U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank
Highway Research Center

Complete Streets—Safety Analysis

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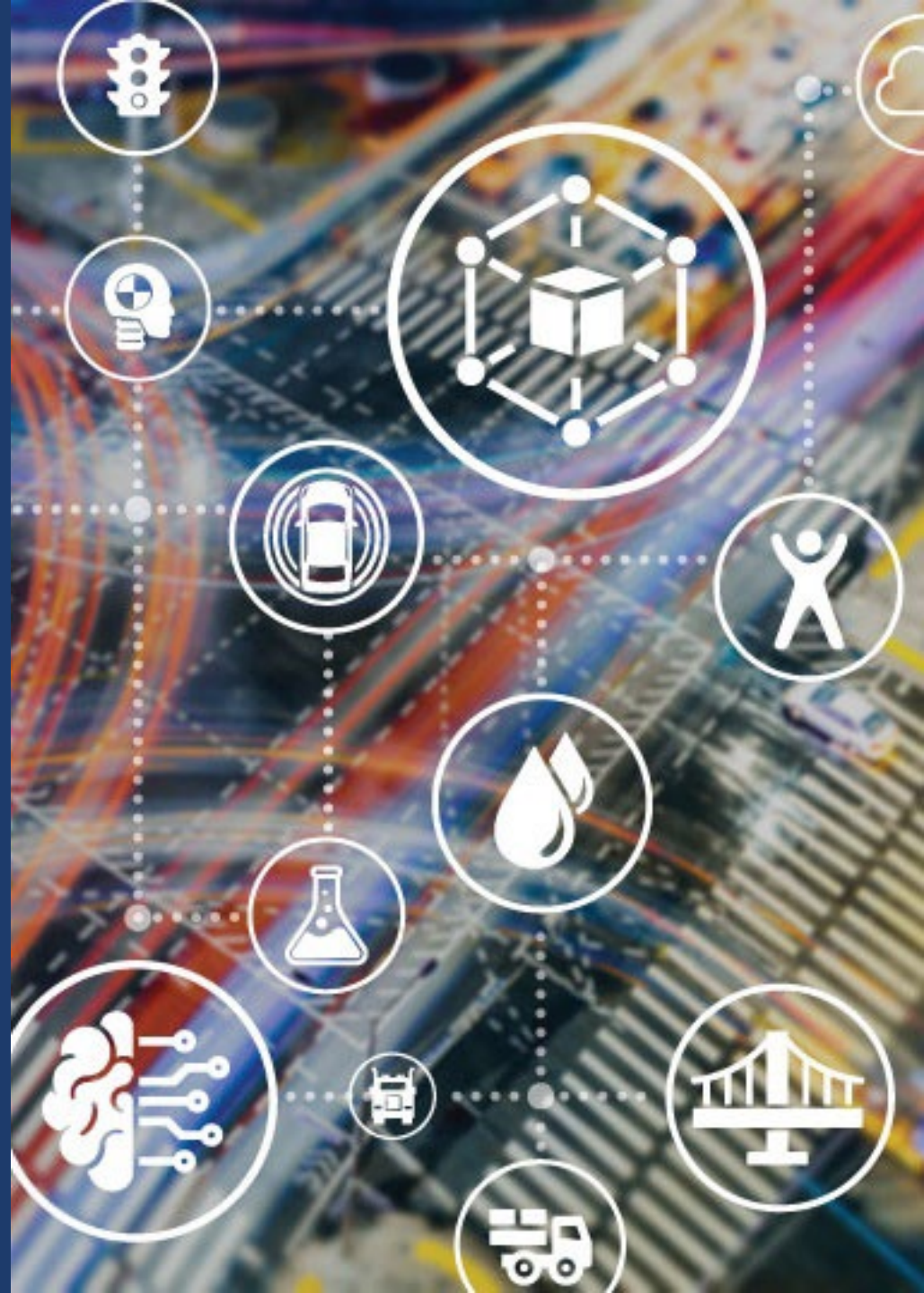

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Welcome

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Agenda

- What are Complete Streets?*
- Project objective and overview.
- Analysis of sample Complete Streets projects and treatments.
- Assessment of Complete Streets treatment crash modification factors (CMFs) (FHWA 2023a).
- CMF combination methods and safety analysis.
- Results and findings.

** Unless otherwise noted, Complete Streets in this presentation refers to the concept of Complete Streets as defined by FHWA (FHWA n.d.a).*

What Are Complete Streets?

- "A Complete Street is safe, and feels safe, for all users" (FHWA n.d.a).
- Complete Streets seek to improve safety, connectivity, and equity.
- FHWA adopted Complete Streets as the default approach to no-access-controlled roadways.
- Complete Streets embody the Safe System Approach (FHWA 2020).
- Complete Streets are increasingly advanced by Federal, State, and local agencies across the United States.

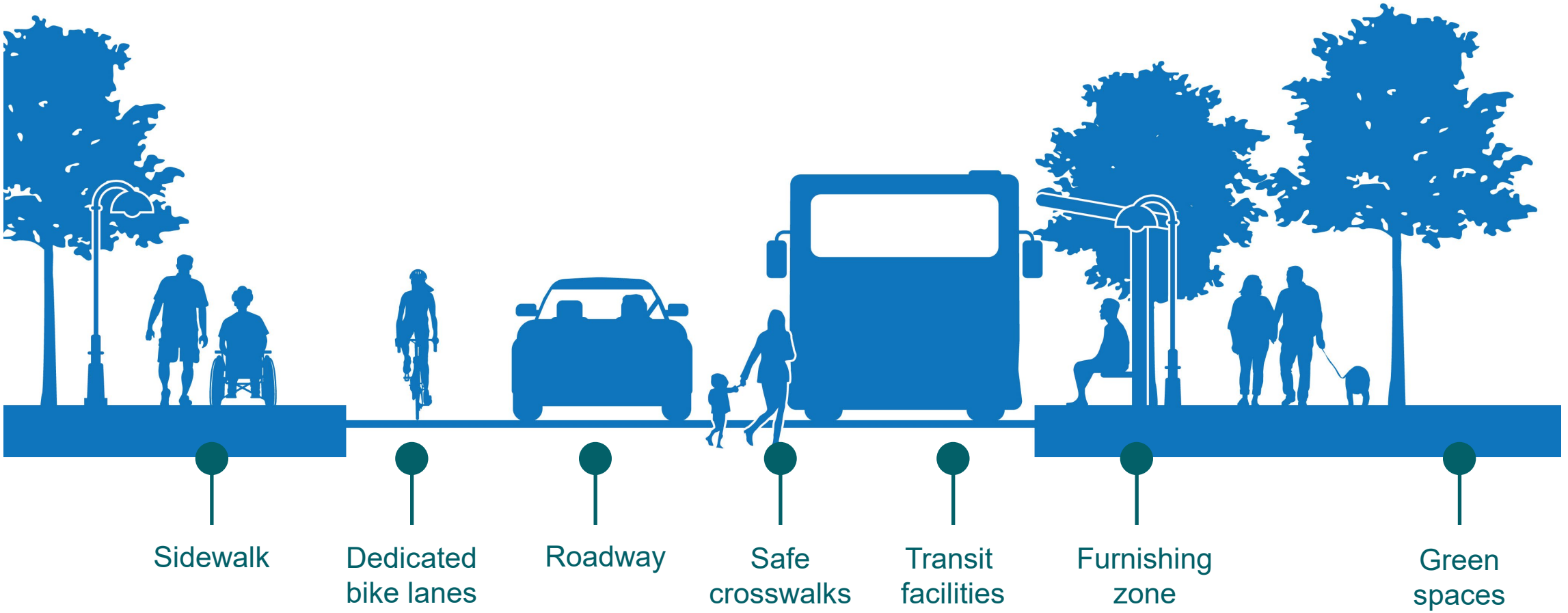
Before

© 2013 Google® Street View (Google 2013).

After

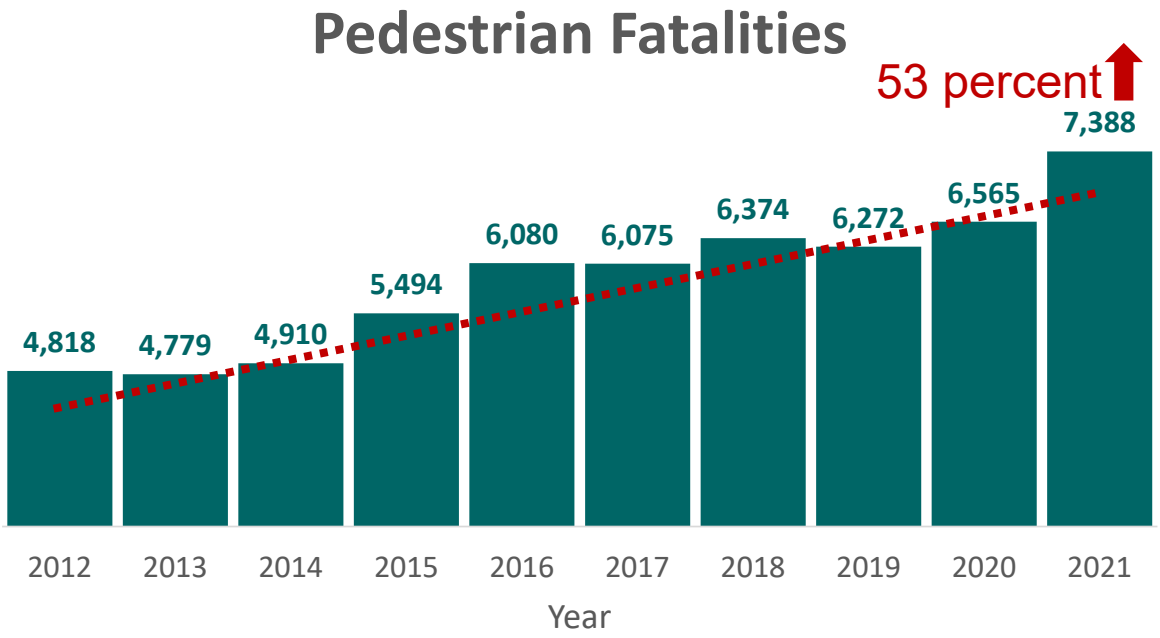
© 2022 Google® Street View (Google 2022a).

Complete Streets Elements



Source: FHWA.

Why Are Complete Streets Important?



Source: National Highway Traffic Safety Administration (NHTSA 2023).

- House Report (H.R.) 116-452 encouraged USDOT to adopt a Complete Streets design model (U.S. Congress 2020).
- *Moving to a Complete Streets Design Model* identified five areas of opportunity (FHWA 2022a).
- FHWA's Complete Streets efforts increased the proportion of Federal-aid funds that help create streets that are safe for all users.

Project Motivation (1/2)

- Data-driven safety analysis (DDSA) for project planning and the alternatives analysis process (FHWA 2022b) has seen growth in recent years.
- Practitioners have greater access to DDSA methods and tools, including CMFs (FHWA 2022b).

CMFs are used to compute the expected change in the number of crashes at a location after implementing a countermeasure (or other change).

Example:

Implement a leading pedestrian interval (LPI) – CMF Identification: 9906.
Crash type: Vehicle/pedestrian.
Crash severity: All.
CMF value = **0.81.**
Implementing an LPI is expected to reduce vehicle/pedestrian crashes by **19 percent** (1.00 – 0.81 = 0.19).

Project Motivation (2/2)

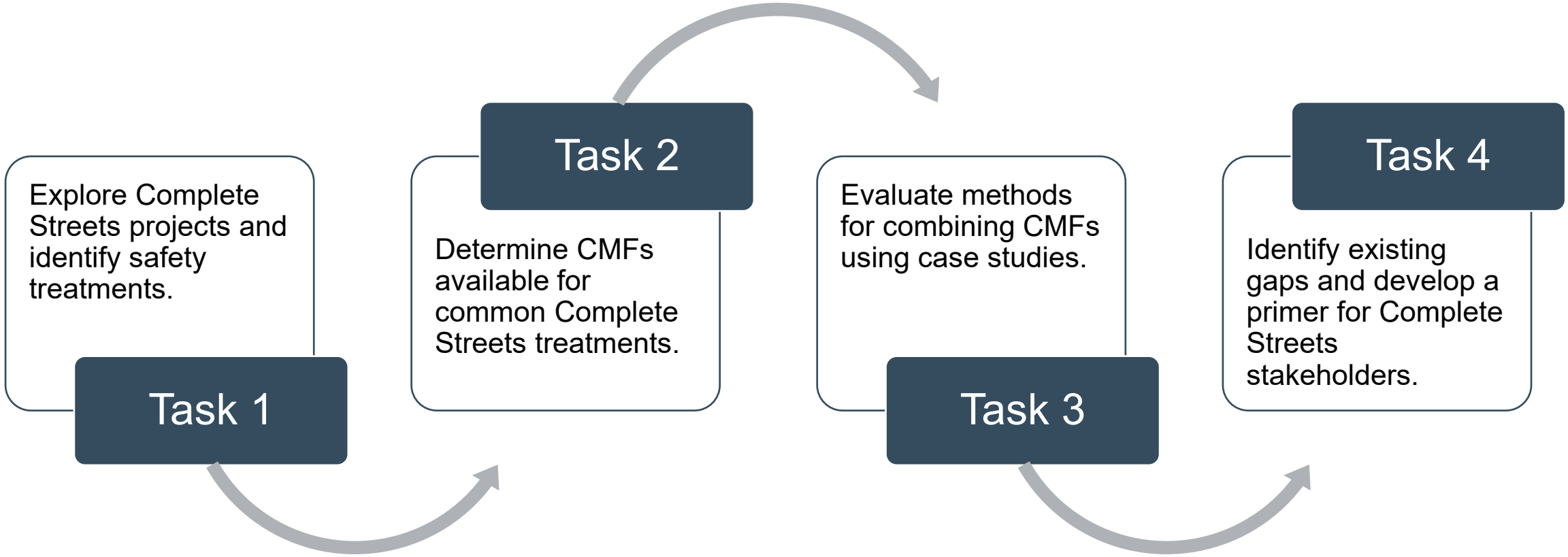
- There is limited availability of CMFs for pedestrian/bicyclist treatments and crash types.
- Complete Streets transformations often include multiple treatments applied in combination.
- Methods for combining CMFs to estimate the safety effects of treatment combinations are at early testing stages.
- Safety analysis challenges and gaps can limit the ability to clearly “see” what the multimodal safety benefits of a Complete Streets project will be.

Addressing these gaps would help support broader implementation of Complete Streets projects, including more widespread applications beyond local roads.

Project Objective

Develop safety analysis report and primer that identifies and describes current CMF capabilities, best practices, and future needs for quantifying the performance of multiple safety treatments that agencies implement simultaneously during the conversion of typical streets to Complete Streets.

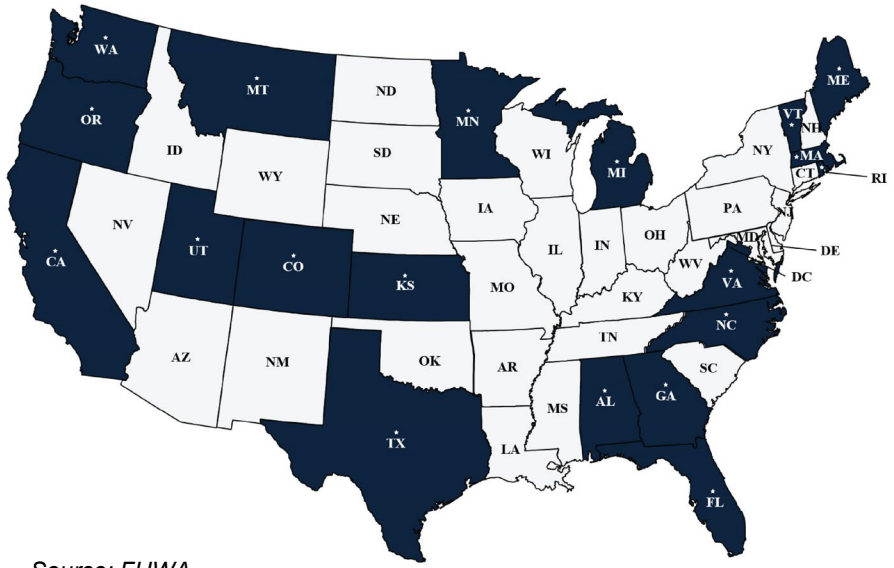
Project Activities



Source: FHWA.

Treatment Combinations

- Gathered sample of 85 Complete Streets projects from across the United States and associated data.
- Analyzed sample, focusing on arterial roadways with speed lin



Source: FHWA.

Data Collected for Each Project
• Area type.
• Functional classification.
• Number of through lanes.
• Median presence.
• Number of intersections.
• Number of segments.
• Construction year.
• Geographic coordinates.
• Route and milepost information.
• Project description.
• Safety treatments implemented.

Complete Streets Safety Treatments

- The 85 projects implemented 80 individual safety treatments.
- These 80 treatments were screened and consolidated to create condensed list of 35 treatments. The project team:
  - Combined similar treatments that had been named differently in project documentation.
  - Combined related treatments that performed a similar function.
  - Excluded treatments related less to safety and more to comfort, aesthetics, or Americans with Disabilities Act compliance (FHWA 2018).
- The treatments on the condensed list were organized into four categories:
  - Pedestrian/bicyclist (ped/bike).
  - Transit.
  - Traffic.
  - Roadway configuration.

Common Treatment Combinations (1/3)

Total Number of Treatments	Number of Projects	Percent of Projects	
1	9	10.6	
2	11	12.9	
3	13	15.3	**62.3 percent**
4	15	17.6	
5	13	15.3	
6	12	14.1	
7	1	1.2	**14.3 percent**
8	2	2.4	
9	6	7.1	
10	1	1.2	
11	1	1.2	
15	1	1.2	
Total	**85**	**100.0**	

Source: FHWA (Porter et al. forthcoming).

Counted the number of treatments applied per project:

- Applied between three and six treatments to 62.3 percent of projects.
- Applied more than seven treatments to 14.3 percent of projects.

Common Treatment Combinations (2/3)

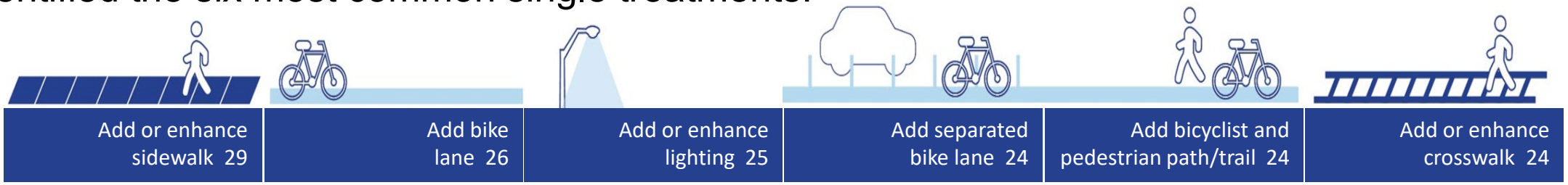
Area Type: Treatment Category	Number of Projects	Percent of Projects
Rural: Ped/bike and roadway configuration	5	71.4
Rural: Ped/bike and traffic and roadway configuration	2	28.6
Rural: Total	**7**	**100.0**
Urban: Ped/bike	3	13.0
Urban: Ped/bike and roadway configuration	17	73.9
Urban: Ped/bike and traffic & roadway configuration	3	13.0
Urban: Total	**23**	**100.0**
Urbanized: Ped/bike (*Urbanized*)	17	30.9
Urbanized: Transit	1	1.8
Urbanized: Ped/bike and transit	2	3.6
Urbanized: Ped/bike and traffic	2	3.6
Urbanized: Ped/bike and roadway configuration	21	38.2
Urbanized: Ped/bike and transit & roadway configuration	5	9.1
Urbanized: Ped/bike and traffic & roadway configuration	6	10.9
Urbanized: Ped/bike and transit and traffic and roadway configuration	1	1.8
Urbanized: Total	**55**	**100.0**

Source: FHWA (Porter et al. forthcoming).

- Examined most common area type and treatment category type(s):
  - Majority were urbanized/urban.
  - Majority (all but one project) included ped/bike treatments.
- Examined most common treatment categories:
  - Ped/bike and roadway configuration: 44.
  - Ped/bike: 20.
  - Ped/bike and traffic and roadway configuration: 11.

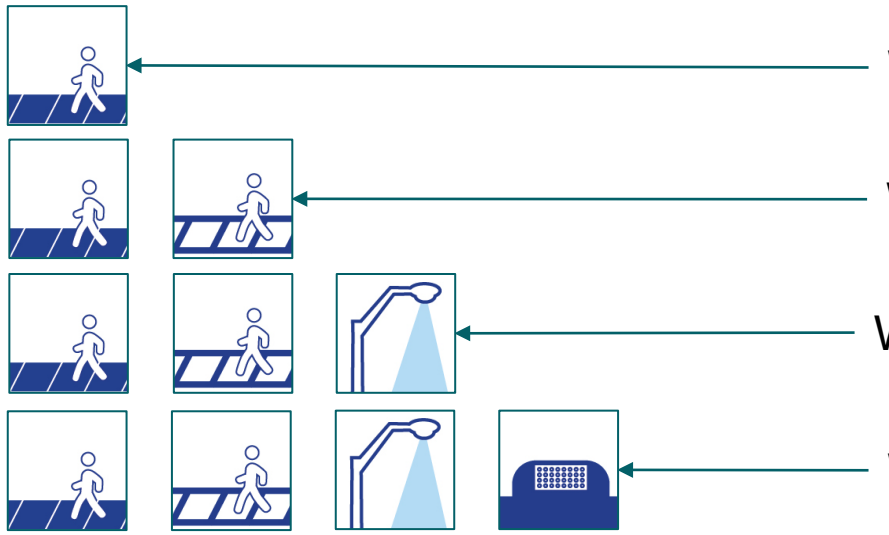
Common Treatment Combinations (3/3)

- Identified the six most common single treatments:



Source: FHWA (Porter et al. forthcoming).

- Analyzed most common combinations of two, three, and four treatments:



With added or enhanced sidewalk (29 projects).

With added or enhanced crosswalk (15 projects).

With added or enhanced lighting (8 projects).

With added curb extension/bulb-out (6 projects).

Source: FHWA (Porter et al. forthcoming).

Diagnostic Validation of Treatment Combinations

Source: FHWA (FHWA 2022b).

- Considers commonalities:
  - Common crash types on arterials.
  - Common treatment combinations applicable to different area types, facility types, project types, etc.
- Draws from additional sources:
  - Project team expertise.
  - FHWA *Complete Street Transformations* scenarios (FHWA 2022c).
  - Scenario appendix of *2022 Atlanta Regional Commission Regional Safety Strategy* (Atlanta Regional Commission 2022).
- Validates findings and identifies additional treatments:
  - Remove shoulder.
  - Convert flush median to raised median.

  } Not included in original list of 80 treatments.
  - Decrease roadway or lane width.
  - Add bus island/floating bus stop or add bus boarding platform.

  } Included in original list of 80 treatments, but not included in most common treatment combinations.

CMF Capabilities and Needs

- Total CMFs for the 80 individual treatments: 718.
- Total CMF availability summarized for 15 most common treatments, plus 4 treatments from diagnostic review.
- Several common treatments without any CMFs:
  - Add curb extension/bulb-out.
  - Convert flush median to raised median.
  - Add bus island/floating bus stop or add bus boarding platform.

CMF Capabilities and Needs (Snapshot)

Summary of CMF availability for treatments that are part of common treatment combinations on Complete Streets (Porter et al. forthcoming).

Treatment Name	Number of Studies	Number of CMFs	Average CMF Star Rating (Min-Max Star Range)	Average CMF (Min-Max CMF Range)	Available Crash Type CMFs: All	Available Crash Type CMFs: Vehicle/pedestrian	Available Crash Type CMFs: Vehicle/bicycle	Other	Most Severe Crash Severity CMF Available
Add bike lane	6	8	2.1 (1-4)	0.68 (0.19-1.49)	X	-	X	-	KABC
Add bicyclist and pedestrian path/trail	2	2	2.0 (2)	0.79 (0.75-0.83)	-	-	X	-	KABCO
Add curb extension/bulb-out	None	-	-	-	-	-	-	-	-
Add or enhance crosswalk (including high visibility)	3	4	2.8 (2-4)	0.60 (0.35-0.81)	X	X	-	X	KABCO
Add or enhance lighting	13	32	3.2 (2-4)	0.69 (0.00-1.39)	X	X	X	X	K
Add or enhance midblock crossing	1	1	4.0 (4)	0.82 (0.82)	-	X	-	-	KABCO
Add or enhance pedestrian and bicyclist signal operation	12	48	3.2 (1-5)	0.85 (0.30-1.10)	X	X	-	X	K
Add or enhance sidewalk	4	8	2.8 (2-3)	1.79 (0.41-3.09)	X	-	X	-	KA
Add or enhance traffic signal operation	25	89	3.1 (1-5)	0.87 (0.23-2.43)	X	X	-	X	K
Add pedestrian-actuated signal or beacon	6	22	3.6 (1-5)	0.66 (0.27-1.18)	X	X	-	X	KABC

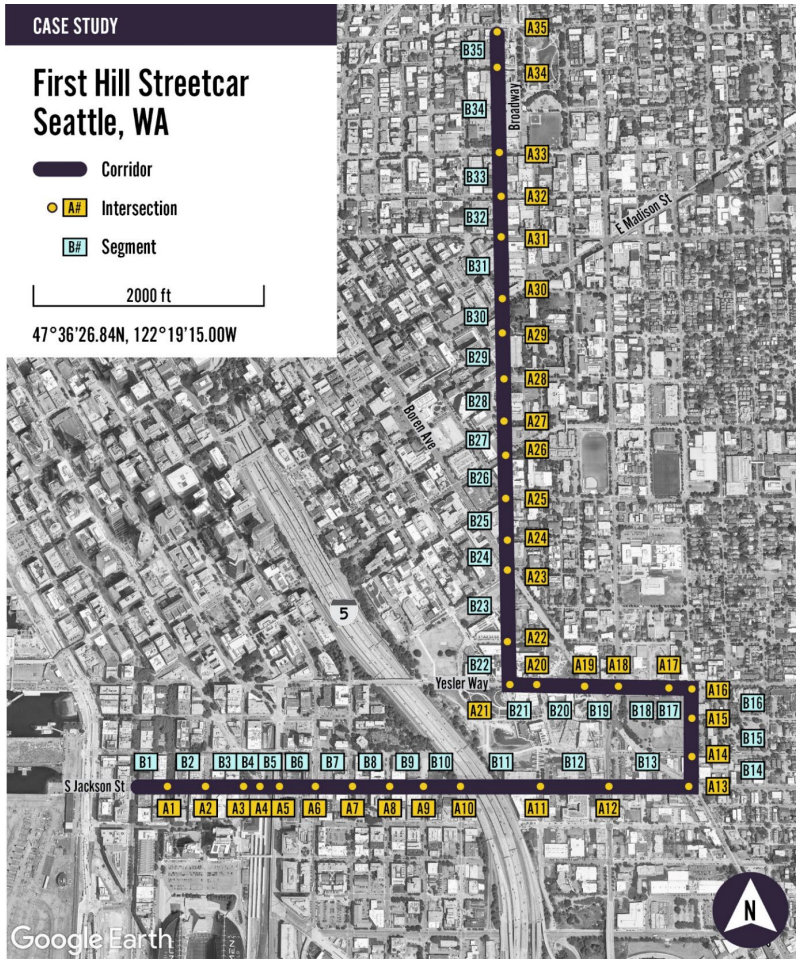
Min = minimum; Max = maximum; KABC = injury crash severities; KABCO = all crash severities; K = fatal crash severity; KA = fatal and suspected serious injury crash severity; X = available.

Case Studies

- Chosen from sample of 85 Complete Streets projects:
  - Feature multiple treatments.
  - Feature constructed projects with 3 or more years of data before and after.
  - Focus on improving pedestrian/bicyclist safety.
- Five case studies (Porter et al. forthcoming):
  - First Hill Streetcar Project, Seattle, WA.
  - Greenough Boulevard Greenway Expansion, Cambridge, MA.
  - Bench Boulevard Project, Billings, MT.
  - Fletcher Avenue Complete Streets Project, Hillsborough County, FL.
  - Highways 28, 29, 104 Project, Glenwood, MN.

Case Study Data Collection (1/2)

- Geolocated crash data collected (5 yr before and after, where possible).
- Volume data collected (gaps in volume data filled by interpolation, assumption).
- *Highway Safety Manual* (AASHTO 2010) segmentation process performed (used to assign data to relevant segments and intersections).
- Safety treatments implemented.
- Applicable CMFs used.
- Combined CMFs for treatment combinations applied.



© 2022 Google ® Earth ™. Modified by authors to highlight the project corridor, intersections, and segments (Porter et al. forthcoming).

Case Study Data Collection (2/2)

2011

© 2011 Google ® Maps (Google Maps 2011).

2014

© 2022 Google ® Maps (Google Maps 2022b).

Treatments applied to the segment in this project:

- Add shared lane marking (sharrow).
- Remove on-street parking.
- Add median.
- Add midblock crossing.
- Add pedestrian signal.
- Add streetcar.
- Add streetcar stop.

Analysis Methods

Analysis Type (Method)	Description
Predictive analysis (P1)	Assumes no volume change from current period to future period.
Predictive analysis (P2)	Projects future period volume by extrapolating year-to-year trend from current period.
Safety effectiveness evaluation (E1)	Assumes no volume change from before period to after period.
Safety effectiveness evaluation (E2)	Projects after-period volume by extrapolating year-to-year trend from before period.
Safety effectiveness evaluation (E3)	Uses observed after period volume.

P1 = predictive analysis method 1; P2 = predictive analysis method 2; E1 = safety effectiveness evaluation method 1; E2 = safety effectiveness evaluation 2; E3 = safety effectiveness evaluation 3.

- Predictive analysis compared what was predicted to what occurred.
- Predictive analysis tried different approaches to create CMF for treatment combinations (the next slide displays only dominant effect, multiplicative (for comparison purposes), and dominant common residual).

Summary of Analysis Results (1/2)

Analysis: CMF Combo Method (Result Type)	First Hill Streetcar	Greenough Blvd	Bench Blvd	Fletcher Ave	Hwy 28, 29, 104
E1: Not applicable (Reduction)	122	16	2	210	18
E1: Not applicable (%)	15	55	2	11	38
E2: Not applicable (Reduction)	88.2	16.0	-1.5	98.2	19.2
E2: Not applicable (%)	11	55	-2	5	39
E3: Not applicable (Reduction)	31.7	11.1	27.2	160.6	13.2
E3: Not applicable (%)	4	38	30	8	31
P1: Dominant Effect (Reduction)	288.0	10.2	20.8	394.2	18.7
P1: Dominant Effect (%)	35	35	23	20	39
P1: Multiplicative (Reduction)	314.0	8.7	28.2	392.0	21.7
P1: Multiplicative (%)	38	30	31	20	45
P1: Dominant Common Residuals (Reduction)	206.5	6.1	21.6	518.6	13.9
P1: Dominant Common Residuals (%)	25	21	24	26	29
P2: Dominant Effect (Reduction)	317.5	10.2	24.1	484.1	18.0
P2: Dominant Effect (%)	39	35	27	24	38
P2: Multiplicative (Reduction)	344.1	8.7	31.3	482.5	21.2
P2: Multiplicative (%)	42	30	35	24	44
P2: Dominant Common Residuals (Reduction)	238.2	6.1	24.8	601.5	13.1
P2: Dominant Common Residuals (%)	29	21	28	30	27

Summary of Analysis Results (2/2)

Analysis: CMF Combo Method (Result Type)	First Hill Streetcar	Greenough Blvd	Bench Blvd	Fletcher Ave	Hwy 28, 29, 104
E1: Not applicable (Reduction)	122	16	2	210	18
E1: Not applicable (%)	15	55	2	11	38
E2: Not applicable (Reduction)	***88.2***	***16.0***	***-1.5***	***98.2***	***19.2***
E2: Not applicable (%)	***11***	***55***	***-2***	***5***	***39***
E3: Not applicable (Reduction)	31.7	11.1	27.2	160.6	13.2
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P2: Dominant Common Residuals (%)	***29***	***21***	***28***	***30***	***27***

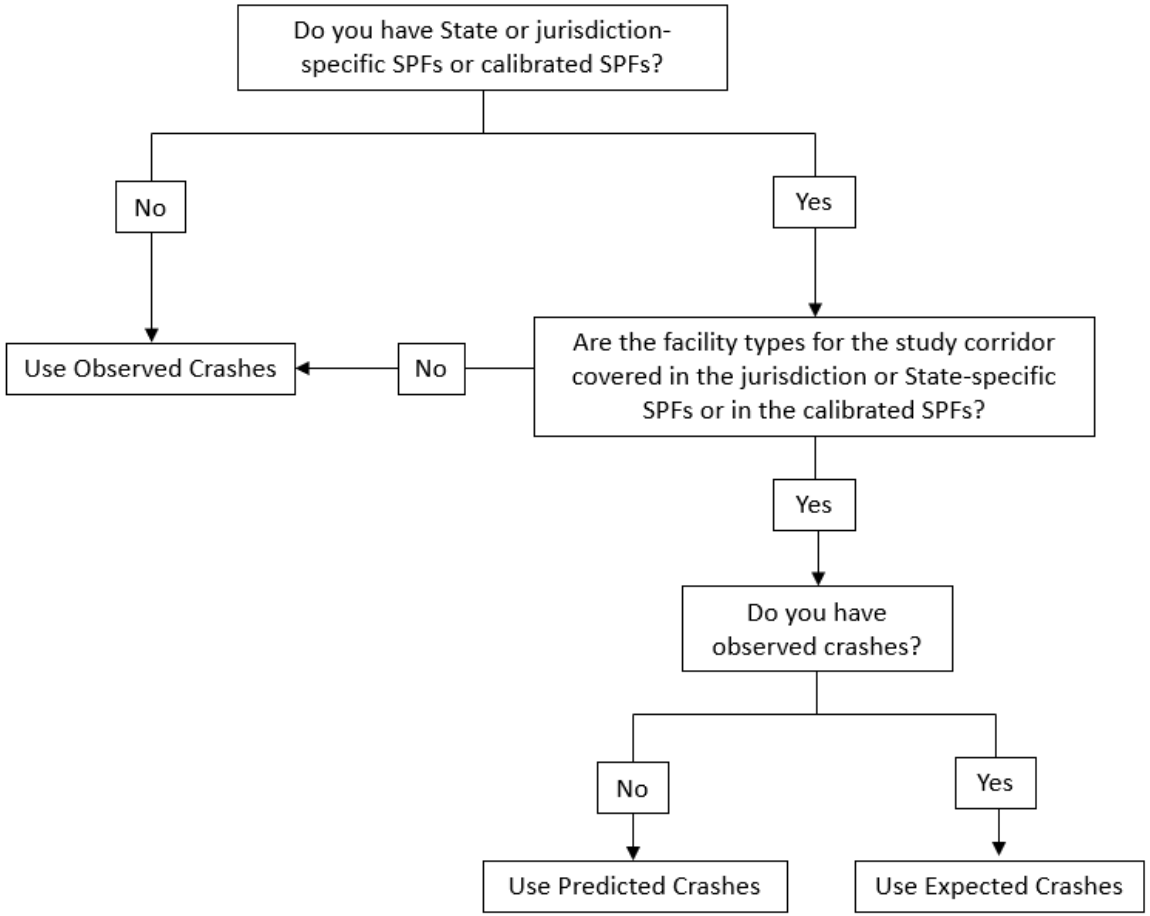
Complete Streets Safety Analysis Primer*

- Summarizes how to estimate combined safety effect of multiple treatments for Complete Streets projects:
  - Predictive analysis (for project planning stage).
  - Safety effectiveness evaluation (for quantifying Complete Streets benefit after construction).
- Describes data needs and preparation, common challenges/limitations, and future research needs.
- Outlines details for both practitioners and researchers.

* *(Porter et al. forthcoming)*

Predictive Analysis

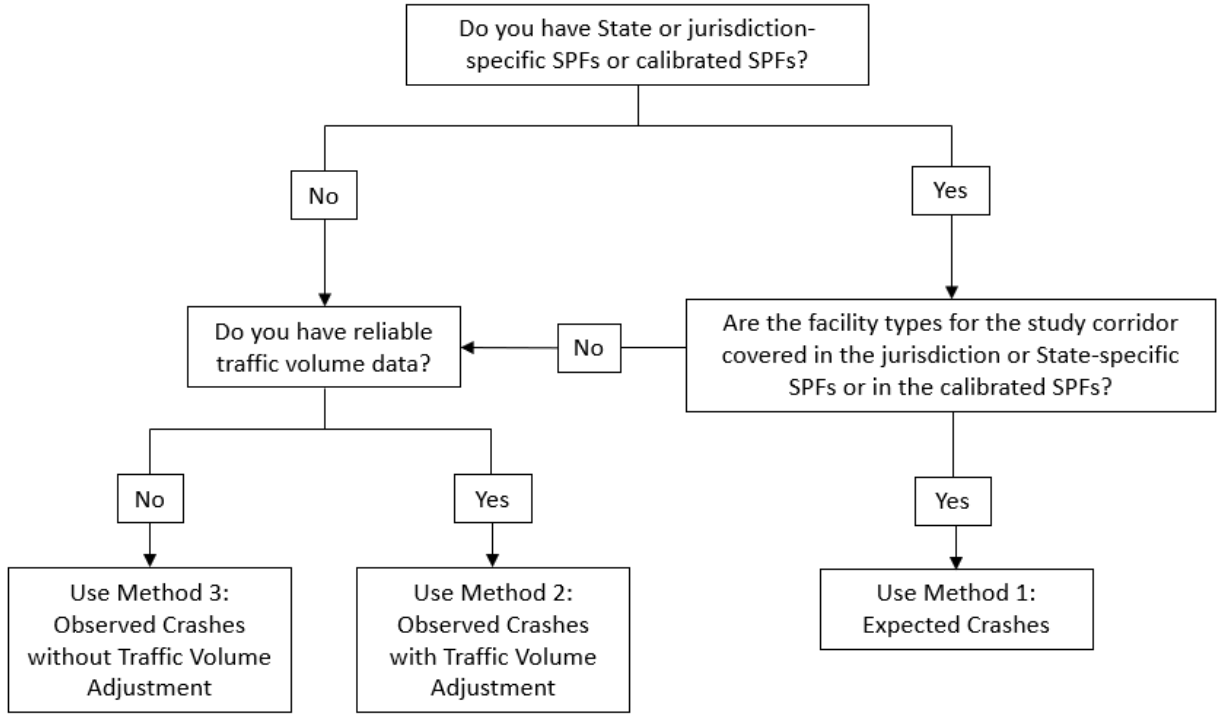
1. Estimate safety performance of future no-build condition (expected, predicted, or observed crashes).
2. Determine CMF for Complete Streets project:
   - Identify CMF for each treatment.
   - Select method for combining CMFs.
3. Estimate safety performance of Complete Streets project.



SPFs = Safety performance functions. *Source: FHWA (Porter et al. forthcoming).*

Safety Effectiveness Evaluation

1. Estimate safety performance in the after period WITHOUT the Complete Streets project (expected crashes or observed crashes with/without volume adjustment).
2. Compare safety performance in the after period WITH and WITHOUT the Complete Streets project.



Source: FHWA (Porter et al. forthcoming).

Report Contains:

- Detailed content on treatment combinations and CMF availability.
- Complete Streets Safety Analysis Primer (Porter et al. forthcoming).
- Catalog of 80 Complete Streets treatments (descriptions, photos, summary of available CMFs).
- Catalog of 11 CMF combination methods.
- Case study descriptions (crash data, volume data, treatments, CMFs applied, and analysis results).

Common Challenges and Limitations (1/2)

- Lack of SPFs (if not available, cannot use predicted or expected crashes).
- Lack of traffic volume data:
  - Most often an issue for cross-streets.
  - In many cases, volume assumptions are made or data are excluded from analysis.
- Lack of pedestrian/bicycle volume data (volume data difficult to obtain).

Common Challenges and Limitations (2/2)

- Attribution of crash or volume changes to Complete Streets projects (difficult to determine volume change that would have occurred without the Complete Streets project).
- Understanding of volume and safety changes to the surrounding network:
  - Complete Streets projects may cause users to shift routes and/or modes.
  - Analysts may need to expand study area to include surrounding network.
- Lack of CMFs for Complete Streets treatments:
  - If CMFs are not available, analysts may not be able to estimate potential benefits of treatments.
  - If CMFs are not available, may need option to develop CMF (using safety effectiveness evaluation).

Conclusions and Recommendations

Explore other potential safety performance metrics:

- Safe System-based metrics:
  - Complete Streets treatment affects on exposure, vehicle speed, user complexity, etc.
  - For example, FHWA Safe System for Intersections method.
- Comprehensive health and safety metrics:
  - Disability-adjusted life years averted.
    (Due to reduced air pollution, increased physical activity, etc.)
  - Quality-adjusted life years gained.
    (Due to increased physical activity, improved mental health, increased accessibility, etc.)

Key Resources

- AASHTO Highway Safety Manual (AASHTO 2010).
- CMF Clearinghouse (FHWA 2023a).
- NCHRP Report 991: Guidelines for the Development and Application of Crash Modification Factors (Carter et al. 2022).
- FHWA Road Safety Data Program (RSDP) (FHWA n.d.b).

  Including RSDP videos for selecting and applying methods to analyze multiple CMFs (FHWA 2023b).

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Questions?

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