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16. Abstract

There are more than 100,000 red light running crashes per year in the U.S., resulting in some 90,000 people injured and 1,000 people killed. More than half of red light running-related fatalities are pedestrians and occupants in other vehicles who are hit by red light runners. Texas is a leading state in red light running fatalities. From 1992 to 1998, Texas ranked second in the number of red light running fatalities, with 11 percent of the national total. Even after relating the numbers to population, Texas ranked very high—fourth place nationwide—with a rate of 3.5 fatalities per 100,000 people in that period. The cost of red light running injuries and fatalities in Texas is between 1.4 and 3.0 billion dollars per year.

This report includes an assessment of factors affecting red light running, a review of red light running trends in the U.S. and in Texas, and an evaluation of the effectiveness of strategies to deal with the problem, including engineering countermeasures, automated enforcement, and educational and awareness programs. The report also includes a series of policy recommendations that, together, should provide useful guidance to transportation officials, legislators, and law enforcement agencies. The recommendations include strategies to define measurable goals and objectives, as well as guidelines for the implementation of engineering countermeasures, improved enforcement, enabling legislation, and educational and public awareness programs. Following similar findings in the literature, the report recommends documenting the extent of the red light running problem and quantifying the impact of red light running crashes, injuries, and fatalities, both in statistical terms and in dollar terms, as a first step in the identification of appropriate solution strategies. The process should then continue with the evaluation and implementation of engineering countermeasures followed, as needed, by the evaluation and implementation of improved enforcement.

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EXECUTIVE SUMMARY

There are about 100,000 red light running crashes per year in the U.S., resulting in some 90,000 people injured and 1,000 people killed. Texas is a leading state in red light running fatalities. From 1992 to 1998, Texas ranked second in the number of red light running fatalities, with 11 percent of the national total. Even after relating the numbers to population, Texas ranked very high—fourth place nationwide—with a rate of 3.5 fatalities per 100,000 people in that period. The cost of red light running injuries and fatalities in Texas is between 1.4 and 3.0 billion dollars per year.

This summary includes a review of red light running factors and trends in the U.S. and Texas; an evaluation of the effectiveness of engineering countermeasures, automated enforcement, and educational and awareness programs; and policy recommendations.

SUMMARY OF FINDINGS

Factors and Trends

A number of intersection factors and human factors influence red light running. How those factors interact to increase or decrease the risk of red light running varies considerably from intersection to intersection. Some factors, mostly intersection-related, point to the need to implement engineering countermeasures to improve traffic flow, improve visibility, and reduce conflicts. Other factors, mostly driver-related, point to the need to also implement strategies such as improved enforcement and public awareness.

Red light running crashes are more likely than other intersection crashes to occur in urban areas. Fatal red light running crashes are more likely to occur during daylight hours. Other environmental factors, e.g., weather, seem to play no significant role in the incidence of red light running crashes. More male drivers are involved in red light running crashes than female drivers. However, for all age groups, the percentage of crashed-involved male drivers who ran the red light is very similar to the percentage of crash-involved female drivers who ran the red light. For drivers under 40 years of age, the percentage of crash-involved drivers who run red lights is highest for drivers who are about 20 years old. For drivers over 40, the percentage of crash-involved drivers who run red lights increases with age. Younger drivers tend to be more involved in red light running situations that include night crashes, alcohol consumption, and/or suspended or revoked driver licenses.

The number of people killed or injured in red light running crashes in Texas has increased substantially over the years. The increase (79 percent from 1975 to 1999) is similar to the increase in the number of people killed or injured in motor vehicle crashes in general, and is also similar to the increase in vehicle miles traveled in the state. About 16 percent of people killed in intersection crashes and 19–22 percent of people injured in intersection crashes are involved in red light running.

Engineering Countermeasures

Engineering countermeasures include signal operation countermeasures (e.g., increasing the yellow interval duration, providing green extension, improving signal coordination, and improving signal phasing), motorist information countermeasures (e.g., improving sight distance, improving signal visibility and conspicuity, and adding advance warning signs), and physical improvement countermeasures (e.g., removing unneeded signals, adding capacity with additional traffic lanes, and flattening sharp curves). Signal operation countermeasures can effectively reduce the incidence of red light running by improving traffic flow characteristics and by reducing the exposure of individual vehicles to situations that might result in red light running. Motorist information countermeasures that focus on attracting the attention of drivers to the signal can effectively reduce the incidence of red light running. Less effective are countermeasures that could cause uncertainty to drivers, e.g., adding a pre-yellow signal indication. Physical improvement countermeasures are more significant in scope and are often part of more substantial improvement projects. For this reason, reductions in red light running are often not evaluated or reported for these types of countermeasures.

Automated Enforcement

Enforcing red light running laws is difficult, dangerous, and, as a result, infrequently done. Some jurisdictions use team enforcement; however, this is more expensive than single officer enforcement. Other jurisdictions use red light confirmation lights that enable a single police officer stationed downstream of a signal to observe red light runners; however, those devices are not effective unless a police officer is present at the site. A number of cities around the country are beginning to implement automated enforcement systems. A review of the effectiveness of those systems reveals that red light cameras are effective deterrence tools and have a positive safety impact, even where the implementation of engineering countermeasures had not preceded the installation and operation of cameras. This does not mean, however, that engineering countermeasures should be ignored in favor of automated enforcement.

The review also shows that red light cameras can contribute to an increase in the number of rear-end crashes; however, this effect is relatively small and temporary. Red light cameras are effective if the number of red light running crashes is significant. Where the number of crashes is already low before implementing the system, the reduction in violations and/or crashes is negligible. Some reports suggest that red light cameras have a positive safety impact beyond just the intersections that have camera installations. However, there is evidence that drivers adjust their behavior depending on which intersections have camera installations in place.

There is strong public support for the use of red light cameras. Opposition to red light cameras is minor but quite vocal, mainly because of a perception that automated enforcement constitutes an intrusion of government power on individual liberties (see following section).

Red Light Running Legislation

The debate over the use of red light cameras includes whether to treat red light running as a criminal or a civil offense, who should be liable for the traffic violation (owner or driver), and the potential loss of privacy through the collection of data. Fine and revenue structure is also a contentious issue. In some cities, vendors supply, install and maintain the equipment, process and mail citations, and collect revenues. In return, the cities pay the vendors a portion of the citation fee. These schemes have received criticism, particularly where there is not proper vendor supervision and there is not a clear correlation between revenue and safety objectives.

If a red light running violation is treated as a civil offense, automated enforcement using only a photograph of the vehicle license plate is less intrusive and less demanding on the courts and public agencies. If a red light running violation is treated as a criminal offense, automated enforcement is more intrusive and requires the identification of the driver, but the individual's right to innocence until proven guilty is not affected. However, the result is lower rates of successfully enforced violations and increased workload on criminal courts. A presumption clause that the registered vehicle owner is the driver and that treats enforcement photographs as "prima facie" evidence could help to maintain the status of the violation as a criminal offense but enable enforcement agencies to treat it similar to a civil offense.

The issue of liability is not so much a question of who is liable for the offense, because the driver is always liable, but how to identify the offender. The options for identifying the driver depend on whether a red light running violation is treated as a civil or a criminal offense.

Individual privacy is protected by the Fourth Amendment of the U.S. Constitution. However, the U.S. Supreme Court has clarified that drivers are in the open view of the public when they operate vehicles and, as a result, the expectation of privacy, as defined in the Fourth Amendment, does not apply. Supreme Court rulings further indicate that the privacy of road users is not compromised as long as the collection, processing, and storage of photographic evidence are well defined and restricted to their inherent purpose.

Educational and Public Awareness Campaigns

A number of initiatives are raising public awareness about red light running. Among them is the Federal Highway Administration (FHWA) Stop Red Light Running Program, which started in 1995 as a safety outreach program combining public education with aggressive enforcement. The literature review identified several issues that deserve attention with current campaigns. In general, it is not clear to what extent existing campaigns recognize differences in expectations and attitudes among drivers, differences between intentional and unintentional red light runners, or differences in red light running patterns by age and other factors.

POLICY RECOMMENDATIONS

General Goals and Objectives

- Develop formalized rating/ranking procedures to determine where red light running really is a problem. The formalized rating/ranking procedures should be knowledge-based and, preferably, geographic information system (GIS)-based to enable the integration of pertinent layers of data that are already residing in (or that may be relatively straightforward to incorporate into) local and state agency GIS databases.
- Formulate quantifiable goals for the future. Possible examples include reducing red light running violations to less than 5 per 10,000 vehicles per intersection in the state, reducing

the number of people killed or injured in red light running crashes to less than 10,000 per year in the state, or reducing the number of red light running fatalities to 40 per year.

- Formulate yearly improvement objectives to attain the goals. As with the goals, the yearly objectives should be as specific and quantifiable as possible.
- Evaluate and compare strategies to meet those goals and objectives, taking into consideration that engineering countermeasures should receive priority over automated enforcement strategies.
- Increase the allocation of traffic safety funds that are dedicated to fighting red light running, particularly in urban areas.
- Monitor the effectiveness of individual strategies on a regular basis and make adjustments as needed.

Engineering Countermeasures

- Conduct a detailed engineering study of the intersection(s) of interest. The analysis should build on the assessment described in the previous section to make sure detailed engineering studies are conducted on intersection(s) that have a documented red light running problem, not just based on anecdotal evidence or hearsay.
- Evaluate countermeasure(s) in terms of potential benefits and implementation costs.
- Monitor the effectiveness of the implementation of the countermeasures on a regular basis and make adjustments as needed. It is important to use both absolute and relative standardized performance measures to properly document the countermeasure impact.
- Develop a "Best Engineering Practices Handbook" for the treatment of red light running problems. This handbook should summarize findings in the literature and provide specific guidelines as to how to treat individual intersections or groups of intersections using engineering countermeasures.

Improved Enforcement

- Improve the capability of local jurisdictions to enforce red light running laws. Improving the quality of red light running law enforcement should rely on appropriate technologies that do not result in additional safety hazards for police officers or the driving public, e.g., by using red light confirmation lights or red light cameras. A summary of recommendations for the implementation of red light cameras follows.

Program Planning and Deployment

- Establish institutional arrangements and partnerships, including police departments, political leaders, citizen safety organizations, and transportation agencies.
- Enact legislation to enable the use of automated enforcement technologies and procedures (see following section).
- Design and implement an ongoing public education and awareness campaign, using lessons learned from other implementations around the country.
- Require that a registered professional engineer prepare construction and as-built plans.
- Document the process of compliance with local and state requirements, including permitting and inspection requirements.

- Use dedicated loop detectors for the activation of the red light cameras to avoid compatibility and lack of resolution issues associated with normal signal actuation vehicle detection loops.
- Provide consistent, adequate grace periods to reduce the impact of red light cameras on unintentional red light runners that might be caught in a "dilemma zone" situation, or to account for inaccuracies associated with the operation of the loop detectors.
- Install advance warning signs to warn drivers about the use of the red light cameras.

Enabling Legislation

- Identify early on whether to treat red light running violations as criminal or civil offenses. This is the responsibility of the state legislature, even though local jurisdictions can pass ordinances to authorize or regulate the use of red light cameras.
- Specify that only a law enforcement agency can operate and control the red light running enforcement program. Private vendors could assist in the process of collecting and processing the data; however, there should be a strict oversight of their activities.
- Require that the operation of an automated enforcement system be for the purpose of improving safety, not for generating revenue.
- Require that any intersection to be considered for automated enforcement undergo a traffic engineering analysis to assess the general geometric and operational characteristics of the intersection and to identify potential engineering countermeasures that should be implemented prior to the deployment of the automated enforcement system.
- Incorporate safeguards in the legislation to ensure the individual's right to confidentiality.
- Specify the maximum number of days a citation must be delivered to the driver/vehicle owner after the alleged red light running violation has taken place.
- Include rebuttal procedures for registered vehicle owners to document their innocence.

Program Management

- Implement reliable internal quality controls.
- Maintain logs and data backups for adequate documentation and follow up.
- Develop efficient data processing capabilities to ensure short turnaround times in the processing and mailing of citations.
- Develop contingency plans to ensure the efficiency of the citation review process.
- Evaluate the effectiveness of the program on a regular basis and communicate the findings to the public.
- Maintain public information centers, supporting regular correspondence, telephone, and web-based processing capabilities.

Educational and Public Awareness Programs

- Develop programs that recognize differences in expectations and attitudes among drivers and that measure the effectiveness of the campaigns based on the type of message that is delivered to each type of driver.

- Develop programs that recognize the difference between unintentional and intentional red light runners, and that recognize the relationship between red light running frequency and driver age.

RED LIGHT RUNNING – A POLICY REVIEW

by

Cesar Quiroga, P.E.
Associate Research Engineer
Texas Transportation Institute

Edgar Kraus
Assistant Transportation Researcher
Texas Transportation Institute

Ida van Schalkwyk
Assistant Research Scientist
Texas Transportation Institute

and

James Bonneson, P.E.
Associate Research Engineer
Texas Transportation Institute

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TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

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LIST OF ACRONYMS, ABBREVIATIONS, AND TERMS

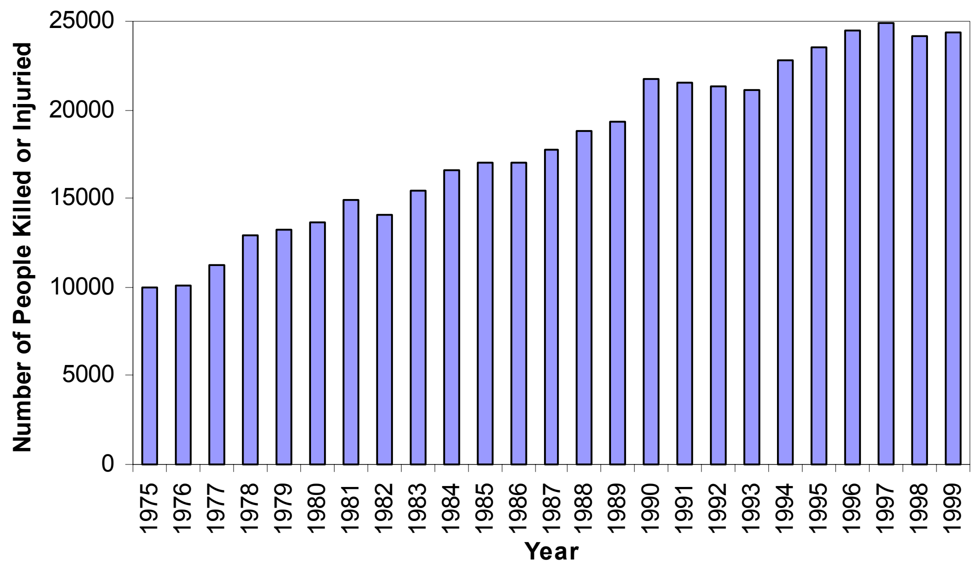
ATM	Automated teller machine
BTS	Bureau of Transportation Statistics
Caltrans	California Department of Transportation
CDS	Crashworthiness Data System
DWI	Driving while intoxicated
EU	European Union
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GES	General Estimates System
GIS	Geographic information system
IIHS	Insurance Institute for Highway Safety
LED	Light emitting diode
MAIS	Maximum abbreviated injury scale
MUTCD	Manual on Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administration
NPTS	Nationwide Personal Transportation Survey
OCR	Optical character recognition
PDO	Property damage only
RLR	Red light running
TTA	Texas Turnpike Authority
TTI	Texas Transportation Institute
TxDOT	Texas Department of Transportation

TxDPS	Texas Department of Public Safety
UFOV	Useful field of view
VMT	Vehicle miles traveled

CHAPTER 1. INTRODUCTION

FHWA has identified red light running as one of the leading causes of urban crashes in the United States. According to FHWA statistics (FHWA, n.d.a), there were 106,000 red light running crashes in the U.S. in 2000 that resulted in 89,000 people injured and 1,036 people killed. More than half of red light running-related fatalities were pedestrians and occupants in other vehicles who were hit by the red light runners. Texas is a leading state in red light running fatalities. Between 1992 and 1998, red light running fatalities in Texas were the second highest in the country, with 11 percent of the national total (Insurance Institute for Highway Safety [IIHS], 2000). Even after relating the numbers to population, Texas ranked very high—fourth place nationwide—with a rate of 3.5 fatalities per 100,000 people in that period. Five Texas cities ranked among the worst 30 U.S. cities in red light running fatalities: Dallas, Corpus Christi, Austin, Houston, and El Paso.

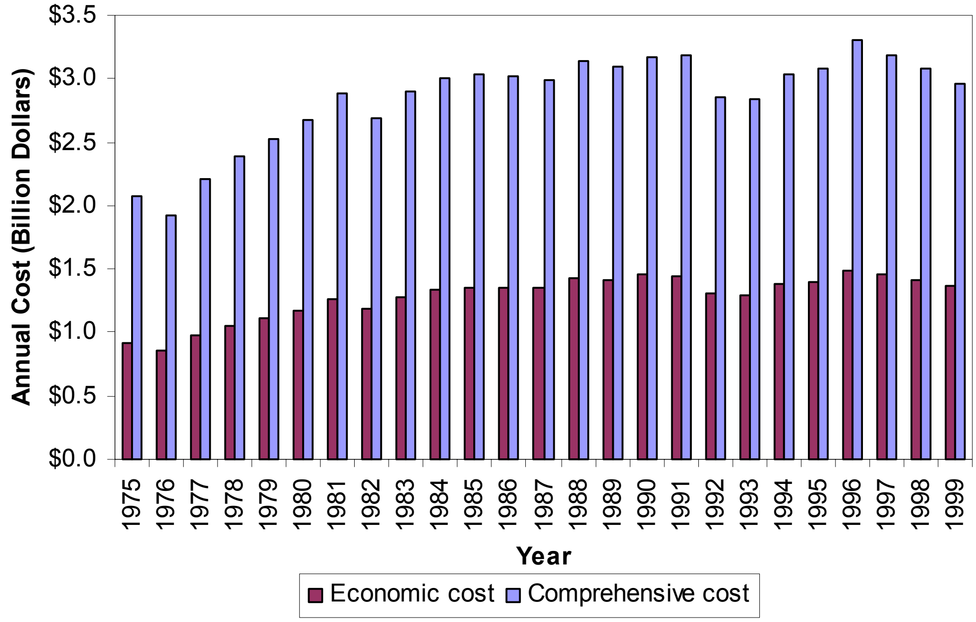
According to Texas Department of Public Safety (TxDPS) crash records (TxDPS, n.d.), the number of reported people killed or injured in red light running crashes in Texas has increased over the years, from about 10,000 in 1975 to about 25,000 in 1999 (Figure 1-1). The societal cost—without including the effect of property damage—has been huge: from 0.9–2.1 billion dollars in 1975 to 1.4–3.0 billion dollars in 1999 (Figure 1-2).



Includes reported number of people killed or who sustained incapacitating, non-incapacitating, or possible injuries (TxDPS, n.d.).

Figure 1-1. People Killed or Injured in Red Light Running Crashes in Texas.

Initiatives such as FHWA's Stop Red Light Running Program (FHWA, n.d.b), along with the continuing development and implementation of engineering and law enforcement strategies nationwide, are raising public awareness about the dangers of red light running. There is, however, considerable debate as to the effectiveness, legality, and even constitutionality of some of the strategies that have been implemented in recent years. The debate is particularly acute in the case of enforcement strategies that rely on automated camera-based detection and enforcement systems because of a perception that such systems could result in an invasion of privacy of individual drivers, result in increased widespread enforcement, and contribute to improperly generated revenues for the owner/operator of the system. The debate is also intense in the case of engineering strategies that involve the modification of signal timing settings, in particular the duration of the yellow and red clearance intervals.



Based on National Highway Traffic Safety Administration (NHTSA)'s unit economic and comprehensive costs (Blincoe, et al., 2002). Figures are expressed in year 2000 dollars.

Figure 1-2. Annual Cost of Red Light Running-Related Injuries and Fatalities in Texas.

OBJECTIVE

Much has been written on the topic of red light running. The literature contains a growing body of knowledge about what works and what does not work. It is critical, therefore, to share that knowledge with legislators, local jurisdictions, engineers, advocacy groups, and other stakeholders to develop a better understanding of the issues and potential solutions. This report includes an assessment of existing legislation and a critical review of strategies to deal with the red light running problem such as engineering countermeasures, automated enforcement, and educational and public awareness programs.

This report is organized as follows:

- Chapter 1 is this introductory chapter.
- Chapter 2 documents factors that affect red light running.
- Chapter 3 documents engineering countermeasures.
- Chapter 4 documents automated enforcement strategies.
- Chapter 5 documents red light running legislation.
- Chapter 6 documents educational and public awareness programs.
- Chapter 7 summarizes conclusions and recommendations.

CHAPTER 2. UNDERSTANDING RED LIGHT RUNNING

Figure 2-1 shows the situation of a vehicle approaching a signalized intersection at the onset of the yellow interval. A driver who decides to stop can stop the vehicle safely before the stop line, provided there is a minimum distance (x_c) from the intersection, which depends on a number of factors including approaching speed, duration of the yellow interval, and perception-reaction time. A driver who decides not to stop can clear the intersection, provided the driver is located within a distance (x_0) from the stop line (which might not be the same as x_c) that allows the driver to clear the intersection safely. In some cases, a driver who decides not to stop (or cannot stop the vehicle in a timely manner) ends up entering the intersection after the signal indication has changed to red. Such a driver is said to have "run the red light."

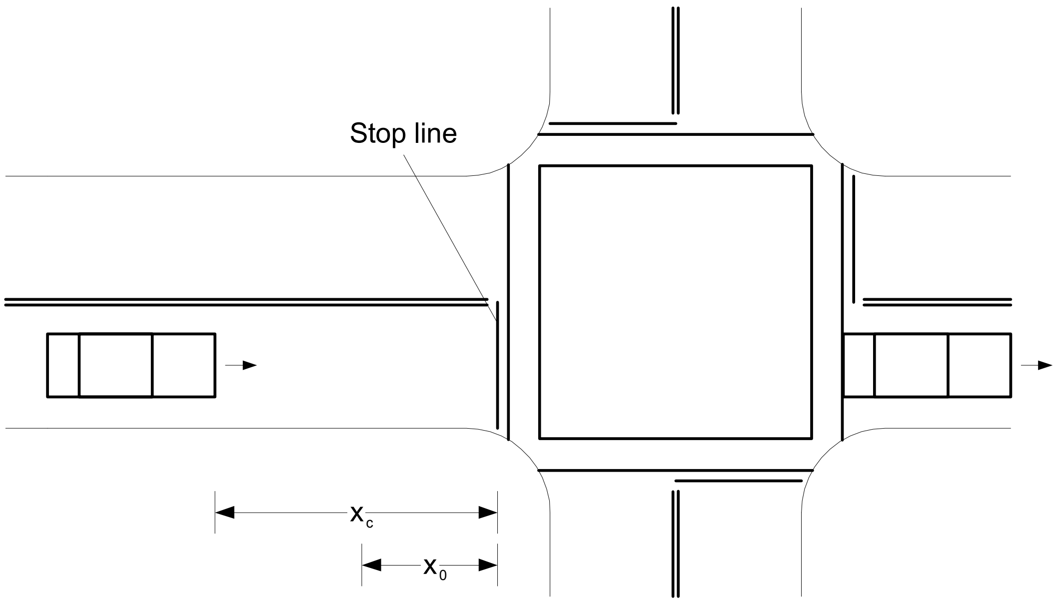


Figure 2-1. Vehicle Approaching Signalized Intersection at the Onset of Yellow.

This chapter provides a summary of findings from the literature in the area of factors that influence red light running. The purpose of the summary is to provide background for better understanding the effectiveness of solution strategies described in subsequent chapters. This chapter includes three sections: intersection factors, human factors, and red light running trends in the U.S. and Texas. Readers should be aware that, in many ways, the factor classification is arbitrary and only serves the purpose of the presentation. In reality, there is considerable overlap and interaction among factors, which complicates the effort to classify factors into simple, clear-cut categories.

In understanding the factors that influence red light running, it is important to clarify that the legal handling of red light running varies from jurisdiction to jurisdiction. Some laws require drivers to completely exit the intersection before the end of the yellow interval. Most laws—including Texas' (Texas Transportation Code Title 7, Section 544.007), however, allow drivers to enter an intersection legally as long as the signal indication is not red—whether or not the indication turns red before the vehicle exits the intersection. These laws follow what is normally referred to as the "permissive yellow rule." As subsequent chapters describe with more detail, some laws differentiate among red light running events depending on the number of seconds after the signal indication turns red when the violation occurs. Some jurisdictions, for example, ignore red light running violations that occur within the first 0.4 seconds after the indication turns red. Other jurisdictions impose much heftier penalties for red light running violations that occur more than 1 second after the indication turns red.

INTERSECTION FACTORS

A number of intersection factors play a role in the occurrence of red light running incidents (Bonneson, Brewer, and Zimmerman, 2001; Van der Horst, 1998; Porter and England, 2000; Baguley, 1988; Mohamedshah, Chen, and Council, 2000; Allsop, Brown, Groeger, and Robertson, 1991; Zegeer and Deen, 1978; Chang, Messer, and Santiago, 1985). Among them are intersection flow rates, frequency of signal cycles, vehicle speed, travel time to the stop line, type of signal control, duration of the yellow interval, approach grade, and signal visibility.

Intersection Flow Rates

Several studies have found a correlation between volumes/flow rates and the incidence of red light running events (Porter and England, 2000; Baguley, 1988) and red light running crashes (Mohamedshah, Chen, and Council, 2000). In general, as the flow rate on the approaches to an intersection increases, the red light running frequency also increases. This is also an indication that intersections with higher traffic volumes are also more likely to experience a higher number of red light running events.

Frequency of Signal Cycles

Many researchers recognize a correlation between the frequency of signal changes and red light running (Porter and England, 2000; Baguley, 1988; Van der Horst and Wilmick, 1986). If the cycle length increases, the hourly frequency of signal changes decreases, which should reduce the exposure of drivers to potential red light running situations (Bonneson, Brewer, and Zimmerman, 2001).

Vehicle Speed

The speed at which a driver is approaching an intersection plays a role in the decision of whether to stop at the intersection. Assuming the same travel time to the intersection, high-speed drivers tend to be less likely to stop than low-speed drivers (Allsop, Brown, Groeger, and Robertson, 1991). Differences between high-speed drivers and low-speed drivers tend to decrease, however, as the travel time to the stop line (assuming a constant approaching speed) decreases.

Travel Time to the Stop Line

The probability of stopping before the stop line when the light changes to yellow depends on the location of the vehicle and the travel time to the stop line. In general, as the available travel time to the stop line increases, the probability of stopping also increases. This relationship is not linear, as Figure 2-2 shows (Bonneson, Brewer, and Zimmerman, 2001). The response in the probability of stopping is particularly strong for travel times in the 2–5 second range. This observation is important because it helps to identify ranges in the duration of the yellow interval—which is usually based on estimates of travel time to the stop line—for which there is a good probability that drivers will be able to stop before the stop line at the onset of yellow.

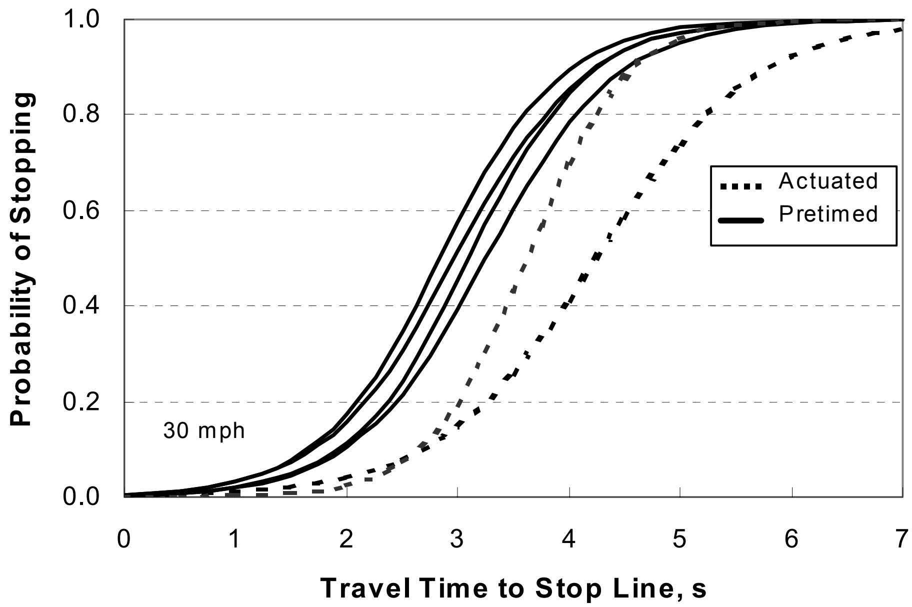


Figure 2-2. Probability of Stopping as a Function of Travel Time and Control Type (Adapted from Bonneson, Brewer, and Zimmerman, 2001).

Type of Signal Control

The type of signal control plays a role in the exposure of drivers to red light running situations. Highway corridors with vehicle-actuated traffic control tend to produce more compact vehicle platoon configurations than pretimed traffic control (Van der Horst, 1998). The result is an increase in the number of drivers who may be exposed to the yellow and/or red indications during "max out" phase terminations in the operation of the system and a reduction in the probability of stopping before the stop line after the light changes to yellow. Figure 2-2 illustrates this effect by showing a lag in the probability of stopping curve for actuated control systems (Van der Horst, 1998; Bonneson, Brewer, and Zimmerman, 2001).

Duration of the Yellow Interval

There is a correlation between the duration of the yellow interval and red light running events. Van der Horst (1998) observed a substantial reduction in the number of red light running events after increasing the duration of the yellow interval from 3 to 4 seconds (in urban areas) and from 4 to 5 seconds (in rural areas). Van der Horst observed a small adjustment in the drivers' stopping behavior, which he attributed to the relatively low increase in the duration of the yellow interval. He noted, however, that long yellow interval durations tend to result in greater variability in the decision making, which could result in an increase in the number of rear-end collisions.

Approach Grade

The approach grade has an effect on the probability that drivers will stop. Drivers on downward approaches are less likely to stop (at a given travel time to the stop line) than drivers on level approaches or upward approaches (Chang, Messer, and Santiago, 1985). The effect is particularly noticeable in the 2–6 second travel time range (Bonneson, Brewer, and Zimmerman, 2001).

Signal Visibility

Signal visibility has long been recognized as a critical factor contributing to red light running. Examples of sight restrictions that can limit the driver's view of the signal include tree foliage, parked vehicles in the immediate vicinity of the intersection, inadequate intersection geometric layouts, and inadequate signal head physical characteristics (such as insufficient number of signal heads, small lens sizes, insufficient lens brightness, and insufficient background contrast).

HUMAN FACTORS

This section discusses a number of human factors that are believed to play an important role in red light running events. Examples of factors that can influence the occurrence of crashes include physical or physiological factors (e.g., strength, vision), psychological or behavioral factors (e.g., reaction time, emotion), and cognitive factors (e.g., attention, decision making) (Olson and Dewar, 2002). The discussion is general because the literature is relatively scarce on the relationship between human factors and red light running. However, to the extent possible, the presentation discusses how the factors could influence red light running.

Vision

Visual impairments have an obvious effect on driving performance, particularly in the case of older drivers (Tarawneh, McCoy, Bishu, and Ballard, 1993). Less clear is the relationship between visual impairments and safety. Following Dewar, Olson, and Alexander (2002), three visual factors that affect the processing of dynamic information play a critical role on crash rates: dynamic visual acuity, angular movement, and movement in depth. Dynamic visual acuity refers to the task of seeing objects that are moving with respect to the eye, whereas angular movement and movement in depth refer to the task of judging the speed of objects crossing or approaching the path of travel. Sims, Owsley, Allman, Ball, and Smoot (1998) compared older drivers who had at least one at-fault crash in the previous 6 years with a control group of older drivers who were crash-free during the same period. They found a strong correlation between the incidence of crashes and useful field of view (UFOV) test results. These results are similar to those obtained previously by Owsley, Ball, Sloane, Roenker, and Bruni (1991). Many drivers who fail the UFOV test have good visual function, suggesting that the UFOV measure is a more effective crash predictor (Dewar, Olson, and Alexander, 2002). A number of factors affect the UFOV, including driver age, vehicle speed, and heavy traffic.

Driver Attention

According to several estimates, 25–50 percent of human causal factors in crashes relate to perception or attention (Dewar, Olson, and Alexander, 2002; NHTSA, 1997a; Stutts, Reinfurt, and Rodgman, 2001). This includes factors such as distraction, inattentiveness, improper lookout, and sleepiness. Stutts, Reinfurt, and Rodgman (2001) evaluated 5 years (1995–1999) of national Crashworthiness Data System (CDS) data to determine the role of driver inattention, in particular driver distraction, in crashes. They observed driver distraction was a factor in over half of the crashes attributed to driver inattention: 8–13 percent of drivers involved in crashes were distracted, 5–8 percent of drivers "looked but didn't see," and 2–3 percent of drivers were sleepy or fell asleep. The most frequently reported source of distraction was persons, objects, or events outside the vehicle (29 percent), followed by adjusting the radio, cassette or CD (11 percent), and other occupants in the vehicle (11 percent). Using a cell phone was associated with 1.5 percent of all crashes. Interestingly, cell phone use has been associated with a significant increase in the risk of motor vehicle crashes. Using crash and cell phone use data from 699 drivers, Redelmeier and Tibshirani (1997) observed that the risk of a crash when using a cellular phone was four times higher than the risk when the cellular phone was not in use.

Driver attention is critical at intersections because of the additional cognitive demands required of drivers at those locations. Hancock, Lesch, Simmons, and Mouloua (2001) observed a 15 percent increase in the number of non-responses to red light activations at signalized intersections while the drivers were using in-vehicle phones. Where drivers reacted to the red light activation, their reactions were slower and drivers braked more intensely. The study also showed differences by gender (female drivers had a longer stopping distance) and by age (drivers age 55–65 suffered a greater proportionate disadvantage in virtually every measure of vehicle control).

Perception-Response Time

Perception-response time is a critical component in the calculation of yellow interval durations. Current guidelines (Eccles and McGee, 2001; FHWA, 2001; McKinley, 2001) suggest using a perception-response time value of 1 second. However, several studies recommend using longer values. Wortman and Matthias (1983) investigated the perception-response time of drivers approaching six signalized intersections at the onset of yellow. At the 85^{th} percentile, perception-response times varied from 1.5–2.1 seconds, with all but one intersection clustering in the 1.8–2.1 second range. Hooper and McGee (1983) found median perception-response times of 1.1 seconds and 85^{th} percentile values of 1.8 seconds. Chang, Messer, and Santiago (1985) obtained similar results. In a summary of perception-response time literature, Olson (2002) reported suggestions for using values in the 0.75–1.5 second range for situations in which the hazard is readily detected and identified, and there are no complications in the decision and response stages. Staplin, Lococo, Byington, and Harkey (2001) recommended using 1.5 seconds to take into account the longer reaction-response times associated with older drivers.

Effect of Other Drivers

Drivers approaching an intersection tend to be affected by neighboring vehicles, including preceding vehicles and following vehicles. Allsop, Brown, Groeger, and Robertson (1991) observed that drivers were more likely to go, therefore increasing the risk of running the red light, if they were closely following other vehicles or if they were being followed closely by other vehicles. In other words, when vehicles approaching a signalized intersection are close together, the probability of stopping decreases. The effect was particularly noticeable for time headways of 2 seconds or less.

There is a close correlation between time headway, distance headway, and flow rate in the context of car following situations. In general, both time headways and the scatter in the distribution of time headways decrease as the flow rate increases, resulting in higher interaction among vehicles and more uniform time headways (May, 1990). Taieb-Maimon and Shinar (2001) observed that drivers tend to adjust their distance headways with speed in an effort to maintain relatively uniform time headways. They also noticed that drivers substantially overestimate their actual time headways.

Other Factors

Drivers know that running a red light is not safe. Boyle, Dienstfrey, and Sothoron (1998) observed that 83 percent of those interviewed considered running a red light dangerous. In another survey (Porter and Berry, 1999), 80 percent of those interviewed indicated they were more likely to engage in aggressive driver behavior other than red light running. However, when faced with time constraints in an urban environment, 28 percent of respondents indicated they would “speed up to beat the light.” Stated reasons included being in a rush (35 percent), to save time (34 percent), frustration with having to stop again (12 percent), and enjoying the thrill of beating the light (3 percent).

The perception of lenient enforcement policies may influence the decision to run a red light or engage in dangerous driving behavior at signalized intersections. Retting and Williams (2000) observed that 46 percent of drivers interviewed (in cities without automated enforcement systems) believed someone who ran a red light was likely to receive a citation. By comparison, the percentage increased to 61 percent in cities with automated enforcement systems. The “permissive yellow rule” mentioned previously requires drivers who receive a green indication to yield the right of way to other vehicles that are still (legally) at the intersection. However, a significant percentage of drivers—60 percent according to a survey cited by Parsonson, Czech, and Bansley (1993)—are unaware of that requirement.

RED LIGHT RUNNING TRENDS IN THE U.S. AND TEXAS

U.S. Trends

According to NHTSA (2001), there were 6.4 million police-reported crashes in the U.S. in 2000, of which 1.5 million—or 24 percent—occurred at intersections. The same year, there were roughly 106,000 red light running crashes in the U.S. (FHWA, n.d.a). In 1996, there were 6.8 million police-reported crashes, of which 2.0 million—or 29 percent—occurred at intersections (NHTSA, 1997b). Using data from the Fatality Analysis Reporting System (FARS) and General Estimates System (GES) databases, Retting, Ulmer, and Williams (1999) estimated about 260,000 red light running crashes in 1996. These figures suggest red light running crashes account for 2–4 percent of all reported vehicle crashes and 7–13 percent of all intersection crashes nationwide.

Red light running is more prevalent in urban areas. Based on a sample of 4,526 crash reports from four urban areas around the country (Akron, OH; New Orleans, LA; Yonkers, NY; and Arlington County, VA), Retting, Williams, Preusser, and Weinstein (1995) found 56 percent of crashes occurred at intersections. They found "ran traffic control" to be the most common type of crash, accounting for 22 percent of urban crashes and 27 percent of injury crashes. They also found injuries were more likely in "ran traffic control" crashes than in other types of crashes: 45 percent of "ran traffic control" crashes had injuries vs. 30 percent for other crashes.

Retting, Ulmer, and Williams (1999) analyzed fatal red light running crash trends using 1992–1996 data from the FARS and GES databases. For the analysis, they only considered fatal crashes for which one driver had committed a red light running violation and both drivers were going straight prior to the crash. The following were the main findings of the study:

- Some 86 percent of fatal red light running crashes occurred on urban roads. By comparison, 42 percent of other fatal crashes occurred on urban roads. Cities with a population of 200,000 or more accounted for 34 percent of all fatal red light running crashes. For those cities, the average rate of fatal red light running crashes was 2.5 crashes per 100,000 residents—with variations between 0.21 and 8.11 crashes per 100,000 residents.
- Both fatal red light running crashes (91 percent) and other fatal crashes (87 percent) occurred primarily during good weather conditions.
- Some 57 percent of fatal red light running crashes occurred during the day. By comparison, 48 percent of other fatal crashes occurred during the day. However, fatal red light running crashes that involved drivers less than 70 years old peaked around midnight, whereas fatal red light running crashes that involved drivers 70 years old or older occurred primarily during the day.
- On average, 74 percent of red light runners and 70 percent of non-runners were male. Of all nighttime red light runners, 83 percent were male. Of all daytime red light runners, 67 percent were male. It may be worth noting that male drivers accounted for roughly 61 percent of the vehicle miles traveled on U.S. roads, according to results from the 1995 Nationwide Personal Transportation Survey (Hu and Young, 1999).
- Some 43 percent of red light runners were younger than age 30. By comparison, 32 percent of non-runners were younger than age 30.
- Police suspected alcohol involvement in about two-thirds of drivers involved in fatal red light running crashes. Police suspected alcohol consumption much more frequently in the case of red light runners than in the case of non-runners—34 percent vs. 4 percent, respectively.
- Red light runners were much more likely to drive with suspended, revoked, or otherwise invalid driver licenses. Younger drivers were more likely to be unlicensed.
- Differences in past crash history between red light runners and non-runners were not significant. However, red light runners were significantly more likely to have prior convictions for driving while intoxicated (DWI) and two or more moving violation convictions of any type.

Texas Trends

Twenty five years of Texas crash data (1975–1999) provided by TxDPS (n.d.) were used in the analyses that follow. In these analyses, a crash-involved driver was assumed to have run a red light if the variable "first contributing factor" was coded "disregard stop and go signal." Readers should note that the threshold for including property damage only (PDO) crashes in the TxDPS database has been increased several times (TxDPS, 1996). Between 1975 and 1995, the dollar damage threshold for PDO crashes (based on the investigating officers' estimate) was raised three times—from $25 per crash in 1975 to $250 worth of damage to the property of any one person in 1978 and to $500 per person in 1990. Starting July 1, 1995, only those PDO crashes that involved one or more vehicles being towed from the scene were entered into the state database. Although it does not pertain to the analysis below, it may be worth noting that the threshold for authorizing a police officer to investigate a crash was increased to $1,000 in 2001 (House Bill 2230, 2001). The time threshold for assuming a fatality is associated with a crash in the TxDPS database has also changed: from within 90 days of the crash date in 1978 to within 30 days of the crash date in 1983 (TxDPS, 1996).

- Between 1975 and 1999, TxDPS recorded 3,073,072 intersection crashes in Texas. In those crashes, 14,490 people were killed. Another 163,753 sustained incapacitating (A-level) injuries; 695,212 sustained non-incapacitating (B-level) injuries; and 1,263,269 sustained possible (C-level) injuries.
- Of the 14,490 people who were killed in intersection crashes, 2,341 (16 percent) were killed in crashes that involved red light running. Of the 163,753 people sustaining A-level injuries in intersection crashes, 31,476 (19 percent) involved red light running. For people sustaining B-level and C-level injuries, 146,301 (21 percent) and 271,631 (22 percent), respectively, were in crashes that involved red light running.
- Figure 2-3 shows the annual number of people who were killed or who sustained A-, B-, or C-level injuries in red light running crashes between 1975 and 1999. Overall, the trends indicate that the number of people killed or injured in red light running crashes has increased over the years. The trends suggest a slight decrease during the late 1990s; however, it is too early to tell whether this trend will be sustained over time.
- Figure 2-4 shows percentages of people killed or who sustained A-, B-, or C-level injuries in crashes in Texas who were involved in red light running between 1975 and 1999. Figure 2-4a shows that red light running was associated with an increasing percentage of intersection injuries and fatalities through the early 1990s. The figures suggest a slight relative decrease during the 1990s; however, it is not clear whether this is a long-term trend or whether the apparent decrease is just part of the "normal" variability of the data.
- Overall, 2.6 percent of all people killed in motor vehicle crashes in Texas, 5.3 percent of people who sustained A-level injuries, 7.3 percent of people who sustained B-level injuries, and 7.7 percent of people who sustained C-level injuries were in crashes that involved red light running (Figure 2-4b). The trends follow a pattern similar to that shown in Figure 2-4a, i.e., an increase through the early 1990s, and a possible, although unclear, decrease during the 1990s.

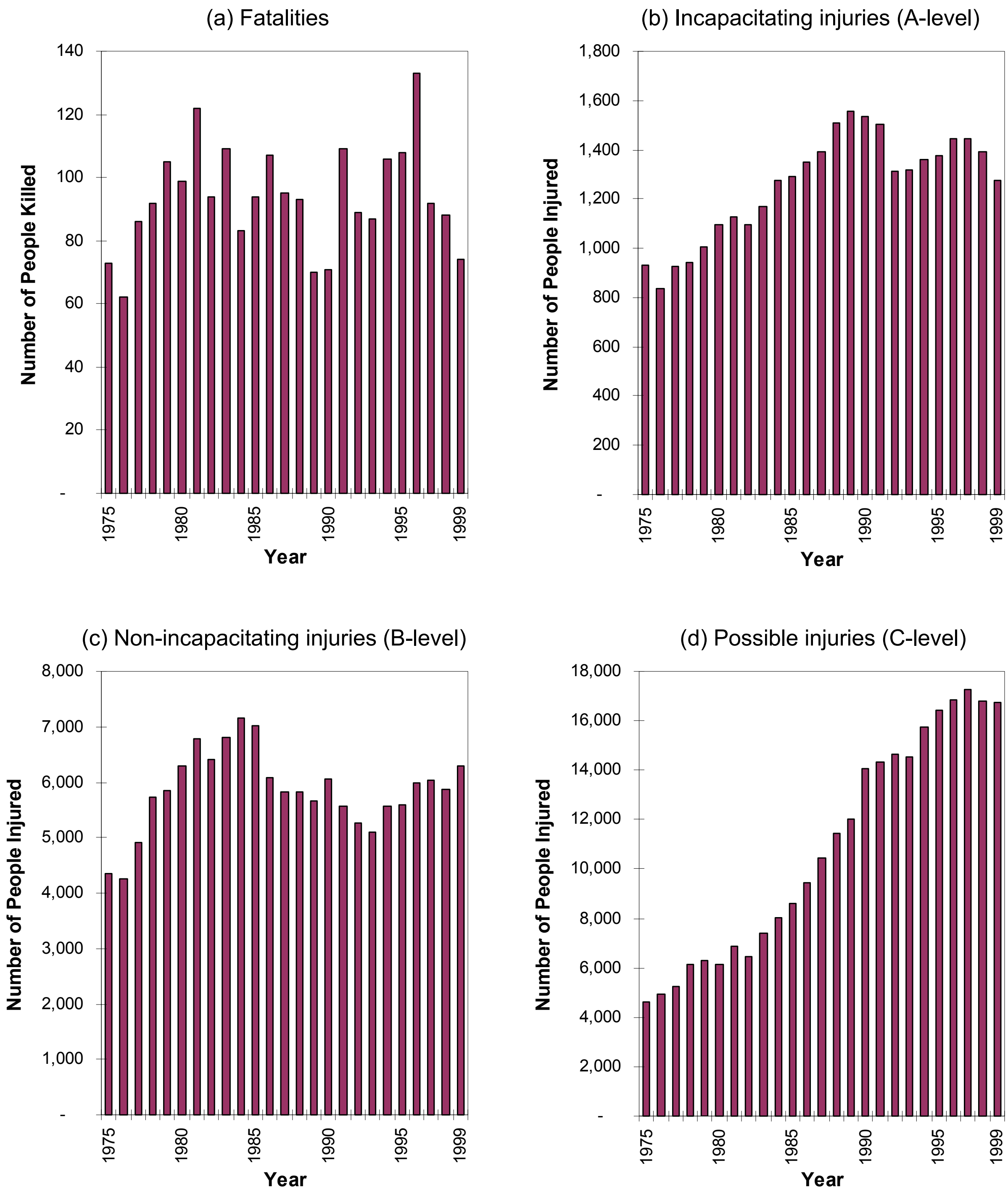
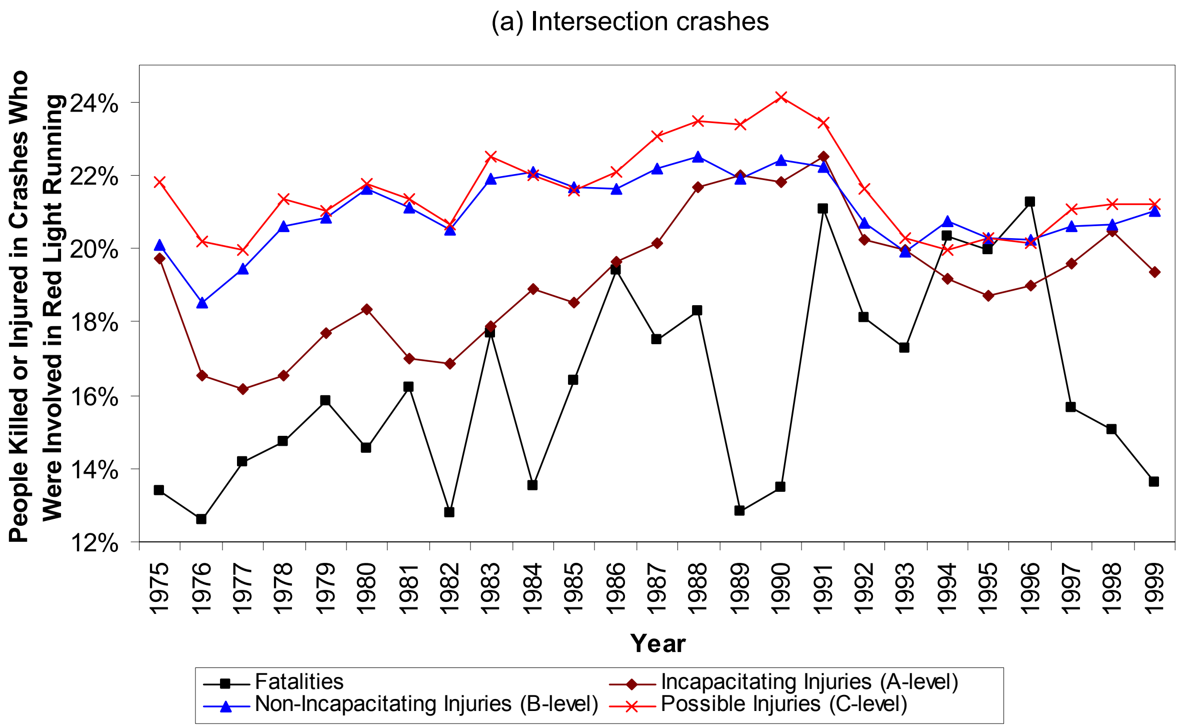


Figure 2-3. People Killed or Injured at Red Light Running Crashes in Texas.



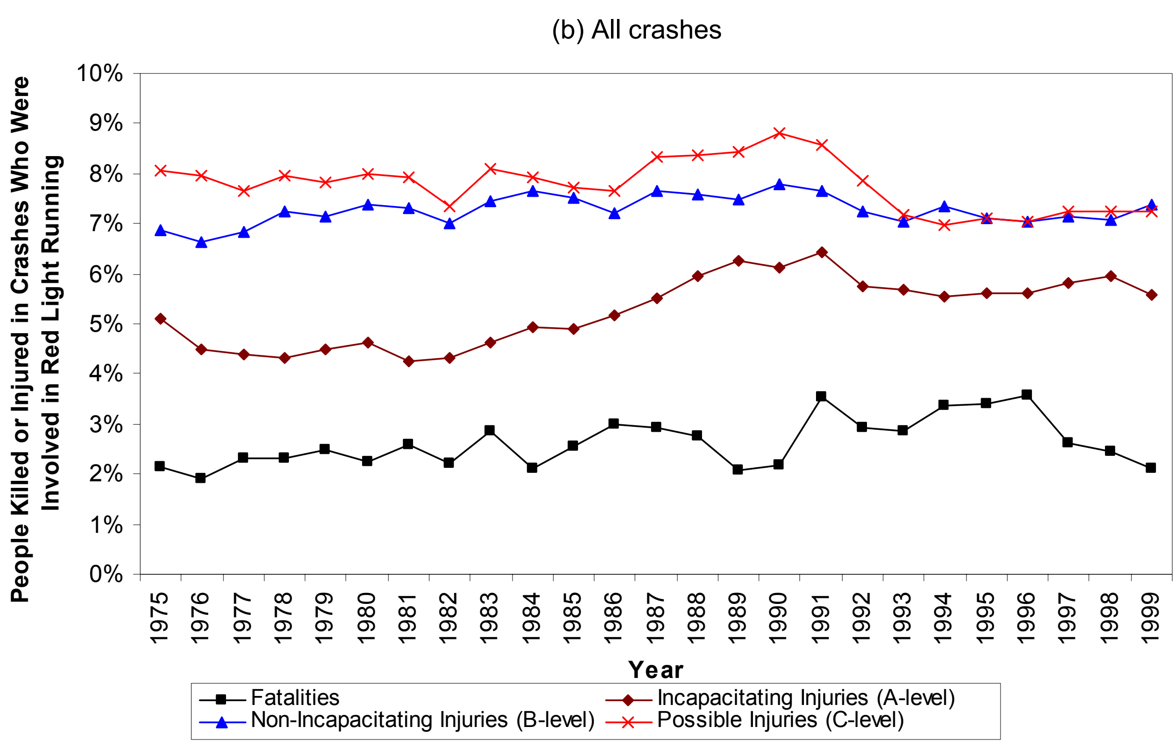


Figure 2-4. Percentage of People Killed or Injured in (a) Intersection Crashes and (b) All Crashes in Texas Who Were Involved in Red Light Running.

- Figures 1-1, 2-3, and 2-4 show that red light running is not a new phenomenon, although, in terms of number of people killed or injured, it is growing. The number of people killed or injured in intersection crashes or in all crashes, in general, has also increased. The rate of growth in the number of people killed or injured has been similar for red light running crashes, intersection crashes, and all crashes. As a result, the percentages of people killed or injured in crashes who were involved in red light running has remained roughly the same over the years. It may be worth noting that the number of vehicle miles traveled (VMT) in Texas grew from 114,478 million in 1980 to 210,874 million in 1999—or 85 percent net increase (Bureau of Transportation Statistics [BTS], n.d.). This value is comparable to the net increase in the reported number of people killed or injured in red light running crashes (79 percent), intersection crashes (81 percent), or all crashes (80 percent) during the same period of time.
- Crash-involved drivers who ran red lights were twice as likely to be suspected by the investigating officers of having "defective eyesight" as were other drivers involved in intersection crashes who did not run red lights (Table 2-1). It should be noted, however, that these percentages are quite small: 0.06 percent and 0.03 percent, respectively.
- Some 4.4 percent of crash-involved red light runners were suspected to be under the influence of alcohol, but only 1.8 percent of drivers who were involved in intersection crashes (but did not run red lights) were coded as suspected of being under the influence of alcohol (Table 2-1).

Table 2-1. Drivers Involved in Intersection Crashes in Texas (1975–1999).

Did the Investigating Officer Suspect the Driver Had "Defective Eyesight"?	Drivers Involved in Intersection Crashes			
	Red Light Runners		All Other Drivers	
	Number	%	Number	%
Yes	347	0.06	1,941	0.03
No	547,417	99.94	5,617,768	99.97
Total	547,764	100.00	5,619,709	100.00

Did the Investigating Officer Suspect the Driver Was Under the Influence of Alcohol?	Drivers Involved in Intersection Crashes			
	Red Light Runners		All Other Drivers	
	Number	%	Number	%
Yes	24,262	4.43	101,259	1.80
No	523,502	95.57	5,518,450	98.20
Total	547,764	100.00	5,619,709	100.00

- Figure 2-5 shows the annual number of male and female drivers who were involved in red light running crashes between 1975 and 1999, by age (left y-axis). Figure 2-5 also shows the percentages of crash-involved male and female drivers who ran red lights, by age (right y-axis). Overall, the older age groups accounted for a relatively small portion of all crash-involved drivers who ran red lights, but of all crashes in which these older drivers were involved, relatively higher percentages of them ran red lights.
- For drivers under 40 years old, the percentage of crash-involved drivers who ran red lights was highest for drivers who were about 20 years of age. For drivers over 40, the percentage of crash-involved drivers who ran red lights increased more or less steadily with age. At age 60, the percentage of crash-involved drivers who ran red lights was similar to the percentage at age 20.

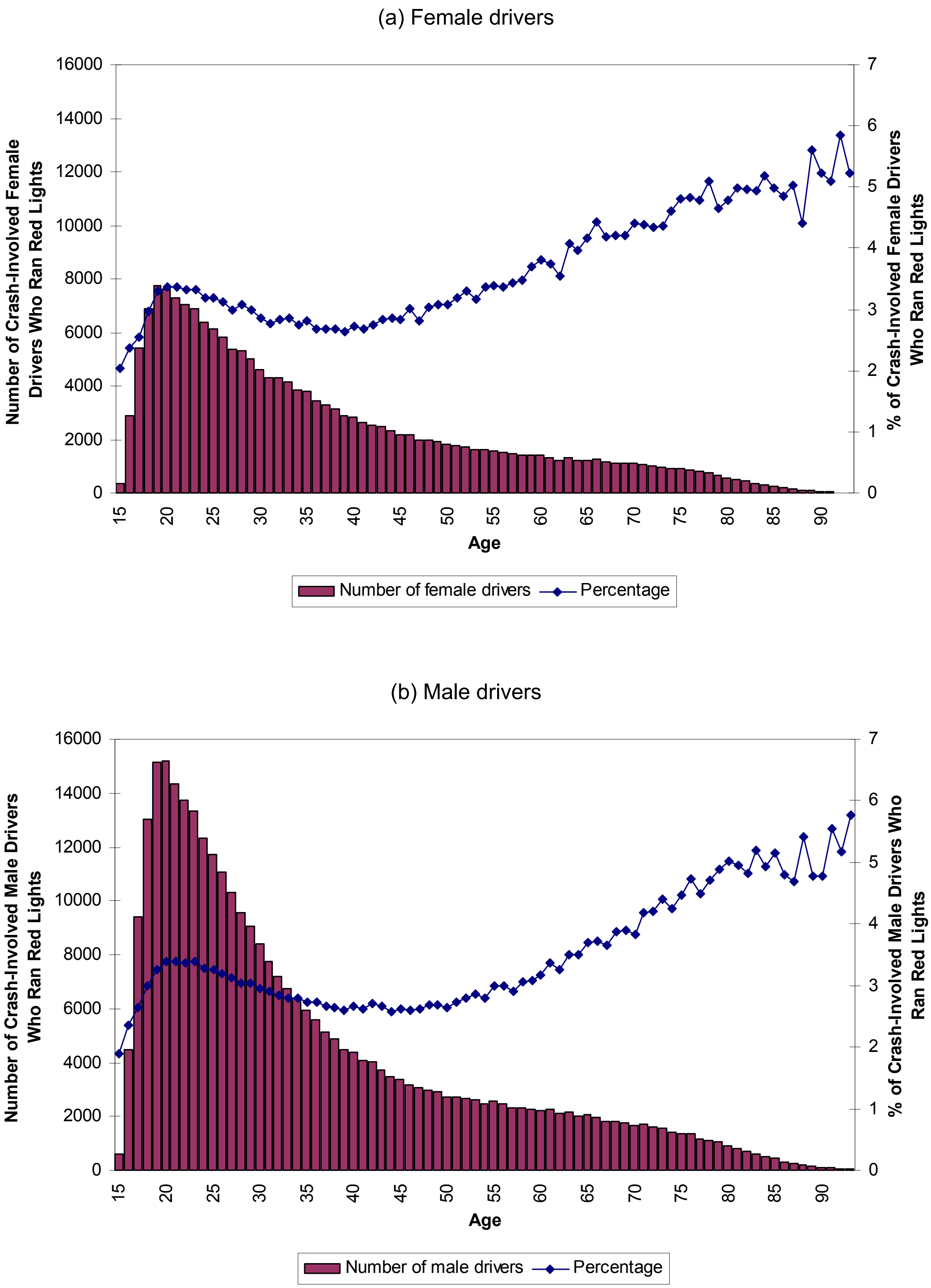


Figure 2-5. Crash-Involved Drivers Who Ran Red Lights by Gender and Age Group in Texas (1975–1999).

- More male drivers are involved in crashes resulting from red light running than female drivers (63 percent vs. 37 percent). However, for all age groups, the percentage of crash-involved male drivers who ran the red light was very similar to the percentage of crash-involved female drivers who ran the red light. For example, 38 percent of crash-involved male drivers who ran the red light were 25 years old or younger. The corresponding percentage for female drivers was 34 percent.
- Of the 3,073,072 intersection crashes recorded in Texas between 1975 and 1999, 235,701 (7.7 percent) were in rural areas and 2,837,371 (92 percent) were in urban areas, where urban areas are defined to be towns or cities regardless of population. Some 5.8 percent of rural intersection crashes and 18 percent of urban intersection crashes involved red light running (Table 2-2).
- Some 78 percent of all intersection crashes occurred during hours of daylight. Of all daylight intersection crashes, 17 percent involved red light running. Of all intersection crashes recorded during hours of darkness, 19 percent involved red light running (Table 2-2). As Figure 2-6 shows, there was considerable variation in the percentage of intersection crashes that involved red light running throughout the day. In general, percentages were lower from 6–8 am and from 3–8 pm.

Table 2-2. Intersection Crashes in Texas by Location and Light Condition (1975-1999).

	Crash Location			
	Rural		Urban	
Intersection Crashes:	Number	%	Number	%
Red Light Running Involved	13,665	5.80	517,404	18.24
Red Light Running Not Involved	222,036	94.20	2,319,967	81.76
Total	235,701	100.00	2,837,371	100.00

	Light Condition			
	Daylight		Dark (Dawn, Dusk)	
Intersection Crashes:	Number	%	Number	%
Red Light Running Involved	402,370	16.82	128,699	18.89
Red Light Running Not Involved	1,989,493	83.18	552,510	81.11
Total	2,391,863	100.00	681,209	100.00

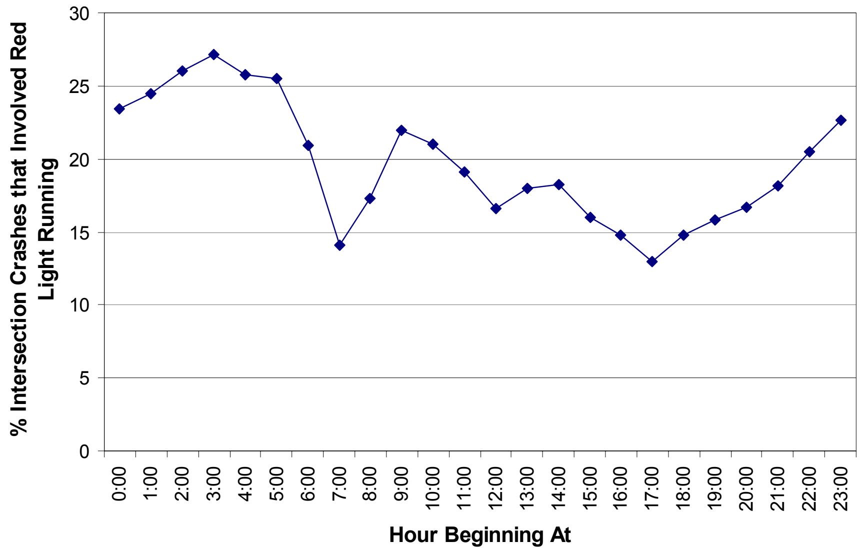


Figure 2-6. Percentage of Intersection Crashes That Involved Red Light Running in Texas, by Hour of Day (1975–1999).

CHAPTER 3. ENGINEERING COUNTERMEASURES

A number of engineering countermeasures are available for addressing red light running problems. In general, a red light running engineering countermeasure involves some type of change to the intersection, its signal operation, and/or its control device equipment. The goal with such changes is to ensure that capacity is sufficient for most hours of the day, sight lines to conflicting movements are adequate, the yellow interval duration is enough for the prevailing speeds, signal indications are conspicuous and fully visible, and progression is not repetitively "causing" drivers to run the red light to stay with the platoon.

This chapter discusses the effectiveness of engineering countermeasures to treat intersections for excessive red light running. For completeness in the presentation, the discussion is divided into the following sections: countermeasure categories, red light running performance measures, and countermeasure effectiveness.

COUNTERMEASURE CATEGORIES

Red Light Running Problem Characterization

Selecting an engineering countermeasure requires an evaluation of the characteristics of red light runners at the problem intersection and the factors that may be causing drivers to run the red light (see Chapter 2 for a more in-depth description of intersection factors and human factors affecting red light running). The assembly of this information requires an engineering study of the intersection, which should include the development of a condition diagram and observation of the traffic movements that may be experiencing significant red light running.

Table 3-1 lists a number of possible red light running scenarios and ways in which drivers typically react to those scenarios. In Table 3-1, "Traffic Movement" refers to typical expectations and experiences of left-turn drivers vs. typical expectations and experiences of through drivers. Relative to a through driver, a left-turn driver is forced (by geometry) to travel through the intersection at a lower speed. A left-turn driver is also more likely to experience longer delays.

"Entry Time into Red" refers to how late into the red indication a red light runner enters the intersection. The number of seconds into red could illustrate potential problems with the information conveyed to drivers as they approach the intersection and/or potential driver indifference to the red light. Drivers who enter the intersection several seconds after the onset of the red indication have likely missed important information about the signal ahead or its red indication. Alternatively, these drivers may have received the necessary information but have consciously decided to run the red.

"Driver's Event Perception" describes the basis for the decision to run the red indication. An "avoidable" red light running event applies to a driver who believes it is possible to safely stop but decides it is in his or her best interest to run the red. In contrast, an "unavoidable" event applies to a driver who either (1) believes it is impossible to safely stop and consciously decides to run the red, or (2) is unaware of the need to stop.

Table 3-1. Red Light Running Scenarios and Typical Driver Reaction Characterizations.

Red Light Running Scenario	Traffic Movement		Entry Time into Red		Driver's Event Perception	
	Left-Turn	Through	Early	Late	Unavoid-able	Avoid-able
Congestion or excessive delay	●	●	●			●
Disregard for red (low threat of citation)	●	●	●	●		●
Judged safe due to low conflicting volume	●	●	●	●		●
Judged safe due to narrow cross street		●	●	●		●
Driver < 2 sec. ahead enters intersection	●	●		●		●
Expectation of green when in platoon		●	●		●	●
Downgrade steeper than expected		●	●		●	
Speed higher than posted limit		●	●		●	●
Unable to stop		●	●		●	
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	●	●	●	●	●	

Countermeasure Selection

After characterizing the red light running problem at an intersection, the engineer can select countermeasures for implementation. Table 3-2 illustrates potential uses of different engineering countermeasure categories for each of the scenarios described in Table 3-1.

Table 3-2. Application of Engineering Countermeasures to Red Light Running Events.

Red Light Running Scenario	Engineering Countermeasure Category		
	Signal Operation	Motorist Information	Physical Improvements
Congestion or excessive delay	●		●
Disregard for red (low threat of citation)			
Judged safe due to low conflicting volume			●
Judged safe due to narrow cross street		●	
Driver < 2 sec. ahead enters intersection	●		
Expectation of green when in platoon	●		
Downgrade steeper than expected	●		
Speed higher than posted limit	●		
Unable to stop	●		
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		●	

Table 3-2 lists three engineering countermeasure categories: signal operation countermeasures, motorist information countermeasures, and physical improvement countermeasures. Table 3-3 provides a sample of available countermeasures within each category. Signal operation countermeasures involve some type of modification to the signal phasing, cycle length, or change interval. Motorist information countermeasures include enhancing the signal display or providing advance information to drivers about the existence of a signal ahead. Physical improvement countermeasures involve substantial modifications to the intersection that intend to solve serious safety or operational problems. A subsequent section in this chapter discusses the effectiveness of each countermeasure with more detail.

Table 3-3. Engineering Countermeasures to Red Light Running.

Countermeasure Category	Specific Countermeasure	Countermeasure Use [1]
Signal Operation (modify signal phasing, cycle length, or change interval)	Increase the yellow interval duration	39%
	Provide green extension	- [2]
	Improve signal coordination	39%
	Improve signal phasing, cycle length	59%
Motorist Information (provide advance information or improved notification)	Provide pre-yellow signal indication	-
	Improve sight distance	20%
	Improve signal visibility and/or conspicuity	47%
	Add advance warning signs	41%
Physical Improvement (implement safety or operational improvements)	Remove unneeded signals	6%
	Add capacity with additional traffic lanes	0%
	Flatten sharp vertical curves	2%
	Soften sharp horizontal curves	-

[1] Data obtained from web survey conducted by the Institute of Transportation Engineers (ITE) (Stollof, 2001).
[2] Not asked during the survey.

Table 3-3 also lists the results of a web survey the Institute of Transportation Engineers (ITE) conducted in 2000 (Stollof, 2001). Out of 1,500 ITE members who received e-mail requests to participate in the survey, 90 individuals responded, including 65 who were employees of city, county, or state transportation agencies. The responses to the survey indicate 77 percent of the respondents have implemented engineering countermeasures to reduce red light running. A large majority of the respondents indicated their jurisdiction had realized a reduction in red light running after implementing the countermeasures. The last column of Table 3-3 indicates the extent to which the responding agencies use specific countermeasures. The percentages shown indicate that improvements to signal phasing and cycle length are used most frequently, followed by improvements to signal visibility, use of advance warning signs, increases in the yellow interval duration, and improvements to signal coordination. Physical changes to the intersection have received the least consideration. This finding is likely a reflection of the significant cost associated with the implementation of these countermeasures.

PERFORMANCE MEASURES

A review of the literature indicates practitioners use several measures to quantify driver behavior at the end of a signal phase. The most commonly used measures are "percent of cycles with one or more red light runners," "hourly red light running rate," and "percent of vehicles that run the red." Other measures related to red light running and its consequences also exist, some of which are listed in Table 3-4.

Table 3-4. Red Light Running Measures of Effectiveness.

Incident	Frequency-Based Measure	Rate Expressions [1, 2]	Location
Entry during yellow interval	1. Vehicles entering during the yellow interval.	...per hour ...per cycle ...per vehicle	...per lane ...per approach ...per intersection
	2. Cycles with one or more entries on yellow.		
Entry during red interval	3. Vehicles entering during the red interval.		
	4. Cycles with one or more entries on red.		
	5. Vehicles in intersection after end of all-red.		
	6. Vehicles entering in first "X" seconds of red.		
Conflict due to red light running	7. Vehicle-vehicle conflict.		

[1] "per vehicle" relates to the total number of vehicles counted for the subject location.
[2] If the numerator and denominator have common units (e.g., cycles with one or more entries per cycle), then the ratio is often expressed as a percentage.

The second column in Table 3-4 lists frequency-based measures. Measure 6 (vehicles entering in first "X" seconds of red) characterizes the type of red light running that is occurring at an intersection. This type of information may help in identifying a treatment. For example, red light running that occurs in the first 0.4 to 1.0 seconds (X = 0.4 or X = 1.0) might be treated by increasing the yellow interval duration.

Dividing a frequency measure by a normalizing factor converts the measure to a rate-based measure. The third column in Table 3-4 lists three typical normalizing factors. For example, Measure 3 (vehicles entering during the red interval) would be reported as a rate in terms of "vehicles running the red per hour," "vehicles running the red per cycle," or "vehicles running the red per total vehicles." These three rates could be quantified for a given lane, approach, or for the overall intersection. Research by Bonneson, Brewer, and Zimmerman (2001) indicates the combined use of both the "per cycle" and "per vehicle" rate variables yields the most appropriate statistic for quantifying the rate of red light running at a particular intersection. This statistic would have units of "red light running per 100,000 vehicle-cycles."

Table 3-4 lists entries during the yellow interval and conflicts due to red light running because these groups of measures also provide some measure of driver behavior at the end of the green phase. The former provides information about the driver's propensity to enter the intersection after the yellow is presented. Intuitively, large rates for this measure would correlate with large red light running rates (especially when the yellow interval duration is fairly typical, say 3–5 seconds). The conflict rate is also a useful measure, as it combines the behavior of drivers on the subject approach with those on the conflicting approaches. Of those listed, this measure is likely to have the best correlation with red light running-related crash rates.

COUNTERMEASURE EFFECTIVENESS

This section documents the effectiveness of specific engineering countermeasures to address red light running problems. Whenever possible, the documentation includes references to the effect of the countermeasures on the frequency of red light running crashes. In most cases, the literature only reports the effect of the countermeasures on the frequency of red light running events. Readers should note that, even though there is a correlation between red light running events and red light running crashes, the correlation is not necessarily linear and that a relative change in the frequency of red light running events does not necessary imply the same relative change in the frequency of red light running crashes. Nonetheless, reporting the effectiveness of the countermeasures in reducing red light running events is useful because it provides an idea of the type of results that can be expected from the implementation of those countermeasures.

Signal Operation Countermeasures

Signal operation countermeasures involve some type of modification to the signal phasing, cycle length, or change interval. This section discusses four countermeasures:

- increase yellow interval duration,
- provide green extension,
- improve signal coordination, and
- improve signal phasing.

Increase Yellow Interval Duration

Increasing the duration of the yellow interval plays a significant role in reducing the frequency of red light running (Figure 3-1). Several researchers have documented this effect, including Van der Horst and Wilmick (1986), Retting and Greene (1997), and Bonneson, Brewer, and Zimmerman (2001). Notice in Figure 3-1 that the decrease is most significant in the 3–5 second range. Yellow interval durations in excess of 5 seconds do not offer additional benefits in terms of reduced red light running. In fact, overly long yellow interval durations could actually result in an increase in the frequency of red light running (Van der Horst and Wilmick, 1986). Although not clearly shown in Figure 3-1 because of the scale, the red light running frequency curve does not become zero for yellow interval durations longer than 5 seconds.

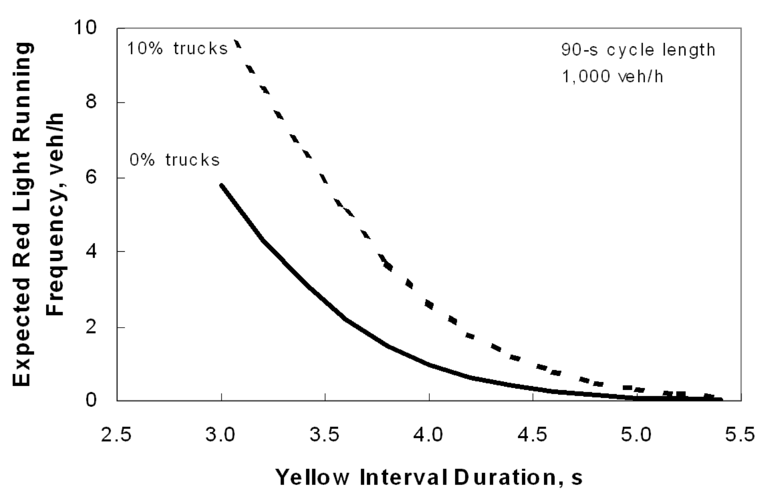


Figure 3-1. Effect of Yellow Duration and Vehicle Mix on Red Light Running (Adapted from Bonneson, Brewer, and Zimmerman, 2001).

The yellow interval duration is one of the most controversial issues surrounding red light running. Engineers usually estimate the yellow interval duration using an equation that traces its origin to the application of the kinematic equations of motion (McKinley, 2001; Liu, Herman, and Gazis, 1996). Over the years, the equation has undergone a few refinements, primarily to include the effect of grade on the probability of stopping and the effect of intersection geometry on the ability of drivers to avoid the "dilemma zone" problem (Liu, Herman, and Gazis, 1996; Eccles and McGee, 2001). Current guidelines (FHWA, 2001; McKinley, 2001) recommend the yellow interval duration to be between 3 and 6 seconds. In situations where the required yellow interval duration exceeds 5 seconds, the guidelines recommend implementing an all-red clearance interval, typically 1–3 seconds, to partially or fully clear vehicles that are entering the intersection at the end of the yellow interval (McKinley, 2001).

One of the reasons that increasing the yellow interval duration can reduce red light running may be related to the way yellow interval duration formulations handle perception-response times. Historically, those formulations assume a perception-response time of 1 second. However, as described in Chapter 2, perception-response times at the onset of yellow could be considerably longer, between 1.5 and 2 seconds. As Figure 3-1 suggests, increasing the yellow interval duration by just 1 second to more properly account for the perception-response time could result in significant reductions in the frequency of red light running. For example, increasing the yellow interval duration from 3 to 4 seconds could result in more than 80 percent reduction in the frequency of red light running.

Provide Green Extension

Green extension (or advance) detection systems use one or more detectors located in advance of the intersection to hold the green as long as the approach is occupied. By holding the green, drivers are less exposed to the yellow indication and the potential "need" to run the red light. Several researchers have documented the effectiveness of green extension systems to reduce red light running. For example, Zegeer and Deen (1978) observed a 65 percent reduction in red light running frequency in connection with the use of a green extension system. Agent and Pigman (1994) recorded the percentage of cycles with red light running at 33 intersections with a green extension system and at 10 intersections without a green extension system. They observed red light running on 3.0 percent of cycles at the intersections with a green extension system vs. 5.5 percent of cycles at the intersections without a green extension system.

Improve Signal Coordination

Bonneson, Brewer, and Zimmerman (2001) found that the frequency of red light running was correlated with the flow rate at the end of the signal phase. This finding stemmed from their observations at intersections with and without signal coordination. They found that some intersections in coordinated signal systems tended to "catch" drivers at the back of the platoon by presenting the yellow indication before the platoon had fully passed through the intersection. In these situations, the recurring pattern of dense platoons on the approach at the onset of yellow significantly increased the frequency of red light running. Van der Horst and Wilmink (1986) also observed this behavior.

Bonneson, Brewer, and Zimmerman (2001) noted that modifications to the signal offset that would minimize the flow rate near the end of the phase could reduce the frequency of red light running in coordinated signal systems. This goal could be achieved by moving the platoon's arrival nearer to the start of the green or by widening the progression band. The resulting reduction in red light running frequency would be directly proportional to the reduction in flow rate during the last 8 seconds of green (i.e., a 10 percent reduction in flow rate would yield a 10 percent reduction in red light running).

Improve Signal Phasing

Data reported by Zegeer and Deen (1978) indicate that the frequency of red light running increases during peak traffic periods (although, relatively speaking, the percentage of intersection crashes that involve red light running tends to decrease during peak traffic periods [Figure 2-6]). This trend implies that red light running also increases with delay. Thus, improvements in signal phasing that reduce delay are also likely to reduce red light running. Bonneson, Brewer, and Zimmerman (2001) developed a model that shows a direct correlation between cycle length and the frequency of red light running. Specifically, the model predicts a reduction in red light running with an increase in cycle length. The rationale for this trend is that longer cycle lengths reduce the number of cycles that occur each hour. Fewer cycles translate into fewer yellow indications and fewer opportunities for drivers to run the red light. The reduction in red light running is directly proportional to the reduction in number of cycles (e.g., a 10 percent reduction in cycles per hour would yield a 10 percent reduction in red light running).

There is one caveat to the aforementioned relationship between cycle length and red light running. Specifically, any benefit of an increased cycle length may be negated if the increase in cycle length also increases delay. Thus, any improvement to signal phasing that can reduce delay and increase cycle length represents the best combination of signal adjustments.

Motorist Information Countermeasures

Motorist information countermeasures are implemented by enhancing the signal display or by providing advance information to the driver about the signal ahead. This section discusses the following countermeasures:

- provide pre-yellow signal indication,
- improve sight distance,
- improve signal visibility and/or conspicuity, and
- add advance warning signs.

Provide Pre-Yellow Signal Indication

Hulbert (1981) reported that as early as 1969 some drivers had learned that a flashing "Don't Walk" indication in the pedestrian signal heads is an indication of the impending signal change. Hulbert suggested this advance information could help drivers to react more safely to the impending onset of yellow; however, he did not include data to support that belief. Other countries, e.g., Mexico and Israel, provide pre-yellow information by flashing the green indication several seconds before the onset of yellow. However, Mahalel and Prashker (1987) found that the technique could reduce safety. Specifically, they found that when a 3-second flashing green preceded a 3-second yellow, there was a corresponding increase in the "indecision zone." This zone represents a length of the intersection approach within which drivers were collectively indecisive about the choice of stopping or going at the onset of yellow. The indecision zone on the approach with flashing green started at 8 seconds of travel time to the stop line and ended at 2 seconds of travel time (compared to 5 seconds and 2 seconds when flashing green was not used). They cited evidence that an increased indecision zone increased the frequency of rear-end crashes.

Improve Sight Distance

Improvements to driver sight distance along the intersection approach intuitively have a beneficial effect on intersection safety. If the sight restriction limits the driver's view of the signal indications, there is likely to be more frequent red light running. Sight distance restrictions of this type are often caused by foliage from trees adjacent to the street. Vehicles parked adjacent to the traffic lanes can also obstruct the driver's view of the signal heads when these heads are pole-mounted on the far right or left side corners of the intersection.

Improve Signal Visibility and/or Conspicuity

Several changes can improve the visibility and/or conspicuity of a signal, in particular the yellow and red signal indications. Examples include increasing the lens size to 12 inches, adding supplemental signal heads, adding a second red indication to each head, adding back plates to the signal heads, adding light emitting diode (LED) signal lenses, and adding a strobe light in the signal indication. Larger, brighter lenses and back plates are particularly effective in situations where drivers might experience color vision deficiencies (Staplin, Lococo, Byington, and Harkey, 2001). Polanis (2002) investigated the effect of increasing signal lens size as well as adding back plates, supplemental signal heads, and a second red indication on crash frequency, using data collected in Winston-Salem, North Carolina. His data correspond to before-and-after periods of approximately equal duration, varying from 36 to 48 months each. As Table 3-5 shows, all four countermeasures resulted in significant reductions in the frequency of right-angle crashes—which implies a similar reduction in red light running.

Table 3-5. Effectiveness of Countermeasures Intended to Improve to Signal Visibility and/or Conspicuity.

Countermeasure	Measure of Effectiveness	Reduction due to Implementation	Sample Size	Reference
Increase signal lens size from 8 to 12 in.	Right-angle crash	47%	55 intersections	1
Add back plates to signal heads	Right-angle crash	32%	6 intersections	1
Add supplemental signal heads	Right-angle crash	47%	11 intersections	1
Add a second red indication to each head	Right-angle crash	33%	9 intersections	1
Add LED signal lenses	Red light running frequency	54%	1 intersection	2
Add a strobe light in the red indication	Right-angle crash	15%	6 intersections	3

[1] Polanis (2002).
[2] Bonneson (2002).
[3] Cottrell (1995).

LED signal indications are intended to improve visibility through a more brilliant display than standard incandescent bulbs. Bonneson (2002) evaluated their effectiveness at reducing red light running at one intersection in Texas. He used a second, control intersection to remove non-treatment effects. Based on the observation of 48 hours of operation, Bonneson found the LED lenses reduced the frequency of red light running by 54 percent at that location.

A strobe light positioned across the middle of the red lens is intended to attract the attention of drivers. The strobe light flashes about 60 times per minute while the red indication is lit. Cottrell (1995) studied the use of a horizontal strobe light in the red signal indication at six intersections in Virginia. Cottrell collected crash data for 3 years before and 3 years after the strobe lights were installed. Despite finding an overall reduction in angle crashes, the variation of change among sites led him to conclude there was no evidence that strobe lights were consistently effective in reducing crashes. It may be worth noting that strobe lights positioned across the middle of the red lens are not included in the Manual on Uniform Traffic Control Devices (MUTCD) (FHWA, 2001).

Add Advance Warning Signs

Advance warning signs forewarn drivers that they are approaching a signalized intersection. Figure 3-2 shows two types of warning signs. Figure 3-2a shows a sign that uses a "signal ahead" symbolic message. Flashing beacons sometimes accompany this sign to ensure drivers detect and interpret the sign's meaning. Polanis (2002) evaluated the effectiveness of this sign at 11 intersections and found it to reduce angle crashes by 44 percent.

(a) Sign with "signal ahead" symbolic message (b) "Be Prepared to Stop When Flashing" sign

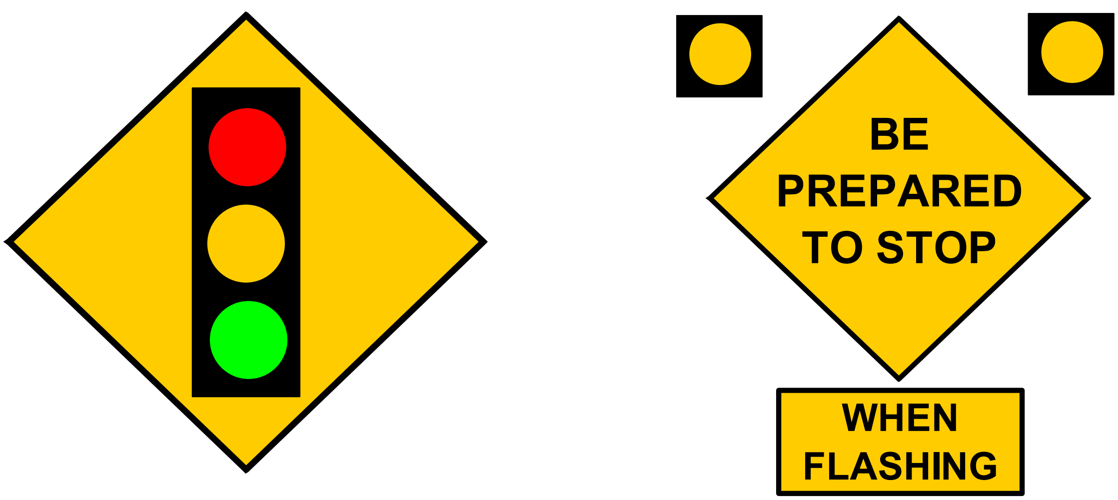


Figure 3-2. Advance Warning Signs.

Figure 3-2b shows a "Be Prepared to Stop When Flashing" sign. This sign has the beacons flashing only during the last few seconds of green. It is sometimes referred to as an "advance warning sign with active flashers." In this mode, the flashing indicates when the signal indication is about to change from green to yellow. Agent and Pigman (1994) compared the frequency of red light running at 16 intersections with no advance warning signs with that at two intersections with signs equipped with active flashers. After observing 100 signal cycles at each intersection, they found the intersections with advance signing had 67 percent fewer red light runners than those with no signs. A more recent study (Farraher, Weinholzer, and Kowski, 1999) revealed similar results. Table 3-6 summarizes these findings.

Table 3-6. Effectiveness of Countermeasures Intended to Provide Advance Information.

Countermeasure	Measure of Effectiveness	Reduction due to Implementation	Sample Size	Reference
Add advance warning sign	Right-angle crash	44%	55 intersections	1
Add advance warning sign with active flashers	Red light running frequency	67%	2 intersections	2
		29%	1 intersection	3

[1] Polanis (2002).
[2] Agent and Pigman (1994).
[3] Farraher, Weinholzer, and Kowski (1999).

Physical Improvement Countermeasures

Physical improvement countermeasures include a group of more substantial modifications to the intersection that are intended to solve serious safety or operational problems. This section discusses the following countermeasures:

- remove unneeded signals,
- add capacity with additional traffic lanes, and
- flatten sharp curves.

In general, these countermeasures are more significant in scope and are often part of more substantial improvement projects. However, because many changes are often undertaken simultaneously, it is difficult to correlate improvements of a specific type, e.g., lower delay, with a specific change. As a result, it is not common to evaluate or report reductions in red light running for these types of countermeasures.

Remove Unneeded Signals

Retting, Williams, and Greene (1998) noted that removing unneeded traffic signals could reduce crashes at low-volume intersections. They evaluated the impact of signal removal at 199 intersections in Philadelphia and found that overall crashes decreased 24 percent.

Signal removal is viable if it is possible to remove the signal without degrading the operation or safety of the intersection. There are several ways to accomplish the removal of signals, including converting the signal control to a multi-way stop control and changing the geometric configuration of the intersection. Examples of potential intersection geometric configurations that may be available to the engineer include median U-turn, quadrant design, continuous flow, and roundabout (Reid and Hummer, 2001; Persaud, Retting, Garder, and Lord, 2001). Persaud, Retting, Garder, and Lord evaluated the conversion of 23 intersections from stop sign and traffic signal control to roundabouts and observed an overall reduction of 40 percent in the number of crashes and 80 percent in the number of injury crashes. For the signalized intersections that undertook a conversion to roundabouts, the reductions were 35 percent and 74 percent, respectively.

Add Capacity with Additional Traffic Lanes

Some drivers run the red light when congestion is present and traffic queues are not fully served at the end of the phase. In these situations, drivers in the queue continue to enter the intersection for several seconds after the onset of red. Logically, they are motivated to run the red out of a desire to avoid the delay associated with waiting for the next green indication. In some instances, the changes to the signal phasing can improve this situation. However, many times congestion indicates the need for additional capacity in the form of additional traffic lanes at the intersection.

Flatten Sharp Curves

Sharp curvature can also complicate the intersection environment and lead to higher levels of red light running. Sharp crest vertical curvature on the intersection approach can limit sight distance to the intersection ahead. In such instances, drivers may not have adequate time to detect and react to the signal indication. Sharp horizontal curvature through the intersection places excessive demands on the driver. The need to safely negotiate the curvature typically takes priority over the driver's monitoring of the signal indication and can precipitate more frequent red light running.

CHAPTER 4. AUTOMATED ENFORCEMENT

Although relatively new in the U.S., automated enforcement strategies have been used abroad for many years. This chapter summarizes the experience with the application of those strategies, both in the U.S. and abroad, and includes a discussion of the advantages and disadvantages, issues, and challenges associated with the implementation of automated enforcement systems. For convenience, this chapter addresses technical and implementation aspects. The next chapter addresses legal and constitutional aspects in more detail and describes examples of legislation across the nation and abroad.

TRADITIONAL OFFICER-BASED ENFORCEMENT

Red light running is an illegal act. Unfortunately, enforcing red light running laws is difficult, expensive, and dangerous (Passetti, 1997; Burris and Apparaju, 1998; Hansen, 1998). Typically, a police officer must observe a red light violation—which normally means the police officer has to have a direct view of the same face of the traffic signal as the violator—and then pursue, stop, and cite the violator. Following the violator into the intersection is dangerous, both for the officer and for other vehicles that may be entering the intersection from other directions at the same time. Alternatively, as it frequently happens, the police officer may decide to let the violation pass without taking enforcement action. One of the obvious disadvantages of this strategy is the message drivers receive that law enforcement agencies do not enforce red light running laws seriously.

To address the safety concern and low citation rates associated with the traditional single-officer enforcement technique, some police departments have experimented with a team enforcement technique. With this technique, an officer who is stationed upstream of a signalized intersection sends a radio message to an officer located downstream of the intersection after observing a red light violation. The second officer then proceeds to stop and cite the violator. Team enforcement programs have higher red light running citation rates and are considered safer for officers than single-officer alternatives. Hansen (1998) reported that experience with team enforcement in Howard County, Maryland, led the State Highway Administration to award grants to law enforcement agencies throughout the Baltimore Metropolitan Region to deploy similar programs. A trade-off associated with team enforcement is its higher operating cost. In Howard County, a single 3-hour enforcement effort could cost more than $360 in personnel costs alone, for an average of $25 for every red light violation citation issued (Hansen, 1998).

As an alternative to team enforcement, some jurisdictions use confirmation lights—also called "rat box" or "red eye" devices—that are installed on the back of traffic signal heads (Milazzo, Hummer, and Prothe, 2001). These devices are turned on every time the red indication is on, allowing a single police officer downstream to observe whether any vehicle enters the intersection while the signal indication is on red. "Rat box" devices eliminate the need for team enforcement and the need for a single police officer to be stationed upstream of the intersection.

Relatively little has been written about the safety impacts of officer enforcement techniques to deal with red light running problems. Tarawneh, Singh, and McCoy (1999) evaluated the effectiveness of police enforcement and media advertising at three signalized intersections in Lincoln, Nebraska. Each of the sites had enforcement during 18 two-hour periods randomly selected from three available periods (7–9 am, 11 am–1 pm, and 4–6 pm). Enforcement used the team enforcement technique. The media campaign was part of FHWA's Stop Red Light Running Program (FHWA, n.d.b) and included providing a variety of marketing materials and public service announcements. The researchers observed a significant reduction in the mean entry time after the onset of yellow. However, the average number of yellow entries per cycle and the average number of red entries per cycle did not decrease significantly.

Cooper (1975) evaluated the effects of increased enforcement on driver behavior at seven intersections (one of which was a control site) in Toronto, Canada. Each location received a different combination of duration and magnitude of enforcement. The total analysis period included 2 weeks of base data collection, 4 weeks of increased enforcement, and 2 weeks when enforcement levels returned to their original state. Cooper observed a significant reduction in the number of intersection violations while increased enforcement was in place. However, the number of violations increased right after increased enforcement ended, suggesting that drivers quickly noticed the lack of police presence and fell back to pre-enforcement violation behavior. This observation is consistent with Hansen's (1998) observation that only frequently repeated enforcement had a positive impact in the number of red light violations in Howard County, Maryland. Cooper also noticed that the most significant decrease in the number of violations occurred when only one police officer was assigned to an intersection for 1 hour/day. Further increases in enforcement did not produce significant additional improvement.

While there is a relationship between the frequency of enforcement, the fear or risk of apprehension, and the degree of compliance, a valid question is whether enforcement has an impact on crashes, injuries, and fatalities. Eger (2002) used county level data on law enforcement and injury crashes in Kentucky to determine whether there was a correlation between the number of injury crashes and law enforcement indicators. Eger observed that the number of police officers had an impact on the number of crashes and estimated that increasing police presence by 4 percent could help reduce the number of injury crashes by 2 percent.

AUTOMATED ENFORCEMENT TECHNOLOGY

Most automated enforcement implementations use camera systems. As Figure 4-1 shows, a red light camera system usually has the following components:

- A camera located upstream of the signalized intersection. This camera is only active during the red interval, more specifically after a predetermined "grace" period, e.g., 0.5 seconds, after the signal turns red. A light flash enables the camera to operate at night.
- Pavement sensors, usually inductive loop detectors, located just prior to the stop line. The sensors detect the speed of the vehicle as it approaches the stop line. Typically, if the speed of the vehicle is larger than a threshold, e.g., 15 or 20 mph, the assumption is the driver will not be able to stop the vehicle before the stop line. If the camera is active—i.e., while the red indication is on—the camera will automatically photograph the rear of the vehicle. Normally, the camera also takes a second photograph of the vehicle after a short period of time, e.g., 0.5 seconds, to show the vehicle in the middle of the intersection, therefore clearly documenting the violation.
- An optional second camera, located downstream of the intersection. This camera is designed to be active only when the first camera is active. Its purpose is to photograph

the driver in jurisdictions where the law requires a positive identification of the driver before issuing a citation.

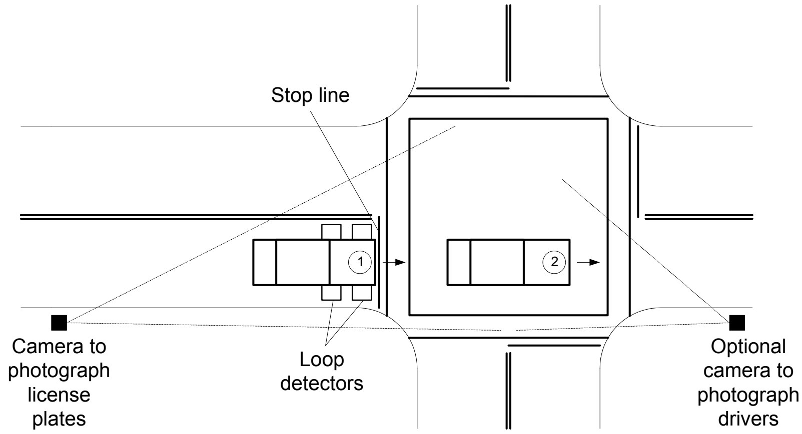


Figure 4-1. Typical Red Light Camera Configuration.

For the purpose of documenting the violation, all photographs have time stamps and also include additional data such as intersection code, the length of the yellow interval, the amount of time the indication was red when the violation occurred, the posted speed limit for that section of roadway, and the vehicle speed when the vehicle crossed the loop detectors.

Camera Technology

There are three types of cameras available for red light running enforcement: 35-mm wet film cameras, digital cameras, and video cameras. Most implementations use 35-mm wet film cameras, although there is a growing trend toward the use of digital cameras. Video cameras are mostly used for documentation purposes but are rarely used for actual enforcement purposes. A summary description of general capabilities and limitations of each type of technology follows. A detailed description of vendors and cameras is available in the literature and is not repeated here (Passetti, 1997; Burris and Apparaju, 1998; Maccubbin, Staples, and Salwin, 2001; McFadden and McGee, 1999; Blackburn and Gilbert, 1995).

Wet Film Cameras

Thirty-five millimeter wet film cameras are the most commonly used type of red light cameras. The cameras are usually placed atop poles or bars equipped with mechanical gears or bearings that enable the raising and lowering of the cameras for maintenance and/or for replacing the film. Most systems produce black-and-white photographs, although some systems also produce color photographs. While black-and-white photographs offer better resolution, contrast, and are less expensive than color photographs, color photographs can more clearly confirm the traffic signal was displaying red at the time of the violation. The cost of 35-mm wet film camera systems is around $50,000–$60,000. This cost includes installation and associated equipment (pole, loop detectors, and camera). Monthly operating costs are approximately $5,000 per camera system (Maccubbin, Staples, and Salwin, 2001).

One of the reasons wet film cameras are popular is the difficulty to tamper with the film, which increases trust in the technology. Two obvious disadvantages are the need to frequently retrieve/replenish the film and the amount of subsequent manual work to process, prepare, and mail citations. Lengthy delays in the preparation of citations—more than 2 weeks as reported in the literature (McFadden and McGee, 1999)—is a frequent complaint.

Digital Cameras

The use of digital cameras for red light running enforcement is increasing. Like their 35-mm wet film camera counterparts, digital cameras are placed atop poles or masts. However, they do not need to be accessed as frequently as wet film cameras, which can result in lower operating costs. Digital cameras are increasing in popularity due to improvements in technology that enable better resolution photographs than older digital systems, better definition of vehicles and license plates, and reduction of problems associated with smears and reflections from headlights. Digital camera systems are usually more expensive than wet film camera systems (up to $100,000) (Maccubbin, Staples, and Salwin, 2001).

Digital camera systems have other advantages compared to wet film camera systems. Perhaps the most significant advantage is the automation of the processing and distribution of citations. Digital photographs can be easily uploaded to a centralized location where software equipped with optical character recognition (OCR) capabilities can recognize license plate numbers automatically. This capability, in turn, makes the identification of vehicle owners more efficient.

Video Cameras

Video cameras are rarely used for enforcement purposes. One of the reasons is current legislation in many states does not allow the use of video recordings as evidence (McFadden and McGee, 1999). However, video cameras are frequently used for documentation purposes. In this case, transportation and/or law enforcement officials install video cameras at selected intersections to document the operation of the signalized intersection, including the occurrence of red light running events.

Because of the increasing popularity of video detection systems for signal actuation, some researchers are beginning to look into the possibility of using those systems for red light running monitoring (Tarko and Naredla, 2002). Video detection systems for signal actuation use “virtual” detectors that act very much like traditional inductive loop detectors. The technology is well understood and its reliability has improved dramatically over the years. The algorithms that work well for signal actuation, however, are not necessarily effective for detecting red light running events. This makes it necessary to define a series of additional “virtual” detectors to avoid an excessive number of false detection events. In a recent set of experiments, for example, using those additional “virtual” detectors resulted in a 67 percent detection rate for through movements and a 32 percent detection rate for left-turn movements (Tarko and Naredla, 2002). The detection rate could certainly improve, particularly for left-turn movements. However, if the technology is viable, it is reasonable to assume future red light camera implementations will rely more on video-based detection systems than on loop detector-based systems.

SAFETY IMPACTS OF RED LIGHT CAMERAS

Sample Cases

Many reports, papers, and mass media articles document safety impacts related to the implementation of red light cameras. Table 4-1 presents a summary of cited documents with an indication of violation reduction figures, angle crash reduction figures, and, if available or applicable, rear-end crash increase figures. A more detailed description of some of the cases follows. For convenience, the description focuses first on U.S. cases.

Table 4-1. Sample of Reports Documenting Safety Impacts of Red Light Cameras.

Jurisdiction	Violation Reduction [1] (%)	Angle Crash Reduction [1] (%)	Rear-End Crash Increase [1] (%)	Source Type	Source
Fairfax, Virginia	44			Journal paper	[2]
Howard County, Maryland	38-52	18-43		Report	[3]
New York City, New York	40			Agency website	[4]
Oxnard, California	42			Journal paper	[5]
Polk County, Florida		7		Report	[6]
San Diego, California	20-24	33	37	Report	[7]
San Francisco, California	42			Journal paper	[8] [9]
Glasgow, Scotland, U.K.	69	62		Agency website, report	[10] [11]
Melbourne, Victoria, Australia	Not significant	Not significant	Significant	Report	[12] [13]
Perth, Western Australia, Australia		40	No increase		[14]
Singapore		65		Journal paper	[15]

1 Readers should keep in mind the percentages shown are not necessarily comparable because different studies used different performance measures and analytical techniques. Attempts at using standard statistical analytical techniques to compare results among studies have found the process challenging and ineffective (Flannery and Maccubbin, 2002).
2 Retting, Williams, Farmer, and Feldman (1999).
3 Department of Public Works and Police Department (2000).
4 New York City Department of Transportation (n.d.).
5 Retting, Farmer, Feldman, and Williams (1999).
6 McFadden and McGee (1999).
7 PB Farradyne (2002).
8 Fleck and Smith (1999).
9 Parking and Traffic Commission (n.d.).
10 Department for Transport, Local Government, and the Regions (2001).
11 Winn (1995).
12 Andreassen (1995).
13 Kent, Corben, Fildes, and Dyte (1995).
14 Office of the Auditor General (1996).
15 Lum and Wong (1998).

Fairfax, Virginia

In 1997, Fairfax began a red light camera program with cameras located at five intersections that had a history of red light running crashes. A review of the program revealed, on average, a 44 percent reduction in red light running violations (Retting, Williams, Farmer, and Feldman, 1999). Before the implementation of the program, the number of violations at the five intersections varied from 14–56 violations per 10,000 vehicles. One year into the implementation of the program, the range in number of violations had decreased to 10–38 violations per 10,000 vehicles. The review also evaluated the number of violations at two non-camera intersections in Fairfax. At those intersections, the range in the number of violations decreased from 38–49 to 19–32 violations per 10,000 vehicles. The reduction was similar to that found at the camera intersections, suggesting the impact of the implementation of automated enforcement went beyond the intersections that had been equipped with cameras. At all intersections, the analysis only counted the number of vehicles that entered the intersection after the grace period (0.4 seconds after the onset of red) and were traveling at least at 15 mph.

The review stated the duration of the yellow interval at all intersections was adequate. However, it did not document actual yellow interval duration data or other characteristics associated with the intersections evaluated such as number of lanes, approaching grades, and 85th percentile speeds. Likewise, the review did not discuss whether any additional countermeasures were in place that could explain the reduction in red light running violations both at the intersections with cameras and at the intersections without cameras.

New York City, New York

New York City has the oldest automated red light camera system in the U.S. The program began operation in 1993 with red light cameras that photograph vehicles, not drivers. In April 1998, the New York City Department of Transportation received authorization from the state legislature to install cameras at 50 locations throughout the city (New York City Department of Transportation, n.d.). Implementation of the program has resulted in a 40 percent reduction in the number of red light running incidents at the locations where the cameras have been installed.

Oxnard, California

In 1997, Oxnard began a red light camera program with cameras located at 10 intersections (California State Auditor, 2002). Site selection criteria included red light running crash history and input from Oxnard police and traffic engineering officials. A review of the program revealed a 42 percent reduction in red light running violations (Retting, Farmer, Feldman, and Williams, 1999). Before implementing the program, the number of violations at the nine intersections varied from 6.5-20 violations per 10,000 vehicles. Four months into the implementation of the program, the range in number of violations had decreased to 2.5–14 violations per 10,000 vehicles. The review also evaluated the number of violations at three non-camera intersections. At those intersections, the range in the number of violations decreased from 5.5–17 to 3.1–14 violations per 10,000 vehicles. The reduction was similar to that found at the camera intersections, suggesting the impact of the implementation of automated enforcement went beyond the intersections that had been equipped with cameras. At all intersections, the analysis only counted the number of vehicles that entered the intersection after the grace period (0.4 seconds after the onset of red) and were traveling at least at 15 mph.

The review stated the duration of the yellow interval at all intersections was adequate. Unfortunately, it did not document actual yellow interval duration data or other characteristics associated with the intersections evaluated such as number of lanes, approaching grades, 85th percentile speeds, posted speed limits, and flow rates.

San Diego, California

In 1998, San Diego began a red light camera program with cameras located at 19 intersections throughout the city (California State Auditor, 2002). Site selection criteria included red light running violation and crash history, input from police and traffic engineering officials, and negative perception of the California Department of Transportation (Caltran)'s permitting process concerning the location of red light cameras on state roads. A recent evaluation of the system indicates red light violations decreased 20–24 percent and angle crashes decreased 33 percent (PB Farradyne, 2002). The reduction occurred primarily during the first 6 months of operation of the system. After that, the number of violations and crashes seemed to stabilize. Rear-end crashes initially increased 37 percent, but over time they decreased again to about the same levels as before automated enforcement started, suggesting rear-end crash increases were not sustained over time. At 3 of the 19 intersections the number of red light running crashes was low both before and after the implementation of the red light cameras. However, the number of citations from one of those intersections represented 25 percent of the total number of citations issued under the red light camera program, indicating that the low crash rate intersections should not have been included in the program.

In 2001, San Diego was forced to suspend issuing red light camera citations. As discussed in the following section, the reason for the suspension was related to the way the city operated the system rather than for safety reasons.

San Francisco, California

In 1996, the city and county of San Francisco installed a series of red light cameras, rotating them among several monitored intersection approaches (Fleck and Smith, 1999). Between 1996 and 1998, the program issued more than 10,000 citations. After 6 months of operation, the number of red light violations had decreased 42 percent and the number of injury crashes had decreased 9 percent (Fleck and Smith, 1999). Around the same period, the number of violations was reported to decrease from 11 per 10,000 vehicles to 6 violations per 10,000 vehicles (Burris and Apparaju, 1998). As of 2000, the number of intersections with red light cameras was 17, with an average of 600 citations issued per month (Parking and Traffic Commission, n.d.).

In selecting the location for the cameras, the program coordinators used criteria such as number of red light running crashes, suggestions from community groups and representatives from the Police Department, geographic distribution, and political and historical factors (Fleck and Smith, 1999; California State Auditor, 2002). Engineering strategies were not part of the original menu of options to address red light running problems. However, the program coordinators noticed that, at least at one particular location where traffic engineers modified the signal progression, red light running decreased dramatically.

Glasgow, Scotland, U.K.

Glasgow began a red light camera program in 1991 with the installation of six cameras at intersections that were chosen based on their crash histories. Following Winn (1995), there was a 69 percent reduction in the number of red light violations at the intersections where the cameras were in operation. There was a 37 percent reduction in the number of red light violations at six control sites where there were no cameras, although this was largely because some of the control sites were approaches to intersections that had red light cameras. Using 3 years worth of before-data and 3 years of after-data, the review found a 62 percent decrease in the number of angle crashes, where the primary contributor was failure to observe the signal.

The review also evaluated the effect of the red light cameras on the distribution of the number of violations after the onset of the red indication. Table 4-2 summarizes the results.

Table 4-2. Number of Violations in Glasgow (Adapted from Winn, 1995).

Time Bin (seconds)	Before	After	Change
0–0.5	138	35	-75%
0.5–1.0	197	63	-68%
1.0–5.0	135	52	-62%
> 5.0	2	5	150%

Melbourne, Victoria, Australia

Melbourne began a red light camera program in 1983. Evaluations of the effectiveness of the program, based on 41 cameras located throughout the city, using crash records from 1979 to 1989, indicated a negligible safety impact resulting from the implementation of the red light cameras (Andreassen, 1995; Kent, Corben, Fildes, and Dyte, 1995). There were not significant reductions in violations or angle crashes and there were not significant differences between camera sites and non-camera sites. However, 75 percent of the sites had very low red light violation rates before 1983, which made those sites inappropriate candidates for the installation of red light cameras. During the evaluation, only 7 percent of the 123 violations observed (out of 38,000 vehicle movements) occurred after the all-red clearance interval. This translates to about 2.3 violations per 10,000 vehicles. There was an increase in rear-end crashes. The analysis did not include a comprehensive assessment of changes in traffic flow characteristics over time, although Andreassen did note that changes at some intersections had taken place, including additional through lanes, left- and right-turn lanes, and signal timing changes.

Perth, Western Australia, Australia

Perth began a red light camera program in 1979 with two cameras. The city expanded the program to 19 cameras in 1993, with a rotation schedule involving 44 intersections. A review of the program by the Office of the Auditor General of Western Australia (1996) found that at the 44 intersections where red light cameras were in operation the average number of angle crashes decreased 40 percent since 1985. By comparison, there was almost no change for the same type of crash at all 920 signalized intersections in Perth over the same period. The review observed an increase in the rate of rear-end crashes, but the increase was temporary. Over a 10-year period between 1985 and 1994, the net change in rear-end crash rates was essentially zero.

Despite the reduction in angle crashes, the Auditor General's report noted the installation of red light cameras did not follow a comprehensive analysis of previous crash data. As a result, there was not a clear correlation between camera selection and locations with a history of crashes.

Singapore

Singapore started an ambitious red light camera program in 1986. As of 1998, about 20 percent of signalized intersections in Singapore were covered by one to three red light camera systems. Lum and Wong (1998) evaluated the effectiveness of the system using a sample of 125 camera intersections. They observed a reduction from 3.2 crashes per intersection in 1986 to 2.1 crashes per intersection in 1993, i.e., an overall reduction of 65 percent. The researchers acknowledged, however, that other factors could have also contributed to the reduction in crashes. To determine the safety impact at camera intersections vs. non-camera intersections, Lum and Wong videotaped a reduced sample of intersections from vantage points using cameras that were not visible to drivers. They observed 88 violations per 10,000 vehicles at non-camera intersections, 49 violations per 10,000 vehicles at one-camera intersections, and 20 violations per 10,000 vehicles at two-camera intersections.

IMPLEMENTATION ISSUES

Aside from technical aspects, a number of implementation issues are critical for evaluating automated enforcement strategies. This section discusses fine and revenue structure, public education and awareness, and public opinion of red light cameras. The following chapter discusses privacy and constitutional issues.

Fine and Revenue Structure

Fine and revenue structures associated with the operation of automated enforcement systems vary widely by state and local jurisdiction. Some states issue citations to positively identify red light running drivers, while other states assume the vehicle owner and the driver are the same person. There are local jurisdictions that own and operate the automated enforcement systems, with the equipment vendors in charge of providing the equipment for a flat fee. There are also jurisdictions where the vendors operate the system, or at least parts of it, and receive a pre-established percentage—typically 15 to 50 percent—of the fine (Maccubbin, Staples, and Salwin, 2001).

Fines vary from $50 to $270. Depending on the state law, a percentage of the fine may go to the state treasury, with the rest going to the local jurisdiction and the equipment vendor. Where the vendor receives a percentage of the fine, there is usually a fee schedule so that as the number of violations processed increases, the percentage of the fine that goes to the vendor decreases.

Fine and revenue structure is one of most contentious issues in the operation of red light running automated enforcement systems. Local jurisdictions usually operate on limited budgets that limit the cities' capability to embark on ambitious automated enforcement plans. In some cases, the federal government has assisted local jurisdictions with grants, as in the case of Los Angeles County, California; Polk County, Florida; Howard County, Maryland; Charleston, South Carolina; and Washington, D.C. (McFadden and McGee, 1999). In an attempt to find alternative funding sources, some cities have reached agreements with equipment vendors where the vendors supply, install, and maintain the equipment, process and mail citations, and collect revenues. In return, the cities pay the vendors a fee, which might be flat or dependent on the number of paid citations.

Critics of automated enforcement strategies regard vendor-operated systems, in particular those in which vendors receive a fee per paid citation, as enforcement for the sake of increasing city revenues and vendor profits instead of enforcement to improve safety (Burris and Apparaju, 1998). Critics further argue that maximizing revenue and improving safety are mutually exclusive objectives because some factors that may contribute to maximize revenue, e.g., insufficient yellow interval durations, tend to compromise safety. In a recent case in San Diego, for example, a vendor located red light cameras at intersections where the duration of the yellow interval was too short and/or there was not a documented history of high crash rates before the installation of the cameras (Cusack and Tait, 2001). Oversight by local authorities was minimal (California State Auditor, 2002), clearly in violation of state law, which required governmental agencies, in cooperation with a law enforcement agency, to operate automated enforcement systems (California v. Allen, 2001). The judge in this case found that the vendor was not a neutral evaluator of the evidence and that there was a conflict of interest between the evaluation process and the vendor's financial interest in the outcome of the evaluation. In a similar case in Denver, Colorado, the judge found the city had violated the law by compensating the vendor for matters other than equipment and by wrongfully delegating police duties (City and County of Denver v. Pirosko, 2002).

Interestingly, a highly aggressive automated enforcement program can actually result in lower revenue in the long run because drivers tend to modify their behavior as they become more aware of the risk of receiving a citation if they run the red light where red light cameras are in place. Proponents of automated enforcement programs argue that such trends prove automated enforcement strategies work. This also means, however, that fee-per-paid-citation schemes are not viable for equipment vendors in the long run—in fact, some vendors prefer flat-fee schemes or flat one-time equipment purchase and installation schemes. If a city decides to enter into a flat-fee agreement with a vendor knowing there is a risk of long-term financial losses, the only justification would be if the potential lower cost to society resulting from fewer crashes, injuries, and fatalities could offset the investment associated with the deployment and operation of an automated enforcement system. The lower cost to society, which is an "externality" a profit-driven organization does not normally need to consider, is a necessary element in the benefit-cost analysis for the local government.

A number of procedures are available to estimate the impact of fewer crashes, injuries, and fatalities. As an example, NHTSA calculates both economic costs—that result from goods and services that must be purchased or productivity that is lost as a result of motor vehicle crashes—and comprehensive costs—which also include intangible consequences of crashes, such as pain and suffering and loss of life—(Blincoe, et al., 2002). Many experts agree the actual cost is somewhere between the economic cost and the comprehensive cost. Table 4-3 summarizes the unit costs recommended by NHTSA. Notice the categories in Table 4-3 are not the same as those of the KABCO scale (K-killed, A-incapacitating injury, B-non-incapacitating injury, C-possible injury, or O-no apparent injury), which most police departments around the country use to report crashes.

Table 4-3. Unit Economic and Comprehensive Costs of Motor Vehicle Crashes (Adapted from Blincoe et al., 2002).

Severity	Descriptor	Economic Cost	Comprehensive Cost
Property damage only (PDO)		$2,532	$2,532
MAIS 0	Uninjured	$1,962	$1,962
MAIS 1	Minor	$10,562	$15,017
MAIS 2	Moderate	$66,820	$157,958
MAIS 3	Serious	$186,097	$314,204
MAIS 4	Severe	$348,133	$731,580
MAIS 5	Critical	$1,096,161	$2,402,997
MAIS 6	Fatal	$977,208	$3,366,388

Unit costs are on a per-person basis for all injury levels. PDO costs are on a per-damaged vehicle basis. MAIS: Maximum abbreviated injury scale. Numbers are expressed in year 2000 dollars.

Public Education and Awareness

Public education and awareness are critical elements for implementing red light camera programs. Regardless of general acceptance trends at the national level (see following sections), local implementations can fail if the local population is not in favor of automated enforcement (McFadden and McGee, 1999; Blackburn and Gilbert, 1995; Turner and Polk, 1998). In general, local acceptance increases if there is a clearly thought out strategy that identifies whether there is indeed a need for automated enforcement and the public is aware of all the necessary implementation steps. Table 4-4 shows commonly used methods used by local jurisdictions across the country to increase public awareness about their red light camera programs.

Table 4-4. Public Education and Awareness Campaign Elements (Adapted from PB Farradyne, 2002).

Jurisdiction	Posters	Mailings	Handouts	Media	Warning Notices	Billboards	Warning Signs	Press Releases	Slogans	Bumper Stickers
Charlotte	●	●	●	●	●	●	●	●	●	●
Fairfax		●		●	●		●	●		
Howard	●		●	●	●		●			
Lincoln				●		●				
New York				●	●		●			
Oxnard	●		●	●					●	●
Polk					●		●			
San Francisco				●	●	●	●	●		
San Diego		●		●			●	●		

Public Opinion of Red Light Cameras

Public opinion about red light cameras varies widely, although in general available reports indicate strong public support for the use of red light running automated enforcement systems.

In a recent study involving more than 2,000 telephone interviews, 80 percent of respondents (in cities with red light cameras) and 76 percent of respondents (in cities without red light cameras) favored the use of automated enforcement systems (Retting and Williams, 2000). The basis for the 2,000 telephone interviews was a 15,000 random telephone number sample in ten cities in the U.S.—five cities with red light cameras and five cities without red light cameras. Support for red light cameras varied by age, with older respondents being more supportive of red light cameras than younger respondents. For example, 85 percent of respondents ages 65 and older supported red light cameras compared to 72 percent of respondents ages 16–24. This result is interesting considering that older drivers, particularly those who are 65 and older, are more likely to be involved in red light running crashes than younger drivers (Figure 2-5).

Other studies have produced similar results. A survey of 1,000 Iowa residents at least 18 years old found 80 percent of respondents supported the use of cameras to reduce red light running (Kamyab, McDonald, Stribiak, and Storm, 2000). A 2001 national survey found 69 percent of respondents favored red light cameras—down from 77 percent in 1999 but still a strong majority (Harris, 2001). There was a considerable difference of support by age: 78 percent of respondents 65 and older supported red light cameras compared to 66 percent of respondents ages 18-29.

In the study by Retting and Williams (2000), 82 percent of respondents in cities with red light camera programs were aware of the system. This result is not surprising given the level of public education and awareness that characterize most red light camera deployments. More surprising was the result that 27 percent of respondents in cities without red light camera programs thought red light cameras were in use in their city. The authors indicated regional or statewide media coverage could have led some interviewees to believe red light cameras were in place in their city. There might be other reasons. One possible reason—which research would need to confirm—is the potential deterrent effect of signal actuation video cameras. Cities are increasingly using special-purpose video cameras instead of inductive loop detectors for the actuation of traffic signals. Those cameras are usually mounted on masts—frequently the same masts as the signal heads—where there is a clear view of the approaching traffic. Most signal actuation video cameras are conspicuous and clearly visible to drivers. However, not too many drivers are aware of the actual function of the cameras. It is reasonable to assume, therefore, that a considerable number of drivers might incorrectly believe signal actuation video cameras are actually being used to monitor whether drivers run red lights. If so, one interesting question would be to what extent the increasing deployment of such cameras in recent years may be having an impact on red light running occurrences.

Opposition to the use of red light cameras might be relatively minor but it is still significant. Opposition may come from drivers who have been caught running red lights or, as mentioned previously, a significant percentage of younger drivers. Opposition also comes from segments of society that tend to reject automated enforcement on the grounds that automated enforcement constitutes an unnecessary intrusion of government power on individual liberties (National Motorists Association, n.d.; Office of the House Majority Leader, n.d.). Some of the issues raised by these groups include effectiveness of automated enforcement, fine and revenue structure, and privacy issues. This chapter addressed the first two issues. The following chapter addresses privacy issues.

CHAPTER 5. RED LIGHT RUNNING LEGISLATION

With the increasing use of automated enforcement systems in the U.S.[1], many states and local jurisdictions have encountered challenges they did not have to face before. Issues such as liability, privacy, and how to treat red light running violations—which have always played a role in the design and enforcement of traffic laws—have now become critical with the introduction of automated enforcement techniques. This chapter addresses those issues and provides necessary background information on legislative strategies and limitations. It also summarizes past and current legislative efforts in a sample of states. In addition, it provides summarized information about past and current legislative strategies and efforts in Europe.

CRITICAL LEGISLATIVE ISSUES

Three critical issues affect red light running legislation: (a) criminal offense vs. civil offense issues; (b) liability of owner/operator; and (c) privacy right issues.

Prosecution of Criminal vs. Civil Offense

Most states consider moving traffic violations criminal offenses. Depending on the severity of the violation (from least serious to most serious), a criminal offense could be a civil infraction, a petty offense, or a misdemeanor. Different types of courts handle criminal offenses, including state trial courts (district courts), county trial courts (county courts), local trial courts (municipal courts), or justice of peace courts (small claims courts).

Some states treat minor traffic violations such as parking or stopping violations as civil offenses. Typically, legislatures enact statutes that allow certain municipalities to handle minor violations locally by passing an ordinance that categorizes the violation as a civil offense. The prosecution of the violation then follows a process called "administrative adjudication" that assigns the case to an administrative court. Decisions issued by the administrative court might include the imposition of fines, costs, and other penalties. Some states now treat red light running violations as civil offenses. By making red light running violations civil offenses, i.e., by decriminalizing the violations, administrative courts have the jurisdiction to prosecute those offenses, therefore reducing the workload and pressure on criminal courts. In general, the civil prosecution process is simpler and faster, resulting in reduced court costs and lower penalty levels.

In a criminal court, the burden of persuasion, or obligation to convince the court as to the validity of the claims, lies with the prosecution. The burden of production, or obligation to present evidence to the court, also lies with the prosecution. The burden of proof requires the prosecution to prove the defendant's guilt "beyond a reasonable doubt." In some cases, however, the evidence is so strong that the case could easily result in an indictment if presented

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[1] Different states use different terminology when describing red light running automated enforcement systems. Examples include "photo traffic enforcement system" (Hawaii), "traffic control photographic system" (North Carolina), "red-light-running camera enforcement system" (California), "traffic control signal monitoring system" (Maryland), "traffic control signal photo detection system" (Utah), "traffic control signal violation monitoring system" (New York), "traffic safety camera system" (Washington), and "photo-red traffic light signal enforcement program" (Virginia). "Photo enforcement system" seems fairly common. For consistency with the rest of the report, however, this chapter uses "automated enforcement system" and "red light cameras."

to a grand jury (the case is said to be "prima facie"—"on its face"). Under these circumstances, the prosecution could file a complaint against the defendant, effectively placing the burden of production (of evidence that there was no violation) on the defendant. The defendant is still "innocent until proven guilty," but the responsibility is now on the defendant to prove his/her innocence.

By comparison, in a civil hearing, the burden of proof is "by preponderance of evidence." This means that if the evidence suggests that more likely than not the violation occurred, the judge may be sufficiently satisfied with the burden of proof requirement and find the accused guilty as charged, unless the defendant can prove his/her innocence. The standard for burden of proof in civil cases is therefore lower, which facilitates the prosecution of minor violations. For instance, in the case of a parking violation, the case is so strong as to place the burden of production on the owner of the vehicle to provide evidence that he/she did not commit the violation.

Liability

The operator of a motor vehicle has legal responsibilities for his/her acts and omissions. This liability is rarely an issue when a police officer directly witnesses a violation and issues a citation on the spot. The situation changes when law enforcement agencies use photographs as evidence of the violation instead of a direct witness. If an automated enforcement system takes photographs of the vehicle and the driver and the driver can be positively identified—assuming the courts accept the photographic evidence, liability is normally not an issue. Unfortunately, requiring a positive identification of the driver when using automated enforcement systems tends to result in low citation rates. In San Francisco, for example, the citation rate was approximately 25 percent of all vehicles photographed running the red light (Fleck and Smith, 1999). The reason is that prosecutors try to avoid having cases dismissed unnecessarily in case a suspect refuses to pay the citation and refuses to appear in court. Normally, if a suspect does not pay a citation and does not appear in court, a prosecutor would request a warrant for the suspect. A judge would issue a warrant only if the judge has a reason to believe the offender and the suspect are the same person. Not having enough evidence in the form of a photograph of the driver as the vehicle runs the red light and positive driver identification would not be enough and would cause the judge to dismiss the citation altogether.

If the automated enforcement system only takes a photograph of the vehicle, it is very difficult if not impossible to determine the driver's identity. The question then becomes how to identify the driver who is liable for that violation. Many state and local laws recognize registered vehicle owners are typically the operators of the vehicles they own. For this reason, it is common to have presumption clauses that the vehicle owner and the suspect are the same person. This strategy enables state and local jurisdictions to target vehicle owners in situations where targeting the actual drivers is difficult (which explains the frequent use of the term "owner liability" in connection with automated enforcement systems). Usually, laws that include presumption clauses also provide the opportunity for the accused to present "affidavits of non-liability." Examples of affidavits of non-liability include testifying under oath that the accused was not the driver of the vehicle, presenting copies of a police report documenting the vehicle had been stolen, or identifying the name of the driver at the time of the alleged violation.

Following Stanek (1998), the U.S. Supreme Court has ruled the presumption clause to be constitutional in situations—e.g., a parking violation—where the societal cost of providing individual right safeguards may outweigh the marginal societal benefit of affording those safeguards. Assuming the vehicle owner and the suspect are the same person is not as strong as proving beyond reasonable doubt that a subject committed the violation. The standard that applies in the case of the presumption clause is lower, therefore easier to meet, which explains why laws that treat traffic violations as civil offenses are able to target vehicle owners. Laws that treat traffic violations as criminal offenses can still target vehicle owners, but those laws usually either include an explicit presumption clause, as well as procedures to rebut that presumption, or have to identify the driver prior to sending a citation by taking a picture of the driver.

Privacy

Cameras are pervasive devices in modern society. Examples include automated teller machines (ATMs), banks, supermarkets, shopping centers, convenience stores, airports, and office buildings. Most of those cameras create a permanent record that may be useful to positively identify individuals in the event of a crime. Cameras are also common in a variety of transportation applications, most notably in transportation management centers, and, as mentioned previously, to actuate signals. Unlike all of those applications, red light cameras are only active part of the time—while the red indication is on—and only create a record of red light violations (assuming obviously the system is operating properly). Depending on whether the law targets the driver or assumes the vehicle owner and the driver are the same person, the record might include both the vehicle and the driver or only the vehicle.

A critical issue with generating a photographic record of a vehicle and/or the driver is the potential violation of individual privacy, which is protected by the Fourth Amendment of the U.S. Constitution. However, the Supreme Court has clarified the claim to the protection of the Fourth Amendment depends upon whether the person has a legitimate expectation of privacy in the invaded place (Rakas v. Illinois, 1978; New York v. Class, 1986). Drivers are in the open view of the public when they operate vehicles and, as a result, the expectation of privacy, as defined in the Fourth Amendment, does not apply (Katz v. United States, 1967; United States v. Martinez-Fuerte, 1976; Texas v. Brown, 1983; Horton v. California, 1990). Further, the Supreme Court has ruled that surveillance by police using an electronic monitoring device such as radar, cameras, radio transmitters, or beepers, is equivalent to following a vehicle on public streets and does not violate the individual's constitutional rights (United States v. Knotts, 1983).

Most state laws consider driving on public roads a privilege rather than a right. Consistent with this view is that the public has a limited right for privacy on public roads and that taking photographs of drivers for enforcement purposes is legal and acceptable. Some states provide a greater protection of privacy within their statutory law, which imposes additional challenges if the state legislatures decide to adopt legislation to enable automated enforcement systems. One such challenge deals with the potential violation of individual privacy rights if the government does not protect and maintain the confidentiality of personal data collected. In this regard, it is critical to identify who is authorized to access, process, and review the photographic evidence produced by the automated enforcement systems. Authorizing a vendor to operate a system without the appropriate oversight and control by the local government can result in abuses or conflicts of interest (California v. Allen, 2001), which can breach the public's confidence in the operation of the system. As a result, state laws often limit disclosure of information as well as use of photographic evidence to the specific use of red light running enforcement.

According to a recent review of the automated enforcement law in California (Naumchik, 1999), automated enforcement systems do not violate autonomy privacy—which involves personal and intimate activities and decisions—because driving through an intersection is not generally performed privately without observers and, as a result, there is not a reasonable expectation of privacy. In contrast, automated enforcement systems could potentially violate informational privacy—which involves information that social norms place in control of the individual—because driving records, which are personal information according to federal statutes, could become public. It is possible to prevent infringement of informational privacy by mandating that photographic evidence remain confidential and limited to authorized personnel. Additional strategies might include prohibiting the use of photographs to prosecute other offenses such as speeding and allowing the review of all photographic evidence by suspects.

RED LIGHT CAMERA LEGISLATION IN THE U.S.

Table 5-1 summarizes the current status of red light camera legislation in the U.S. More detailed listings are available in the literature and are not repeated here (National Conference of State Legislatures, n.d.; IIHS, 2002). A closer look at state laws that allow automated enforcement systems shows great differences in terms of appropriate use and limitations. Some laws focus on hours of operation of the system, camera locations, size of municipality, or overall number of red light cameras allowed. Other laws focus on amount and use of citation fees, presence of a police officer, presence of warning signs, and how and within what period of time the citation must be delivered to the offender. In many cases, successful bills allowed for a prototype installation and included the requirement of a report to the legislature on the experience with the prototype. Those types of bills usually included a "sunset" expiration clause for the program.

Some states have experimented with automated enforcement systems without the backing of enabling legislation but have found those experiments to be short-lived. For example, the city of Anchorage, Alaska, implemented an automated speed enforcement system in 1996 without enabling legislation. After considerable public opposition to the program and a lawsuit, the Alaska Supreme Court ruled that the presence of a police officer was required at the time of the violation. The city discontinued the program the same year (Savage, 2002).

Table 5-1. States That Have Experimented with Red Light Camera Legislation in the U.S.

State	Automated Enforcement Law (Year First Enacted)	Type of Offense (Year of Change)	Photograph	Comment
Alabama	No	Criminal	-	
Arizona	No	Civil	Driver, license plate	Automated speed enforcement since 1986, automated red light running enforcement since 1996, both without enabling legislation.
California	Yes (1995)	Criminal	Driver, license plate	
Colorado	Yes (1997)	Civil (since 1999)	License plate	
Connecticut	No	Criminal	-	
D.C.	Yes (1996)	Civil	Not specified	
Delaware	Yes (1995)	Civil (since 2001)	License plate	
Florida	No	Civil	-	
Georgia	Yes (2001)	Civil (since 2001)	License plate	
Hawaii	Yes (1998)	Civil	License plate	Demonstration project, repealed 05/2002.
Illinois	No	Criminal	-	2-year pilot program at railroad crossings (since 07/2001).
Maryland	Yes (1997)	Civil (since 1997)	License plate	
New Jersey	No	Criminal	-	Automated speed enforcement prohibited (since 1992).
New York	Yes (1988)	Civil	License plate	Sunset 12/2004.
North Carolina	Yes (1997)	Criminal, civil by ordinance if municipality qualifies (since 1997)	Not specified	
Oregon	Yes (2001)	Criminal, civil by ordinance if municipality qualifies (since 2000).	Driver, license plate	Automated speed enforcement allowed by separate law 4 hours per day since 1995.
Rhode Island	No	Civil	-	
Texas	No	Criminal	-	
Utah	No	Criminal	-	Automated speed enforcement allowed (since 1996).
Virginia	Yes (1995)	Criminal, civil by ordinance if municipality qualifies (since 1995).	License plate	Sunset on 07/2005.
Washington	Yes (2000)	Criminal	Not specified	Law refers to pilot project at four intersections.
Wisconsin	No	Criminal	-	Automated speed enforcement prohibited (since 1995)

A description of the red light camera legislation effort in Arizona, California, Texas, and Virginia follows.

Arizona

The Arizona Transportation Code specifies that a traffic and/or vehicle violation is a civil offense unless the statute defining the violation provides otherwise (Arizona Transportation Code Title 28, Section 121). Because red light running does not qualify for an exception under Chapter 3, it is considered a civil offense. This provision facilitated the implementation of automated enforcement systems. Arizona began automated speed enforcement in 1986 and automated red light running enforcement in 1996, both in Paradise Valley. Currently, red light cameras are also used in Peoria, Scottsdale, Mesa, Tempe, Chandler, and Phoenix. Although red light running is a civil offense, the enforcement systems take pictures of both the driver and the license plate. Citations are sent to the vehicle owner. The owner may rebut the citation by sending a copy of his or her driver's license. If the photo on the driver's license does not match the photo of the driver who ran the red light, the citation is dismissed. The owner is also asked to identify the driver but is not required to do so. The City of Chandler and the City of Tempe send a picture of the violation along with the citation. The City of Scottsdale plans to do so in the near future. If passengers are visible on the picture, their faces are blackened on the copy to protect their privacy. The original photo is not altered.

Since the introduction of automated enforcement, a few bills have attempted to limit or even prohibit their use. House Bill 2484 (1997) failed after the second reading. This bill included some restrictions on the use of information obtained by such systems and imposed a maximum fine of $5 per violation. Senate Bill 1415 (1997) also failed after the second reading. It would have required a municipality to receive voter approval before implementing an automated enforcement program.

Failed Senate Bill 1167 (2001) proposed that no portion of a fine or civil penalty collected through the use of a automated enforcement systems could be paid directly to any private vendor or operator of the system, and would prohibit payments to a private vendor or operator based on a percentage of imposed fines or civil penalties. Failed House Bill 2278 (2001) proposed to hold the registered owner of a vehicle liable for a traffic violation and specified the process to admit, deny, or transfer liability to the actual driver. In addition, this bill would have required automated enforcement systems to only take pictures of the rear of a violating vehicle.

California

California is the only other state, besides Arizona and Oregon, that has automated enforcement systems that take photographs of the driver and the license plate. California also has one of the highest fines in the nation for running a red light, currently $271.

Senate Bill 1802 (1994), signed into law as Chapter 1216, enabled the operation of automated enforcement systems at railroad crossings. The law requires the system to photograph both the vehicle's license plate and the driver. Senate Bill 833 (1995), signed into law as Chapter 922, extended Chapter 1216 to authorize the use of automated enforcement systems at official traffic control signals, but included a sunset date of January 1, 1999. The law required citations to be mailed to the registered owner. Senate Bill 1136 (1998), signed into law as Chapter 54, deleted the January 1, 1999 sunset date, in effect allowing the use of automated enforcement systems to continue indefinitely.

Assembly Bill 2522 (2000), signed into law as Chapter 833 (“Pedestrian Safety Act of 2000”), excluded the use of automated enforcement systems and photo radar for speed enforcement purposes by any jurisdiction. Assembly Bill 2908 (2000), signed into law as Chapter 860, required a city council or county board of supervisors to conduct a public hearing on the proposed use of automated enforcement systems prior to entering into a contract for the use of those systems. Senate Bill 1403 (2000), signed into law as Chapter 1035, added that the owner suspected of a violation must receive notice within 15 days.

Senate Bill 667 (2001), signed into law as Chapter 496, required minimum yellow interval durations at intersections equipped with automated enforcement systems to follow Caltrans' Traffic Manual.

Still under consideration is Senate Bill 2016 (2002). This bill requires government agencies that operate automated enforcement systems to determine the locations for placement of the equipment and provide ongoing supervision of the equipment's use. The bill also specified that a contract between a government agency and a manufacturer of such equipment could not include provisions for compensation based on the number of citations resulting from the use of the equipment. The bill was in response to the lawsuit against the city and county of San Diego, which, as described in the previous chapter, resulted in the dismissal of about 300 tickets. The judge found a conflict of interest because the automated enforcement system contractor operated and maintained the system, processed the tickets, and, at the same time, was paid a percentage of each ticket.

Texas

Texas has made several attempts to amend the State Transportation Code to allow automated enforcement systems. Senate Bill 1512 (1995), which was signed into law, implemented an automated highway-railroad grade crossing enforcement system demonstration project in Texas. It required TxDOT to install and operate an automated highway-railroad grade crossing enforcement system in conjunction with no more than 10 automatic gates. TxDOT was to conclude the demonstration project by August 31, 1997 and report its findings to the Governor, the Legislature, and the director of the Legislative Budget Board before January 1, 1998.

House Bill 916 (1995) tried to enact a statewide red light running program: it proposed to authorize a municipality, by ordinance, to implement a “photographic traffic-control system,” making the owner of a vehicle liable for a civil penalty if the vehicle runs a red light. The bill allowed municipalities to prescribe the amount of the civil penalty. It also clarified that a photograph taken by a photographic traffic control system was admissible in an administrative adjudication hearing and was evidence enough to support a finding that the vehicle identified in the photograph ran the red light. It included possible exceptions from liability for owners of rented, leased, and stolen cars. The bill passed the Senate and was returned to the House, where it ended. Similar to House Bill 916, House Bill 365 (1999) tried to authorize a municipality to implement by ordinance a “photographic traffic monitoring system.” The bill was left pending in the Public Safety Committee.

House Bill 1152 (1999) would have passed legislation for automated enforcement systems in municipalities of 150,000 of more. The bill passed the Public Safety Committee and was amended several times after the second reading in the House. Two amendments gutted the bill, one that reduced the maximum imposable fine to $10 and the other one that required each automated enforcement system site to display a warning sign and each citation mailed to read "Big Brother Is Watching You!" The bill was subsequently tabled.

Senate Bill 1487 (1999) would have implemented an automated enforcement system on toll roads and on the state highway system. The bill passed the Senate and was read a second time in the House after passing the Transportation Committee. The bill failed in the House after the second reading. In contrast, Senate Bill 454 (2001) was signed into law. This bill, which is an adaptation of Senate Bill 1487 (1999), allows TxDOT and the Texas Turnpike Authority (TTA) to implement automated enforcement systems for toll facilities on the state highway system. This bill only allows this technology to be used for the enforcement of toll violations and makes it an offense to operate a vehicle on a state toll highway facility without paying the proper toll.

House Bill 1115 (2001) tried again to enable legislation to allow the implementation of red light running automated enforcement systems. Similar to House Bill 916 (1995) and House Bill 365 (1999), House Bill 1115 attempted to impose a civil penalty upon the owner of the vehicle, regardless of who operated the vehicle. The bill was gutted after the second reading in the House by an amendment that reduced the maximum imposable fine from $75 to $10. Following a series of record vote requests, the bill failed to pass to engrossment with a final vote of 71-71.

After House Bill 1115 failed to pass, the City of Richardson requested an opinion from the Texas Attorney General concerning the implementation of automated enforcement systems (Goolsby, 2001). The City of Garland also requested an opinion from the Attorney General, but later decided to withdraw the request (Driver, 2001). In its request, the City of Richardson asked (a) whether it was necessary to have the backing of state legislation for the city to be able to decriminalize the disregard of a traffic control signal, and (b) whether an ordinance that decriminalizes the disregard of a traffic control signal would be constitutional. The city based its request on the 1995 changes to the Texas Transportation Code that allowed the decriminalization of parking and stopping violations (Texas Transportation Code Title 7, Section 682.001) and the subsequent 1999 amendment that limited the application of the law to municipalities with a population greater than 30,000 and council-manager government, or municipalities with a population greater than 500,000 (Texas Transportation Code Title 7, Section 682.002).

The Attorney General's opinion (Cornyn, 2002) was that the City of Richardson could not adopt an ordinance to make a traffic control violation a civil offense because such an ordinance would conflict with state law, which makes traffic control violations criminal offenses (Texas Transportation Code Title 7, Section 542.301), and cities are prohibited from enacting ordinances that conflict with state law. In the Attorney General's opinion, however, the city was not prohibited from adopting an ordinance to use red light running automated enforcement, provided the evidence obtained enabled the positive identification of the driver.

Virginia

Virginia is one of the most active states in automated enforcement legislation. Between 1995 and 2001, the Virginia legislature introduced 41 automated enforcement-related bills, five of which became laws. House Bill 2587 (1995), signed into law as Chapter 492, enabled eligible jurisdictions to install and operate automated enforcement systems at no more than 25 intersections at any one time. The bill specified the photographic evidence constituted prima facie evidence. It also included a presumption clause that the registered owner of the vehicle was the vehicle operator at the time of the violation as well as procedures for rebutting the presumption—including filing an affidavit or testifying that the vehicle owner was not the operator of the vehicle or that the vehicle had been stolen prior to the alleged violation. The bill specified any penalties could not be part of the operating record of the person or used for motor vehicle insurance purposes. The sunset date for the law was July 1, 1998.

House Bill 428 (1996), signed into law as Chapter 392, prohibited private entities from obtaining records regarding owners of vehicles failing to comply with traffic signals but allowed such private entities to receive compensation for providing a traffic light signal violation monitoring system. However, only an employee of the locality could swear to or affirm the certificate necessary for the presumption that the registered owner of the vehicle was the vehicle operator. The bill also delayed the sunset of Chapter 492 until July 1, 2000. Senate Bill 315 (1998), signed into law as Chapter 663, extended the sunset to July 1, 2005.

Senate Bill 775 (1999), signed into law as Chapter 884, included liability for vehicle lessees or renters. It also mandated that each summons mailed had to include a notice of the right to rebut the presumption that the summoned person was the operator of the vehicle through filing of an affidavit, and instructions for filing such affidavit.

Senate Bill 414 (2000) passed both the House and the Senate but received a veto from the Governor. The bill proposed to add four counties and five cities in Virginia to the list of municipalities eligible for automated enforcement. The Governor vetoed the bill with the argument that a defendant would have to prove his/her innocence, which was contrary to the basic presumption of innocence until proven guilty that characterizes the U.S. system of justice (Senate Bill 414 Governor's Veto, 2000).

House Bill 356 (2000), signed into law as Chapter 575, included the requirement for an automated enforcement system to take at least one photograph of the vehicle before it illegally enters the intersection and at least one photograph after the vehicle has illegally entered that intersection.

The 2001–2002 legislature discussed 15 bills related to transportation-related automated enforcement systems. None of the bills became law, and only one bill—House Bill 807 (2002), was moved to 2003. This bill authorizes the use of automated enforcement systems for speeding enforcement in all municipalities.

RED LIGHT CAMERA LEGISLATION IN EUROPE

Automated enforcement in European countries has a longer history than in the U.S. Not surprisingly, many of the legal issues local and state jurisdictions in the U.S. are facing now are also issues European countries have faced in the past. In recent years, a main focus area within the European Union (EU) has been to find ways to harmonize laws and procedures across EU countries. This section summarizes some of the main findings of a study completed in 1999 in an effort to harmonize automated enforcement system procedures in Europe (Jaeger, White, and Malenstein, 1999).

Liability Issues

In general, traffic violations are criminal offenses, but they can be civil offenses by local ordinance. As in the U.S., the driver of a motor vehicle in the EU is responsible for a traffic violation, but, under certain circumstances, the registered owner of the vehicle can be prosecuted (Table 5-2). Penalties for violations are usually fines, which can be either fixed or based on predetermined criteria. For example, in Germany the penalty is roughly the equivalent of $50 if the violation occurs within 1 second after the onset of red. However, if the violation occurs more than 1 second after the onset of red, the penalty increases to about $250 and includes a 1-month suspension of the driver license. If the owner of the vehicle contests the citation and either refuses or is unable to identify the driver in the photograph, the court cannot convict the owner. However, by law the vehicle owner must control the use of the vehicle at all times. Therefore, the court might require the owner to keep a driver's log for 6 months to a year. The driver's log must summarize each trip including the name and address of the driver, date and time of the trip, and the driver's signature. The vehicle owner must present the log to enforcement officers upon request.

Table 5-2. Sample of EU Member States That Allow Automated Enforcement of Traffic Laws.

State	Liability
Belgium	Driver or owner (if driver not identified)
Finland	Driver
France	Driver or owner (if driver not identified)
Germany	Driver
Italy	Driver or owner (if driver not identified)
The Netherlands	Driver or owner (if driver not identified)
Spain	Driver or owner (if driver not identified)
United Kingdom	Driver or owner (if driver not identified)
Switzerland [1]	Driver

[1] Not an EU member state: included for completeness.

In Finland, the fine for any vehicle code violation is based on the net income of the violator. The law prescribes a basic fine amount correlated to income: the higher the income, the higher the basic fine amount. The judge then multiplies the basic fine amount by a factor value based on the circumstances of the violation.

In The Netherlands, the vehicle owner has up to 48 hours to identify the driver after receiving the violation notification by mail. If the owner fails to comply with this requirement, the law assumes the owner is the driver and the driver is subject to prosecution. Failure to pay a citation for a violation results in an automatic 25 percent increase of the fine. After the third notification, the fine is increased by 50 percent and the court can deduct the value of the fine from the violator's bank account. The law permits appeals that, if successful, result in the refund of all paid penalties.

In Belgium, the legislation is similar to that in The Netherlands. The registered owner is presumed to have committed the violation unless the vehicle owner can provide the identity of the driver. By comparison, in France the owner only has to provide proof that he or she was not the driver to be released from prosecution.

Privacy Issues

European legislation ruled on the protection of private information in 1995 (European Parliament and Council of the European Union, 1995). The ruling included the use of data obtained from automated enforcement systems. The legislation protects personal data during data processing and/or exchange and specifies conditions for the authorized uses of such data. Law enforcement agencies can only capture, process, and store personal data needed to ensure that the record of a violation is admissible as evidence in court. Information that does not pertain directly to the violation is prohibited. In Germany, for example, prosecutors who wish to use a photograph showing a red light running violation must first make sure passengers cannot be identified—by blackening or blurring their faces—before the photograph is admissible in court. In order to protect individual privacy rights, some countries require all analysis of recorded data to be performed on-site. This means that analysts can only transfer data that correspond to confirmed violations from the recording location to a storage device.

Enforcement Equipment Standards

Several European countries require that independent organizations test and approve all enforcement system devices before evidence from those systems is admissible in court. The independent testing organization must not be affiliated with law enforcement agencies or equipment manufacturers. All equipment must meet measurement accuracy and acceptable tolerance specifications and conform to environmental tests to ensure the equipment can function properly in the field.

An international standard for automated enforcement systems exists only for non-digital speed-enforcement devices (Organisation Internationale de Metrologie Legale, 1990). This standard is the basis for all national requirements for speed enforcement systems within EU countries, although there are considerable implementation differences within individual countries. Depending on the country, sensor components, digital camera components, and hardware and software components (including data protection and encryption) may be subject to testing and approval.

CHAPTER 6. EDUCATIONAL AND PUBLIC AWARENESS PROGRAMS

There is very little documentation on the effectiveness of educational and public awareness campaigns to address red light running problems. Sometimes, those campaigns are part of the implementation of other programs such as automated enforcement programs where the need to educate the public about the existence and function of the programs is critical to ensure public acceptance. This makes evaluating the effectiveness of the educational and public awareness campaigns to reduce red light running violations and crashes more difficult. This chapter describes some of the educational and public awareness activities included in FHWA's Stop Red Light Running Program and its implementation in Texas. The chapter also includes a description of issues including driver education, driver attitudes and expectations, and aggressive driving.

FHWA'S STOP RED LIGHT RUNNING PROGRAM

FHWA officially launched the Stop Red Light Running Program in 1995 as a safety outreach program that combined public education with aggressive enforcement (FHWA, n.d.b). The program, which now covers more than 200 communities, provides materials, design layouts, and ideas for local awareness campaigns. It also provides technical and program support for local initiatives and news releases by FHWA on red light running-related issues. Even though the official rollout was 1995, the program actually started earlier with a series of focus groups in 1992 and 1994. Results from the focus groups led FHWA to implement a program based on the following assumptions (FHWA, n.d.c):

1. The target audience would be experienced, adult drivers, who are generally law abiding but who also do not consistently comply with traffic control devices.
2. The campaign would not focus on yellow lights due to local jurisdiction differences as to whether or not entering the intersection during the yellow cycle was an offense.
3. The campaign had to include a very real threat of enforcement for any campaign message to work. And,
4. Drivers knew they were wrong in running red lights, but had developed a well-defended position based on low experience of being ticketed or being involved in a crash.

In 1998, the program began the "National Stop on Red Week" campaign. This event, which takes place during the first full week of September every year, focuses on raising awareness among the general public about the dangers of red light running. As part of the campaign, FHWA provides online resources and guidelines for local efforts in promoting "Stop on Red Week" in the community. The campaign includes a number of activities including encouraging proclamations by governors and state legislators; encouraging schools to ask children to wear red during that week; hanging posters in high-visibility areas such as schools and local businesses; and encouraging the use of donated advertising space on billboards, buses, cabs, and at gas stations.

FHWA's own assessment of the program suggests public awareness about the dangers of red light running has increased considerably since the introduction of the program (FHWA, n.d.c). Whether that increase in awareness has translated into reductions in the number of red light running crashes and/or injuries is subject to debate, although FHWA has reported cases where the number of crashes has decreased. FHWA indicates that in some cases where police have written more citations, and this fact has been publicized, the public perception about receiving a citation for running a red light has increased.

One of the local implementations of the FHWA Stop Red Light Running Program was the "Stop Red Light Running" program run by the University of Texas Health Science Center at San Antonio (2001). The focus of this program was to promote awareness about the dangers of red light running and to provide educational materials—in English and Spanish—to high schools, driver education schools, community educators, and trauma coordinators. No information about the effectiveness of the program is currently available.

EDUCATIONAL AND PUBLIC AWARENESS ISSUES

Driver Education

Driver education is a common requirement for prospective drivers before they can obtain a driver license. After obtaining a driver license, however, a driver rarely, if ever, has to attend driver education classes again. There are a few exceptions, e.g., in the case of drivers who commit a traffic violation and receive a citation or drivers who are required by their employers to attend defensive driving classes before using corporate vehicles. Possibly because of the lack of formal requirements to attend refresher courses, even veteran drivers are sometimes ignorant about basic traffic laws and regulations. For example, most drivers apparently are not aware that if they receive a green indication they still have to yield the right-of-way to other vehicles or pedestrians that are in the intersection (Parsonson, Czech, and Bansley, 1993). Instructional materials and even official driver manuals are sometimes not clear on the subject. As an illustration, the Texas Drivers Handbook (TxDPS, 2000) warns drivers facing a steady green light to watch for vehicles and pedestrians in the intersection, but does not explicitly require those drivers to yield the right-of-way to any vehicles or pedestrians that are still in the intersection.

Driver Attitudes and Expectations

Whether driver education and public awareness campaigns are effective depends on the expectations and attitudes of the targeted drivers. In a recent study, Ulleberg (2002) identified six subgroups of drivers ages 16 to 19 in Norway and evaluated the effect of a safety campaign on each of the six subgroups of drivers. The safety campaign focused on generating awareness about the risks associated with crashes, enhancing positive traffic safety attitudes, and promoting safe driving among teenage drivers. The campaign included mass media advertisements, Internet resources, road safety knowledge contests, and free T-shirts and CDs. Table 6-1 summarizes the observations made during the study. As Table 6-1 shows, Subgroups 2 and 5 were "high-risk" subgroups, characterized by high levels of sensation-seeking behavior, anger, anxiety, and aggression. Although the campaign targeted mainly those two groups, Ulleberg's observation was that those subgroups were the least responsive to the safety campaign. Subgroups 1 and 3, considered "low-risk," were the most responsive to the safety campaign. The feedback profile for female and male drivers was very similar, although, in general, female drivers tended to be more positive about the campaign than male drivers.

Table 6-1. Evaluation of Safety Campaign by Different Subgroups for 16-19 Year Old Drivers (Ulleberg, 2002).

Subgroup	Characteristics of Subgroup	Evaluation of Campaign by Subgroup
1	Well-adjusted emotionally, calm, low scores in sensation seeking, aggression, and anxiety.	Consistently higher ratings than Subgroup 2.
2	High scores on driving anger and relatively irresponsible, non-conforming, and egoistic.	The least satisfied by the campaign, likely to find it boring, disappointing. Felt they did not relate to the campaign.
3	Very high scores in anxiety and altruism while showing low scores in sensation-seeking, disrespect for rules, and driving anger.	Consistently higher ratings than Subgroup 2.
4	High scores in sensation-seeking and altruism but shows respect for laws and rules and is relatively unselfish.	Consistently higher ratings than Subgroup 2.
5	High levels of sensation-seeking, driving anger, anxiety and aggression. Tends to easily become frustrated and irritated.	Poorer ratings than Subgroups 1, 3, and 4.
6	Low scores for sensation seeking and risk-taking but low concern for others.	Poorer ratings than Subgroups 1, 3 and 4. Felt they did not relate to the campaign.

Aggressive Driving

In recent years, there has been a growing level of awareness about the dangers of aggressive driving. In a national survey involving 6,000 drivers, 83 percent of respondents indicated red light running constituted aggressive driving (Boyle, Dienstfrey, and Sothoron, 1998). Red light running was the fourth most cited example of aggressive driving, after passing school buses that had the red lights flashing (95 percent), racing another driver (90 percent), and driving through a stop sign without slowing (84 percent). It may be worth noting the survey did not differentiate between intentional red light running and unintentional red light running. In any case, the survey is important because it illustrates the degree to which drivers consider red light running a critical problem that needs to be addressed.

At the 1999 Symposium "Aggressive Driving and the Law" (NHTSA, 1999), participants identified a range of strategies to deal with the aggressive driving problem, covering areas such as statutory approaches, uses of applied technology, sentencing, community leadership, and enforcement. In the area of public awareness, the participants identified the following strategies:

- involve a wide range of stakeholders during the development and dissemination of educational and public awareness campaigns, including educators, law enforcement personnel, prosecutors, judges, insurers, medical community, advertising, and civic groups;
- develop messages that are clear and uniform, localized, and personalized; and
- develop educational materials that are innovative and make use of appropriate technologies.

In response to state and congressional requests for materials to increase the level of awareness about aggressive driving, NHTSA developed a package called "Stop Aggressive Driving" (NHTSA, n.d.). This package includes kit materials such as editorials, articles, press releases, a brochure, mail-back cards, and camera-ready cartoons for newspapers, newsletters, and magazines. No information about the effectiveness of the program is currently available. Other organizations, such as the AAA Foundation for Traffic Safety (n.d.), have also developed outreach materials to raise awareness about aggressive driving.

CHAPTER 7. SUMMARY OF FINDINGS AND RECOMMENDATIONS

Chapters 2–6 provided an assessment of factors affecting red light running, a review of trends in the U.S. and Texas, and an evaluation of the effectiveness of groups of strategies to deal with the problem, including engineering countermeasures, automated enforcement, and educational and awareness programs. This chapter provides a summary of the findings and a series of policy recommendations that, together, should provide useful guidance to transportation officials, legislators, and law enforcement agencies.

SUMMARY OF FINDINGS

Red Light Running Factors and Trends

There are two main groups of factors that influence red light running: intersection factors and human factors. Intersection factors refer to intersection characteristics and ways in which those characteristics affect driver behavior. Examples include number of approaching vehicles to the intersection, frequency of signal cycles, type of signal control, travel time to the stop line, vehicle speed, duration of the yellow interval, approach grade, and signal visibility. Human factors refer to driver characteristics and ways in which those characteristics affect the likelihood of a driver to run a red light. Examples of human factors include vision, driver attention, perception-response time, and the effect of other drivers.

How intersection factors and human factors interact to increase or decrease the risk of red light running varies considerably from intersection to intersection, which, in turn, has an impact on the selection of countermeasures to address the problem. For example, some of the factors, mostly intersection-related, point to the need to implement engineering countermeasures to improve traffic flow, improve visibility, and reduce conflicts. Other factors, mostly driver-related, point to the need to also implement strategies such as improved enforcement and public awareness. The emphasis, therefore, should be on the adoption of strategies that follow a balanced engineering/enforcement/education approach.

The literature review also included an analysis of red light running trends both in the U.S. as a whole and in Texas. Some relevant trends are summarized below:

- Fatal red light running crashes are more likely than other fatal crashes to occur during daylight hours. Other environmental factors, e.g., weather, seem to play no significant role in the incidence of red light running crashes.
- Fatal red light running crashes are more likely than other crashes to occur in urban areas.
- Red light running crashes are more likely than other intersection crashes to occur in urban areas.
- For drivers under 40 years old, the percentage of crash-involved drivers who run red lights is highest for drivers who are about 20 years of age. For drivers over 40, the percentage of crash-involved drivers who run red lights increases with age. By age 60, the percentage of crash-involved drivers who run red lights is similar to the percentage at age 20. Considering that older drivers tend to drive much less aggressively than younger drivers, the finding that red light running among older drivers is at least as prevalent as among younger drivers seems to dispel the notion that red light running is mostly (or

only) due to aggressive driving behavior. This finding notwithstanding, younger drivers do tend to be more involved in red light running situations that include night crashes, alcohol consumption, and/or suspended or revoked driver licenses.
- More male drivers are involved in red light running crashes than female drivers. However, for all age groups, the percentage of crashed-involved male drivers who ran the red light is very similar to the percentage of crash-involved female drivers who ran the red light.
- The number of reported people killed or injured in red light running crashes in Texas has increased substantially over the years (79 percent between 1975 and 1999). This increase is similar to the increase in the number of people killed or injured in intersection crashes (81 percent) or in all crashes in general (80 percent) and is also comparable to the increase in VMT in Texas over the same period of time (85 percent). Overall, about 16 percent of people killed in intersection crashes and 19–22 percent people injured in intersection crashes are involved in red light running.

Engineering Countermeasures

A number of engineering countermeasures are available to address red light running problems, including signal operation countermeasures, motorist information countermeasures, and physical improvement countermeasures. Relevant findings from the literature review include the following:

- Signal operation countermeasures involve some type of modification to the signal phasing, cycle length, or change interval. Examples include increasing the yellow interval duration, providing green extension, improving signal coordination, and improving signal phasing. Signal operation countermeasures can effectively reduce the incidence of red light running by improving traffic flow characteristics and by reducing the exposure of individual vehicles to situations that might result in red light running. A review of current practices to calculate yellow interval durations identified the need to lengthen the perception-reaction time used in the formulations—currently 1 second—because of evidence that this value is too short and does not adequately represent the perception-reaction time of most drivers on the road.
- Motorist information countermeasures include enhancing the signal display or providing advance information to drivers about the existence of a signal ahead. Examples of motorist information countermeasures include providing pre-yellow signal indication, improving sight distance, improving signal visibility and conspicuity, and adding advance warning signs. In general, the review shows that countermeasures that focus on attracting the attention of drivers to the signal, e.g., by improving signal visibility and/or conspicuity and by adding advance warning signs, can effectively reduce the incidence of red light running. Less effective are countermeasures that could cause uncertainty to drivers, e.g., by providing a pre-yellow signal indication. Interestingly, the review did not find the use of strobe lights positioned across the middle of the red lens to be particularly effective to reduce red light running crashes.
- Physical improvement countermeasures involve modifications to the intersection that intend to solve serious safety or operational problems. Examples of physical improvement countermeasures include removing unneeded signals, adding capacity with

additional traffic lanes, and flattening sharp curves. In general, these countermeasures are more significant in scope and are often part of more substantial improvement projects. For this reason, it is not common to evaluate or report reductions in red light running for these types of countermeasures.

Enforcement

Red light running is an illegal act. Unfortunately, enforcing red light running laws is difficult and dangerous and, as a result, infrequently done. Some police departments use team enforcement methods with police officers located both upstream and downstream of targeted signalized intersections. Team enforcement methods have higher red light running citation rates and are considered safer for officers than single-officer methods. However, team enforcement is more expensive. As an alternative to team enforcement, some jurisdictions use confirmation lights—also called “rat box” or “red eye” devices— that eliminate the need for team enforcement and the need for a single police officer to be stationed upstream of the intersection. These devices have contributed to make the enforcement of red light running laws more effective. Unfortunately, they require physical police presence, which can be challenging in situations where there are shortages in law enforcement personnel.

To address the limitations of traditional enforcement techniques, many police departments around the country are beginning to consider automated enforcement alternatives. A review of the effectiveness of the implementation of several automated enforcement systems, as well as the implementation of similar systems in other countries, reveals the following common trends:

- Red light cameras are effective deterrence tools and can have a significant positive safety impact. There are reductions in violations and crashes even in jurisdictions where the implementation of engineering countermeasures had not preceded the installation and operation of cameras. This does not mean, however, that engineering countermeasures should be ignored in favor of automated enforcement.
- Red light cameras can contribute to an increase in the number of rear-end crashes. However, the increase in rear-end crashes is relatively small and temporary.
- Red light cameras are effective only in situations where the number of red light running crashes is significant. Where the number of crashes is already low before implementing the system, the reduction in violations and/or crashes is negligible.
- Red light cameras appear to have a positive safety impact beyond just the intersections that have camera installations. Some authors in the literature call this effect a “halo” or “spill over” effect. Based on the experience from Singapore, however, it is reasonable to assume that, over time, drivers tend to memorize which intersection approaches have cameras and adjust their behavior accordingly.
- Fine and revenue structure is one of most contentious issues in the operation of red light running automated enforcement systems. In an attempt to find funding sources for the implementation of the systems, some cities have reached agreements with equipment vendors where the vendors supply, install, and maintain the equipment, process and mail citations, and collect revenues. In return, the cities pay the vendors a portion of the citation fee. However, these schemes have received considerable criticism, particularly

in cases where the cities have failed to supervise the work of the vendors and have not properly established a correlation between revenue and safety objectives.

- In general, available reports indicate strong public support for the use of red light cameras. Opposition to red light cameras is relatively minor but quite vocal, particularly from those who reject automated enforcement because of the perception that automated enforcement constitutes an unnecessary intrusion of government power on individual liberties.
- Most studies only focus on enforcement aspects and only marginally assess the effect of other factors such as traffic volumes, geometric characteristics of the intersections analyzed, signal timing characteristics, or whether signal actuation video cameras had been in place at the time of the evaluation. This makes it difficult to assess the actual impact of the red light cameras because of the effect that those other factors could have had on the number of red light running violations and/or crashes.
- It is difficult to compare results from different studies because of differences in data collection methodologies, analytical techniques, and performance measures. Attempts at using standard statistical analytical techniques to compare results among studies have found the process challenging and ineffective.

Red Light Running Legislation

Enforcing red light running laws has become controversial in the U.S. after the introduction of automated enforcement systems to this country. The debate focuses mostly on whether to treat red light running as a criminal offense or as a civil offense, who should be liable for the traffic violation (registered vehicle owner or driver), and the potential loss of privacy through the collection of data, which may include pictures of the vehicle and/or the driver. Other issues that have generated debate are collection and distribution of revenue generated by automated enforcement systems. A review of the literature on this subject indicates the following:

- Automated enforcement can be used whether red light running is a civil or a criminal offense. As a civil offense, automated enforcement using only vehicle identification is less intrusive and less demanding on the courts and public agencies. However, a civil offense also implies a loss in the individual's right to be presumed innocent until proven guilty. On the other hand, a system that only identifies the vehicle does not collect visual information about the driver, in effect protecting individual privacy rights better than a system that takes photographs of both vehicle and driver. As a criminal offense, automated enforcement is more intrusive and requires the identification of the driver, but the individual's right to be innocent until proven guilty is not affected. However, lower rates of successfully enforced violations and increased workload on criminal courts should be expected. A presumption clause that the owner is the driver and that treats enforcement photographs as "prima facie" evidence could help to maintain the status of the violation as a criminal offense but enable enforcement agencies to treat it similar to a civil offense.
- The issue of liability is not so much a question of who is liable for the offense, because the driver is always liable, but how to identify the offender. The options for identifying the driver depend on whether red light running is a criminal or a civil offense.

- Supreme Court rulings indicate that the privacy of road users is not compromised by automated enforcement systems, as long as the collection, processing, and storage of photographic evidence are well defined and restricted to their inherent purpose.
- Enacting enabling legislation is necessary before attempting to implement an automated enforcement system, even where statutory law does not indicate the need for additional legislation. Enabling legislation makes it possible to specify requirements and restrictions concerning system, data, and revenue management, as well as legal and administrative procedures. Regulation also ensures that potential public issues are addressed before the start of the program.

Educational and Public Awareness Campaigns

A number of initiatives nationwide have contributed to raise public awareness about the dangers of red light running. FHWA launched the Stop Red Light Running Program in 1995 as a safety outreach program that combined public education with aggressive enforcement. The program, which now covers more than 200 communities, provides materials, design layouts, and ideas for local awareness campaigns. It also provides technical and program support for local initiatives and news releases on red light running-related issues. In 1998, the program began the "National Stop on Red Week" campaign. This event, which takes place during the first full week of September every year, focuses on raising awareness among the general public about the dangers of red light running.

The literature review on educational and public awareness campaigns identified several issues that deserve attention. In general, it is not clear to what extent existing campaigns recognize differences in expectations and attitudes among drivers, differences between intentional and unintentional red light runners, or differences in red light running patterns by age and gender. These issues point to the need to develop campaigns that target the needs of individual groups, as opposed to one-size-fits-all strategies.

POLICY RECOMMENDATIONS

General Goals and Objectives

Long-term vision and goals are frequently easy to formulate; however, expressing vision and goals in terms of specific objectives that rely on quantitative measures to determine the effectiveness of the application of specific solution strategies is considerably more difficult. Recommendations for formulating those objectives for addressing red light running problems include the following:

- Document the extent of the red light running problem and quantify the impact of red light running crashes, injuries, and fatalities both in statistical terms and in dollar terms. The amount and detail of the documentation process would obviously depend on the scale of the analysis (e.g., state, local, individual intersection). The documentation process should aim at the identification of general trends and impacts, but, more importantly, it should aim at the development of formalized rating/ranking procedures that would allow decision makers, planners, and engineers to determine where red light running really is a problem and where to focus the implementation of solution strategies. Unfortunately, current documentation procedures are too informal and rely mostly on anecdotal evidence. As a result,

  - o Engineers and planners frequently do not know where red light running is a problem. In some cases, they use listings from the crash databases, but, for the most part, they rely on "indirect" indicators such as personal perception, letters from citizens and/or decision makers, and pressure from the media to develop a list of, say, 20 "top" or "typical" intersections where red light running is a problem. Considering that a typical large urban area has thousands of signalized intersections, it is not hard to imagine that the informal procedure to rate/rank red light running locations is likely to produce highly inaccurate results.
  - o Even when analysts use crash location listings, those analysts frequently ignore recognized statistical phenomena such as spatial correlation, regression to the mean, and significance. As a result, solution strategies may be implemented that (a) do not really address the needs of the targeted intersections, (b) target intersections that do not have a red light running problem to begin with, and/or (c) miss intersections that do have a red light running problem.

  The formalized rating/ranking procedures should be knowledge-based and, preferably, geographic information system (GIS)-based to enable the integration of pertinent layers of data that are already residing in (or that may be relatively straightforward to incorporate into) local and state agency GIS databases. Examples of layers of data include crash data, traffic volume and traffic generator data, city street network, location of signalized intersections, geometric characteristics of intersections and intersection approaches and/or recent aerial or satellite imagery, type of signal control, signal timing data, and law enforcement activity data. Such a system could be used both for diagnostic purposes and as a management tool.

- Formulate specific goals for the future. The goals should be as specific and quantifiable as possible because they will constitute the target against which all relative improvements will be measured. Examples of possible goals include the following:
  - o To reduce red light running violations to less than 5 violations per 10,000 vehicles for each signalized intersection in the state.
  - o To reduce the number of people killed or injured in red light running crashes from 25,000 to less than 10,000 per year in the state.
  - o To reduce the number of red light running fatalities from about 100 to 40 per year in the state (this would make red light running fatalities in Texas similar to those in New York).
  - o To reduce the number of red light running fatalities from about 100 to less than 6 per year in the state (this would make Texas the state with the lowest red light running fatality rate in the country).
- Conduct a sensitivity analysis to evaluate the impact, both in safety terms and dollar terms, of accepting more lenient or more stringent goals. For example, based on the trends shown in Figures 1-1 and 1-2, the average cost of a red light running crash in Texas in 1999 was about $90,000 (not including property damage). Reducing the number of people killed or injured in red light running crashes from the current level of around 25,000 to 10,000 could result in a net benefit to society of about $1.35 billion per year. By comparison, reducing the number of people killed or injured in red light

running crashes to 20,000 could result in a much lower benefit to society of about $0.45 billion per year.
- Formulate yearly improvement objectives to attain the goals. As with the goals, the yearly objectives should be as specific and quantifiable as possible.
- Evaluate and compare strategies to meet those objectives, taking into consideration that engineering countermeasures should receive priority over automated enforcement strategies. Specific recommendations for implementing appropriate strategies are discussed in the following sections.
- Increase the allocation of traffic safety funds that are dedicated to fighting red light running, particularly in urban areas, where the proportion of red light running crashes with respect to other types of crashes is much larger than for rural areas. Increasing the allocation of safety funds to fight red light running is critical in Texas, given its rank with respect to other states in terms of red light running-related injuries and fatalities and the enormous societal cost associated with those injuries and fatalities.
- Monitor the effectiveness of individual strategies on a regular basis and make adjustments as needed.

Engineering Countermeasures

Engineering countermeasures should receive priority over automated enforcement for addressing red light running problems. Specific recommendations for the implementation of engineering countermeasures include the following:

- Conduct a detailed engineering study of the intersection(s) of interest, which should include the development of a condition diagram and observation of the traffic movements that may be experiencing significant red light running. The analysis should build on the assessment document described in the previous section to make sure detailed engineering studies are conducted on intersection(s) that have a documented red light running problem, not just based on anecdotal evidence or hearsay.
- Evaluate countermeasure(s) in terms of potential benefits and implementation costs. The evaluation should include both a safety evaluation and an economic evaluation. Table 7-1 summarizes some of the possible signal operation countermeasures, motorist information countermeasures, and physical improvement countermeasures available.
- Monitor the effectiveness of the implementation of the countermeasures on a regular basis and make adjustments as needed. For monitoring and comparison purposes, it is important to use standardized performance measures that take into consideration both the absolute number of red light running violations, crashes, injuries, and fatalities, as well as their relative incidence with respect to cycle frequency and flow rate. The monitoring should also include a characterization of the distribution of vehicles both during the yellow indication and during the red indication.
- Develop and disseminate a "Best Engineering Practices Handbook" for the treatment of red light running problems. This handbook should summarize findings in the literature and provide specific guidelines as to how to treat individual intersections or groups of intersections using engineering countermeasures.

Table 7-1. Engineering Countermeasures to Red Light Running.

Countermeasure Category	Specific Countermeasure
Signal Operation (modify signal phasing, cycle length, or change interval)	Increase the yellow interval duration
	Provide green extension (advance detection)
	Improve signal coordination
	Improve signal phasing, cycle length
Motorist Information (provide advance information or improved notification)	Improve sight distance
	Improve signal visibility and/or conspicuity
	Add advance warning signs
Physical Improvement (implement safety or operational improvements)	Remove unneeded signals
	Add capacity with additional traffic lanes
	Flatten sharp vertical curves
	Soften sharp horizontal curves

Improved Enforcement

Drivers need to receive the message that if they run red lights, the chances of receiving a ticket are substantial. Therefore, it is critical to improve the capability of law enforcement agencies to enforce red light running laws. In this process, however, it is important to remember that enforcement strategies should not replace the need for first improving the physical road and intersection environment characteristics that may be causing drivers to run red lights.

Improving the quality of red light running law enforcement should rely on appropriate technologies that do not result in additional safety hazards for police officers and the driving public. This report described two of those technologies: confirmation lights—also called "rat box" or "red eye" devices—and automated enforcement. Confirmation lights are not effective in situations where there are shortages in law enforcement personnel to adequately conduct patrols and enforce the law. Under these circumstances, it may be necessary to consider automated enforcement alternatives. A summary of recommendations for the implementation of automated enforcement systems follows. More detailed recommendations are available in the literature (Blackburn and Gilbert, 1995; Burris and Apparaju, 1998; California State Auditor, 2002; McFadden and McGee, 1999; Milazzo, Hummer, and Prothe, 2001; Oregon Department of Transportation and Oregon Traffic Control Devices Committee, 2001; Passetti, 1997; PB Farradyne, 2002).

Program Planning and Deployment

- Establish institutional arrangements and partnerships, including police departments, political leaders, citizen safety organizations, and transportation agencies.
- Enact legislation to enable the use of automated enforcement technologies and procedures (see following section). It is also critical to avoid implementing automated enforcement systems without the backing of enabling legislation.
- Design and implement an ongoing public education and awareness campaign, using lessons learned from other implementations around the country. The campaign should clearly state the program objectives, describe the operation of the automated enforcement

equipment in non-technical terms, and describe the advantages of automated enforcement over manual enforcement. It should also explain other measures being taken to improve safety at intersections, discuss the use of the automated enforcement program revenues, and provide adequate information to the public through telephone, mass media, and web-based information centers.

- Require that a registered professional engineer prepare both construction plans and as-built plans.
- Document the process of compliance with local and state requirements, including permitting and inspection requirements. This step is important to ensure that all intersections for which automated enforcement systems have been recommended have similar chances of actual implementation, regardless of whether the intersections are located on local roads or state roads.
- Use dedicated loop detectors for the activation of the red light cameras to avoid compatibility and lack of resolution issues associated with normal signal actuation vehicle detection loops. The dedicated loop detectors should be located immediately upstream of the approach stop line to clearly document the time a violating vehicle enters the intersection.
- Provide consistent, adequate grace periods to reduce the impact of the automated enforcement on unintentional red light runners that might have been caught in a "dilemma zone" situation, or to account for inaccuracies associated with the operation of the loop detectors.
- Install adequate, advance warning signs to warn drivers about the operation of the red light cameras.

Enabling Legislation

- Identify early on whether to treat a red light running violation as a civil offense or as a criminal offense. This is the responsibility of the state legislature, even though local jurisdictions can enact ordinances to authorize or regulate the use of red light cameras. A presumption clause that the vehicle owner and the driver are the same person can help to maintain the status of the violation as a criminal offense but enable enforcement agencies to treat it similar to a civil offense. Another strategy could be to treat a red light running violation as a criminal offense by default, but then give local jurisdictions the power to decide by local ordinance whether to treat the violation as a civil offense.
- Specify that only a law enforcement agency can operate and control the red light running automated enforcement program. Private vendors can assist in the process of collecting and processing the data; however, there should be a strict oversight of their activities to ensure the trust of the public on the operation of the system.
- Require that the operation of an automated enforcement system be for the purpose of improving safety, not for generating revenue. However, the law should provide flexibility by establishing a reasonable penalty schedule to allow local jurisdictions to try to recoup the cost to operate the system. To ensure transparency, fees paid to private vendors should not depend on the number of citations sent and/or paid.
- Require that any intersection to be considered for automated enforcement undergo a traffic engineering analysis. The purpose of the analysis should be to assess the general geometric and operational characteristics of the intersection and to identify potential

engineering countermeasures that should be implemented prior to the deployment of the automated enforcement system.
- Incorporate safeguards in the legislation to ensure that the individual's right to confidentiality is maintained. In particular, the legislation should specify that the evidence collected in the form of vehicle and/or driver photographs can only be used for prosecuting red light running violations. The law should also include provisions for handling information that is not directly relevant to the red light running violation. Examples include not showing passengers in photographs, limiting the length of time a camera operator can keep photographic evidence, or prohibiting the release of any photographic evidence to outside parties.
- Specify the maximum number of days a citation must be delivered to the driver/vehicle owner after the alleged red light running violation has taken place. The law should make citation delivery by mail legal, followed by delivery in person if the registered vehicle owner does not respond within a pre-established number of days. The citation should be signed by a police officer, taking into consideration that the preparation of the citation, as well as the police officer's signature, could be completed in an electronic medium.
- Incorporate explicit rebuttal procedures for registered vehicle owners to document their innocence.
- Clarify what constitutes a red light running violation and specify the inclusion of "grace" periods after the onset of red within which the red light camera system must not be active.

Program Management

- Implement reliable internal quality controls using, if necessary, double blind reviews for each violation.
- Maintain logs and data backups for adequate documentation and follow up.
- Develop efficient data processing capabilities to ensure short turnaround times in the processing and mailing of citations.
- Develop contingency plans to ensure the efficiency of the citation review and approval process.
- Evaluate the safety effectiveness of the program on a regular basis and communicate the findings to the public. The effectiveness should be measured using valid safety-related measures, e.g., number of injury crashes at the intersection(s), number of red light running violations, or number of fatalities. Other measures, e.g., number of citations or total revenue, which might be useful to analyze other aspects of the program, should only be used as secondary measures.
- Maintain public information centers, supporting regular correspondence, telephone, and web-based processing capabilities, to address general inquiries about intersection problems and traffic safety concerns, as well as specific inquiries regarding the operation of the automated enforcement program.

Educational and Public Awareness Programs

Educational and public awareness programs are important components in the implementation of other programs such as automated enforcement where the need to educate the public about the existence and function of the programs is critical to ensure public acceptance. There is very little documentation on the effectiveness of educational and public awareness campaigns to address red light running problems. However, based on the literature review, it may be possible to formulate a few recommendations for the implementation of those campaigns. Those recommendations are listed below.

- Develop programs that recognize differences in expectations and attitudes among drivers and that measure the effectiveness of the campaigns based on the type of message that is delivered to each different type of driver. One-size-fits-all educational and public awareness strategies are not likely to be very effective.
- Develop programs that recognize the difference between unintentional red light runners and intentional red light runners. This means recognizing that not all red light running is a sign of aggressive driving behavior. At the same time, however, it is important to highlight that red light running is an illegal, unsafe act and that there are consequences for running the red light.
- Develop strategies that recognize the relationship between red light running frequency and driver age. From the analysis, it is clear that aggressive educational programs should be implemented to reduce red light running among young drivers (i.e., drivers who are 25 years old or younger). However, because the percentage of crash-involved drivers who run the red light increases with age after drivers reach 40 years of age, it is also important to develop meaningful educational programs that are appropriate for older drivers.

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