Low-Cost Countermeasure to Reduce Red Light Running at Signalized Intersections and Interstate On-Ramps

Eric J. Fitzsimmons, Ph.D., P.E. (Kansas State University)
Steven D. Schrock, Ph.D., P.E. (University of Kansas)
Tomas Lindheimer*, Ph.D. (Texas A&M Transportation Institute)
Kwaku Boyake*, Ph.D. (University of Tennessee – Knoxville)

10th International Conference on Urban Traffic Safety
Edmonton, Canada
July 8-12, 2018
Concurrent Session #3

Presentation Outline

• Some background on Kansas
• Background on red light running
• Why this study was performed
• Countermeasure
• Three case studies
  – Small college town
  – Suburban area
  – Interstate ramps
• Effectiveness
• Significant findings
Kansas

- Middle of the United States
- Agriculture state
- 2.9 million population, largest metropolitan Wichita (Kansas City, KS is second)
  - 35th in the United States
- Kansas Department of Transportation (KDOT) located in Topeka, KS
- Lower population count, high infrastructure numbers

Federal Interstate, US Highway and Kansas Highway system

- 140,378 centerline miles total - 4th highest in United States
  - 114,106 rural – 3rd highest in the United States
  - 15,666 urban
  - 10,606 Federal and State
- 25,863 bridges – 4th highest in the United States
  - 19,449 located in rural areas
Drive Up From Calgary

I-70

Alberta Highway

Background

- Red light running continues to be a serious safety concern at signalized intersections in the United States
- Red light running (RLR) was a factor in 676 fatalities in 2009 (FHWA, 2011)
- Approximately 50% of fatalities were passengers, pedestrians, and bicyclist (NHTSA, 2015)
- RLR crashes have an economic impact of approximately $14 billion annually (FHWA, 2015)
  - 93% of drivers consider red light running unacceptable
  - 1 in 3 drivers admitted to running a red light in the past month
Background

RLR resulted in 683 fatalities and 133,000 injuries in 2012 (IIHS, 2013)

- 36% RLR driver
- 12% passengers in RLR vehicle
- 46% occupants of vehicles that did...
- 6% pedestrian, bicyclist, other

RLR Fatalities by Type of Road User (IIHS, 2013)

Engineering Countermeasures

- **Signal Adjustments**
  - All red clearance
  - Yellow change interval
  - Green extension
  - Signal coordination

- **Motorist Information**
  - Advance warning signs
  - Signal conspicuity and visibility

- **Physical Improvement**
  - Removal of signals
  - Improve geometry
  - Signalized intersections to roundabouts.
  - Increase lane capacity
Why This Study Was Performed?

- The Kansas Department of Transportation recognizes that fatal and serious injury crashes at signalized intersections continue to be the second highest location for crashes in the state
- **Kansas does not allow automated enforcement**
- KDOT wanted to explore countermeasures that cities could easily afford and install without a vendor or contractor
2016 Kansas Crashes By Location

Rural vs. Urban Crashes and Fatalities
Confirmation Lights

- $99 - $120 USD per light
- Wired directly into the signal aspect
- Word or warning – these lights come with three wires and the ground wire will short out the entire intersection
  - Lots of cursing and horn honking by drivers
- Mounted to either the pole, mast-arm, or top/bottom of the signal
- Lights can be off-the shelf or custom ordered through a lighting distributor
- Commercial grade LED lights were found to be more robust with temperature changes
- 30-45 minutes install time per light
Pelco Confirmation Lights (360°)

Pelco Confirmation Light

800-Lumen 9-watt LED light bulb

McCain Enforcer Light (Directional)
Performance Metrics

- Countermeasure effectiveness is traditionally determined by a reduction in vehicle crashes at the installation site (Bonneson et al. 2002)
  - Three years before and three years after
- Analysis may include a cross-sectional analysis
  - Countermeasure at site 1 compared to countermeasure at site 2
  - Spillover / halo effects with control sites analysis
- However, stakeholders and policy traditionally want to know effectiveness immediately to justify expenses
- Safety surrogate analysis (cross-sectional and before-after)
  - A quantifiable variable that has been shown by research to relate to and/or contribute to vehicle crashes
Performance Metrics

- Surrogate limitations
  - The relationship between violations and crashes is weak (Hallmark et al. 2011) due to the fact that crashes are rare and random events and that not all RLR violations are risky, especially in the all-red phase
  - RLR violations are sometimes not risky (e.g. in the all-red phase)
  - Bonneson et al. 2002 found a non-linear relationship between RLR crash experience and violation rate

Working With Law Enforce

- Traffic enforcement is not an easy job – limited resources with other officer responsibilities
- Worked closely with city traffic engineers and police officers to find a common ground for countermeasure deployment
- Police ride-alongs were conducted to understand how RLR is enforced and their limitations
- Crash data did not align with intersection citation data
Case Study – Lawrence, Kansas (13 sites)

Methodology

Before Study
- Between October and November 2012
- Morning (7-9 a.m.)
- Evening (4-6 p.m.)

Blue Light Installation
- July 1-2, 2013 @ 9-10 a.m.

1 Month After Study
- Between August 6 - 22, 2013
- Morning (7-9 a.m.)
- Evening (4-6 p.m.)

3 Months After Study
- Between October and November 2013
- Morning (7-9 a.m.)
- Evening (4-6 p.m.)
Cameras’ positions @ intersection

Camera view showing intersection features

Crashes Caught on Camera
Data Collection

- 624 hours of video during the study period
- Recorded red light running violations and violation type (almost all single vehicle)
- Z statistic test for proportions (RLR violations)
- Chi Square test of independence (for time into red)

Analysis

Left turning violations

<table>
<thead>
<tr>
<th>Site Category</th>
<th>Violation Rate (per TEV)</th>
<th>Percent Change</th>
<th>P Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>1 month</td>
<td>3 months</td>
</tr>
<tr>
<td>Treatment Sites</td>
<td>18.8</td>
<td>8</td>
<td>10.8</td>
</tr>
<tr>
<td>Spillover Sites</td>
<td>5.5</td>
<td>2.4</td>
<td>3.7</td>
</tr>
<tr>
<td>Control Sites</td>
<td>4.6</td>
<td>4.4</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Through movement violations

<table>
<thead>
<tr>
<th>Site Category</th>
<th>Violation Rate (per TEV)</th>
<th>Percent Change</th>
<th>P Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>1 month</td>
<td>3 months</td>
</tr>
<tr>
<td>Treatment Sites</td>
<td>5.6</td>
<td>0.9</td>
<td>7.5</td>
</tr>
<tr>
<td>Spillover Sites</td>
<td>5.6</td>
<td>4.8</td>
<td>9.5</td>
</tr>
<tr>
<td>Control Sites</td>
<td>3.1</td>
<td>3.6</td>
<td>6.6</td>
</tr>
</tbody>
</table>
Time Into Red

- Time into red indicates how long it takes for the RLR violation to occur after the signal indication is shown to the driver.
- Previous research has shown that 95% of RLR violations occur within the first two seconds of red indication (Beeber, 2011).
  - All-red phase is built into the ring and barrier for this very reason.
- Left-turn-opposed and right-angle crashes likely to occur more than three seconds into the phase (Bonneson and Zimmerman, 2004).

Time into Red – Treatment Sites

<table>
<thead>
<tr>
<th>Study Period</th>
<th>Number of Violations</th>
<th>Chi-Square Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤ 2 seconds</td>
<td>&gt;2 seconds</td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>40</td>
<td>2</td>
<td>0.939</td>
</tr>
<tr>
<td>1 month</td>
<td>15</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>40</td>
<td>2</td>
<td>3.41</td>
</tr>
<tr>
<td>3 months</td>
<td>22</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
Significant Findings

- Police officers noted that the confirmation lights helped with enforcement, especially during nighttime enforcement.
- Before RLR violations decreased from 18.8 to 10.8 violations per TEV three months after installation (approx. 43% reduction)
  - Due to the threat of enforcement
  - Due to the value of the lights that heighten the attention by the driver
- Found a “spillover effect” at the adjacent intersections with minimal change at the control sites.
- Found no statistically significant change in RLR violations time into red.
- However, it was found violations occurred greater than 2 seconds into the red phase.

Case Study – Overland Park, Kansas
Site Identification

- Identified possible deployment locations with the help of the Overland Park Police Department
  - Arterials with speed limits between 30 and 50 mph
  - Protected left turn phases
  - Four-legged intersections
  - Safe locations for police officers to pull over and enforce

- Considered 9 signalized intersections
  - Crash data were not considered

Intersections Considered
Treatment Sites

- 75th St. and Metcalf Ave.
- College Blvd. and Quivira Rd.

Spillover and Control Sites
Public Campaigns

- [https://www.youtube.com/watch?reload=9&v=gyAtcvslyZc](https://www.youtube.com/watch?reload=9&v=gyAtcvslyZc)

Data Collection

- All intersections were recorded during the morning and afternoon peak hours
  - 7AM to 9AM; 4PM to 6PM
- Data were collected 1 month before, 1 month after, and 3 months after installation
- Data were collected using vehicle detection cameras mounted on the mast-arm
- 583 hours of video were reduced
- Movement count per lane were also recorded
- Through and left turning movements were only considered
Overhead Video

Volume

<table>
<thead>
<tr>
<th></th>
<th>Deployment</th>
<th>Spillover</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>37,066</td>
<td>73,012</td>
<td>89,364</td>
</tr>
<tr>
<td>1 Month</td>
<td>20,880</td>
<td>61,597</td>
<td>79,949</td>
</tr>
<tr>
<td>3 Month</td>
<td>36,681</td>
<td>75,759</td>
<td>89,689</td>
</tr>
</tbody>
</table>

KU Kansas State University
Left Turn Violations

Left Turn RLR Rate
Through Movement Violations

- Deployment: Before - 18, 1 Month - 17, 3 Month - 21
- Spillover: Before - 70, 1 Month - 42, 3 Month - 41
- Control: Before - 38, 1 Month - 54, 3 Month - 40

Through RLR Rate

- Deployment: Before - 6.0, 1 Month - 10.2, 3 Month - 6.9
- Spillover: Before - 11.0, 1 Month - 7.9, 3 Month - 6.2
- Control: Before - 5.0, 1 Month - 8.0, 3 Month - 5.2
Limitations and Significant Findings

- Glare from the sun and LED intensity during early more hours
- Changes in RLR violations were not statistically significant
- Public awareness campaign received positive feedback from the community and city
- Program has expanded to other cities in the metropolitan area
Why Interstate Ramps?

- The City of Overland Park crash data indicated that a high number of RLR crashes occurred with the left turning movement onto the ramp.
- This movement is very hard to enforce by police officers and usually requires more than one officer.
- Many times there is not an area for a police officer to sit and monitor the signal, sometimes if a motorcycle is used for enforcement that can use the sidewalk.
- Gap in knowledge, especially with red light running research.
Typical Ramp Configuration

Research Objectives

• Determine the effectiveness of directional confirmation lights to reduce RLR violations for left-turning movement onto Interstates ramps
  – Before and after violation analysis
  – 24 hours of data (peak and off-peak hours)

• Keys to answering these objectives
  – Targeted enforcement by city police officers
  – Would the confirmation lights encourage targeted enforcement?
  – What effects would the targeted enforcement have on violations?
Data Collection

- Intersection movements were captured by PTZ cameras at intersections and recorded by the city
- 24 hours of data were collected on Tuesday, Wednesday, or Thursday
- Seven sites were recorded

Data Collection Methodology

- Data Collected from August 2014 – December 2014
- Manual data reduction which took approximately 1,512 hours
- Before, 1 month after installation, and 3 months after installation
- A vehicle that crossed the stop line after the red aspect was shown was considered a red light running violation
- Vehicles that were already in the intersection during the red phase were not considered a violation
- Data that were also recorded for possible relationships
  - Number of vehicles (exposure)
  - Types of vehicles (fleet mix influence)
  - Violations per lane / violation configuration
Violation configuration

- 2 lane left turning movement at sites

Targeted Enforcement

- The City of Overland Park helped the research team by conducting a targeted enforcement campaign prior to and after installation of the confirmation lights at all study sites
- 41 days before and 168 days after installation
- The city knows where police cars are located at all times, but did not release this information to the research team due to security reasons (some randomness in the study that could not be quantified)
- The police department recorded days and times when the officers wrote RLR citations in the “area” of each site
- “Area” boundaries could not disclosed so possible halo/spillover effects could have been occurring
Results – Left Turning Movement
Per 10,000 entering vehicles

Peak and Off-Peak Hours
Per 10,000 entering vehicles

**indicates reduction statistically significant at 0.05 level of significance using a z-test of proportions
Peak and Off-Peak Hours

**Per 10,000 entering vehicles**

**Citation Information**

<table>
<thead>
<tr>
<th>Site Category</th>
<th>Officers Deployed</th>
<th>Citations made</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before Study</td>
<td>After Study</td>
</tr>
<tr>
<td>Treatment Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quivera N</td>
<td>84</td>
<td>137</td>
</tr>
<tr>
<td>Quivera S</td>
<td></td>
<td>137</td>
</tr>
<tr>
<td></td>
<td></td>
<td>462</td>
</tr>
<tr>
<td>Control Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antioch N</td>
<td>11</td>
<td>70</td>
</tr>
<tr>
<td>Antioch S</td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>Metcalf N</td>
<td>28</td>
<td>65</td>
</tr>
<tr>
<td>US 69 E</td>
<td>23</td>
<td>34</td>
</tr>
<tr>
<td>US 69 W</td>
<td></td>
<td>48</td>
</tr>
</tbody>
</table>

**41 days before and 168 afterwards**
Normalized Citation Data to 41 days and number of officers

<table>
<thead>
<tr>
<th>Site Category</th>
<th>Officers Deployed per day</th>
<th>Citations made per day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before Study</td>
<td>After Study</td>
</tr>
<tr>
<td>Treatment Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quivera N</td>
<td>2</td>
<td>0.81</td>
</tr>
<tr>
<td>Quivera S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antioch N</td>
<td>0.26</td>
<td>0.41</td>
</tr>
<tr>
<td>Antioch S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metcalf N</td>
<td>0.68</td>
<td>0.38</td>
</tr>
<tr>
<td>US 69 E</td>
<td>0.56</td>
<td>0.20</td>
</tr>
<tr>
<td>US 69 W</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Limitations and key findings

- Due to security reasons the police department was no able to tell us officer enforcement schedule and location of citations – in other words, useful but not 100% accurate
- Very important to consider peak and off-peak hours
- Reduction in red light running violations during after periods
- Positive feedback from officers and community leaders
Useful Reports

• Automated Enforcement
• Low-cost countermeasures

Thank you

Eric J. Fitzsimmons, Ph.D., P.E.
Assistant Professor
Kansas State University
Department of Civil Engineering
fitzsimmons@k-state.edu
785-532-0889