TTI: 0-7036

Texas A&M Transportation Institute

Guidance for TxDOT Innovative Intersections

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Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

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Guidance for TxDOT Innovative Intersections

Project 0-7036 Research Findings and Guidelines

Literature Review

- Benefits of innovative intersections
- Types of innovative intersections
- Comparing different alternatives
- What else should be considered?

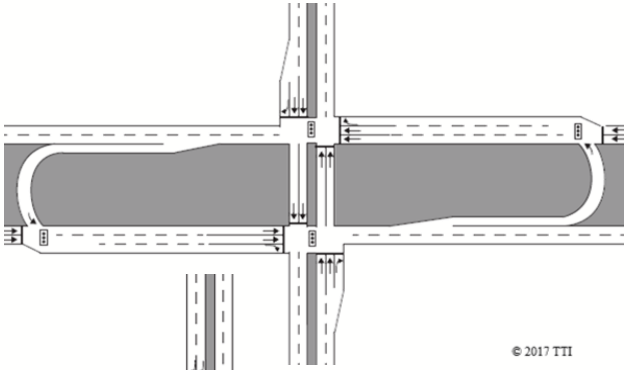

Benefits
Safety Benefits
Capacity Benefits
Reducing the number of conflicting points
Reducing the number of signal phases (more green time vs amber and red)
Need for less right of way
Reduced emissions resulted from reduced delay

Types of Innovative Intersections

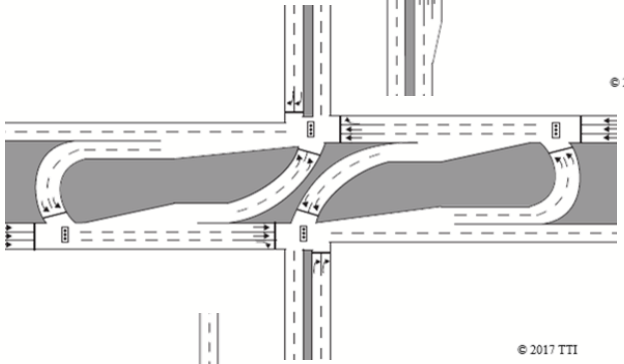
- **U-Turn-Based**
  - Median U-Turns (MUTs)
  - Restricted Crossing U-Turns (RCUTs)
  - J-Turn Intersections
- **Crossover-Based**
  - Displaced Left-Turns (DLTs)
  - Diverging Diamond Interchanges (DDIs)
- **Other**
  - Quadrant Roadway (QRs)
  - Jughandle Intersections
  - Continuous Green T Intersections (CGTs)
  - Offset T Intersections
  - Single Point Urban Interchanges (SPUIs)

Types of U-Turn Based Intersections

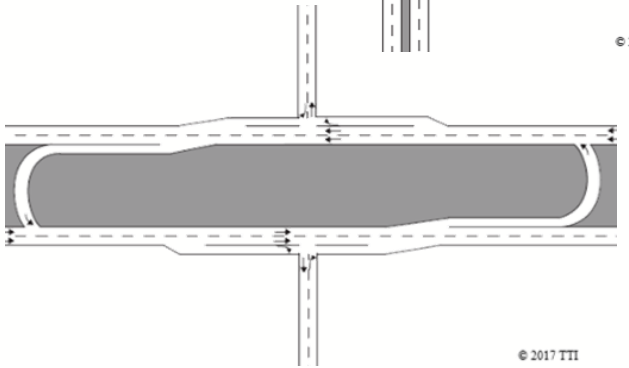
MUT



RCUT

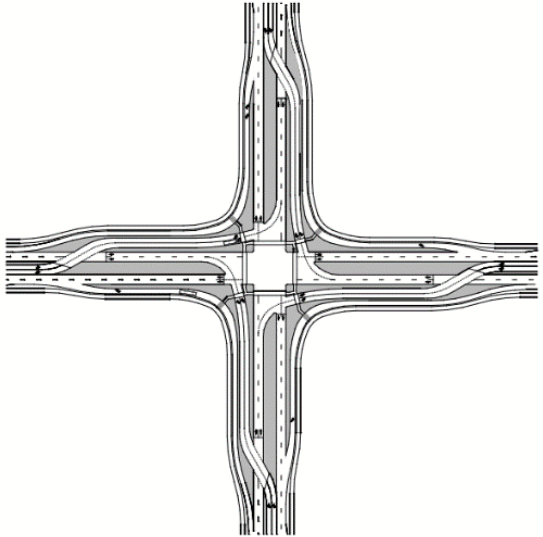


J-Turn



Source to all figures: Source: Chrysler et al.

Types of Cross-Over Based Intersections

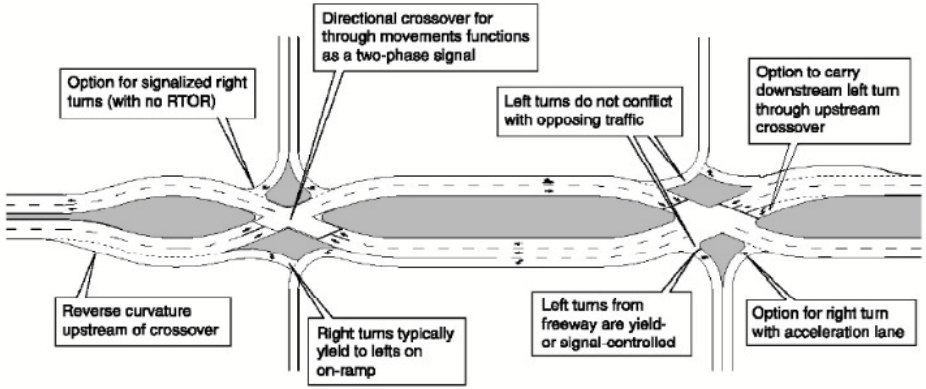


DLT

Source: Steyn et al.

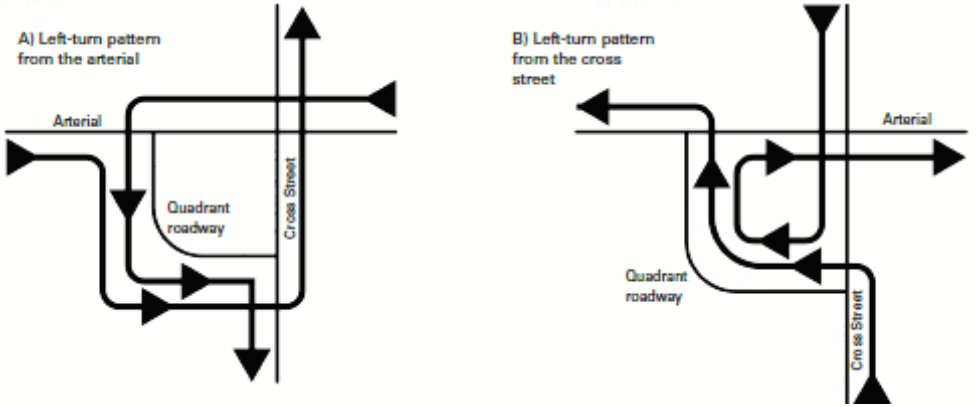
DDI

Source: TXDOT website



Source: FHWA DDI Informational Guide - Exhibit 1-1

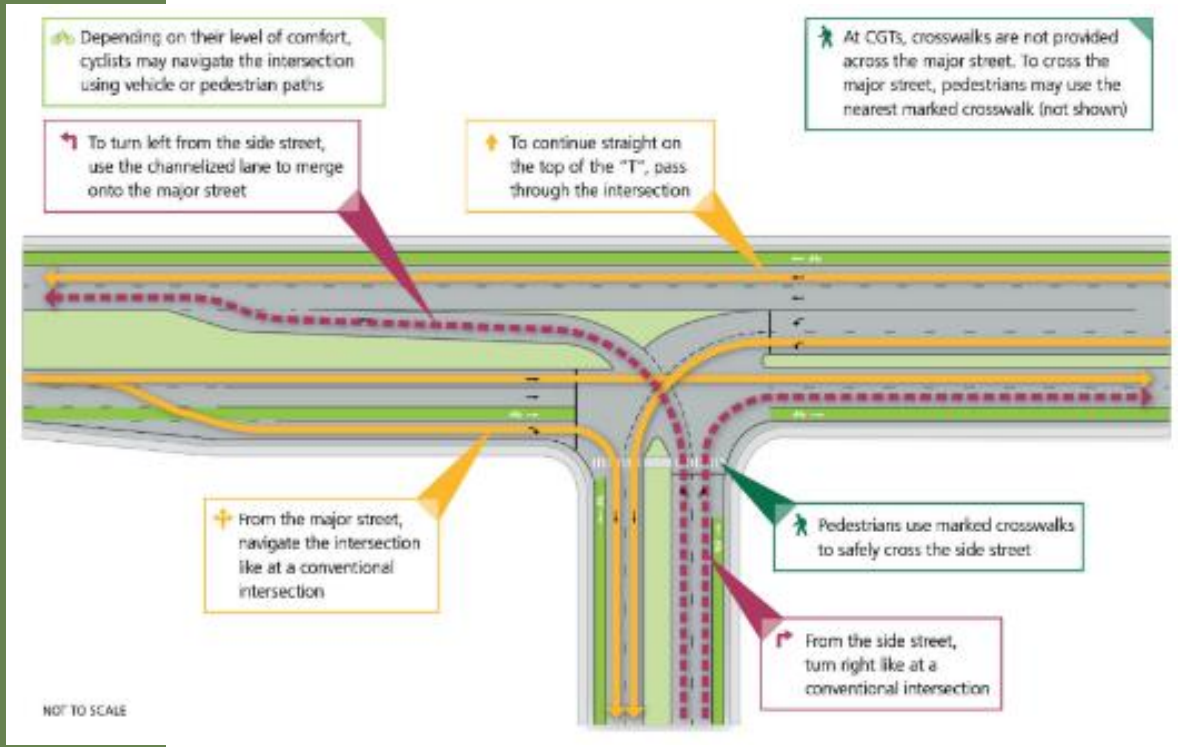
Types of Other Innovative Intersections



QR Intersections with Left Turn

Source: Hughes et al

Types of Other Innovative Intersections



CGT Intersection

Source: FHWA

Which One is Better?

How to choose one design over another?

Design Selection

- Single MOEs
  - Queue Estimation Models
  - Delay Models (HCS)
- Multi Objective Models
  - **FHWA's ICE tool**
    - Stage1: Scoping (short listing possible alternatives)
    - Stage2: Alternative Selection
  - Other states' ICE tools
  - Various research and state tools

Pedestrians and Bicyclists at Innovative Intersections, NCHRP 948

- NCHRP Report 948 used design flag method to evaluated each alternative for 20 conditions
  - NO FLAG: no unusual concern about that aspect of the pedestrian or bicyclist movement
  - YELLOW FLAG: concern that that aspect of the movement could be inconvenient or uncomfortable
  - RED FLAG: concern that that aspect of the movement could lead to more crashes

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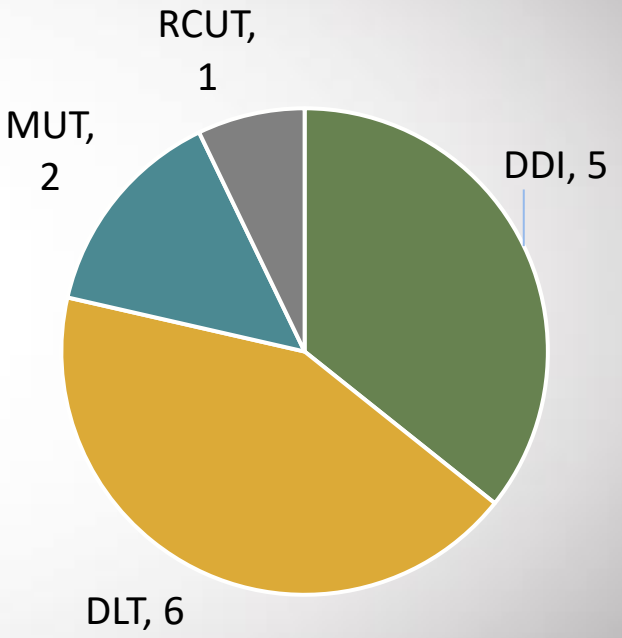
TxDOT Innovative Intersections

SAFETY REVIEW

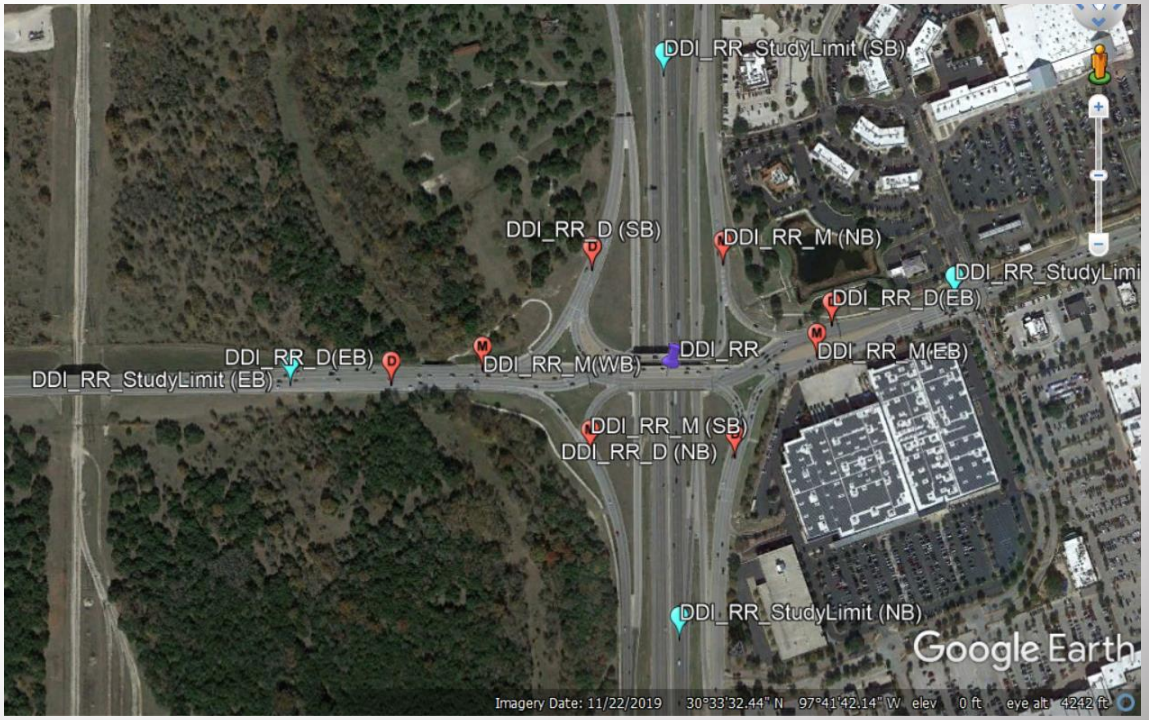
Safety Review

- Identified crashes (using CRIS) within the boundary area of the innovative intersection
- Determined top conflict areas within the innovative intersection boundaries
- Investigated if or how specific features of the innovative intersection are associated with the crashes



Setting Study Site Limits for Crash Selection

- Identify the **boundary limits** based on intersection type
- Determine **study limit** using stopping sight distance (based on posted speed limit) upstream of boundary point



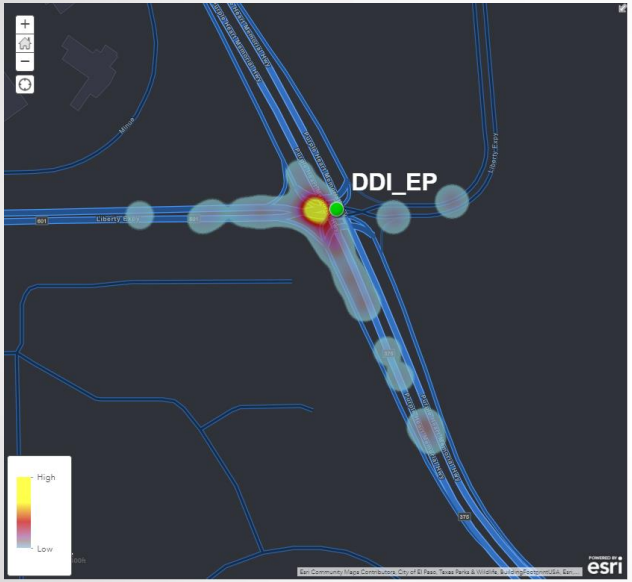
Filtering Crashes

- Crash data divided into five groups:
  - During period
  - Before period
  - After period
  - Prior to before period
  - More that 3 years after
- Removing crashes at neighboring intersections
- At DDIs and DLTs: remove freeway crashes

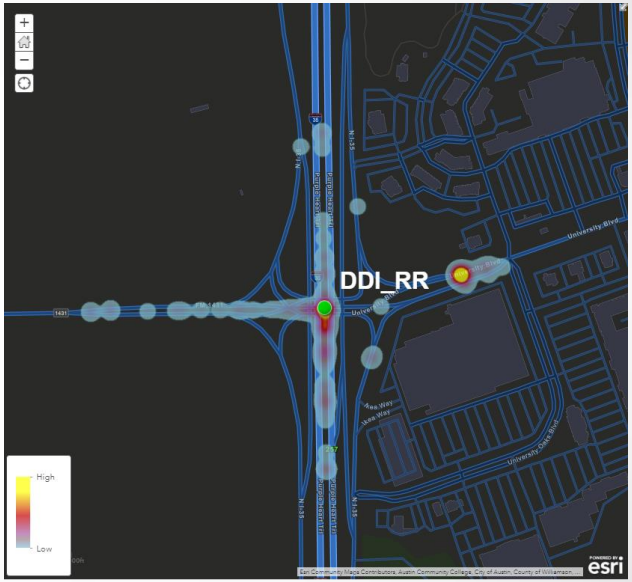
Crash Exploratory Analysis

Intersection	Crashes in Before Period	Months in Before Period	Crashes in After Period	Months in After Period	Crashes in Recent Period[1]	Months in Recent Period
DDI_AU	18	36	10	11	NA[2]	NA
DDI_CS	97	36	9	8	NA	NA
DDI_EP	5	36	48	36	30	28
DDI_RR	80	36	151	36	50	13
DDI_TC[3]	0	NA	2	36	1	10
DLT_AU1	75	36	62	36	34	27
DLT_AU2	77	36	73	36	65	27
DLT_CP	64	36	104	36	NA	NA
DLT_SA	539	36	55	6	NA	NA
DLT_SM1	117	36	122	36	95	30
DLT_SM2	145	36	172	36	103	28
MUT_AU	9	36	19	36	44	29
MUT_CS	33	36	6	16	NA	NA
RCUT_AU	55	36	59	36	5	12
Grand Total	1315	36	892	Varies	429	Varies

Hot Spots within Diverging Diamond Intersections

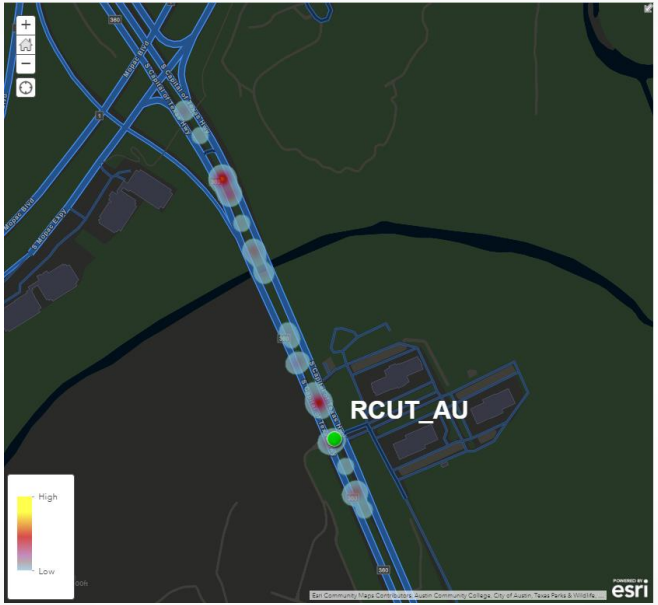


DDI El Paso (48 crashes)



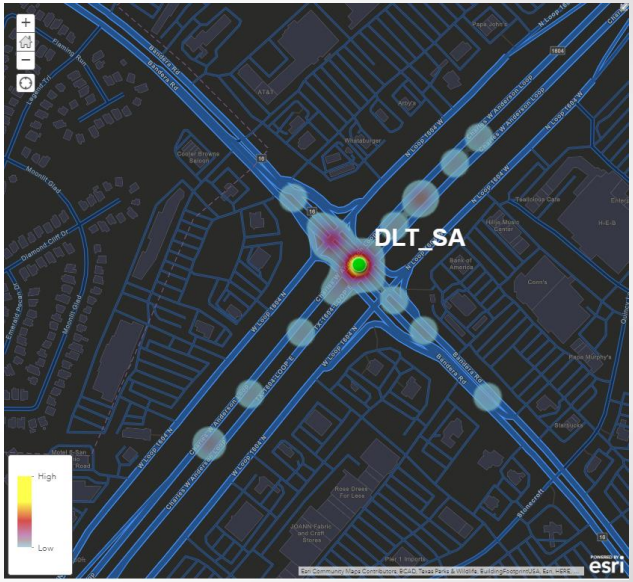
DDI Round Rock (151 crashes)
Back of queue potential issue

Hot Spots within Restricted Crossing U-Turn Intersection



RCUT Austin (59 crashes)

Hot Spots within Displaced Left-Turn Intersections



Crash Severity

Severity	DDI Before	DDI After	DLT Before	DLT After	MUT Before	MUT After	RCUT Before	RCUT After
A	3%	1%	1%	1%	2%	4%	0%	0%
B	16%	15%	11%	14%	21%	8%	15%	0%
C	22%	15%	20%	18%	7%	12%	20%	14%
K	1%	1%	0%	0%	2%	0%	0%	0%
O	58%	68%	67%	66%	67%	76%	65%	86%
Grand Total	100%	100%	100%	100%	100%	100%	100%	100%

More than a 9-point increase in PDO crashes in after period (i.e., fewer severe crashes

Movement

Movement	DDI Before	DDI After	DLT Before	DLT After	MUT Before	MUT After	RCUT Before	RCUT After
Left Turn (LR)	31%	4%	29%	19%	12%	4%	2%	0%
Left/Right (LT-RT)	0%	0%	0%	0%	0%	0%	0%	0%
Right Turn (RT)	3%	2%	8%	9%	2%	12%	2%	0%
Straight	66%	94%	63%	72%	86%	84%	96%	100%
Grand Total	100%	100%	100%	100%	100%	100%	100%	100%

→ Reduction in percent of left-turn crashes in the after period.

Crash Type

Crash Type	DDI Before	DDI After	DLT Before	DLT After	MUT Before	MUT After	RCUT Before	RCUT After
Angle	15%	5%	15%	20%	7%	16%	4%	0%
Head-on	27%	2%	16%	14%	0%	4%	2%	0%
Other	0%	0%	0%	0%	0%	0%	0%	0%
Rear-end	12%	19%	10%	12%	7%	8%	31%	34%
Sideswipe	34%	55%	52%	43%	21%	20%	51%	51%
Single Vehicle	11%	20%	7%	11%	64%	52%	13%	15%
Grand Total	100%	100%	100%	100%	100%	100%	100%	100%

→ Reduction in percent of head-on crashes in the after period for DDI

Summary

- Visual analysis: most crashes occurred at the center of the intersection
- Factors that contributed to crashes more in the after period were:
  - Vehicle changing lanes
  - Attention diverted from driving
  - Slowing/stopping for traffic
- Key findings of safety analysis:
  - Reduction in the percent of left-turn crashes
  - Severity of the crashes reduced (higher percentage of crashes occurring in the after period were non-injury crashes)

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TxDOT
Innovative Intersections

RCUTs Field Study and Simulation

Identify Field Study Locations

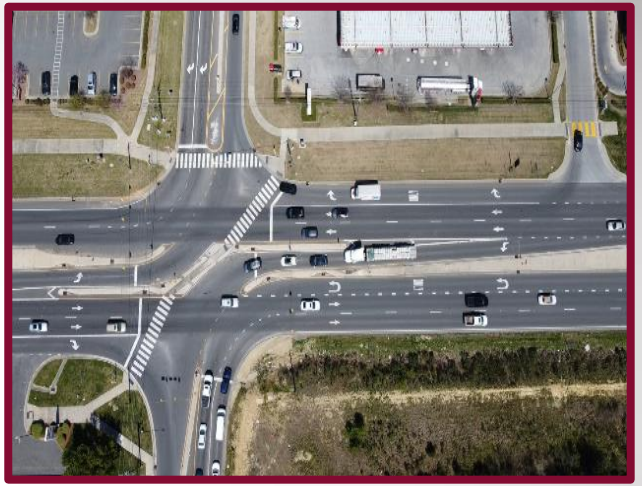
- Focusing on RCUTs
  - Want to know tradeoffs with regards to distances between main intersection and U-turn intersections
- Limited sites in Texas
- Identified 2 good sites in North Carolina

US-74 & Sardis Church Road
North Carolina

US-74 & Faith Church Road
North Carolina

Field Data Collection & Reduction

- Data collection used drone mounted cameras, 2 vendors
  - Challenges with weather
  - Challenges with covering the full length of the corridor
    - One vendor tried to use 5 drones simultaneously, recording perpendicular
    - Other vendor used 2 drones recording at an angle
- Field data used to calibrate simulation model



Changed Lane?	Approach Lane	Departure Lane	Vehicle Type		Grand Total
			Truck	Passenger Car	
Yes	3	5	0	1	1
		6	0	1	1
	4	5	0	3	3
		6	0	46	46
		7	0	10	10
Yes Total			0	61	61
Grand Total			7	438	445

Movement	Articulate Truck	Box Truck	Passenger Car	Pickup Truck	Work Van	Grand Total
W-WB-Th	664	393	11176	520	264	13017
W-WB-U	1	2	584	1	1	589
E-EB-Th	228	446	7655	119	419	8867
E-EB-U	6	14	46	1	3	70

Simulation

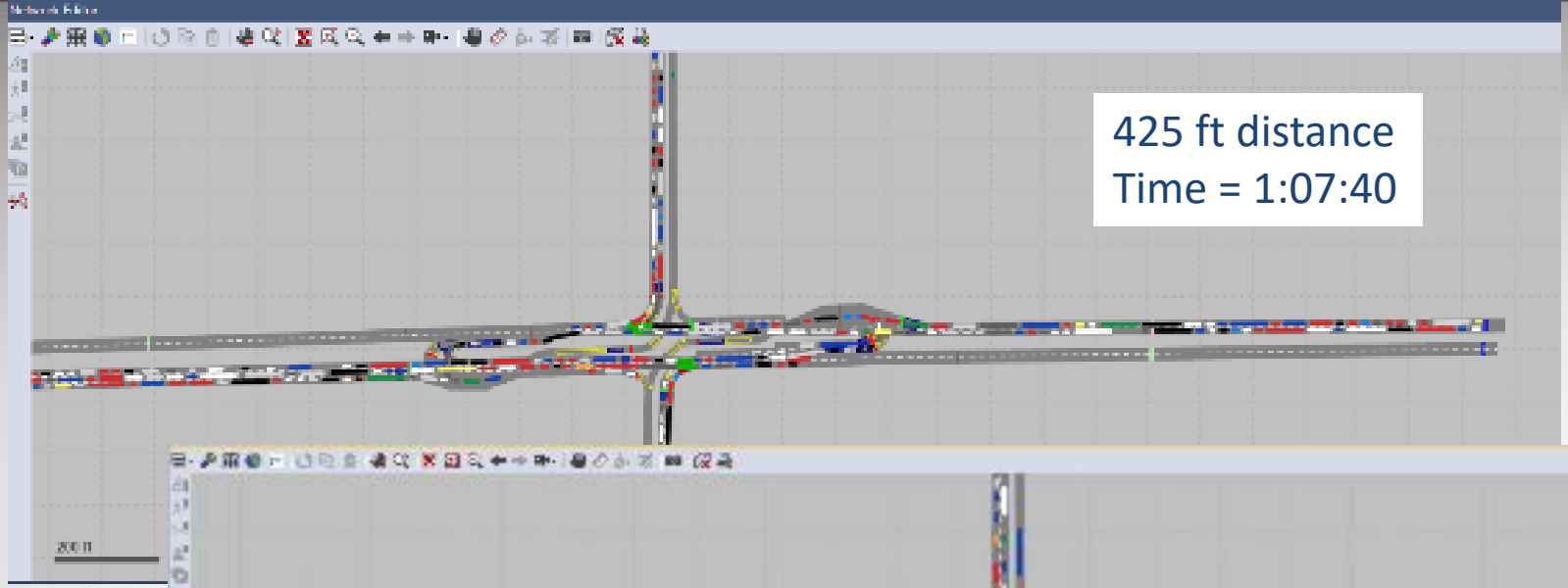
- Several simulation models developed to investigate effects of spacing
- Key parameters were modified to create different scenarios.

Main Models:

- No RCUT
- 425 ft
- 700 ft
- 1000 ft
- 1500 ft
- 2000 ft

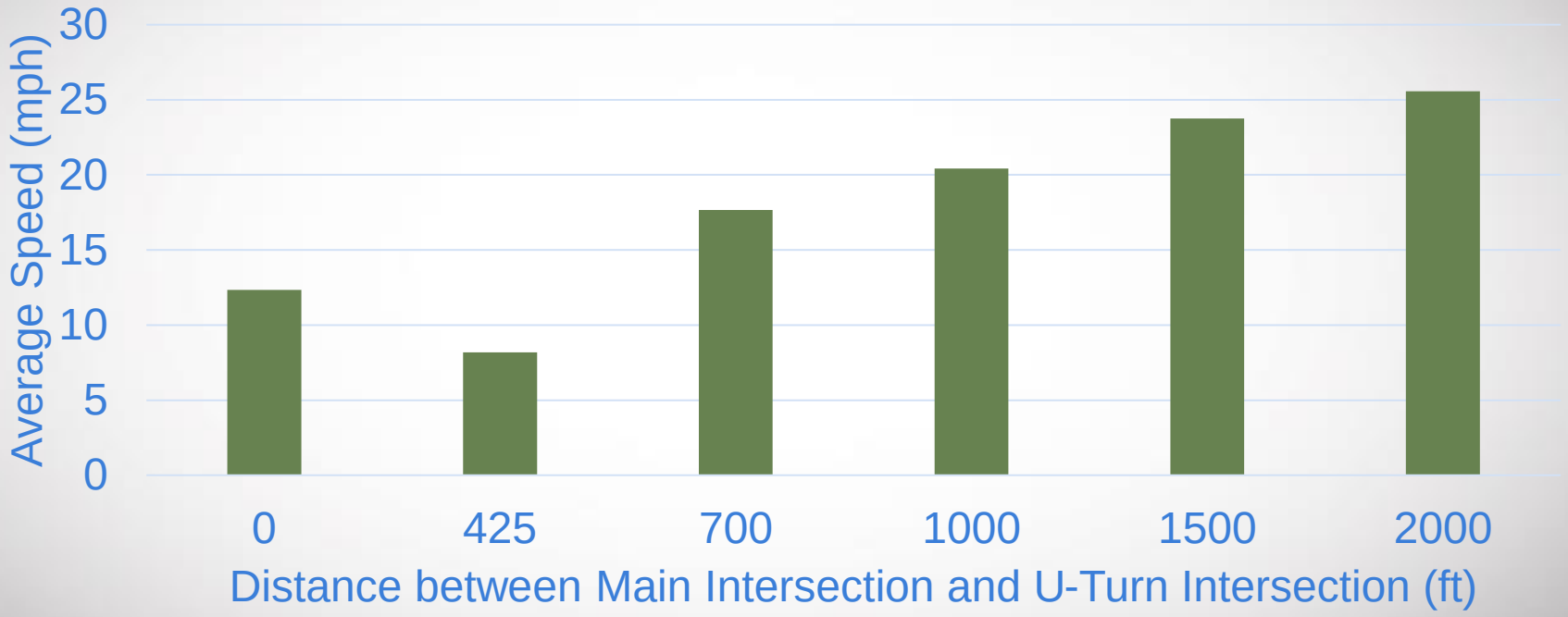
For each model:

- Major road volume (vpd): 10000, 15000, and 20000
- Minor road volume (vpd): 2000, 4000, 6000, 8000, 10000, 12000, 14000
- Left-turn percent: 10, 20 or 30 percent
- Truck percent: 5, 22, or 35 percent, or heavy truck percent: 2.5, 5.5, or 8.75%

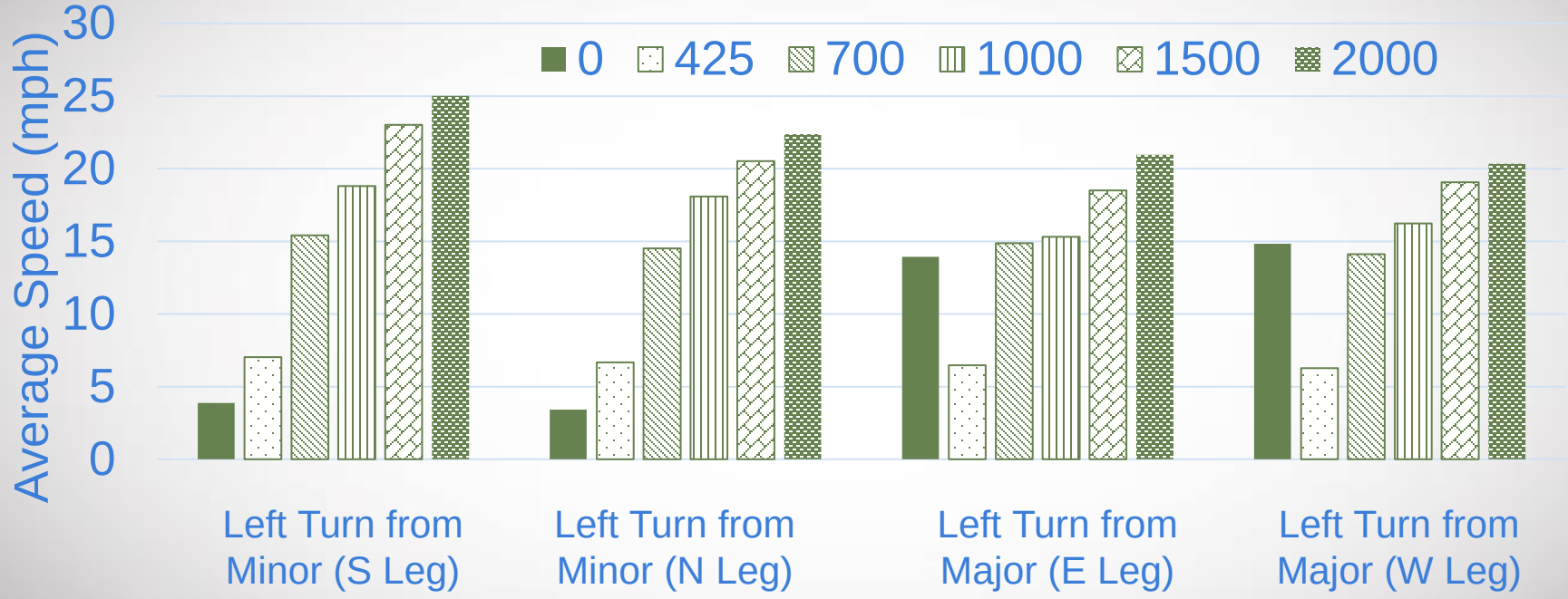

425 ft distance
Time = 1:07:40


1000 ft distance
Time = 1:07:09

Average Corridor Speed by Distance between Main Intersection and U-turn

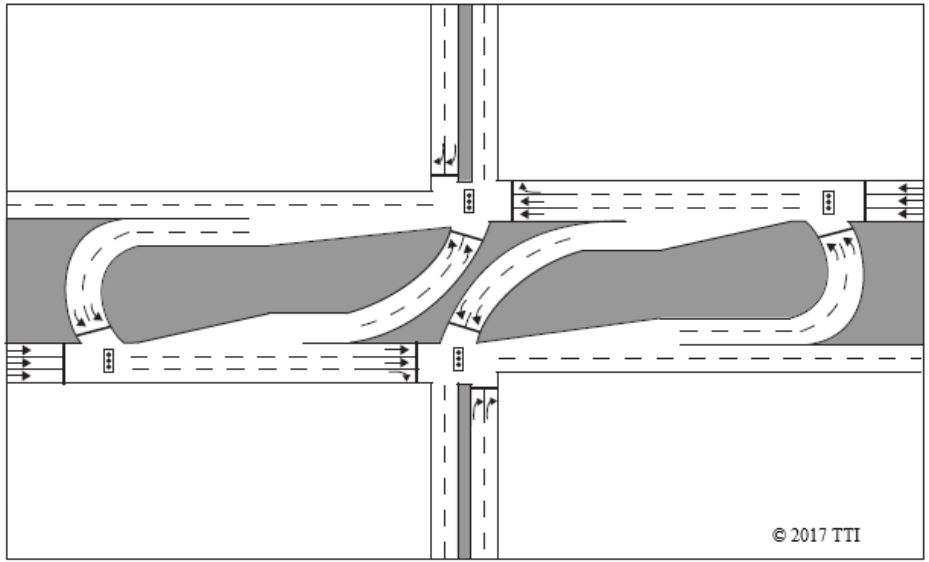


Average Speed by Path and Distance between Main Intersection and U-Turn



Summary

- Simulation found spacing of 2000 ft between main intersection and U-turn intersections to have highest speeds; although spacing of 1000 ft or 1500 ft was within 5 mph



Alternative Intersections

- We are seeing more use in Texas
- Are associated with fewer left-turn crashes / national research are finding overall crash reductions
- Select design features are important, for example:
  - Spacing between main intersection and U-turn intersections
  - Use of loons at U-turn intersections

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For more…

https://tti.tamu.edu/documents/0-7036-R1.pdf