NATIONAL ACADEMIES *Sciences Engineering Medicine*

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Pedestrian Analysis—Current Practice, Resources, and Applications

September 27, 2022

1:00 – 2:30 PM

NOVEMBER 2022 UPDATE

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Beth Ewoldsen at Bewoldsen@nas.edu

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.

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AICP Credit Information

1.5 American Institute of Certified Planners Certification Maintenance Credits

You must attend the entire webinar

Log into the American Planning Association website to claim your credits

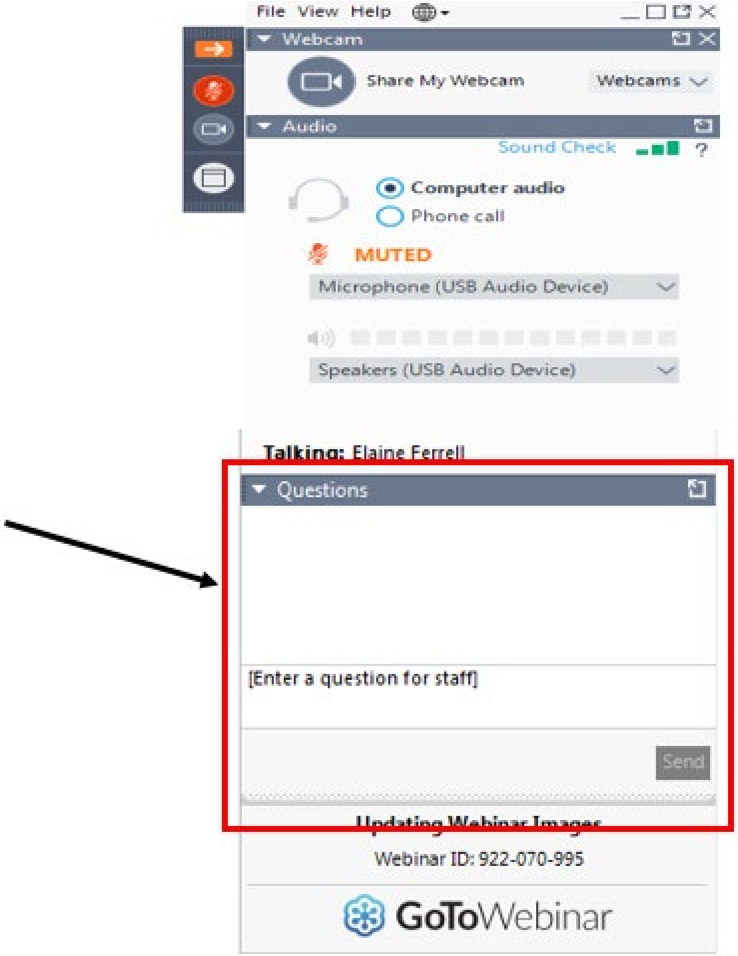
Contact AICP, not TRB, with questions

Learning Objectives

- Identify the purpose and applications for the guide
- Understand how pedestrian crossing safety countermeasures influence pedestrian satisfaction and delay
- Apply tools for predicting pedestrian delay and satisfaction at pedestrian crossings

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today’s presenters

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NCHRP Report 992

Pedestrian Analysis: Current Practice, Resources, and Applications

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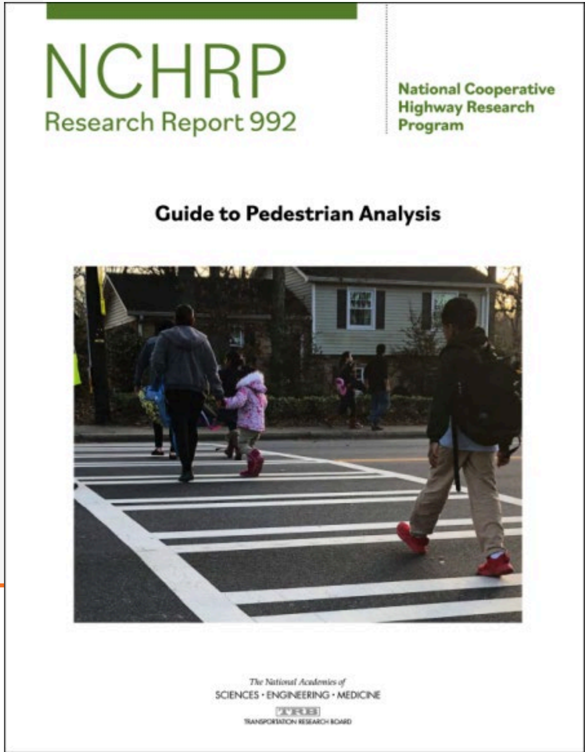


TRB Webinar | September 2022

Project Genesis and Objectives

- **Project developed by combining two research problem statements**
  - “Enhancing Pedestrian Volume Estimation and

    Developing HCM Pedestrian Methodologies for Safe and Sustainable Communities”
- **Objectives**
  - Identify techniques for efficiently and accurately estimating pedestrian volume and exposure
  - Determine factors affecting pedestrian flow at the facility level
  - Determine how pedestrian safety improvements on the roadway and in signal timing designs should be reflected in the *Highway Capacity Manual* (HCM) pedestrian level of service (LOS) methodology
  - Recommend enhancements to current HCM pedestrian methodologies

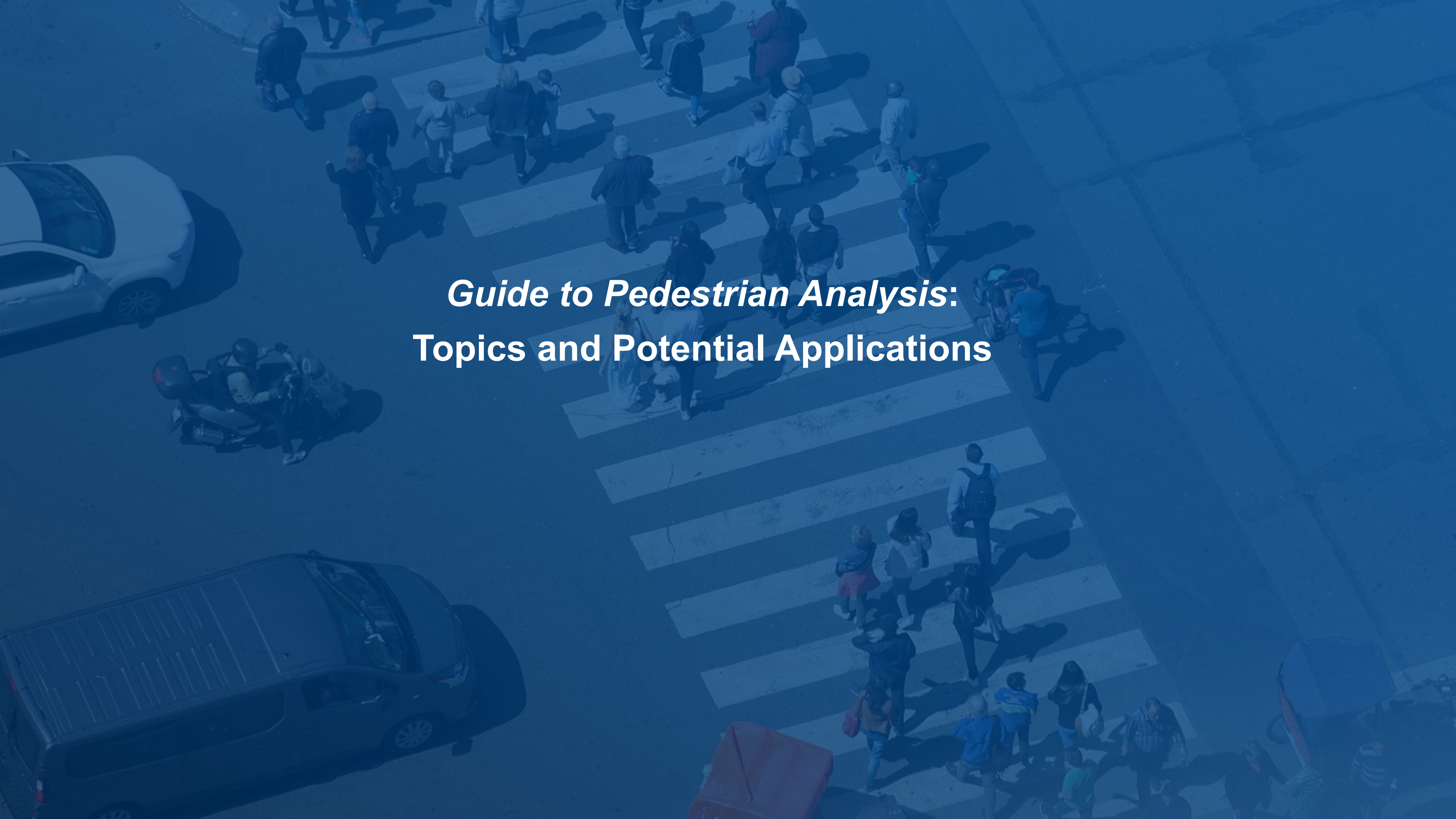
Project Approach

- **State-of-the-practice review**
  - Volume and exposure estimation, safety performance, pedestrian operations
  - Pedestrian network analysis
  - Material incorporated into *NCHRP Report 992: Guide to Pedestrian Analysis*
- **Original research**
  - Effects of pedestrian safety countermeasures on pedestrian satisfaction and delay
    - Separate NCHRP project (17-84) was addressing effects on safety
  - Improved pedestrian delay estimation methods for signalized intersections
  - Material incorporated into both *NCHRP Report 992* and HCM 7th edition (HCM7)
    - Both published in 2022

Agenda

- Guide's topics and potential applications
- Key findings on pedestrian satisfaction at crossings
- Methods and tools for predicting pedestrian satisfaction and delay

Guide to Pedestrian Analysis: Topics and Potential Applications



Types of Pedestrian Performance Measures

- **Operations**
  - Pedestrian counterparts to motor vehicle measures
  - Delay, density, flow, space, capacity
- **Quality of Service**
  - Measures of how well pedestrian facilities operate from a pedestrian's perspective
  - Incorporates multiple factors that a roadway agency can influence
    - Examples: sidewalk width, separation from traffic, traffic volume/speed, ped delay
- **Walkability**
  - Measures of facility attractiveness to pedestrians
  - Adjacent land use, aesthetics, wayfinding, sun/shade, safety/security, functionality

Kittelson & Associates / Kelly Blume

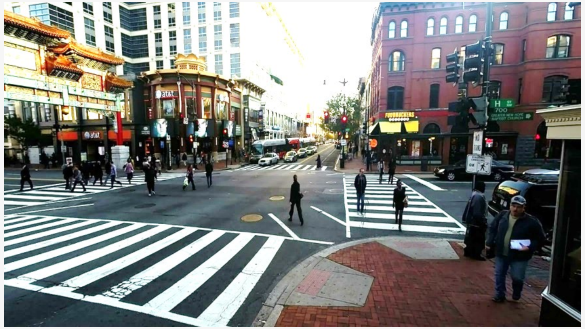
Kittelson & Associates / Lee Rodegerdts

pedbikeimages.org/Dan Burden

Pedestrian Operations Application Examples

- **Designing sidewalk/facility width to accommodate a given number of pedestrians**
  - Special events (e.g., sports events, concerts, fairs)
  - Large city downtowns, cruise ship ports
  - Allocating space for business uses (e.g., café seating, outdoor displays)
  - Off-street paths
- **Providing sufficient space to store and serve pedestrians**
  - Transit stops
  - Pedestrian storage and circulation at signalized intersection street corners
  - Pedestrian interactions and platooning while using signalized crosswalks
- **Evaluating pedestrian delay**
  - Likelihood of risky behavior
  - Comparing delay by mode, estimating overall person delay

Kittelson & Associates / Paul Ryus



Kittelson & Associates / Alex Pochowski

Pedestrian Operations Influences Safety

Kittelson & Associates / Paul Ryus

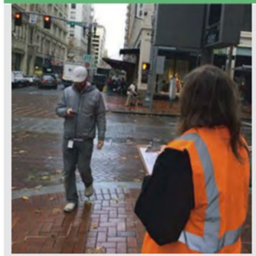
- **Persons spill out of the sidewalk circulation zone before the sidewalk's capacity is reached**
  - For example, walking in the street to get around slower pedestrians
- **Likelihood of crossing against the traffic signal increases as pedestrian delay increases**
  - Very likely to comply with signals when expected delay is ≤10 seconds
  - Pedestrians become impatient when delays >30 seconds
- **Pedestrian operations methods used in building & passenger facility design**
  - For example, time required to clear a subway platform and get passengers out of the station in case of fire

Pedestrian Safety Analysis Application Examples

- **Supporting decision-making related to improving pedestrian safety (e.g., estimating exposure)**
  - Select counting methods (e.g., is a screenline count or an intersection count needed? Is a short-term or long-term count needed? Are there site constraints?)
  - Estimate pedestrian volumes
  - Estimate pedestrians' exposure to crash risk

Toolbox 2-1. Common methods for collecting pedestrian counts.

Counting Methods



Source: Kittelson & Associates, Inc.

Manual counts in the field can be collected by using paper sheets, traffic count boards, clicker counters, or smartphone apps. They are most appropriate for short-duration counts. Data collectors can capture pedestrian crossing volumes at an intersection or screenline counts along a roadway or path.

Typical Usage

Manual counts are typically used to obtain supplemental data such as age, gender, use of a mobility aid, or pedestrian signal compliance; when an intersection count is desired; or when a multimodal count (e.g., cars, trucks, bicycles, pedestrians) is desired. Counts can be performed by agency staff, consultants, or volunteers; in all cases, data collector training is essential to obtain good results.

Advantages
- Can be accurate with training
- Can capture directional counts and user characteristics
- Minimal equipment costs

Disadvantages
- High labor cost
- Only for short-term counts
- Data cannot be verified

Ease of Installation
- Requires data collector training

Cost
- Very high

Source: Kittelson & Associates, Inc.

Manual counts from video are considered the most accurate method of collecting bicycle and pedestrian counts, since the video can be paused or rewound as necessary to accurately count large volumes or groups of pedestrians. As with manual field counts, user characteristics such as gender, age, and pedestrian signal compliance can also be collected. While manual counts are relatively inexpensive for short-duration counts, they are unsuitable for longer counts because of high labor costs when the data are being reduced.

Typical Usage

Manual counts from video have a similar application to manual counts in the field but are typically collected by a specialized data collection firm. A practitioner survey found that 44% of respondents who performed pedestrian counts used manual counts from video data as part of their pedestrian data collection program (*2*).

Advantages
- High accuracy
- Can capture directional counts and user characteristics
- Fewer personnel than in-field counts
- Data can be verified

Disadvantages
- High labor cost

Ease of Installation
- Requires video camera set-up

Cost
- Very high

Pedestrian Safety Analysis Application Examples, cont

- **Selecting safety analysis methods**
  - Crash-based
  - Systemic (risk-based)
  - Hybrid (both crash-based and systemic)
- **Selecting risk factor-appropriate pedestrian safety countermeasures, e.g.:**
  - Raised crosswalk/speed table
  - Median crossing (refuge) island
  - R1-6 sign installed as a gateway treatment
  - Pedestrian hybrid beacon
  - Leading pedestrian interval
  - Rectangular rapid-flashing beacon
  - Curb extension
  - Pedestrian lighting

Table 3-2. Examples of pedestrian safety countermeasures.

Countermeasure	CMF or Other Estimated Pedestrian Safety Benefit	Example
High-visibility crosswalk—vertically arranged street markings designed to improve the visibility of the crosswalk as compared with traverse parallel lines.	0.52 in urban locations (*35*) 0.63 for high-visibility yellow/green markings in urban school zones (*36*) In both studies, high-visibility markings replaced standard parallel markings.	 Source: pedbikeimages.org/Dan Burden.
Raised crosswalk/speed table—an elevated section of pavement with a marked crosswalk to encourage drivers to slow down.	0.55 (*37*) for areawide traffic calming	 Source: pedbikeimages.org/Brandon Whyte.

Pedestrian Quality of Service Application Examples

- **Evaluating pedestrian satisfaction using specific facilities**
  - Crossing a street
  - Walking along a street
  - Using an off-street path
- **Evaluating user satisfaction changes when street space is reallocated among modes**
  - Motor vehicle drivers & passengers
  - Pedestrians
  - Bicyclists
  - Transit passengers

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Factors Affecting Pedestrian Quality of Service

- **Assessing the "effectiveness" of countermeasures**
  - Reduce serious crashes
  - Increasing driver yielding
  - Improve pedestrian satisfaction
- **Predicting distributions of pedestrian who would be satisfied with their crossing experience based on:**
  - their probability of crossing without delay
  - the type(s) of crossing treatment used (i.e., unmarked crosswalk, marked crosswalk, median refuge island, RRFB)

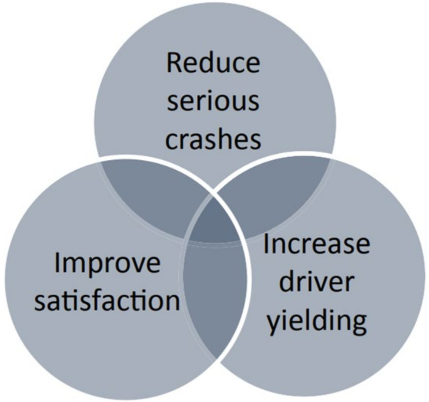


Figure 3-4. Evaluation of countermeasure effectiveness.

Table A-1. Level-of-service criteria for pedestrian satisfaction at uncontrolled crossings.

LOS	Condition	Level of Satisfaction
A	$P_D < 0.05$	Nearly all pedestrians would be satisfied.
B	$0.05 \le P_D < 0.15$	At least 85% of pedestrians would be satisfied.
C	$0.15 \le P_D < 0.25$	Less than one-quarter of pedestrians would be dissatisfied.
D	$0.25 \le P_D < 0.33$	Less than one-third of pedestrians would be dissatisfied.
E	$0.33 \le P_D < 0.50$	Less than one-half of pedestrians would be dissatisfied.
F	$P_D \ge 0.50$	The majority of pedestrians would be dissatisfied.

Note: LOS = level of service; P_D = proportion of pedestrians giving a rating of dissatisfied or worse.
Source: *NCHRP Web-Only Document 312* (*5*).

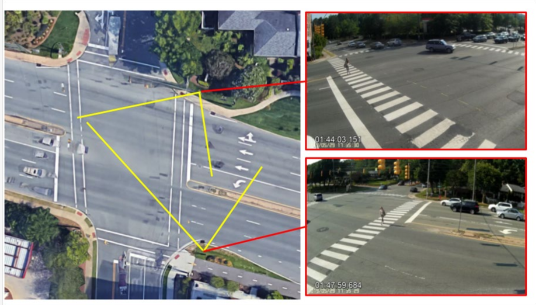
Key Findings on Pedestrian Satisfaction at Pedestrian Crossings

Methods

- **Three-pronged approach:**
  - Field surveys of pedestrians + video to identify the conditions experienced by surveyed pedestrians
    - Relate pedestrian satisfaction to crosswalk-related factors
  - Longer-duration video observations of pedestrian–vehicle interactions at same crosswalks on different days
    - Do countermeasures affect these interactions?
  - Data from naturalistic walking study at same crosswalks, when participants happened to pass through them
    - Measure participants’ stress levels using biosensing wristbands

Data Collection

- Data collection in 2 cities
  - Chapel Hill, NC (spring 2019)
  - Portland, OR (summer 2019)
- Three countermeasures (RRFBs, LPIs, median islands)
  - 10 treated sites & 10 control sites per countermeasure
  - Control sites matched to treated sites based on
    - Posted speed
    - AADT
    - Number of through lanes
    - Travel direction (one-way or two-way)
- Control sites a mix of marked and unmarked crosswalks

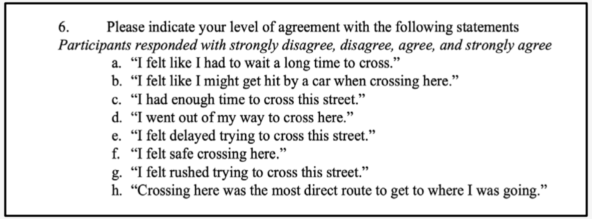


Surveys

- Pedestrians intercepted after making crossing
- Asked to rate satisfaction with crossing experience
  - Very satisfied, satisfied, dissatisfied, very dissatisfied
- Asked about trip purpose, trip length, familiarity with crossing, and if diverted to use the crossing
- Video observations of surveyed pedestrians
  - Delay, motorist yielding, avoidance maneuvers
- Field data collection about site characteristics
- Crossing ratings compared to crossing experiences


How would you rate your crossing experience?

- Very satisfied
- Satisfied
- Dissatisfied
- Very dissatisfied


6. Please indicate your level of agreement with the following statements

Participants responded with strongly disagree, disagree, agree, and strongly agree

a. "I felt like I had to wait a long time to cross."
b. "I felt like I might get hit by a car when crossing here."
c. "I had enough time to cross this street."
d. "I went out of my way to cross here."
e. "I felt delayed trying to cross this street."
f. "I felt safe crossing here."
g. "I felt rushed trying to cross this street."
h. "Crossing here was the most direct route to get to where I was going."

Uncontrolled Pedestrian Crossing Findings

- Surveyed **435** pedestrians immediately after they had crossed one of **40** uncontrolled crossings in Chapel Hill, NC and Portland, OR
- **Results**
  - Pedestrians' satisfaction was mostly determined by **feeling safe** and **not delayed** when crossing the street
  - RRFBs (w/ median islands) and median islands alone offered pedestrians stronger perceptions of safety and unhindered travel than marked and unmarked crosswalks
  - Strong inverse relationship between speed limit and satisfaction

Median Island

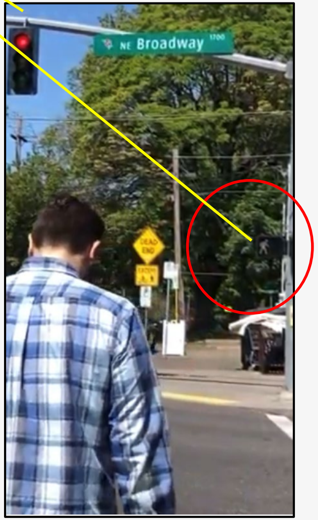
RRFB

Unmarked Crossing

Signalized Intersections Findings

- Surveyed **267** pedestrians immediately after they had crossed one of **20 signalized crossings with and without LPIs** in Chapel Hill, NC and Portland, OR
- **Results**
  - Pedestrians' satisfaction was mostly determined by **feeling safe** and **not delayed** when crossing the street
  - **Little difference** between satisfaction levels for the signalized crossings **with and without LPIs**
  - Increase in **left-turning volume** for minor roads associated with decrease in satisfaction

Signalized Intersection with LPI

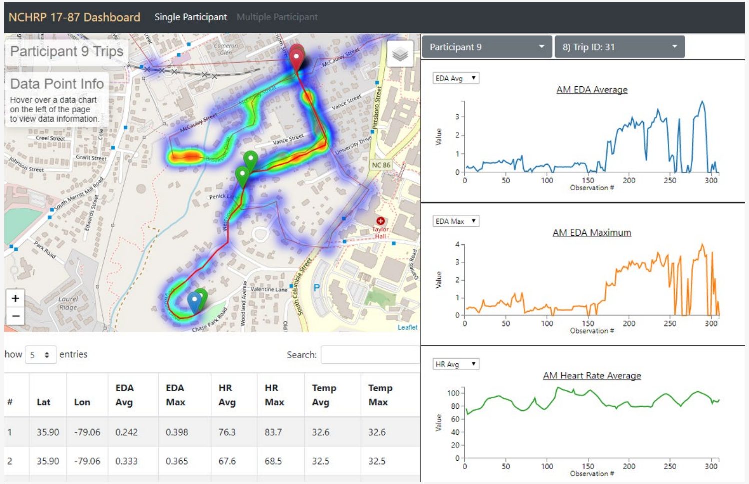


Video Observation Findings

- •Looked at pedestrian delay, crossing time, percent yielding, percent crossings with no vehicle interaction, percent legal crossers, percent 2-stage crossers
- •Uncontrolled crossings
- •Motorist yielding rates higher at treated (RFFB, median island) sites than at untreated (marked/unmarked xwalk) sites
- •Signalized crossings
- •Pedestrian signal compliance better at LPI sites than at control sites

Naturalistic Walking Study

- Purposes:
  - Compare survey and video observations with pedestrian stress readings at study crosswalks
  - Evaluate variations in pedestrian stress during trip
- 15 recruited participants made normal walking trips over the course of a week
  - Wore Empatica E4 biosensing wristband
    - Measures skin conductance (stress), heart rate
  - Carried GPS unit
    - Provides location to match to wristband data

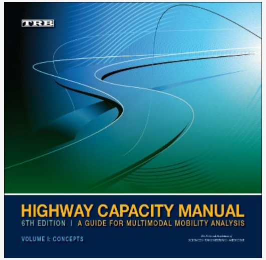


Naturalistic Study Findings

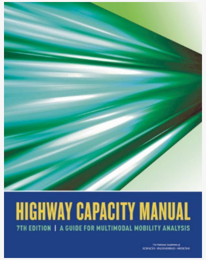
- No significant relationship found between stress and
  - Crossings at study sites
  - Crossings generally
- Stress level
  - Higher on collector & arterial roadways
  - Higher in industrial and mixed-use environments
  - Lower in low-density residential, forest, park, and university campus settings
- Heart rate
  - Higher on collectors & in industrial, mixed-use settings
  - Lower on paths & in environments with AADT < 4,000

Methods and Tools for Predicting Pedestrian Delay and Satisfaction

Pedestrian Analysis Methods in the HCM



- **HCM6 methods**
  - Uncontrolled crossings
    - Pedestrian delay
  - Signalized crossings
    - Pedestrian delay (one leg, one stage)
    - Pedestrian quality of service (QOS)
  - Urban streets
    - Pedestrian density
    - Pedestrian QOS
  - Off-street paths
    - Pedestrian density
    - Number of bicycle meeting/passing events



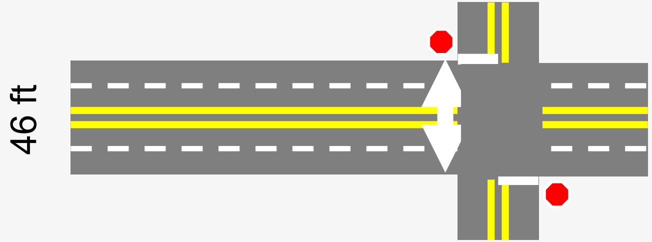
- **New and *updated* methods in HCM7**
  - Uncontrolled crossings
    - *Pedestrian delay* (driver yielding)
    - **Pedestrian satisfaction**
  - Signalized crossings
    - **Pedestrian delay** (multiple legs, multiple stages, signal phasing options)
  - Urban streets
    - *Pedestrian QOS* (street-crossing difficulty)

Uncontrolled Pedestrian Crossings: Methods

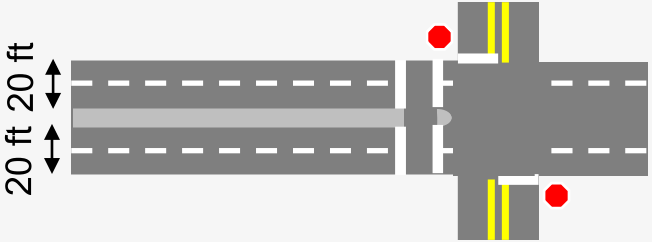
- Method to estimate average pedestrian delay is sensitive to
  - Crossing width
  - Assumed pedestrian speed (e.g., average pedestrian, 15th-percentile pedestrian)
  - Traffic volume
  - Motorist yielding behavior
- Method to estimate average pedestrian (dis)satisfaction making the crossing is sensitive to
  - Ability to cross immediately (adequate gap)
  - Delay if not able to cross immediately
  - Daily traffic (relates to street width/speed)
  - Specific crossing treatments
    - Marked crosswalk, median island, RRFB (studied treatments)
    - Any treatment that improves yielding or shortens crossing distances will show a satisfaction benefit

NCHRP Project 17-87 data collection

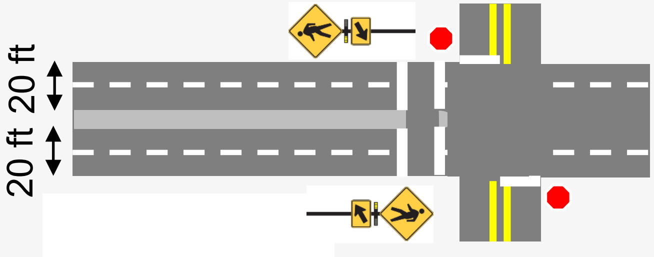
Uncontrolled Pedestrian Crossings: Example Calculation



- 1,700 veh/h (peak hour), 50/50 directional split, AADT = 21,250, average ped
- **Existing crossing:**
  - Locally measured yielding rate = 0%
  - P(delayed crossing) = 99.7%, average delay >> 60 s
  - P(dissatisfaction) = 86% → LOS = F



- **Add median island and crosswalk markings:**
  - Locally measured yielding rate = 50%
  - P(delayed crossing) = 76%, average delay = 6 s
  - P(dissatisfaction) = 21% → LOS = C



- **Also add rectangular rapid-flashing beacons (RRFBs):**
  - Locally measured yielding rate = 80%
  - P(delayed crossing) = 76%, average delay = 3 s
  - P(dissatisfaction) = 3% → LOS = A

Uncontrolled Pedestrian Crossings: Motorist Yielding

- **Project compiled information about yielding rates for various safety countermeasures**
- **Added new data collected during the project**
- **Yielding rates for same treatment vary by location**
  - Differences in posted speed, pedestrian activity, driver culture, enforcement practices, etc.
- **Recommend using local yielding rates when available**

	Yield Rate (%)		Sample Size
Crossing Treatment	**Average**	**Range**	**(sites)**
No treatment (unmarked)	24	0–100	37
Crosswalk markings only (any type)	33	0–95	58
Crosswalk markings, plus:			
Pedestal-mounted flashing beacon	26	0–52	2
Overhead sign	35	12–57	2
Overhead flashing beacon (push-button activation)	51	13–91	14
Overhead flashing beacon (passive activation)	73	61–76	29
In-roadway warning lights	58	53–65	11
Median refuge island	60	0–100	21
Pedestrian crossing flags	74	72–80	6
In-street pedestrian crossing signs	76	35–88	20
Rectangular rapid-flashing beacon (RRFB)	82	31–100	64
School crossing guard	86	—	1
School crossing guard and RRFB	92	—	1
Pedestrian hybrid beacon (HAWK)	91	73–99	37
Mid-block crossing signals, half signals	98	94–100	13

HCM7, Exhibit 20-28

Uncontrolled Pedestrian Crossings: Potential Applications

- **Can compare potential crossing treatments on the basis of**
  - Safety (NCHRP Project 17-84, future HSM 2)
  - Pedestrian delay (NCHRP 992/HCM7)
  - Pedestrian satisfaction (NCHRP 992/HCM7)

- **Can incorporate pedestrian delay into a broader analysis**
  - Evaluate overall person delay
  - Compare delay of an average pedestrian with that of a slower pedestrian
  - Estimate likelihood of risky behavior

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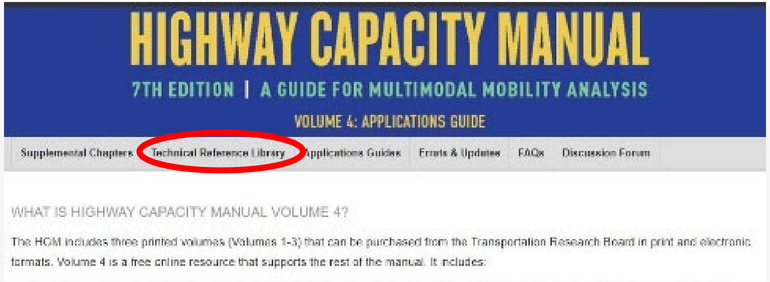
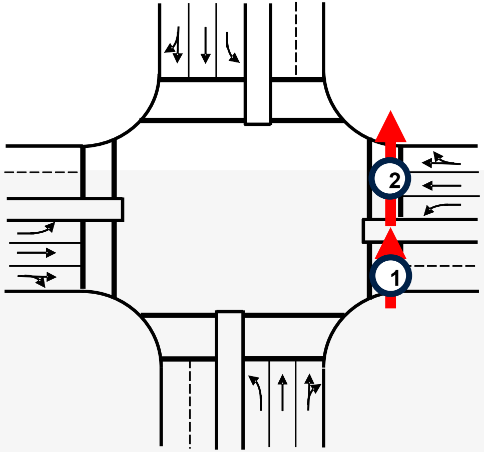
Uncontrolled Pedestrian Crossings: Tool

- **Spreadsheet computational engine for estimating delay, satisfaction, pedestrian LOS**
- **Available on HCM Volume 4**
  - HCMVolume4.org
  - Site requires free, one-time registration
  - Don't need to own the HCM to access the site
  - Technical Reference Library section > Chapter 20
    - "Uncontrolled Pedestrian Crossing LOS and Delay Computational Engine (Build 2022-05-04)"

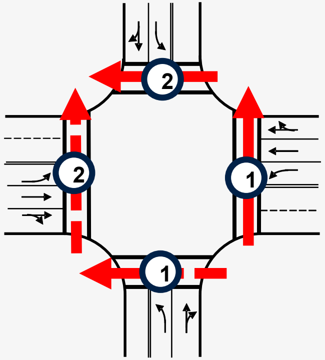


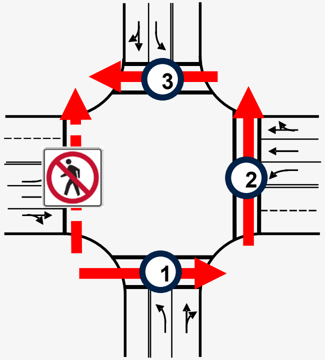
	A	B	C	D	E	F	G	H	I
1	Scenario	**Existing**	**Mitigated**				**Yielding Rate**		
2	Crossing type	Median island	Island + RRFB		**Crossing Type**	**Worse**	**Average**	**NCHRP 17-87**	**Custom**
3	AADT	21,250	21,250		Unmarked	0.00	0.24	0.21	0.24
4	*K*-factor	0.08	0.08		Marked	0.20	0.33	0.56	0.33
5	Peak-hour vehicular flow rate (veh/h) (optional)				Median island	0.50	0.60	0.80	0.60
6	Initial crossing width, L (ft)	20	20		RRFB	0.70	0.82	0.79	0.82
7	Total crossing width (lanes)	4	4		Island + RRFB	0.80	0.88	0.93	0.88
8	Ped speed, S_p (ft/s)	4.0	4.0						
9	Ped start-up and end clearance time, t_s (s)	1.0	1.0		**Variable**	**Coefficient**	**Existing**	**Mitigated**	
10	Yielding behavior	Worse	Worse						
11					KAADT	-0.0438	21.250	21.250	
12	Critical headway, t_c (s)	6.0	6.0		RRFB	1.9572	0	1	
13	Vehicular flow rate, v (veh/s)	0.236	0.236		Marked	0.9843	1	1	
14	Group critical headway, $t_{c,G}$ (s)	6.0	6.0		Median Island	1.5496	1	1	
15	Motorist yielding rate, M_y	50%	80%		Intercept	0.9951	1	1	
16	First-stage width, N_L (lanes)	2	2		Delayed	-1.9059	1	1	
17	Probability of a blocked lane, P_b	50.75%	50.75%						
18	Probability of a potentially delayed crossing, P_d	75.75%	75.75%						
19	Probability of all blocking vehicles yielding on the first potential yielding event, $P(Y_1)$	31.43%	56.48%						
20	Probability of a non-delayed crossing, P_{nd}	48.06%	67.03%						
21									
22									
23	Log odds (no delay)	2.60	4.56						
24	Odds (no delay)	13.44	95.15						
25	Satisfied probability (no delay)	93.1%	99.0%						
26	**Dissatisfied probability (no delay)**	**6.9%**	**1.0%**						
27	Log odds (slowed)	0.69	2.65						
28	Odds (slowed)	2.00	14.15						
29	Satisfied probability (delay)	66.6%	93.4%						
30	**Dissatisfied probability (delay)**	**33.4%**	**6.6%**						
31	**Dissatisfied Probability (weighted)**	**20.7%**	**2.9%**						
32	**LOS**	**LOS C**	**LOS A**						

Signalized Pedestrian Crossings: Delay Method



- **HCM7 adds delay estimation methods for additional crossing situations**
  - One leg in two stages
  - Two legs in two stages
  - Crosswalk closure (three-leg crossing vs. one-leg)
  - Exclusive pedestrian phases
  - Coordinated actuated signal with permissive period
  - Free signal operation
- **Methods sensitive to**
  - Signal timing
  - Crosswalk lengths
  - Assumed pedestrian speed



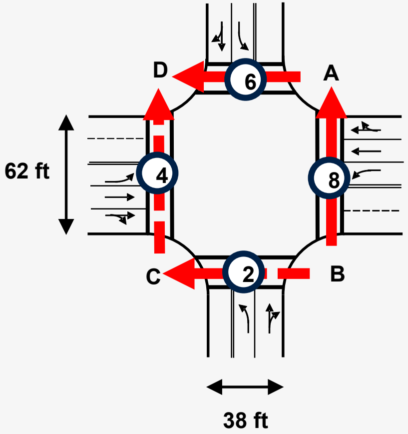


Signalized Pedestrian Crossings: QOS Method

- **HCM7 retains the previous HCM method for evaluating pedestrian crossing satisfaction**
- **Method sensitive to**
  - Conflicting traffic volume, traffic speed
  - Pedestrian delay
  - Number of traffic lanes crossed
  - Channelizing island presence
- **Can be applied to individual signalized crossings or combined when evaluating a longer stretch of street (HCM "segment" or "facility")**
- **Produces a "pedestrian level of service index" value**
  - Index value (1 = best, 6 = worst) can be converted to a level of service A-F letter if desired, or used on its own

Kittelson & Associates / Paul Ryus

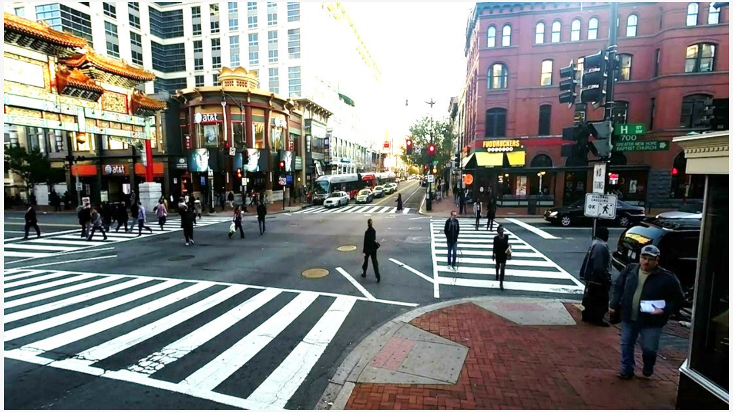
Signalized Pedestrian Crossing: Example Delay Calculation



- Cycle length = 90 s, actuated (push button to cross) ped phases
- Walk displayed for 5 s for all ped phases
- Relative start time of ped phases: Φ2 = 11 s, Φ4 = 61 s, Φ6 = 13 s, Φ8 = 59 s
- **Crossing from Corner "B" to Corner "D":**
  - Average delay if using Phases 2 & 4 = 50.5 s
  - Average delay if using Phases 8 & 6 = 40.2 s
  - Based on the signal timing, a randomly arriving pedestrian at Corner "B" would be served first by Phase 8 53.3% of the time
  - Average delay for the diagonal crossing is the probability-weighted average of the two choices = 45.0 s
- Method (but not yet the computational engine in full) can also accommodate skewed intersections with parallel crosswalks having different lengths

Signalized Pedestrian Crossings: Potential Applications

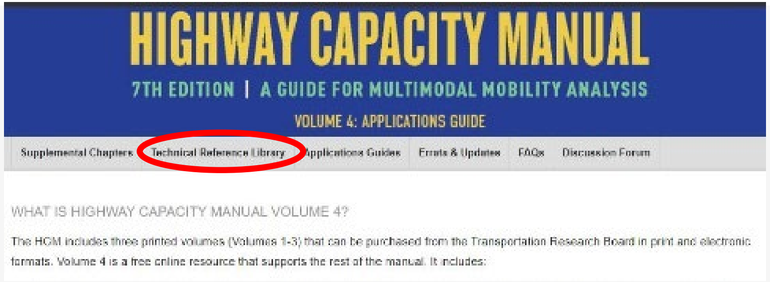
- **Optimize signal timing to minimize pedestrian delay**
- **Analyze overall person delay for the intersection** (motorists, pedestrians, bicyclists, transit passengers)
- **Compare different signal phasing and crosswalk design options**
- **Compare delay of an average pedestrian with that of a slower pedestrian**
- **Estimate likelihood of risky behavior** (crossing on red)
- **Crosswalk-closure method could be extended to analyze a series of crosswalks along a path**
  - For example, through alternative intersection forms such as restricted crossing U-turn intersections
- **Evaluate pedestrian satisfaction** (using pre-existing HCM method)

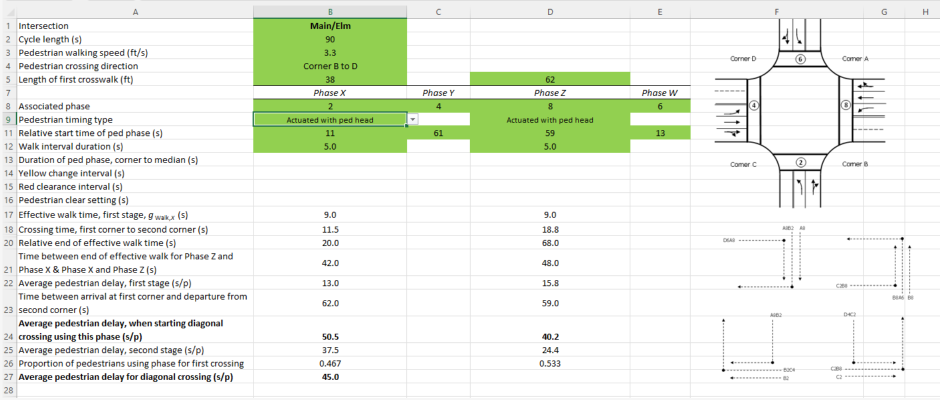


Kittelson & Associates / Alek Pochowski

Signalized Pedestrian Crossings: Tool

- **Spreadsheet computational engine for estimating delay**
  - One leg, one stage
  - One leg, two stages
  - Two legs, two stages
- **Available on HCM Volume 4**
  - HCMVolume4.org
  - Technical Reference Library section > Chapter 19
    - "Signalized Pedestrian Crossing Delay Computational Engine (Build 2022-06-17)"





	A	B	C	D	E
1	Intersection	**Main/Elm**			
2	Cycle length (s)	90			
3	Pedestrian walking speed (ft/s)	3.3			
4	Pedestrian crossing direction	Corner B to D			
5	Length of first crosswalk (ft)	38		62	
7		*Phase X*	*Phase Y*	*Phase Z*	*Phase W*
8	Associated phase	2	4	8	6
9	Pedestrian timing type	Actuated with ped head		Actuated with ped head	
11	Relative start time of ped phase (s)	11	61	59	13
12	Walk interval duration (s)	5.0		5.0	
13	Duration of ped phase, corner to median (s)				
14	Yellow change interval (s)				
15	Red clearance interval (s)				
16	Pedestrian clear setting (s)				
17	Effective walk time, first stage, $g_{Walk,X}$ (s)	9.0		9.0	
18	Crossing time, first corner to second corner (s)	11.5		18.8	
20	Relative end of effective walk time (s)	20.0		68.0	
21	Time between end of effective walk for Phase Z and Phase X & Phase X and Phase Z (s)	42.0		48.0	
22	Average pedestrian delay, first stage (s/p)	13.0		15.8	
23	Time between arrival at first corner and departure from second corner (s)	62.0		59.0	
24	**Average pedestrian delay, when starting diagonal crossing using this phase (s/p)**	**50.5**		**40.2**	
25	Average pedestrian delay, second stage (s/p)	37.5		24.4	
26	Proportion of pedestrians using phase for first crossing	0.467		0.533	
27	**Average pedestrian delay for diagonal crossing (s/p)**	**45.0**			
28					

Urban Streets: Multimodal LOS

- Method already in the HCM, minor update by NCHRP Project 17-87 to address street-crossing difficulty
- Method designed for analysts to compare trade-offs of reallocating the street right-of-way
- Pedestrian and bicycle LOS indexes predict how modal users would rate their experience (1 = best, 6 = worst)
- Pedestrian and bicycle index values are directly comparable to each other
- Index values can be used as-is and/or converted to a LOS letter (A-F)

Kittelson & Associates / Chris Romano

Urban Street Multimodal LOS Index Factors

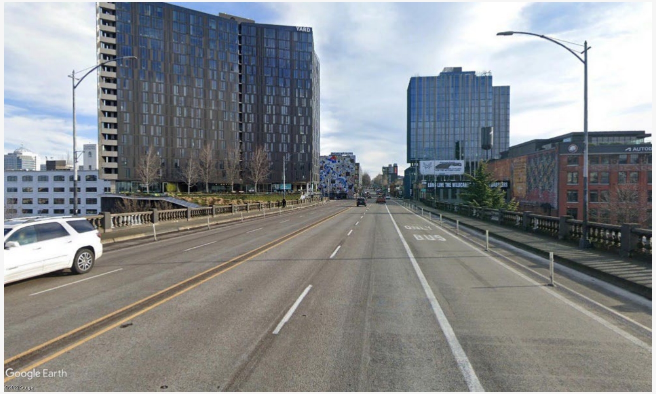
- **Pedestrian factors: Links** (between signals)
  - Sidewalk width (no sidewalk = 0 ft)
  - Separation from traffic (including landscape buffers, bike lanes, parking lanes, and shoulder when present)
  - Motorized vehicle volume and speed
  - On-street parking presence and occupancy, physical buffer presence (e.g., street trees, bollards)
- **Additional ped factors: Segments** (link + downstream signalized crossing)
  - Pedestrian LOS index for the crossing
  - Street-crossing difficulty between signals
- **Similar types of factors for the bicycle mode**
  - Includes heavy vehicle percentage, pavement quality
- **Transit index based on how ridership changes in response to changes in QOS (e.g., frequency, crowding, reliability, speed)**

Kittelson & Associates / Dorett Oosterhoff

Example: Street Cross-Section Reallocation

- **Burnside Bridge, Portland, OR**
- **2014**
  - 6-foot sidewalk
  - 6-foot bicycle lane
  - Three 12-foot lanes eastbound
  - 1,932 veh/h eastbound, posted speed = 30 mph
  - 11 buses/hour, all seats full
- **2022**
  - 6-foot sidewalk
  - 6-foot bicycle lane with 1.5-foot buffer
  - 10.5-foot bus lane
  - Two 10.5-foot travel lanes
  - For sake of example, all other values unchanged

Kittelson & Associates / Lee Rodegerdts



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Example: Street Cross-Section Reallocation

- **2014**
  - Automobiles: 18.3 mph average speed (including signal delay) = LOS C
  - Pedestrians: LOS score = 3.17 = LOS C
  - Bicycles: LOS score = 2.80 = LOS C
  - Buses: 10.9 mph average speed, LOS score = 2.40 = LOS B
- **2022**
  - Automobiles: 10.3 mph average speed = LOS F
  - Pedestrians: LOS score = 1.33 = LOS A
  - Bicycles: LOS score = –5.42 = LOS A
  - Buses: 12.9 mph average speed, LOS score = 1.91 = LOS A

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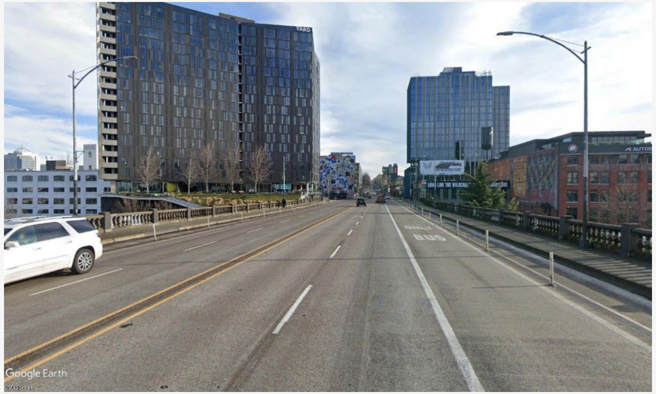
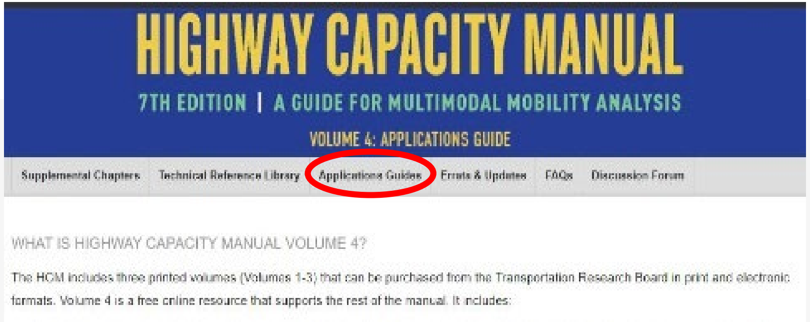


Urban Street Multimodal LOS: Tool

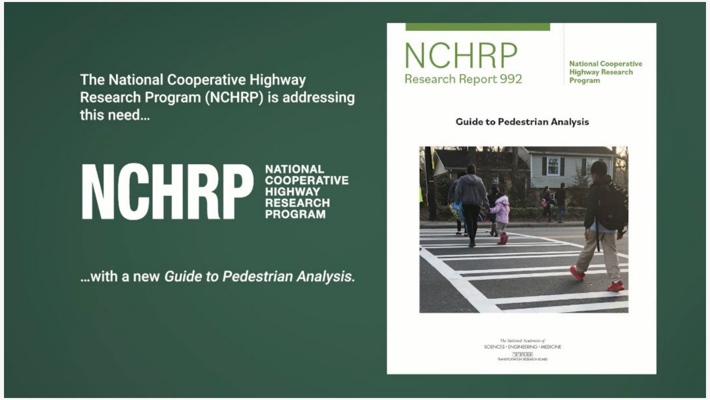
- **Spreadsheet computational engine for estimating LOS**
  - Pedestrians, bicycles, transit
  - Link-level calculation (i.e., between intersections)
- **Available on HCM Volume 4**
  - HCMVolume4.org
  - Applications Guide section > Planning Guide (PPEAG) > Computational Engines
    - “Urban street multimodal LOS planning tool (Build 2018-06-21)”



	A / B	C	D	E	F	G	H
1	**PART 1: INPUT DATA**						**Street Name and Direction**
2	Cross street at end of section	Alder St	Beech St	Cedar St	Date St	Elm St	Fir St
3			*Traffic Characteristics*				
4	Traffic volume in direction of travel (veh/h)	500	706	809	9	978	925
5	% heavy vehicles	3%	5%	5%	2%	5%	5%
6	% segment with occupied on-street parking	50%	50%	50%	0%	50%	50%
7	Midblock vehicle speed or speed limit (mph)	50	35	35	30	35	35
8			*Roadway Geometry and Condition*				
9	Number of through lanes in direction of travel	2	2	2	1	2	2
10	Median presence	Yes	No	No	No	No	No
11	Outside travel lane width (ft)	12.0	12.0	12.0	12.0	12.0	12.0
12	Bicycle lane width (ft)	6.0	0.0	0.0	5.0	0.0	0.0
13	Parking lane/shoulder width (ft)	8.0	8.0	8.0	0.0	8.0	8.0
14	Gutter width (ft)	1.0	1.0	1.0	1.0	1.0	1.0
15	Landscape strip/furnishing zone width (ft)	0.0	0.0	0.0	5.0	0.0	0.0
16	Sidewalk width (ft)	14.0	10.0	10.0	8.0	7.0	5.0
17	Street tree/barrier presence	No	No	No	Yes	Yes	No
18	Pavement condition rating (5 = excellent, 1 = poor)	3.5	3.5	3.5	3.5	3.5	3.5
19			*Transit Service*				
20	Bus stop presence	Yes	Yes	Yes	Yes	Yes	Yes
21	Bus frequency - local (bus/h)	4	2	4	4	4	4
22	Bus frequency - express (bus/h)	0	0	5	0	0	0
23	Shelter provided	Yes	No	Yes	No	No	No
24	Bench provided	Yes	No	Yes	No	No	No
25	Passenger load - local	All seats full	Many seats avail.	Many seats avail.	Many seats avail.	Many seats avail.	Many seats avail.
26	Passenger load - express			Some standees			
27	Actual or scheduled bus speed - local (mph)	12.5	17.5	7.5	7.5	7.5	7.5

Resources and More Information

- **NCHRP Website** (https://www.trb.org/Publications/Blurbs/182687.aspx)
  - *NCHRP Research Report 992: Guide to Pedestrian Analysis*
  - Project final report: NCHRP Web-only Document 312
  - Video introducing the guide
  - Additional presentation materials
- **HCM Volume 4** (https://www.HCMVolume4.org)
  - Latest versions of the computational engines
  - Example problems in the Supplemental Chapters section
    - Chapter 31: Signalized Intersections: Supplemental
    - Chapter 32: Two-Way Stop-Controlled Intersections: Supplemental
- **HCM 7th Edition**
  - Methods incorporated into Chapters 18 (urban streets), 19 (signalized crossings), and 20 (uncontrolled crossings)
    - Methods also documented in NCHRP Report 992, Appendix A



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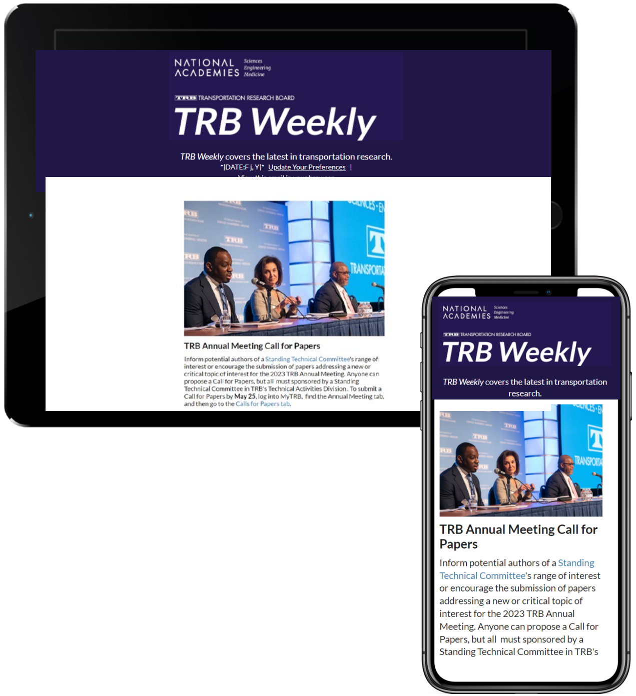

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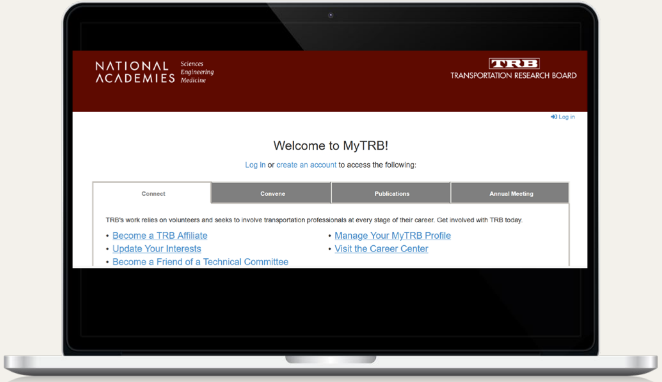

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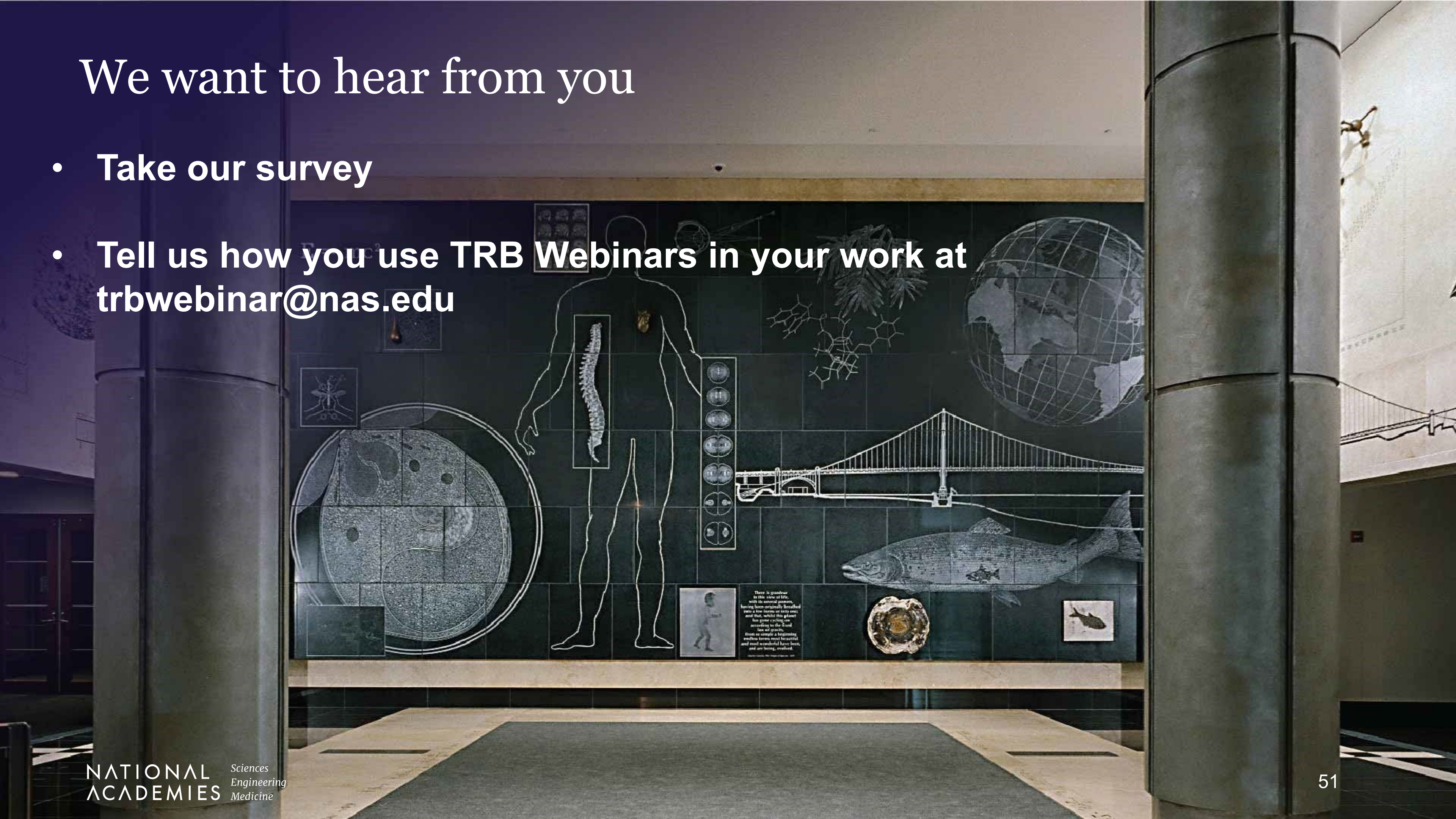

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