



Safety Evaluation of the Flashing Yellow Arrow Treatment

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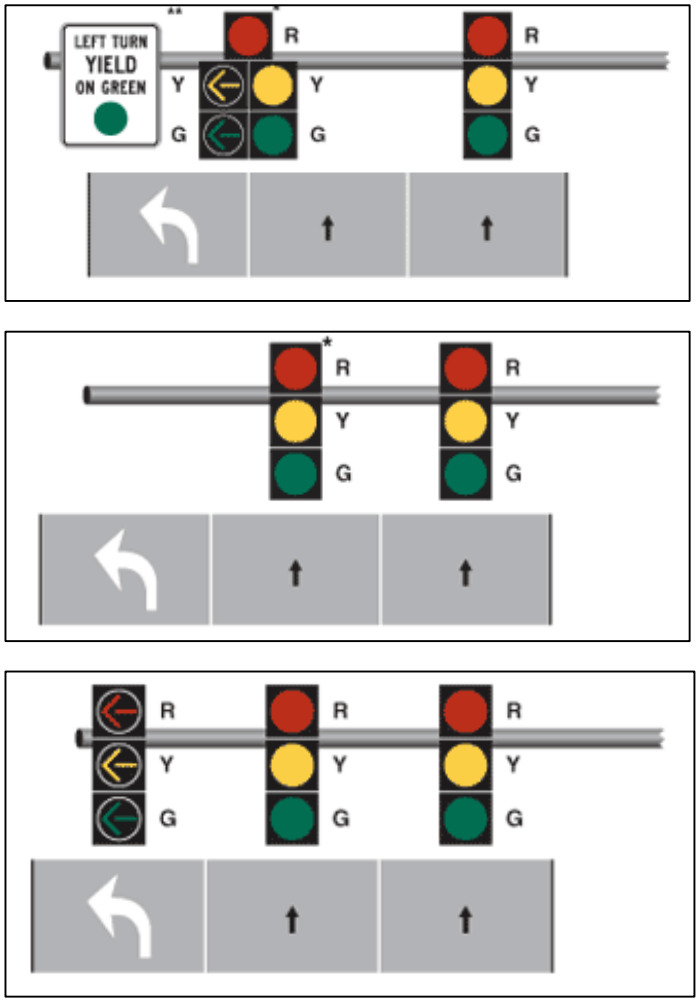
  - Nevada DOT
  - North Carolina DOT
  - City of Norman, Oklahoma
  - Oklahoma DOT
  - City of Edmond, Oklahoma
  - Oregon DOT

Conversion to Flashing Yellow Arrow (FYA)



Background

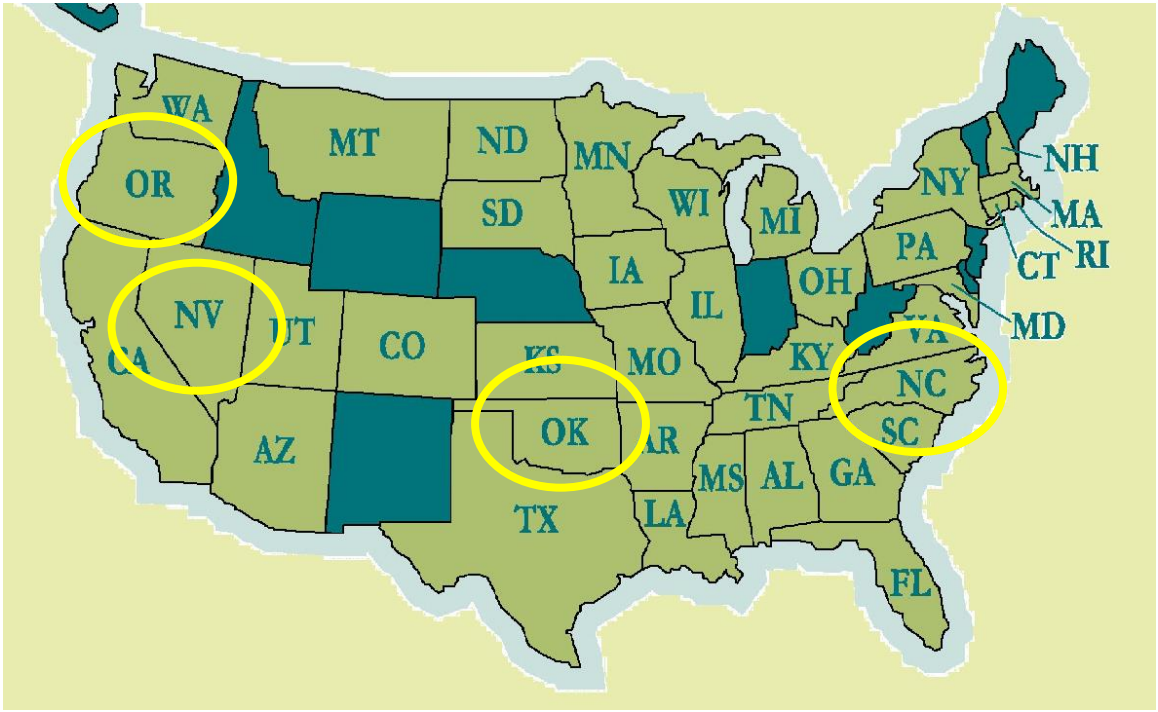
- Past studies showed decrease in crashes after FYA (unless converted from protected left turn)
- Most studies used only one state
- NCHRP 17-35 used multiple states but only had 32 sites which had not been protected before FYA

Objective

- Measure overall safety effect of FYA conversion through an before-after empirical Bayes study
- Use large group of converted signals from multiple states
- Develop CMFs for:
  - Total intersection crashes
  - Intersection Injury and fatal crashes
  - Intersection Rear End Crashes
  - Intersection Angle Crashes
  - Intersection Left Turn Crashes
  - Intersection Left Turn with Opposing Through Crashes (LTOT)

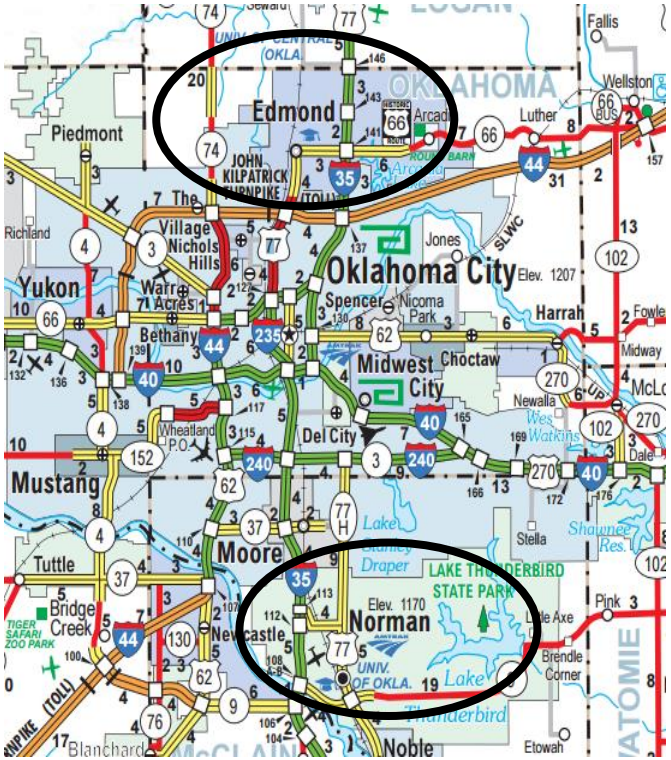
Data

- Oklahoma
- Oregon
- Nevada
- North Carolina



Oklahoma

- City of Norman conducted a "blanket" installation of FYA from 2011 to 2013
- All signalized intersections with exclusive left turn lanes
- Most were 5-section protected-permissive signal heads to 4-section FYA heads

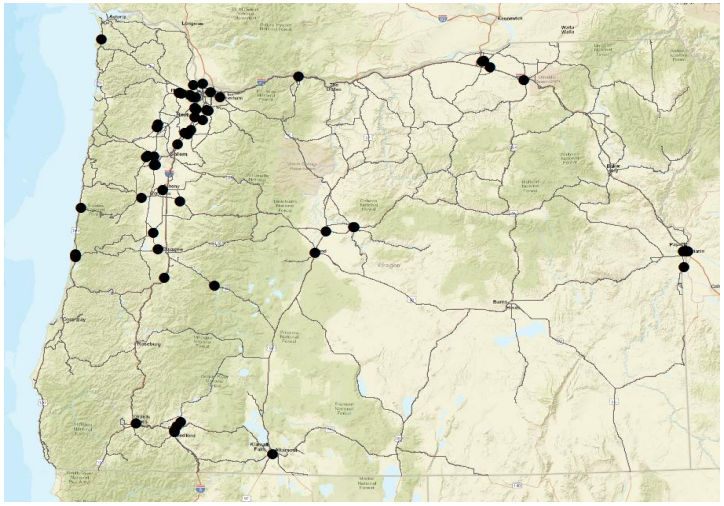


Source: Oklahoma State Travel Map 2016

- Reference/comparison group had to be identified from another similar city (Edmond)

Oregon

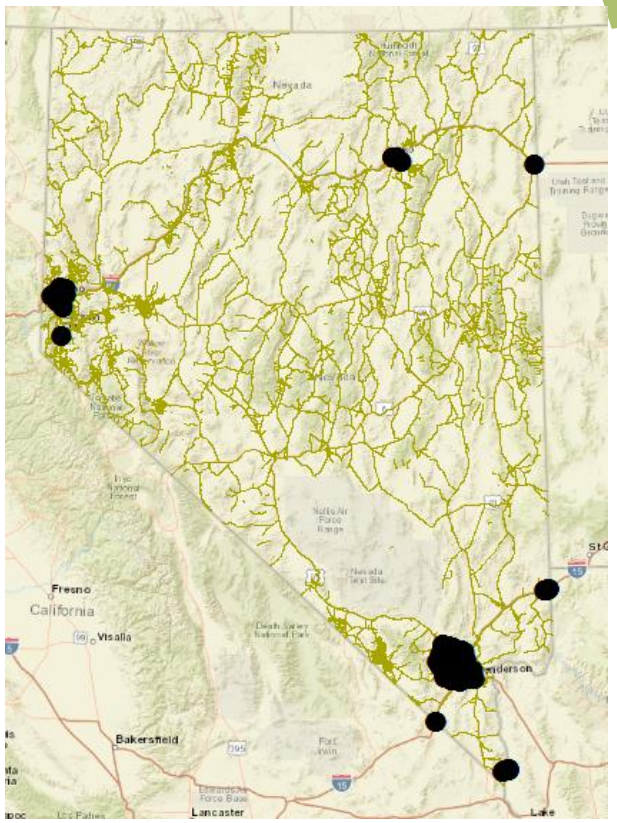
- Oregon DOT has been installing FYA statewide for years (early adopter)
- Preconversion mix of protected-permissive (majority), permissive, and protected
- Almost all FYA are 4-section head
- Reference/comparison group identified from statewide signal inventory



Source: ESRI

Nevada

- Statewide installations of FYA from 2011 to 2013
- All were 5-section protected-permissive signal head to a 4-section FYA head
- Early installations were high crash locations; later ones more systemic
- Reference/comparison group identified from planned FYA installations and very recent FYA installations



Source: ESRI

North Carolina

- NCDOT provided data from their evaluation of FYA
- Reference/comparison sites identified from lists of future FYA installations and very recent FYA installations
- Preconversion mix of protected-permissive (majority), permissive, and protected

Source: NCDOT

Treatment Categories

Category	# Sites
Traditional PPLT to FYA PPLT on one road (3-leg)	40
Traditional PPLT to FYA PPLT on one road (4-leg)	136
Traditional PPLT to FYA PPLT on both roads (4-leg)	64
Permissive or traditional PPLT to FYA permissive on one road (4-leg)	25
Permissive to FYA permissive on one road (4-leg)	12
At least one protected approach to FYA PPLT (4-leg)	18
At least one protected approach to FYA PPLT with time of day changes (4-leg)	12

Note: 307 treated sites and 408 Reference/Comparison Sites from the 4 States

Safety Performance Functions (SPFs)

- Separate SPFs by State by Crash Type
  - AADT (Major and Minor)
  - Number of Legs
  - Left turn phasing (maximum left turn protection)
  - Number of through lanes on the major road
  - Presence/absence of median on the major road
  - Number of approaches with left turn lanes
- SPF Form:

$$Y = \exp\left(a_0 + a_1X_1 + a_2X_2 + \cdots .. a_nX_n\right)$$

Y = predicted number of crashes
X's are site characteristics
a's are coefficients

CMF Results – Conversions from Protected/Permissive and Permissive

Treatment Category	Total	KABC	LT	LTOT
Traditional PPLT to FYA PPLT on one road (3-leg)	**0.85**	**0.79**	0.80	0.85
Traditional PPLT to FYA PPLT on one road (4-leg)	**0.89**	**0.80**	**0.75**	**0.62**
Traditional PPLT to FYA PPLT on both roads (4-leg)	**0.82**	**0.78**	**0.62**	**0.51**
Permissive or traditional PPLT to FYA permissive on one road (4-leg)	1.00	**0.81**	**0.73**	**0.73**
Permissive to FYA permissive on one road (4-leg)	0.92	**0.79**	**0.61**	**0.55**

Note: **CMFs in bold statistically different from 1.0 at the 0.05 significance level**

CMF Results – Conversions from Protected

Treatment Category	Total	KABC	LT	LTOT
At least one protected approach to FYA PPLT (4-leg)	1.05	1.01	**1.55**	**1.91**
At least one protected approach to FYA PPLT with time of day changes (4-leg)	0.97	1.09	1.27	1.15

Note: **CMFs in bold statistically different from 1.0 at the 0.05 significance level**

CMF by State for Traditional PPLT to FYA PPLT on one road (4-leg)

State	Total	KABC	LT	LTOT
Oklahoma	1.13	0.92	0.80	0.73
Oregon	**0.72**	**0.71**	**0.58**	**0.58**
Nevada	0.96	0.94	1.18	n/a
North Carolina	**0.89**	**0.77**	**0.63**	**0.61**

Note: **CMFs in bold statistically different from 1.0 at the 0.05 significance level**

Economic Analysis

- Benefit
  - Crash rates from study sites
  - Crash costs from USDOT
- Cost
  - Oklahoma and Oregon provided cost information; Illinois DOT evaluation report also contained cost information
  - Assumed cost was $6,000 per approach leg (conservative)
  - Service life assumed to be 10 years
  - Assumed no additional annual maintenance cost compared to the previous signal head

Crash Modification Function for LTOT crashes in Category 2

- Traditional PPLT to FYA PPLT on one road (4-leg)

- $CMF = 0.694 \times (Exp\ bef\ per\ year)^{-0.2626}$

Exp bef per year = the EB expected LTOT crashes per year at the intersection level in the before period (i.e., before the FYA was implemented).

Economic Analysis

Treatment Category	B/C ratio
Traditional PPLT to FYA PPLT on one road (3-leg)	84:1
Traditional PPLT to FYA PPLT on one road (4-leg)	69:1
Traditional PPLT to FYA PPLT on both roads (4-leg)	56:1
Permissive or traditional PPLT to FYA permissive on one road (4-leg)	144:1
Permissive to FYA permissive on one road (4-leg)	89:1

Limitations

- Left turn volumes were not available
- Evaluation focused on intersection level crashes
  - Could not reliably determine approach level crashes from coded crash reports






STOP
STOP
STOP
VII
VIII
IX
STOP
STOP
STOP
I
II
III

Questions?


20

WATCH FOR
ENTERING
TRAFFIC
WATCH FOR
ENTERING
TRAFFIC

SLOW


AHEAD
STOP