U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank Highway Research Center

Wrong Way Driving (WWD) Low-Cost Safety Improvements Workshop

Evaluation of Low-Cost Safety Improvements Pooled Fund Study

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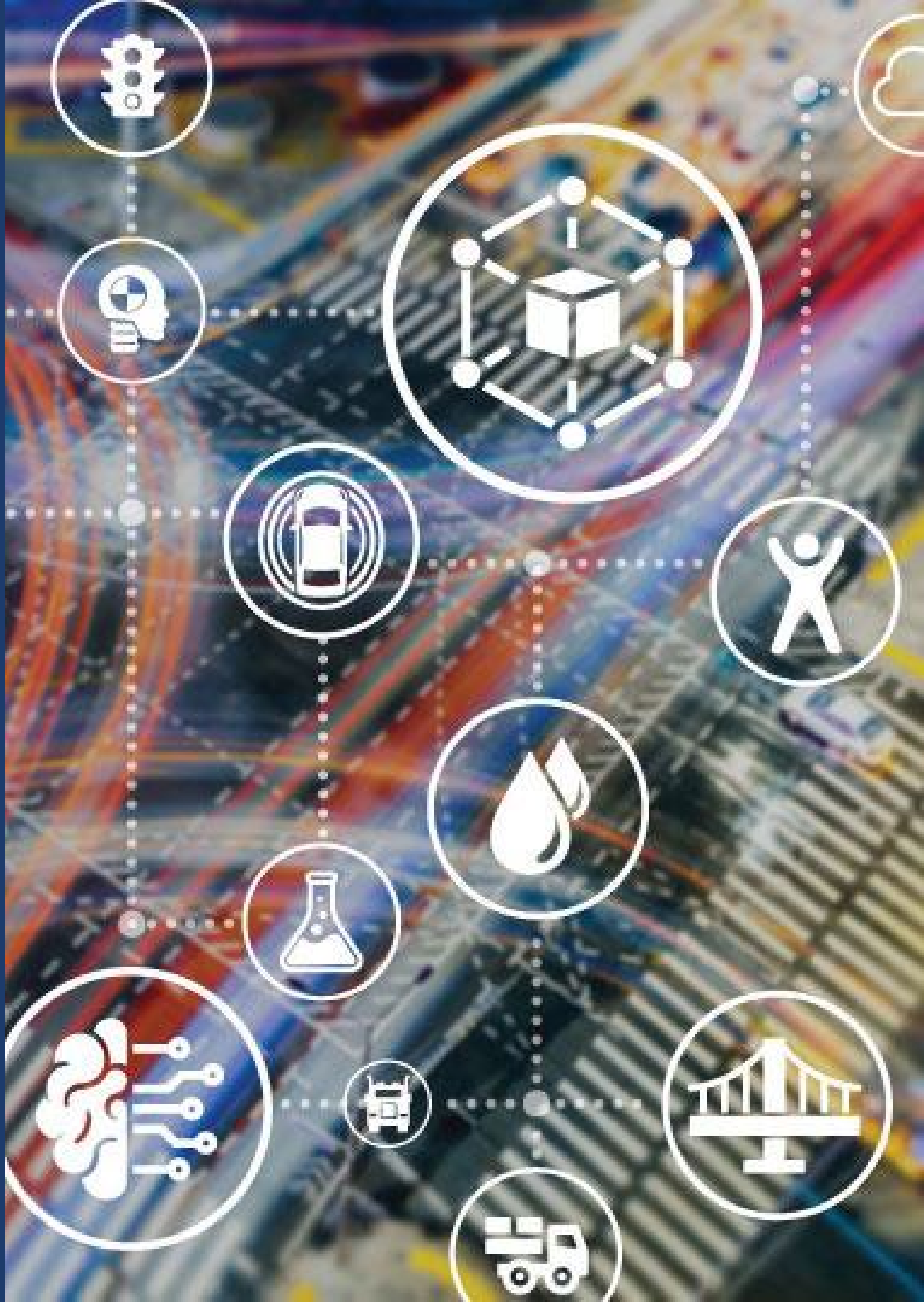

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Abbreviations

B/C	Benefit / Cost
CMF	Crash modification factor
DNE	Do not enter
MUTCD	*Manual on Uniform Traffic Control Devices*. (1)
OW	One way
POE	Point of entry
Signed	Displaying vertical signage
TCD	Traffic control device
Unsigned	Not displaying any vertical signage
WWD	Wrong-way driving
WW	Wrong way

All images source: FHWA.[1]

[1]Federal Highway Administration (FHWA). 2009. *Manual on Uniform Traffic Control Devices for Streets and Highways.* Washington, DC: FHWA.

Developing CMFs and Economic Effectiveness for WWD Crashes

Study Overview

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Federal Highway Administration
Turner-Fairbank
Highway Research Center

Study Objectives

- The first objective of this study is to quantify the safety effectiveness of WWD countermeasures like CMFs.
- The second objective of this study is to assess the economic viability of WWD countermeasures.

WWD Crash Characteristics

- WWD crashes represent a small portion of total freeway crashes.
- WWD crashes are usually head-on or fixed-object collisions.
- WWD crashes lead to more fatalities and injuries than other crash types.

CMFs And Economic Effectiveness for WWD Countermeasures

This study focused on freeways and found the following:

- WW crashes are extremely rare.
- WW crash occurrences are often recorded miles from the WW POE.
- WW crashes could be prevented by varying features or applying treatments at the POE.

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Data Collection

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WWD Crashes on TX and FL Freeways

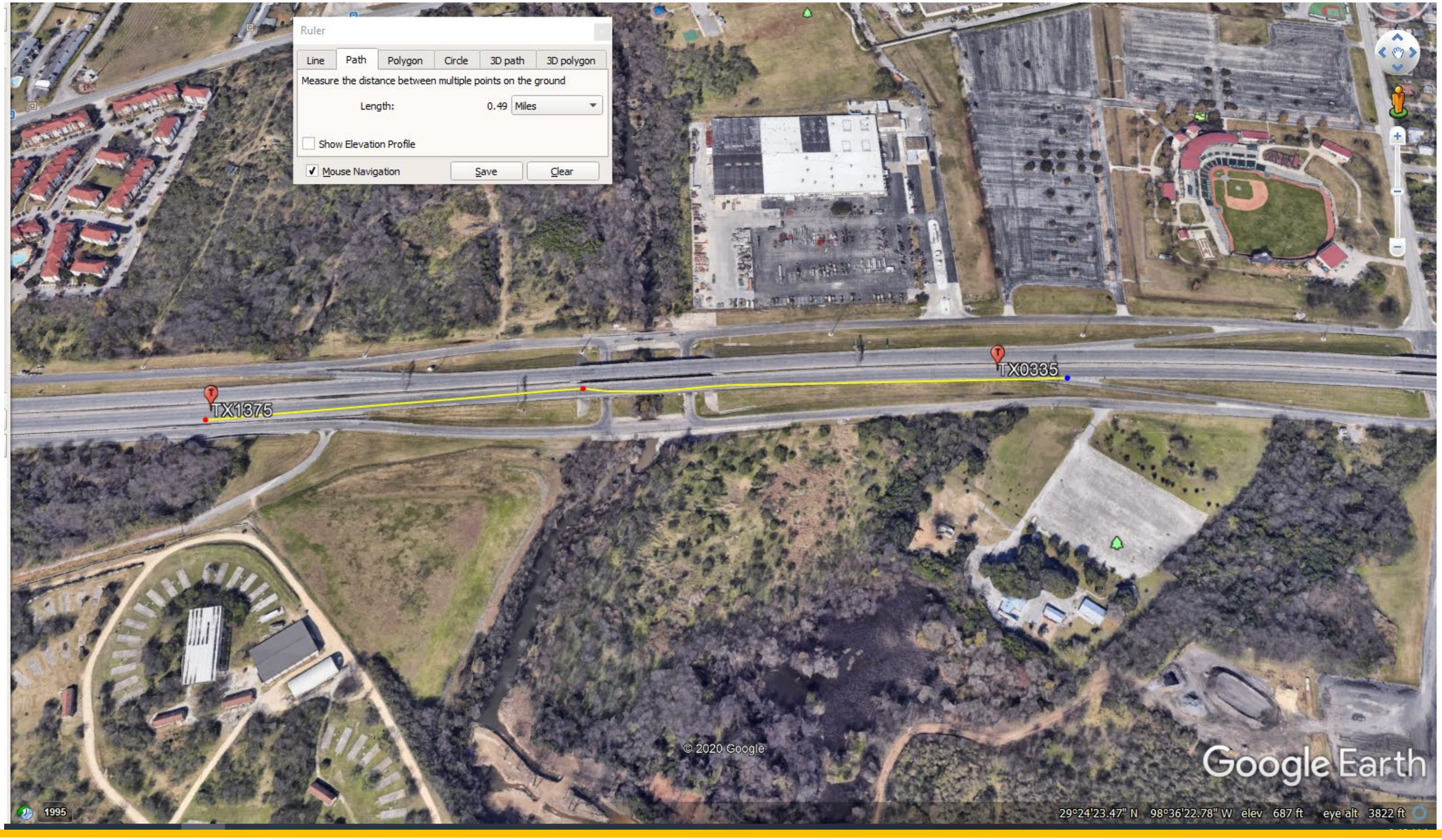
Route Class	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Avg.	Total
Texas	--	148	132	173	156	173	210	192	113	187	207	169.1	169.1
Florida	43	47	27	40	37	43	48	38	--	--	--	40.4	323

- Phase I ------
- Phase II ——

Data Collection Protocol

1. Identify WWD crashes and their locations.
2. Identify a "corridor" length starting from the WWD crash location downstream to a maximum distance.
3. Identify all POEs for the WWD crash along that corridor.
4. Collect geometric and TCD data at each POE.
5. Review crash narratives to determine the POEs.

Sample of Data Collection Flow



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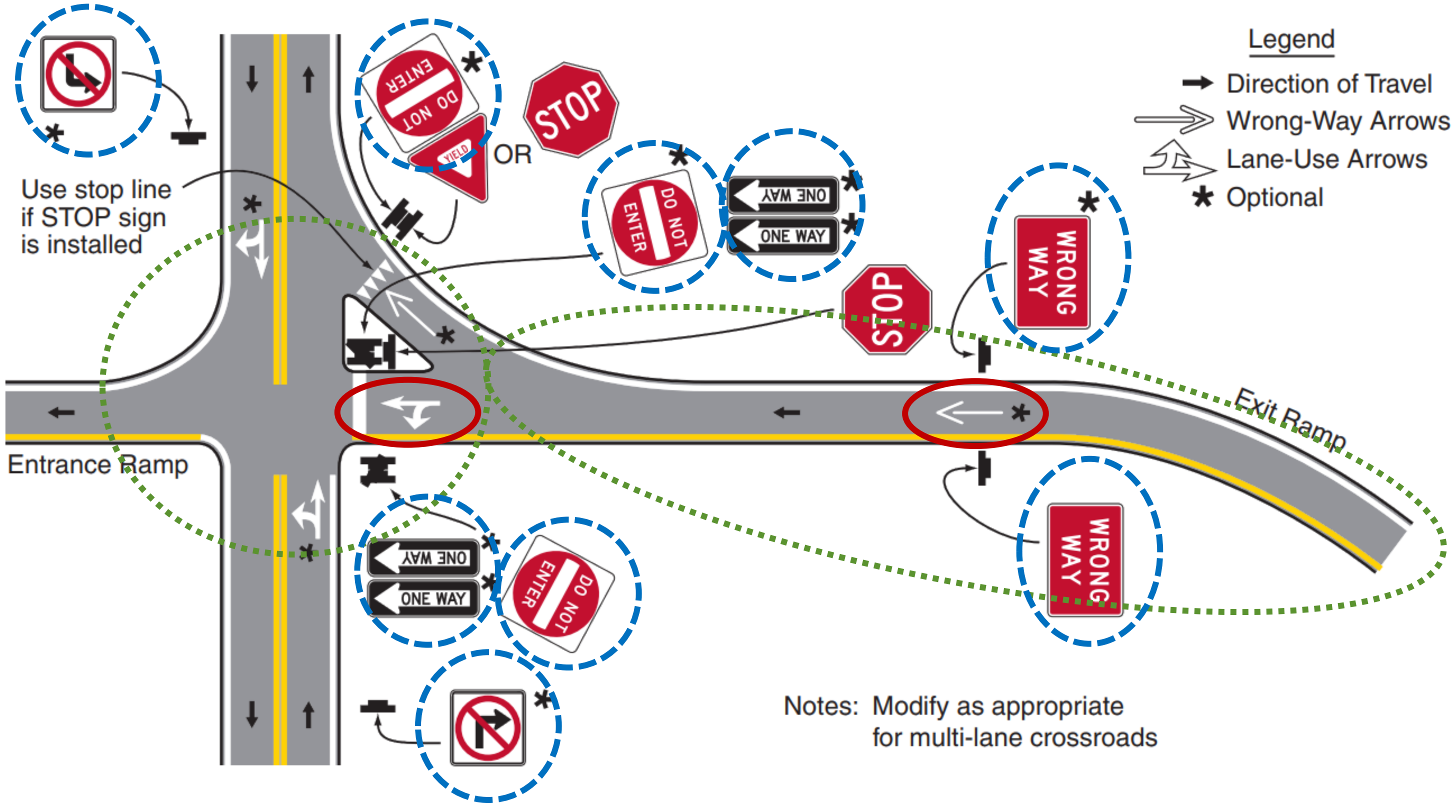
WWD Countermeasures At POE

Conventional TCDs:

- Signs.
- Markings.

Geometric features:

- Ramp and cross-road features.
- Frontage road access.



Mandatory and optional signs and markings at the exit terminal (Source MUTCD)

Source: FHWA.(1)

(1)Federal Highway Administration (FHWA). 2009. *Manual on Uniform Traffic Control Devices for Streets and Highways.* Washington, DC: FHWA.

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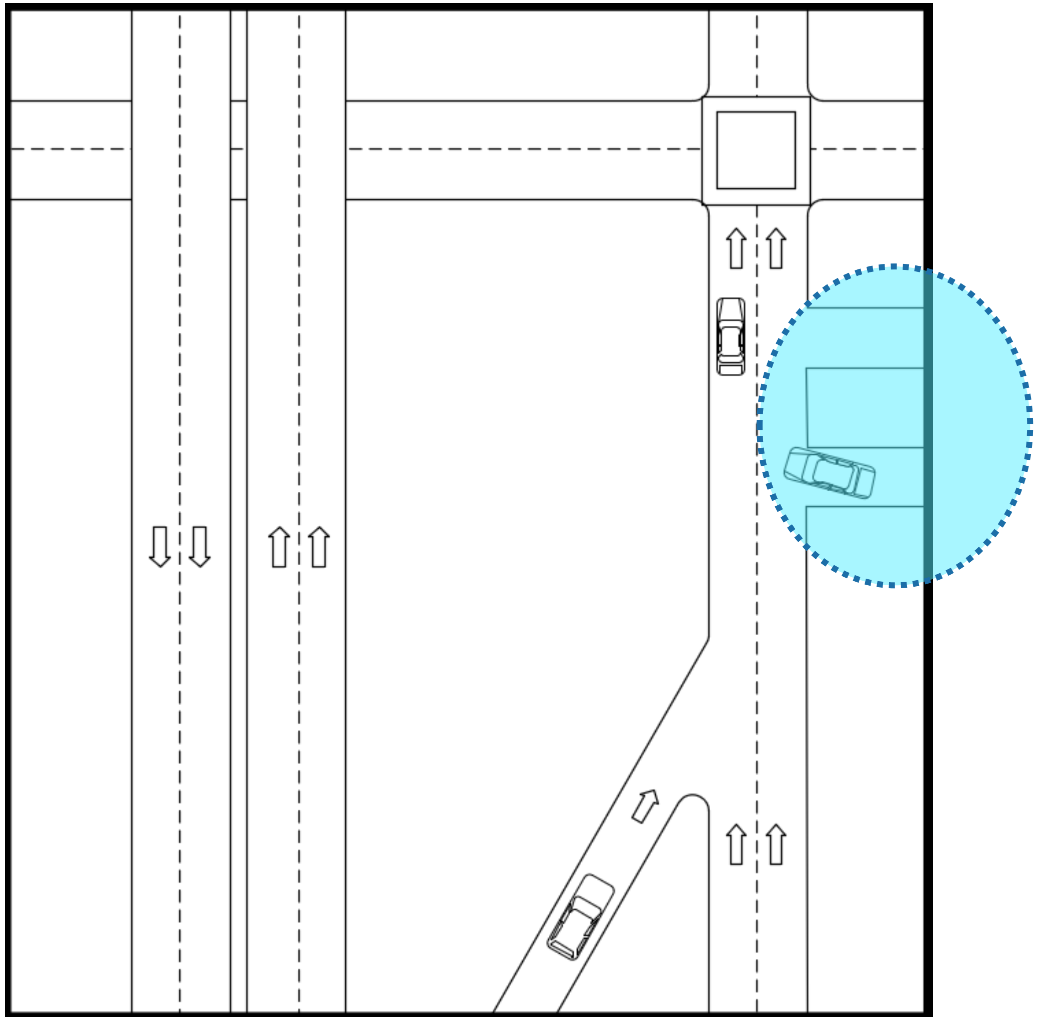
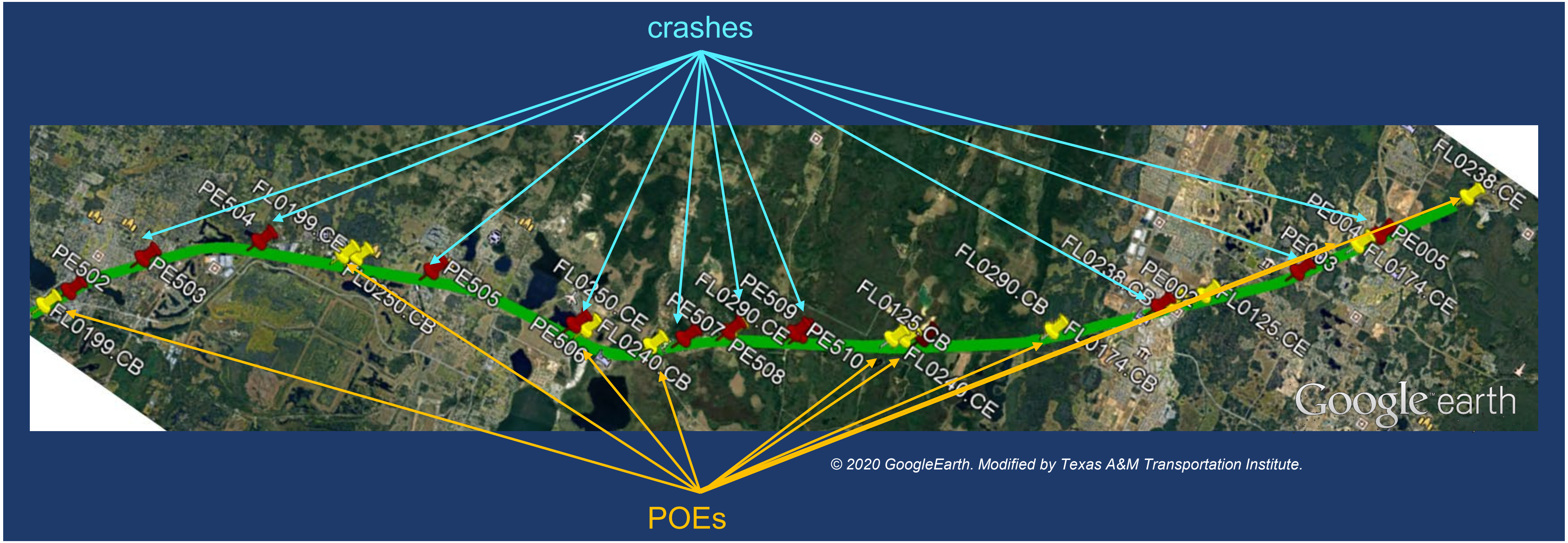


Identifying WWD Crashes and Entry Points



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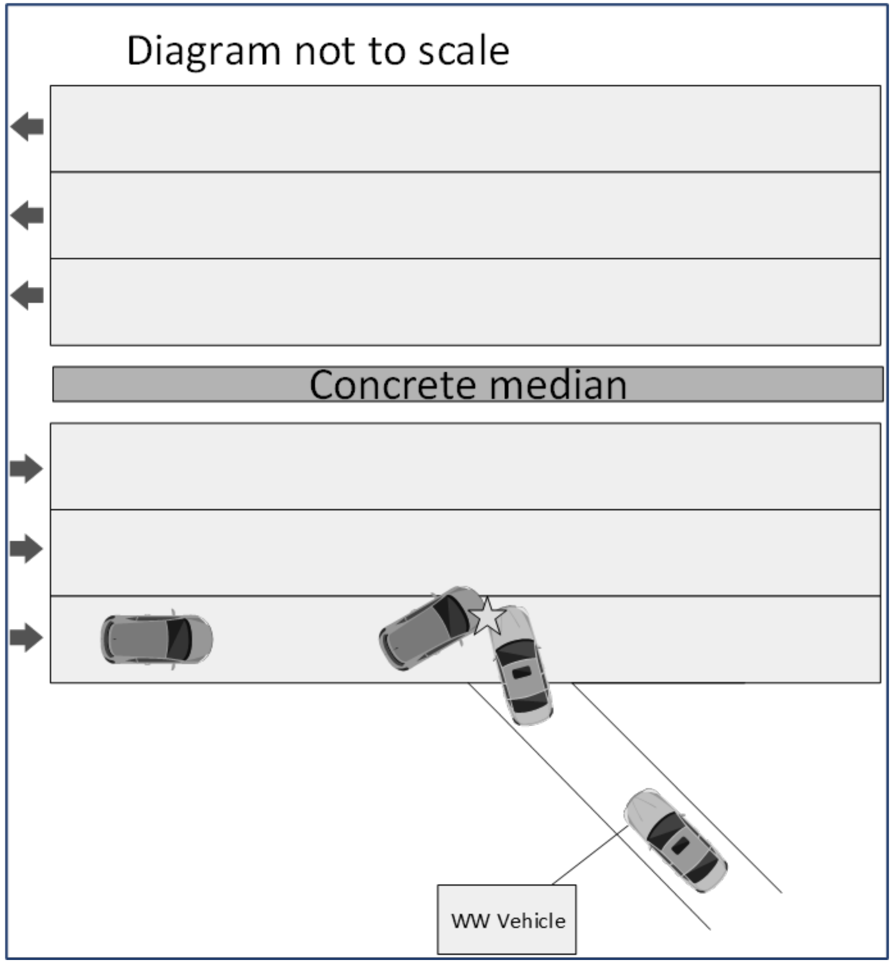
From which POE did each crash come?

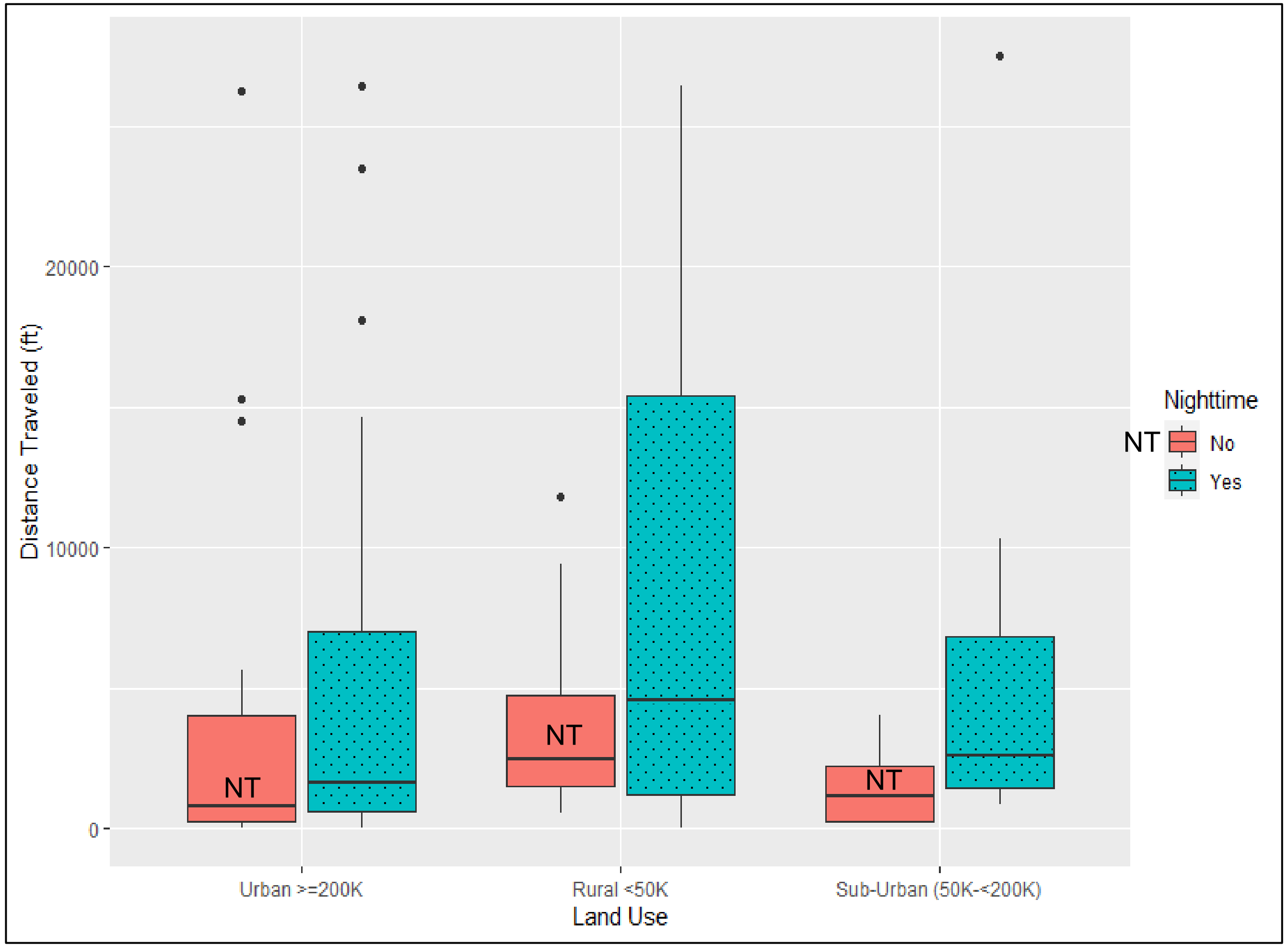
Review of Crash Narratives in TX

The intent of this review of text and narrative diagrams was to quantify relationships between POE and crash location.



In-Depth Review of TX Crash Narratives

- The researchers searched to identify POEs in narratives from 2011 through 2020 (1,300+ TX crash narratives).
- The POE could be identified for a total of 192 crashes in that period.
- The period from 2016-2019 was supplemented with non-crash corridors and used for analysis.



Characteristics of WWD Distances Travel prior to Crash

	Observation	Average (mi)	Minimum (mi)	Maximum (mi)	Std dev (mi)
Overall	192	0.71	0.0	5.21	0.97

WWD Crash Databases

Two databases:

- Phase I database: 68 WWD crashes and 406 POEs.
- Phase II database: 891 WWD crashes and 2,843 POEs.

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Methodology and Analysis

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Analyses at a Glimpse

Databases used for the two-stage analysis:

1. Phase 1: A smaller database of locations with POEs known for every crash.
2. Phase 2: A larger database of crashes linked to a set of potential originating POEs.

Phase 1 Analysis: POE Known for Crash

The phase 1 analysis included:

- A binomial regression of WWD crash risk (i.e., probability of WWD crash).
- Non-WWD crash locations (randomly selected).

The explanatory variables included:

- Distance traveled from POE to WWD crash location.
- POE geometric features.
- Time of day.

Phase 1 Results

- Longer WWD travel distances are more likely at night.
- Higher WWD risk with increasing number of driveways and unsigned T-intersections (frontage roads).
- Lower WWD risk with increasing number of signed T-intersections (frontage roads).

Phase 2

The phase 2 analysis included:

- A binomial regression of WWD crash risk.
- The phase 1 locations (i.e., crash risk = 1.0 for actual POE ; the crash risk = 0.0 for all other potential POEs nearby).
- The non-WWD crash locations (WWD risk for all potential POEs = 0.0).
- The total combined risk of WWD crash nearby POEs defined as 0.85 (i.e., farthest linked POE can be as far as the 85th percentile of known WWD travel distances).

Phase 2 Data Subsets

- Data were subdivided by State (FL and TX).
- State data were subdivided into four categories by POE type:
  - Freeway exits at frontage roads intersecting divided roadways.
  - Freeway exits at frontage roads intersecting undivided roadways.
  - Freeway exits at intersections on divided roadways.
  - Freeway exits at intersections on undivided roadways.

Phase 2 Data Subsets

- Analyses yielded various statistically significant results in TX.
- Analyses yielded only one statistically significant result in FL dataset.
- FL dataset was about one-third the size of the TX database.

Phase 2 Results Overview for Frontage Roads

- Number of driveways directly proportional to WWD crash risk.
- Number of signed T-intersections inversely proportional to WWD crash risk.
- Types of TCDs with statistically significant reductions of WWD crash risk:
  - WW sign.
  - OW sign.
  - Stop bar at point of intersection.
  - Lane path (turning lanes).

Phase 2 Results Overview for Off-Ramps at Intersections

- WWD crash risk increases with an increasing number of lanes at an intersection located on an undivided street.
- TCDs associated with reduced WWD crash risk:
  - DNE Signs.
  - Pavement markings:
    - Stop bar.
    - Lane use arrow.
    - WW arrow.

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CMF Results

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Countermeasures at Frontage Roads

Countermeasure	Crash Type	CMF	Lower Limit 95 Percent Confidence	Upper Limit 95 Percent Confidence	Signif.
Remove driveway from frontage[a]	Day WWD	0.870	0.823	0.919	***
Remove driveway from frontage[a]	Night WWD	0.912	0.849	0.980	*
Add signs at a frontage T- intersection[a]	Day WWD	0.622	0.912	0.450	*
Additional WW sign at cross-street intersection[a]	Day WWD	0.490	0.296	0.810	**
Lane path through cross-street intersection[a]	Night WWD crashes	0.387	0.186	0.803	*

* Significant at the 95.0 percent confidence level.
** Significant at the 99.0 percent confidence level.
*** Significant at the 99.9 percent confidence level.
a. Base condition: frontage road intersecting divided cross street.

Countermeasures at Intersections with Off-Ramps

Countermeasure	Crash Type	CMF	Lower Limit 95 Percent Confidence	Upper Limit 95 Percent Confidence	Signif.
Ramp lane removal from intersection[a]	Day WWD crashes	0.435	0.232	0.814	*
Ramp lane removal from intersection[a]	Night WWD crashes	0.561	0.326	0.965	~
Lengthening 100 ft of off-ramp[a]	Day WWD crashes	0.928	0.852	1.010	~
Adding STOP_Bar, WW Arrow, or LANEUSE Arrow[a]	Day WWD crashes	0.189	0.028	1.299	~
Adding STOP_Bar, WW Arrow, or LANEUSE Arrow[a]	Night WWD crashes	0.227	0.055	0.944	*
Adding DNE sign[b]	Day WWD crashes	0.358	0.177	0.723	**
Adding DNE sign[b]	Night WWD crashes	0.307	0.149	0.630	**

~ Significant at the 90.0 percent confidence level.
* Significant at the 95.0 percent confidence level.
** Significant at the 99.0 percent confidence level.
a. Base condition: frontage road intersecting divided cross street.
b. Base condition: off-ramp at undivided cross street intersection.

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Economic effectiveness

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Estimation of B/C Ratios for Redundant WW Sign

- WWD daytime crashes averaged 0.491 in 3 yr (per combined TX and FL dataset).
- WWD daytime crash reduction of an estimated 51 percent for each additional WW sign in a corridor.
- Sign and post replacement assumed to occur every 2 yr and yielded the following B/C ratios:
  - B/C ratio = 30.27 for adding 1 redundant WW sign at each POE.
  - B/C ratio = 22.52 for adding 2 redundant WW signs at each POE.
  - B/C ratio = 14.00 for adding 4 redundant WW signs at each POE.

Estimation of B/C Ratios for Redundant DNE Sign

- WWD nighttime crashes averaged 0.714 in 3 yr (per combined TX and FL dataset).
- WWD nighttime crash reduction of 69 percent for each additional DNE sign in a corridor.
- Sign and post replacement assumed to occur every 2 yr yielded the following B/C ratios:
  - B/C ratio = 56.22 for adding 1 redundant DNE sign at each POE.
  - B/C ratio = 38.00 for adding 2 redundant DNE signs at each POE.
  - B/C ratio = 21.4 for adding 4 redundant DNE signs at each POE.

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Conclusions

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Recommendations for Frontage Roads

- Recommendations for access management along frontage road segments:
  - Fewer driveways and unsigned T-intersections between off-ramp and cross-road intersections.
  - Appropriate signs at frontage T-intersections.
- Recommendations for at frontage-road/crossroad intersections:
  - Consider the use of optional OW and WW signs.
  - Apply and enhance pavement markings:
    - Stop bars.
    - Lane paths for turning lanes.

Concluding Remarks and Recommendations for Off-Ramps at Intersections

- Off-ramp geometric design considerations include the following facts:
  - Fewer ramps at intersections are linked to a lower risk of WWD crashes.
  - Shorter ramps are linked to an increased risk of WWD crashes.
- TCDs to consider include the following:
  - Vertical signage:
    - DNE signs.
    - Possibly others (not supported by statistical analyses).
  - Pavement markings and delineation:
    - Stop bars.
    - WW arrows.
    - Lane use arrows.

Questions?

Discussion?

Thank You!

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