Applying the Highway Safety Manual at the Corridor Level

Louisiana Safety Summit - October 2015

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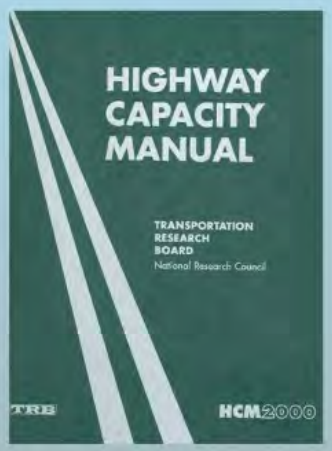
ARCADIS

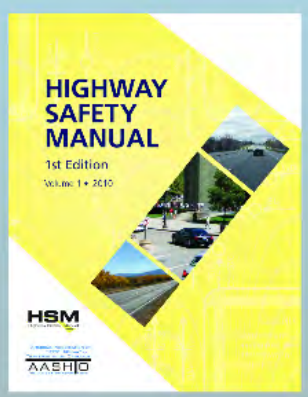
DOTD
LOUISIANA DEPARTMENT OF TRANSPORTATION & DEVELOPMENT

CH2MHILL

Background: HSM in Planning

HSM Vision Akin to HCM





Planning

Design

Volume 1 (Part A)
Introduction Human Factors Fundamentals

Introduction and Overview (Chapter 1)
Human Factors (Chapter 2)
Fundamentals (Chapter 3)

Volume 1 (Part B)
Road Safety Management Process

Network Screening (Chapter 4)
Diagnosis and Countermeasure Selection (Chapter 5 and 6)
Economic Appraisal and Prioritization
(Chapter 7 and 8)
Safety Effectiveness Evaluation (Chapter 9)

Planning

Design

Existing Conditions

Alternative 1

Alternative 2

Alternative 3

Volume 1 (Part A)
Introduction Human Factors Fundamentals

Introduction and Overview (Chapter 1)
Human Factors (Chapter 2)
Fundamentals (Chapter 3)

Volume 1 (Part B)
Road Safety Management Process

Network Screening (Chapter 4)
Diagnosis and Countermeasure Selection (Chapter 5 and 6)
Economic Appraisal and Prioritization
(Chapter 7 and 8)
Safety Effectiveness Evaluation (Chapter 9)

Volume 2 (Part C)
Predictive Method (SPFs)

Rural Two-Lane Roads (Chapter 10)
Rural Multilane Roads (Chapter 11)
Urban Suburban Arterials (Chapter 12)

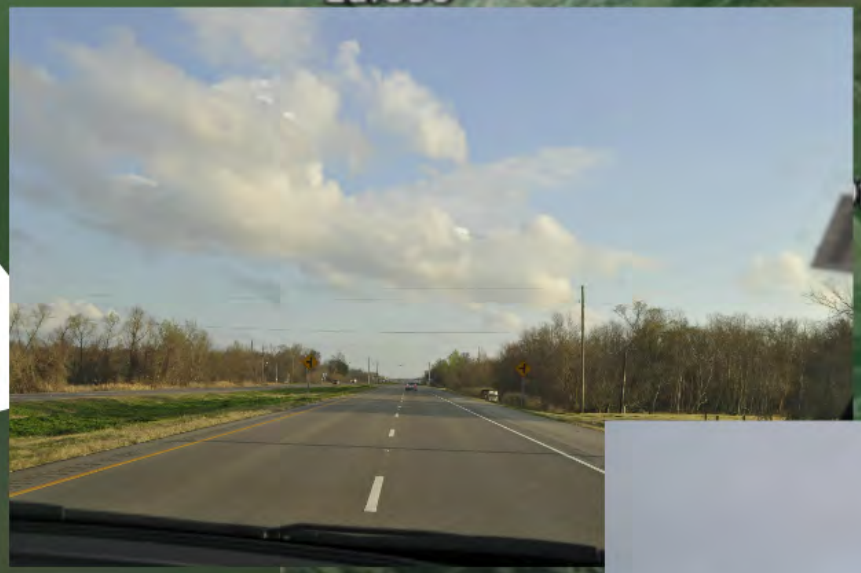
Methodology
Safety Performance Functions
Crash Modification Factors
Calibration
Applications
Example problems
References

Part C also has CMFs! But meant to be used with SPFs

Volume 3 (Part D)
Crash Modification Factors (CMFs)

Roadway Segments (Chapter 13)
Intersections (Chapter 14)
Interchanges (Chapter 15)
Special facilities, Geometric situations, and Networks (Chapter 16 and 17)

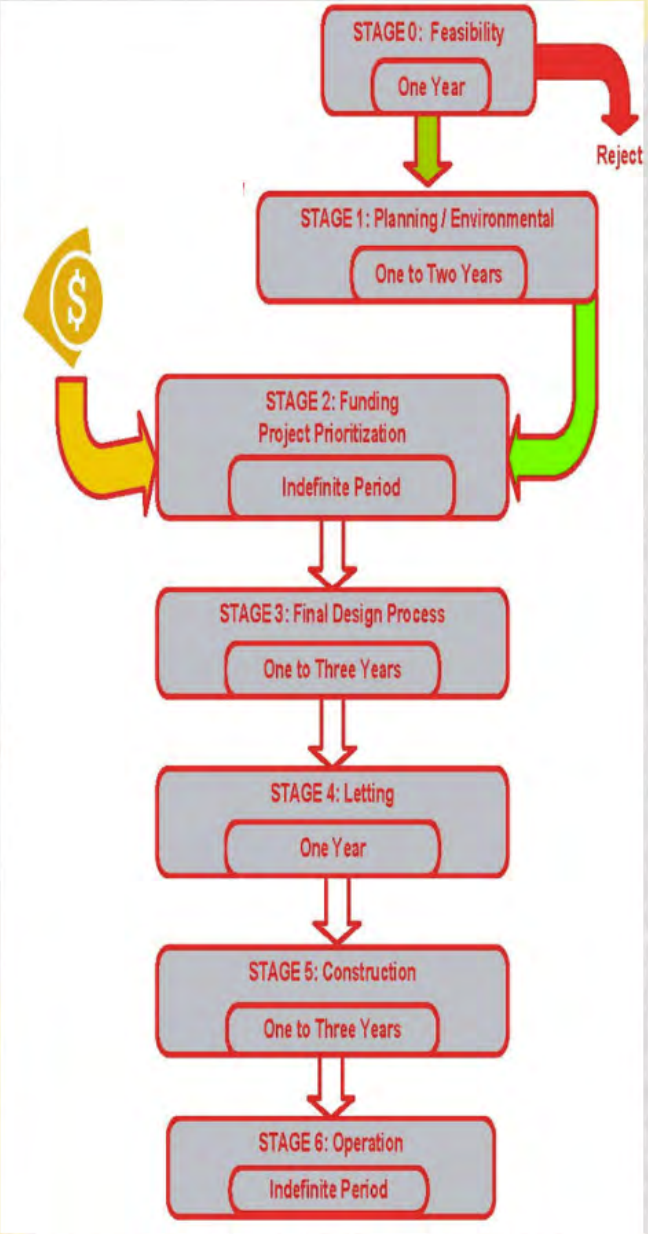
Mississippi
Case Study
Louisiana
Baton Rouge
New Orleans
Lower Lafourche
Grand Isle
Port Fourchon
oogle earth
andsat
D, NOAA, U.S. Navy, NGA, GEBCO
Google



- 16 Mile Corridor
- 4 lane Divided
- Speed Limit 50-65 mph
- Rural in Character
- but Urban Designation
- 75 Median Openings
- Few with Dedicated Turn Lanes
- Heavy Truck Traffic

Project Purpose & Need

- Perform a "Stage 0" Feasibility Study
- Number of access and conflict points a safety concern
- Crash rate at one particular intersection 3 times higher than statewide average

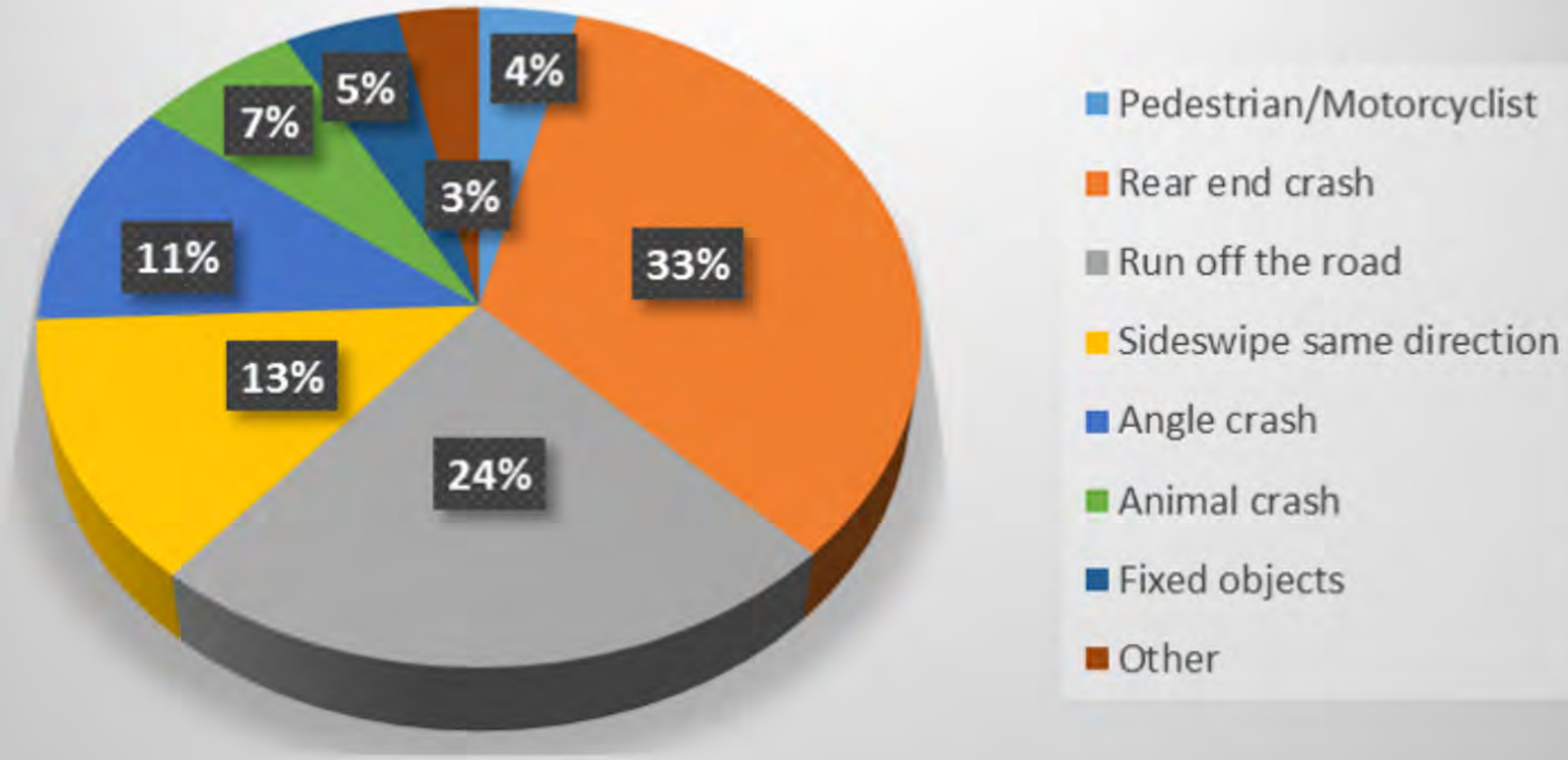


Crash History

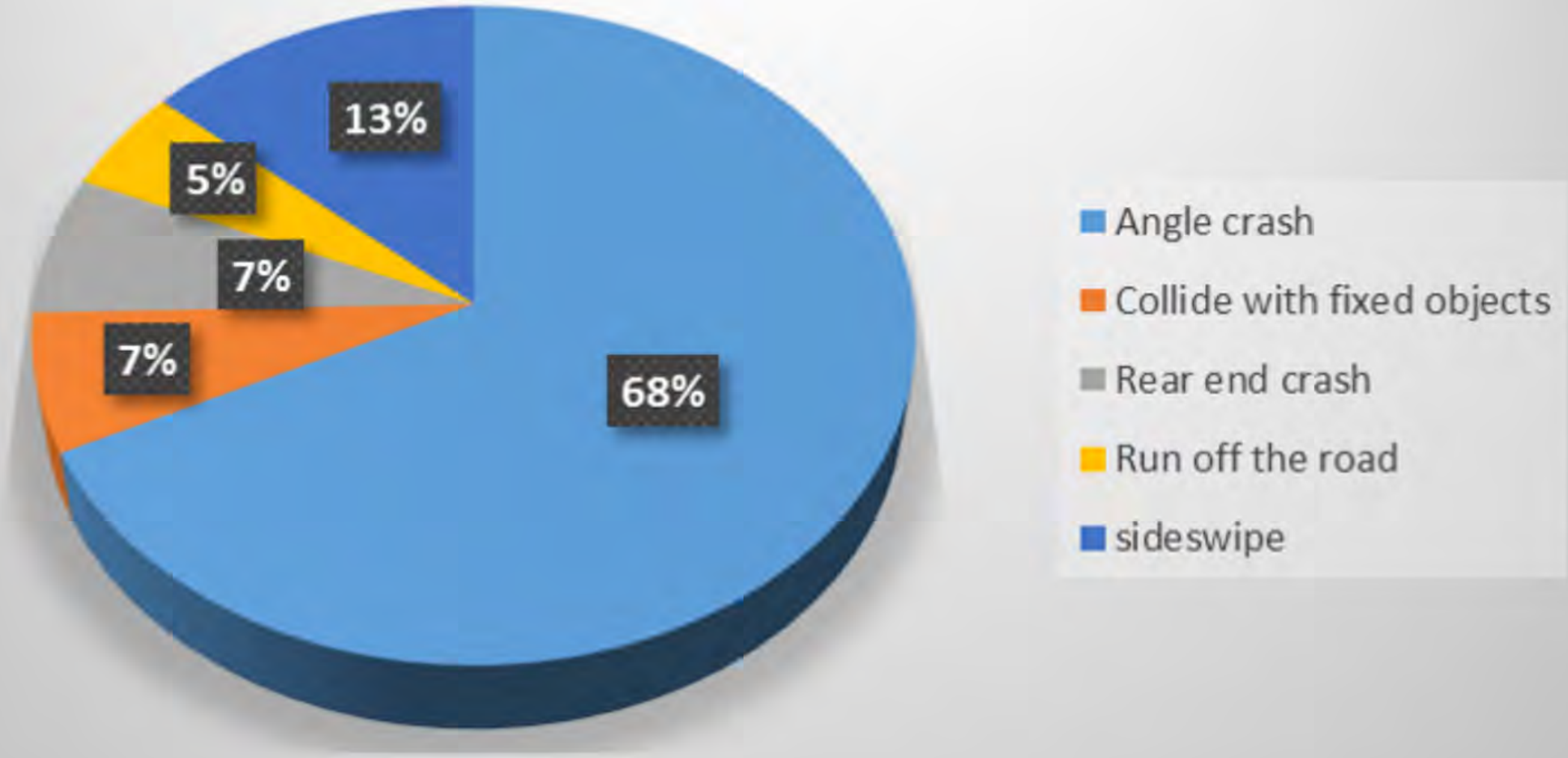
- Crash data examined 2010-2012
- On Segments: majority rear-end and run off road
- At Intersections: majority angle crashes

Crash Severity	Segment Crash Frequency	Intersection Crash Frequency	All Crashes
PDO	130	56	186
Injury	70	23	93
Fatal	2	5	7
Total	202	84	286

Crash Type for Segment Crashes



Crash Type for Intersection Crashes



Traffic Patterns

- ADT range: 10,000 to 18,000 vpd
- 23% trucks
- Most intersections operate at LOS C or better
- Capacity (along with safety) improvements only needed at particular intersection (LA 3235 & LA 3162)

No-Build Design Year (2039) Capacity

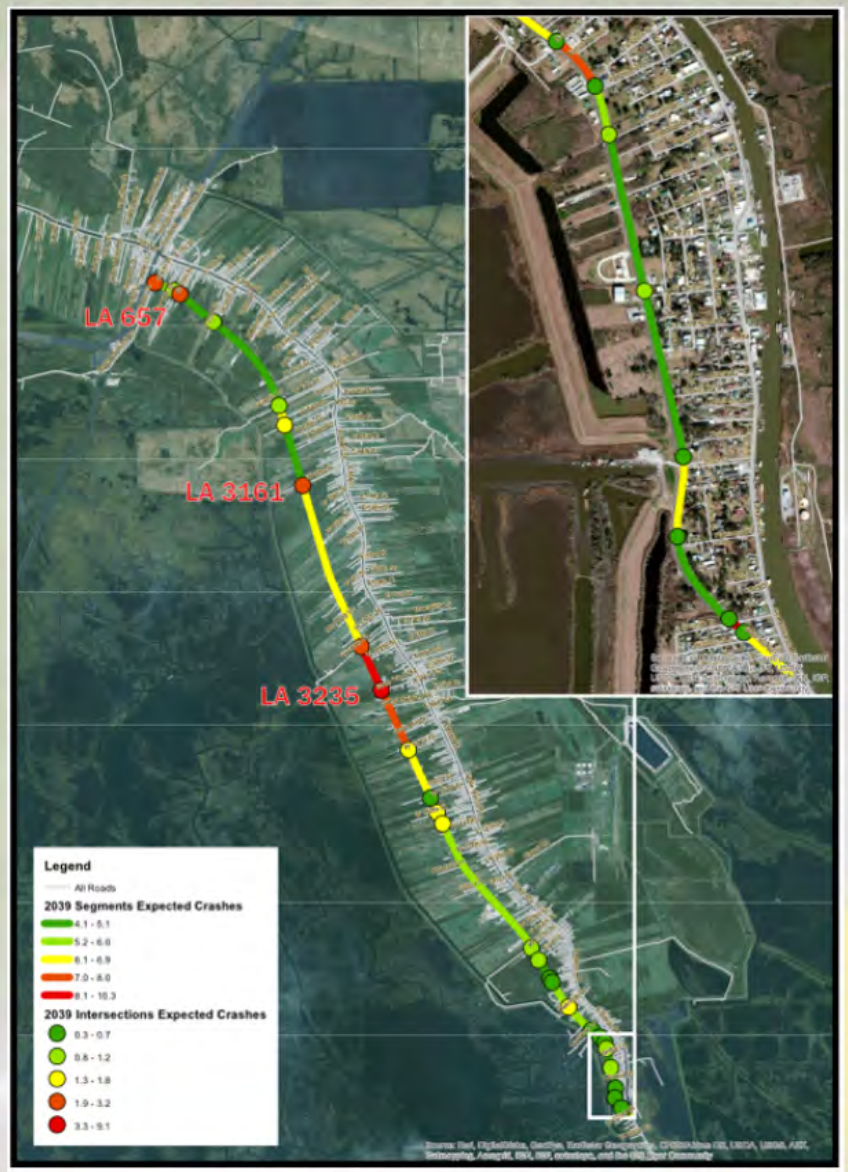
Intersection with LA 3235	Northbound		Southbound		Westbound		Eastbound	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM
LA 24	48 / 23	E / C	NA	NA	8 / 8	A / A	-	-
LA 857 (signal)	20 / 21	C / C	16 / 24	B / C	28 / 29	C / C	12 / 19	B / B
LA 3161	-	-	9 / 11	A / B	18 / 35	C / E	NA	NA
LA 3162 (signal)	37 / 37	D / D	40 / 37	D / D	68 / 49	E / D	48 / 54	D / D
LA 1					28 / 15	D / C	14 / 26	B / D

-	Free movement or low traffic volume.
sec/veh	Seconds per vehicle.
	Turn or U-turn
NA	No approach.

No-Build Design Year (2039) Capacity

Intersection with LA 3235	Northbound		Southbound		Westbound		Eastbound	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM
LA 24	48 / 23	E / C	NA	NA	8 / 8	A / A	-	-
LA 657 (signal)	20 / 21	C / C	16 / 24	B / C	28 / 29	C / C	12 / 19	B / B
LA 3161	-	-	9 / 11	A / B	18 / 35	C / E	NA	NA
LA 3162 (signal)	32 / 32	C / C	40 / 32	D / C	63 / 49	E / D	46 / 54	D / D
LA 1	-	-	-	-	26 / 15	D / C	14 / 26	B / D

-	Free movement or low traffic volume.
sec/veh	Seconds per vehicle.
	Turn or U-turn.
NA	No approach.

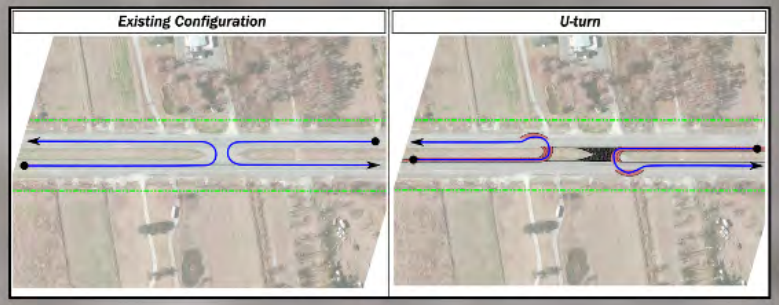


In short: Needs to Addressed

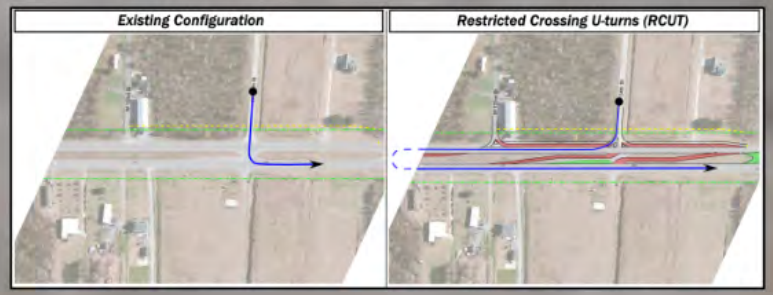
- Access points along corridor
- Conflict points between vehicles
- Total crashes along corridor
- Fatalities
- Delay at key intersection

Alternative Concepts

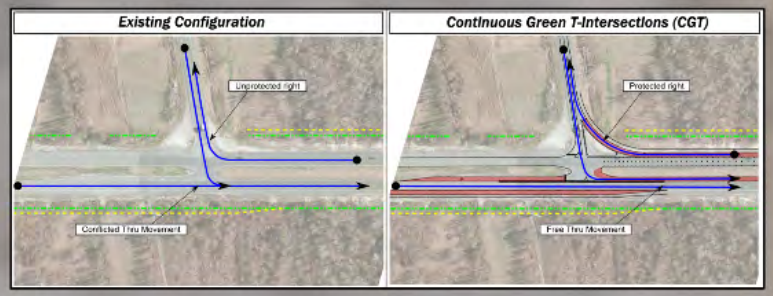
Directional U-Turn



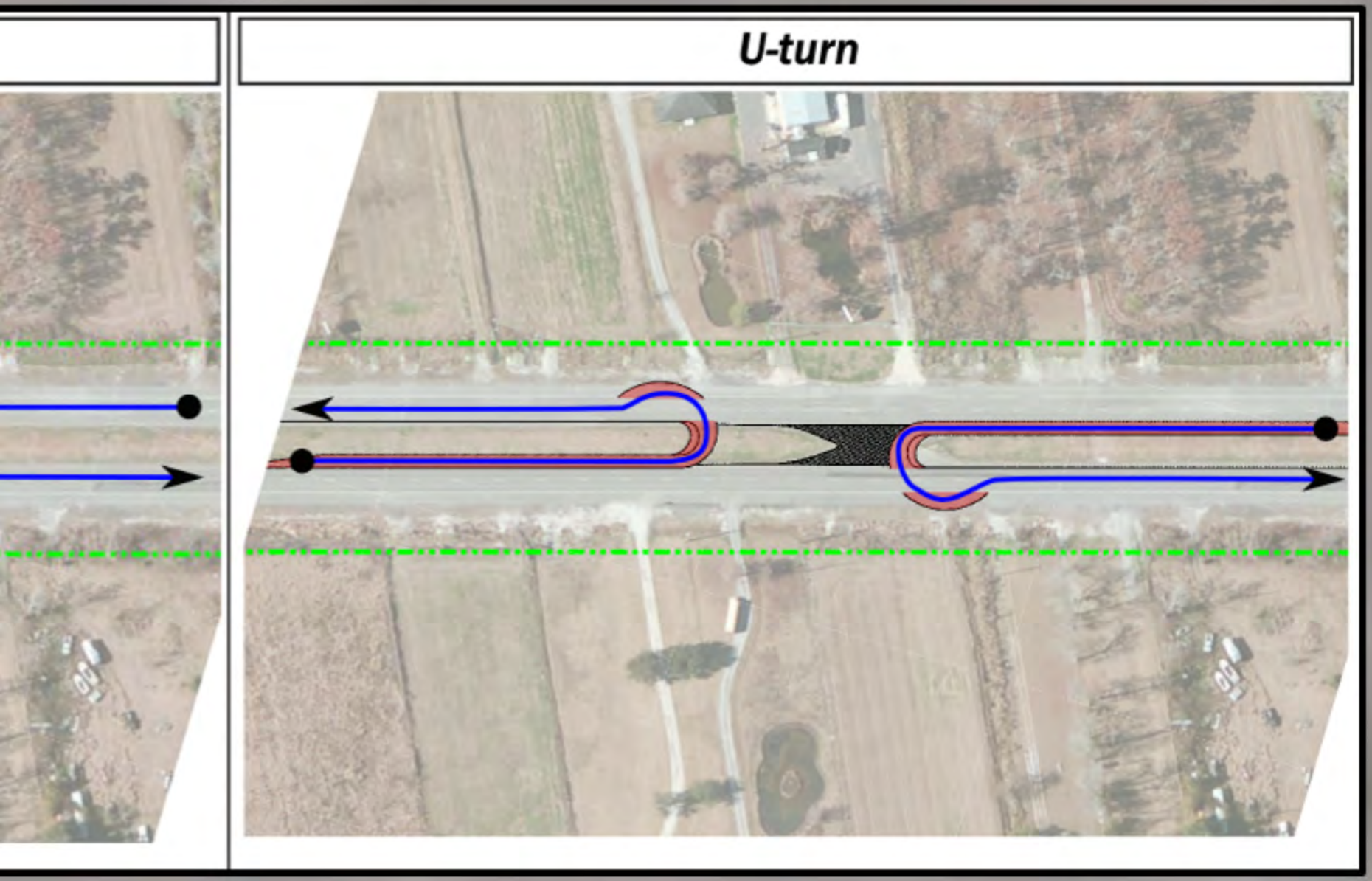
RCUT



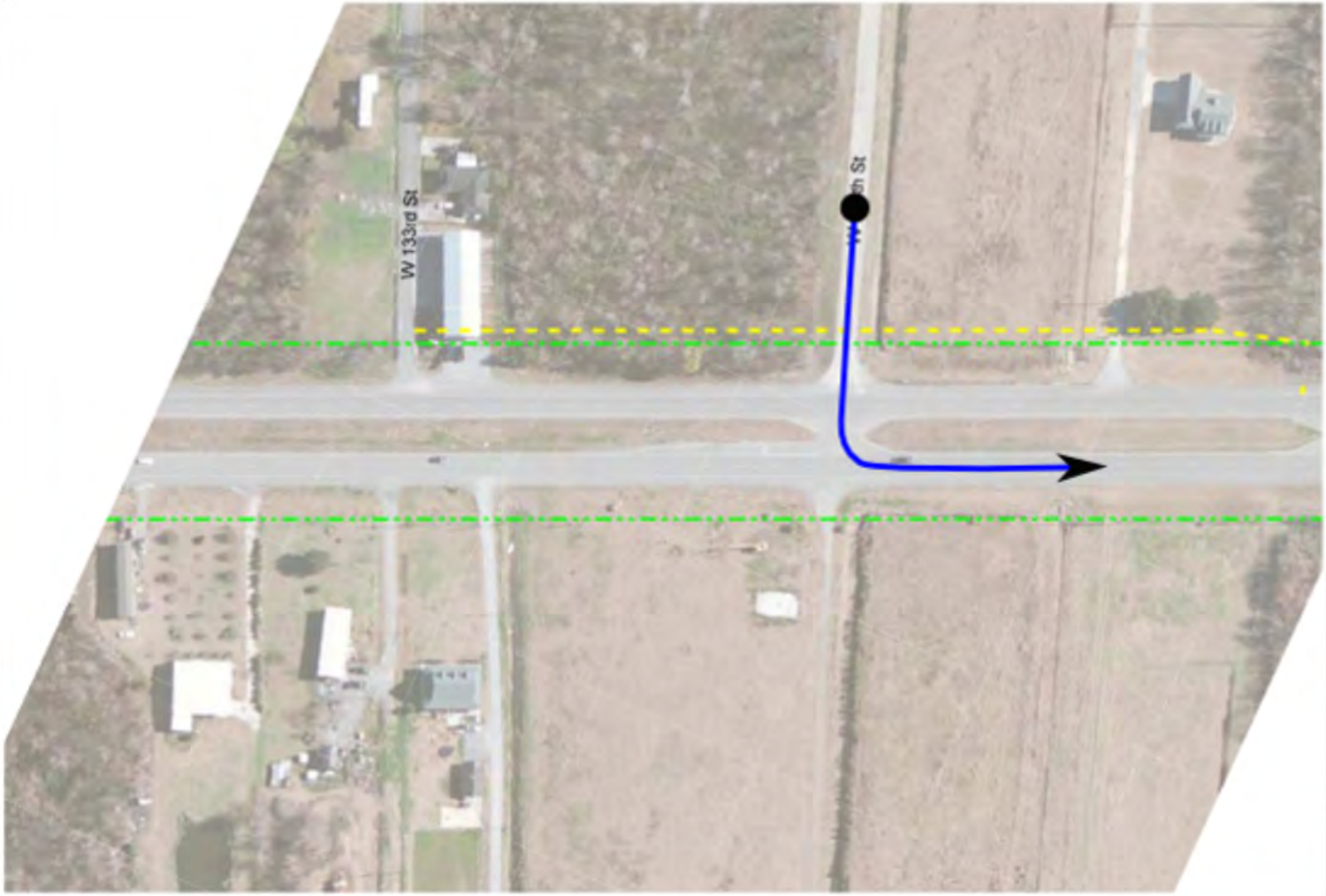
Left-turn Acceleration Lane or CGT



Existing Configuration


U-turn

Existing Configuration



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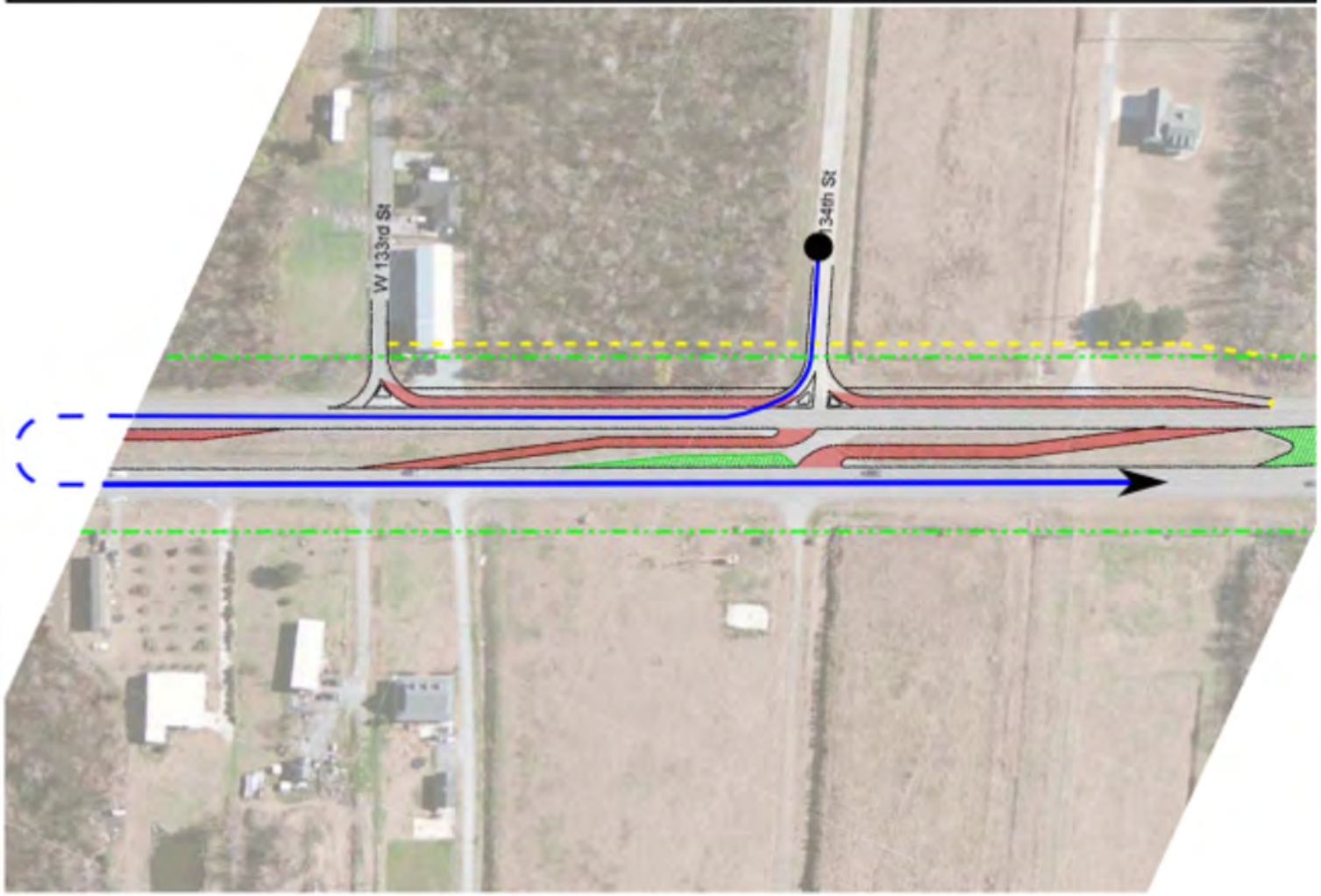
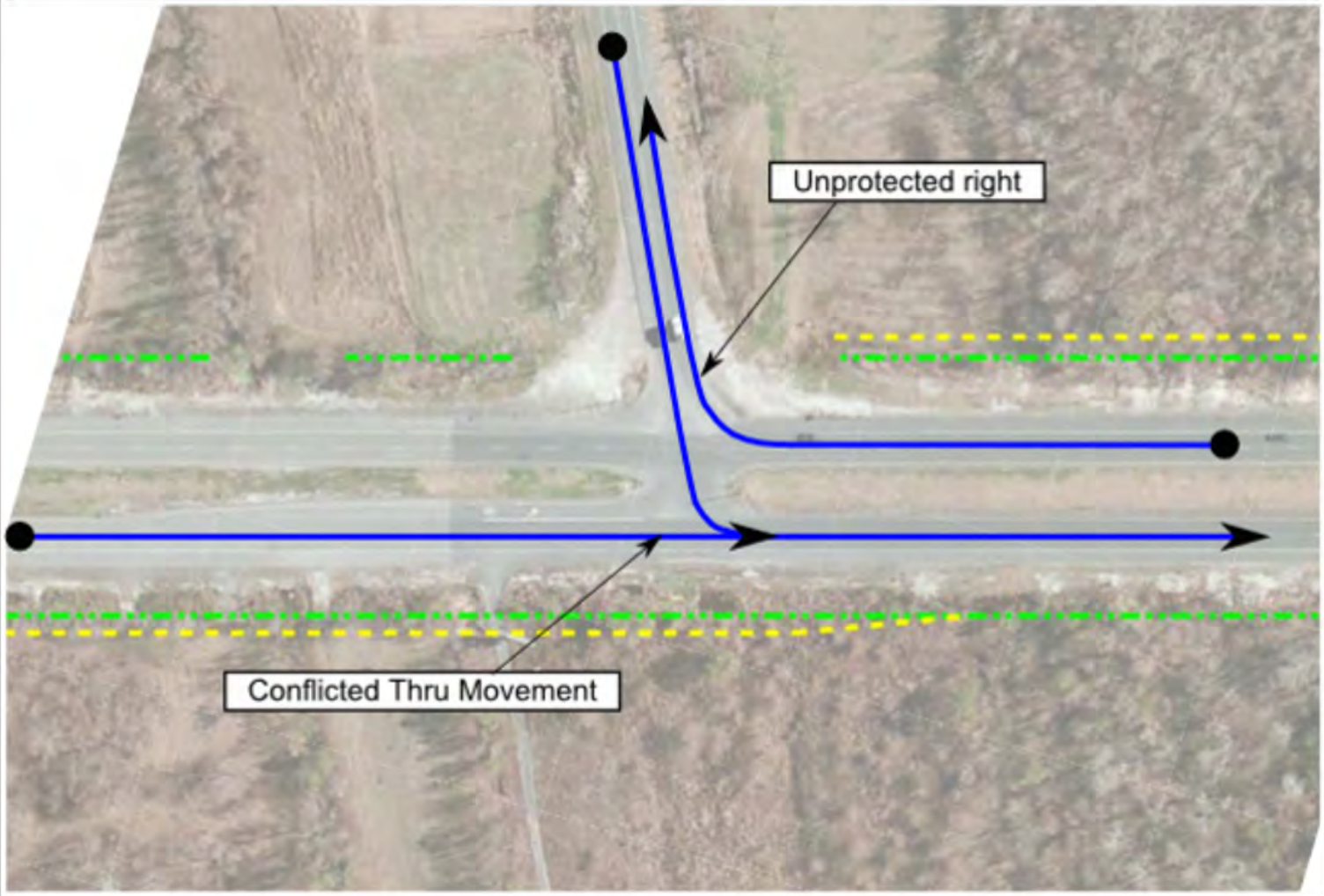
Restricted Crossing U-turns (RCUT)



Existing Configuration



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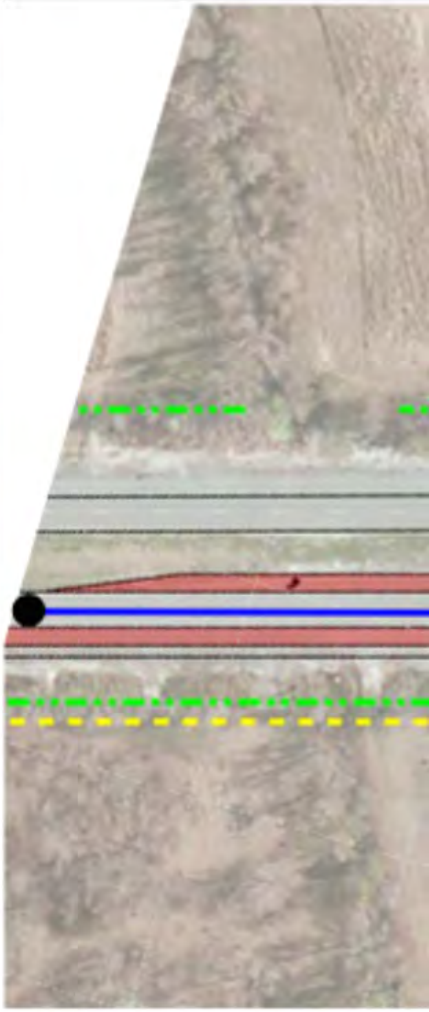
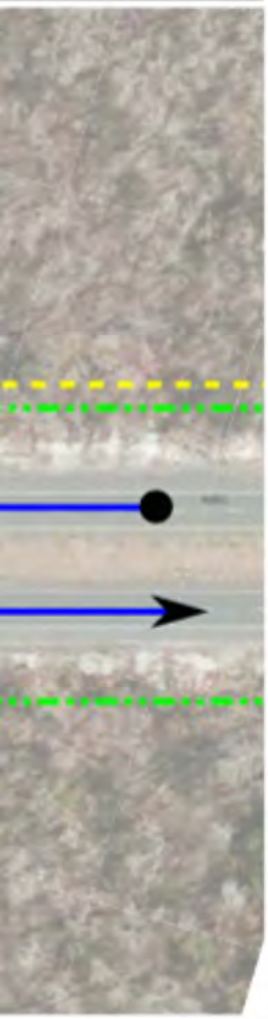
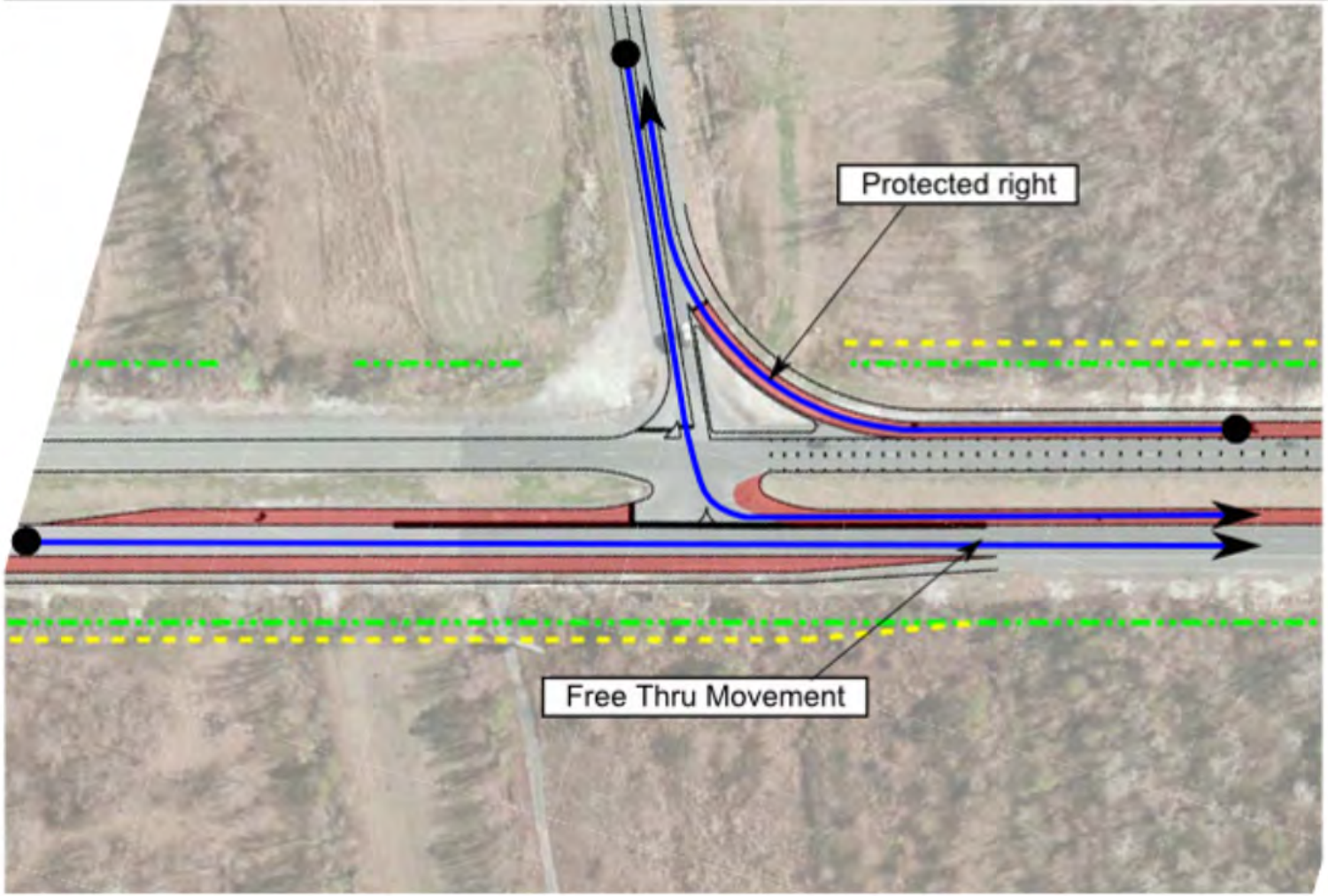




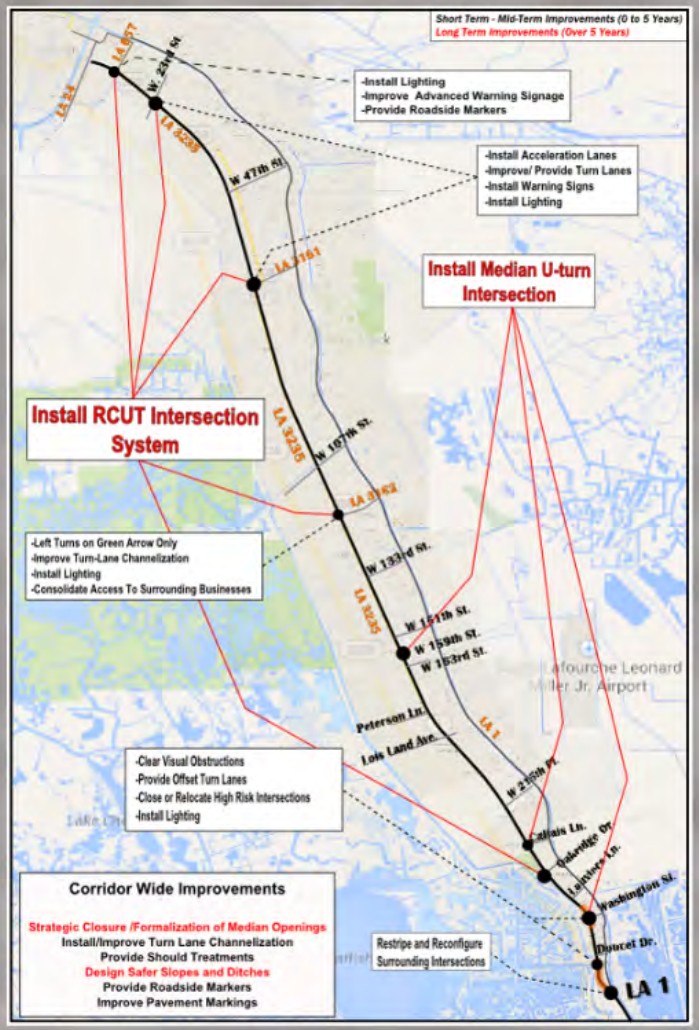
Continuous Green T-Intersections (CGT)



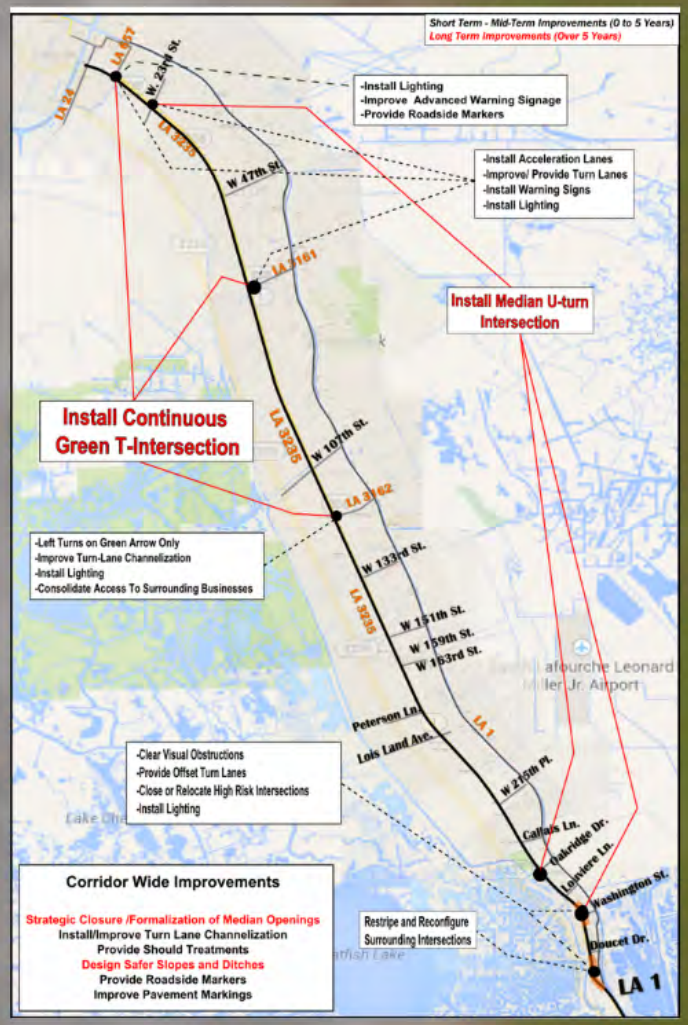
Alternatives

- 3 Major Intersections along route
- 72 other "curb-cut" median openings

Alternative 1 - Apply RCUT Intersections at major intersections and minor cross-streets, then median U-turns



Alternative 2 - Apply CGT Intersection at major intersections, then median U-turns



How to Apply HSM?

- Part C (SPFs) does not account for access management improvements
- Part D has few quality CMFs for access management

Solution? Combine both parts!

- Calculate expected crashes under No-build using Part C methods
- Group together segments/intersections with same treatments
- Sum expected crashes for like segments/intersection
- Apply Part D CMF to sum to determine change in expected crash frequency

Existing Corridor

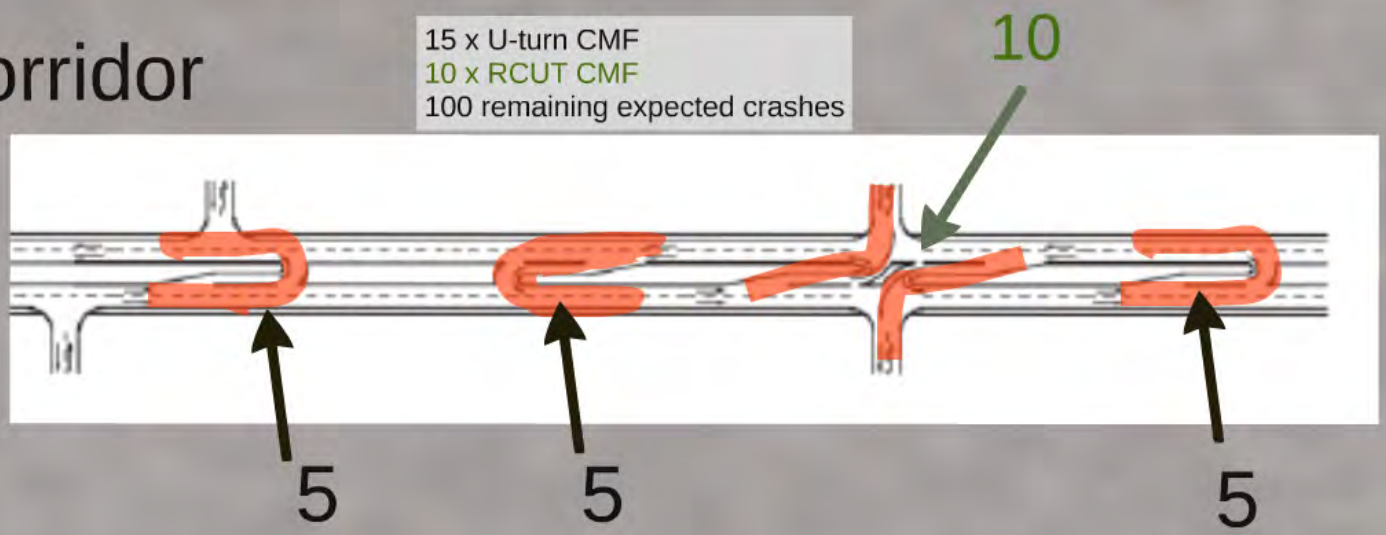
100 Expected Crashes

No-Build Corridor

125 Expected Crashes

Build Corridor

15 x U-turn CMF
10 x RCUT CMF
100 remaining expected crashes



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Expecte
Crashes

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15 x U-turn CMF
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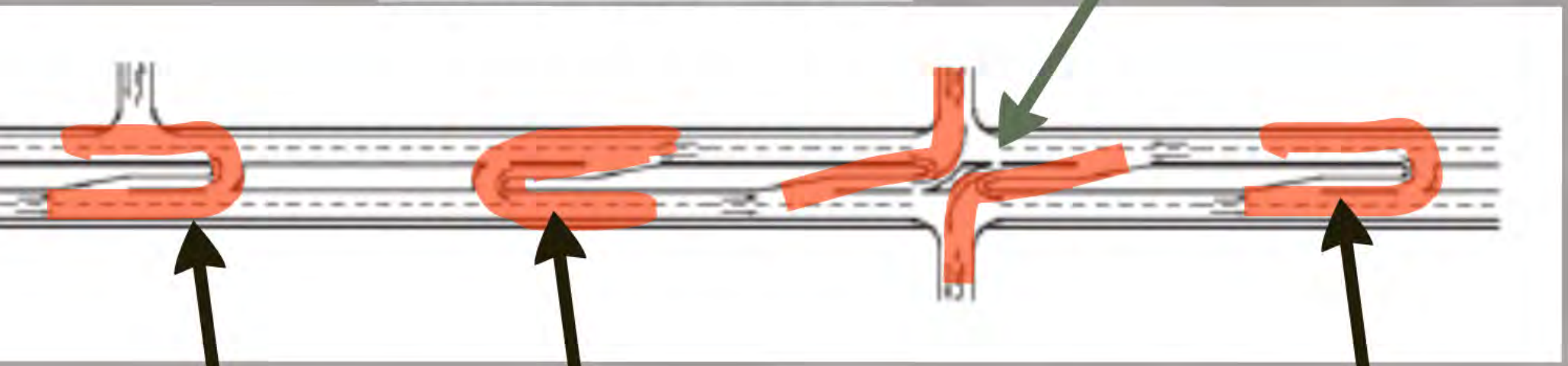
100 remaining expected crashes

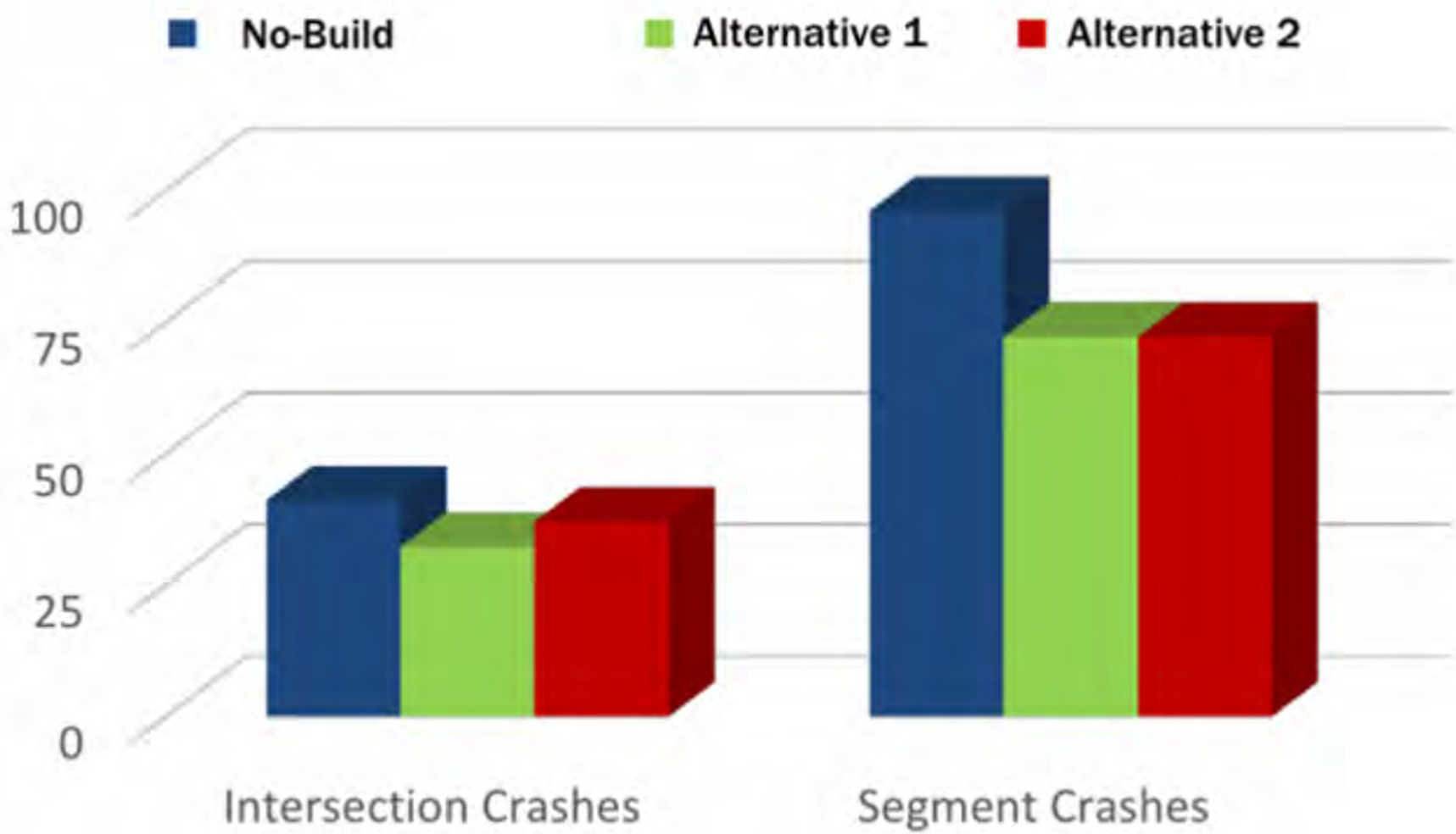


Safety Analysis - HSM

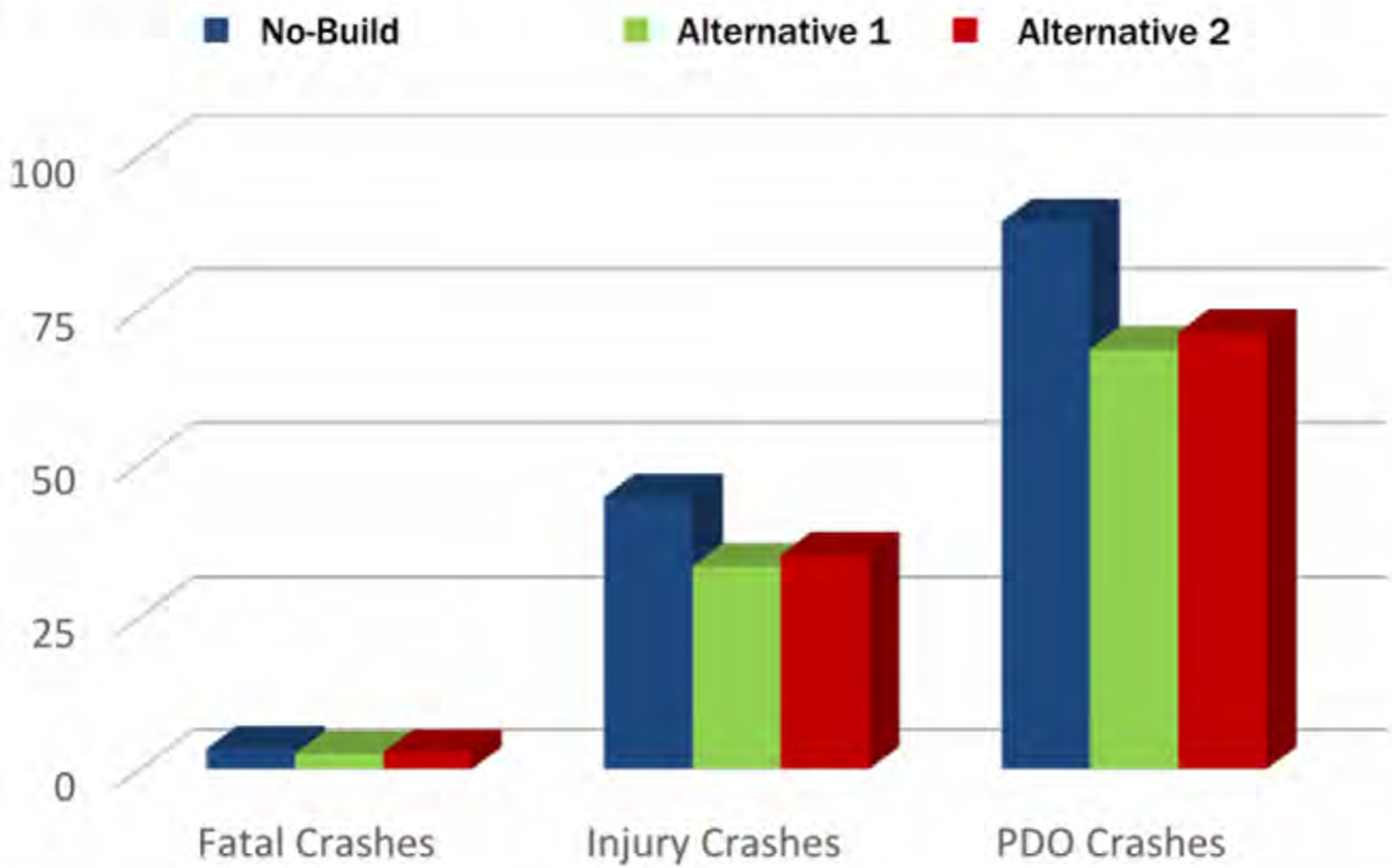
Four CMFs utilized from CMF Clearinghouse

	Proposed Treatments(Countermeasure) and Associated Collision Types Affected (Mitigated)			
	Treatment (Countermeasure)	Collision Type Affected	Crash Modification Factor	Star Rating from CMF Clearinghouse
Segments	Enhance the pavement markings	Run-off-the-road, head-on	0.78	2 stars
	Convert a full median opening to two separate U-turns	Left turn	0.95	3 stars
Intersections	Convert minor road stop-controlled intersection to RCUT	Left turn	0.93	3 stars
	Add right-turn lanes at two approaches	Angle	0.74	N/A

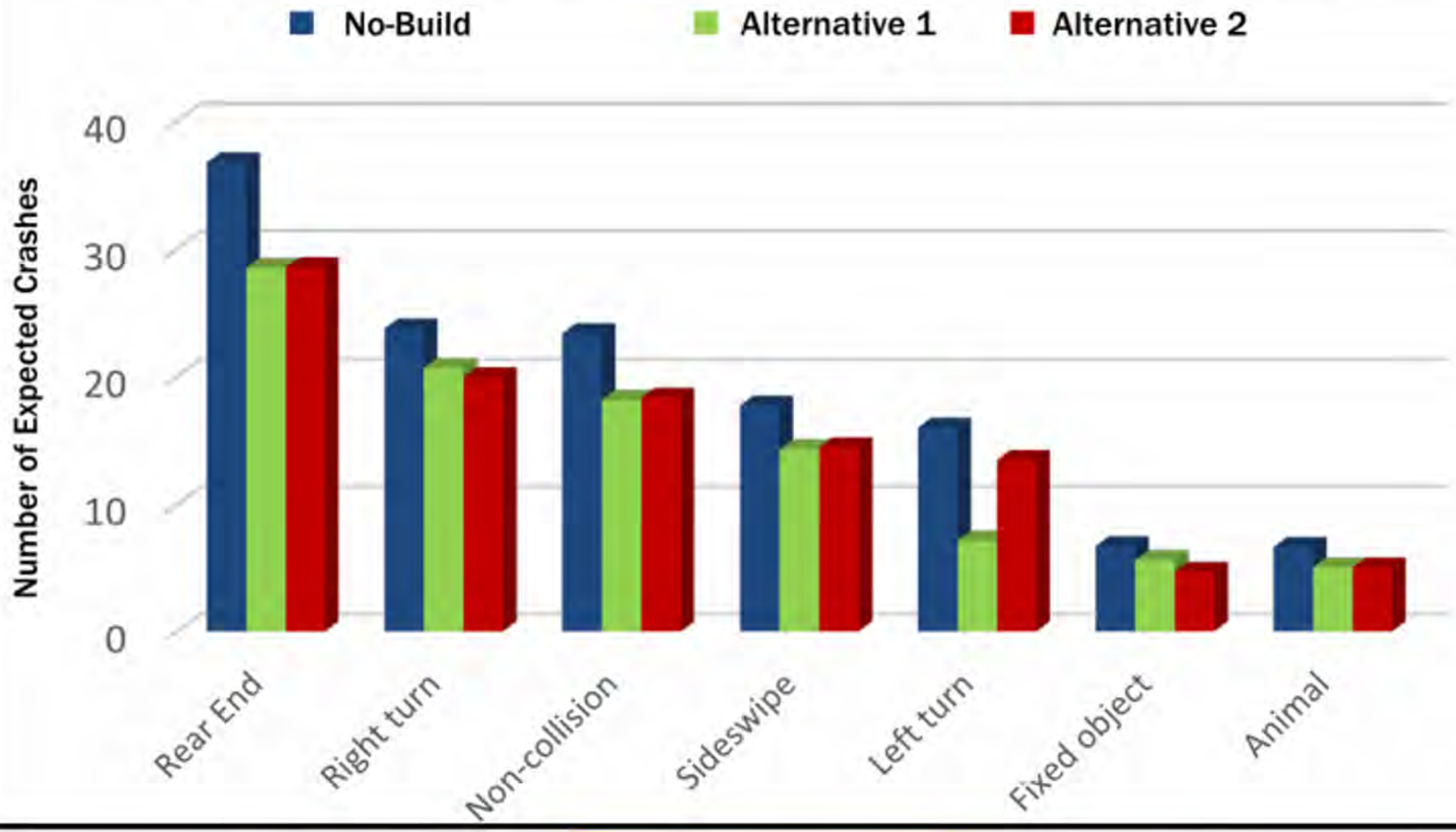
LA 3235 Crash Frequency - Future Year (2039)



LA 3235 Crash Severity - Future Year (2039)



LA 3235 Crash Collision Type - Future Year (2039)



B/C Comparison

- Alternative 1 found to have greater crash benefits and also lower costs.
- Crash benefits of each alternative monetized for B/C comparison

LA 3235 Benefit Cost Ratio Analysis

Improvement Name: Alternative 1

Project Information						
Roadway Name		From	To	Study Period Begins	Study Period Ends	Discount Rate
LA 3235		LA 24	LA 1	2019	2039	3%
Project Benefit						
Site Type	Crash Severity	Annual Crash Frequency Reduction		Cost per Crash	Annual Benefit	Total Benefit
Intersection	Fatal (K)	0.14		$4,376,304	$602,245	$8,950,886
	Incapacitating (A)	0.32		$2,037,475	$659,734	$9,815,183
	Non incapacitating (B)	1.34		$306,905	$412,410	$6,135,615
	Possibly Injury (C)	1.55		$11,036	$17,158	$255,187
	PDO (O)	4.74		$3,292	$15,590	$231,933
	Subtotal	8.19			$1,707,131	$25,397,803
Segment	Fatal (K)	0.30		$4,376,304	$1,324,160	$19,700,160
	Incapacitating (A)	1.26		$2,037,475	$2,560,800	$38,098,244
	Non-incapacitating (B)	2.54		$306,905	$778,610	$11,583,755
	Possibly Injury (C)	3.37		$11,036	$37,245	$554,113
	PDO (O)	15.80		$3,292	$52,026	$774,013
	Subtotal	23.28			$4,752,842	$70,710,286
Total		31.37			$6,459,973	$96,108,090
Project Cost						
Site Type	Number	Improvement Description		Service Life	Initial Cost	Total Cost
Intersection	1	Restricted crossing U-turn		15	$2,655,000	$4,359,148
	2	Left-turn lanes		15	$1,784,000	$2,929,082
	3	Right-turn lanes		15	$1,590,000	$2,610,560
	Subtotal				$6,029,000	$9,898,786
Segment	1	Install formalized U-turn		15	$9,634,000	$15,817,698
	2	Remove crossover		15	$1,036,000	$1,700,969
	Subtotal				$10,670,000	$17,518,667
Total					$16,699,000	$27,417,453
Benefit Cost Ratio Calculation						
Total Benefit		$96,108,090	Total Cost	$27,417,453	B/C=	3.51

Note:
1. The benefit cost ratio is calculated with the present worth method (the base year is 2018)
2. Total benefit (cost) refers to benefit (cost) for the whole 20-year analysis time period (2019 to 2039)
3. Crash cost adopted from LADOTD website
4. Discount rate is assumed to be 3%

LA 3235 Benefit Cost Ratio Analysis

Improvement Name: Alternative 2

Project Information						
Roadway Name		From	To	Study Period Begins	Study Period Ends	Discount Rate
LA 3235		LA 24	LA 1	2019	2039	3%
Project Benefit						
Site Type	Crash Severity	Annual Crash Frequency Reduction		Cost per Crash	Annual Benefit	Total Benefit
Intersection	Fatal (K)	0.06		$4,376,304	$273,038	$4,062,110
	Incapacitating (A)	0.15		$2,037,475	$289,101	$4,449,873
	Non incapacitating (B)	0.61		$306,905	$186,973	$2,781,681
	Possible Injury (C)	0.70		$11,036	$7,774	$115,695
	PDO (O)	2.15		$3,292	$7,068	$105,150
	Subtotal	3.67			$773,956	$11,514,507
Segment	Fatal (K)	0.30		$4,376,304	$1,324,160	$19,700,160
	Incapacitating (A)	1.26		$2,037,475	$2,560,800	$38,098,244
	Non-incapacitating (B)	2.54		$306,905	$778,610	$11,583,755
	Possible Injury (C)	3.37		$11,036	$37,245	$554,113
	PDO (O)	15.80		$3,292	$52,026	$774,013
	Subtotal	23.28			$4,752,842	$70,710,286
Total		26.95			$5,526,798	$82,224,794
Project Cost						
Site Type	Number	Improvement Descriptions		Service Life	Initial Cost	Total Cost
Intersection	1	Continuous intersection		15	$4,203,100	$6,895,820
	2	Left-turn lanes		15	$144,000	$236,428
	3	Right-turn lanes		15	$1,836,000	$3,014,459
	Subtotal				$6,180,000	$10,146,707
Segment	1	Install formalized U-turn		15	$11,188,000	$18,369,351
	2	Remove crossover		15	$1,127,000	$1,850,378
	Subtotal				$12,315,000	$20,219,530
Total					$18,495,000	$30,366,237
Benefit Cost Ratio Calculation						
Total Benefit		$82,224,794	Total Cost	$30,366,237	B/C=	2.71

Note:
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4. Discount rate is assumed to be 3%

LA 3235 Benefit Cost Ratio Analysis

Improvement Name: Alternative 1

Project Information					
Roadway Name	From	To	Study Period Begins	Study Period Ends	Discount Rate
LA 3235	LA 24	LA 1	2019	2039	3%

Project Benefit					
Site Type	Crash Severity	Annual Crash Frequency Reduction	Cost per Crash	Annual Benefit	Total Benefit
Intersection	Fatal (K)	0.14	$4,376,304	$602,245	$8,959,886
	Incapacitating (A)	0.32	$2,037,475	$659,734	$9,815,182
	Non-incapacitating (B)	1.34	$306,905	$412,410	$6,135,615
	Possibly Injury (C)	1.55	$11,036	$17,153	$255,187
	PDO (O)	4.74	$3,292	$15,590	$231,933
	Subtotal	8.10		$1,707,131	$25,397,803
Segment	Fatal (K)	0.30	$4,376,304	$1,324,160	$19,700,160
	Incapacitating (A)	1.26	$2,037,475	$2,560,800	$38,098,244
	Non-incapacitating (B)	2.54	$306,905	$778,610	$11,583,755
	Possibly Injury (C)	3.37	$11,036	$37,245	$554,113
	PDO (O)	15.80	$3,292	$52,026	$774,013
	Subtotal	23.28		$4,752,842	$70,710,286
Total		31.37		$6,459,973	$96,108,090

Project Cost					
Site Type	Number	Improvement Description	Service Life	Initial Cost	Total Cost
Intersection	1	Restricted crossing U-turn	15	$2,655,000	$4,359,143
	2	Left-turn lanes	15	$1,784,000	$2,929,082
	3	Right-turn lanes	15	$1,590,000	$2,610,560
	Subtotal			$6,029,000	$9,898,786
Segment	1	Install formalized U-turn	15	$9,634,000	$15,817,698
	2	Remove crossover	15	$1,036,000	$1,700,969
	Subtotal			$10,670,000	$17,518,667
Total				$16,699,000	$27,417,453

Benefit Cost Ratio Calculation					
Total Benefit	$96,108,090	Total Cost	$27,417,453	B/C=	3.51

Note:
1. The benefit cost ratio is calculated with the present worth method (the base year is 2019).
2. Total benefit (cost) refers to benefit (cost) for the whole 20-year analysis time period (2019 to 2039)
3. Crash cost adopted from LADOTD website
4. Discount rate is assumed to be 3%

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LA 3235 Benefit Cost Ratio Analysis

Improvement Name: Alternative 2

Project Information					
Roadway Name	From	To	Study Period Begins	Study Period Ends	Discount Rate
LA 3235	LA 24	LA 1	2019	2039	3%

Project Benefit					
Site Type	Crash Severity	Annual Crash Frequency Reduction	Cost per Crash	Annual Benefit	Total Benefit
Intersection	Fatal (K)	0.06	$4,376,304	$273,038	$4,062,110
	Incapacitating (A)	0.15	$2,037,475	$299,101	$4,449,873
	Non-incapacitating (B)	0.61	$306,905	$186,973	$2,781,681
	Possibly Injury (C)	0.70	$11,036	$7,776	$115,693
	PDO (O)	2.15	$3,292	$7,068	$105,150
	Subtotal	3.67		$773,956	$11,514,507
Segment	Fatal (K)	0.30	$4,376,304	$1,324,160	$19,700,160
	Incapacitating (A)	1.26	$2,037,475	$2,560,800	$38,098,244
	Non-incapacitating (B)	2.54	$306,905	$778,610	$11,583,755
	Possibly Injury (C)	3.37	$11,036	$37,245	$554,113
	PDO (O)	15.80	$3,292	$52,026	$774,013
	Subtotal	23.28		$4,752,842	$70,710,286
Total		26.95		$5,526,798	$82,224,794

Project Cost					
Site Type	Number	Improvement Description	Service Life	Initial Cost	Total Cost
Intersection	1	Continuous intersection	15	$4,200,000	$6,895,820
	2	Left-turn lanes	15	$144,000	$236,428
	3	Right-turn lanes	15	$1,836,000	$3,014,459
	Subtotal			$6,180,000	$10,146,707
Segment	1	Install formalized U-turn	15	$11,188,000	$18,369,151
	2	Remove crossover	15	$1,127,000	$1,850,378
	Subtotal			$12,315,000	$20,219,530
Total				$18,495,000	$30,366,237

Benefit Cost Ratio Calculation					
Total Benefit	$82,224,794	Total Cost	$30,366,237	B/C=	2.71

Note:
1. The benefit cost ratio is calculated with the present worth method (the base year is 2019).
2. Total benefit (cost) refers to benefit (cost) for the whole 20-year analysis time period (2019 to 2039)
3. Crash cost adopted from LADOTD website
4. Discount rate is assumed to be 3%

Conclusions

- HSM can applied in different ways to determine best planning solution
- Few Access Management CMFs found in current document and online...but more research underway

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