

Geometric Design Elements to Reduce Wrong-Way (WW) Entry at Freeway Interchanges



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March, 2017

Why People Drive Wrong-way?

➤ WW Entry: I-65 Exit 284

➤ 35h video

➤ <https://www.youtube.com/watch?v=QrhUMbCITgY>

➤ **13** WW movements



(Image: Google Earth)



Presentation Outline

1. **Wrong-Way Driving(WWD) Crash History**
2. **Existing Design Guidelines**
3. **Wrong-Way(WW) Movements at Different Interchanges**
4. **Effect of Geometric Elements on WWD**
 - **WWD Crash Analysis**
 - **Field Study of GPS Devices**
5. **Proven Geometric Design Elements**



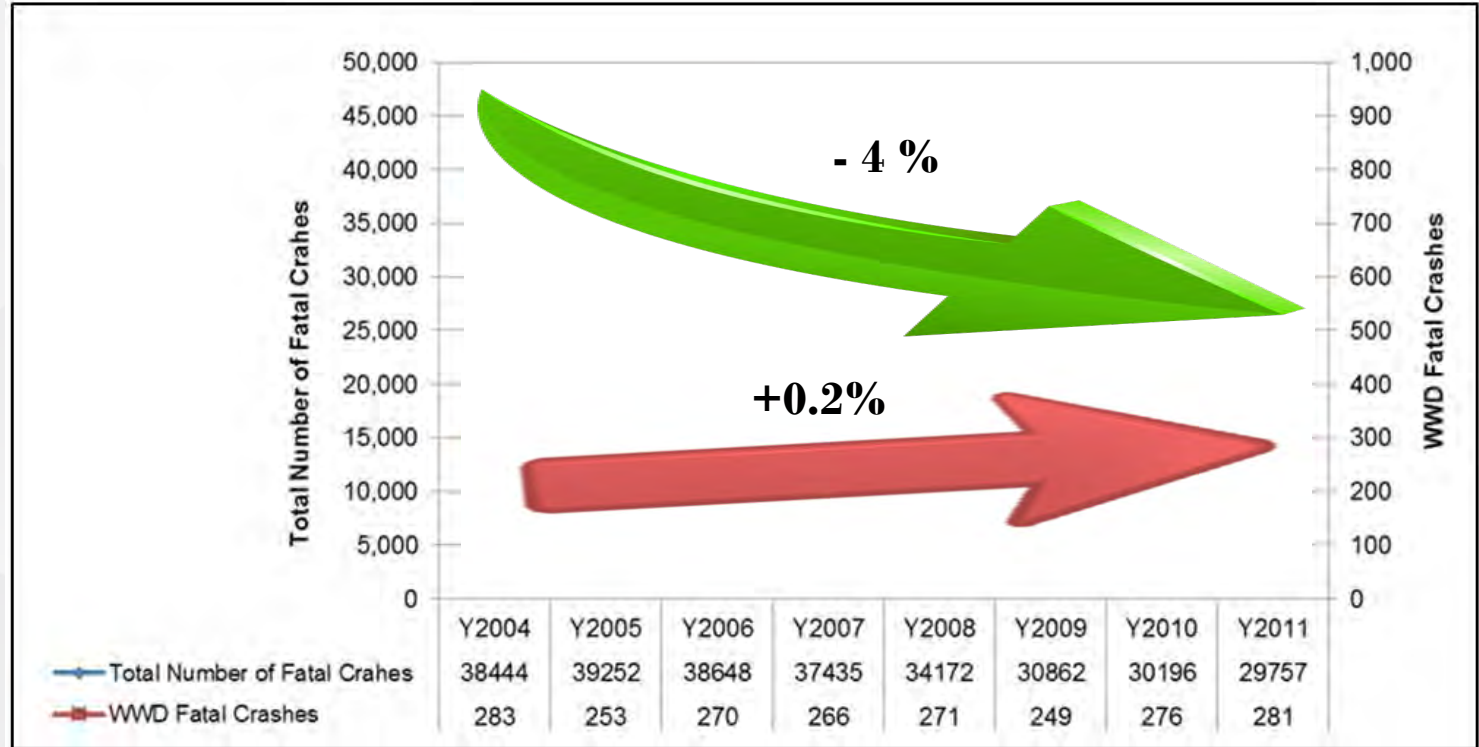
01

Wrong-Way Driving(WWD) Crash History



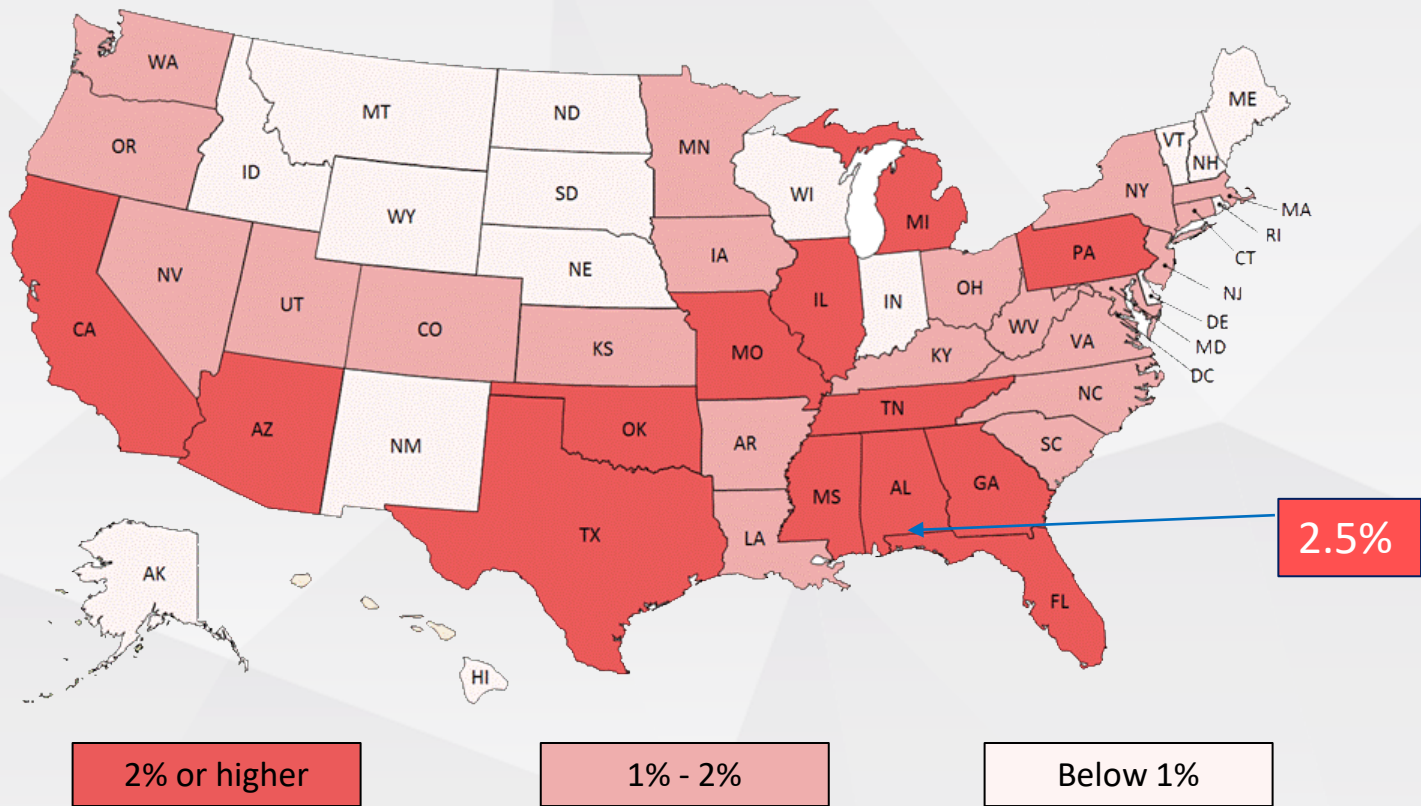
National Trend of WWD Fatal Crashes (2004-2011)

WWD is **rare**
but very
severe!!!





Average and Percentage of WWD Fatalities in Each State (2004-2011)



(IDOT WWD Guideline)



Number of WWD Crashes in Alabama

	Year					
	2009	2010	2011	2012	2013	Total
Freeway Crashes	11,023	11,433	11,967	11,258	11,358	57,039
WWD Crashes	17	16	25	16	19	93
Percent	0.15%	0.13%	0.20%	0.14%	0.16%	0.16%
	No. of Persons					
Killed	4	2	6	2	4	18
A-Injury	7	4	18	7	11	47
B-Injury	2	10	6	7	3	28
C-Injury	3	1	6	1	5	16
PDO	22	27	44	38	25	156
	No. of Crashes					
Freeway Fatal Crashes	77	93	88	86	83	427
WWD Fatal Crashes	4	2	4	2	2	14
Percent	5.2%	2.2%	4.5%	2.3%	2.4%	3.3%



Top Counties in Number of WWD

Ranking	County	No. of WWD Crashes	Percent
1	Jefferson	31	33.3%
2	Mobile	14	15.1%
3	Baldwin	5	5.4%
3	Madison	5	5.4%
5	Montgomery	4	4.3%
5	St Clair	4	4.3%
7	Butler	3	3.2%
7	Macon	3	3.2%
7	Tuscaloosa	3	3.2%
Total		72	77.4%



Top Five Routes in terms of WWD

Route	Frequency	Percent	Length (mi)	Percent of Total Mileage
I-65	29	31.2%	367.0	35.4%
I-59	25	26.9%	241.4	23.3%
I-10	10	10.8%	66.3	6.4%
I-20	7	7.5%	214.7	20.7%
I-85	6	6.5%	80.0	7.7%
Total	77	82.8%	969.4	93.6%



Area Type

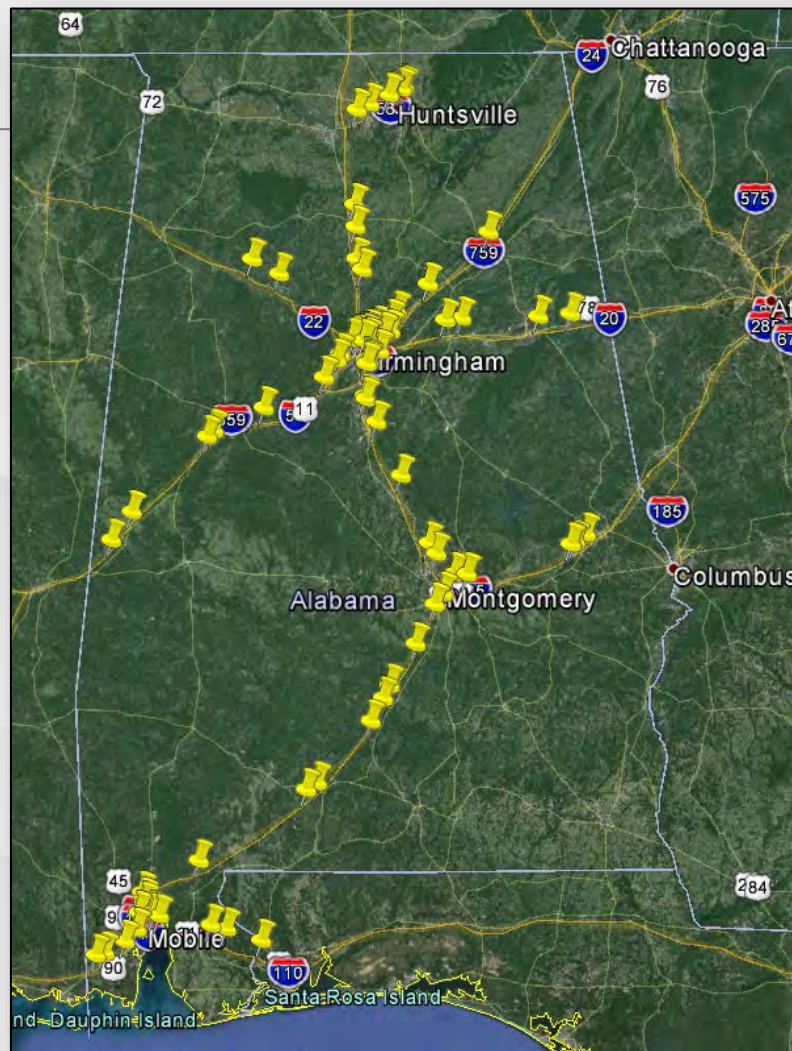
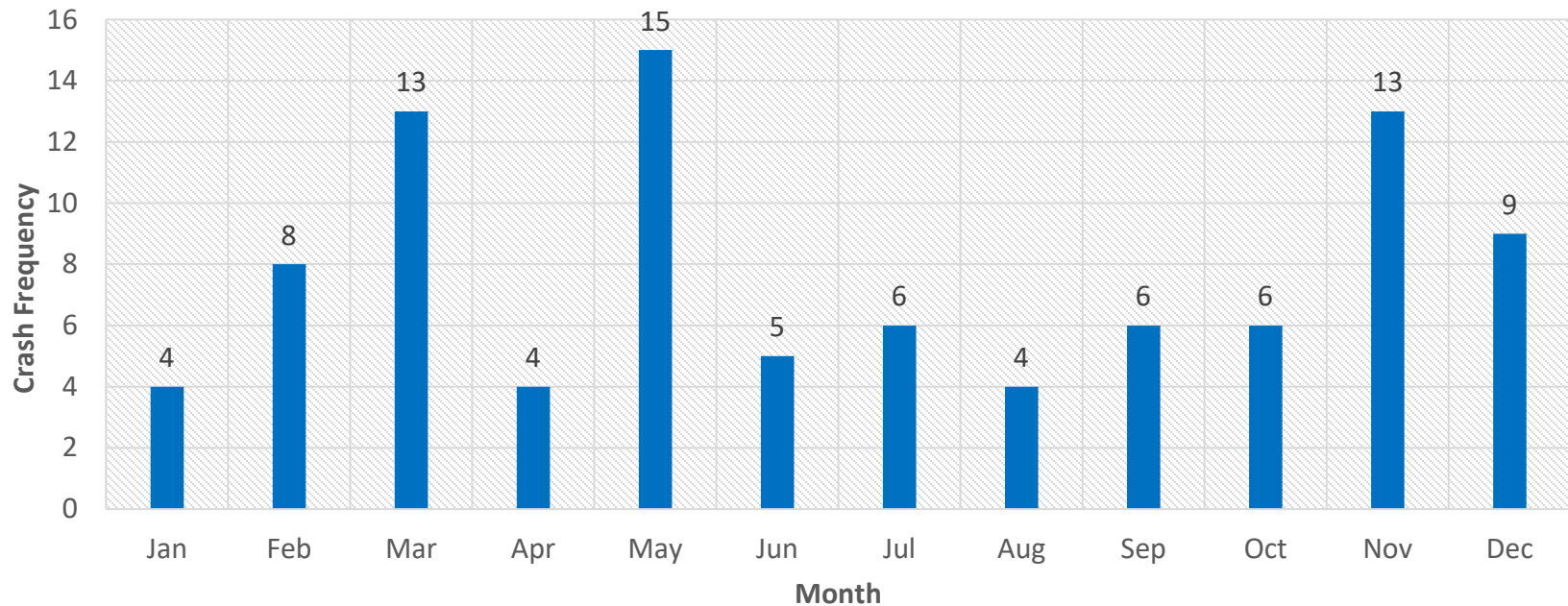


Image: Google Earth

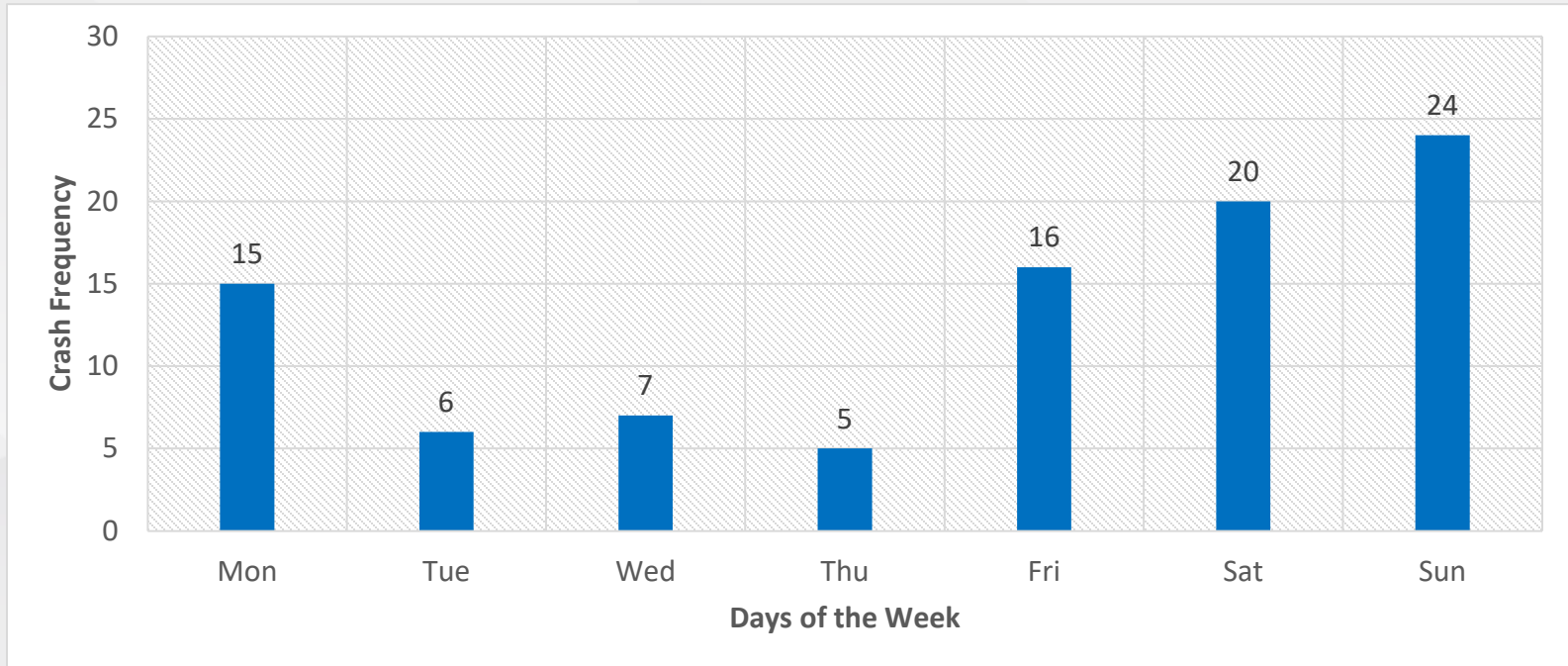


Temporal Distribution: Month



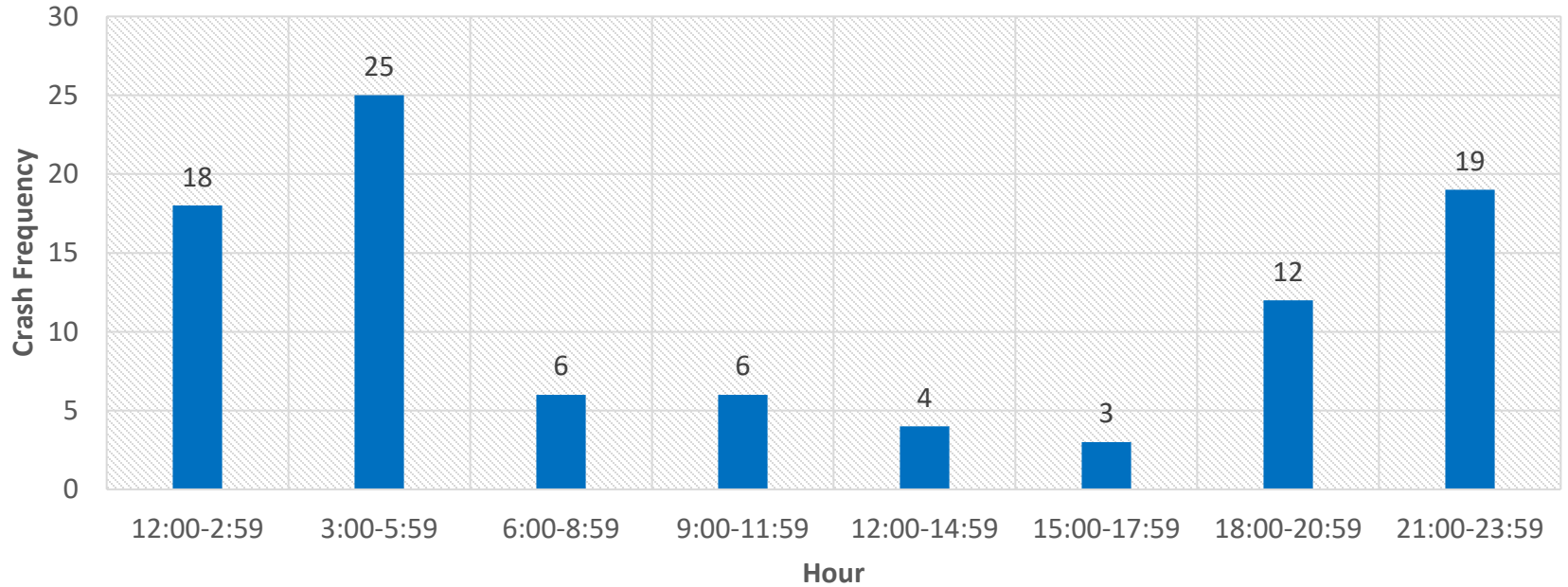


Temporal Distribution: Day





Temporal Distribution: Hour



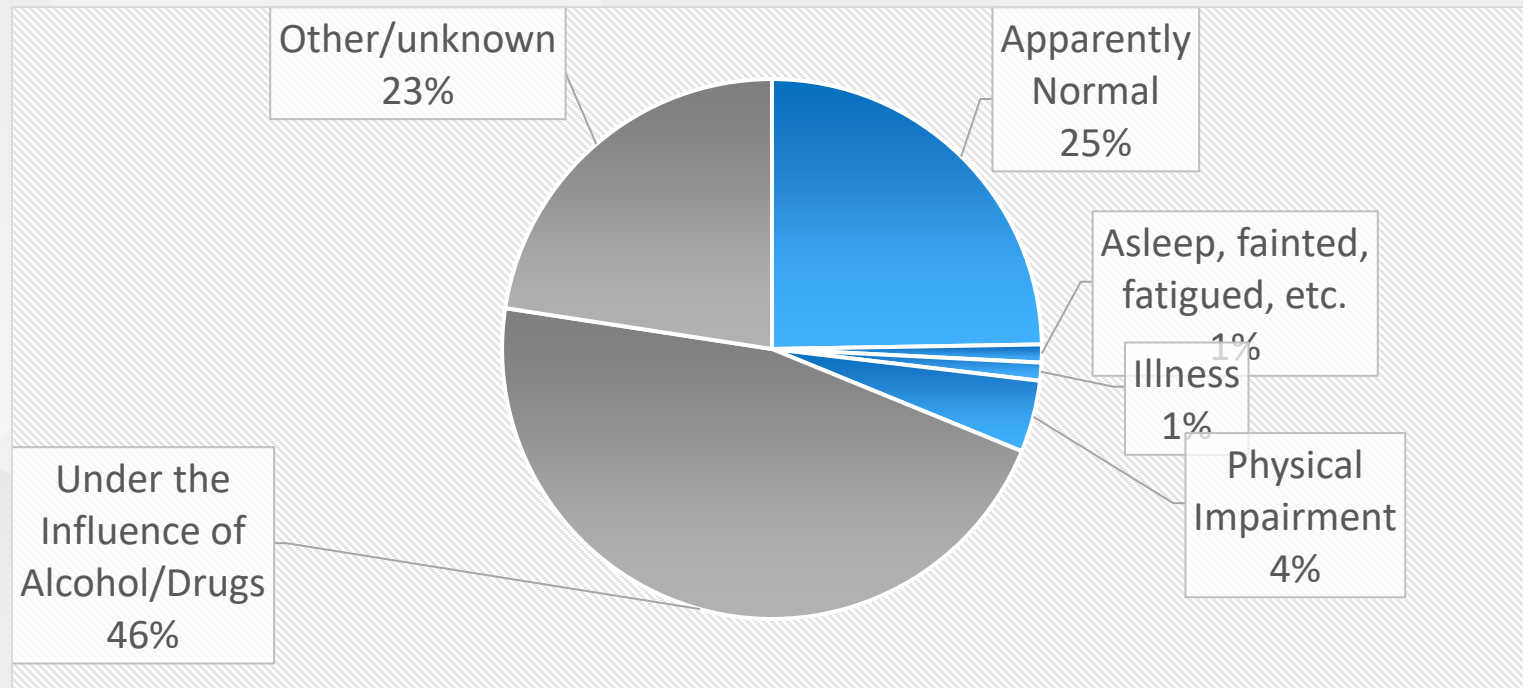


WW Driver Characteristics: Age

Age Group	No. of Drivers	Percentage of Total
Less than 24	17	18.3%
25-34	21	22.6%
35-44	14	16.1%
45-54	8	8.6%
55-64	4	4.3%
Over 65	24	25.8%
Unknown	5	5.4%
Total	93	100.0%

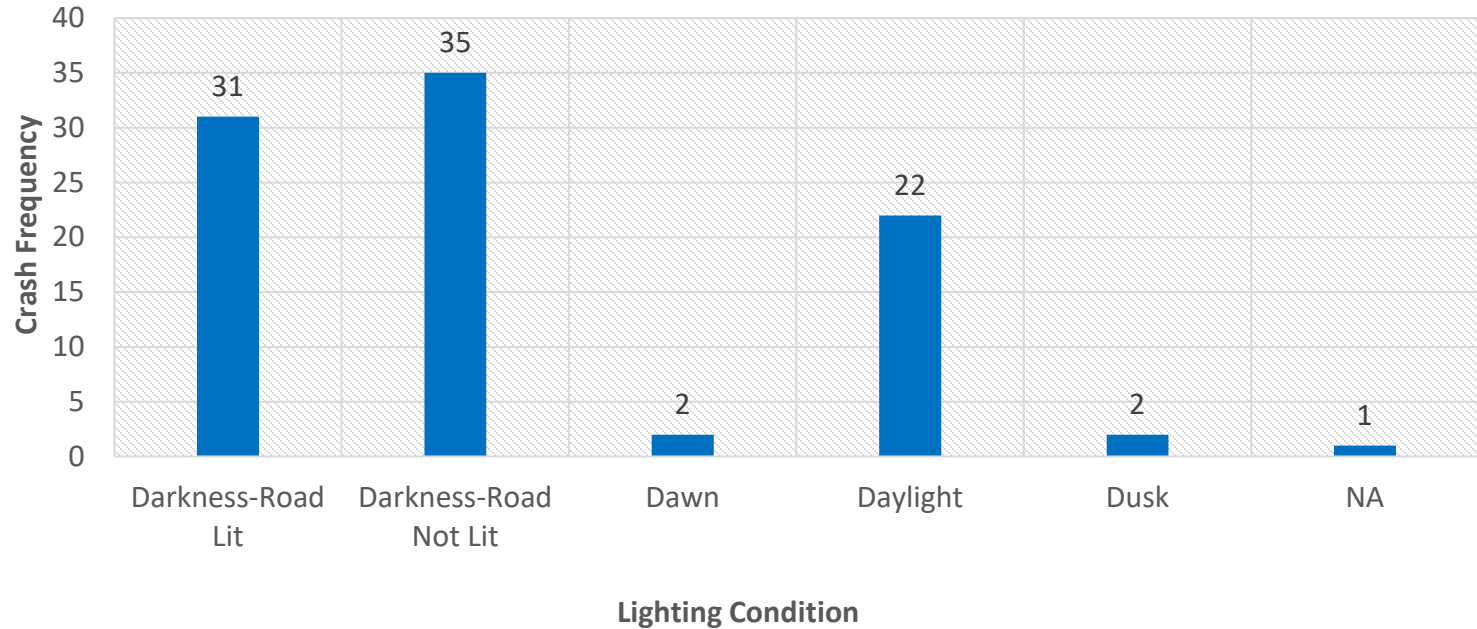


WW Driver Characteristics: **Condition**





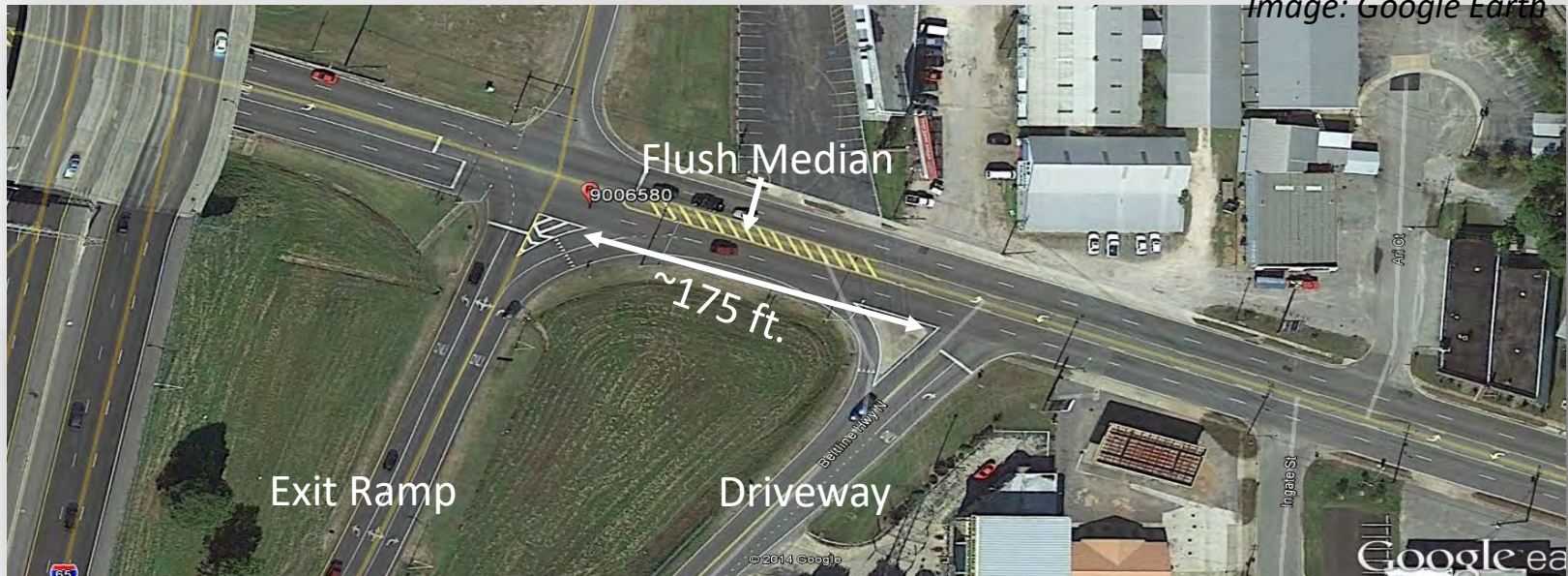
Roadway Lighting Condition





General Issues with Geometric Design

- **Driveways Close to Exit Ramp**
- **Channelizing Island and Angular Break**
- **30% Locations with Raised Median**



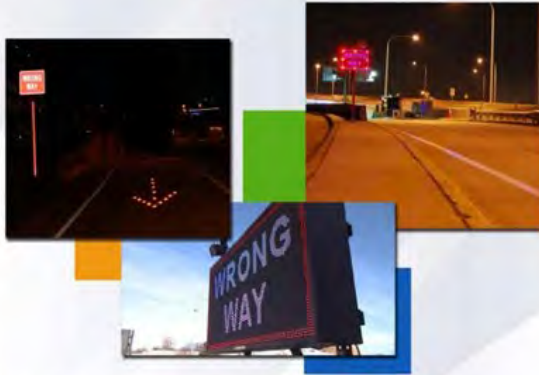


02

Existing Design Guidelines



GUIDELINES FOR REDUCING WRONG-WAY CRASHES ON FREEWAYS



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May 2014

A Policy on Geometric Design of Highways and Streets

2011
8th Edition



AMERICAN TRAFFIC SAFETY SERVICES ASSOCIATION

EMERGING SAFETY COUNTERMEASURES FOR WRONG-WAY DRIVING

AMERICAN TRAFFIC SAFETY SERVICES ASSOCIATION



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Geometric Design Examples

✓ **Geometric Elements**

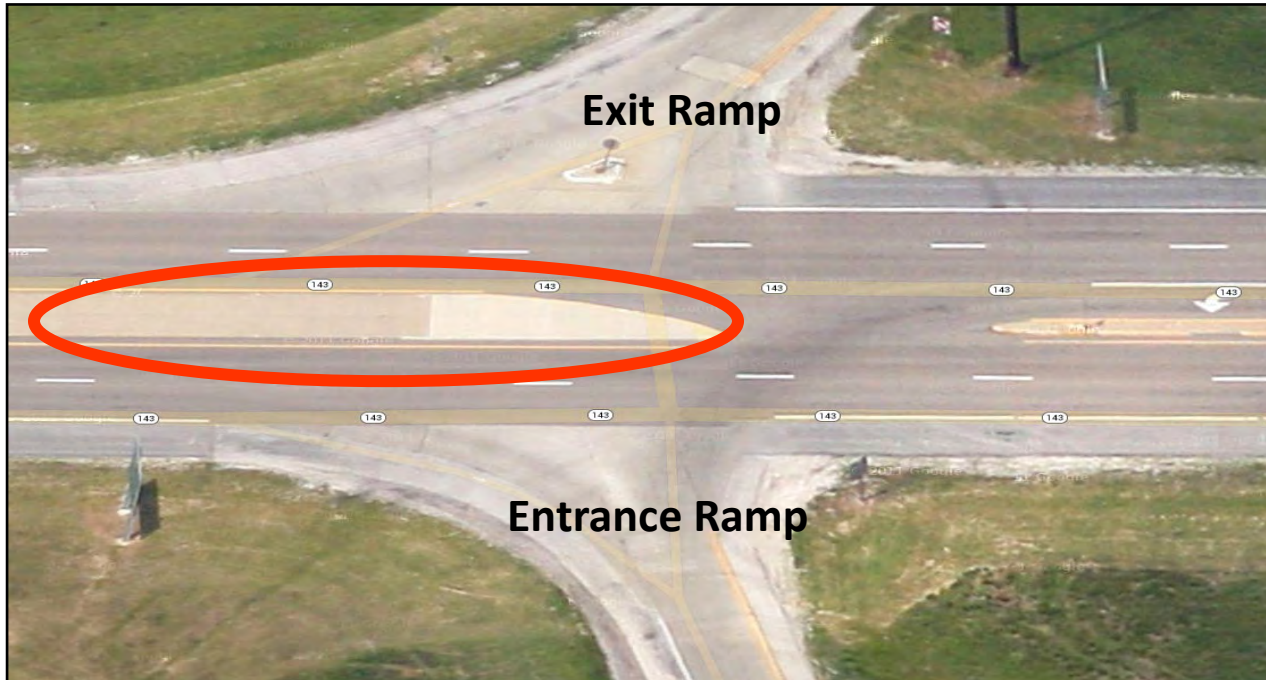
- Raised Median
- Control Radius
- Channelizing Island

✓ **Geometric Design Examples of Conventional Diamond Interchanges**

✓ **Geometric Design Examples of Partial Cloverleaf Interchanges**

Geometric Elements

Raised Medians: Wherever left-turn wrong-way maneuvers from a crossroad onto exit ramps are a major of concern.



Geometric Elements

Median Barrier: When the proximity of exit and entrance ramps can cause confusion to drivers (e.g. Trumpet interchanges).



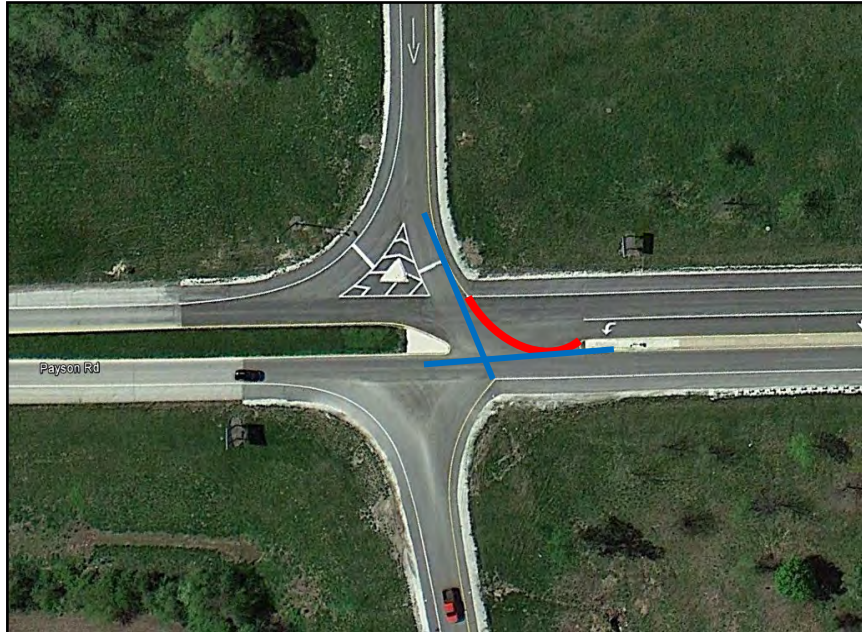
Geometric Elements

NOTE: Concrete barriers or guardrails as median barriers can cause a sight distance problem for drivers on the crossroad if used to separate adjacent entrance and exit ramps at partial cloverleaf interchanges.



Geometric Elements

Note: If a curve is used as the control radius, the crossroad centerline, and not the edge of the crossroad, should be considered as the tangent line.

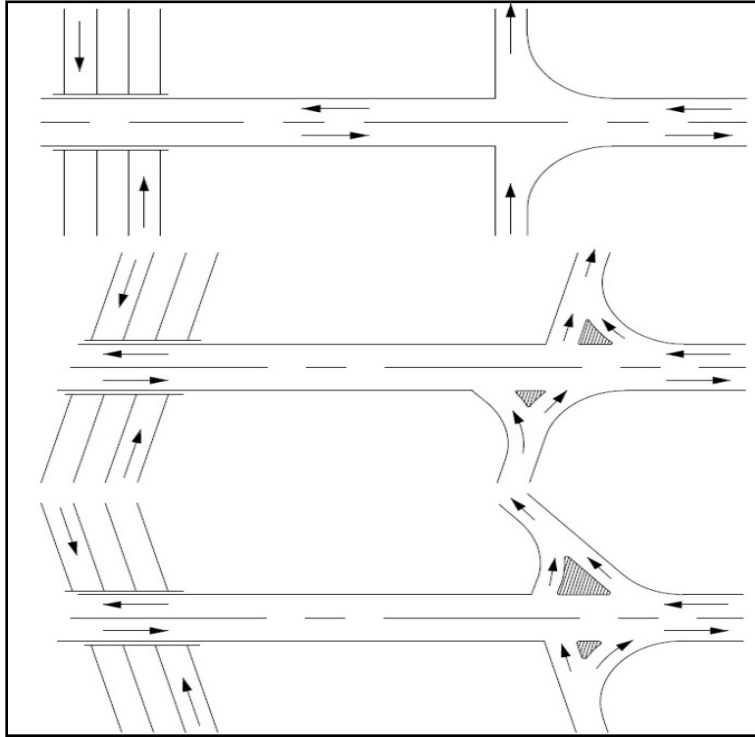


Geometric Elements

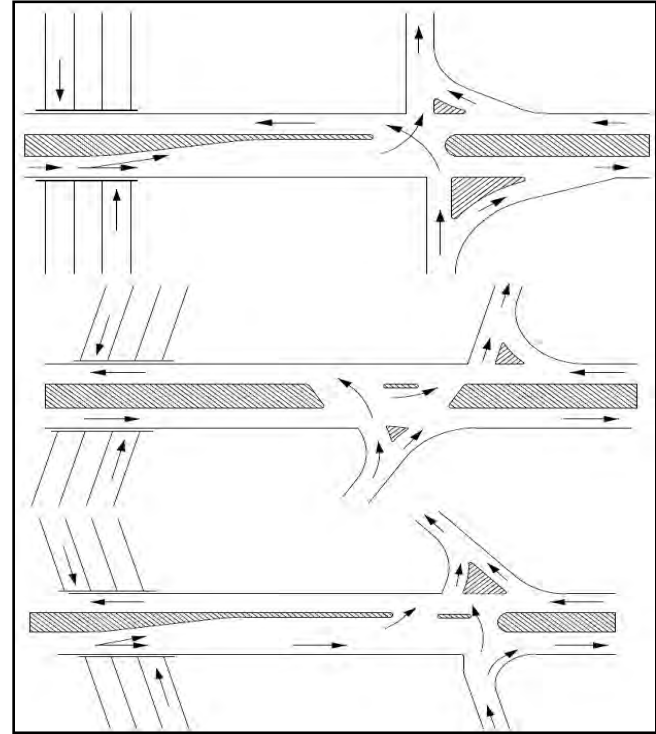
Channelizing Island: An effective way to reduce wrong-way movements, especially among older drivers. This element can reduce the width of the exit ramp throat.



Geometric Design Examples of Conventional Diamond Interchanges

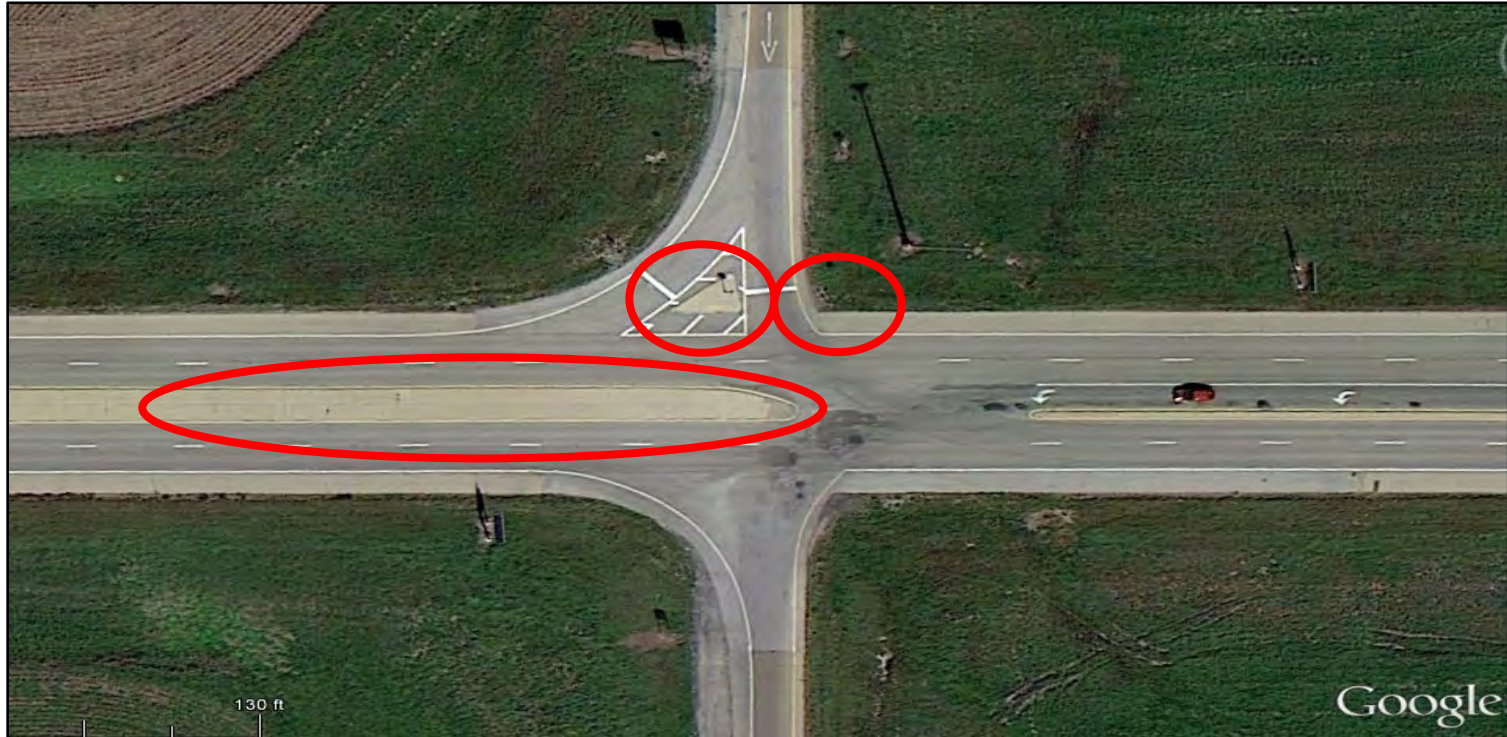


Two-Lane Crossroad Design



Divided Crossroad Design

Geometric Design Examples of Conventional Diamond Interchanges





03

Wrong-Way(WW) Movements at Different Interchanges



Wrong-Way Entry

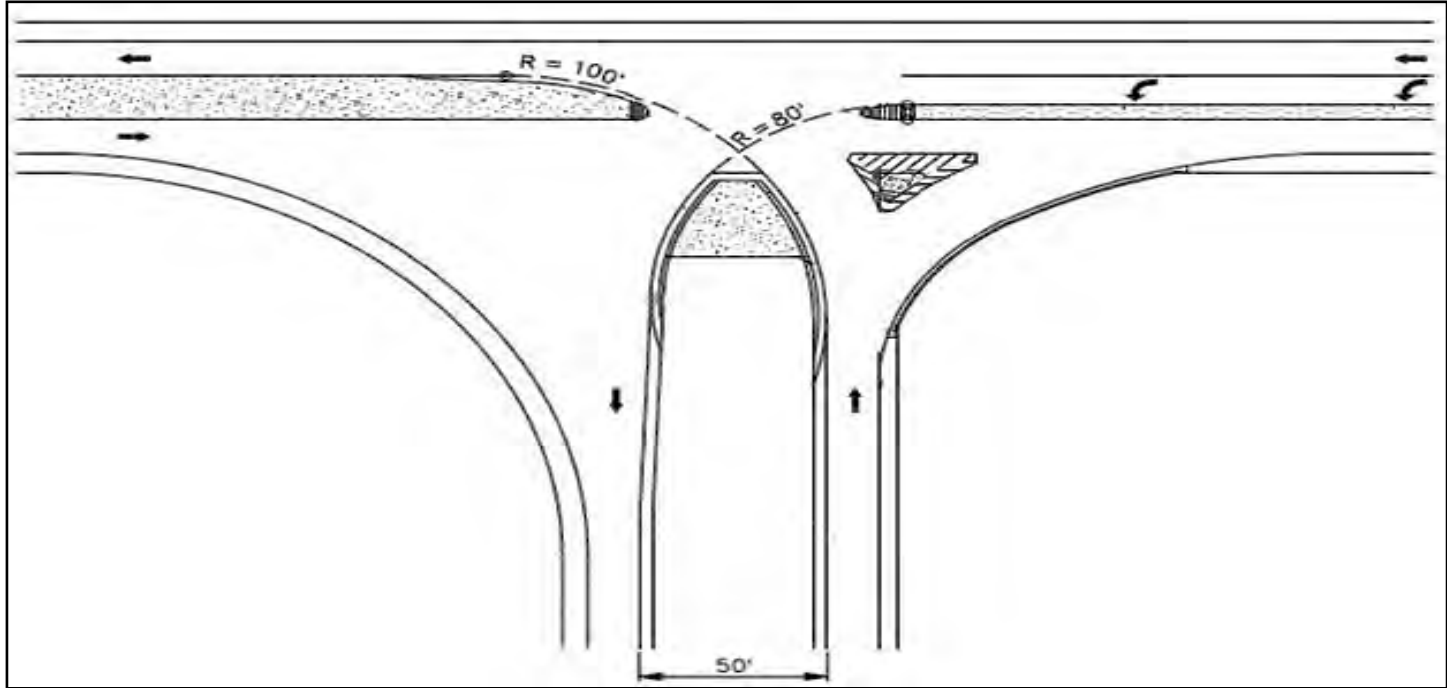
- ❖ **Common entry points**
 - Entering from the exit ramp – **the most prevalent one!**
 - Cross the median
 - U-turn on freeway

- ❖ **Partial cloverleaf (**Parclo**) interchanges among most susceptible interchanges in terms of WWD entry**
 - Close exit and entrance ramp (two-way ramp)

Table 4.14 Interchange Ranking by Type Using WWD Crash Rate

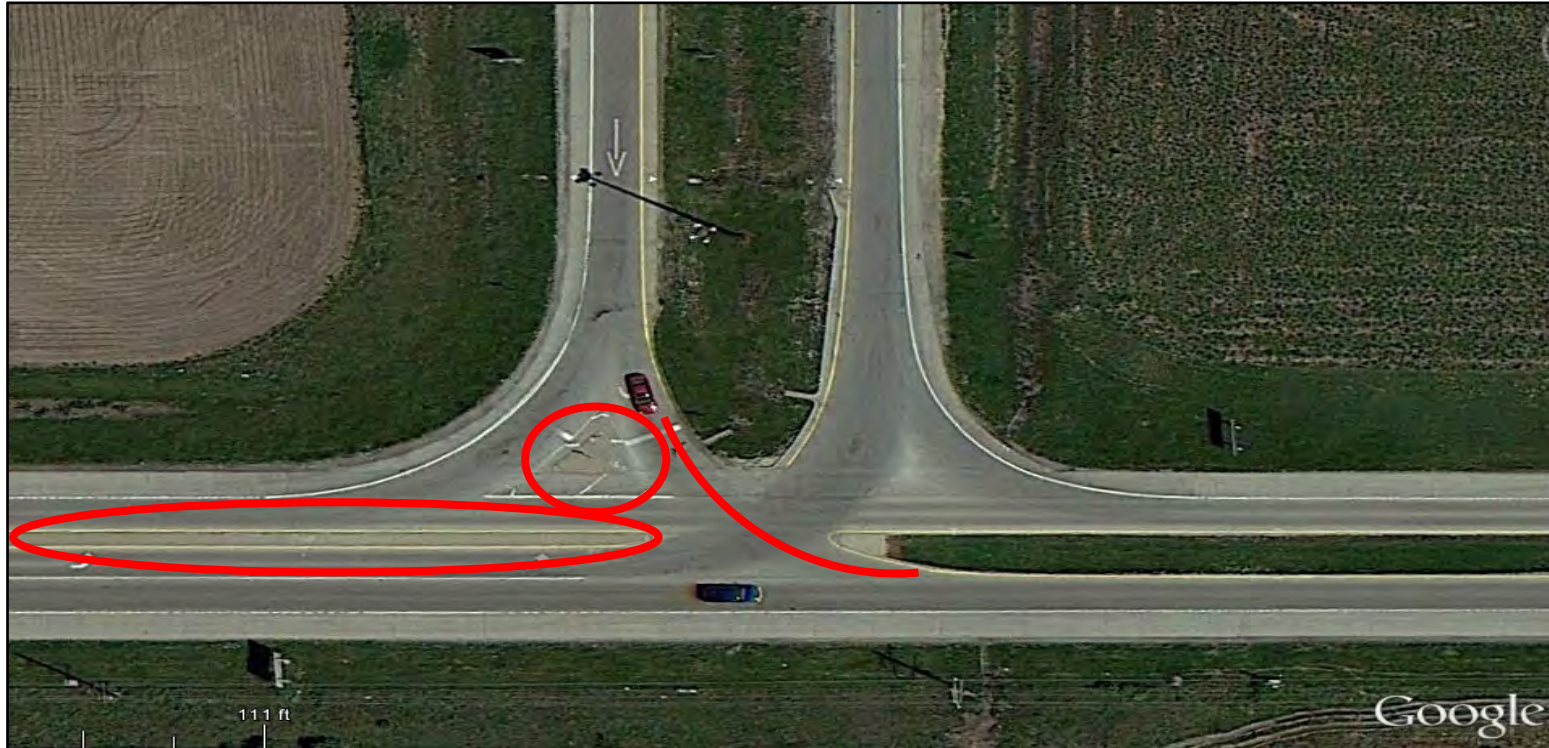
Interchange Type	Record ed (E_0)	1 st Entry Point (E_1)	Estimated	2 nd Entry Point (E_2)	Estimated	Total No. of Int. in AL (N_{int})	WWD Crash Rate (CR_{int})	Rank
Parclo	5		5		7	25	6.72	1
Half Diamond	0		7		5	15	5.07	2
Cloverleaf	0		2		2	5	4.80	3
Modified Diamond/Parclo	3		10		9	37	4.76	4
Diamond	14		36		32	173	4.02	5
Freeway Feeder	2		2		5	19	4.00	6
Diamond with Frontage Road	0		1		1	4	3.00	7
Directional	0		1		2	16	1.00	8
Rest Area	0		1		2	19	0.84	9
Total	24		65		65	313	4.03	—

Geometric Design Examples of Partial Cloverleaf Interchanges



Typical Ramp-Crossroad Design for a Two-Quadrant Partial Cloverleaf Interchange Proposed by IDOT

Geometric Design Examples of Partial Cloverleaf Interchanges





04

Effect of Geometric Elements on WWD

- ☐ WWD Crash Analysis
- ☐ Field Study of GPS Devices

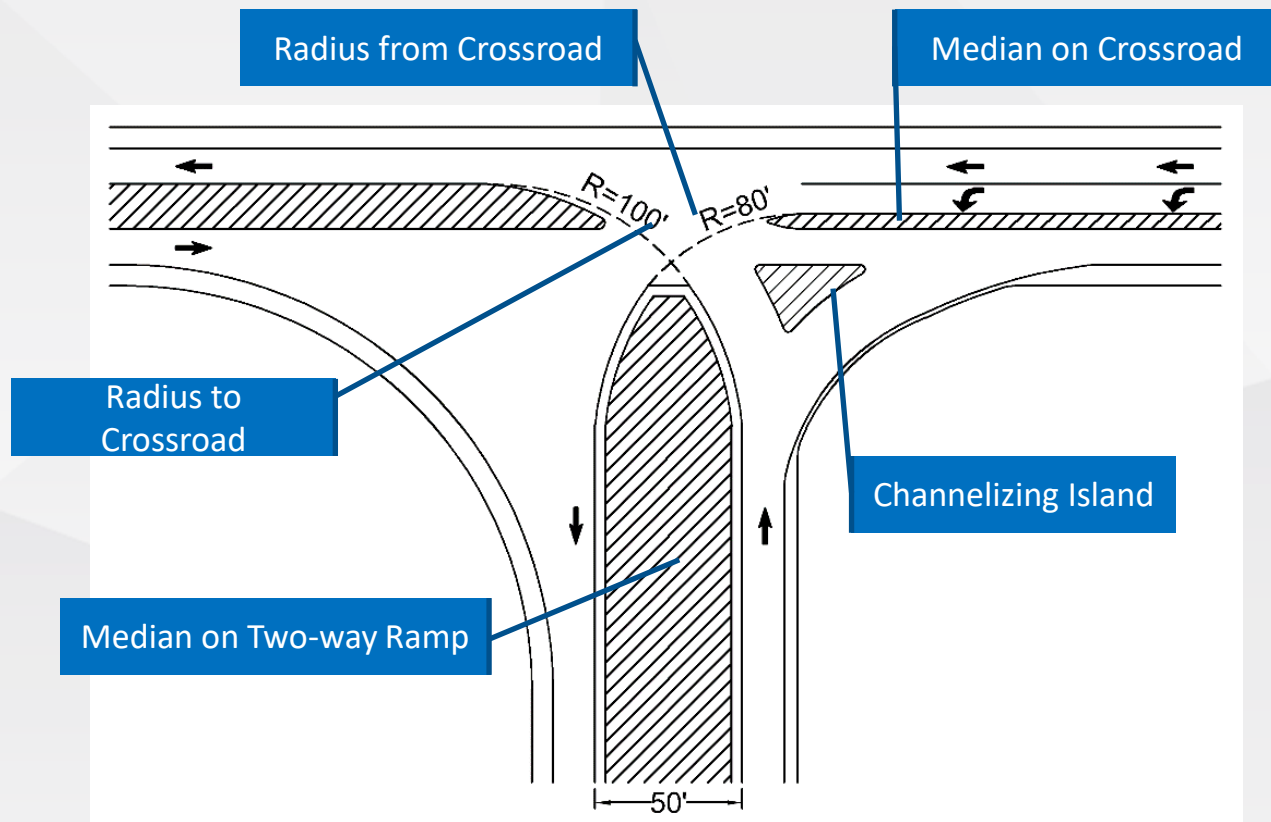


Potential Geometric Design Elements

- 1) Control Radius
- 2) Median Type on Crossroads
- 3) Median Width on Two-way Ramps
- 4) Intersection Balance
- 5) Distance to Access Point in the Vicinity of the Interchange
- 6) Intersection Angle
- 7) Channelizing Island



IDOT Design Guidelines





WWD Crash Analysis

❖ Crash data and study method

- WWD crash data from Alabama(5 years) and Illinois(10 years)
- ❖ 172 two-way ramps at 97 parclo interchanges
- ❖ 65 WWD crashes originating from 54 locations
- Binary logistic regression analysis, significant level $p=0.05$
- Odds Ratio (OR) as the relative measure of effect



Logistic Regression Analysis Results

Variable	Category	OR
Control/Corner Radius from Crossroad	50 ft and less	Reference
	51 to 60 ft	1.76
	61 to 70 ft	1.55
	71 to 80 ft	1.97
	81 to 90 ft	4.67
	91 to 100 ft	3.39
	More than 100 ft	2.27
Type of Median on Crossroad	Non-traversable	Reference
	Traversable	1.94
Median between Exit and Entrance Ramps	10 ft and less	Reference
	11 to 20 ft	1.13
	21 to 30 ft	1.89
	31 to 40 ft	0.25
	41 to 50 ft	0.79
	51 to 60 ft	0.28
	More than 60 ft	0.19

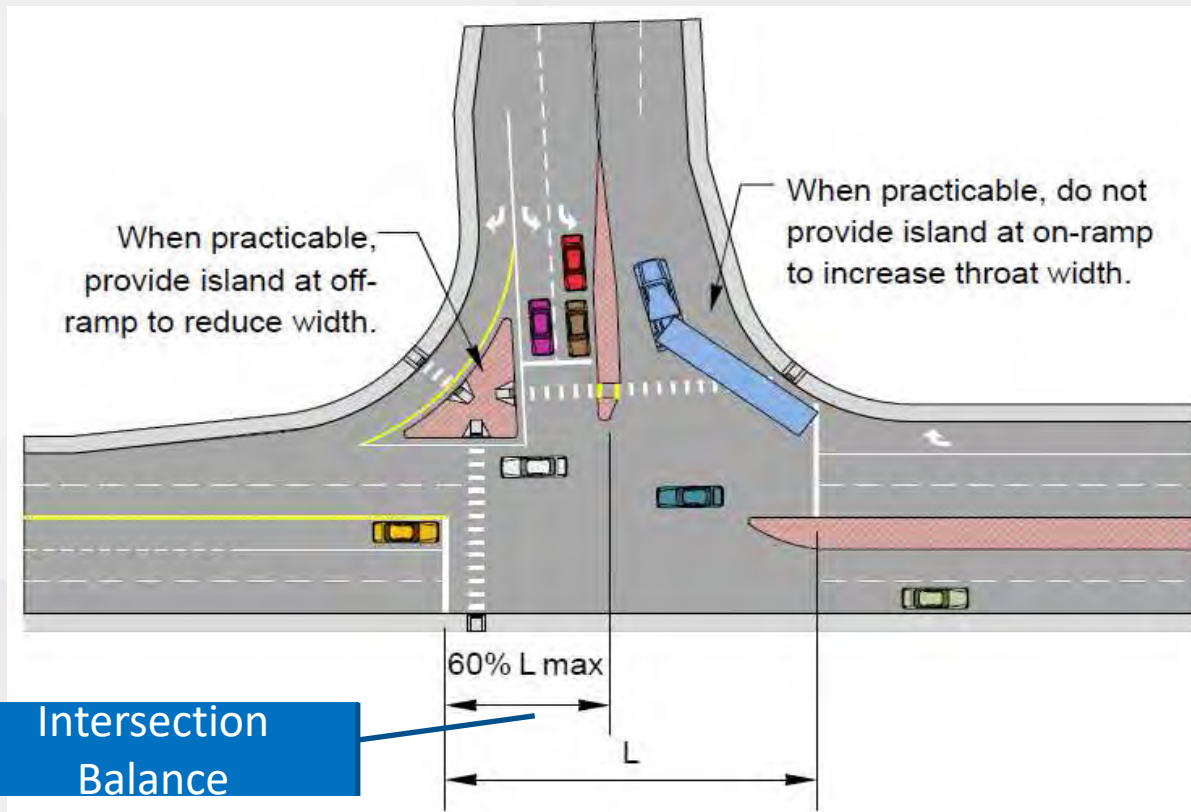


Logistic Regression Analysis Results (continued)

Variable	Category	OR
Distance to Access Point in the Vicinity of the Interchange	300 ft and less	Reference
	301 to 600 ft	1.16
	601 to 900 ft	0.68
	901 to 1,200 ft	0.69
	1,201 to 1,500 ft	0.60
	More than 1,500 ft	0.63



WSDOT Design Guideline





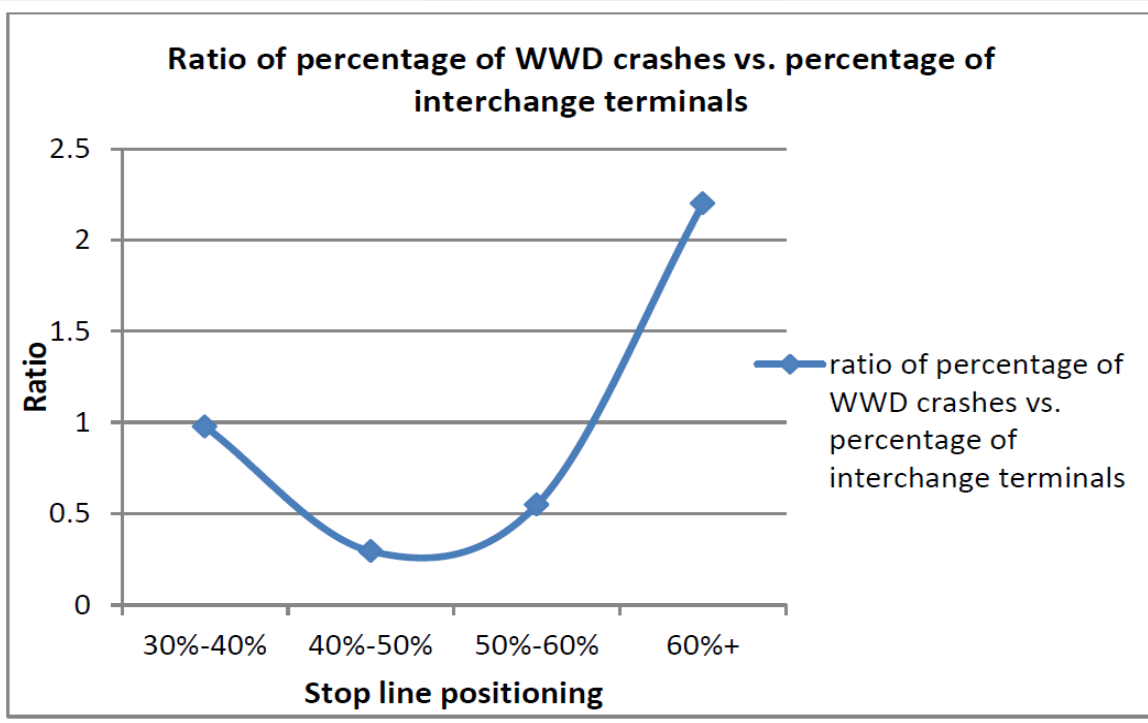
A Real-World Example of Intersection Balance



(Google Earth)



Impact of Intersection Balance on WW Crashes



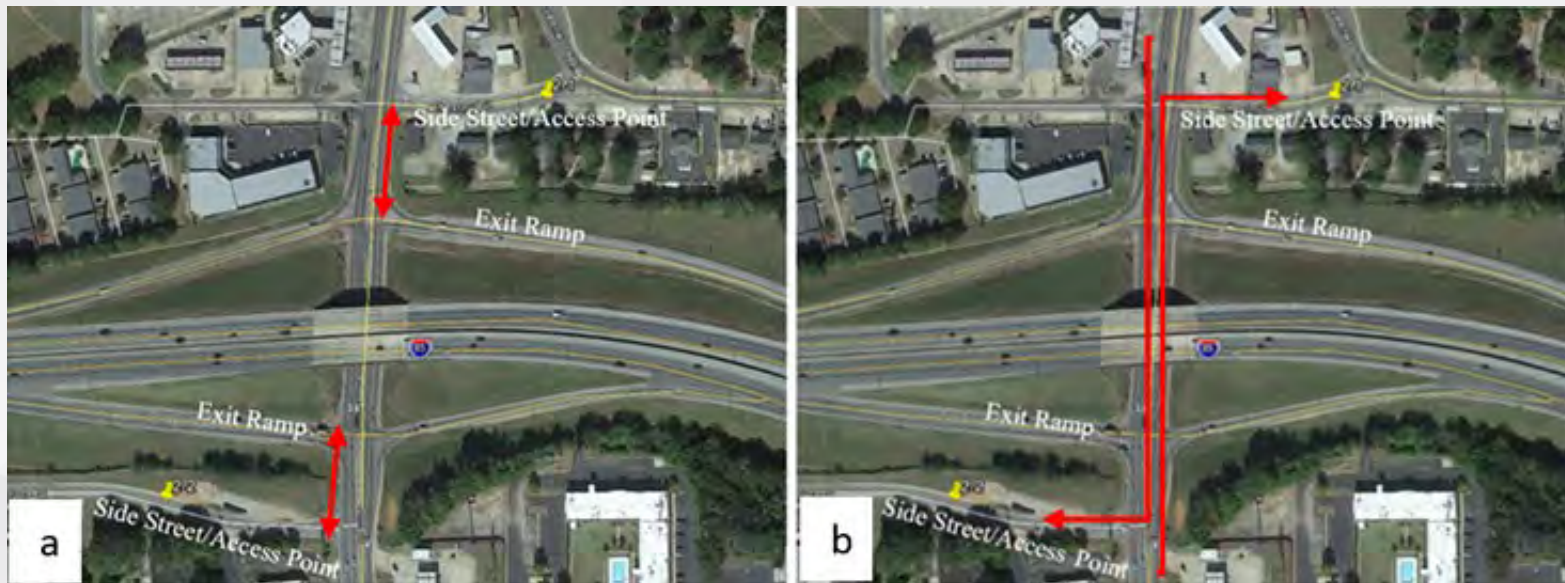


Field Study of GPS Devices

- **Objective: To determine the minimum spacing between exit ramps and access points based on the accuracy of common GPS devices**
- **5 GPS Devices (Apple map, Google map, Garmin nuvi 2557/ 2797/ 40)**
- **10 Interchanges with Close Side Streets**



Field Experiment Scenario Design



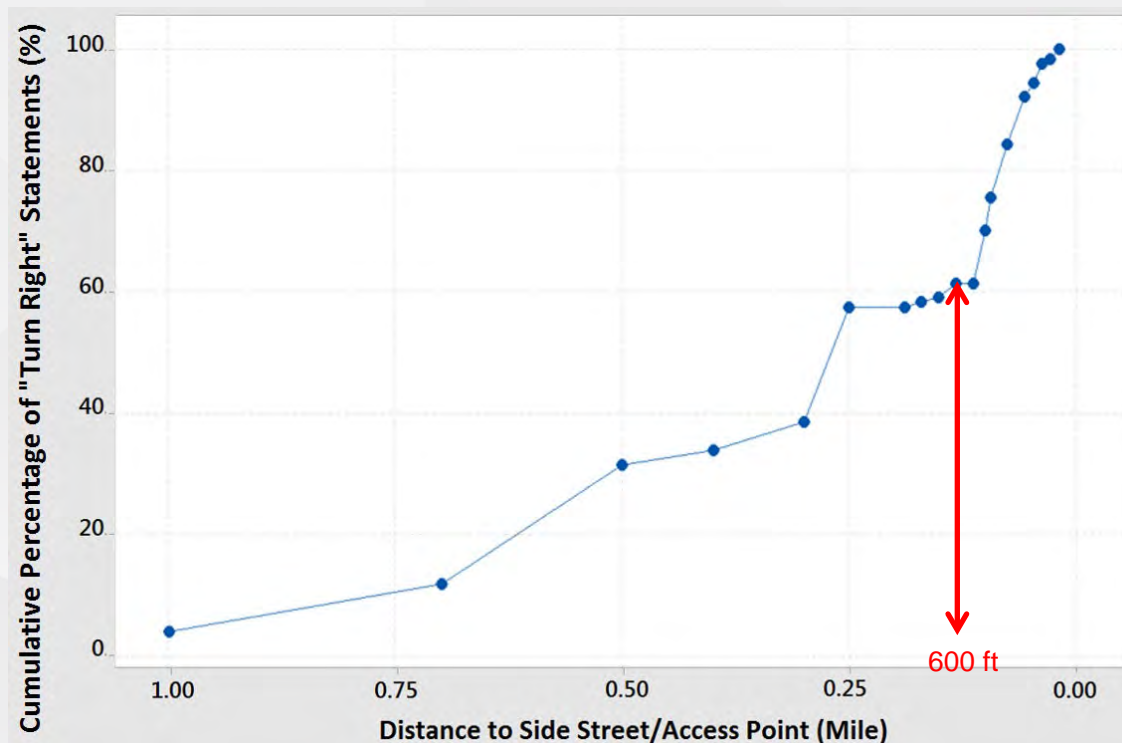
a: Spacing between side streets and exit ramps

b: Field test driving routes

(Google Earth)



% of Wrong Announcement by GPS VS. Access Spacing



Cumulative percentage of "Turn Right" statements by GPS devices/navigation



05

Proven Geometric Design Elements Can Reduce WWD



Proven Geometric Design Elements (WWD Crash Analysis)

Control/Corner Radius less than **80ft** from Crossroad will be less likely to cause WWD.



Traversable median are **twice** more prone to WWD entries.

Median width of **30+ft** between ramps was found to be less vulnerable to WWD entries.



Intersection balance can affect drivers' view of entrance ramps, resulting in more WWD crashes.

Access points located less than **600ft** to the exit ramps increase the likelihood of WWD crashes.





Proven Geometric Design Elements (GPS Study)

1. All study GPS devices gave “wrong message” when destination access points were located less than **100ft** from exit ramps.
2. The likelihood of WWD incidents increased significantly when the access points were located less than **600ft** from exit ramps.
This result is consistent with WWD crash data analysis.



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