elias, PE
  - Senior Engineer, Kittelson & Associates, Inc.
  - Member, Planning & Preliminary Engineering subcommittee of the TRB HCQS Committee

Learning Objectives

- Understand the range of potential multi-modal urban street analyses:
  - By urban street element (link, intersection, segment, facility)
  - By level of analysis detail (planning, operations, design)
- Identify the multi-modal performance measures that the HCM can estimate
- Identify potential applications of the HCM's multimodal urban streets method to actual projects

Presentation Overview

- Urban street system elements
- HCM's multimodal performance measures
- Modal perception score framework
  - Transit passengers
  - Pedestrians
  - Bicycles
  - Automobile travelers
- Case study examples
- Summary and wrap-up

Presentation Overview

- Urban street system elements
- HCM's multimodal performance measures
- Modal perception score framework
- Case study examples
- Summary and wrap-up

Urban Street System Elements

- Signalized Intersections (Chapter 19)
- Unsignalized intersections
  - Two-way STOP-controlled intersections (Chapter 20)
  - All-way STOP-controlled intersections (Chapter 21)
  - Roundabouts (Chapter 22)
  - Ramp terminals and alternative intersections (Chapter 23)
- Links (Chapter 18)
- Segments (Chapter 18)
- Facilities (Chapter 16)

Urban Street System Elements: Boundary Intersections

- Boundary intersections divide a street into segments
- These are any intersection where traffic control can require the street's traffic to stop or yield
  - Typically traffic signals, roundabouts, all-way stops
  - Does not include (un)signalized crosswalks, fire station driveways, railroad crossings, drawbridges, etc.

Image © 2016 Google

Urban Street System Elements: Intersections

- Boundary intersections
  - Operations of both urban street and cross street analyzed
- Non-boundary intersections, driveways, and mid-block crosswalks
  - Turning and crossing movements can be analyzed

Image © 2016 Google

Urban Street System Elements: Links

- Portion of segment between boundary intersections
- Particularly used in pedestrian and bicycle analysis

Image © 2016 Google

Urban Street System Elements: Segments

- Measured stop bar to stop bar from one boundary intersection to the next
- Each street direction is analyzed separately
- Analysis considers both the downstream boundary intersection (e.g., delay) and what happens between boundary intersections

Image © 2016 Google

Urban Street System Elements: Facilities

- Composed of two or more contiguous segments
- Consider starting a new facility when a significant change occurs in one of these characteristics:
  - Cross-section (particularly number of through lanes)
  - Annual average daily traffic volume
  - Roadside development density and type
  - Vehicle speed

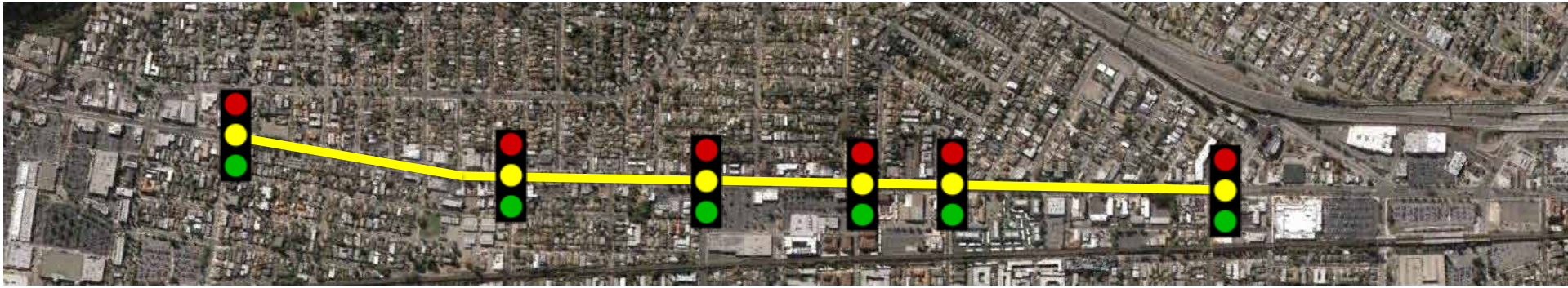


Image © 2016 Google

Which System Elements to Study?

- System elements to study will depend on the analysis study area and purpose
- For example
  - Multimodal corridor analysis, access management plan: Facility (and all its subelements)
  - Traffic impact study: Intersections, possibly segments
  - District or citywide pedestrian or bicycle plan: Links, possibly intersections and segments

Presentation Overview

- Urban street system elements
- HCM's multimodal performance measures
- Modal perception score framework
- Case study examples
- Summary and wrap-up

Performance Measures: Facilities and Segments

Mode	Travel Speed	Perception Score	LOS Letter	Other
	✓	✓	✓	stop rate, critical facility v/c ratio
	✓	✓	✓	pedestrian space
	✓	✓	✓	
	✓	✓	✓	segment wait–ride score

Performance Measures: Links

Mode	Travel Speed	Perception Score	LOS Letter	Other
				
		✓	✓	pedestrian space
		✓	✓	
				

Performance Measures: Signalized Intersections

Mode	Delay	LOS Letter	Other
	✓	✓	v/c ratio, various queuing measures
	✓	✓	street corner & crosswalk circulation areas, perception score
	✓	✓	perception score

Performance Measures: TWSC Intersections

Mode	Delay	LOS Letter	Other
	✓	✓	v/c ratio, 95th-percentile queue
	✓	✓	Can also be used for mid-block crosswalks (including driver yielding behavior effects)
			Limited guidance for analyzing bike ops

Performance Measures: AWSC Intersections

Mode	Delay	LOS Letter	Other
	✓	✓	v/c ratio, 95th-percentile queue
			Limited guidance for analyzing ped ops
			Limited guidance for analyzing bike ops

Performance Measures: Roundabouts

Mode	Delay	LOS Letter	Other
	✓	✓	v/c ratio, 95th-percentile queue
			Guidance to use two-way stop/midblock crossing method with care
			Guidance to analyze bicyclist as pedestrian and/or vehicle

Which Performance Measures to Use?

- Performance measures will depend on the analysis purpose and the study area environment
- For example
  - Pedestrian space/circulation area measures useful for downtowns of major cities and for special events
  - Vehicle/modal delay is the starting point for determining person delay
  - Perception scores are designed to facilitate multimodal comparisons
  - Queuing may be a bigger operational issue than delay

Presentation Overview

- Urban street system elements
- HCM's multimodal performance measures
- Modal perception score framework
- Case study examples
- Summary and wrap-up

Development of the HCM's Multimodal Method

- Method originally developed by NCHRP Project 03-70
  - Described in NCHRP Report 616
  - Testing described in NCHRP Web-only Document 158
  - Pedestrian and bicycle components based on research previously commissioned by the Florida DOT
- Method designed to evaluate operational trade-offs of various street designs in terms of travelers' perception of the quality of service provided
- Method provides modal perception scores that use a common scale, allowing direct comparisons of QOS

Traveler Perception Modeling

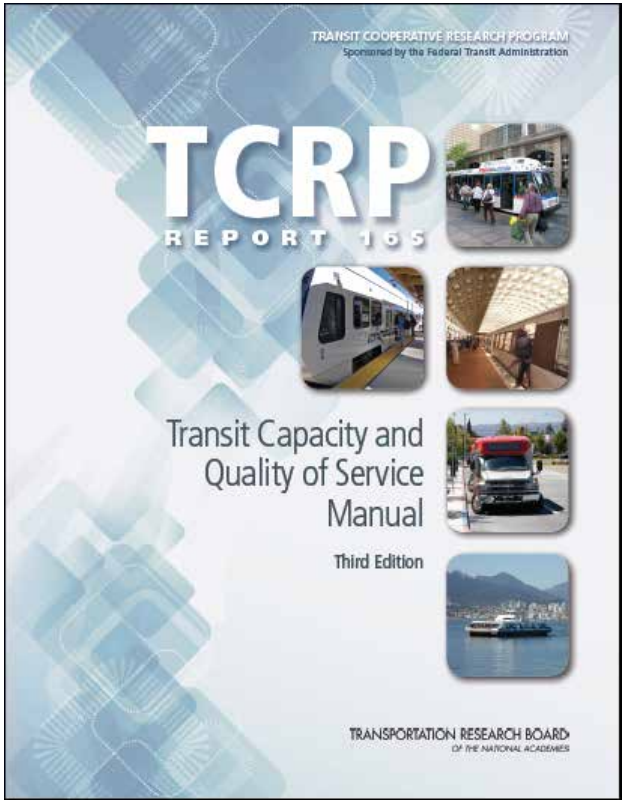
- Pedestrian, bicycle, automobile modes:
  - Video lab participants rated videos depicting various urban street environments
  - Service quality was rated on an A-F scale
  - Regression analysis used to identify relationships between urban street characteristics and participants' ratings
- On-street transit mode
  - Passenger response to service quality changes (as measured by changes in ridership) used in developing the model

Traveler Perception Scores

- HCM's models predict modal traveler satisfaction with conditions on an urban street
- Perception score is open-ended, with lower scores meaning better perceived service quality
- Pedestrian, bicycle, transit perception scores can be used to determine LOS for those modes
  -

Transit Analysis in an HCM Context

- Segment and facility analysis only
- On-street transit service only
  - Bus, streetcar, portions of light rail
- Intended to be used alongside ped, bike, auto perception scores
- Refer to the TCQSM for transit-specific analysis methods and performance measures
  - TCRP Report 165



Transit Analysis: Segments

- Key service quality components:
  - Service frequency
  - Perceived travel time rate
    - Actual travel time rate (minutes per mile)
    - Reliability (excess wait time at stop)
    - On-board crowding
    - Shelter/bench at stop
  - Pedestrian LOS
- Measures service quality
  - Getting to bus stop
  - Waiting for bus
  - On-board bus

Transit Analysis: Facilities

- Facility perception score is a length-weighted average of the segment scores
- Can be converted to a LOS letter

Pedestrian Analysis: Links

- Key service quality components:
  - Sidewalk width (=0 feet if no sidewalk)
  - Separation from motorized vehicle traffic
    - Bike lane, parking lane, landscape strip
    - Barriers (occupied parking, street trees, etc.)
  - Traffic volume and speed in the outside through lane
- Link score can be used by itself, if desired

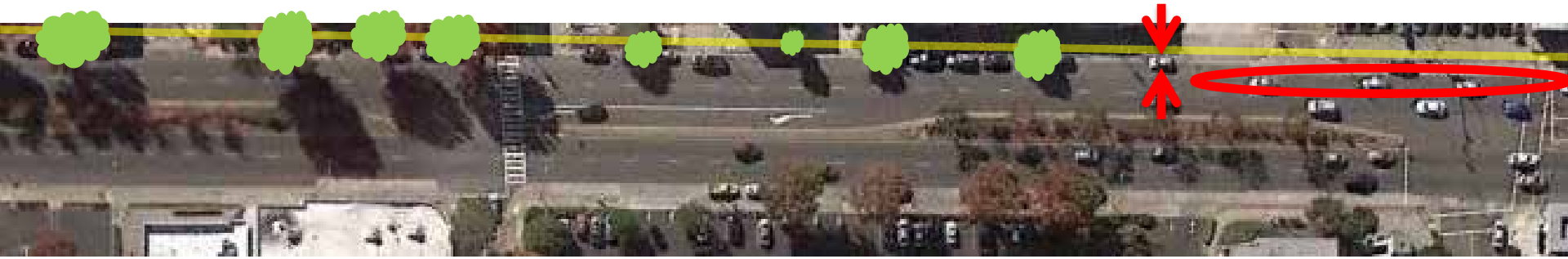


Image © 2016 Google

Pedestrian Analysis: Signalized Intersections

- Key service quality components:
  - Number of traffic lanes crossed on crosswalk
  - Disturbance by motorized vehicle traffic
    - Traffic volume, speed in parallel through lane
    - Total traffic volume over crosswalk
    - Permitted left-turn, right-turn-on-red volume over crosswalk
  - Number of right-turn channelizing islands

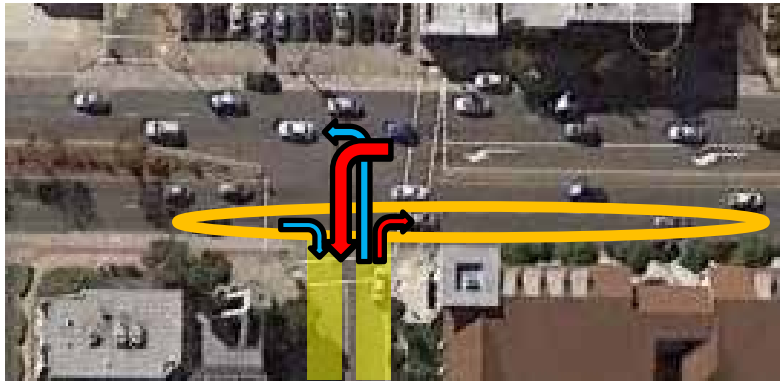


Image © 2016 Google

Pedestrian Analysis: Segments

- Combines link and intersection perception scores
- Added factor: street-crossing difficulty
  - Lower of the delay crossing street at a legal crossing point or diverting to a signalized intersection
- Ped space also used in determining LOS
  - Only a factor with high ped volumes (>1,000 ped/h)

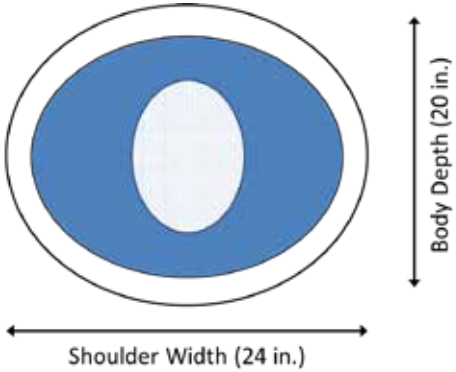
Image © 2016 Google

Pedestrian Analysis: Facilities

- Facility score is a travel time–weighted average of the segment scores
  - Changed from distance-based weighting in HCM 2010

Changes to Pedestrian Content in the HCM 6th Edition

- Pedestrian body ellipse (Chapter 4)
  - Body depth element increased by 2 inches (5 cm) to account for changes in U.S. population from the 1970s to the 2010s



- Facility and segment ped LOS scores now weighted by travel time/delay
- Incorporation of HCM 2010 clarifications and errata
  - Link-only analysis
    - Clarifies that it does not consider ped space
    - Uses LOS scale from original research, rather than segment scale
  - Definitions of intermediate calculation variables

Bicycle Analysis: Links

- Key service quality components:
  - Bicycle lane width (=0 feet if no bicycle lane)
  - Separation from motorized vehicle traffic
    - Width of outside through lane + bike lane + shoulder/parking lane
  - Traffic volume, speed, and heavy vehicle percentage in the outside through lane
  - Presence of occupied on-street parking
  - Pavement condition

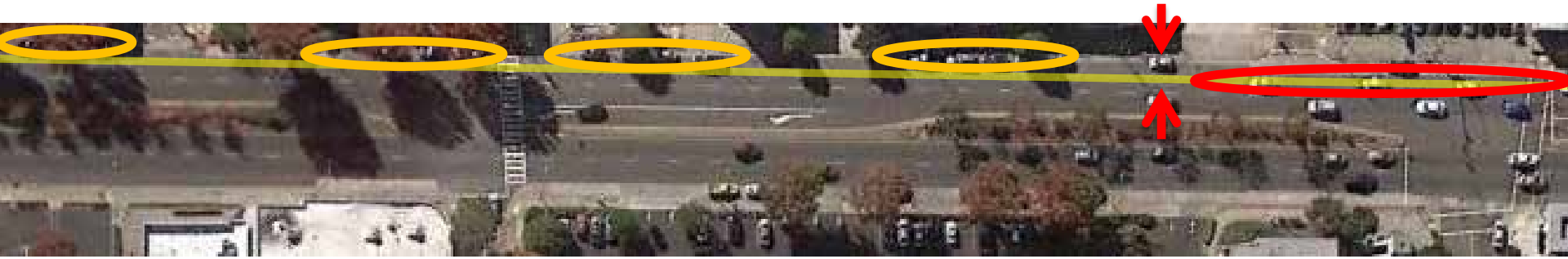


Image © 2016 Google

Bicycle Analysis: Signalized Intersections

- Key service quality components:
  - Cross-street width
  - Separation from motorized vehicle traffic on approach
    - Width of outside through lane + bike lane + shoulder/parking lane
  - On-street parking occupancy within 250 feet of intersection

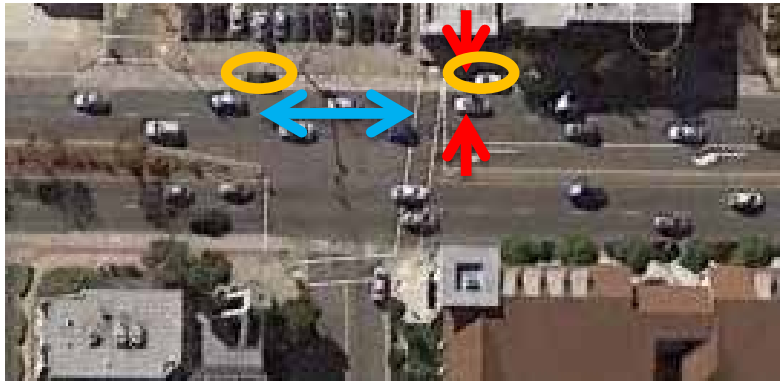


Image © 2016 Google

Bicycle Analysis: Segments and Facilities

- Segment score combines link and intersection perception scores
  - Additional factor: number of access points (right side)
- Facility score is a travel time–weighted average of the segment scores
  - Change from the HCM 2010

Image © 2016 Google

Changes to Bicycle Content in the HCM 6th Edition

- Facility and segment bicycle LOS scores now weighted by travel time/delay
- Incorporation of HCM 2010 clarifications and errata
  - Link-only analysis uses LOS scale from original research, rather than segment scale

Automobile Traveler Perception Score

- Segment and facility analysis only
- Only produces a perception score: no corresponding LOS letter
  - Uses the same numeric scale, however
- Designed to be used alongside ped, bike, transit methods
- Service quality components:
  - Proportion of intersections with left-turn lanes
  - Spatial stop rate (stops per mile)

Presentation Overview

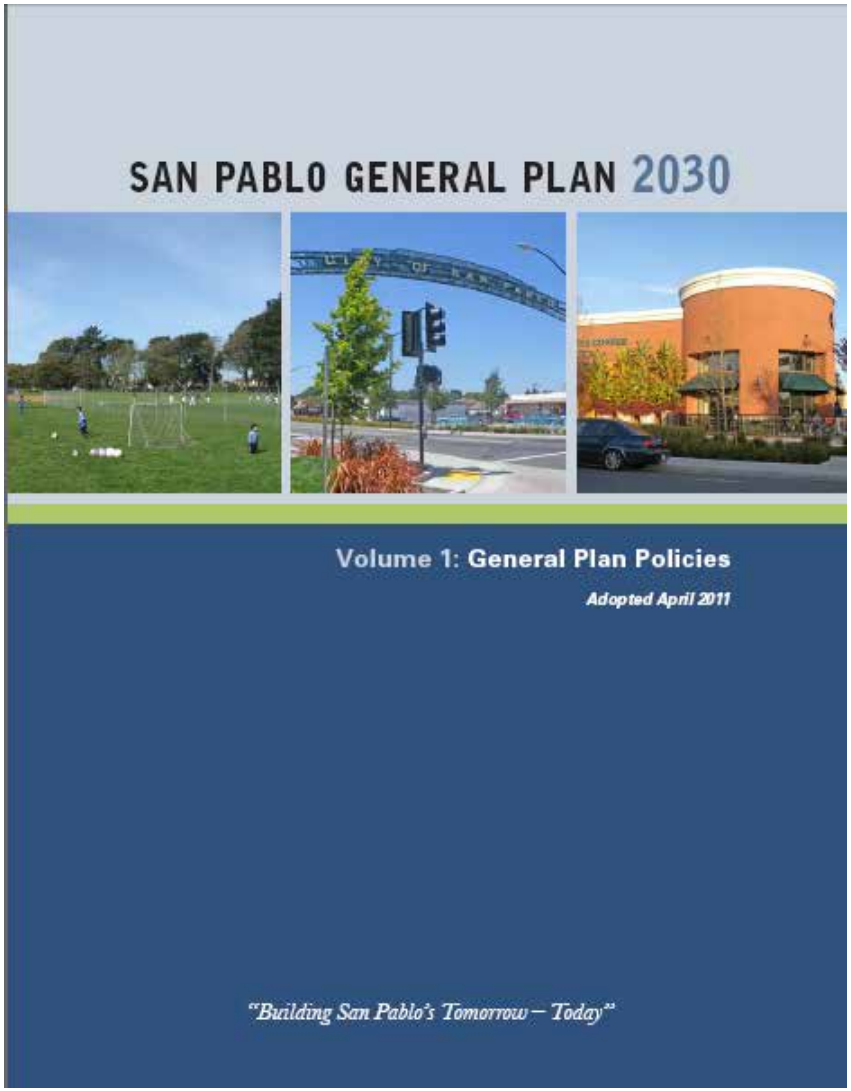
- Urban street system elements
- HCM's multimodal performance measures
- Modal perception score framework
- Case study examples
- Summary and wrap-up

Example Applications

- Use of MMLOS for general (comprehensive) plans
  - San Pablo, CA
- Baseline analysis for a region
  - Jacksonville, FL
- Project-specific use of MMLOS (road diet)
  - Pasadena, CA

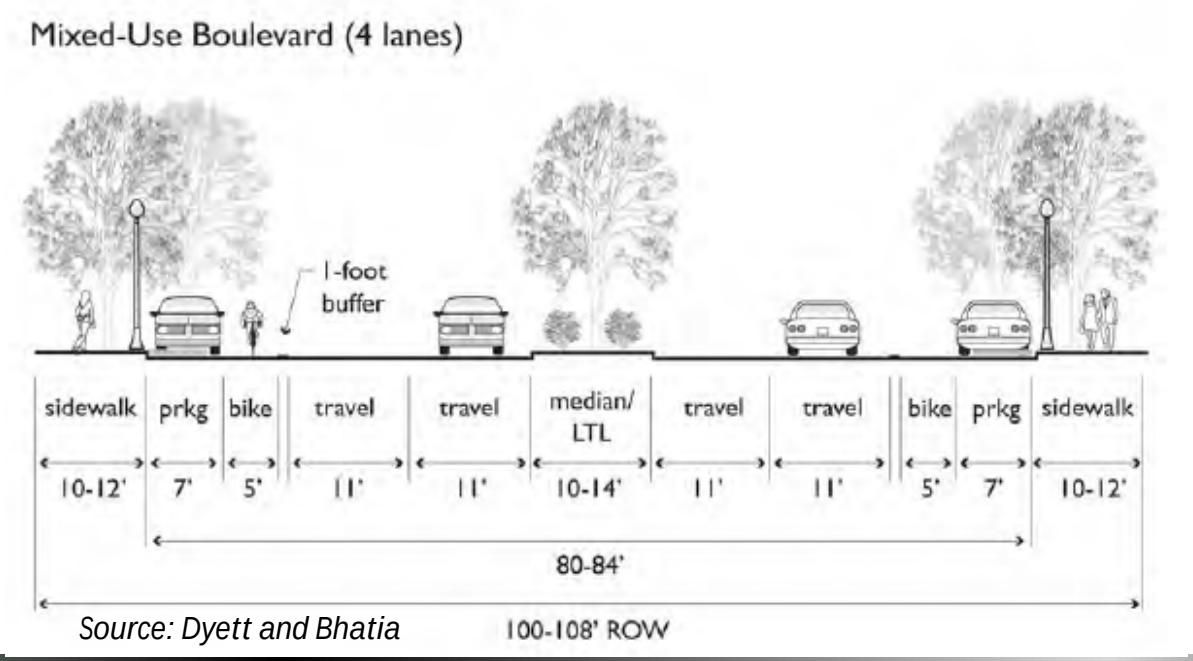
Application 1: General (Comprehensive) Plan

- City of San Pablo, CA
- Incorporated multimodal performance



Application 1: General (Comprehensive) Plan

- Complete Street general policies
- Designation of circulation system
  - Move away from motorist-only perceptions
  - Incorporate more multimodal designations



Source: Dyett and Bhatia

Application 1: General (Comprehensive) Plan

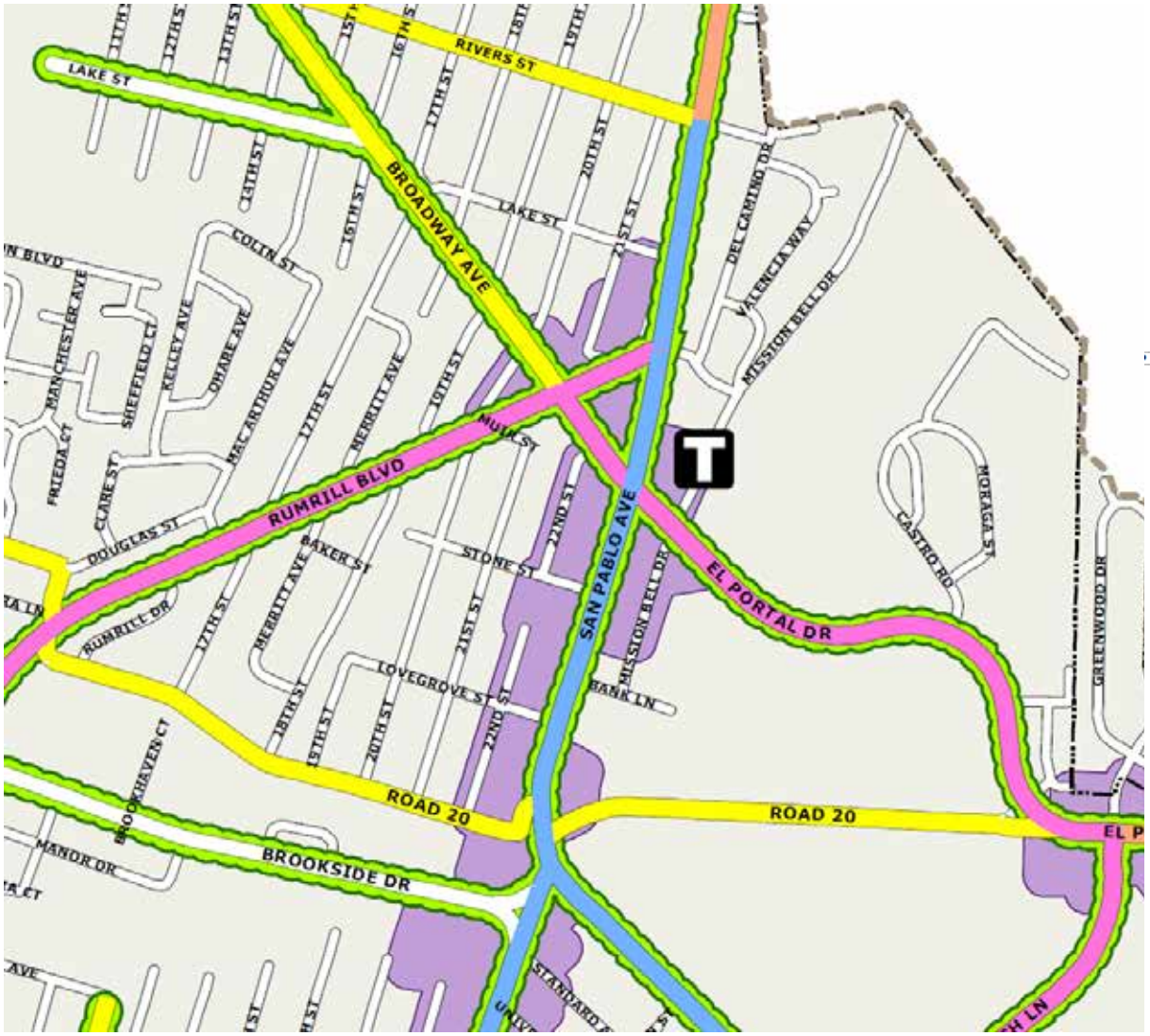


Figure 5-1

Proposed Roadway System

- State Highway
- Mixed Use Boulevard
- Urban Arterial
- Auto Arterial
- Avenue
- Local
- Major Transit Hub
- Pedestrian Priority Zone
- Green Street Overlay
- Planning Area
- City Limits
- Railroads

Application 1: General (Comprehensive) Plan

§ Prioritization of different street types by mode

Table 5.2-1 Transportation Facilities Matrix

Facility	*Transit*	*Bicycles*	*Pedestrians*	*Trucks*	*Automobiles*
State Highway	□	×	×	□	□
Auto Arterial	□	□	○	■	■
Urban Arterial[1]	■	■	□	○	■
Mixed Used Boulevard	■	□	■	□	□
Avenue	○	□	□	○	□
Local	○	□	□	×	□

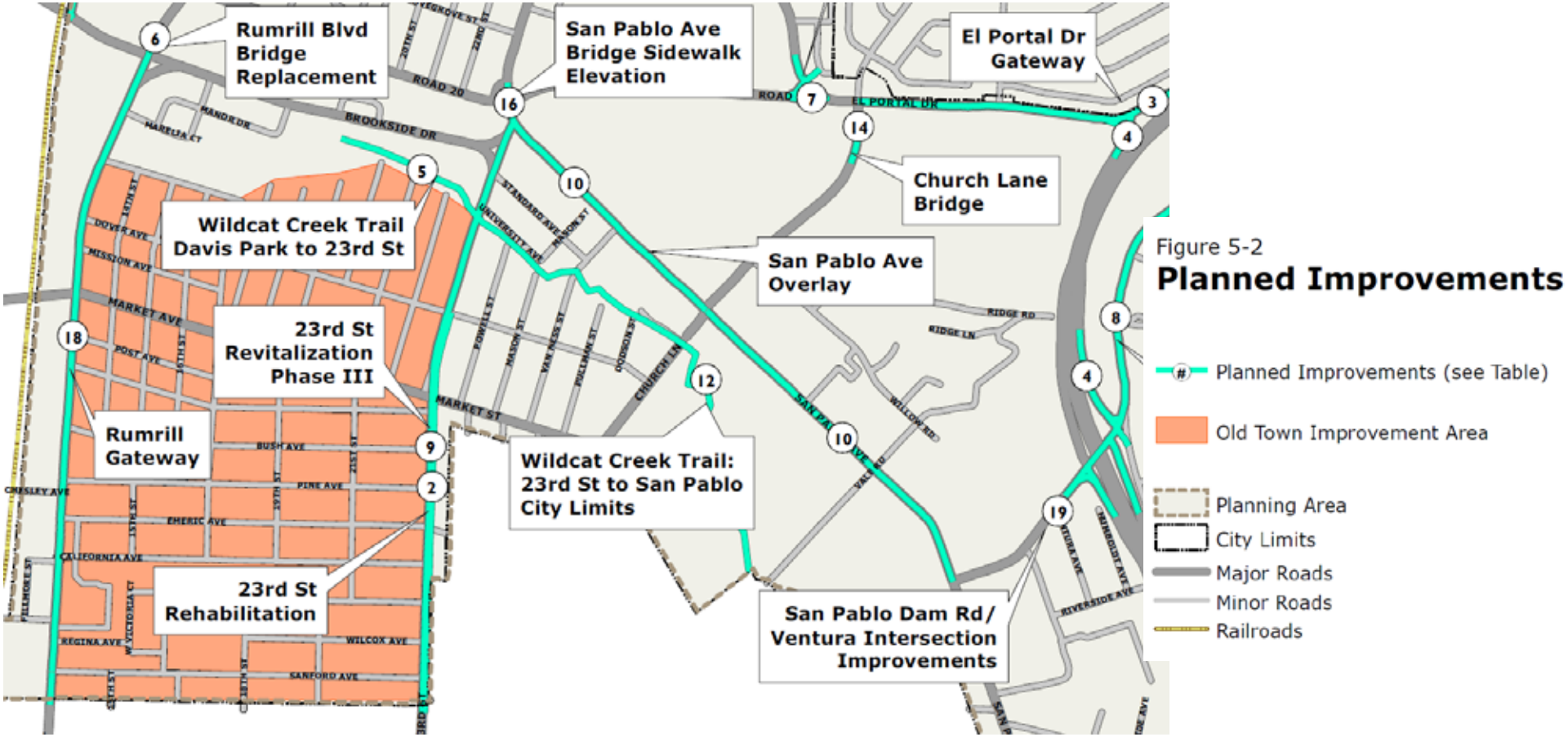
■ = Dominant
□ = Accommodated
○ = Incidental
× = Prohibited

[1] Transit has priority over bicycles on Urban Arterials, where conflicts exist.

Application 1: General (Comprehensive) Plan

CITY OF SAN PABLO
City of New Directions

§ More robust determination of improvements

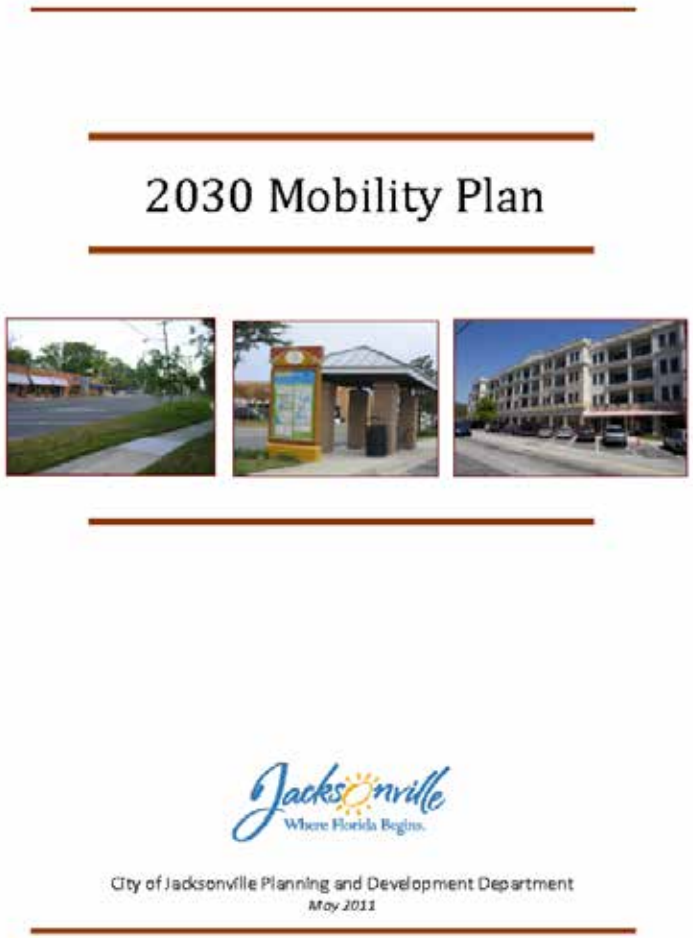


Application 1: General (Comprehensive) Plan

- Benefits of MMLOS
  - Provided baseline LOS for all travel modes
    - Reasonableness of LOS standards
  - Multimodal roadway designations
    - Provides guidelines for improvements
    - Informs mitigation requirements
    - Provides an analysis tool
  - Developed policy standards
    - Prioritize specific modes on particular streets

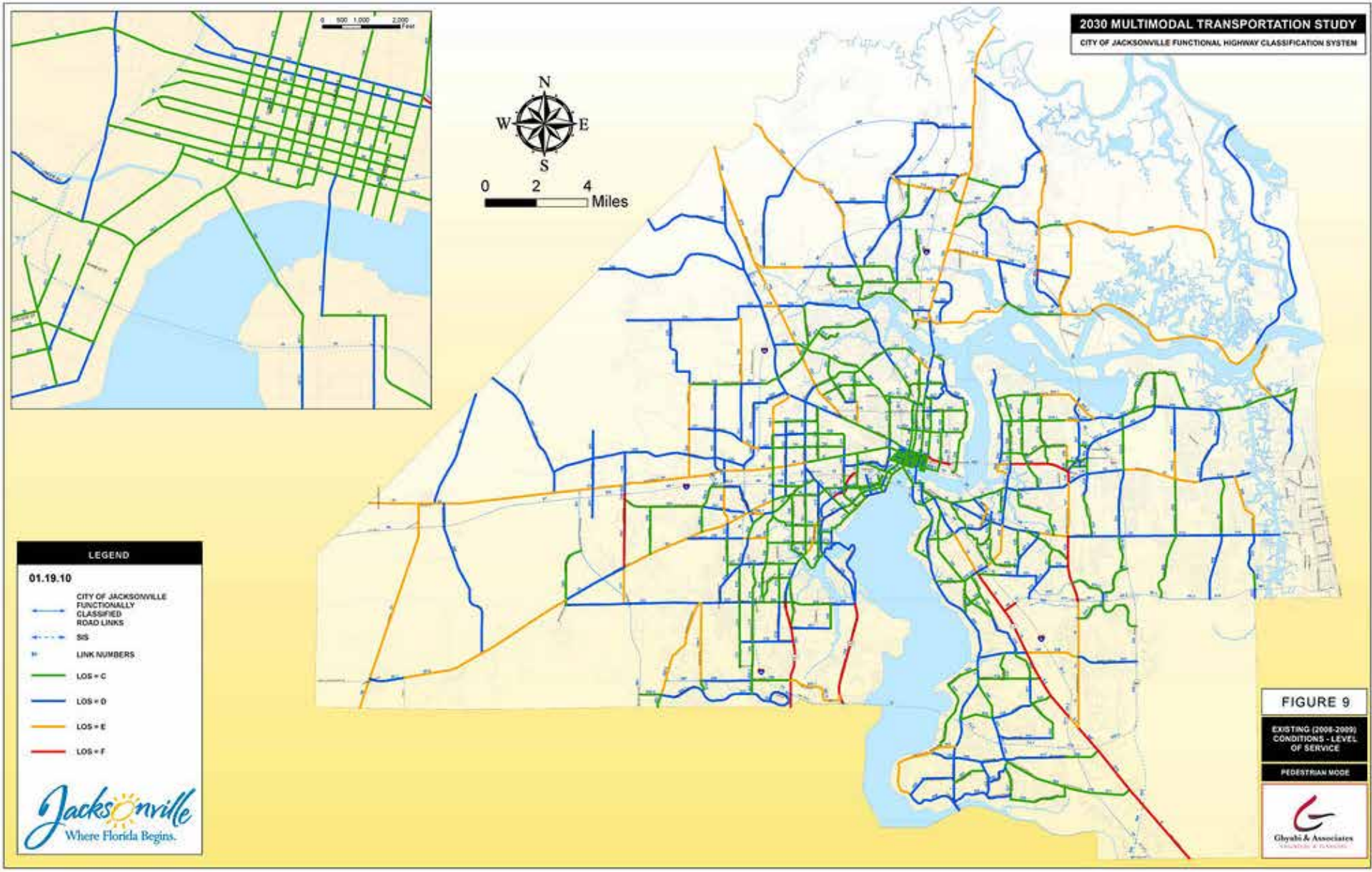
Application 2: Cataloging MMLOS for a Region

- City of Jacksonville, FL
- City has been ranked one of the most dangerous cities for pedestrians
- Used MMLOS to classify existing conditions
  - Used to determine where to make pedestrian improvements



Application 2: Cataloging MMLOS for a Region

Application 2: Cataloging MMLOS for a Region



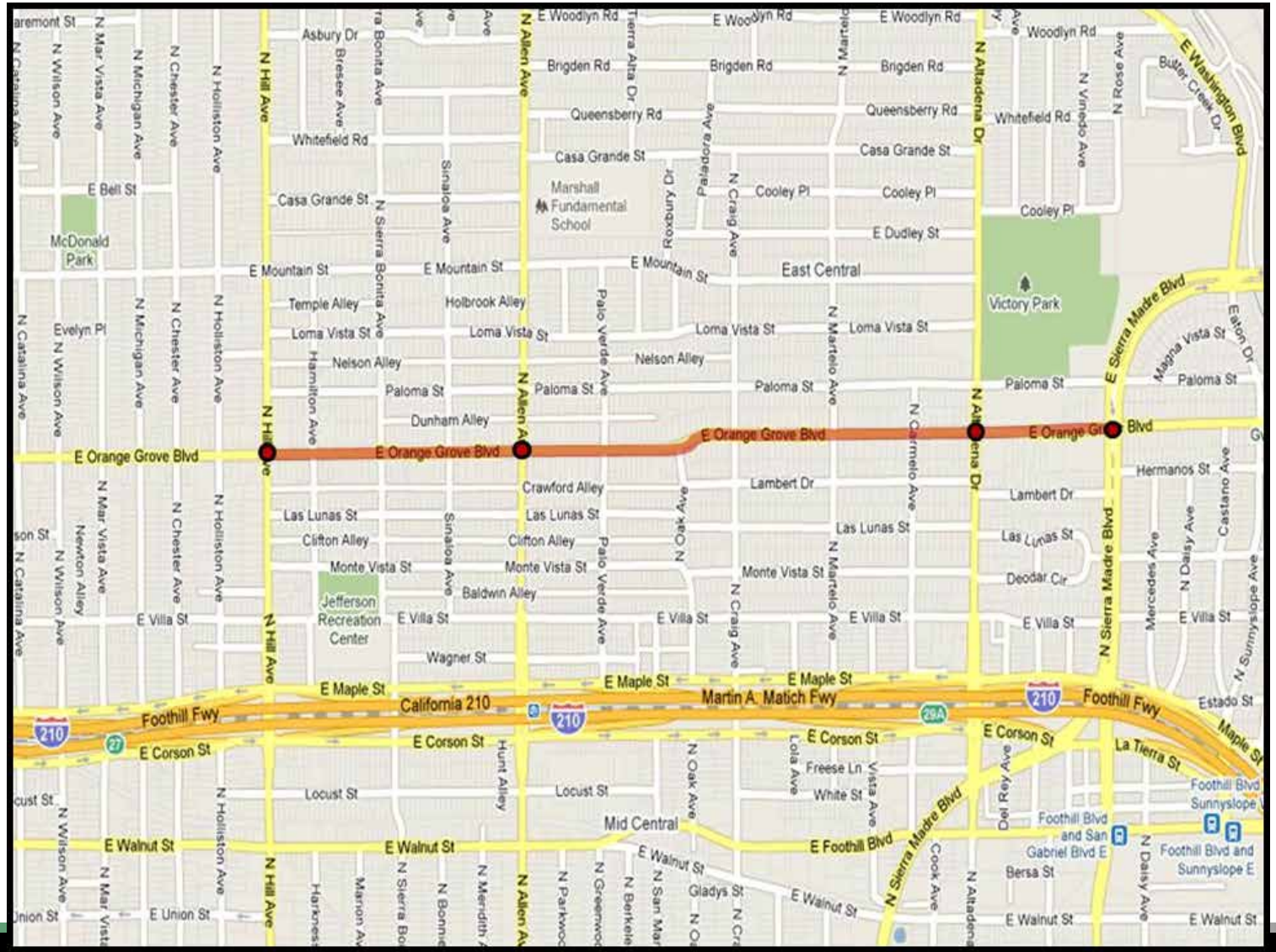
Application 3: Road Diet

- Pasadena, CA
- City considered a road diet on Orange Grove Boulevard
- MMLOS was used to assess tradeoffs between different modes

City of Pasadena Road Diet Evaluation

- When implementing a road diet, many concerns arise including:
  - How will the lane reduction affect the auto mode?
  - Will transit operations be affected?
  - How much will the bicycle mode improve as a result of adding bike lanes?
  - Will there be any benefit to pedestrians?
- Orange Grove Blvd. was analyzed using multimodal LOS to address these concerns

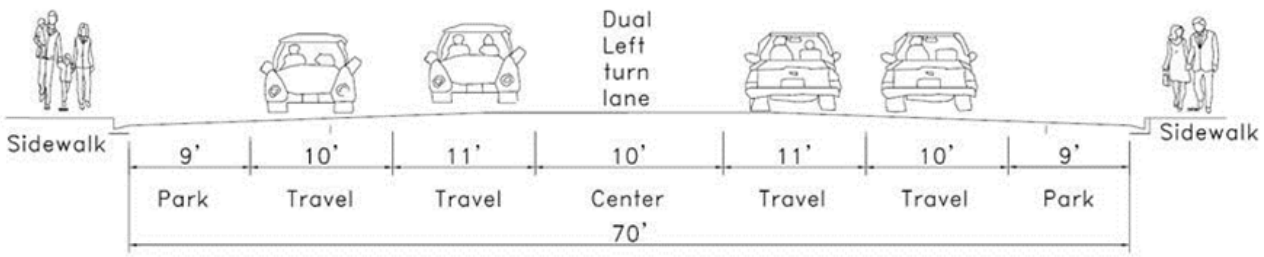
City of Pasadena Road Diet Evaluation



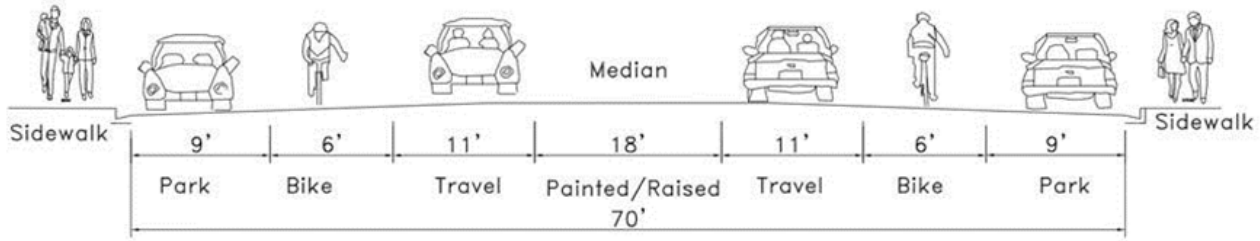
11,200 ADT

1.6 Miles

City of Pasadena Road Diet Evaluation



Existing Cross Section



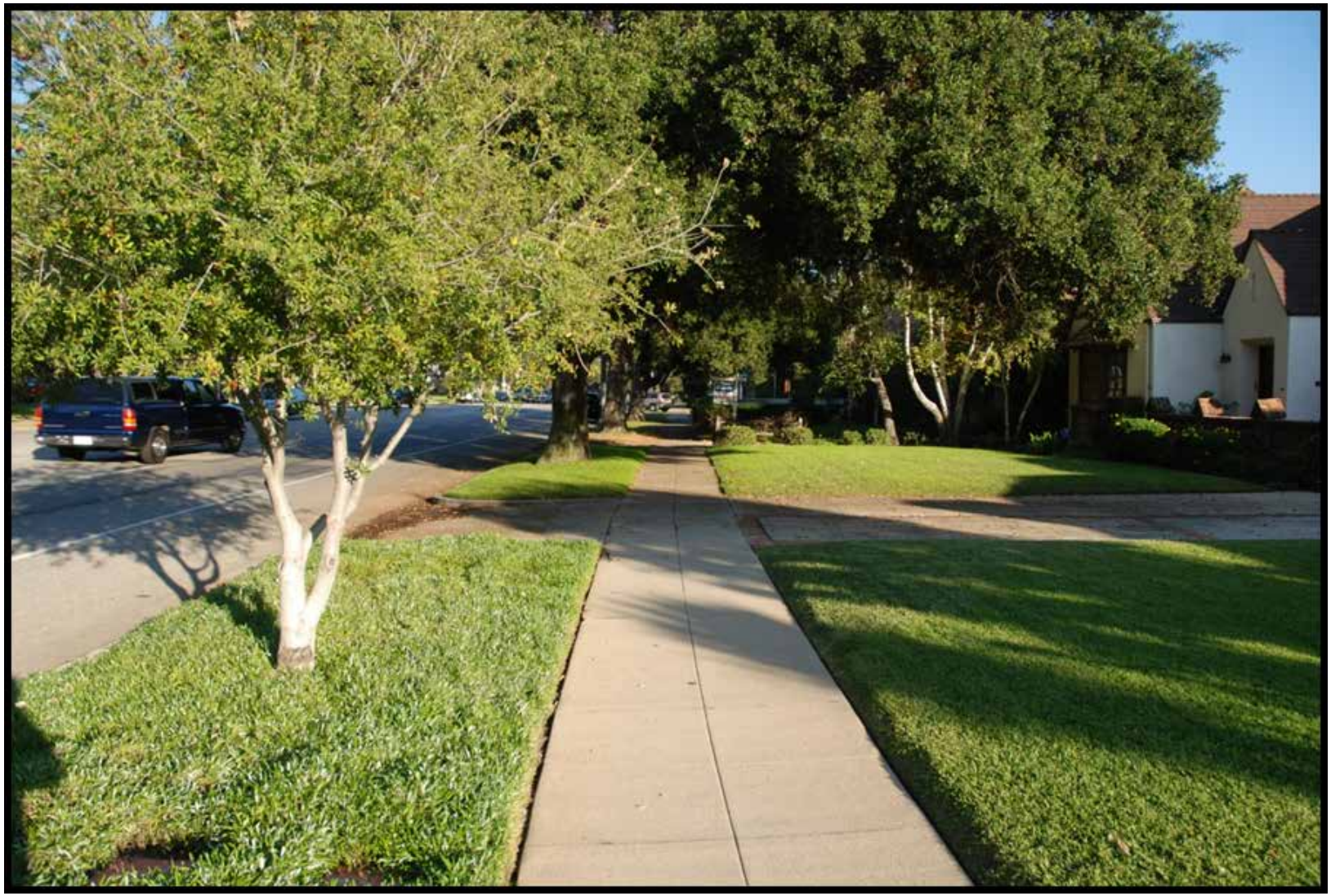
Proposed Cross Section

City of Pasadena Road Diet Evaluation

- Issues with current cross-section
  - No bicycle facilities
  - Light traffic volumes for a large right-of-way (ROW) roadway
  - Higher speeds and wider crossing width which detract from a neighborhood feel

City of Pasadena Road Diet Evaluation

City of Pasadena Road Diet Evaluation



City of Pasadena Road Diet Evaluation

§ Auto LOS Findings

- Auto is affected by slower vehicle speeds on the corridor

Orange Grove Boulevard - Facility PM					
	Mode	Existing Score (LOS)	Road Diet Score (LOS)	Difference	% Change
EB	Auto	2.33 (B)	2.57 (B)	0.24	10.3%
	Transit	3.23 (C)	3.19 (C)	-0.04	-1.2%
	Bicycle	3.44 (C)	2.73 (B)	-0.71	-20.6%
	Pedestrian	2.89 (C)	2.63 (B)	-0.26	-9.0%
WB	Auto	2.32 (B)	2.45 (B)	0.13	5.6%
	Transit	3.09 (C)	3.05 (C)	-0.04	-1.3%
	Bicycle	3.33 (C)	2.66 (B)	-0.67	-20.1%
	Pedestrian	2.84 (C)	2.58 (B)	-0.26	-9.2%

City of Pasadena Road Diet Evaluation

§ Transit LOS Findings

- Auto speed decreased (-)
- Pedestrian LOS improved (+)

Orange Grove Boulevard - Facility PM					
	Mode	Existing Score (LOS)	Road Diet Score (LOS)	Difference	% Change
EB	Auto	2.33 (B)	2.57 (B)	0.24	10.3%
	Transit	3.23 (C)	3.19 (C)	-0.04	-1.2%
	Bicycle	3.44 (C)	2.73 (B)	-0.71	-20.6%
	Pedestrian	2.89 (C)	2.63 (B)	-0.26	-9.0%
WB	Auto	2.32 (B)	2.45 (B)	0.13	5.6%
	Transit	3.09 (C)	3.05 (C)	-0.04	-1.3%
	Bicycle	3.33 (C)	2.66 (B)	-0.67	-20.1%
	Pedestrian	2.84 (C)	2.58 (B)	-0.26	-9.2%

City of Pasadena Road Diet Evaluation

Bicycle LOS Findings

- Slower auto speeds (+)
- Fewer through lanes for same volume (-)
- Exclusive bike lane (+)

Orange Grove Boulevard - Facility PM					
	Mode	Existing Score (LOS)	Road Diet Score (LOS)	Difference	% Change
EB	Auto	2.33 (B)	2.57 (B)	0.24	10.3%
	Transit	3.23 (C)	3.19 (C)	-0.04	-1.2%
	Bicycle	3.44 (C)	2.73 (B)	-0.71	-20.6%
	Pedestrian	2.89 (C)	2.63 (B)	-0.26	-9.0%
WB	Auto	2.32 (B)	2.45 (B)	0.13	5.6%
	Transit	3.09 (C)	3.05 (C)	-0.04	-1.3%
	Bicycle	3.33 (C)	2.66 (B)	-0.67	-20.1%
	Pedestrian	2.84 (C)	2.58 (B)	-0.26	-9.2%

City of Pasadena Road Diet Evaluation

Pedestrian LOS Findings

- More vehicles in lane nearest pedestrians (-)
- Increased space between auto and ped (+)
- Slower auto speeds (+)

Orange Grove Boulevard - Facility PM					
	Mode	Existing Score (LOS)	Road Diet Score (LOS)	Difference	% Change
EB	Auto	2.33 (B)	2.57 (B)	0.24	10.3%
	Transit	3.23 (C)	3.19 (C)	-0.04	-1.2%
	Bicycle	3.44 (C)	2.73 (B)	-0.71	-20.6%
	Pedestrian	2.89 (C)	2.63 (B)	-0.26	-9.0%
WB	Auto	2.32 (B)	2.45 (B)	0.13	5.6%
	Transit	3.09 (C)	3.05 (C)	-0.04	-1.3%
	Bicycle	3.33 (C)	2.66 (B)	-0.67	-20.1%
	Pedestrian	2.84 (C)	2.58 (B)	-0.26	-9.2%

Presentation Overview

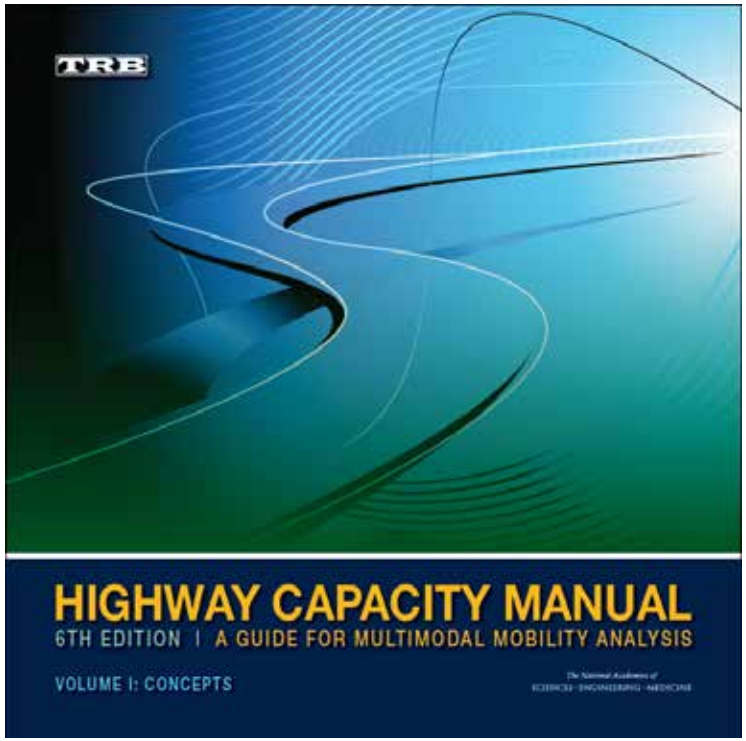
- Urban street system elements
- HCM's multimodal performance measures
- Modal perception score framework
- Case study examples
- Summary and wrap-up

Multimodal Operations Are Part of a Broader Analysis

- The HCM provides tools for multimodal operational analysis of points, segments, and facilities
- Other multimodal considerations are also important
  - Safety
  - Accessibility
  - Network connectivity
- No one tool or performance measure can tell the whole story
- Nevertheless, the HCM can be a valuable resource for evaluating trade-offs in how the street right-of-way is allocated between modes

Still More to Do...

- Research needed on multimodal quality of service for missing system elements
  - Roundabouts, all-way stops, ramp terminals, alternative intersections
- Research needed to update ped density methods for very crowded downtown environments



Resources Available on HCM Volume 4

- hcmvolume4.org
- Background of the method
  - NCHRP Report 616 (method development)
  - NCHRP Web-only Document 158 (field tests of method)
- Additional transit-specific methods and measures
  - TCRP Report 165
    - Transit Capacity & Quality of Service, 3rd Edition

Questions?

Today's Speakers

- *Kittleson & Associates:*
  - *Aaron Elias*, aelias@kittelson.com
  - *Paul Ryus*, PRyus@kittelson.com

Get Involved with TRB

- Getting involved is free!
- Join a Standing Committee (http://bit.ly/2jYRrF6)
- Become a Friend of a Committee (http://bit.ly/TRBcommittees)
  - Networking opportunities
  - May provide a path to become a Standing Committee member
- ***Sponsoring Committee: AHB40***
- For more information: www.mytrb.org
  - Create your account
  - Update your profile

TRB turns 100 on November 11, 2020

Help TRB:

- Promote the value of transportation research;
- Recognize, honor, and celebrate the TRB community; and
- Highlight 100 years of accomplishments.

Learn more at

www.TRB.org/Centennial

MOVING IDEAS: ADVANCING SOCIETY—100 YEARS OF TRANSPORTATION RESEARCH