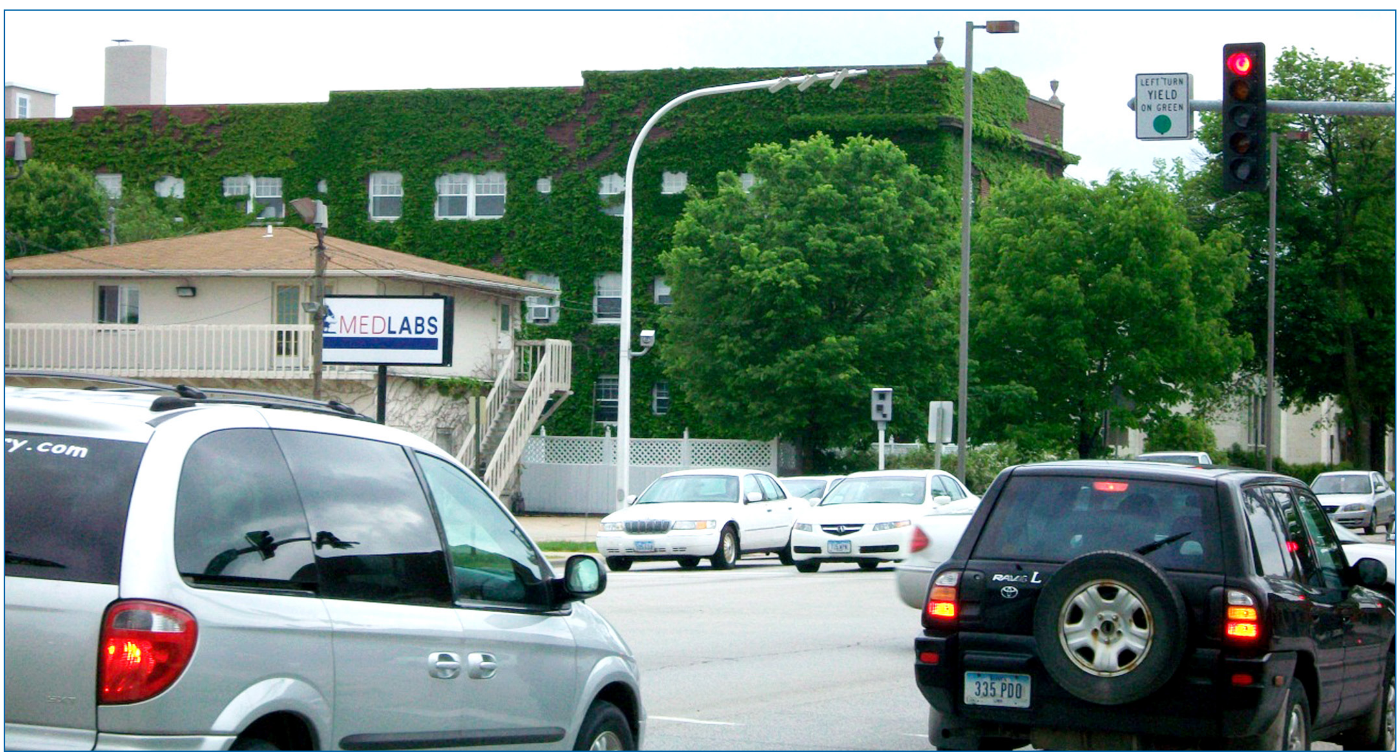
Toolbox of Countermeasures to Reduce Red Light Running

MTC
MIDWEST TRANSPORTATION CONSORTIUM

Final Report
April 2012



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The mission of the Center for Transportation Research and Education (CTRE) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, and reliability while improving the learning environment of students, faculty, and staff in transportation-related fields.

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16. Abstract

Red light running (RLR) is a problem in the US that has resulted in 165,000 injuries and 907 fatalities annually. In Iowa, RLR-related crashes make up 24.5 percent of all crashes and account for 31.7 percent of fatal and major injury crashes at signalized intersections.

RLR crashes are a safety concern due to the increased likelihood of injury compared to other types of crashes.

The research team developed this toolbox for practitioners to address RLR crashes. The Four Es—Engineering, Enforcement, Education, and Emergency Response—should be used together to address RLR problems.

However, this toolbox focuses on engineering, enforcement, and education solutions. The toolbox has two major parts:

- Guidelines to identify problem intersections and the causes of RLR at intersections
- Roadway-based and enforcement countermeasures for RLR

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Introduction

Background

In 2009, red light running (RLR) resulted in 676 fatalities in the US. This represented 10 percent of all intersection-related fatalities as well as two percent of all roadway fatalities in 2009 (FHWA 2011). In addition, the Insurance Institute for Highway Safety (IIHS) estimates that 130,000 people were injured in crashes in 2009 due to red light running (IIHS 2011b).

RLR is a safety issue, which 93 percent of respondents of the American Automobile Association (AAA) 2010 Traffic Safety Culture Index considered unacceptable; yet, more than 30 percent of respondents admitted to running a red light in the last 30 days when they could have safely stopped (AAA 2010).

A review was conducted of the Iowa Department of Transportation (DOT) crash database for 2010 to determine the magnitude of RLR crashes in Iowa. A total of 6,007 crashes occurred at signalized intersections in 2010. Crashes at signalized intersections were defined as those coded as a non-freeway intersection that also had presence of a traffic signal noted.

RLR crashes accounted for 1,525 crashes. RLR crashes were defined as crashes where the major cause or contributing circumstances were listed as ran traffic signal or failure to yield right of way on right turn on red. Consequently, 24.5 percent of crashes at signalized intersections in Iowa were found to be due to RLR.

In addition, RLR crashes were found to make up 31.7 percent of fatal and major injury crashes.

Common crash types associated with RLR include right angle, side swipe opposite direction, and failure to yield making left turn (for permissive left signal phases).

The research team developed this toolbox for practitioners to address RLR crashes. The Four Es—Engineering, Enforcement, Education, and Emergency Response—should be used together to address RLR problems.

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- Guidelines to identify problem intersections and the causes of RLR at intersections
- Roadway-based and enforcement countermeasures for RLR

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Problem Intersection Identification

Engineering Process to Identify Problems

The Institute of Transportation Engineers (ITE) (2003) developed five steps to identify RLR safety problems:

1. Identify the existence of a red-light-running problem
2. Conduct an analysis to investigate the causes of the problem
3. Identify potential countermeasures
4. Identify the cost-effective and appropriate countermeasure
5. Implement the countermeasure at intersection

Data Collection for RLR Problem Intersections

Given that intersection geometry, signal timing, and traffic flow all have a significant impact on RLR frequency, it is necessary to collect intersection data before identifying countermeasures. The information to collect includes crash history, traffic volume, intersection geometry, lane configuration, traffic control type, traffic signal design and programming, pavement condition, and site surveys.

It is important to access the most recent crash history data for the intersection. The crash type and causes should be studied for each lane approach. Collision diagrams and crash reports are useful in identifying the types and causes of crashes. Crash data should be obtained through local jurisdictions.

It is also important for an engineer to visit the intersection in person and identify problems using engineering judgment. Figure 1 illustrates the Iowa DOT crash report diagram, which can be used to identify types of crashes at the intersection.

Step 8.

Indicate On This Diagram What Happened
Use one of these outlines to sketch the scene of your accident, writing in street or highway names or numbers.

Initial Travel Direction
(prior to coded Vehicle Action)
1 - North
2 - East
3 - South
4 - West
9 - Unknown

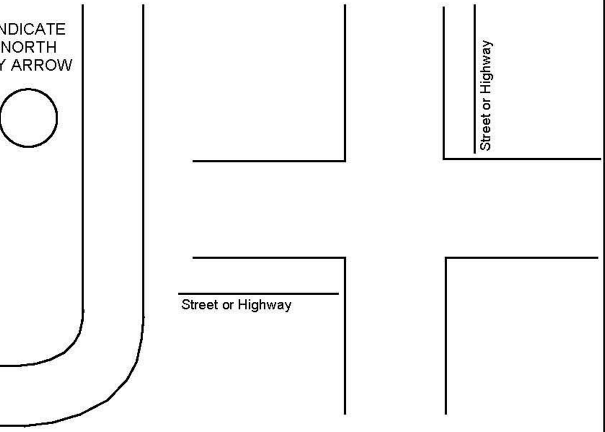
N W E S

INDICATE NORTH BY ARROW

Original Direction of Travel: *(Example: Vehicle going north then turning left, code 'N' for Original Direction of Travel)*

Vehicle 1 ________ Vehicle 2 ________

________________ Street or Highway



Description

____

____

____

____

____

____

____

Did Peace Officer investigate? ☐ Yes ☐ No Department ________________

If you did not have automobile liability insurance coverage for this accident, please check this box ☐.

If you had automobile liability insurance coverage for this accident, please complete insurance information below:

Failure To Complete Insurance Coverage Information Requested Below May Result In A Suspension Of Your Driving And/Or Registration Privileges.

Step 9.

Name of Insurance Company **(Not Agent)** Providing Insurance To Cover Your Liability For Damage Or Injury To Others:

____

Name of Agent Who Sold Policy ________________

Agent Address ________________

Policy No. ________ Policy Period: From ________ To ________

V.I.N. No.________________

Name of Driver ________________

Name of Owner ________________

Name of Policyholder ________________

Step 10.

Date	Signature of Driver of Vehicle No. 1	If Signed By Person Other Than Driver, Give Reason

IMPORTANT: This accident should also be reported directly to your insurance company. Failure to report may jeopardize your automobile liability insurance.

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Figure 1. Iowa DOT Motor Vehicle Accident Report diagram page

Checklist for Identifying RLR Problems at Intersections

ITE (2003) and Quiroga et al. (2003) identified some important intersection characteristics related to RLR. Problems could be identified based on the checklist for signalized intersections in Figure 2. For example, the sight distance check should be performed during a field investigation.

Use of Intersection Diagrams

ITE (2003) suggests using intersection diagrams to collect information and help engineers understand the RLR problem at intersections. Also, an intersection condition diagram should be drawn to help engineers identify the potential problem areas.

The diagram should include information about the intersection such as street width, pavement marking, lane configurations, turning bay lengths, signal control types, speed limits, driveways near the intersection, pedestrian walkways, and fixed objects that may block the driver's view. Figure 3 shows a sample intersection field inspection form from ITE.

- ☐ Visibility and Conspicuity Features:
    - ☐ Sight distance to signals
    - ☐ Number of signals
    - ☐ Position of signals
    - ☐ Line of sight for visibility restricted signals
    - ☐ Brightness of signals, day and night
    - ☐ Conspicuity
- ☐ Signal Control Parameters:
    - ☐ Coordination with adjacent signals
    - ☐ Timing and cycle length
    - ☐ All-red clearance interval, if used
- ☐ Geometric Features:
    - ☐ Grade of approach lanes
    - ☐ Pavement condition
- ☐ Traffic Operations Features:
    - ☐ Vehicle approach speed
    - ☐ Right-turn-on-red
    - ☐ Pedestrian usage
    - ☐ Truck volume

Figure 2. Checklist for problem identification at signalized intersections

INTERSECTION FIELD INSPECTION FORM

LOCATION INFORMATION

Intersection Identification:________________________________ with____

Approach Name:____ Direction Heading:____________

PART 1. CHECK SIGNAL VISIBILITY

Type of Signal Mounting: Span Wire Mast Arm Pole Structure — Sight Distance to the Signal: ______ *feet*

Requires Advance Warning Sign? Y N — Advance Signal Warning Sign Present: Y N

Is anything blocking the view of the signals? Y N If yes, describe______________________________________

Can signal faces on other approaches be seen? Y N If yes, do these signals have visors, shields, or programmable lenses? Y N

PART 2. CHECK SIGNAL CONSPICUITY

Could visual clutter detract from the signal? Y N

Are the signal indications confusing? Y N

If yes, explain:______________________________

____

Are backplates present? Y N

Are backplates necessary? Y N

Are other glare-reducing steps needed? Y N

Signal lens type: Incandescent LEDs

Signal Lens Size Adequate?:

- Red signal lens size: 8 inch 12 inch
- Distance from stop line to signal: ______ *feet*
- Near side signal? Y N
- Is existing size adequate? Y N

Number of Signal Heads Adequate?

- Total number of signal heads for major movement: ______
- Total number of lanes for major movement: ______
- Is existing number adequate? Y N

Signal Heads Placement Adequate? Y N

PART 3. CHECK SIGNAL CONTROL PARAMETERS

Grade (as decimal) g =__________ (uphill is positive)

Approach speed *V* =__________ *mph*

Cross street width *W* =__________ *feet*

Calculate the needed change period *(CP)* for this approach using agency practice or the following equation:

$$CP = \underbrace{1.0 + \frac{1.47 * V}{(20 + 64.4g)}}_{\text{Yellow}} + \underbrace{\frac{W + 20}{1.47 * V}}_{\text{All-red}}$$

	Actual Value	Calculated Value	Is Existing Adequate?
Yellow Interval	__________	__________	Y N
All Red Interval	__________	__________	Y N

PART 4. CHECK OTHER FACTORS

Is horizontal location adequate? Y N — Pavement condition on approach: Adequate Polished Severely Rutted

Should signal warranting study be conducted? Y N — Other concerns:______________________________

PART 5. IDENTIFY PROMISING COUNTERMEASURES

Visibility Deficiency

___ Install additional signals on near side
___ Change signal mounting
___ Install SIGNAL AHEAD sign
___ Install Advance Warning Flashers
___ Remove/relocate sight obstruction
___ Install programmable lenses
___ Install shields and visors
Other____

Conspicuity Deficiency

___ Add signals to achieve one per lane
___ Replace with LED lens type
___ Replace with 12" signal head
___ Install double red signal
___ Install/enhance backplates
___ Install rumble strips on approach
___ Install near side signal

Signal Timing Operation Deficiency

___ Change yellow interval
___ Add/change all-red interval

Other Measures

___ Determine if signal is warranted
___ Consider roundabout or innovative design
___ Improve pavement condition

Inspection By: ________________________________ Date:____________

Figure 3. Intersection Field Inspection Form (ITE)

RLR Countermeasures

Engineering countermeasures can be categorized into signal operations, motorist information, and physical improvements. Signal operation countermeasures include changing cycle lengths or optimizing signals in the network. Motorist information countermeasures are used to enhance the signal display or provide advance warning before the signalized intersection. The physical improvement category includes reconstruction of the existing intersection, such as replacing a signalized intersection with a roundabout.

Enforcement countermeasures referenced in this report include traditional and automated enforcement.

Information contained in this report provides a cross-section of treatments that have been applied to reduce RLR. Before selecting and applying a particular treatment, practitioners should consult the Manual on Uniform Traffic Control Devices (MUTCD) and other appropriate guidelines to ensure that the appropriate standards and practices are being followed. MUTCD experimental approval may be required for some treatments.

Following is an overview of the countermeasures discussed in this report, grouped by category.

Signal Operation

- Study and apply requirements/guidance from Part 4 of the MUTCD (2009)
- Change signal interval duration
  - Provide green-extension (Dilemma-Zone detection)
  - Increase yellow interval duration
  - Add or increase all-red clearance interval
- Coordinate signals
- Optimize signals
- Provide protected left-turn phasing

Motorist Information

- Improve signal visibility
  - Add signal heads (supplemental near-side signal)
  - Increase size of signal display
  - Try different signal mounting configurations
  - Add advance warning signs
  - Use advance warning for end of green
  - Use of countdown timers for pedestrians
- Improve Signal Conspicuity
  - Use of redundancy (two signal heads visible for each lane)
  - Use signal backplates
  - Use of LED signal lens
  - Use of visor and louvers

Physical Improvement

- ♦ Remove unneeded signals at intersections per MUTCD guidance
- ♦ Consider a roundabout intersection design
- ♦ Improve sight distance to the signals

Enforcement

- ♦ Use of traditional enforcement
- ♦ Use of downstream red signal indication lights
- ♦ Install red light running cameras (automated enforcement)

Table 1 shows countermeasures according to the possible causes of red light running. Possible causes can be identified during the site investigation phase and, then, the corresponding countermeasures should be implemented to address the problem area.

Table 1. Engineering and enforcement countermeasures by possible RLR cause (Bonneson et al. 2002)

	Engineering Countermeasure Categories			
Possible Cause of RLR	Signal Operation	Motorist Information	Physical Improvement	Enforcement
Congestion or excessive delay	♦		♦	
Disregard for red				♦
Judged safe due to low conflicting volume			♦	♦
Judged safe due to narrow cross street				♦
Judged safe due to following < 2 sec behind vehicle in front				♦
Expectation of green when in platoon	♦			
Downgrade steeper than expected	♦			
Speed higher than posted limit	♦			
Unable to stop (excessive deceleration)	♦			
Pressured by closely following vehicle	♦			
Tall vehicle ahead blocked view		♦		
Unexpected, first signal encountered		♦		
Not distracted, just did not see signal		♦		
Distracted and did not see traffic signal		♦		
Restricted view of signal		♦	♦	
Confusing signal display		♦		

The remainder of this report includes a toolbox of possible countermeasures that can to be used at signalized intersections to address signal violations.

For each countermeasure, this toolbox includes a description of the countermeasure along with information about its effectiveness, a list of advantages and disadvantages, and supplemental information about appropriateness as needed/available.

When available, crash modification factors (CMFs) from the Federal Highway Administration (FHWA) CMF Clearinghouse (at www.cmfclearinghouse.org) are summarized for the corresponding countermeasure. A CMF is a multiplicative factor that can be used to estimate the expected number of crashes after implementing a particular countermeasure at a specific site.

For example, if the CMF for Countermeasure A = 0.90 for sideswipe crashes and the current annual number of crashes is 15, the expected number of crashes after implementation of Countermeasure A = 0.90 x 15 = 13.5 crashes (for a reduction of 1.5 crashes).

A star rating system is used to indicate the quality or confidence in the CMF based on study parameters including study design, sample size, standard error, potential bias, and source of data. The scale is 1 to 5 with 5 being the highest rating.

Increase Yellow Interval Duration

Description

The yellow interval at an intersection should be of sufficient duration to safely allow a vehicle to pass through the intersection from the onset of the yellow and before the onset of the red phase. Drivers have expectations for the yellow light duration based on past experiences. An improperly timed signal may influence a vehicle to violate the signal.

Section 4D.26 of the MUTCD (2009) provides guidance that yellow intervals should be no less than 3 seconds and no more than 6 seconds and should be based on the minimum yellow interval equation (1) from ITE, which is dependent on vehicle speed and reaction time.

Equation (1)

$$Y = t + \frac{1.47 \times V_{85}}{2(a + Gg)}$$

Y = yellow duration in seconds

t = reaction time = 1 s

V_{85} = 85th percentile speed in mi/h

a = deceleration = 10 ft/s^2

G = grade in ft/ft (+ uphill, - downhill)

g = acceleration due to gravity = 32.2 ft/s^2

Increasing the yellow time beyond the required minimum is a potential countermeasure to address RLR.

Effectiveness

Bonneson and Zimmerman (2004) found an increase of the yellow phase by 1 second can potentially reduce RLR frequency by 50 percent. Retting et al. (2008) found a 36 percent reduction in the odds ratio of vehicles running a red light after the yellow intervals were increased by 1 second at two intersections in Philadelphia, Pennsylvania.

Advantages

- Low cost
- Fast implementation

Disadvantages

- Decreases intersection capacity
- Increases intersection delay
- Potential for drivers to adapt to the longer yellow resulting in continued red light running

Appropriateness

According to Bonneson and Zimmerman (2004), if the yellow interval is 5.5 seconds or more, increasing the yellow phase will have little impact on reducing red light running.

Increase All-Red-Clearance Interval Duration

Description

An all-red clearance interval is defined as when all signals at an intersection display a red phase to allow vehicles that entered during the yellow interval to safely clear the intersection before the red phase is displayed. If an all-red interval is used, extending that phase may be another possible countermeasure.

Effectiveness

The use of an all-red clearance or lengthening of that interval is not likely to alter driver behavior, but this could decrease the chance of a crash happening if a driver does run the red light.

Datta et al. (2000) added an all-red interval to three intersections in Detroit, Michigan and found a significant reduction in right-angle crashes. However, Souleyrette et al. (2004) found that, over time, increasing the red-clearance interval did not reduce crashes in Minneapolis, Minnesota. The first year saw a reduction of approximately one crash per intersection, but crashes returned to previous levels after one year.

Polanis (2002), on the other hand, saw a 5.5 percent increase in right-angle crashes and a 9.8 percent increase in total crashes when a one second all-red interval was added to seven intersections in North Carolina. The report did not indicate if these increases were statistically significant.

Advantages

- Low cost
- Easy to implement

Disadvantages

- Decreases intersection capacity
- Increases intersection delay
- When drivers are aware that an all-red phase is provided, they may be more likely to enter the intersection late into the yellow interval and/or run a red light if they know there is a period with no conflicting movements

Increase Green Extension on Actuated Signal Timing

Description

Adding a green phase extension at an intersection involves using a detector to determine if a vehicle is traveling in the dilemma zone at the beginning of the yellow interval at a speed that would not permit a stop before entering the intersection.

If a vehicle within the dilemma zone is detected, the green interval is extended to allow the vehicle to pass through the intersection safely. The green extension is limited, however, and drivers who consistently take advantage of this feature may still violate the red signal.

Effectiveness

Several studies have been conducted on the effectiveness of the green-extension countermeasure. Zeeger and Deen (1978) found that a green-extension reduced right-angle crashes by about 31 percent and rear-end crashes by 75 percent.

As cited by Bonneson et al. (2002), Agent and Pigman (1994) conducted a study at 33 intersections in which 10 of the 33 intersections didn't have a green-extension system. The RLR frequency was 3 percent of total cycle length at intersections with the green-extension system and 5.5 percent at intersections without a green extension system.

Archer and Young (2009) conducted a study that used microsimulation modeling to determine the effects of various treatments in reducing red light running and found that using dilemma zone protection resulted in an expected decrease of red light runners of 14.5 percent, the majority of which were expected to be heavy vehicles.

Bonneson et al. (2002) found that providing the green extension reduced RLR frequency by 45 to 65 percent in a synthesis of previous research.

Advantages

- Low cost

Disadvantages

- Benefits are negated when the extended green cycle ends
- Drivers may intentionally speed up if they know additional time will be provided
- Increased delay to side-street traffic

Appropriateness

Green extension should be used only at signals with actuated or semi-actuated timing.

Signal Optimization

Description

Signal optimization involves using appropriate software to optimize signal timing for current traffic conditions either at an individual signal or along a corridor. An appropriately-timed signal should reduce delay and add capacity to the intersection, while also reducing driver frustration due to cycles that are either too short or too long in duration (ITE 2003).

Effectiveness

Bonneson et al. (2002) found that an increase in the cycle length of 20 seconds resulted in a crash modification factor of 0.75 to 0.85, depending on the initial cycle duration. The researchers also found that decreasing the cycle length by 20 seconds resulted in a crash modification factor of 1.2 to 1.5. (A crash modification factor greater than 1.0 indicates an increase in crashes.)

Agent et al. (1996) listed a crash reduction factor (CRF) of 10 percent for improving signal timing. This reduction factor was based on a survey of states and existing literature.

Advantages

- Reduction in overall delay
- Cost-effective

Disadvantages

- Decreasing cycle length may expose drivers to more yellow and red signals

Signal Coordination

Description

Signal coordination involves timing signals to move platoons of vehicles through a corridor of intersections with minimal stopping.

Effectiveness

Quiroga et al. (2003) found that improving signal coordination can reduce the frequency of RLR by 39 percent. This was based on data from a survey by ITE (Stollof 2001).

A study by Shinar et al. (2004) found that drivers at non-synchronized signalized intersections were seven times more likely to run a red light compared to those at a synchronized signalized intersection. In this same study however, the researchers found that as congestion increased the likelihood of running the red light for the two signal synchronization types became approximately equal.

Advantages

- Low cost
- Reduces delay for major road traffic

Disadvantages

- Can increase delay to minor road traffic
- If coordinated inappropriately, can cause increase in red light running

Appropriateness

According to the 2009 MUTCD Section 4D.01: "Traffic control signals within 1/2 mile of one another along a major route or in a network of intersecting major routes should be coordinated, preferably with interconnected controller units. Where traffic control signals that are within 1/2 mile of one another along a major route have a jurisdictional boundary or a boundary between different signal systems between them, coordination across the boundary should be considered."

Additional Signal Heads

Description

According to Section 4D.11 of the MUTCD (2009), a minimum of two or more signal heads shall be installed at major roads. To address RLR problems, one signal head per lane (as shown in Figure 4) can be added to improve visibility.

Table 2 lists the minimum number of signal faces required by the MUTCD (2009). Pedestal- mounted signals, in addition to overhead, are also recommended.

Figure 4. Example of one signal head per lane at Jordan Creek Parkway and EP True Parkway in Des Moines, Iowa

Table 2. Recommended minimum number of primary signal faces for through traffic on approaches with posted, statutory or 85th percentile speed of 45 mph or higher (MUTCD 2009 Table 4D-1)

Number of Through Lanes on Approach	Total Number of Primary Through Signal Faces for Approach*	Minimum Number of Overhead-Mounted Primary Through Signal Faces for Approach
1	2	1
2	2	1
3	3	2**
4 or more	4 or more	3**

* A minimum of two through signal faces is always required (See Section 4D.11).These recommended numbers of through signal faces may be exceeded. Also, see cone of vision requirements otherwise indicated in Section 4D.13.
** If practical, all of the recommended number of primary through signal faces should be located overhead.

Effectiveness

Felipe et al. (1998) found that using both overhead and post-mounted heads at the same site is more effective than all post-mounted or all overhead configurations.

Supplemental pole-mounted signals can be used to increase the signal visibility. If one signal is provided for each lane, there will be a potential crash reduction for all crashes of 28 percent, rear-end crashes by 28 percent, and right-angle crashes by 46 percent.

Polanis (2002) saw right-angle crashes decrease by 46.5 percent when an auxiliary signal head was added at 11 intersections in Winston-Salem, North Carolina with five of the intersections seeing statistically-significant decreases to right-angle crashes.

Also, according to Section 4D.11 of the MUTCD (2009): *"Locating primary signal faces overhead on the far side of the intersection has been shown to provide safer operation by reducing intersection entries late in the yellow interval and by reducing red signal violations, as compared to post-mounting signal faces at the roadside or locating signal faces overhead within the intersection on a diagonally-oriented mast arm or span wire."*

The CMF Clearinghouse cites a study by Sayed et al. (2007), which lists the CMFs below for improving visibility of signals at urban signalized intersections. Improvements include a combination of one or more of the following countermeasures: upgrade in signal lens size, installing new backboards, use of reflective tape to existing backboards, and use of additional signal heads.

- 0.93 for all crashes (star rating = 4)
- 0.97 for fatal, serious injury, and minor injury crashes (star rating = 4)

Advantages

- Improves traffic operation
- Moderate cost

Disadvantages

- Additional signal heads to maintain
- Signal supports may not be adequate for additional weight

Increase Signal Head Size

Description

The size of the signal display can increase the visibility of red lights at signalized intersections as shown in Figure 5. A 12 in. signal head is recommended to increase the signal visibility for older signal heads. All new signals are required to have the 12 in. indications (MUTCD 2009, Section 4D.07).

Figure 5. Comparison of signal head sizes with 12 in. red lenses on top and 8 in. lenses on bottom (FHWA 2009)

Effectiveness

Polanis (2002) increased the signal heads from 8 in. diameter to 12 in. for at least one approach of an intersection in 55 locations where the 8 in. head was found to be substandard. The researchers found that right-angle crashes at the approaches with the treatment decreased by 47 percent while total crashes declined by 9.9 percent. Srinivasan et al. (2008) saw a similar reduction in right-angle crashes as Polanis (47 percent), but also saw an increase in total crashes (3 percent).

The CMF Clearinghouse cites a study by Sayed et al. (2007), which lists the CMFs below for improving visibility of signals at urban signalized intersections. Improvements include a combination of one or more of the following countermeasures: upgrade in signal lens size, installing new backboards, use of reflective tape to existing backboards, and use of additional signal heads.

- 0.93 for all crashes (star rating = 4)
- 0.97 for fatal, serious injury, and minor injury crashes (star rating = 4)

Another study cited by the clearinghouse (Polanis 1999) lists a CMF of 0.54 (star rating = 2) for installation of larger signal heads.

The study by Srinivasan et al. (2008) received a CMF of 0.58 for replacing an 8-inch red signal head with a 12-inch signal head (CMF star rating = 4).

Advantages

- Required under new MUTCD (2009)
- Moderate cost

Appropriateness

Any new signal is required to have a 12 in. signal indication unless it meets certain conditions listed in the MUTCD 2009 (Section 4D.07).

Signal-Mounting Configuration

Description

Signals can be mounted in a variety of configurations. These configurations include on poles at street corners, overhead on mast arms, overhead on span wires, or even overhead on trusses at large intersections. Changing the signal configuration from pole-mounted to an overhead configuration has been found to increase safety.

Effectiveness

Schattler et al. (2011) found that RLR rates were lower at a statistically-significant level for mast-arm mountings compared to both span- and post-mounted configurations. The researchers found post-mounted signals to exhibit the highest RLR rate compared to the span and mast-arm configurations.

The researchers also determined that fewer vehicles entered an intersection during the yellow phase when using a mast-arm or span-wire configuration compared to post-mounted, yet no difference could be found between the mast-arm and span-wire configurations.

Thomas and Smith (2001) studied 33 projects in Iowa where pole-mounted signals were replaced by mast-arm mountings and found that right-angle crashes were reduced by 66 percent.

The CMF Clearinghouse cites several studies that show the following CMFS for converting a signal from a pedestal-mount to a mast arm:

- 0.51 (star rating = 3) and 0.71 (star rating = 3) for all crashes (Rodegerdts et al. 2004; McGee et al. 2002)
- 0.56 (star rating = 3) for fatal, serious, and minor injury crashes (Rodegerdts et al. 2004)
- 0.59 (star rating = 3) for rear-end crashes (Rodegerdts et al. 2004)
- 0.88 (star rating = 2) and 0.37 (star rating = 2) for angle crashes (Rodegerdts et al. 2004; McGee et al. 2002)

Advantages

- Overhead mounting more clearly indicates which lane is controlled by a specific signal
- Visibility of signals mounted overhead are less often hampered by large vehicles

Disadvantages

- May be less aesthetically pleasing compared to pole mounted
- Mast arm or span wire mountings are more costly than simple pole or pedestal mounts

Appropriateness

According to the MUTCD (2009, Section 4D.11 with Table 4D-1), for roadways with speeds of 45 mph or higher: “If practical, all of the recommended number of primary through signal faces should be located overhead.”

Advance Warning Signs

Description

The Signal Ahead sign (W3-3), shown in Figure 6, can be used to warn drivers of the presence of a signalized intersection ahead. In addition, the MUTCD (2009) allows the combined use of a warning beacon with the Signal Ahead sign. The sign should be located prior to the intersection based on the approach speed (MUTCD 2009, Table 2C-4).

Figure 6. Signal Ahead sign, W3-3 (MUTCD 2009)

Effectiveness

Polanis (2002) found a 44 percent reduction in right-angle crashes when using the Signal Ahead sign at 11 existing signalized intersections.

The CMF Clearinghouse cites a study by Polanis (1999), which provides a CMF of 0.65 for angle crashes (star rating = 2) for installation of advance warning signs.

Advantages

- Low cost
- Effective in appropriate applications

Disadvantages

- If overused or used inappropriately, drivers may become de-sensitized to the sign as well as to other warning signs
- Additional signs to maintain

Appropriateness

The Signal Ahead or other appropriate warning sign shall be used when sight distance is not adequate as per Table 4D-2 (MUTCD, 2009). It may also be used to emphasize the existence of a traffic signal even when sight distance is met.

Advance Warning Flashers

Description

Another advance warning sign configuration is the Be Prepared to Stop sign, W3-4, supplemented with a When Flashing plaque, W16-13P. There are two variations of the sign, which use either the word message as seen in Figure 7 or a symbolic signal ahead shown in Figure 6.

Figure 7. Be Prepared to Stop When Flashing assembly (MUTCD 2009)

Both assemblies feature yellow beacons that flash for a set amount of time before the signal enters the yellow phase (ITE 2003). This additional warning allows drivers increased time and distance to reduce speed and stop.

Effectiveness

Agent and Pigman (1994) as cited by Bonneson et al. (2002), conducted a study comparing the frequency of red light running at 16 intersections without advance warning signs with two intersections with signs and active beacons. The researchers observed 100 signal cycles and found 67 percent fewer red light runners at signals without advance warning than those without active beacons.

Farraher et al. (1999) studied the effect of advance warning beacons at one intersection by using a motion-imaging-recording-system technology in Minnesota. The study found the warning sign with active beacons reduced the RLR frequency by 29 percent.

Agent et al. (1996) suggested a 25 percent CRF when using intersection advance warning beacons based on surveys of states and literature.

Messer et al. (2004) found that the reduction in RLR within the first 5 seconds of red to be about 40 to 45 percent when using a system that provided advance warning at the end of the green phase based on a study of two sites in Texas.

Advantages

- Provides additional warning and reaction time
- Especially effective for large, commercial vehicles
- Relatively low-cost improvement

Disadvantages

- Can increase the dilemma zone
- Drivers may rely on the sign rather than checking signal changes

Appropriateness

Advance warning beacons are most appropriate on high-speed roadways. When a Be Prepared to Stop sign is used in advance of a traffic control signal, it shall be used in addition to a Signal Ahead sign and shall be placed downstream from the Signal Ahead (W3-3) sign (MUTCD, 2009 Section 2C.36).

LED Signal Modules

Description

A light emitting diode (LED) traffic signal module consists of many individual small LED lights as shown on the right side of Figure 8. These LEDs can be used in signals to replace traditional incandescent bulbs to increase signal face visibility.

Figure 8. Comparison between incandescent bulb signals (left) and LED signals (right)

Effectiveness

Bonneson et al. (2002) found that when adding LED lighting to the yellow indications that at least a 13 percent reduction in RLR can be realized.

Advantages (ITE 2003)

- Energy-efficient (using 90 percent less energy than typical bulbs)
- Brighter than traditional incandescent bulbs
- Longer life-span (6 to 10 years compared to 12 to 15 months)
- Reduction in signal indication outages
- Reduction of traffic disturbance due to less maintenance
- Longer battery backup operation time during power outages

Disadvantages

- Potential for glare which could affect driver vision at night (ITE 2003)
- Snow accumulation (as LED lights don't generate as much heat as incandescent bulbs)

Redundant Signal Heads

Description

If an intersection presents a visibility deficiency, a redundant signal head can be used to improve the conspicuity of the signal. Figures 9 and 10 illustrate redundant signal head configurations that can be used according to the MUTCD (2009).

Figure 9. Field use of two red signal heads (FHWA 2004)

Effectiveness

Polanis (2002) studied the use of redundant signals at nine intersections in Winston-Salem, North Carolina. The researchers found a 33.1 percent decrease in right-angle crashes. Decreases were statistically significant at five of the nine intersections.

However, Srinivasan et al. (2008) found that crashes at eight intersections with dual red signal heads increased slightly (though not significantly) and therefore had no impact on RLR-related crashes (CMF of 1.05, star rating of 3).

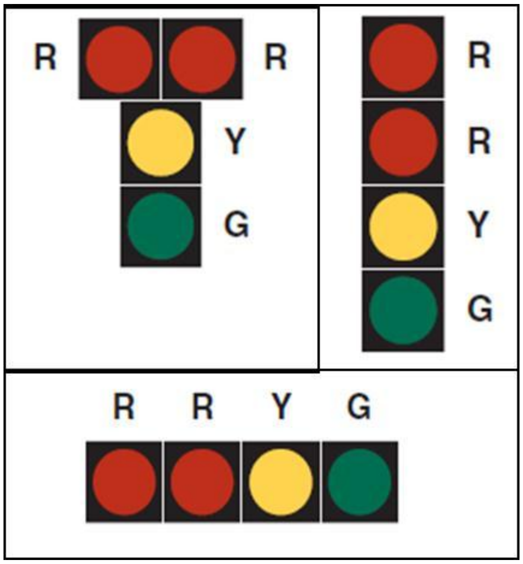

Figure 10. Redundant red light signal configurations (MUTCD 2009 Figure 4D-2)

Advantages

- Draws more attention to the signal
- Relatively low-cost improvement

Disadvantages

- Dual red faces may be confusing to some drivers

Protected Left-Turn Signal Phase

Description

At many intersections, permitted or permitted/protected left-turn signal phases are used. Permitted phasing requires left-turning vehicles to find an appropriate gap in the opposing traffic flow to complete a safe turning movement. While waiting for a gap, drivers may pull forward into the intersection and, if they are not able to find a gap during the green interval, they may be left to clear the intersection after the red phase is given. Or, perhaps more commonly, drivers may fail to judge a proper gap before making the left turn. Either of these driver actions can result in crashes.

Figure 11. Left Turn Signal sign (MUTCD 2009 R10-10)

The use of a protected-only left-turn signal phase eliminates these potential conflicts. In addition, a Left Turn Signal sign (as shown in Figure 11) may be used to help differentiate the signal heads for left-turning traffic from through movements.

Effectiveness

Agent et al. (1996) listed an expected crash reduction of 25 percent for all crashes and 70 percent for left-turning crashes when adding a protected-only left-turn phase. Studies by Maze et al. (1994) and Hallmark and Mueller (2004) found that protected left-turn phasing provided the best option to reduce crashes. None of the studies, however, looked specifically at RLR-related crashes.

A Left Turn Signal sign is recommended to reduce driver misinterpretation of the signal heads; however, no research could be found that studied the effectiveness of the sign in reducing crashes.

The CMF Clearinghouse cites a study by Srinivasan et al. (2008), which provides a CMF of 0.021 for angle crashes (star rating = 4) and a CMF of 0.975 for all crashes (star rating = 3) when permissive or permissive/protected left-turn phasing is changed to protected phasing.

Advantages

- Low to moderate cost
- Addresses other types of left-turning crashes besides those related to red light running

Disadvantages

- Increases delay at intersection
- Only impacts left-turning vehicles (not a general solution to red light running)

Appropriateness

Protected left- turn phasing in general is most appropriate in the following conditions (Agent 1985, Cottrell 1986, Koupai and Kothari 1999):

- Speed limit greater than 45 mph
- Three or more opposing through lanes
- Dual left turn lanes are present
- Reduced sight distance
- Left turn crash problem
- Large number of left-turn conflicts

Use of protected-only left-turn phasing to address red light running is most appropriate when crash records indicate a significant frequency of left-turn opposed or left-turn sideswipe crashes.

Signal Backplates

Description

Signal backplates are used to minimize light reflection and to increase the contrast between the signal indication and the background (MUTCD 2009, Section 4D.12). This may be especially beneficial for east-west traffic due to potentially difficult visibility during sunrise and sunset.

Regular backplates are shown in Figure 12. Some agencies have used retroreflective and/or fluorescent yellow borders on traffic signal backplates to increase visibility as shown in Figure 13.

The FHWA (2011) suggests use of the treatment as a countermeasure for red light running. According to the MUTCD "A yellow retroreflective strip with a minimum width of 1 inch and a maximum width of 3 inches may be placed along the perimeter of the face of a signal backplate to project a rectangular appearance at night" (MUTCD 2009, 4D.12). Figures 13 and 14 show 3 in. borders in daylight and at night.

Figure 12. Signal backplate (Siemens 2011)

Effectiveness

Bonneson et al. (2002) conducted a study of 10 sites in Texas and found intersections that had signals with backplates saw an average RLR of 1.9 veh/h compared to 3.4 veh/h at signals without backplates. In addition, the researchers developed modification factors concluding that adding backplates to signal heads would result in a CMF of 0.75, or a 25 percent reduction in RLR frequency.

A study by Polanis (2002) in Winston-Salem, North Carolina found the installation of signal backplates has the potential for a 31 percent reduction in right-angle crashes. This reduction was found after examining changes in crash rates at six intersections.

The FHWA (2011) cites three studies where the retroreflective border was added to traffic signal backplates. Decreases in crashes were noted in all three studies from 19.7 to 38.9 percent for all crashes and from 31.8 to 76.8 percent for injury crashes. The FHWA (2011) also reported on an installation of signal backplates by the South Carolina DOT (SCDOT) where total crashes decreased by 28.6 percent and injury crashes decreased by 36.7 percent.

Figure 13. 3 in. retroreflective borders on signal backplates (FHWA 2011)

Figure 14. Retroreflective borders at night (FHWA 2011)

The CMF Clearinghouse cites a study by Sayed et al. (2005), which provides a CMF of 0.85 for all crashes (star rating = 4) when three-inch yellow retroreflective sheeting is added to signal backplates.

The clearinghouse also cites a study by Sayed et al. (2007), which lists the CMFs below for improving visibility of signals at urban signalized intersections. Improvements include a combination of one or more of the following countermeasures: upgrade in signal lens size, installing new backboards, use of reflective tape to existing backboards, and use of additional signal heads.

- 0.93 for all crashes (star rating = 4)
- 0.97 for fatal, serious injury, and minor injury crashes (star rating = 4)

Advantages

- Low cost
- Potentially effective in many applications

Disadvantages

- Additional items to maintain
- Signal heads more prone to movement during high winds (Fuller 2007)
- May require additional loading on support pole due to wind loading (Fuller 2007)

Appropriateness

The retroreflective yellow backplate countermeasure should be justified before implementation (Kamyab et al. 2002)

According to the MUTCD (2009, Section 4D.12): "If the posted or statutory speed limit or the 85th-percentile speed on an approach to a signalized location is 45 mph or higher, signal backplates should be used on all of the signal faces that face the approach. Signal backplates should also be considered for use on signal faces on approaches with posted or statutory speed limits or 85th-percentile speeds of less than 45 mph where sun glare, bright sky, and/or complex or confusing backgrounds indicate a need for enhanced signal face target value".

In addition, according to the MUTCD (2009, 4D.11) All signal faces should have backplates on higher speed roadways.

Improve Sight Distance

Description

Sight distance is usually impaired by sharp horizontal and/or vertical curves, street furniture, vegetation, and other objects near the intersection. Poor sight distance can contribute to higher RLR frequency when drivers do not have sufficient time to detect or react to signal changes.

The recommended minimum sight distance for signals at intersections is shown in Table 3 (MUTCD 2009 Table 4D-2).

Table 3. Recommended minimum sight distance for signal visibility (MUTCD 2009)

85th-Percentile Speed	Minimum Sight Distance
20 mph	175 feet
25 mph	215 feet
30 mph	270 feet
35 mph	325 feet
40 mph	390 feet
45 mph	460 feet
50 mph	540 feet
55 mph	625 feet
60 mph	715 feet

Distances are derived from stopping sight distance plus an assumed queue length for shorter cycle lengths (60 to 75 sec)

If the current intersection design cannot satisfy the minimum sight distance, a Signal Ahead sign (Figure 6) should be used to warn drivers. It is important to install traffic signals within the cone of sight for drivers and to maintain a consistent warning sign location along the roadway.

When horizontal and/or vertical curvature decrease sight distance, the problem is more difficult and costly to solve. In other instances, sight distance can be improved by removing vegetation objects.

Effectiveness

Agent et al. (1996) recommended a CRF of 30 percent when improving sight distance at intersections. This was developed from information from one state as well as five previous studies. This CRF applies to all crashes and not only those related to RLR.

Advantages

- Addresses all crashes types

Disadvantages

- Often large cost involved, especially if reconstruction is necessary

Remove Unnecessary Signals

Description

If a signalized intersection is located on lower-volume roads/streets or if the signals do not meet MUTCD warrants, conversion to a Stop-sign-controlled intersection may be appropriate. If a traffic signal is not warranted, motorists may think the signal is unnecessary, which can lead to disrespect for signal indications.

The installation of a traffic signal should be warranted based on traffic volumes, pedestrian volumes, safety concerns, etc. Signalization at some intersections may no longer meet MUTCD warrants after a period of time. Therefore, some traffic signals could be replaced effectively with Stop-sign control.

Although covered in another section of this toolbox, roundabouts are another alternative to signalization and eliminate RLR crashes entirely.

Effectiveness

Persaud et al. (1997) removed un-warranted traffic signals at 199 intersections in Philadelphia, Pennsylvania and saw a 24 percent reduction in total number of crashes and a 46.3 percent reduction in severe right-angle crashes.

As cited in the ITE (2003) report on Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running, Kay et al. (1980) converted 26 signalized intersections to four-way stop-controlled intersections and right-angle crashes were reduced by at least one crash per year. For intersections converted to two-way stop-controlled intersections, there was a reduction in rear-end crashes, although an increase in right-angle crashes occurred.

Advantages

The advantages to replacing an unwarranted signal intersection with two-way stop control as reported by ITE (2003) based on a study by Kay et al. (1980) included the following findings:

- Total delay per vehicle was reduced by 10 sec
- Idling delay per vehicle was reduced by 5 to 6 sec
- Numbers of stops were reduced from 50 percent to 20 to 25 percent depending on the traffic volume split on major and minor roads
- Fuel consumption was reduced by approximately 0.002 gal per vehicle

Disadvantages

- May not be publicly accepted
- Removal may be costly

Appropriateness

Recommendations for removing a traffic signal are listed in Section 4B.02 of the MUTCD (2009). These recommendations include performing an engineering study to determine if the signal is still justified.

If a signal is no longer warranted the following steps should be followed:

1. Determine the appropriate traffic control to be used after removal of the signal
2. Remove any sight-distance restrictions as necessary
3. Inform the public of the removal study
4. Flash or cover the signal heads for a minimum of 90 days and install the appropriate stop control or other traffic control devices
5. Remove the signal if the engineering data collected during the removal study period confirms that the signal is no longer needed and no traffic control problems were encountered during the trial period

Traditional Enforcement

Description

Traditional enforcement involves a law officer in the field witnessing a traffic signal violation and issuing a citation to the violator immediately after the occurrence. Officers will sometimes work in teams, with one officer observing the red-light violation and a second officer, upon notification, stopping the violator and issuing a citation.

Effectiveness

While traditional law enforcement is considered to be an effective tool to reduce RLR, no studies could be found that examined that impact.

Advantages

- Targets those who run red lights directly
- Accepted method of enforcement

Disadvantages

- Public safety concerns if officers must pursue violators through a red light or at high speeds to issue a citation
- Additional staffing requirements when using the team technique

Appropriateness

Traditional enforcement should be used as needed when police officers are available, unless other means of enforcement are identified. These enforcement efforts should be very visible to have the desired effect and maximum impact on driver behavior.

Red Signal Indication Lights

Description

Red signal indication lights (also known as white lights, rat boxes, and tattletale lights) are a tool to assist traditional law enforcement in detecting signal violations. Red signal indication lights can be installed above or below a signal head that permits 360 degree visibility or directly behind the signal head to allow downstream observation.

These lights are wired in parallel with the signal so that, as the red phase begins, the indication light illuminates simultaneously. Red signal indication lights eliminate the need for a team effort by allowing a single officer to observe an intersection for red-light violations from a downstream position, eliminating the need to pursue a violator through the intersection and therefore avoiding a potential safety concern (Hsu et al. 2009)

Effectiveness

Reddy et al. (2008) found that the number of red-light violation citations issued increased significantly (approximately 40 percent) in two years after red signal indication lights were installed, compared to an equal time period prior to installation in Hillsborough Country, Florida.

The red signal indication lights apparently assisted officers in apprehending red-light violators. When interviewed by the researchers, officers opined that the red signal indication lights made traffic signal enforcement easier.

The study also found the crash frequency and rate of RLR-related crashes decreased by 30 percent and 47 percent, respectively, at intersections equipped with red signal indication lights in the 12 months after installation, compared to the 36 months prior to use of this tool.

Advantages

- Relatively easy to install
- Low cost
- Increases safety for the public and law officers involved in red light enforcement

Disadvantages

- Still requires officers, one per intersection, to enforce red-light violations and sufficient staff is not always available
- Pursuit and apprehension of violators is still necessary

Appropriateness

Red signal indication lights should be used when sufficient enforcement staff is available to be in the field. This tool may work best with a targeted enforcement program for reducing RLR.

Automated Enforcement

Description

Automated enforcement involves the installation and use of cameras and associated equipment, as shown in Figure 15, to detect and identify traffic signal violations as a surrogate to traditional law enforcement. These cameras generally use radar, video, and proprietary software to detect and record RLR.

The exact design and system varies with the vendor. A vendor generally furnishes and operates the equipment, providing images and/or video to an agency where a law enforcement officer reviews the potential violation and decides whether to issue a citation. Figure 14 shows the equipment used in Cedar Rapids, Iowa.

Figure 15. Red light camera equipment in Cedar Rapids, Iowa

Effectiveness

Many studies have shown the effectiveness of RLR cameras in reducing both red-light violations and associated crashes.

Studies have found the reductions in violations due to red-light cameras to be in the range of 18 percent to more than 90 percent (Retting 2010 and Bochner and Walden 2010) in cities such as Oxnard, California (Retting et al. 1999a), Fairfax, Virginia (Retting et al. 1999b), and Chapel Hill and Raleigh, North Carolina (Cunningham and Hummer, 2004).

Studies have also examined the effect that cameras have on crashes. Reductions in right-angle crashes have been found in many studies. In addition, multiple studies have found that, at camera-equipped intersections, total and rear-end crashes also decrease.

Cunningham and Hummer (2004) conducted a study in North Carolina where they found RLR cameras reduced total crashes, RLR- related crashes, angle crashes, and rear-end crashes by 17 percent, 22 percent, 42 percent, and 25 percent, respectively.

Fitzsimmons et al. (2007) also saw reductions in total, right-angle, and rear-end crashes of 44 percent, 90 percent and 40 percent, respectively, in Council Bluffs, Iowa where, during the same time period, control intersections experienced decreases of 11.8 percent in total crashes and an increase of 29 percent in rear-end crashes.

Retting and Kyrychenko (2002) found that crashes in Oxnard, California decreased by 7 percent for total crashes, 32 percent for right-angle crashes, and a small, but not statistically-significant increase in rear-end crashes of 3 percent once red-light cameras were installed.

A study by Malone et al. (2010) looked at crash rates in Calgary, Alberta, Canada for five to seven years after red-light cameras had been in place and found right-angle crashes decreased by 48.2 percent and rear-end crashes decreased by 8 percent (but the rear-end crash decrease was not statistically-significant).

A study by the IIHS (2011) found that red-light cameras contributed to saving approximately 159 lives in 14 US cities with populations greater than 200,000 from 2004 through 2008. The IIHS also found the per capita fatality rate in the 14 large cities with red-light cameras fell 35 percent from 1992 through 1996 (the time period when the cameras were not in place) to 2004 through 2008 (the period when the cameras were active). This comparison was to the 48 large cities that did not have cameras in place during either period, but saw a 14 percent drop in per capita fatality rates between the two periods.

Although several studies have shown a reduction in rear-end crashes, several other studies have found that rear-end crashes have increased at intersections while right-angle crashes decreased.

Council et al. (2005) saw this when studying seven jurisdictions in three states where they estimated a 24.6 percent reduction in right-angle crashes and a 14.9 percent increase in rear-end crashes.

Washington and Shin (2005) saw similar results in Scottsdale, Arizona where, in total, angle, and left-turn crashes, the decreases were 11, 20, and 45 percent, respectively, while rear-end crashes increased by 41 percent.

A report by Burkey and Obeng found that red-light cameras in Greensboro, North Carolina did not result in a statistically-significant change to right-angle crashes, but that rear-end crashes did increase at a statistically-significant level. However, the results of this report have been challenged (Kyrychenko and Retting 2004) due to the flaws in selection of control intersections and the construction of an "erroneous statistical model."

The CMF Clearinghouse cites several studies that show the following CMFS for implementation of RLR enforcement cameras:

- 0.80 (star rating = 4) for all crashes (Hallmark et al. 2010)
- 0.75 (star rating = 4) and 0.67 (star rating = 4) for all angle crashes (Persuad et al. 2005; Shin and Washington 2007)
- 0.84 (star rating = 4) for serious and minor injury angle crashes (Persuad et al. 2005)
- 0.60 (star rating = 3) for red light running related crashes (Hallmark et al. 2010)
- 1.15 (star rating = 5), 1.45 (star rating = 4), and of 0.98 (star rating = 4) for all rear-end crashes (Persuad et al. 2005; Shin and Washington 2007; Hallmark et al. 2010)

Advantages

- Do not require an officer in the field for pursuit on busy streets
- Able to identify all offenders
- Reduces violations and serious impact crashes at signalized intersections

Disadvantages

- Public perception
- May increase rear-end crashes
- Generally identifies only the vehicle and not the driver, so repeated offenses do not affect driving record

Appropriateness

Automated enforcement can be used at most intersection approaches. Sufficient sight distance should be available so that drivers are able to see the advance warning signs.

Recommendations in Applying RLR Enforcement Cameras

RLR camera enforcement frequently sparks a significant amount of debate. While the cameras have been shown to be effective, their use is sometimes interpreted as an infringement on privacy and as a means for agencies to generate revenue rather than address safety. In light of this, the authors make the following recommendations:

- Other less intrusive countermeasures should be considered first. It is recommended that an engineering study be conducted to select these countermeasures. Agencies should document other strategies that were tried prior to adoption of the cameras and share this information with the public.

- Signal timing, including the clearance interval, should be checked first to ensure that signal timing is appropriate.

- Although there is a correlation between RLR violations and RLR crashes, not all intersections with a high number of violations are also high crash locations. Cameras are most appropriate and most easily defended when they are used only at locations with a documented history of RLR crashes. Furthermore, it is recommended that an agency select locations most appropriate for RLR camera enforcement based on an engineering study, rather than working with a camera vendor to select locations.

- Cities should be transparent and inform the public about the purpose of the cameras before installing them. A carefully-planned public information campaign is recommended prior to adopting an automated enforcement program. The City of Cedar Rapids used media and social media to educate and inform the public about their cameras. Press releases were put out before any cameras became active. In addition, a one month warning period was in place at the beginning of implementation where warnings were issued in place of violations to allow drivers time to get used to the cameras.

  Cedar Rapids also released a brochure with many frequently-asked questions (FAQs) and they maintain a FAQ section on their website at www.cedar-rapids.org/government/departments/police/Documents/FAQ%20ATE.pdf. Cedar Rapids also released a video on youtube at www.youtube.com/watch?v=wRbUkoQY3ec&feature=player_embedded, where the police Captain explained the review process an officer carries out before determining whether or not to issue a violation. Overall, Cedar Rapids has been very proactive in educating the public on use of the cameras.

- RLR camera enforcement systems usually offer the option to record violations using either several still images or a short video capture. The Cedar Rapids police felt use of the video allows them to "see the context" of a violation so they can determine situations when a driver should be given the benefit of the doubt. In addition, the video option may be more powerful when viewed by drivers who can clearly see themselves running the red light. For these same reasons, the authors recommend using the short video capture option.

- Agencies should have a clear policy on how they will determine whether to issue a ticket. Most of the cities in Iowa that the team has worked with used the guideline that if the officer would not have ticketed a driver in the field for an RLR violation, they will not issue a ticket using the camera system. Scenarios where the agency would not issue a ticket should be clearly defined. These situations often include funeral processions, a vehicle sliding thorugh the intersection due to adverse weather, or sight restrictions due to a lead vehicle. Having a policy that can be explained to violators will improve the perception of fairness.

- After installation, camera locations should be monitored to ensure that the cameras are effective in reducing crashes.

Roundabouts

Description

A roundabout is a one-way, circular intersection, where entering vehicles must yield to traffic circulating within, as shown in Figure 16. The curved geometry of the circular roadway and low entry angles lead to low vehicular speeds in roundabouts (speed limits range from 15 to 25 mph).

This design reduces and even eliminates some types of severe crashes, such as right- and left-angle crashes, while reducing the severity of all crashes due to the low speeds.

Figure 16. Roundabout intersection (Hillary Isebrands)

Effectiveness

Persaud et al. (2001) found, when converting an urban signalized intersection to a roundabout, a 35 percent reduction in total crashes and a 74 percent reduction in injury crashes could be expected based, on an analysis of four intersections. Also, due to the geometric and operating nature of roundabouts, right-angle crashes are virtually nonexistent (Persaud et al. 2001).

Also, in NCHRP Report 572, the conversion of nine signalized intersections to roundabouts was examined and found a 48 percent reduction in all crashes and a 77.7 percent reduction in injury and fatal crashes (Rodegerdts et al. 2007).

According to Roundabouts: An Informational Guide (2nd edition), high rates of right-angle crashes at an intersection are potentially correctable by roundabouts (Rodegerdts et al. 2010).

Advantages

- Potential to reduce crash severity (angle of entry and low speeds)
- Reduced number of conflict points when compared to signalized intersections

Disadvantages

- May not accommodate pedestrians well
- May require more right of way than standard intersections
- Limited capacity
- New users require education and experience to navigate effectively
- Costly to construct

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