Technical Report Documentation Page

1. Report No. FHWA/TX-04/4196-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle REVIEW AND EVALUATION OF ENFORCEMENT ISSUES AND SAFETY STATISTICS RELATED TO RED-LIGHT-RUNNING		5. Report Date September 2003 6. Performing Organization Code
7. Author(s) James Bonneson, Karl Zimmerman, and Cesar Quiroga		8. Performing Organization Report No. Report 4196-1
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135		10. Work Unit No. (TRAIS) 11. Contract or Grant No. Project No. 0-4196
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080		13. Type of Report and Period Covered Research: September 2002 - August 2003 14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.
Research Project Title: Safety Impact of Red-Light-Running in Texas: Where is Enforcement Really Needed?

16. Abstract

The problem of red-light-running is widespread and growing; its cost to society is significant. A wide range of potential countermeasures to the red-light-running problem exist. Unfortunately, guidelines are not available for identifying "problem" intersections and whether engineering or enforcement countermeasures are appropriate at a particular intersection. Moreover, there has been concern voiced over the validity of various methods used to identify problem locations, especially when automated enforcement is being considered. There has also been concern expressed that engineering countermeasures are sometimes not fully considered prior to the implementation of enforcement. The objectives of this research project are to: (1) quantify the safety impact of red-light-running at intersections in Texas, and (2) provide guidelines for identifying truly problem intersections and whether enforcement or engineering countermeasures are appropriate.

This report documents the findings from the first year of a two-year project. During the first year, data were collected to quantify the character and extent of red-light violations and related crashes in Texas. Data were also collected to quantify the effectiveness of intersection traffic control enforcement. The findings from a review of the literature on red-light-running and an analysis of red-light-running crash data are included in this report. A procedure for identifying and quantifying red-light-running-related crashes is described.

17. Key Words Signalized Intersection, Red-Light-Running, Right Angle Collisions	18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif.(of this report) Unclassified	20. Security Classif.(of this page) Unclassified	21. No. of Pages 116	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

REVIEW AND EVALUATION OF ENFORCEMENT ISSUES AND SAFETY STATISTICS RELATED TO RED-LIGHT-RUNNING

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Report 4196-1
Project Number 0-4196
Research Project Title: Safety Impact of Red-Light-Running in Texas: Where is Enforcement Really Needed?

Sponsored by the
Texas Department of Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

September 2003

TEXAS TRANSPORTATION INSTITUTE
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College Station, Texas 77843-3135

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NOTICE

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ACKNOWLEDGMENTS

This research project was sponsored by the Texas Department of Transportation and the Federal Highway Administration. The research was conducted by Drs. James Bonneson, Karl Zimmerman, and Cesar Quiroga with the Texas Transportation Institute.

The researchers would like to acknowledge the support and guidance provided by the project director, Mr. Wade Odell, and the members of the Project Monitoring Committee, including: Mr. Punar Bhakta, Mr. Mike Jedlicka, Mr. Danny Magee, Mr. Ismael Soto (all with TxDOT), and Mr. Walter Ragsdale (with the City of Richardson). In addition, the researchers would like to acknowledge the valuable assistance provided by Mr. George Balarezo, Mr. Ho Jun Son, and Mr. Greg Morin during the conduct of the field studies and the subsequent data reduction activities. Their efforts are greatly appreciated.

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CHAPTER 1. INTRODUCTION

OVERVIEW

Retting et al. (*1*) found that drivers who disregard traffic signals are responsible for an estimated 260,000 "red-light-running" crashes each year in the U.S., of which about 750 are fatal. These crashes represent about 4 percent of all crashes and 3 percent of fatal crashes. Retting et al. also found that red-light-running crashes accounted for 5 percent of all injury crashes. This over-representation (i.e., 5 percent injury vs. 4 percent overall) led to their concluding that red-light-running-related crashes are typically more severe than other crashes.

A recent review of the Fatality Analysis Reporting System (FARS) database by the Insurance Institute for Highway Safety indicated that an average of 95 motorists die each year on Texas streets and highways as a result of red-light violations (*2*). A ranking of red-light-running-related fatalities on a "per capita" basis indicates that Texas has the fourth highest rate in the nation. Only the states of Arizona, Nevada, and Michigan experienced more red-light-running-related fatalities per capita. Moreover, the cities of Dallas, Corpus Christi, Austin, Houston, and El Paso were specifically noted to have an above-average number of red-light-running-related crashes (on a "per capita" basis) relative to other U.S. cities with populations over 200,000.

An examination of the Texas Department of Public Safety (DPS) crash database by Quiroga et al. (*3*) revealed that the reported number of persons killed or injured in red-light-running-related crashes in Texas has grown from 10,000 persons/yr in 1975 to 25,000 persons/yr in 1999. They estimate that these crashes currently impose a societal cost on Texans of $1.4 to $3.0 billion annually.

The problem of red-light-running is widespread and growing; its cost to society is significant. A wide range of potential countermeasures to the red-light-running problem exist. These countermeasures are generally divided into two broad categories: engineering countermeasures and enforcement countermeasures. A study by Retting et al. (*4*) has shown that countermeasures in both categories are effective in reducing the frequency of red-light-running.

Unfortunately, guidelines are not available for identifying "problem" intersections and whether engineering or enforcement is the most appropriate countermeasure at a particular intersection. Moreover, there has been concern voiced over the validity of various methods used to identify problem locations (*5, 6*), especially when automated enforcement is being considered. There has also been concern expressed that engineering countermeasures are sometimes not fully considered prior to the implementation of enforcement (*5, 6, 7*).

RESEARCH OBJECTIVE

The objectives of this research project are to: (1) quantify the safety impact of red-light-running at intersections in Texas, and (2) provide guidelines for identifying truly "problem" intersections and whether enforcement or engineering countermeasures are appropriate. These objectives will be achieved through the satisfaction of the following goals:

1. Identify the frequency of crashes caused by red-light-running at intersections on the Texas highway system and in the larger Texas cities.
2. Develop guidelines for identifying intersections with abnormally high rates of red-light-running based on this data.
3. Develop guidelines for identifying the most effective class of countermeasure (i.e., enforcement or engineering) for application at a given intersection.

The research conducted during the first year of the project was focused on fulfilling the first goal.

RESEARCH SCOPE

This research project deals with red-light-running that occurs at signalized intersections on the Texas highway system and in the larger Texas cities. The project also deals with techniques for identifying, describing, and evaluating enforcement countermeasures that are legally allowed and in use in Texas.

RESEARCH APPROACH

This project's research approach is based on a two-year program of field study, evaluation, and guideline development. It will ultimately yield a guideline document to assist in the identification of problem locations and the effective implementation of red-light-running countermeasures. During the first year of the research, the extent of red-light-running on the Texas highway system and in the larger Texas cities has been quantified. In the second year, selected enforcement countermeasures will be evaluated.

The main product of this research will be a *Red-Light-Running Handbook*. This document will provide technical guidance for engineers who desire to locate intersections with a red-light-running problem and minimizing this problem in a cost-effective manner. It will also provide quantitative information on the effectiveness of the more promising countermeasures.

CHAPTER 2. REVIEW OF ENFORCEMENT ISSUES RELATED TO RED-LIGHT-RUNNING

OVERVIEW

This chapter reviews the issues related to enforcement of traffic signal indications at an intersection. The scope includes both officer and camera enforcement activities as well as their effectiveness in reducing violations, crashes, or both. Initially, a section is provided to review the activities that typically precede the implementation of a focused enforcement activity (e.g., problem location identification, application of engineering countermeasures, public awareness campaign). Then, a section is provided that describes the types of enforcement countermeasures often used to combat red-light-running and the effectiveness of these countermeasures.

PRECURSORS TO ENFORCEMENT

This section describes the issues that often need to be addressed when dealing with a red-light-running-related problem. Initially, two alternative treatment approaches are described. Then, the factors considered during the identification of a problem location are discussed. Next, the role of engineering countermeasures is summarized. Finally, the objectives and content of a public information campaign are reviewed.

Serial versus Parallel Treatment Approach

The best approach in dealing with perceived red-light-running problems is generally recognized as one that combines engineering, education, and enforcement. However, there is some debate as to how and when to use countermeasures in any one of these three categories. A review of the literature on this topic indicates that many authors (and agencies) prefer a "serial" treatment approach where engineering countermeasures are considered first, followed by education (via a public information campaign), then enforcement (*6, 8*). This process, as outlined by Milazzo et al. (*7*), is summarized in Figure 2-1.

Recommended Process for Implementing Countermeasures

1. Conduct a traffic engineering study to verify the extent and cause of the problem.
2. If feasible, implement traffic engineering countermeasures.
3. If feasible, consider implementation of officer enforcement.
4. If previous countermeasures are unsuccessful or infeasible, consider camera enforcement.
   a. Ensure public safety is the primary goal when making financial arrangements.
   b. Conduct a public information campaign regarding the camera enforcement program.
   c. Implement systems at intersections with the highest potential for crash reduction.
   d. Monitor system effectiveness to verify benefits.

Figure 2-1. Typical Serial Countermeasure Treatment Approach (*7*).

As indicated by Figure 2-1, the first step in the serial treatment approach is to confirm that a problem truly exists. Evidence of a problem might be an exceptionally large frequency of red-light violations, related crashes, or both. Next, the engineer considers engineering countermeasures before resorting to enforcement. If it is found that engineering countermeasures are not effective or feasible, then officer enforcement is tried. Camera enforcement is only considered as a last resort and then, only when accompanied by public information campaign and follow-up evaluation.

A review of the red-light camera programs in California by the state auditor (*6*) revealed that some traffic engineers believe that engineering countermeasures (e.g., adjusting the yellow interval duration) will have a limited effect on drivers that deliberately run the red indication. They feel that a "parallel" treatment approach that combines engineering, education, and enforcement is more effective. The parallel treatment approach was also recommended in a recently published guideline document describing a 10-step process for implementing a red light camera program (*9*).

One benefit of the parallel treatment approach is that a wide array of resources is immediately concentrated on solving one traffic problem. Obvious problems with this approach are: (1) its implementation is expensive (relative to a serial approach), and (2) if a reduction in crashes is realized, it is very difficult to determine the incremental effectiveness of the individual countermeasures. In contrast, a serial approach will facilitate the study of individual countermeasure effectiveness. If this effectiveness were known, it would be possible for an agency to optimize the cost-effectiveness of its treatment program and possibly fund it for a longer period of time. This ability would be particularly useful if the more significant resources used to support the parallel approach diminish over time.

Intersection Selection Process

Problem Location Identification

The identification of an intersection with a red-light-running problem is typically based on consideration of several criteria. These criteria range from the frequency of red-light violations, to the frequency of red-light-running-related crashes, to the frequency of citizen complaints. Most of these criteria are based on quantitative data. Several of the more commonly used criteria are identified by the letter "P" in the last column of Table 2-1.

Milazzo et al. (*7*) indicate that six cities in North Carolina use only the frequency of right-angle crashes to identify problem locations. They often attempt to confirm the existence of the problem through on-site observation and conversations with enforcement agencies. Finally, when deciding whether to use camera enforcement, the city works with an automated enforcement vendor to determine which locations will produce a sufficient number of violations to offset the cost of the enforcement equipment and its operation. It was noted that one vendor requires an intersection approach to experience a minimum of 25 violations per day before it can justify the installation of its equipment at that location.

Table 2-1. Criteria Used to Select Intersections for Camera Enforcement.

Basis for Criteria	Selection Criteria	Percent Cities Using Criteria [1]	Use [2]
Data	Accidents from motorists running red lights	86	P
	Red-light violations	43	P
	Traffic volume	43	P
	Costs associated with accidents	29	P
	Total (all) crashes	29	P
	Broadside (angle) crashes	14	P
	Increased revenue	14	C
Judgment of local government staff	Informal input from police, community, and city/county representatives	100	P
	Geographic distribution of enforced locations	71	C
	Technical suitability of an intersection for a camera system	57	C
	Negative perceptions of state DOT permitting process	57	C
	Concerns over sufficient police capacity for traffic enforcement	43	C
	Recent or planned intersection improvements	14	C
	Safety of police during traffic enforcement	14	C
	Expected "spillover" effects at other intersections	14	C
	Funding source	14	C

Notes:

1 - Percentages are based on interviews with the city traffic engineer in seven California cities (*6*). They reflect the response to a question about the criteria used to identify intersections suitable for camera enforcement. The percentages do not add to 100 percent because each city uses more than one criteria.

2 - Letters designate how criteria are used. P - problem location identification. C - suitability for camera enforcement.

A crash-frequency-based procedure is also used by Howard County, Maryland to identify problem intersections. Walter (*10*) indicates that county engineers review right-angle crash data to identify problem locations. Then, they conduct a field study of red-light-running frequency. If there are more than 30 red-light violations per day, the cost of installing and operating camera enforcement equipment is determined to be justified.

Bonneson et al. (*11*) describe an alternative method for locating problem intersections. This method considers both red-light violations and related crashes. Instead of looking at just the total number of violations, the method focuses on the *difference* between the observed and expected violations (where the expected violations represent an average for a group of typical intersections of similar volume). Problem intersections are defined as those having a large difference between the observed and expected violations. Additional consideration is given to those intersections with a recurring frequency of red-light-running-related crashes. The advantage of this approach is that it is intended to direct resources to truly abnormal locations (i.e., locations where efforts to implement a countermeasure will be cost-effective).

Suitability for Camera Enforcement

Once a problem intersection is identified, additional criteria are often considered to determine whether the intersection is suitable for camera enforcement. In this context, "suitability" refers to whether it is possible to install a camera system and whether the system will be cost-effective. The criteria commonly used to determine suitability are identified by the letter "C" in the last column of Table 2-1. The criteria listed in this table were reported by the California state auditor and are based on interviews with the city traffic engineer in seven cities (*6*). In general, each city uses between three and nine of the criteria listed in the table to make its determination of whether an intersection has a red-light-running problem and whether it is suitable for camera enforcement.

Engineering Countermeasures

Several individuals have investigated the causes of red-light-running and reviewed the practices of agencies dealing with the associated problems (*7, 11, 12*). Each has recommended that a traffic engineering study precede the implementation of engineering countermeasures. The objective of this study is to identify factors that might be contributing to the red-light-running problem. These factors may include yellow interval duration, signal head visibility, unusual geometry, or excessive delay. Measurements of signal violation and conflict frequency are suggested as being useful in quantifying the extent of the problem. Information obtained from the study would then be used to identify the most cost-effective combination of engineering countermeasures.

Engineering countermeasures can be placed into three categories, depending on their method of implementation. These categories are identified in Table 2-2 along with some common countermeasures. Signal Operation countermeasures are implemented through modification to the signal phasing, cycle length, or yellow interval. Motorist Information countermeasures are implemented through enhancements to the signal display or by providing advance information to the driver about the existence of a signal ahead. The Physical Improvement category includes a group of more substantial modifications to the intersection that are intended to solve serious safety or operational problems.

The effectiveness data presented in Table 2-2 reflects the findings from a combination of before-after studies and a review of the literature by Bonneson et al. (*11*). In general, the percentages associated with red-light violation frequency are likely to be more reliable than those for red-light-running-related crashes. This observation is based on a review of the statistical techniques that underlie the reported percentages. The effectiveness of some countermeasures is not shown in the table because they have not been formally studied. Nevertheless, their ability to reduce red-light violations and related crashes is intuitive and widely recognized, especially when operations or visibility are improved by their implementation (*4, 12*).

Table 2-2. Engineering Countermeasures to Red-Light-Running (*11*).

Countermeasure Category	Specific Countermeasure	Reported RLR Effectiveness [1]	
		Violation Frequency	Related Crashes
Signal Operation (modify signal phasing, cycle length, or change interval)	Increase the yellow interval duration	-50 to -70%	--
	Provide green-extension (advance detection)	-45 to -65%	--
	Improve signal coordination	Varies [2]	--
	Improve signal operation (increase cycle length 20 s)	-15 to -25% [3]	--
Motorist Information (provide advance information or improved notification)	Improve sight distance	--	--
	Improve visibility of signal (12" lens, add heads)	--	-33 to -47%
	Improve visibility of signal with yellow LEDs [4]	-13%	--
	Increase conspicuity of signal with back plates	-25%	-32%
	Add advance warning signs without flashers	--	-44%
	Add advance warning signs with active flashers	-29 to -67%	--
Physical Improvement (implement safety or operational improvements)	Remove unneeded signals	--	-24%
	Add capacity with additional traffic lanes	--	--
	Flatten sharp curves	--	--

Notes:
1 - Negative values indicate a reduction. "--": data not available. RLR: red-light-running.
2 - Red-light violations may increase with improved coordination if a portion of the platoon arrives near the end of the phase; however, this increase can be offset by the larger cycle length typically required for good progression.
3 - Reductions associated with an increase in cycle length may not be realized if motorist delay increases significantly.
4 - LED: light emitting diode. Signal indication utilizes LEDs as the light source instead of an incandescent bulb.

Public Awareness Campaign

In 1995, the FHWA began a program targeting red-light-running. An initial element of the program was to organize the efforts of 32 cities desiring to reduce red-light violations, crashes, or both. Each of the cities that participated in the program was required to administer a combined public awareness campaign and enforcement activity. A review of the campaign's effectiveness by Kamyab et al. (*13*) indicated that the campaign did reduce red-light-running in the participating cities.

A review of the aforementioned FHWA campaign (and other campaigns) by PB Farradyne (*14*) indicated that there are generally three main themes of an effective campaign. These themes and their associated objectives are:

- Educate drivers on red-light-running hazards (objective: stimulate a voluntarily change in the driver's behavior).
- Use the media to open communications between elected officials and the public about the extent of the problem and the need for treatment (objective: gain public support for treatment).

- Provide motorists advance warning that enforcement will be increased in the near future (objective: minimize negative public reaction and avoid accusations of deception).

A wide range of methods are often used to convey the campaign message and heighten motorist awareness. Some of the more commonly used methods include: posters, mass mailings, hand outs, electronic media commercials, billboards, warning signs, and bumper stickers (*14*). Methods less commonly used, but recommended by PB Farradyne (*14*), include: (1) outreach efforts to schools, driver education, and community groups; (2) maintenance of a website with program information and answers to frequently-asked questions; (3) regular surveys of public opinion, support, and awareness of the program.

A review of the literature indicates that the effectiveness of public awareness campaigns is rarely quantified and reported. This limitation is likely due to the fact that campaigns are almost always conducted in parallel with heightened enforcement. A study by Tarawneh et al. (*15*) evaluated the effectiveness of a four-week public awareness campaign that used radio commercials, television commercials, posters, and billboards. A before-after study at three of the city's 200 signalized intersections revealed that red-light violations had decreased by 70 percent. This reduction was higher than expected for a public awareness campaign. Tarawneh et al. speculated that the targeted enforcement that was taking place in a different part of the city may have had a spillover effect and could account for some of the observed decrease.

ENFORCEMENT PROGRAMS

This section describes the enforcement programs being used to address red-light-running problems. Initially, the various goals of these programs are reviewed. Then, the characteristics of the officer enforcement program and the camera enforcement program are described. Finally, the effectiveness of these two programs are synthesized from the literature.

Program Goals

The need to establish specific goals for an enforcement program is an important, and early, step in the process of treating problem intersections (*9*). These goals provide a benchmark by which program success can be measured. The data gathered for this assessment can also be used to report program effectiveness and justify continued program operation. The goals can specify one or more target safety measures such as crashes or violations. They can also indicate a reasonable expected reduction in the target measure, with complete elimination of the problem as the most extreme expectation. For example, the FHWA's "Stop Red Light Running Program" implies that a reasonable goal is to eliminate red-light-running. An independent advocacy group has adopted the name "The National Campaign to Stop Red Light Running." This name also implies a goal of eliminating red-light-running.

There is little doubt that increasing enforcement will reduce red-light violations and related crashes. However, it is also likely that there is a point of diminishing returns where further increases in enforcement effort bring little additional safety benefit. In this context, the cost of providing sufficient enforcement to eliminate red-light-running could exceed the available financial resources of most cities. And, even if these resources were available, it could be reasonably argued that they could be more cost-effectively used to combat other road safety problems. This argument suggests that elimination of red-light-running may be an unreasonable goal for most cities.

The notion that it is reasonable to establish a goal that tolerates a minimum number of violations may seem indefensible. However, it is based two practical realities. First, engineers, police officers, and elected officials are required to use public funds in the most cost-effective manner possible. Second, some drivers will occasionally violate traffic laws, regardless of the likelihood of citation or its cost. These drivers will invariably be distracted at a critical time as they approach the intersection and run the red indication. Based on these two realities, establishing a goal of cost-effectively *minimizing* red-light violations is logically more defensible (from the standpoint of net benefit derived by society) than one of *eliminating* red-light violations.

Another factor to consider when setting program goals is that the frequency of red-light violations increases with traffic volume (*11, 13*). It is possible that high-volume intersections may unfairly stand out as having a critically high frequency of red-light violations when, in fact, their violation *rate* (expressed in terms of violations per 1000 vehicles) is quite low and suggests that they are relatively safe. This same argument could be made using red-light-running-related crashes. Regardless, reducing red-light-running at a given intersection to a minimum level consistent with other intersections of similar volume level would appear to be a defensible goal.

In summary, reasonable goals should be set prior to the conduct of an enforcement program. These goals should be based on achieving a level of reduction in crashes or violations that: (1) is cost-effective in its use of enforcement, (2) recognizes that a small number of violations will always occur, and (3) is reasonable and acceptable to both the engineer and the public.

Types of Enforcement

Enforcement activities used to treat road safety problems can be categorized as one of two types: officer (manual or traditional) and camera (sometimes referred to as "automated"). Typical methods by which each of these two types are used to deal with red-light-running is described in this section.

Officer Enforcement

Single-Officer Technique. The traditional approach for enforcing traffic control laws involves stationing one officer upstream of a signalized intersection such that he or she has a direct view of both signal indications and any vehicles approaching the intersection. If the officer witnesses a red-light violation, he or she can then pursue, stop, and cite the violator. However, following the violator into the intersection is dangerous for both the officer and the other motorists that may be entering the intersection (*16, 17*).

Team Technique. To address the safety concern associated with the single-officer enforcement technique, some police departments have experimented with a team enforcement technique. With the team technique, one officer is stationed upstream of the signalized intersection, and a second officer is located downstream of the intersection. When the "upstream" officer observes a violation, he or she sends a radio message to the "downstream" officer, who then proceeds to stop and cite the violator. Team enforcement techniques have higher red-light-running citation rates and are considered safer for officers than the single-officer technique (*16*).

Hansen (*16*) reports a positive experience with the team technique in Howard County, Maryland. In fact, the success of this program led the Maryland State Highway Administration to award team enforcement grants to law enforcement agencies throughout the Baltimore Metropolitan Region. One disadvantage of the team technique is its high cost. Hansen noted that a single three-hour enforcement effort could cost more than $360 in personnel costs alone (or about $25 for every red-light violation citation issued). As a result, Howard County decided to pursue camera enforcement techniques.

In his report, Hansen (*16*) did not indicate the cost associated with processing a camera enforcement citation or the fine for running the red indication. However, a report by Maccubbin et al. (*18*) indicates that the fine for a red-light violation in Howard County is $75. Although there are likely to be issues other than cost associated with Howard County's decision to use camera enforcement, it would appear that personnel costs were not a factor as there would appear to be a $50 return (= $75 − $25) to the county for each officer-issued citation.

Enforcement-Light Technique. As an alternative to team enforcement, some jurisdictions use enforcement lights (also called "rat boxes," "red eye devices," or "tattletale lights") (*7*). An enforcement light can be attached to the signal head or to the signal mast arm. The latter type of installation is shown in Figure 2-2. These lights are illuminated while the traffic signal indication is red. They allow a single officer stationed downstream of the signal to observe vehicles entering the intersection and note whether the signal indication is red. Enforcement lights eliminate the need for team enforcement and thus, have a lower operating cost (*7*).

Benefits of Officer Enforcement. Zaal (*19*) indicates that the benefit of officer enforcement, relative to camera enforcement, is that red-light violators are apprehended immediately after the violation. He cites evidence that the immediacy of the "punishment" (i.e., a citation) has a more lasting, corrective effect on the driver than receipt of a camera-based citation several weeks after the offense. He also notes that police presence at an intersection may have a residual benefit in terms of reducing other types of violations (e.g., speeding, improper left turns, etc.).

Equipment Configuration and Cost. Although relatively new in the U.S., automated enforcement systems have been used abroad since the 1970s (*9, 20*). Most automated enforcement implementations use camera systems, such as that shown in Figure 2-3. The positioning of the camera relative to the intersection, as well as the location of its pavement sensors, is shown in Figure 2-4.

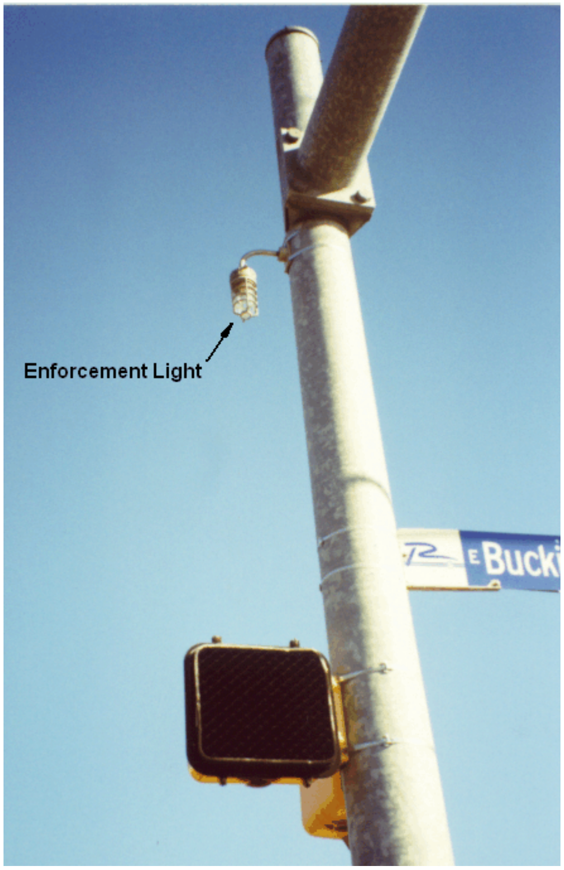

Figure 2-2. Enforcement Light.

Figure 2-3. Enforcement Camera.

As Figure 2-4 indicates, a red-light camera system usually has the following components:

- The camera is located upstream of the signalized intersection. This camera is active only during the red interval. More specifically, it becomes active after a predetermined grace period (e.g., 0.3 s) lapses following the change to a red indication.
- Pavement sensors, usually inductive loop detectors, are located just ahead of the stop line. The sensors detect the speed of the vehicle as it crosses the stop line. Typically, if the speed

of the vehicle is larger than a threshold value (e.g., 15 or 20 mph) the assumption is that the driver will not be able to stop before the stop line. If the camera is active, then it 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 s) to show it in the middle of the intersection, therefore clearly documenting the violation.

- An optional camera is 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's face. This photograph is needed in jurisdictions where the law requires a positive identification of the driver before issuing a citation.

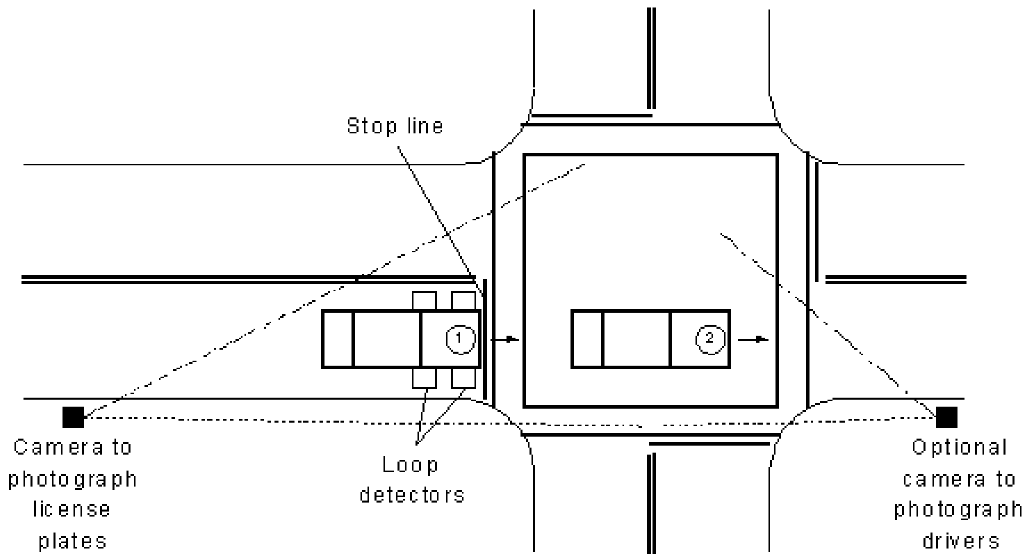

Figure 2-4. Typical Camera Enforcement Configuration (*3*).

All photographs are time-stamped for the purpose of documenting the violation. They also include additional data such as the yellow interval duration, 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.

Depending on the technology (wet-film or digital), implementing a red light camera system at a typical intersection could cost anywhere from $50,000 to $60,000, with installation (loop detectors, cabinet, mounting pole) adding from $10,000 to $25,000 (*9, 17*). Operating costs are reported by Maccubbin et al. (*18*) to be in the vicinity of $5000 per month.

The violation for red-light-running may be treated as a civil or criminal offense, depending on the relevant state statutes. Tickets for civil offenses are sent by mail to violators. Prosecution of the violation as a criminal offense requires proof that the individual committed the offense (e.g., a frontal photograph) and is adjudicated in a criminal court with a fine levied by a judge. Fines can range from $50 to $270 (*18*).

Grace Period. It has been observed that more than one-half of the red-light-running occurs in the first 0.5 s of red, and 80 percent occurs in the first 1.0 s of red (*11*). Thus, a camera with a grace period of 0.5 s should record about one-half of the red-light violations that occur.

A recent review of grace period values used throughout the world revealed that 0.5 s is the "international standard," and that 0.3 s is commonly used in the U.S. (*6*). A similar review by Milazzo et al. (*7*) of U.S. practice indicated a range of 0.1 to 0.3 s being used as the grace period. Based on their analysis of issues related to the grace period, Milazzo et al. recommended the use of a 0.4-s grace period, with a possible increase for approaches with a significant downgrade.

Program Effectiveness

Basic Measures of Effectiveness

To identify and implement cost-effective countermeasures, both the cost and the effectiveness of viable countermeasures need to be quantified. Countermeasure effectiveness should be uniformly assessed in terms of its effect on both violation frequency and crash frequency. At present, most agencies applying a red-light-running treatment program are not assessing the effectiveness of the treatments using sound statistical techniques and study designs (*9, 18*). Moreover, a wide range of measures of effectiveness are used for the evaluation, making comparison among jurisdictions and aggregation of findings impossible. This section describes the range of measures being used to quantify countermeasure effectiveness and some of the underlying issues associated with them.

Red-Light Violations. A review of the literature indicates that several measures are used to quantify red-light violations. The more commonly used measures include: "percent of cycles with one or more red-light-runners," "hourly red-light violation rate," and "percent of vehicles that run the red." These measures are all based on the frequency of red-light-running normalized by exposure to the event. Table 2-3 identifies four frequency-based measures related to red-light violations.

The first column in Table 2-3 lists the frequency-based measures that can be used to quantify the red-light violations. Each of these measures can be converted into a rate-based measure by using one or more exposure factors. Three exposure factors are listed in column 2 of Table 2-3. For example, Measure 1 can 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." As indicated by the last column of the table, frequencies or rates can be quantified for a given lane, approach, or for the overall intersection. Given that the exposure measures can be combined, there are 72 (= 4 ×6 ×3) possible measures of effectiveness that can be derived from the four frequency-based measures in Table 2-3.

Table 2-3. Red-Light Violation Measures.

Frequency-Based Measure	Exposure [1, 2]	Location
1. Vehicles entering during the red interval	...per hour ...per cycle ...per vehicle	...per lane ...per approach ...per intersection
2. Cycles with one or more entries on red		
3. Vehicles in intersection after end of all-red		
4. Vehicles entering in first "*X*" seconds of red		

Notes:

1 - "per vehicle" relates to the total number of vehicles counted for the subject location (it could also be represented as per 1000 vehicles, per 10,000 vehicles, or per million vehicles).

2 - If the numerator and denominator have common units (e.g., cycles with one or more entries per cycle), then the ratio is often multiplied by 100 and expressed as a percentage.

A review of the literature indicates that no less than 10 of the 72 measures identified in Table 2-3 have been used to quantify countermeasure effectiveness. In recognition of the many measures being used, Bonneson et al. (*11*) recommended the use of "red-light violations per 10,000 vehicle-cycles." Their recommendation is based on the finding that red-light violations are highly correlated with both traffic volume and the number of signal cycles that occur each hour. They argue that computation of a violation rate using these exposure factors will facilitate the equitable comparison of intersections among jurisdictions and a better understanding of factors that cause red-light-running.

Of course, comparability of violation rates among jurisdictions will only be possible if all agencies define violation rates using a common grace period. Given that it may be impossible to have all agencies actually use the same grace period, it may be necessary to adjust violation data to an equivalent, common grace period. Adjustments that yield the equivalent of a 0.0-s grace period would provide the most complete evaluation of the red-light-running problem. This adjustment would inflate the number of violations observed by a camera when using a non-zero grace period.

Concerns about the Use of Citation Data. A primary role of enforcement is to deter motorists from committing violations. Hence, citation data are likely to show an initial increase at the start of a heightened enforcement program and then a reduction as the program matures. This time dependency makes it difficult to accurately quantify overall program effectiveness using citation data. Moreover, citation rate is used by many agencies as a measure of officer productivity. This usage introduces possible bias because it encourages officers to chose enforcement methods and locations that maximize the number of citations they write. For these reasons, the frequency of citations should be avoided as a measure of effectiveness for an enforcement program.

Red-Light-Running-Related Crashes. A review of the literature indicates that several measures are used to quantify red-light-running crashes. The more commonly used measures include: "right-angle crashes" and "red-light-running-related crashes." These measures are all based on crash frequency and severity, as normalized by exposure or location. Table 2-4 identifies three frequency-based measures commonly associated with red-light-running crashes.

Table 2-4. Red-Light-Running Crash Measures.

Frequency-Based Measure	Severity	Exposure[1]	Location
1. Total (all) crashes	...fatal ...injury (& fatal) ...all	...per month ...per vehicle	...per treated approach ...at treated intersection ...intersection related[2] ...per city (all intersections)
2. Red-light-running-related crashes			
3. Angle crashes			

Notes:

1 - "per vehicle" relates to the total number of vehicles counted for the subject location (could also be represented as per 100,000 vehicles or per million vehicles).

2 - "intersection related" - a crash at or within a specified distance of the subject intersection that is caused by the intersection's operation.

Each of the measures listed in the first column of Table 2-4 can be converted into a rate-based measure by using one or more exposure factors. Two exposure factors are listed in column 3. For example, Measure 3 can be reported as a rate in terms of "angle crashes per month" or "angle crashes per 100,000 vehicles." As indicated by the last column of the table, frequencies or rates can be quantified for a given approach, intersection, or city (or state). The "per city" location is often used to quantify the overall effects of an area-wide enforcement program where spillover effects are anticipated. Given that the exposure measures can be combined, there are 108 possible measures of effectiveness that can be derived from the three frequency-based measures listed in Table 2-4.

Of the measures listed in Table 2-4, "red-light-running-related" crashes have proven difficult to quantify (*9*). This difficulty lies in the fact that many states do not flag crashes as being caused by a red-light violation. Instead, these red-light-running-related crashes are often identified using the more general category of "disregard stop and go signal" or "failure to obey traffic control." In those instances where intersection control is identified as "signalized," a red-light-running-related crash is sometimes identified using the combination of "right-angle crash" and "failure to obey" (*1, 14*). While this practice is likely to identify a large percentage of the red-light-running-related crashes, it is also likely that some non-red-light-running-related crashes will be included and that some red-light-running-related crashes will be excluded (e.g., left-turn-opposed crashes).

In short, the extrapolation of countermeasure effectiveness to other locations or the combination of measures of effectiveness obtained from separate research projects is practically impossible without a consistently applied definition of a "red-light-running-related" crash. Resolution of this problem will not be a simple undertaking as it will likely require changes in the attributes included in many crash databases. Until this happens, the most logical safety measure is crashes at signalized junctions where "failure to obey traffic control" (or equivalent) is listed as a primary contributing factor.

Officer Enforcement Effectiveness

Overt Deployment. Officer enforcement is generally recognized has having an immediate, positive effect of reducing red-light violations. The extent of this impact appears to vary, depending on whether the officer (and vehicle) is visible. Bankhead and Herms (*21*) found that the visible presence of uniformed officers reduced the frequency of intersection crashes by at least 12 percent. Similarly, Cooper (*22*) found that visible police presence reduced traffic control violations by 28 percent, provided that the enforcement activity was sustained for at least one hour each day.

Covert Deployment. The covert deployment of officers for red-light-running enforcement appears to be less effective than the overt (or visible) deployment method. The only drivers affected by a covert deployment include those receiving the citation and a portion of those that pass by while the citation is being written. Between citations, the officers remain mostly hidden from view and largely ineffective (*23*).

A study of a combined public awareness campaign and covert officer enforcement by Tarawneh et al. (*15*) revealed that covert officer enforcement made no incremental reduction in the number of red-light violations, beyond that realized through the public awareness campaign. This finding is not surprising given two facts: (1) that covert officer enforcement is effectively equivalent to camera enforcement, and (2) a time-trend analysis by PB Farradyne (*14*) indicates that camera enforcement systems do not reach their full effectiveness until after six months of operation. Hence, it is logical that covert officer enforcement would have to be sustained for a similar amount of time to realize a similar level of effectiveness. Relatively little has been written about the safety impacts of officer enforcement effectiveness.

Targeted Enforcement. Because of the labor intensive nature of officer enforcement, most agencies target intersections with a high frequency of red-light violations or red-light-running-related crashes. The rationale for this approach is that the return on the officers' time will be maximized because they will issue a large number of citations. This approach is also viewed as being responsive to public concerns because it can have an immediate impact on the frequency of red-light-running. It is also consistent with the process used by many agencies when identifying intersections suitable for camera enforcement. Zaal (*19*) cites several reports that speak positively about the merit and effectiveness of this approach. Both Cooper (*22*) and Bankhead and Herms (*21*) used this method in their studies of overt officer enforcement effectiveness.

Random Enforcement. An alternative to the targeted enforcement approach is random enforcement. Edwards and Brackett (*24*) speculated that the *random* selection of location and time for a short-term (i.e., one or two hours) enforcement activity would substantially increase the officers' citywide effect on violations. This approach has the advantage of allowing enforcement agencies to cover a larger geographic area with limited staff resources. A noted side benefit was that the short-term presence of the officers does not give an impression of over-policing in a given area.

The random enforcement approach was implemented in Queensland, Australia, and studied by Newstead et al. (*25*). A total of 40 road segments (0.3 to 6.0 miles in length) were randomly selected in each of 279 police precincts. The average segment received two, two-hour enforcement visits per year. An analysis of crash frequency in the "before" and "after" periods indicated that crashes were reduced by 11 percent.

Amount of Enforcement. While there is logically a relationship between the amount of enforcement and the frequency of violations, a valid question is whether the amount of enforcement has a regional impact on crash frequency. Eger (*26*) used county-level data to determine whether there was a correlation between the number of injury crashes and amount of enforcement. He observed that the number of police officers on patrol had an impact on the number of crashes and estimated that one additional police officer per county (i.e., a 4 percent increase in staff size) could reduce the number of injury crashes by 2 percent.

A more substantial analysis of the effect of enforcement level on crash frequency was conducted by Elvik (*27*). He reviewed eight studies of regional enforcement effectiveness and developed a "best fit" relationship between the amount of enforcement used and the regional reduction in injury crashes. This relationship is shown in Figure 2-5. It should be noted that the "amount of enforcement" referenced in this figure is based on officer-hours per day.

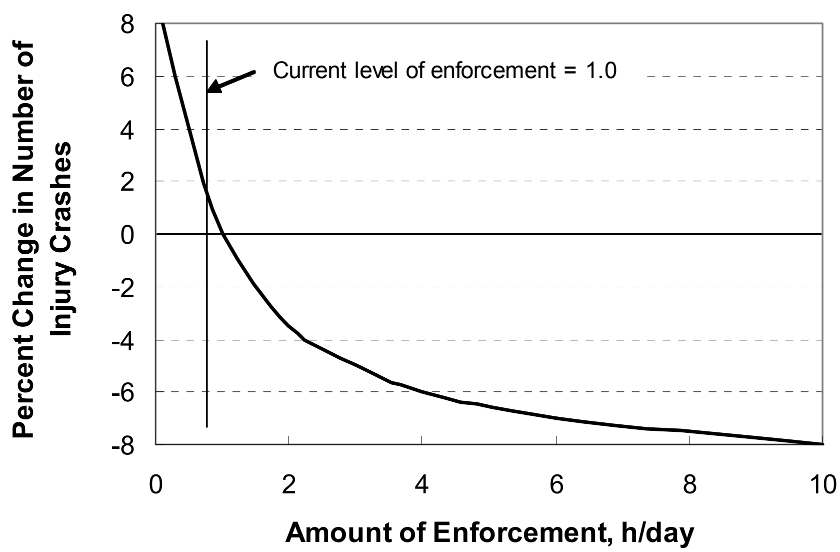

Figure 2-5. Relationship between Amount of Enforcement and Regional Crash Reduction.

The trend in Figure 2-5 indicates that a 100 percent increase in the amount of enforcement (i.e., from 1.0 to 2.0 on the *x*-axis) was found to result in a 4 percent reduction in regional crashes. Additional increases further reduced crashes, but the amount of the reduction diminished.

Elvik (*27*) used the relationship in Figure 2-5 to evaluate the cost-effectiveness of officer enforcement in Norway. Overall, he found that the estimated benefit of additional officer enforcement outweighed its cost by a factor of four (i.e., a benefit-cost ratio of 4.0). This ratio was also found to exceed the benefit-cost ratio of all other safety programs (e.g., road safety audits, driver training, improvements to road design, new vehicle safety standards, etc.).

Temporal Effectiveness. Cooper *(22)* conducted an evaluation of the effects of increased enforcement on driver performance and safety 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 study period lasted eight weeks and included two weeks of before data collection, four weeks of increased enforcement, and two weeks when enforcement levels returned to their pre-study state. The officers were highly visible at all times during the enforcement activity.

Cooper *(22)* observed a 28 percent reduction in the number of intersection violations while increased enforcement was taking place. However, the effectiveness of the enforcement diminished rapidly once the officers left the intersection. This effect is shown in Figure 2-6 using the post-enforcement violation data reported by Cooper.

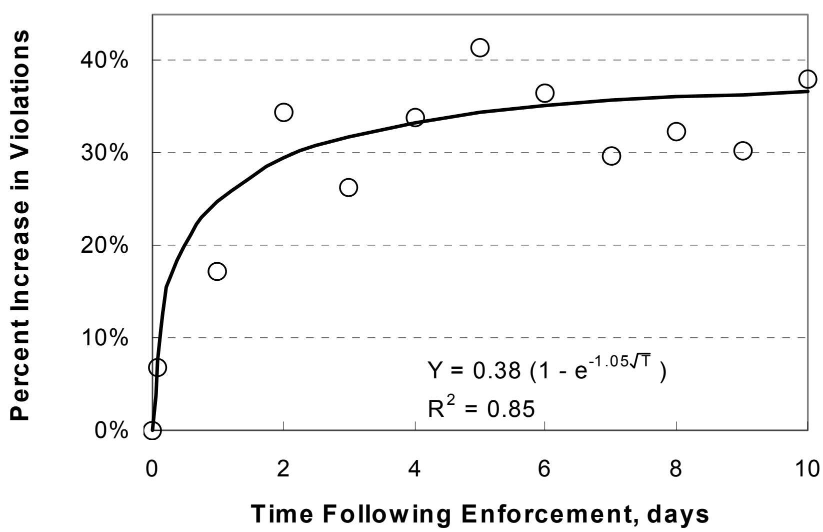

Figure 2-6. Increase in Violations Following an Overt Officer Enforcement Activity.

The trend in Figure 2-6 suggests that violation rates increase by 19 percent after about 10 hours and 38 percent after about six days. Given that the original reduction due to officer presence was 28 percent, this trend implies that one-half the benefit of officer presence was lost after 10 hours, and that all of it was lost after six days. Cooper *(22)* also noted that this trend was uninfluenced by the amount of time the officers were present each day (i.e., one, two, or three hours).

Camera Enforcement Effectiveness

The effectiveness of camera enforcement in reducing the number of red-light-runners has been widely reported. A useful summary of these reports is provided by Maccubbin et al. *(18)*. They found that camera enforcement reduced red-light violations between 20 and 87 percent, depending on the jurisdiction. However, they also noted that many of the studies were not conducted by independent agencies using suitable statistical techniques. As a result, the findings from many of the non-independent evaluations were suspect. A careful examination of the reports reviewed by Macubbin et al. indicated that those listed in Table 2-5 are likely an accurate reflection of the observed trends.

Table 2-5. Effectiveness of Camera Enforcement.

Jurisdiction	Change in Violations [1]	Change in Crash Frequency [1, 2]				Reference
		Related [3]	Angle	Rear-End	Total	
Melbourne, Victoria, Australia	--	--	-13%	20%	--	*28*
Perth, Western Aust., Australia	--	--	-40%	--	--	*29*
Glasgow, Scotland	-59%	--	--	--	--	*30*
Fairfax, Virginia	-44%	--	--	--	--	*20*
Oxnard, California	-40%	--	(-32%)	(3%)	(-7%)	*31, 32*
San Francisco, California	-42%	(-9%)	--	--	--	*8*
State of California	--	-36% (-10%)	--	--	--	*6*
Charlotte, North Carolina	--	-20%	--	--	--	*7*
San Diego, California	--	-31%	--	37%	--	*14*

Notes:
1 - Negative values denote a reduction in frequency. Positive values denote an increase.
2 - Values listed are for the specific intersection receiving the camera enforcement. Values in parentheses are for the entire city or region influenced by the camera enforcement program.
3 - Red-light-running-related crashes are estimated using a combination of crash database attributes.
"--" - data not reported.

Except as noted, the percentages in Table 2-5 indicate the changes in violation or crash frequency at camera-enforced intersections. These percentages indicate that camera enforcement was found to reduce the frequency of red-light violations between 40 and 59 percent. Camera enforcement was also found to reduce red-light-running-related crashes between 20 and 36 percent (between 9 and 10 percent on a citywide basis). Three studies found that camera enforcement was associated with an increase in rear-end crashes. This adverse side-effect of camera enforcement is discussed in the next two paragraphs.

Rear-End Crashes. The Office of the Majority Leader of the U.S. House of Representatives (*5*) has taken issue with many of the camera-effectiveness studies. They claim that these studies do not address effectiveness in terms of all crashes. It is the contention of this office that rear-end crashes increase as a result of increased enforcement and may partially offset any reduction in angle crashes. The Office cites the studies by Andreassen (*28*) and by PB Farradyne (*14*) as evidence in support of their claim. Data reported by Retting (*32*) also support this claim. It should also be noted that PB Farradyne found that the frequency of rear-end crashes returned to their "pre-enforcement" levels at the camera-enforced intersections after about three years of camera enforcement.

An indication of the degree to which the increase in rear-end crashes offsets the reduction in right-angle crashes is revealed in statistics reported by Retting et al. (*32*). They examined the change in "total" crashes (i.e., all crash types combined) at 125 intersections in Oxnard, California. Of these 125 intersections, 11 had enforcement cameras. As a result of the use of cameras, angle crashes were reduced by 32 percent, but rear-end crashes increased by 3 percent. In combination, the citywide impact of camera enforcement was a net reduction of 7 percent in total crashes.

Spatial Effectiveness. Two separate studies by Retting et al. (*20, 31*) examined the effect of camera enforcement on other, non-camera-enforced intersections in the same city. In one study, they found that non-camera-enforced intersections experienced a 34 percent reduction in violations while the camera-enforced intersections experienced a 44 percent reduction in violations (*20*). In the second study, they found that non-camera-enforced intersections experienced a 50 percent reduction in violations while the camera-enforced intersections experienced only a 40 percent reduction (*31*). No explanation was offered as to why the non-camera-enforced intersections had a larger reduction percentage than the camera-enforced intersections.

Data reported by the California state auditor for six cities was examined to determine if camera enforcement had a spillover effect on crash frequency (*6*). As noted in Table 2-5, the auditor reported an average statewide reduction in red-light-running-related crash frequency of 10 percent. However, the auditor also noted that the effect on individual cities ranged between a 21 percent decrease and a 5 percent increase.

A closer examination of the California data (*6*) indicated that, in a given city, the crash reduction percentage at non-camera-enforced intersections was correlated with the crash reduction percentage at camera-enforced intersections. It was also correlated with the time that the enforcement program had been operational. A "crash reduction" ratio is defined herein to account for this correlation in crash reduction percentages. This ratio represents the quotient of the crash reduction percentage for the non-camera-enforced intersection and that for the camera-enforced intersection. Crash reductions occurred at all camera-enforced intersections. A positive ratio indicates that the non-camera-enforced location also experienced a reduction in red-light-running-related crashes. A ratio of 1.0 would indicate that the reduction at the non-camera location is equal to that at the camera-enforced location. The relationship between this ratio and the duration of the camera enforcement program is shown in Figure 2-7.

The trend in Figure 2-7 suggests that crashes actually increase at non-enforced intersections during the first 25 months of enforcement activity. This finding indicates that red-light violations migrated to the neighboring intersections during the initial months of the camera enforcement program. Only those cities for which enforcement was operational for two years or more show a reduction in crashes (i.e., a beneficial spillover effect). Those cities with enforcement programs in place for three or more years experienced the most significant spillover effect. The trend line in Figure 2-7 suggests that, after five years of camera operation, the crash reduction percentage at non-camera locations will increase to about one-half of that found at the enforced intersections.

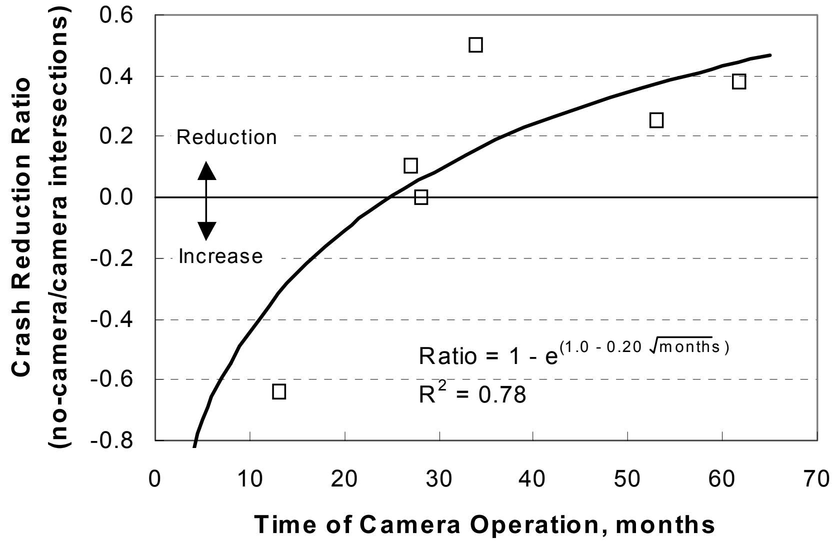

Figure 2-7. Effect of Program Duration on Crash Reduction at Non-Enforced Intersections.

Assessment Process. The conduct of a formal before-after study of the effectiveness of a camera enforcement activity is essential to the justification of a camera enforcement system (*9*). However, the details of study design and data analysis are not a trivial undertaking. All too often, studies are lacking sufficient rigor to offer convincing evidence of a camera's true effect on violations or crash frequency. One problem that frequently emerges is the lack of a valid "before" data set (*14*). Agencies often desire to use the camera system to record the "before" violation data; however, the camera's presence invariably influences driver behavior and introduces a bias in the "before" data.

A second problem that emerges when attempting to evaluate countermeasure effectiveness is the simultaneous implementation of numerous countermeasures. While this type of "shotgun" approach is likely to yield an immediate impact on violations, it is very difficult to determine the individual contribution of each countermeasure. This knowledge would be extremely useful to an agency if it desired to reduce its resource investment over time by eliminating (or discontinuing) countermeasures that have negligible effect.

A third problem that emerges in the countermeasure assessment process is the inherent tendency for crash data to exhibit a regression-to-the-mean behavior. This effect is particularly significant when a treated intersection is selected because it has a high frequency of crashes. With rare exception, the studies reported in the literature that quantify the effectiveness of camera enforcement have not accounted for this effect (*33*). As a result, the reported crash reduction percentages are likely to overestimate camera effectiveness (perhaps by as much as a factor of 2.0).

Regression-to-the-mean is also likely to exist in red-light violation data. Bonneson et al. (*11*) describe a technique that can be used to eliminate regression effects from the estimate of a countermeasure's expected violation reduction percentage. Techniques for removing regression-to-the-mean bias in crash data are described by Retting et al. (*32*) and by Hauer (*34*).

CHAPTER 3. REVIEW OF SAFETY STATISTICS RELATED TO RED-LIGHT-RUNNING

OVERVIEW

This chapter summarizes selected statistics that collectively describe the extent of red-light-running and its impact on intersection safety. Initially, the extent of red-light-running is quantified through a review of the various violation rates reported in the literature. Also included is an investigation of the frequency of red-light-running relative to the time at which it occurs following the onset of the red indication. Following this examination of red-light-running events, the effects of red-light-running on crash frequency are discussed.

RED-LIGHT-RUNNING EVENTS

This section describes two statistics that characterize red-light violations. Specifically, the statistics examined include violation rate and entry time of the red-light-running driver. Also examined is the effect of delay on the frequency of red-light violations.

Violation Rates

Red-light violation rates are widely reported in the literature (*8, 20, 31, 35, 36, 37*). They are expressed in terms of the ratio of violation frequency and some measure of exposure (e.g., hour, signal cycles, total vehicles, etc.). The full range of violation rates was discussed previously with regard to Table 2-3.

In Singapore, Lum and Wong (*35*) observed 8.8 violations per 1000 vehicles at intersections without camera enforcement. In the same city, Chin (*36*) found the average red-light-running rate was 0.33 violations per signal cycle. In the United Kingdom, Baguley (*37*) measured red-light-running at seven intersections. The data he reported indicates that drivers run the red at an average rate of 5.3 violations per 1000 vehicles.

Bonneson et al. (*11*) found that the frequency of red-light-running is highly correlated with traffic volume and the number of times the yellow indication is presented per hour (i.e., the number of signal cycles per hour). Based on this finding, they recommended the use of "red-light violations per 10,000 vehicle-cycles." They suggest that this statistic accurately normalizes the frequency of red-light-running in terms of two logical exposure measures (i.e., volume and yellow interval frequency), unlike the various statistics cited in the previous paragraph.

Based on a study of 10 intersections in Texas, Bonneson et al. (*11*) reported an average red-light-running rate of 1.0 violations per 10,000 vehicle-cycles. The frequency of red-light-running that coincides with this rate is shown in Figure 3-1. The trends in this figure indicate that red-light-running increases with increasing approach flow rate and with decreasing cycle length. For typical cycle length and flow rate combinations, the average busy intersection may experience between 2.0 and 6.0 red-light violations per hour.

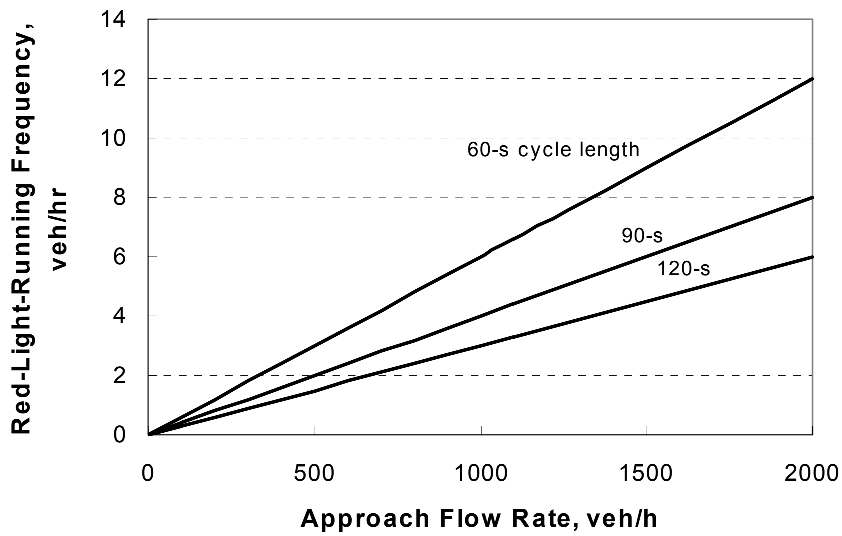

Figure 3-1. Effect of Flow Rate and Cycle Length on Red-Light-Running Frequency.

The examination of violation rates reported in the literature revealed significant differences in the definition of a red-light violation. Those studies that used an enforcement camera to measure violation frequency typically defined the violation as being an "any entry to the intersection after the grace period elapses." The issue in this instance is that the grace period typically varies among cities and camera vendors. Moreover, studies using manual observation typically define a violation as any entry after the onset of red (i.e., no grace period is used). These differences pose significant challenges to the comparison and interpretation of red-light violation rates among studies. A procedure to convert the violation rates obtained from various studies to a common grace period is needed to facilitate accurate comparisons and analysis of trends.

Entry Time of the Red-Light-Running Driver

Bonneson et al. (*11*) examined the extent to which a red-light-runner enters after the end of the yellow interval. Their findings are shown in Figure 3-2. Also shown is the extent to which a red-light-runner enters after the end of the all-red interval. The trends in this figure are based on 541 signal phases where at least one vehicle ran the red. In 60 of these 541 phases, the last red-light-runner to enter did so after the end of the all-red interval.

The trends in Figure 3-2 indicate that more than one-half of the red-light violations occurred in the first 0.5 s of red. The average red-running driver entered about 0.7 s after the end of the yellow interval. About 80 percent of the drivers entered within 1.0 s after the end of the yellow interval. This latter statistic is consistent with the trend reported by Lum and Wong (*38*). The most flagrant violation occurred when a driver entered 14 s after the all-red interval ended.

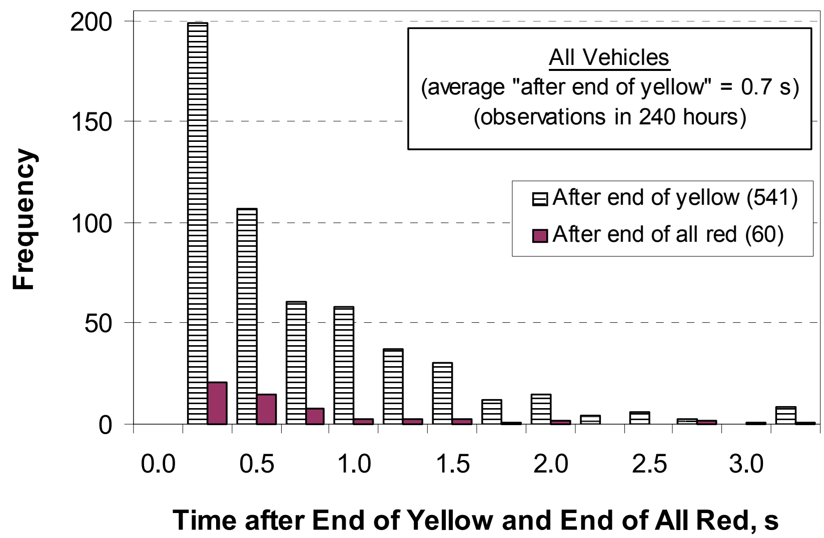

Figure 3-2. Frequency of Red-Light-Running as a Function of Time into Red.

Effect of Entry Time on Crash Frequency

The time after the end of the yellow indication at which the red-light-runner enters the intersection is logically correlated with the potential for a right-angle collision. As this "time into red" increases, crash frequency is also likely to increase. For example, drivers who run only the first 0.5 s of red are not likely to be involved in a crash because the conflicting vehicles typically have not yet begun to move into the intersection. On the other hand, drivers entering the intersection 2.0 s or more after the end of the yellow are likely to collide with a crossing vehicle.

The potential for a right-angle crash is logically influenced by the duration of the all-red interval. This interval is used to ensure that drivers who enter the intersection just at the end of the yellow interval have sufficient time to reach the far side of the intersection before a conflicting movement receives a green indication. Right-angle crashes are not likely to occur during the all-red interval. However, the potential for a right-angle crash is likely to increase with a vehicle's entry time after the end of the all-red interval.

In addition to right-angle crashes, left-turn-opposed crashes can also be caused by red-light violations, especially when the left-turn movement can turn permissively through gaps in the oncoming through traffic stream. In this situation, the left-turn driver waiting in the intersection at the end of the phase (i.e., onset of yellow) is highly motivated to complete the turn. This left-turn driver often assumes that (1) the approaching driver is also presented with a yellow indication and (2) the approaching driver will slow and stop if at all possible (i.e., that they will not try to run the red). Following these assumptions, the left-turn driver often turns in front of the approaching through vehicle as the yellow indication ends. If the through driver decides to run the first second of red (regardless of whether there is an all-red interval), a left-turn-opposed crash may occur.

Milazzo et al. *(7)* gathered enforcement camera photo log data for 27 right-angle crashes and seven left-turn-opposed crashes for the purpose of evaluating the relationship between entry time and crash occurrence. They found that all of the right-angle crashes occurred more than 3.0 s after the onset of the red indication (the median entry time was 6.7 s). In contrast, the left-turn-opposed crashes occurred sooner, with a median entry time of 1.9 s. Milazzo et al. did not indicate the extent to which the all-red interval influenced the time of crash occurrence.

Effect of Entry Time on Camera Violation Rates

As noted previously, enforcement cameras that use a grace period underestimate the true frequency of red-light-running. The trends in Figure 3-2 suggest that a grace period of 0.5 s will underestimate the true violation rate more than 50 percent. While these violations are not likely to be as problematic (from a safety standpoint) as those that occur several seconds after the end of the yellow interval, they should be included in the computation of violation rates such that they can be compared to the rates reported by other sources. Preferably, camera violation counts would be inflated to account for those violations occurring during the grace period. This adjustment would facilitate the assessment of relative trends and regional influences on red-light-running by allowing engineers to compare violation rates from different sources on an equitable basis.

Influence of Delay on Red-Light Violations

It is generally recognized that driver frustration due to excessive delay can lead to red-light-running. A survey by Porter and Berry *(39)* provided some insight into the reason why drivers run the red indication. One survey question asked what the respondent would do as a driver if he or she was "late" and faced with a red signal indication. Of the respondents who indicated they would run the red indication in this situation, the reasons offered by 80 percent of them related to their desire to eliminate further delay.

Observations at one busy intersection in Richardson, Texas, indicate that a red light is violated once every five minutes on average and once every two minutes during the peak traffic periods *(40)*. These times translate into 12 and 30 violations per hour during the off-peak and peak periods, respectively. Because delays tend to be higher during peak periods, these observations are further evidence that delay can influence a driver's propensity to run the red indication.

Bonneson et al. (*11*) published an equation for predicting the expected red-light-running frequency. This equation was derived as an expected value using a probability of stopping distribution following the onset of the yellow indication. The calibrated equation is:

$$E[R] = \frac{Q}{C} \frac{1}{0.927} \ln\left[1 + e^{0.927(\alpha - Y)}\right] \quad \textbf{(1)}$$

with,

$$\alpha = (2.30 + 0.0435\,V - 0.334\,Bp - 0.0180\,L_p + 0.220\,R_p) \times \frac{1}{0.927} \quad \textbf{(2)}$$

where,

E[R] = expected red-light-running frequency, veh/h;
α = travel time at which the probability of stopping is 0.5, s;
Q = approach flow rate, veh/h;
C = cycle length, s;
Y = yellow interval duration, s;
Bp = presence of back plates on the signal heads, (1 if present, 0 if not present);
V = average running speed, mph;
L_p = clearance path length, ft; and
R_p = platoon ratio (0.33 = poor progression, 1.0 = random arrivals, 2.0 = good progression).

By definition, Equation 2 predicts the travel time (in seconds) associated with a 50 percent chance of going (i.e., not stopping) in response to the yellow indication. Factors that increase this travel time also increase the frequency of red-light running.

Messer and Bonneson *(41)* found that the average travel time at which drivers enter the intersection after the onset of yellow ranges from 2.0 to 2.3 s travel time, depending on speed. They also found that this travel time increased with increasing volume-to-capacity ratio. They offered the following equation for computing the average travel time of the last driver to enter after the onset of the yellow indication:

$$t_y = 1.48 + 0.027\,V + 6.40\,(X - 0.88)\,I_X \quad \textbf{(3)}$$

where,

t_y = average travel time of last driver to enter after yellow onset, s;
X = volume-to-capacity ratio; and
I_X = indicator variable, (1 if $X > 0.88$, 0.0 otherwise).

Equations 2 and 3 predict effectively the same driver characteristic: the travel time of the last driver to enter after yellow onset. If it can be assumed that the distribution of these times is approximately normal, then the mean and median travel times are effectively equal. In which case, the volume-to-capacity ratio term in Equation 3 can be combined with Equations 1 and 2 as follows:

$$E[R] = \frac{Q}{C} \frac{1}{0.927} \ln\left[1 + e^{(2.30 + 0.0435\,V - 0.334\,Bp - 0.0180\,L_p + 0.220\,R_p + 5.93\,(X - 0.88)\,I_X - 0.927\,Y)}\right] \quad \textbf{(4)}$$

Equation 4 represents the logical synthesis of two, separately calibrated models. However, it will require calibration using a common database before it can be used for practical purposes. Nevertheless, it can still be used to examine the likely effect of volume-to-capacity ratio on red-light-running frequency. Extension of this model to delay should follow easily given the direct relationship between delay and volume-to-capacity ratio. It is important to note that Equation 4 suggests that volume-to-capacity ratios less than 0.88 do not have an effect on the frequency of red-light-running.

Figure 3-3 illustrates the effect of volume-to-capacity ratio on the frequency of red-light-running, as predicted by Equation 4. The trends shown in this figure indicate the significant effect of congestion (as exhibited by volume-to-capacity ratios of 0.9 or more) on the frequency of red-light-running. In fact, these trends suggest that an intersection with a volume-to-capacity ratio of 1.0 is likely to have 80 percent more red-light-running than an intersection with a ratio of 0.88 or less.

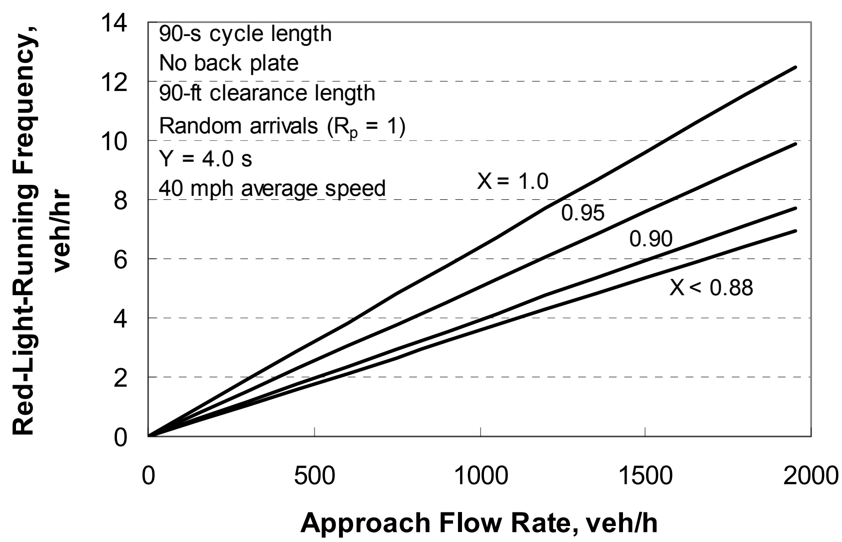

Figure 3-3. Effect of Volume-to-Capacity Ratio on Red-Light-Running Frequency.

RED-LIGHT-RUNNING-RELATED CRASHES

This section examines the issues associated with the identification of red-light-running-related crashes in public agency crash databases. These issues relate to: (1) the challenges of using the available attributes in these databases to accurately identify crashes caused by red-light-running, and (2) to the extensive under-reporting of the less severe crashes allowed by most agencies. Also examined is the severity of red-light-running-related crashes, relative to other crashes. Finally, the societal cost implications of these crashes is examined.

Identifying a Red-Light-Running-Related Crash

Red-Light-Running-Related Crashes

There is an inherent difficulty in using most crash databases to accurately quantify the frequency of red-light-running-related crashes. This difficulty lies in the fact that many cities and states do not flag crashes as being caused by red-light-running. As a result, red-light-running-related crashes are often identified using a combination of "right-angle crash" and either "disregard stop and go signal" or "failure to obey traffic control"(*9*).

Unfortunately, use of the aforementioned attribute combination for identifying a right-turn-related crash is not perfect. For example, "disregard stop and go signal" can include signaling devices other than a traffic control signal (e.g., flashing beacon, lane use control signal). It can also include maneuvers that are not true red-light-running events (e.g., right-turn on red after stop) (*9*). The "failure to obey traffic control" attribute is even more vague as it typically includes a wider range of control devices (e.g., stop sign, lane markings, officer, etc.). While use of the aforementioned attribute combination is likely to identify a large percentage of the red-light-running-related crashes, it is also likely that some non-red-light-running-related crashes will be included and that some red-light-running-related crashes will be excluded from the subset database.

In short, an accurate identification of the true number of red-light-running-related crashes is difficult at best (as it may require a manual review of the crash report) and impossible at worst (should the original report be destroyed or not contain sufficient details of the crash). Unfortunately, many agencies currently report the frequency of "red-light-running-related crashes" but do not explain the method by which they identify these crashes (*6, 8*). This practice makes it very difficult to confidently compare the crash data or countermeasure effectiveness that is reported by different agencies. Extrapolation of findings to other locations and combining measures of effectiveness is practically impossible without a consistently applied definition of a "red-light-running-related" crash.

Right-Angle Crashes

In recognition of the aforementioned challenges, many agencies have decided to focus their analysis on right-angle crashes because it is the one crash type most commonly associated with a red-light violation (*28, 29, 32*). However, Milazzo et al. (*7*) have pointed out that a significant percentage of red-light-running-related crashes involve at least one left-turning vehicle. The data they report indicate that these crashes may constitute about 20 percent of the red-light-running-related crashes. Hence, the use of right-angle crashes as a screening criterion may result in only about 80 percent of the actual red-light-running-related crashes being identified.

Left-Turn-Opposed Crashes

As noted in the preceding paragraph, red-light violators are also believed to be responsible for some left-turn-opposed crashes that occur when the left-turn movement is "permissive" (i.e., the left-turning driver can legally turn through gaps in the oncoming through traffic stream during the through phase). Logically, a reduction in red-light violations would result in a reduction in both angle and left-turn-opposed crashes, if the left-turn movement is permissive. However, no study of countermeasure effectiveness could be found that examined the change in left-turn-opposed crashes.

Rear-End Crashes

There has been some concern expressed that camera enforcement is associated with an increase the frequency of rear-end crashes (*5*). It is theorized that drivers react to the heightened level of red-light-running enforcement by increasing their likelihood to stop after the onset of yellow. This increased likelihood is believed to be the reason that rear-end crashes have been found to increase at some intersections with cameras (*14, 28, 32*). In recognition of this concern, several engineers have determined that it is important to consider both right-angle and rear-end crashes when evaluating camera effectiveness. For example, one city (*7*, p. 35) defines red-light crashes as consisting of all right-angle crashes and one-half of the rear-end crashes. Similarly, at least one researcher (*33*) has evaluated the effectiveness of camera enforcement using the *total* number of right-angle and rear-end crashes.

Red-Light-Running-Related Crash Severity

Crash Type Distribution

Red-light-running is generally recognized as a problem that poses a significant safety hazard. The extent of the safety problem can be appreciated through a review of the FARS database. This database was reviewed to determine the distribution of fatal crashes in Texas and the U.S. The results of this review are summarized in Table 3-1.

The data in Table 3-1 illustrate the distribution of fatal crashes reported in Texas and the U.S. for 2001. Five crash attributes were used to identify the relevant red-light-running-related crashes. These attributes included:

- Traffic Control: stop and go signal,
- Intersection Relationship: at intersection or intersection-related,
- First Harmful Event: collision with a second vehicle,

- Manner of Collision (i.e., Crash Type):   right-angle, and
- Contributing Factor: disregard of traffic control devices or officers.

It should be noted that "left-turn-opposed" was not explicitly included in the categories associated with Manner of Collision. It is likely that these crashes are distributed among the angle, side-swipe, and head-on categories. It should also be noted that a few right-turn-on-red crashes may be excluded by the use of these five attributes.

Table 3-1. Fatal Crash Frequency Distribution for 2001.

Traffic Control & Intersection Relationship	First Harmful Event	Manner of Collision	Texas			United States		
			Contributing Factor		Total	Contributing Factor		Total
			Dis. Signal [1]	All Other		Dis. Signal [1]	All Other	
Signal-controlled junction (or junction related)	With second vehicle	Angle	**118**	229	347	**953**	2661	3614
		Rear-end	2	51	53	15	425	440
		Side-swipe	0	7	7	2	41	43
		Head-on	2	17	19	22	171	193
		Other	0	0	0	0	4	4
	With object	--	3	33	36	58	721	779
	Total signalized junctions:		125	337	**462**	1050	4023	**5073**
Other	all	all	--	--	2848	--	--	32,722
Total Fatal Crashes:			--	--	**3310**	--	--	**37,795**
Red-Light-Running-Related Crash Distribution [2]								
Percent of total signalized junctions: [3]			26	50	75	19	53	71
Percent of total fatal crashes:			4	7	11	3	7	10

Notes:
1 - Disregard traffic control devices or traffic officers.
2 - Red-light-running-related crashes defined as all right-angle crashes with a second vehicle at (or related to) a signal-controlled intersection where disregard of the control device is a related factor.
3 - Underlined values are significantly different (95 percent level of confidence in this claim).
"--" not applicable.

The data in Table 3-1 indicate that there were 118 fatal red-light-running-related crashes in Texas in 2001, or about 26 percent of the fatal crashes at signal-controlled junctions. In contrast, there were 953 fatal red-light-running-related crashes in the U.S. representing 19 percent of the fatal crashes at signal-controlled junctions crashes. A statistical analysis of these percentages indicates that Texas has a significantly higher percentage of fatal red-light-running-related crashes than the U.S. as a whole.

Some additional points are worth noting, as they relate to the trends in Table 3-1. First, it should be noted that a majority of the signalized intersection right-angle crashes did not have "disregard of the control device" as a contributing factor (i.e., 229 of 347 in Texas, 2661 of 3614 in the U.S.). This trend suggests that an analysis of red-light-running countermeasure effectiveness that is focused only on angle crashes (without regard to contributing factors) may be misled by the inclusion of crashes that are not red-light-running related.

Second, the number of fatal rear-end crashes is relatively low when expressed as a percentage of all fatal signal-controlled junction crashes. Specifically, rear-end crashes accounted for only 11 percent (= 100 × 53/ 462) of the fatal crashes in Texas and 9 percent of those in the U.S. Rear-end crashes typically account for 30 to 40 percent of all intersection crashes (*42*). It is possible that some rear-end crashes are being associated (by the officer or analyst) with an upstream, unsignalized driveway when they should be recorded as related to the signalized intersection. In this situation, "proximity to a driveway" is mistakenly used for location identification as opposed to "crash cause" (i.e., back up of a queue from the signalized intersection).

Third, the relative contribution of red-light-running-related crashes to the total number of fatalities should be noted to provide the proper context for addressing it as a problem. Specifically, red-light-running-related crashes constituted about 3 percent of all fatal crashes in the U.S. in 2001. Similarly, they accounted for about 4 percent of the fatal crashes in Texas in 2001.

Geographic Distribution of Crashes

A recent review of the FARS database by the Insurance Institute for Highway Safety provides some indication of the consequences of red-light-running in Texas (*2*). The data from this analysis are reproduced in Table 3-2.

The data shown in Table 3-2 indicate the number of fatalities associated with red-light-running-related crashes and a "fatality rate." This rate is expressed in terms of the number of fatalities per 100,000 persons. The locations are ranked in terms of their fatality rate. The rankings indicate that Texas has the fourth highest fatality rate (with an average of 95 red-light-running-related fatalities per year). Only the states of Arizona, Nevada, and Michigan had more fatalities per capita than Texas. In addition, five Texas cities ranked in the top 28 cities with the highest red-light-running-related fatality rate.

Relationship to All Intersection Crashes

As discussed in the preceding section, red-light-running causes a significant portion of the fatal crashes at signalized intersections. However, it also causes many non-fatal crashes. In particular, there are likely to be several hundred injury crashes and an equal number of property-damage-only (PDO) crashes for every fatal crash. Unfortunately, the PDO crash is difficult to accurately quantify because of recent trends to increase the crash reporting threshold. For example, Texas law currently requires the use of a $1000 (per vehicle) crash cost reporting threshold. This threshold has been used since 2001. Prior to that time, a threshold of $500 crash cost was used between 1990 and 2001 and a $250 crash cost was used before 1990 (*3*). In contrast, many other cities and states use a threshold of $250 per crash. These differences make comparison of crash trends difficult between Texas and these other cities and states.

Table 3-2. Geographic Distribution of Fatal Red-Light-Running-Related Crashes.

Unit	Rank	Location	RLR Fatalities [1] Between 1992-1998	Population 1992-1998	Fatality Rate [2] (fatalities per 100,000 persons)
City	1	Phoeniz, AZ	122	1,125,599	10.8
	2	Memphis, TN	49	614,067	8.0
	3	Mesa, AZ	26	333,756	7.8
	4	Tucson, AZ	34	445,840	7.6
	5	St. Petersburg, FL	18	237,480	7.6
	6	Birmingham, AL	18	256,386	7.0
	7	**Dallas, TX**	**73**	**1,047,816**	**7.0**
	13	**Corpus Christi, TX**	**15**	**275,536**	**5.4**
	16	**Austin, TX**	**26**	**527,653**	**4.9**
	21	**Houston, TX**	**80**	**1,742,794**	**4.6**
	28	**El Paso, TX**	**25**	**584,343**	**4.3**
State	1	Arizona	305	4,280,990	7.1
	2	Nevada	59	1,529,841	3.9
	3	Michigan	355	9,655,540	3.7
	4	**Texas**	**663**	**18,677,046**	**3.5**

Notes:
1 - RLR: red-light-running.
2 - Rank based on fatality rate.

The distribution of crash severity, as reported by several agencies, was examined to determine the effect of differences in reporting threshold (*7, 43, 44*). The results of this analysis are shown in Table 3-3. The data in this table are categorized as red-light-running-related and signalized-intersection-related crashes. Crashes in the latter category include all crashes related to the intersection (including red-light-running crashes). The data identified as "U.S." were obtained from the FARS database as well as the General Estimates System (*44*).

There are several interesting trends in Table 3-3. First, the ratio of injury crashes per fatal crash ranges between 128 and 184 for the red-light-running-related crashes. For intersection-related crashes, the corresponding range is between 136 and 200. This trend suggests that red-light-running-related crashes are slightly more severe than the typical intersection crash. This trend is also evidenced in the "percent injury crashes" row and is consistent with the trend reported by Retting et al. (*1*).

Table 3-3. Distribution of Crash Severity.

Severity [1]	Red-Light-Running-Related Crashes			Signalized-Intersection-Related Crashes		
				Associated [2]	At the Intersection	
	Texas	Austin	Richardson	U.S.	Richardson	N. Carolina
Fatal crashes per year	95	5	1	2703	2	32
Injury crashes per year	13,694	615	123	486,000	467	4345
PDO crashes per year	7454	--	96	834,000	476	4385
Total crashes per year	21,243	--	220	1,322,703	946	8762
Number of years	4	5	3	1	3	1
Distribution of Crashes by Severity						
Injury-to-fatal ratio	144	128	184	180	200	136
Percent injury crashes	64	--	56	37	49	50
Percent PDO crashes	35	--	44	63	50	50
Reference:	by authors	(*43*)	by authors	(*44*)	by authors	(*7*)

Notes:
1 - PDO: property-damage-only crash.
2 - Crashes associated with a signalized intersection may occur at (or within) the intersection or along its approaches.
"--" - data not available.

A second trend in Table 3-3 relates to the percentage of PDO crashes. This percentage ranges between 35 and 44 percent for red-light-running-related crashes and between 50 and 63 percent for intersection-related crashes. The 63 percent value associated with the FARS data (i.e., the column headed U.S.) is consistent with values reported by others (*45, 46, 47*). PDO percentages less than 63 percent reflect fewer reported PDO crashes and are likely due to an increase in the reporting threshold in Texas in recent years.

Relationship between Red-Light Violation Rate and Crash Rate

A review of the literature revealed only one reference that related red-light violation rate with crash rate. Specifically, Bonneson et al. (*11*) compared the violation rate observed during one six-hour day at 12 intersection approaches with the three-year crash history for these approaches. Only right-angle and left-turn-opposed crashes were included in their analysis. The average (two-way) daily traffic demands on the subject approach leg varied from 7000 to 49,000 vehicles per day. Non-linear regression techniques were used to calibrate an exponential model. The trends predicted by this model are illustrated in Figure 3-4.

The trend lines in Figure 3-4 indicate that crash frequency is higher on those approaches with higher red-light violation rates. The concave shape to the trend lines indicates that the rate of increase in crashes declines with an increase in violation rate. This relationship suggests that drivers become more careful at intersections they perceive to have more frequent red-light violations (or perhaps, more safety problems in general). The trends also confirm that crash rate increases with an increase in crossroad daily traffic volume ADT_c.

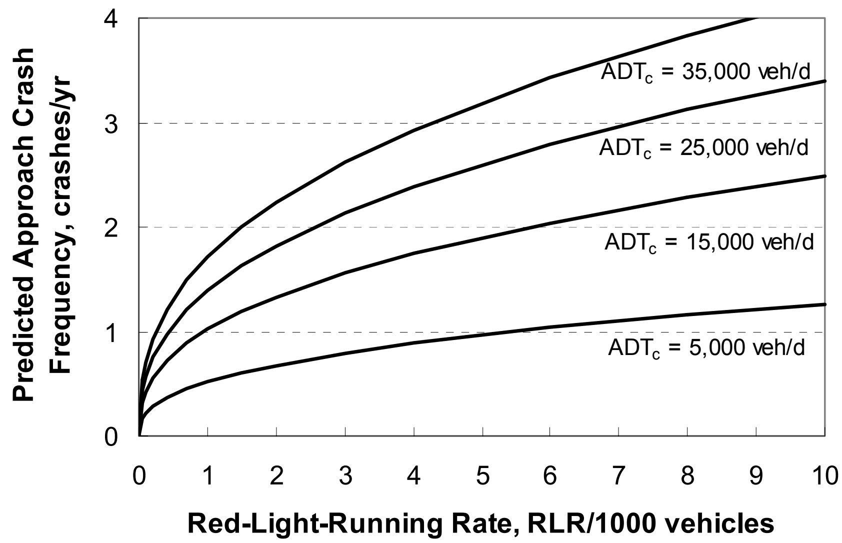

Figure 3-4. Relationship between Red-Light Violation Rate and Crash Rate.

Cost of Red-Light-Running Crashes

An examination of the DPS crash database by Quiroga et al. (*3*) revealed that the reported number of persons killed or injured in red-light-running-related crashes in Texas has grown from 10,000 persons/yr in 1975 to 25,000 persons/yr in 1999. They estimate that these crashes currently impose a societal cost on Texans of $1.4 to $3.0 billion annually.

CHAPTER 4. DATA COLLECTION PLAN

OVERVIEW

This chapter documents the data collection plan for six studies. Collectively, these studies are intended to provide information about: (1) the characteristics of red-light violations, (2) the characteristics of red-light-related crashes, and (3) the effectiveness of enforcement programs. Within each of these three categories, the literature review documented in Chapters 2 and 3 identified several areas where additional research was needed to achieve the project objectives. Six studies were identified to address each of these research needs. These studies are identified in Table 4-1.

Table 4-1. Study Descriptions.

Study Description [1]	Information Category [2]		
	Characteristics of Red-Light Violations	Characteristics of Red-Light Crashes	Effectiveness of Enforcement Programs
1. Distribution of RLR-Related Crashes by Type and Cause		Chapter 3	
2. Influence of Delay on Red-Light Violations	Chapter 3		
3. Influence of Officer Enforcement on Crash Frequency			Chapter 2
4. Influence of Red-Light Violations on Related Crashes		Chapter 3	
5. Distribution of RLR-Related Crashes by Time-into-Red		Chapter 3	
6. Influence of Camera Enforcement on Crash Frequency			Chapter 2

Notes:
1 - RLR: red-light-running.
2 - Chapter listed indicates where the need for this study was discussed.

The analysis of the data collected for Study 1 is the subject of discussion in Chapter 5. The data collected for Studies 2 through 6 will be analyzed during the next year of this project. At that time, the findings from all the analyses will be used to develop guidelines for identifying and treating intersections with red-light-running-related safety problems.

DATA COLLECTION PLANS FOR INDIVIDUAL STUDIES

This section describes the data collection plan for each of the six studies. Each plan is discussed in a separate subsection. Within each subsection, the objective of the study is defined; the data collected are identified; the source of these data is described, and the method by which they were collected is detailed.

Study 1 - Distribution of Red-Light-Running-Related Crashes by Type and Cause

Objective of Study

The objective of this study is to characterize crashes that are red-light-running related. The development of these characterizations was based on an examination of the crash database attributes most commonly used to describe a red-light-running crash. The crash attributes considered include:

- Intersection Relationship: at intersection, associated with intersection;
- First Contributing Factor: driver inattention, disregard signal, etc.; and
- Crash Severity: PDO, injury, fatality.

The severity data were used to estimate the degree of crash under-reporting that occurs in Texas and to compute the average cost of a red-light-running-related crash. These findings were then used with the DPS database to estimate the impact and extent of red-light-running in Texas.

Database Composition

The database assembled for this study consisted of the details associated with each crash occurring in the vicinity of a signalized intersection. Most of these details were extracted from the actual crash report used by Texas peace officers (i.e., Form ST-3). They include:

- distance from intersection,
- time of crash,
- travel direction of each vehicle,
- factors contributing to the crash,
- number of injuries, and
- severity of injuries.

A sample crash report is included in the Appendix.

In addition to the extraction of the above data, the narrative and collision diagram on the crash record were used to determine the following crash attributes:

- Crash Type: right-angle, left-turn-opposed, etc.; and
- Red-Light-Running Relationship.

Study Sites

Crash reports were gathered for 25 intersections in each of three cities. These reports coincided with crashes occurring in the vicinity of the subject intersection during the three most recent calendar years for which the records were available. The intersections included in the study were selected randomly such that the corresponding crash data reflected a cross section of typical urban Texas intersections. In this instance, "typical" was defined to include a speed limit in the range of 30 to 45 mph, adequate driver sight distance along the intersection approaches, visible pavement markings, and uncongested traffic operation. This approach was reasoned to provide a reasonable basis for extrapolation of trends to all urban intersections in Texas. The cities within which these intersections are located include: Corpus Christi, Garland, and Irving.

Data Acquisition Approach

A traffic engineer with each of the aforementioned cities was contacted and their assistance requested for this study. This assistance included: (1) identifying 25 randomly selected intersections, (2) making available crash reports for photocopy, and (3) providing traffic count information. The research project resources (i.e., labor and funding) were made available to the agency to minimize the cost of copying the crash reports.

The data collection schedule is identified in Table 4-2. Crash reports and volumes were acquired during Task 1. These data were entered into a spreadsheet database as part of Subtask 3.1. The analysis of these data took place during Subtask 3.2. The findings are described in Chapter 5.

Table 4-2. Data Collection Schedule for Study 1.

Task	Fiscal Year 2003												Fiscal Year 2004											
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
1. Evaluate State-of-the-Practice	■	■	■																					
2. Develop Data Collection Plan		□	□	□	□																			
3. Evaluate Safety Impact of RLR				■	■	■	■	■	■															
4. Evaluate RLR Factors						□	□	□	□	□	□													
5. Prepare Research Report										□	□	□												
6. Procedure to Identify Problem Locations													□	□	□	□								
7. Evaluate Effectiveness of Enforcement													□	□	□	□	□	□						
8. Procedure to Identify Countermeasures																	□	□	□	□	□			
9. Develop RLR Handbook																		□	□	□	□	□	□	
10. Prepare Research Report																						□	□	□
Legend:	■	Task associated with study.											□	Other research tasks.										

Study 2 - Influence of Delay on Red-Light Violations

Objective of Study

The objective of this study is to expand the database used to calibrate the red-light violation prediction model developed for TxDOT Project 0-4027 (*11*). Specifically, this database will be expanded to include motorist delay. Thereafter, it will be used to examine the relationship between red-light violation frequency and delay. If a statistically significant relationship is found, it will be incorporated into the prediction model (shown previously as Equation 1).

Database Composition

The data listed in Table 4-3 were collected to create the expanded database. Specifically, they were collected for the through traffic movement at each of several study sites. A study "site" is defined here to be one intersection approach.

Table 4-3. Data Collected for Study 2.

Site-Specific Data	Signal-Cycle-Specific Data
Yellow and All-Red interval duration	Cycle length
Geometry (lane assignments, grade)	Count of vehicles crossing stop line
Approach speed limit	Count of vehicles crossing stop line during last 8 s of green
Signal phasing	Count of trucks crossing stop line
Running speed (100 observations)	Count of vehicles crossing stop line after red indication
--	Count of trucks crossing stop line after red indication
--	Time last vehicle crosses stop line after red indication
--	Count of queued vehicles (to facilitate delay estimate)

With the exception of the queued-vehicle-count data, all of the data listed in Table 4-3 is consistent with the data in the database assembled for Project 0-4027. The queued-vehicle-count data were added to facilitate the estimation of approach control delay. These data were extracted from videotape recordings of traffic conditions at each site. The procedure for data extraction and reduction followed that described in Appendix A, Chapter 16 of the *Highway Capacity Manual* (*48*).

Queued-vehicle-count data were also extracted from the videotapes recorded during Project 0-4027. A total of 73 hours of traffic operation at 16 sites were reviewed for this purpose.

The signal-cycle-specific data listed in Table 4-3 were collected during a minimum of six hours of observation at each study site. The study period included at least one peak traffic hour. One videotape recorder was used to record the signal-cycle-specific data on each intersection approach. A second videotape recorder was used to record the number of queued vehicles on the intersection approach. This second recorder was used to record queuing conditions during one 15-minute period near the start of each of the six hours. The average delay estimate obtained from this sample was assumed to be representative of the entire hour.

A sampling technique was also used to estimate the approach running speed. This speed sample was taken for through vehicles that arrived during the green indication and proceeded through the intersection. In this manner, the speed that was measured reflected that of the population of drivers who would have to react to the onset of a yellow indication. Measurement of 100 vehicle speeds using this technique was computed to provide an estimate of the average running speed with a precision of ±1.0 mph or less.

Study Sites

Red-light violations were recorded at eight study sites (i.e., two approaches at each of four intersections). The study sites were located in the City of Irving and included only those intersections for which crash reports were acquired in Study 1. This approach to site selection facilitated an examination of the relationship between red-light violations and crash history in Study 4. The intersections studied were selected from the list of 25 intersections for which crash reports were obtained. Additional criteria used for site selection included:

- approach speed limit should be between 30 and 55 mph,
- pavement markings should be clearly visible,
- approaching drivers should have a clear view of the signal heads for 7-s travel time,
- intersection should be in an urban or suburban area,
- no more than three through lanes on the intersection approach,
- minimum approach volume of 400 veh/hr/lane during the peak hour, and
- current average daily traffic estimate should be available for each intersecting street.

It was considered desirable if all of these criteria could be satisfied by each study site. The degree to which they are satisfied would logically be reflected in the usefulness of the findings, in terms of their applicability to a large number of intersections. However, it was also recognized that these criteria were goals rather than objectives because it was not possible to fulfill all the criteria given the time and resources available to the site selection process.

Of the three cities identified in Study 1, only the City of Irving had not recently undertaken an enforcement program targeting intersection traffic control violations. The Cities of Corpus Christi and Garland had each participated in TxDOT's Selective Traffic Enforcement Projects (STEPs) during recent years. This heightened level of enforcement activity would make it difficult to correlate crash history with current red-light violation trends (which is the focus of Study 4). Therefore, it was determined that the four intersections studied should all be located in Irving. In this manner, the data collected at these intersections would satisfy the selection criteria for both Study 2 and Study 4.

Field Study Procedures

Each field study consisted of the simultaneous study of two opposing approaches at a signalized intersection. At any one study site, one video camera was mounted on a tripod located behind the curb at a point about 150 ft upstream of the stop line. This camera was pointed toward the intersection and used to record red-light violations, counts, and signal indications during the six-hour study. Its location is illustrated in Figure 4-1.

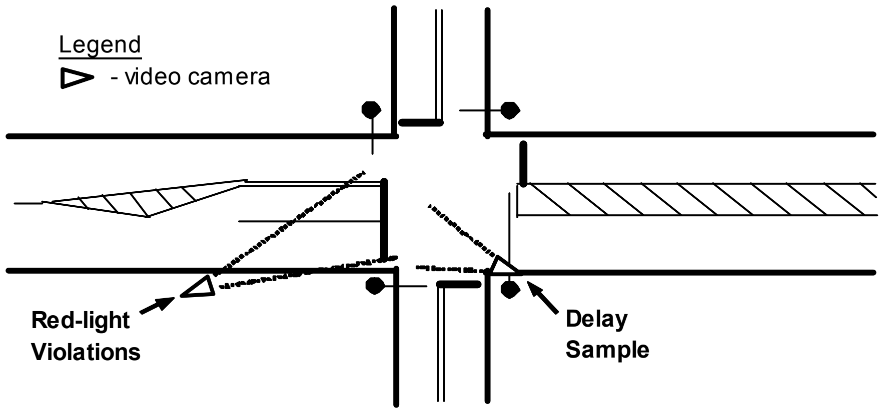

Figure 4-1. Video Camera Location during Data Collection.

A second camera was also located on the same approach as the "violation" camera. This camera was located near the stop line and pointed toward oncoming vehicles. It was used to monitor approach traffic and record the number of queued vehicles for one 15-minute period during each of the six study hours.

The clocks for both cameras were synchronized at the start of the study. In this manner, the queue information recorded by the second camera could be coordinated with the signal indication status information recorded by the first camera. Both types of information were needed for the delay computation.

The data collection schedule for this study is identified in Table 4-4. The field study took place in Irving during the first week of May 2003. It represented the work activity for Subtask 4.1. The data reduction took place during the Summer of 2003 and represented Subtask 4.2. The analysis of these data will occur during the next year of the project (i.e., Fiscal Year 2004).

Study 3 - Influence of Officer Enforcement on Crash Frequency

Background

The effect of officer enforcement on traffic violations was described in Chapter 2. The findings cited in this chapter suggest that: (1) targeted officer enforcement of specific intersections only reduces crashes by a few percentage points, and (2) the reductions are often short-lived (i.e.,violation rates return to pre-enforcement levels within a hour or two after the officer leaves the intersection). The more successful officer enforcement efforts were found to be those that were: (1) implemented on an "area-wide" basis with innovative enforcement strategies (e.g., increased presence, random location selection), and (2) inclusive of a public awareness campaign (e.g., media advertisement, public meetings, posters, etc.).

Table 4-4. Data Collection Schedule for Study 2.

Task	Fiscal Year 2003												Fiscal Year 2004											
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
1. Evaluate State-of-the-Practice	□	□	□																					
2. Develop Data Collection Plan		□	□	□	□																			
3. Evaluate Safety Impact of RLR				□	□	□	□	□	□															
4. Evaluate RLR Factors						■	■	■	■	■	■													
5. Prepare Research Report										□	□	□												
6. Procedure to Identify Problem Locations													□	□	□	□								
7. Evaluate Effectiveness of Enforcement													□	□	□	□	□	□						
8. Procedure to Identify Countermeasures																	□	□	□	□	□			
9. Develop RLR Handbook																		□	□	□	□	□	□	
10. Prepare Research Report																						□	□	□
Legend:	■	Task associated with study.											□	Other research tasks.										

Through its Traffic Safety Section, TxDOT has awarded grants, called Intersection Traffic Control STEPs (ITC-STEPs), to local law enforcement agencies in Texas. The purpose of these grants is to facilitate heightened enforcement efforts at intersections where the crash history indicates a disproportionately high number of crashes are occurring. Eighteen Texas cities have participated in the ITC-STEP program since it started in 1997. Each program includes an area-wide enforcement activity and a public awareness campaign. Most programs last for one or two fiscal years. At the conclusion of the program, the participating agency submits a report documenting program success. Items listed in the report include:

- number and type of citations/arrests issued as part of STEP-funded enforcement,
- number and type of citations/arrests issued by participating agency,
- number of STEP enforcement hours worked,
- number of intersection traffic-control-related crashes,
- number of presentations conducted in support of the grant,
- number of persons attending presentations,
- number of community events in which STEP officers participated (i.e., health fairs, booths),
- number of media exposures (i.e., news releases and interviews), and
- number of public information and education materials distributed (e.g., key tags).

The research team discussed enforcement effectiveness with several city traffic engineers, administrators in TxDOT's Traffic Safety Section, and police departments. The conclusion reached from these discussions was essentially the same as the findings documented in Chapter 2. Specifically, "area-wide" enforcement is preferred by enforcement agencies when charged with making significant reductions in traffic violations. Targeting specific intersections for enforcement is viewed as not being cost-effective in terms of the investment of the officer's time relative to number of violations (and crashes) reduced.

The STEP funds enable enforcement agencies to focus their efforts on particular types of violations (e.g., intersection traffic control) and reduce the frequency of these violations through a combination of heightened enforcement and public awareness. The disadvantages of this type of "area-wide" enforcement are: (1) that it is costly to implement, and (2) the simultaneous use of innovative enforcement strategies and public awareness activities makes it impossible to determine the relative effectiveness of any one activity. With rare exception, the program cannot be sustained by the local agency after the STEP grant funding is expended.

It is interesting to note that, if the effectiveness of the innovative strategies and public awareness activities were individually quantified, then the local enforcement agency might be able to develop and implement a sustainable enforcement program targeting control violations. In this regard, a sustainable program would be tailored to fit within the agency's budget and would include only the one or two most effective strategies or activities. Unfortunately, the effectiveness of the individual strategies and activities used in the ITC-STEP program has not been quantified.

Objective of Study

The objective of this study is to quantify the effect of area-wide officer enforcement of intersection traffic control on red-light-running-related crashes. Activities directed at achieving this objective focused on the ITC-STEP program administrated by TxDOT. A database was established using the information provided in the agency reports (as described in the previous section). It is envisioned that the findings from an analysis of these data will provide a quantitative relationship relating the level of enforcement and public awareness activity to the frequency of red-light-running-related crashes. A "before-after" study approach will be used to quantify the incremental effect of the STEP-related enforcement activities at the participating cities.

Database Composition

The database developed during this study describes the citywide history of enforcement activities, public awareness events, and signalized intersection crashes. The observational unit in the database is a "one year" record of activities, events, and crashes. The "year" is defined by the beginning and ending dates of the STEP program funding year (i.e., 10/1 through 9/30).

A two or three-year crash history for each city was gathered for the years prior to implementation of the STEP program. The city's crash history was also gathered for each year that it participated in the STEP program. These data were obtained from the DPS crash database. The database assembled for this study includes all red-light-running-related crashes at signalized intersections in each city, as determined by the crash location, traffic control, and contributing factor data filed with each crash report.

Quantitative data describing the enforcement strategies and public awareness activities conducted as part of the STEP program were obtained from the program evaluation report (or, when necessary, the monthly performance reports) submitted by the program participants. Most of these data were previously listed in the Background section. All reports were obtained from TxDOT's Traffic Safety Section.

Demographic information for each city represented in the database was also gathered. As with the crash data, the observational unit was a one-year period, as defined by the STEP funding year. These data reflect demographic conditions present during each of the funding years represented by the crash data. Demographic data collected include:

- population of city,
- number of registered vehicles in city,
- number of licensed drivers in city, and
- number of full-time police officers employed by city (or officers assigned to traffic control).

These data were gathered from the DPS and the city police departments, as appropriate.

Study Sites

Table 4-5 identifies eight Texas cities that have participated in the ITC-STEP program between the years 1997 and 2000. These cities were included in the database assembled for this study. They were selected because their participation occurred during one or more years for which crash data were also available from the DPS database.

Table 4-5. Cities Included in Database for Study 3.

Type	City	STEP Funding Year			
		1997	1998	1999	2000
ITC-STEP Participant	Austin	Before	Before	Before	✔
	Bryan	Before	Before	✔	✔
	Dallas	Before	Before	Before	✔
	Denton	Before	Before	Before	✔
	Fort Worth	Before	Before	Before	✔
	Garland	Before	Before	✔	✔
	Midland	Before	Before	Before	✔
	Plano	Before	Before	✔	✔
Comparison	College Station				
	Corpus Christi				
	Pasadena				
Corresponding Dates:		10/1/96 to 9/30/97	10/1/97 to 9/30/98	10/1/98 to 9/30/99	10/1/99 to 9/30/00

Note:
✔ - participated in ITC-STEP program.

Data were also collected for three “comparison” cities. These cities were selected because they did not participate in the ITC-STEP during funding years 1997 through 2000. These comparison cities are listed in Table 4-5. The crash history for these cities was used to control for the changes in crash frequency that may occur during the analysis years for reasons other than the influence of STEP activities.

Data Acquisition Approach

The data collection schedule is identified in Table 4-6. The STEP data were gathered during Task 6. The DPS and TxDOT’s Traffic Safety Section were contacted during the summer of Fiscal Year 2003 for the purpose of obtaining the data needed to assemble the database. These data will be analyzed during Subtask 7.3. The results of this analysis are expected to be available at the end of January 2004.

Table 4-6. Data Collection Schedule for Study 3.

Task	Fiscal Year 2003												Fiscal Year 2004											
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
1. Evaluate State-of-the-Practice	□	□	□																					
2. Develop Data Collection Plan		□	□	□	□																			
3. Evaluate Safety Impact of RLR				□	□	□	□	□	□															
4. Evaluate RLR Factors						□	□	□	□	□	□													
5. Prepare Research Report										□	□	□												
6. Procedure to Identify Problem Locations										●	●	●	□	□	□	□								
7. Evaluate Effectiveness of Enforcement													■	■	□	□	□	□						
8. Procedure to Identify Countermeasures																	□	□	□	□	□			
9. Develop RLR Handbook																		□	□	□	□	□	□	
10. Prepare Research Report																						□	□	□
Legend:	■	Task associated with study.											□	Other research tasks.										

Note:
● - Data collection activities for Task 6 began in June of Fiscal Year 2003.

Study 4 - Influence of Red-Light Violations on Related Crashes

Background

A relationship between red-light violation rate and crash frequency was reported by Bonneson et al. (*11*) for TxDOT Project 0-4027. Their analysis related the violation rate observed during one typical day on each of 12 intersection approaches with the crash history of that approach, as shown previously in Figure 3-4. The crash history used in this analysis included the “right-angle” and “left-turn-opposed” crashes that had occurred on the approach during the previous three years. The relationship they found indicated that the combined frequency of right-angle and left-turn-opposed crashes was higher on approaches with higher red-light violation rates. The quality of fit to the data was good, but the number of sites was limited; hence, data from several more sites were determined to be needed.

Objective of Study

The objective of this study is to quantify the relationship between the red-light violation rate and red-light-running-related crash frequency at typical intersections. Red-light-running-related crashes were determined by careful analysis of officer crash reports for eight intersection approaches. Specifically, the crash data from Study 1 and the red-light-running data from Study 2 were used for this study; no additional data were collected. Ultimately, the calibrated relationship between violation rate and crash frequency will be used to develop guidelines for identifying intersection approaches with a red-light-running problem based on an examination of their crash history.

An alternative study approach was considered that included the use of red-light violation data from existing enforcement cameras at intersections in other states. For this approach, the crash history for a camera-enforced approach would be compared with the red-light violations recorded by the camera for the same time period. The advantage of this approach is that the crash history and the violation frequency would be "synchronized" because they represent a common time period. The disadvantage of this approach is that the continuous camera enforcement being applied at the subject intersection approach reduces the red-light violation rate relative to a typical intersection. Because this approach does not yield information about the "typical" intersection, it was not considered further.

Database Composition

The data collected for previous studies were combined for this study. Specifically, the crash data from Study 1 and the violation data from Study 2 were combined to provide the desired database composition. The resulting database pairs the three-year crash history of each intersection approach with the red-light violation rate observed on this approach during a six-hour study. In addition, the database includes the average daily volume on the subject approach and the average daily volume on the cross street. Finally, these data were combined with that collected for Project 0-4027.

Study Sites

The sites selected for this study are the same as those selected for Study 2. These sites were found to be suitable for a study of the influence of delay on red-light violations and for the combined study of the relationship between violation rate and crash history. With regard to the latter study, it was verified that there was no organized effort underway by the City of Irving Police Department that might change driver red-light-running behavior (e.g., TxDOT's Selective Traffic Enforcement Projects) during the most recent three years. Two approaches at each of four intersections were included in this study.

Data Acquisition Approach

The data assembly and analysis schedule is identified in Table 4-7. Crash data were assembled during Tasks 1 and 3, as part of Study 1. Red-light violation data were assembled during Task 4, as part of Study 2. The crash and violation data will be analyzed during Task 6 (Subtask 6.1), which is scheduled for completion by the end of December 2003.

Table 4-7. Data Collection Schedule for Study 4.

Task	Fiscal Year 2003												Fiscal Year 2004											
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
1. Evaluate State-of-the-Practice	□	□	□																					
2. Develop Data Collection Plan		□	□	□	□																			
3. Evaluate Safety Impact of RLR				□	□	□	□	□	□															
4. Evaluate RLR Factors						□	□	□	□	□	□													
5. Prepare Research Report										□	□	□												
6. Procedure to Identify Problem Locations													■	■	□	□								
7. Evaluate Effectiveness of Enforcement													□	□	□	□	□	□						
8. Procedure to Identify Countermeasures																	□	□	□	□	□			
9. Develop RLR Handbook																		□	□	□	□	□	□	
10. Prepare Research Report																						□	□	□
Legend:	■	Task associated with study.											□	Other research tasks.										

Study 5 - Distribution of Red-Light-Running-Related Crashes by Time-into-Red

Objective of Study

The objective of this study is to quantify the relationship between the "time into red" and the frequency of red-light-running-related crashes. It was noted in Chapter 2 that some countermeasures reduce red-light-running during the first few seconds of red. However, it was also noted in Chapter 3 that crashes often occur several seconds after the onset of red. These two facts together suggest that some countermeasures may not significantly reduce red-light-running-related crashes. For example, if it is found that red-light-running crashes never occur in the first five seconds of red, then improvements in to signal visibility or conspicuity may be more effective at reducing crashes than increasing the yellow interval duration. The findings of this study will shed light on this issue and form the basis for guidelines regarding countermeasure selection.

Database Composition

The database assembled for this study includes crash-related data, traffic control settings, traffic volume, and geometric conditions for selected intersections. The crash-related data consist of the information that is recorded on the crash report or in the photographed image of a red-light violation. The specific types of data collected are listed in Table 4-8.

Table 4-8. Data Collected for Study 5.

Category [1]	Description	Data Source [2, 3]			
		RLR Photo	Crash Report	Agency Files	Field Survey
Crash	Duration of time lapsed between the presentation of the red indication and the crash	P			
	Speed of the red-light-running vehicle	P			
	Travel direction at the intersection (e.g., left-turn)	S	P		
	Date and time of crash	S	P		
	Crash type (e.g., right angle)	S	P		
	Number of injuries and severity		P		
	Contributing factor(s)		P		
Traffic Control	Left-turn phasing (permitted, protected, protected/permitted)				P
	Yellow interval duration	P			S
	All-red interval duration			P	S
	Approach speed limit	S			P
Volume	Annual average daily traffic			P	
Geometry	Approach grade				P
	Number of left, through, and right-turn lanes on subject street	S			P
	Number of left, through, and right-turn lanes on cross street				P

Notes:
1 - Traffic control, volume, and geometric data are specific to the street on which the red-light-running vehicle traveled.
2 - RLR: red-light-running.
3 - P: primary source of data. S: secondary source of data. The secondary source of data was used when the primary data source was not available or was inconclusive.

The crash-related data included in the database were acquired from the photolog archive maintained by two city agencies with camera enforcement equipment. Practical limitations on data archiving and storage capacity limited the number of years for which crash data were available. Nevertheless, the database includes only crashes occurring during the most-recent three years for which data are available. All of these data were gathered during the visit to each city for which crash and photolog data were acquired.

Study Sites

A desirable goal of gathering data describing a minimum of 100 crashes was established for this study. This goal was intended to ensure statistical stability in any trends found in the data. To achieve this goal, it was rationalized that crash data for three to five intersections (each with camera enforcement) in each of two cities would be needed.

Several agencies known to have camera enforcement were contacted to solicit their participation in this project. Those agencies having the most cameras in operation for the greatest length of time were contacted first. A key criterion used in selecting these cities or counties was the availability of archived photos of red-light violations that resulted in a crash.

Fifteen individuals representing nine city (or county) transportation departments in four states were contacted for the purpose of obtaining their assistance with this study. Of these agencies, only four indicated a willingness to provide the necessary assistance. From these four, two agencies were ultimately selected based primarily on their level of interest in supporting this research project. These two agencies were the City of Phoenix, Arizona, and the City of Mesa, Arizona.

An initial review of the crash records at the two participating cities indicated that the minimum desired sample size would not be achievable. This realization was a result of three factors. First, the presence of enforcement cameras had a significant effect on reducing the frequency of red-light-running-related crashes in the selected cities, beyond that expected based on a review of the literature on camera effectiveness. Second, it was revealed that the cameras oftentimes did not photograph the actual crash. This finding was due to several causes (e.g., the red-light violator did not travel in a lane monitored by the camera, the camera was located at a different intersection on the day of the crash). Third, many of the enforcement cameras in the two cities studied had not been in service for more than 18 months.

Based on the aforementioned challenges to achieving the desired sample size, two approaches were undertaken to maximize the amount of data collected for this study. First, the number of intersections included in the database was expanded to include all of the intersections for which the city had enforcement camera equipment in operation during the previous three years. This approach expanded the database to include 20 intersections (8 in the city of Phoenix and 12 in the city of Mesa). Data for a total of 27 crashes were obtained from these intersections.

A second approach used to maximize the amount of crash data gathered for this study involved the use of crash photos obtained from other cities and researchers. A total of 30 crash photos were obtained in this manner. It was recognized that these data sources did not provide all of the data listed in Table 4-8 (i.e., only that data listed in the column headed with "RLR Photo").

Data Acquisition Approach

The data assembly and analysis schedule for Study 5 is identified in Table 4-9. The agency contacts took place during the months of April and May in Fiscal Year 2003. The agency visits followed in late June. The data gathered at each site will be organized, reduced, and analyzed in Task 7.

Table 4-9. Data Collection Schedule for Study 5.

Task	Fiscal Year 2003												Fiscal Year 2004											
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
1. Evaluate State-of-the-Practice	□	□	□																					
2. Develop Data Collection Plan		□	□	□	□																			
3. Evaluate Safety Impact of RLR				□	□	□	□	□	□															
4. Evaluate RLR Factors						□	□	■	■	■	■													
5. Prepare Research Report										□	□	□												
6. Procedure to Identify Problem Locations													□	□	□	□								
7. Evaluate Effectiveness of Enforcement													□	□	■	■	□	□						
8. Procedure to Identify Countermeasures																	□	□	□	□	□			
9. Develop RLR Handbook																		□	□	□	□	□	□	
10. Prepare Research Report																						□	□	□
Legend:	■	Task associated with study.											□	Other research tasks.										

Study 6 - Influence of Camera Enforcement on Crash Frequency

Background

Chapter 2 highlighted a large number of articles and reports citing crash reductions attributed to the use of enforcement cameras and the limitations of most of these studies. In fact, a recent report by McGee and Eccles *(49)* states, "Nearly every study and crash analysis [of red-light-related crashes] reviewed had some experimental design or analysis flaw" (*49*, p. 2). After a rigorous review of the published literature, they concluded that, "it appears that automated enforcement...can be an effective countermeasure. However, there is not enough empirical evidence based on statistically rigorous experimental design to state that conclusively."

The study design problems described in Chapter 2, and amplified by McGee and Eccles *(49)*, cannot be overcome by a simple re-analysis of the data from existing intersections. The problems stem from design limitations (e.g., lack of comparison sites, confounding of public awareness campaigns with camera enforcement, etc.) that cannot be resolved by reexamination of the data.

In recognition of the problems found by McGee and Eccles *(49)*, the FHWA contracted with Ryerson Polytechnic University, Toronto, Canada, to use a statistically rigorous experimental design to separately quantify:

- the effect of cameras on crashes at the intersection approaches with cameras,
- the effect of cameras on crashes at nearby intersections, and
- the incremental effect of public awareness campaigns when combined with cameras.

This research project is scheduled for completion in the Spring of 2004.

Objective of Study

The objective of this study is to quantify the effect of camera enforcement on crash frequency. This effect could be quantified in the form of a crash reduction percentage or as a regression-based crash prediction equation. The resulting crash reduction percentage or prediction equation would then be used to develop a procedure for identifying the most promising countermeasure for treating a problem intersection.

Status

In light of the very relevant, timely, and rigorous research project being undertaken by FHWA, Study 6 has been held in abeyance until Fiscal Year 2004. In the interim, the progress of the FHWA study has been monitored. Should the FHWA project achieve its objectives, the findings should be available to this project in time to be incorporated into its products. Should the FHWA project be delayed or its products not be relevant to this project, then Study 6 will be formally designed and executed.

CHAPTER 5. IDENTIFYING AND EVALUATING RED-LIGHT-RUNNING-RELATED CRASHES

OVERVIEW

This chapter summarizes an analysis of crash data for the purpose of identifying the safety consequences of red-light-running. Initially, issues related to identifying red-light-running-related crashes are discussed. Then, issues related to agency under-reporting of some crashes are examined. Next, a procedure is described that can be used to screen large databases for likely red-light-running-related crashes and adjust for under-reporting of property-damage-only crashes. Finally, these procedures are used to quantify the safety impact of red-light-running in Texas.

Challenges of Crash Data Analysis

Several comprehensive guides that deal with the treatment of red-light problems recommend an evaluation of the red-light-running-related crash history for the subject intersection or intersections prior to countermeasure selection (*9, 12, 50*). This recommendation includes efforts to: (1) quantify the frequency of red-light-running-related crashes, and (2) identify the characteristics and causes of these crashes. Both types of information are essential to the identification of problem intersections and the selection of countermeasures. However, extracting this information from a crash database is challenging.

There are three types of crash databases available for the purpose of identifying and quantifying red-light-running-related crashes. In this context, database "type" refers to the database format (i.e., written or electronic) and, in the case of the electronic databases, the extent to which the data in the written reports are accurately and fully reproduced. All three types are used in Texas.

One database consists of the written officer crash reports (an example report is provided in the Appendix). Another database is the electronic "transcription" of the written reports. This database is a verbatim transcription of the written reports, except that neither the officer's narrative opinion nor crash diagram are included. The third database is also an electronic version of the written reports; however, some of the information on the reports is "interpreted" to accommodate the reporting techniques of the agencies in a common region (e.g., large city, county, or state). The database maintained by the DPS is an example of this third type of database. All three database types are described in Table 5-1, as they relate to the evaluation of red-light-running-related crashes.

As indicated in Table 5-1, none of the three databases have an attribute that identifies a crash as being caused by red-light-running. As a result, red-light-running-related crashes are identified using a combination of database attributes, the narrative, and the diagram. The exclusive use of database attributes to identify red-light-running-related crashes is attractive because of its simplicity, but it will likely result in the omission of a small percentage of red-light-running-related crashes.

Table 5-1. Red-Light-Running-Related Crash Database Attributes.

Attribute	Database Types	Attribute Availability	Comment
Red-Light-Running Relationship	Written Report	Not provided	Determination of red-light-running relationship is based on analyst's interpretation of narrative opinion and diagram.
	Electronic Transcription	Not provided	Cannot be determined because narrative and diagram are excluded from database.
	Electronic Interpretation	Not provided	Cannot be determined because narrative and diagram are excluded from database.
Crash Type (e.g., right-angle)	Written Report	Not provided	Determination of crash type based on analyst's interpretation of narrative opinion and diagram.
	Electronic Transcription	Provided	Determination of crash type based on data entry operator's interpretation of officer's narrative opinion and diagram.
	Electronic Interpretation	Provided	Determination of crash type based on data entry operator's interpretation of officer's narrative opinion and diagram.
Crash Location	Written Report	Provided	Gather reports associated with two intersecting streets.
	Electronic Transcription	Provided	Search for records associated with two street names.
	Electronic Interpretation	Not provided	Search for reports where: (a) crash is located within ±0.1 mile of milepost[1] nearest intersection, and (b) Traffic Control attribute is set to "Stop and Go Signal."
Intersection Relationship	Written Report	Provided	Determination of relationship is based on officer's report (especially the distance between crash and intersection).
	Electronic Transcription	Provided	Determination of relationship is based on officer's report (especially the distance between crash and intersection).
	Electronic Interpretation	Provided	Determination is based on data entry operator's interpretation of report information. Information is translated into either "at intersection" or "intersection-related."

Note:

1 - Milepost is used by the DPS to reference crashes on state highways. Block number is used instead of milepost by some cities and sometimes by the DPS to reference crashes not on state highways.

One attribute commonly used to identify red-light-running-related crashes is Contributing Factor. This attribute typically has a category that indicates disregard for the signal indication (e.g., "disregard stop and go signal"). However, this category can also be used for non-red-light-related violations. For example, "disregard stop and go signal" can include maneuvers that are not true red-light-running events (e.g., right-turn on red after stop) (*9*). Similarly, "failure to obey traffic control" is even more vague as it typically identifies crashes associated with a wider range of control devices (e.g., stop sign, lane markings, etc.). The use of "right-angle crash" can also misidentify red-light-running-related crashes as it generally includes any crash of two vehicles on the crossing streets. While these crash attributes are likely to identify a large percentage of the red-light-running-related crashes, they are also likely to allow some non-red-light-running-related crashes to be included in the subset database.

The ability to accurately locate crashes associated with a particular signalized intersection (or intersections) is an important consideration when searching for problem locations. By definition, the written report and the electronic transcription databases explicitly include the names of the two streets or highways that form the nearest intersection. For the electronic interpretation database, crash location is based on the nearest milepost or block number. This approach makes it more difficult to accurately locate crashes associated with a specific signalized intersection.

As a result of the aforementioned challenges, some agencies have resorted to a manual review of the written crash reports on an intersection-by-intersection basis for the purpose of identifying red-light-running-related crashes. During this review, the analyst considers all of the information listed on the crash report including (1) the investigating officer's narrative opinion of what happened during the crash and (2) the officer's diagram of vehicle position just before and after the crash. The disadvantages of this approach are that it is labor intensive and that it requires access to the written report.

In summary, the accurate identification of red-light-running-related crashes is difficult. Use of electronic databases may lead to inaccurate assessments of the frequency of these crashes. Many agencies currently report the frequency of "red-light-running-related crashes" but do not explain the method by which they identify these crashes (*6, 8*). This practice makes it difficult to have confidence in the accuracy of the reported findings. Moreover, it makes it difficult to confidently compare crash data or countermeasure effectiveness reported by different agencies. Extrapolation of findings to other locations and combining measures of effectiveness is practically impossible without a consistently applied definition of a "red-light-running-related" crash.

Objective

The objectives of this research task are to: (1) characterize red-light-running-related crashes, (2) develop methods for identifying these crashes, (3) develop methods for quantifying their frequency, and (4) assess their impact on Texas motorists. This objective was achieved by conducting a detailed review of the written reports for more than 3300 crashes at 70 signalized intersections in three Texas cities. These data were used to develop useful characterizations and prediction methods. Finally, these methods were applied to the DPS's electronic crash database to estimate the impact of red-light-running on Texas motorists.

DATABASE EXAMINATION

Data Collection

The database assembled for this analysis was derived from the information provided on the written crash report. This information included all relevant descriptors of the crash and the conditions present during the crash. It also included: (1) the officer's narrative opinion of what happened during the crash and (2) the officer's diagram of vehicle position just before and after the crash. The details of this data collection activity are described in Chapter 4 for Study 1.

Reports for all crashes that occurred at each of 25 typical intersections for the years 1999, 2000, and 2001 were requested from eight Texas cities. Three of these cities (Corpus Christi, Garland, and Irving) were able to provide the desired written crash reports. In one city, only 20 intersections were found that were determined to be "typical." As a result, data were obtained for *four* years at this city to provide some equity in terms of the number of "intersection-years" of data reflected in the database. All total, 3338 crash reports were obtained for 70 intersections.

The crash reports were manually reviewed to determine the crash type and whether the crash was a result of a red-light violation. The officer's narrative opinion and diagram were critical to this determination. Only those crashes that were definitively a result of a red-light violation were identified as such in the database. It was not possible to determine whether a crash was related to a red-light violation for 57 of the reports reviewed (i.e., 1.7 percent).

Database Summary

A summary of the database assembled for this investigation is provided in Table 5-2. The crashes listed in this table represent all crashes related to (i.e., associated with) the intersection. This relationship was determined by reviewing the crash location information on the crash report. Specifically, an "intersection-related" crash was one where the written report included the names of both intersecting streets and, if appropriate, the distance between the crash and the intersection.

The percentages in the last column of Table 5-2 (i.e., Total RLR/Total All) are an indication of the "concentration" of red-light-running-related crashes within a particular crash type. For example, 72 percent of right-angle crashes are red-light related. The values in column 7 (i.e., Percent of Total) define the distribution of red-light-running-related crashes (and the distribution of all crashes) among the various crash types. The distribution of red-light-running-related crashes did not vary significantly among the cities; however, the distribution of all crashes did vary among cities. The Index listed in the last column indicates the "risk" of association with a red-light-running-related crash. Crash types with a risk value larger than 1.0 are more likely to be red-light-running related.

The following observations are made with regard to the data in Table 5-2:

1. Fifteen percent of all intersection-related crashes are caused by a red-light violation.
2. Eighty-four percent of red-light-running-related crashes are right-angle crashes.
3. Fifteen percent of the red-light-running-related crashes are left-turn-opposed (i.e., a left-turning vehicle colliding with an oncoming through vehicle).
4. Only 72 percent of the right-angle crashes identified are due to a red-light violation.
5. The chance that a crash is red-light-running related increases by a factor of 4.67, if it is known to be a right-angle crash.
6. The typical intersection has about 2.2 reported red-light-running-related crashes each year.
7. The typical intersection in City 1 has about 27.5 crashes reported per year, which is three times higher than reported in City 2 or 3.
8. There is a disproportionately low number of rear-end crashes being reported in City 2.

Table 5-2. Intersection-Related Crash Type Distribution.

Category	Crash Type	Crashes by City			Total	Percent of Total, % [4]	Total RLR/ Total All, %
		City 1	City 2	City 3			
Red-Light-Running-Related (RLR) [1]	Right-angle	153	187	83	423	84	72
	Head-on	2	0	2	4	1	7
	Left-turn-opposed	25	33	17	75	15	10
	Rear-end	0	0	0	0	0	0
	Sideswipe	1	0	0	1	0	0
	Other two-vehicle	0	0	0	0	0	0
	Single-vehicle	1	2	0	3	1	2
	Subtotal	182	222	102	506	100	15
	Percent of Total, %	36	44	20	100		**Index** [5]
	Crashes/intersection/yr [3]	2.4	3.0	1.3	2.2		
All [2]	Right-angle	251	228	107	586	18	4.67
	Head-on	41	5	13	59	2	0.50
	Left-turn-opposed	357	280	141	778	23	0.65
	Rear-end	1180	85	236	1501	45	0.00
	Sideswipe	175	46	55	276	8	0.00
	Other two-vehicle	3	1	0	4	0	0.00
	Single-vehicle	56	46	32	134	4	0.25
	Subtotal	2063	691	584	3338	100	
	Percent of Total, %	62	21	17	100		
	Crashes/intersection/yr [3]	27.5	9.2	7.3	14.5		
Number of Years		3	3	4	10		
Number of Intersections		25	25	20	70		

Notes:
1 - RLR: red-light-running.
2 - All: all crashes associated with the intersection including those at the intersection and those on its approaches.
3 - The underlined number in this row is a weighted average annual intersection crash frequency (it is not a total).
4 - H_o: No difference in distribution of RLR-related crashes among cities. $X^2 = 0.44$; $n = 2$; $p = 0.80$; cannot reject.
H_o: No difference in distribution of All crashes among cities. $X^2 = 516$; $n = 10$; $p = 0.0001$; reject H_o.
5 - Index: ratio of "Percent of Total for RLR crashes" to "Percent of Total for all crashes."

Observation 4 provides some information about the usefulness of using the Crash Type attribute to identify red-light-running-related crashes. It suggests that analysts who screen an electronic database based on "right-angle" crash type (in the hope of identifying red-light-running-related crashes) may be misled by the crashes they find. Specifically, about 28 percent of the pool of right-angle crashes will *not* be related to red-light-running. These extraneous crashes may mislead the identification of intersections with a red-light-running problem, misdirect the selection of the best countermeasure, or misrepresent the effectiveness of this countermeasure. In addition, 16 percent of red-light-running-related crashes will *not* be in the pool of right-angle crashes (per Observation 2).

Observations 7 and 8 suggest that there are some differences in crash reporting, recording, or both in each city. It is possible that some types of crashes are actually more likely to occur in one city compared to another. However, it is more likely that the distribution of crashes is the same among cities and that either: (1) some types of crashes are not as likely to be reported in some cities or (2) some types of crashes (e.g., rear-end) are identified as mid-block crashes in some cities and as intersection-related crashes in others. An examination of the crash type distribution for only those crashes that occur "at" the intersection could shed some light on this disparity among cities. This examination is described in the next section.

ISSUES OF CRASH DATA ANALYSIS

The review of crash databases in Chapter 3 identified the following database attributes as being useful to the accurate identification of red-light-running-related crashes:

- Intersection Relationship,
- Traffic Control,
- Crash Severity, and
- First Contributing Factor.

Issues associated with the use of each of these attributes are outlined in the following paragraphs.

Intersection Relationship is intended to indicate whether a crash is related to the adjacent signalized intersection. As such, in its most useful form, Intersection Relationship provides the distance between the crash and the nearest signalized intersection whenever the crash has been determined by the investigating officer to be caused by some aspect of that intersection's operation. However, as noted in the previous section, there exist some significant differences among cities in terms of the methods they use to locate a crash relative to the intersection.

It has also been noted (in the context of Table 5-1) that the use of a database with "interpreted reports" poses some challenges in terms of locating the crashes at specific signalized intersections. Use of this type of database requires the analyst to screen crashes based on the Traffic Control attribute. This usage assumes that all crashes occurring at a signalized intersection will have the Traffic Control attribute recorded as "stop and go signal." However, the strength of this assumption has not been tested.

In Chapter 3 it was noted that the level of reporting varies among agencies, depending on the crash damage cost threshold used. Cities using a relatively high threshold do not include in their crash database many of the PDO crashes that occur.

Finally, it was suggested in the previous section that the use of Crash Type (i.e., right-angle) to screen red-light-running-related crashes may not yield an accurate subset database. Other database attributes, such as First Contributing Factor, may be needed to identify and quantify red-light-running-related crashes.

The usefulness of the Crash Type attribute as a means of identifying red-light-running-related crashes was discussed in the previous section. The remainder of this section more fully addresses the usefulness of Intersection Relationship, Traffic Control, Crash Severity, and First Contributing Factor.

Intersection Relationship

The effect of reported crash location was examined to determine whether the differences in crash type distribution among cities was possibly due to differences in the city's method of locating crashes relative to the intersection. The results of this analysis are summarized in Table 5-3.

The following observations are made with regard to the data in Table 5-3:

1. Thirty percent of crashes at the intersection are red-light-running-related.
2. Ninety-nine percent of the red-light-running-related crashes occur "at" the intersection.
3. City 2 recorded only 2 percent (11) of its crashes as being away from the intersection.

The finding that 30 percent of all crashes at the intersection are red-light-running is slightly larger than the 16 to 20 percent reported by Mohamedshah et al. (*51*). The difference is likely due their use of several state crash databases and some combination of "right-angle" or "disregard stop and go signal" attribute categories. As shown in Table 5-2, the use of only "right-angle" as a surrogate for red-light-running crashes would yield a red-light-running crash estimate of 18 percent, which is in the range reported by Mohamedshah et al.

Observation 2 provides a useful result related to identifying red-light-running crashes. Specifically, when an electronic crash database is used to identify red-light-running crashes, it should be screened to include only those crashes that occur "at" the intersection. Less than 1 percent of all red-light-running crashes would be inappropriately screened out by this technique. However, the fact that only 30 percent of the crashes obtained by this screen are truly red-light-running related suggests that one or more additional attributes are needed to identify and quantify red-light-running-related crashes.

Table 5-3. Intersection-Related Crash Distribution.

Category	Intersection Relationship	Crashes by City			Total	Percent of Total, %	Total RLR/ Total All, %
		City 1	City 2	City 3			
Red-Light-Running-Related	At Intersection	179	222	101	502	99	30
	1 to 25 ft	1	0	1	2	0	0
	26 to 50 ft	2	0	0	2	0	0
	51 to 75 ft	0	0	0	0	0	0
	76 to 100 ft	0	0	0	0	0	0
	101 to 150 ft	0	0	0	0	0	0
	151 ft to 200 ft	0	0	0	0	0	0
	201 ft or more	0	0	0	0	0	0
	Subtotal	182	222	102	506	100	15
	Percent of Total, %	36	44	20	100		**Index [2]**
All [1]	At Intersection	689	680	316	1685	50	1.98
	1 to 25 ft	378	1	154	533	16	0.00
	26 to 50 ft	574	1	63	638	19	0.00
	51 to 75 ft	197	0	17	214	6	0.00
	76 to 100 ft	211	3	14	228	7	0.00
	101 to 150 ft	5	1	4	10	0	0.00
	151 ft to 200 ft	7	1	8	16	0	0.00
	201 ft or more	2	4	8	14	0	0.00
	Subtotal	2063	691	584	3338	100	
	Percent of Total, %	62	21	17	100		
Number of Years		3	3	4	10		
Number of Intersections		25	25	20	70		

Notes:
1 - All: all crashes associated with the intersection including those at the intersection and those on its approaches.
2 - Index: ratio of "Percent of Total for RLR crashes" to "Percent of Total for all crashes."

Observation 3 indicates that many of the crashes that are likely occurring in City 2 in the vicinity of the intersection are not being identified as such on the officer crash report. It is consistent with the low number of rear-end crashes also reported by this city (see Observation 8 associated with Table 5-2). This finding may reflect a policy of this city to locate crashes by block location (i.e., as mid-block crashes) unless they occur within the intersection conflict area.

Based on the significant differences in intersection relationship and crash type distribution among cities, it was decided to focus the analysis of red-light-running-related crashes on only crashes identified as occurring "at" the intersection. All subsequent analyses in this chapter are consistent with this decision.

Table 5-4 presents the distribution of crashes occurring *at* the 70 signalized intersections. The data in this table can be compared with that in Table 5-2, which lists the distribution of all crashes *related* to the intersection. As shown in the upper half of this table, the distribution of red-light-running crashes is very similar to that in Table 5-2. Statistical analysis of this distribution (as indicated by the "Percent of Total" column) indicates that it does not vary among the cities.

Table 5-4. Intersection Crash Type Distribution.

Category	Crash Type	Crashes by City			Total	Percent of Total, % [2]	Total RLR/ Total All, %
		City 1	City 2	City 3			
Red-Light-Running-Related	Right-angle	152	187	83	422	84	84
	Head-on	1	0	1	2	0	6
	Left-turn-opposed	25	33	17	75	15	10
	Rear-end	0	0	0	0	0	0
	Sideswipe	0	0	0	0	0	0
	Other two-vehicle	0	0	0	0	0	0
	Single-vehicle	1	2	0	3	1	4
	Subtotal	179	222	101	502	100	30
	Percent of Total, %	36	44	20	100		**Index [3]**
All [1]	Right-angle	178	227	97	502	30	2.80
	Head-on	18	5	10	33	2	0.00
	Left-turn-opposed	338	279	139	756	45	0.33
	Rear-end	95	80	31	206	12	0.00
	Sideswipe	41	43	20	104	6	0.00
	Other two-vehicle	0	1	0	1	0	0.00
	Single-vehicle	13	44	13	70	4	0.25
	Subtotal	683	679	310	1672	100	
	Percent of Total, %	40	41	19	100		
Number of Years		3	3	4	10		
Number of Intersections		25	25	20	70		

Notes:
1 - All: all crashes at the intersection. Crashes on the intersection approaches are *not* included.
2 - H_o: No difference in distribution of RLR-related crashes among cities. $X^2 = 0.41$; $n = 2$; $p = 0.81$; cannot reject.
H_o: No difference in distribution of All crashes among cities. $X^2 = 41$; $n = 10$; $p = 0.0001$; reject H_o.
3 - Index: ratio of "Percent of Total for RLR crashes" to "Percent of total for all crashes."

The "concentration" percentages in the last column of Table 5-4 (i.e., Total RLR/Total All) and the distribution percentages in column 7 describe the "quality" and "quantity," respectively, of the red-light-running-related crash estimates obtained using the Intersection Relationship attribute and one any one Crash Type attribute. Specifically, the last column indicates that 84 percent of the right-angle crashes at an intersection are truly red-light related (quality). Column 7 indicates that 84 percent of red-light crashes have a right-angle crash type (quantity). Footnote 2 indicates that the distribution of red-light-related crashes by crash type in column 7 is independent of city effects.

An analysis of the distribution of "all" crashes indicates some variation among the cities. The amount of this variation has been reduced by 90 percent relative to Table 5-2 (i.e., X^2 from Table 5-2 = 516, X^2 from Table 5-4 = 41). Moreover, a closer look at the distribution of "all" crashes indicates that City 2 and City 3 are not significantly different from one another. On the other hand, City 1 has about 7 percent more left-turn-opposed crashes and 7 percent fewer right-angle crashes than the other two cities. Although there is sufficient variation in the data to preclude statistical confidence, these findings suggest that the distribution of "all" crashes is a reasonable estimate of the distribution of crashes at typical intersections (although the values may vary by a few percent among cities).

Traffic Control

The crash database provided by the DPS can be described as consisting of interpreted reports. As explained in the discussion associated with Table 5-1, this type of database locates crashes on a "milepost" basis (cities that use this method often use block numbers). The interpretation is provided by the DPS data-entry operator, who converts the intersection location on the report to a milepost referencing system. In contrast, the location information provided on the written crash report is often specific to the intersection related to the crash and, when appropriate, the distance from this intersection.

One method by which the crashes for specific signalized intersections can be located using the interpretation-based database is to locate the milepost (or block number) of each intersection. The disadvantage of this approach is that it is labor intensive to identify the milepost locations of a sizeable number of intersections. Moreover, it is impossible to have absolute certainty that all crashes associated with a specific intersection are extracted from the database due to the 0.1-mile resolution used with the milepost system.

Another method by which the crashes for a large number of signalized intersection crashes can be located is by the combined use of the Intersection Relationship attribute (i.e., "at") and the Traffic Control attribute (i.e., "stop and go signal"). This method can be used to accurately locate signalized intersection crashes when data for a large number of intersections is desired but the location of any specific intersection is not required (e.g., a city-wide summary). The disadvantages of this method are: (1) that data for a specific intersection is not obtained, and (2) that the actual number of intersections included in the database can only be estimated.

Of the two methods, the latter is attractive for many regional and statewide analyses; however, its accuracy is dependent on whether the Traffic Control attribute is consistently used by the investigating officer to identify a crash at a signalized intersection. Table 5-5 provides some insight into the use of this attribute by the officers in three cities.

Table 5-5. Intersection Traffic Control Type Distribution.

Category	Traffic Control Type	Crashes by City			Total	Percent of Total, %[2]	Total RLR/ Total All, %
		City 1	City 2	City 3			
Red-Light-Running-Related	Not indicated (blank)	8	10	4	22	4	23
	No control/inoperative	1	1	0	2	0	7
	Stop and go signal	167	205	89	461	92	32
	Stop sign	2	2	1	5	1	45
	Flashing red light	1	2	0	3	1	30
	Center stripe or divider	0	1	7	8	2	14
	Other	0	1	0	1	0	2
	Subtotal	179	222	101	502	100	30
	Percent of Total, %	36	44	20	100		**Index**[3]
All[1]	Not indicated (blank)	43	45	9	97	6	0.67
	No control/inoperative	4	21	2	27	2	0.00
	Stop and go signal	575	583	267	1425	85	1.08
	Stop sign	3	5	3	11	1	1.00
	Flashing red light	2	8	0	10	1	1.00
	Center stripe or divider	28	11	17	56	3	0.67
	Other	28	6	12	46	3	0.00
	Subtotal	683	679	310	1672	100	
	Percent of Total, %	40	41	19	100		
Number of Years		3	3	4	10		
Number of Intersections		25	25	20	70		

Notes:
1 - All: all crashes at the intersection. Crashes on the intersection approaches are *not* included.
2 - H_o: No difference in distribution of RLR-related crashes among cities. $X^2 = 6.2$; $n = 4$; $p = 0.19$; cannot reject.
H_o: No difference in distribution of All crashes among cities. $X^2 = 17$; $n = 6$; $p = 0.01$; reject H_o.
3 - Index: ratio of "Percent of Total for RLR crashes" to "Percent of Total for all crashes."

The following observations are made with regard to the data in Table 5-5:

1. Eighty-five percent of all crashes at the intersection are identified as having a "stop and go signal" for traffic control.
2. Ninety-two percent of all red-light-running-related crashes are identified as having a "stop and go signal" for traffic control.

The finding that 85 percent of all crashes at signalized intersections are identified as having a "stop and go signal" for traffic control is encouraging. However, it also indicates that police officers are indicating other types of traffic control for 15 percent of the crashes. It is likely that other types of control are indicated in those cases where the crash is more directly related to another control device at the intersection. For example, when one of the vehicles involved in a crash at a signalized intersection is a right-turn vehicle in a stop-controlled free-right-turn lane, the Traffic Control attribute may be recorded as "stop sign."

A statistical analysis of the distribution of crashes indicates that there is no significant difference among the three cities with regard to the distribution of red-light-running-related crashes. In contrast, there is a statistically significant difference among cities in the distribution of all crashes. This difference is relatively small and stems from deviations of less than 3 percent among cities for any one control type.

Crash Severity

Red-light-running frequently results in severe crashes at urban signalized intersections (*1, 52*). However, it also causes many non-injurious crashes. In fact, it is likely to cause more PDO crashes than injury crashes (see discussion associated with Table 3-3). Unfortunately, the PDO crash frequency is difficult to accurately quantify because of variation among cities in the reporting threshold used by its enforcement agencies. Moreover, recent trends to increase the crash reporting threshold will likely further degrade the accurate count of PDO crashes (*3, 53*).

Texas law currently requires the use of a $1000 (per vehicle) crash cost reporting threshold. This threshold has been used since 2001. Prior to that time, a threshold of $500 crash cost was used between 1990 and 2001, and a $250 crash cost was used before 1990 (*3*). However, crash cost is difficult to assess. Also, some city police departments routinely file reports for crashes costing less than the threshold amount as a service to the public. Finally, many agencies outside of Texas still use a threshold of $250 per crash. As a result, the number of PDO crashes varies widely among cities and states. This variation makes difficult any comparison of crash trends between cities in Texas and between Texas and other states.

Issues Associated with Crash Severity and Reporting Threshold

The distribution of crash severity, as reported by three cities, was examined to determine if there were different reporting thresholds being applied. The results of this analysis are shown in Table 5-6. The following observations are made with regard to the data in this table:

1. Fifty-seven percent of red-light-running crashes (= 0 + 4 + 19 + 34) are injury crashes (i.e., K, A, B, or C).
2. Fifty-two percent of all crashes (= 0 + 3 + 16 + 33) are injury crashes.
3. Fifty percent of all *non*-red-light-running-related crashes are injury crashes.
4. The probability of a crash having an "A" severity is increased by a factor of 1.33 if the crash is red-light-running related.
5. The probability of a crash being an injury crash is increased by a factor of 1.10 (= 57 /52) if the crash is red-light-running related.
6. The percentage of all crashes that are PDO ranges from 42 to 55 percent.

Table 5-6. Intersection Crash Severity Distribution.

Category	Severity [3]	Crashes by City			Total	Percent of Total, % [2]	Total RLR/ Total All, %
		City 1	City 2	City 3			
Red-Light-Running-Related	K	0	2	0	2	0	40
	A	8	12	1	21	4	41
	B	26	56	13	95	19	35
	C	52	68	50	170	34	31
	PDO	93	84	37	214	43	27
	Subtotal	179	222	101	502	100	30
	Percent of Total, %	36	44	20	100		**Index** [4]
All [1]	K	2	2	1	5	0	0.00
	A	17	29	5	51	3	1.33
	B	78	150	41	269	16	1.19
	C	209	214	121	544	33	1.03
	PDO	377	284	142	803	48	0.90
	Subtotal	683	679	310	1672	100	
	Percent of Total, %	40	41	19	100		
Number of Years		3	3	4	10		
Number of Intersections		25	25	20	70		
Distribution of Crashes by Severity							
RLR	Injury/Total, %	48	62	63	57		1.10
	PDO/Total, %	52	38	37	43		0.90
All	Injury/Total, %	45	58	54	52		
	PDO/Total, %	55	42	46	48		

Notes:
1 - All: all crashes at the intersection. Crashes on the intersection approaches are *not* included.
2 - H_o: No difference in distribution of RLR-related crashes among cities. $X^2 = 23$; $n = 4$; $p = 0.0001$; reject H_o.
H_o: No difference in distribution of All crashes among cities. $X^2 = 50$; $n = 6$; $p = 0.0001$; reject H_o.
3 - Crashes are identified by the most serious injury that results. K: fatal injury. A: Incapacitating injury. B: Non-incapacitating injury. C: Possible injury. PDO: property damage only.
4 - Index: ratio of "Percent of Total for RLR crashes" to "Percent of Total for all crashes."

Collectively, these observations indicate that red-light-running-related crashes are more severe than the typical intersection crash. This finding is likely due to the high speeds often associated with one or both of the colliding vehicles and the likelihood that one vehicle is typically struck in the side (which provides a lower level of protection for the occupants).

Retting et al. (*52*) reported that 45 percent of red-light-running-related crashes involve injury, whereas only 30 percent of other crashes involve injury. These statistics can be compared with the 57 and 50 percent, respectively, reported in Observations 1 and 3. It is likely that the higher percentages found in Table 5-6 are reflective of a higher reporting threshold relative to the database analyzed by Retting et al. (it should also be noted that the data they analyzed was for 1990 and 1991). Use of a higher reporting threshold since that time limits the number of PDO crashes in the database and, thereby, can bias the database toward the more severe crashes.

Observation 6 describes the percentage of PDO crashes in the database and the wide variation in these percentages among cities. The largest PDO percentage of 55 percent at City 1 is close to the value of 58 percent derived from Table 28 of *Traffic Safety Facts 2000* (*44*). This report characterizes crashes using a nationwide database. Closer examination of the data for City 1 indicates that 48 percent of its red-light-running-related crashes are injury crashes and 44 percent of its *non*-red-light-running-related crashes are injury crashes. These numbers are closer to the values reported by Retting et al. (*52*) (i.e., 45 and 30 percent, respectively). They would likely be very similar if a slightly lower reporting threshold were used by City 1 such that about 58 percent of the reported crashes were PDO.

In summary, the reporting threshold used by the three cities is higher than the nationwide average of 58 percent. As a result, many PDO crashes are not included in their crash databases. City 2 is notably deficient in the number of PDO crashes reported. More importantly, however, is the fact that different reporting thresholds make it difficult to compare the distribution of crashes among cities or make generalizations about the extent of the red-light-running problem among cities. Of the three cities, data found in other sources suggests that City 1 has the most representative distribution of crashes by severity.

Adjustment Factor for Under-Reported PDO Crashes

If the true percentage of PDO crashes that occur in a given city (or state) can be identified, then the following relationship can be used to compute a correction factor to adjust the city's (or state's) database to more accurately estimate the PDO crashes that occur:

$$R = \frac{100 - PDO}{100 - PDO_{ref}} \times \frac{PDO_{ref}}{PDO} \qquad \textbf{(5)}$$

where:

R = threshold adjustment factor for a given database;
PDO = percentage of PDO crashes in the given database; and
PDO_{ref} = true percentage of PDO crashes.

In application, the reported PDO crash frequency in a given database would be multiplied by the threshold adjustment factor R to estimate the actual number of PDO crashes. If the reference percentage obtained from *Traffic Safety Facts 2000* (*44*) is used (i.e., 58 percent), the estimate will likely reflect the number of crashes that would have been reported had a $250 crash cost threshold been used.

First Contributing Factor

It was suggested in a previous section that the use of Crash Type (i.e., right-angle) would not yield an very accurate estimate of the frequency of red-light-running-related crashes. The use of First Contributing Factor (i.e., disregard stop and go signal) is another database attribute that could be used with, or instead of, Crash Type to identify and quantify red-light-running-related crashes. The merit of its exclusive use is discussed in this section. Its use in combination with other attributes is discussed in a subsequent section.

The attribute category "disregard stop and go signal" is one of several choices available for Contributing Factor. In fact, there are more than 70 possible contributing factors that the officer can choose from when characterizing a crash (e.g., defective or no headlamps, failed to control speed, failure to yield right of way during left turn, under the influence of alcohol, etc.). Moreover, the officer typically has the option of listing several contributing factors for each of the drivers involved in the collision. As a matter of routine, an officer will list the most likely contributing factor first. It is this "first contributing factor" that is the subject of discussion in this section.

One question that arises in the use of the First Contributing Factor is, "Will a red-light-running-related crash be missed if only the *first* contributing factor is used to screen the database?" An examination of this issue revealed that less than 0.1 percent of all crashes have "disregard for stop and go signal" indicated as the second or later contributing factor. Thus, it can be safely concluded that "disregard for stop and go signal" is the most likely cause of a red-light-running-related crash, relative to other contributors, and it is always listed first on the report when it is applicable.

The distribution of crashes by first contributing factor are listed in Table 5-7. The following observations are made with regard to the data in this table:

1. Sixty-four percent of red-light-running-related crashes are identified by using "disregard stop and go signal."
2. Fifteen percent of red-light-running-related crashes are identified by using "disregard stop sign or light."
3. Ninety-seven percent of "disregard stop and go signal" crashes at a signalized intersection are truly red-light-running-related.
4. Ninety-three percent of "disregard stop sign or light" crashes at a signalized intersection are truly red-light-running-related.
5. If a crash is identified as being due to "disregard of stop and go signal," the likelihood of it being red-light-running-related increases by a factor of 3.20

Table 5-7. Intersection First Contributing Factor Distribution.

Category	First Contributing Factor	Crashes by City			Total	Percent of Total, %[2]	Total RLR/ Total All, %
		City 1	City 2	City 3			
Red-Light-Running-Related	Not indicated (blank)	6	5	0	11	2	28
	Disregard stop and go signal	102	147	72	321	64	97
	Disregard stop sign or light	32	30	14	76	15	93
	Driver inattention	3	17	1	21	4	23
	Failed to control speed	1	2	1	4	1	3
	Failed to yield - turning left	7	1	2	10	2	2
	Other	28	20	11	59	12	15
	Subtotal	179	222	101	502	100	30
	Percent of Total, %	36	44	20	100		**Index**[3]
All[1]	Not indicated (blank)	22	16	2	40	2	1.00
	Disregard stop and go signal	104	154	73	331	20	3.20
	Disregard stop sign or light	33	33	16	82	5	3.00
	Driver inattention	7	76	10	93	6	0.67
	Failed to control speed	58	55	10	123	7	0.14
	Failed to yield - turning left	289	202	115	606	36	0.06
	Other	170	143	84	397	24	0.50
	Subtotal	683	679	310	1672	100	
	Percent of Total, %	40	41	19	100		
Number of Years		3	3	4	10		
Number of Intersections		25	25	20	70		

Notes:
1 - All: all crashes at the intersection. Crashes on the intersection approaches are *not* included.
2 - H_o: No difference in distribution of RLR-related crashes among cities. $X^2 = 7.1$; $n = 4$; $p = 0.13$; cannot reject H_o.
H_o: No difference in distribution of All crashes among cities. $X^2 = 112$; $n = 12$; $p = 0.0001$; reject H_o.
3 - Index: ratio of "Percent of Total for RLR crashes" to "Percent of Total for all crashes."

Observation 2, that 15 percent of the red-light-running-related crashes are identified by using "disregard stop sign or light," suggests that a mistake is often being made by the investigating officer. A subsequent review of many of these "misidentified" crashes indicates this to be the case. It is likely due to the fact that the box to check denoting this factor is located just below the more logical choice of "disregard of stop and go signal." The fact that their first two words are the same probably contributes to this problem. Therefore, it is logical that these two choices should be combined when screening with this attribute. Their combined use should identify 79 percent (= 64 + 15) of the red-light-running-related crashes.

The high percentages noted for Observations 3 and 4 suggest that two attributes (i.e., "disregard of stop and go signal" and "disregard of stop sign or light") are very capable of identifying *only* red-light-running-related crashes. In fact, only about 4 percent of the crashes identified using these attributes are not related to a red-light violation. In comparison, Table 5-4 indicates that about 16 percent of the crashes identified as "right-angle" are not related to a red-light violation. Therefore, it appears that First Contributing Factor (and the combined use of "disregard of stop and go signal" or "disregard of stop sign or light") may be better suited to identifying truly red-light-running-related crashes than Crash Type (using "right-angle").

A statistical analysis was conducted of the distribution of crashes among the three cities. The results of this analysis indicate that there is no significant difference among the three cities with regard to the distribution of red-light-running-related crashes. In contrast, this distribution is significant for the distribution of all crashes. Based on these findings, it is concluded that the distribution of First Contributing Factor at signalized intersections is effectively independent of city effects when it is used to identify and quantify red-light-running-related crashes.

ACQUIRING RED-LIGHT-RUNNING CRASH DATA

As discussed with regard to Table 5-1, the investigating officer's written crash report forms the most accurate database from which red-light-running crash data can be obtained. Based on the findings from the previous section, it appears that a search for red-light-running-related crashes using an electronic database will miss some red-light-running-related crashes and mislabel some crashes as red-light-running related. Unfortunately, the labor involved in the analysis of the written reports is prohibitive when it is desired to characterize red-light-running on a citywide or statewide basis. In these situations, a procedure is needed to identify and quantify red-light-running-related crashes with reasonable accuracy. A procedure is developed in this section that can be used when the resources are not available to evaluate the written reports.

The findings of the previous section indicate that two crash attributes (i.e., Crash Type and First Contributing Factor) have the potential to identify a large majority of red-light-running-related crashes with only few mislabeled crashes. In the case of First Contributing Factor, it was also noted that two attribute categories (i.e., disregard of stop and go signal, disregard stop sign or light) in combination were able to identify more red-light-running-related crashes (with no loss in accuracy) than either attribute category alone. From these findings, the following question is raised, "What combination of attributes and attribute categories will identify the most red-light-running crashes with the fewest mislabeled crashes?"

The approach taken in this section is to develop a procedure for identifying the combination of attributes and attribute categories that yields the "optimal" number of red-light-running crashes. Once identified, these attribute categories could be used to screen other databases such that the resulting subset database: (1) includes a large number of red-light-running-related crashes, (2) misses few red-light-running-related crashes, and (3) mislabels few crashes.

Procedure for Identifying Likely Red-Light-Running-Related Crashes

An approach based on economic principles is adopted for the purpose of developing a procedure for identifying the optimal attribute category combination. The approach is based on the concept of "net benefit," where the optimal combination is the one that offers the largest difference between its "benefit" and its "cost." In this context, the benefit of a specific attribute combination is defined as the true number of red-light-running crashes associated with that combination. The cost is based on the total of the missed red-light-running-related crashes and the mislabeled crashes. The net benefit for attribute combination *i* is computed as:

$$NB_i = B_i - C_i \tag{6}$$

with,

$$B_i = Nt_i \tag{7}$$

$$C_i = \left[Nr_i - Nt_i\right] + \left[\sum_i (Nt) - Nt_i\right] \tag{8}$$

where:

NB_i = net benefit for attribute category combination *i*;
B_i = benefit of using attribute category combination *i*;
Nt_i = true red-light-running-related crashes associated with attribute category combination *i*;
$C_{i,j}$ = cost of using attribute category combination *i*; and
Nr_i = crashes reported as having attribute category combination *i*.

The first term in brackets in Equation 8 represents the number of mislabeled crashes that result when attribute category combination *i* is used as a surrogate for red-light-running-related crashes. The second term in Equation 8 represents the number of missed red-light-running-related crashes. The summation in this second term (i.e., $\Sigma(Nt)$) yields the total number of true red-light-running-related crashes in the database.

Equations 6, 7, and 8 can be combined to yield:

$$NB_i = 3\,Nt_i - Nr_i - \sum_i (Nt) \tag{9}$$

Given that the objective is to maximize the net benefit among competing alternatives, the last term in Equation 9 can be eliminated because it is a constant for all *i* combinations being considered. The remaining two terms can be used to compute a "relative" net benefit. Moreover, when applied to a specific crash database, the variables *Nt* and *Nr* represent sample statistics, each having a random component. As a result, the net benefit obtained from Equation 9 represents an expected value. Thus, the equation for computing the expected relative net benefit associated with a specific attribute category combination is:

$$E[NB_i] = 3\,Nt_i - Nr_i \qquad \textbf{(10)}$$

The variance of the expected relative net benefit can be estimated as:

$$VAR[NB_i] = 9\,Nt_i + Nr_i \qquad \textbf{(11)}$$

When evaluating a specific attribute category combination, the expected relative net benefit should be sufficiently large as to offer some assurance that it is, in fact, significantly different from 0.0. This test can be made using the following rule:

$$E[NB_i] > 2.0\sqrt{9\,Nt_i + Nr_i} \qquad \textbf{(12)}$$

In this equation, the term under the radical (i.e., $\sqrt{\ }$) represents the standard deviation of the expected relative net benefit.

If the condition in Equation 12 is satisfied, then the expected relative net benefit for combination *i* is significant and can be compared with the expected net benefit of all other combinations. The combination with the largest net benefit should yield the optimal subset of red-light-running crashes. Given that the relative net benefit of one alternative is not dependent on that of another combination, the net benefit of two or more attribute category combinations can be added together to assess their combined net benefit. Consideration of all possible attribute category combinations in this manner will thereby yield the optimal attribute category combination. This procedure is illustrated by example in the next section.

Examination of Alternative Attribute Category Combinations

Equations 10, 11, and 12 were used to evaluate two database attributes. The objective was to identify the optimal combination of attribute categories for identifying red-light-running-related crashes. The attributes considered included Crash Type and First Contributing Factor. The crash data for three cities in Texas (as described in the preceding section) were used for this evaluation. The data used were initially screened to include only crashes at signalized intersections. The results are listed in Table 5-8.

Table 5-8. Examination of Database Attributes.

Attribute	Attribute Category	True RLR Crashes	Assumed RLR Crashes [1]	Mis-labeled Crashes	Missed RLR Crashes	Net Benefit	Std. Devi-ation	Cumu-lative Benefit [2]
Crash Type	Right-angle	422	502	80	80	764	66	<u>764</u>
	Other two-vehicle	0	1	1	502	-1	1	--
	Head-on	2	33	31	500	-27	7	--
	Single-vehicle	3	70	67	499	-61	10	--
	Sideswipe	0	104	104	502	-104	10	--
	Rear-end	0	206	206	502	-206	14	--
	Left-turn-opposed	75	756	681	427	-531	38	--
First Contributing Factor	Disregard stop and go signal	321	331	10	181	632	57	632
	Disregard stop sign or light	76	82	6	426	146	28	<u>778</u>
	Defective or no brakes	4	5	1	498	7	6	--
	Fleeing or evading police	2	2	0	500	4	4	--
	Under influence - alcohol	4	9	5	498	3	7	--
	Fatigued or asleep	2	4	2	500	2	5	--
	Failed to yield - stop sign	2	4	2	500	2	5	--
Crash Type and First Contributing Factor	Angle & Disregard ...signal	270	274	4	232	536	52	536
	Angle & Disregard ...sign.	66	68	2	436	130	26	666
	Left-turn & Disregard...signal	48	52	4	454	92	22	<u>758</u>
	Angle & Driver inattention	16	23	7	486	25	13	--
	Left-turn & Disregard...sign	10	14	4	492	16	10	--
	Angle & Driver inattention	9	11	2	493	16	10	--

Notes:

1 - "Assumed RLR" crashes represent all crashes associated with the attribute category listed. They are judged to be RLR crashes since the truth of whether the crash is a consequence of RLR is not included in most electronic crash databases.

2 - Underlined values represent the optimal category (or combination of categories) for the corresponding attribute (or attributes).

The information in Table 5-8 indicates that the "right-angle" category produces the maximum net benefit (i.e., 764) for the Crash Type attribute. When used on the three-city crash database, it identified 502 right-angle crashes. By implication, these 502 crashes would be assumed to be red-light-running related. However, a manual review of the written reports revealed that only 422 of the crashes were truly red-light-running related (i.e., that 80 crashes were mislabeled). The review also revealed that there were truly 502 red-light-running-related crashes in the three cities of which 80 crashes were missed by the exclusive use of the "right-angle" attribute. The data in the "Net Benefit" column indicates that the net benefit for all other crash type categories is negative. This implies that no other crash type category is viable for consideration as a screen for red-light-running-related crashes.

The data in the middle portion of Table 5-8 indicate that several categories of First Contributing Factor have a positive net benefit. The net benefit for “disregard stop and go signal” (i.e., 632) is largest, so it is a better predictor than any of the other categories listed. This net benefit also exceeds the standard deviation by a factor of 2.0, so it is significantly different than 0.0 and thus, the attribute is “viable” for consideration. The fact that 632 is less than 764 indicates that “right-angle” is a better screen for red-light-running crashes than “disregard stop and go signal.”

When both “disregard stop and go signal” and “disregard stop sign or light” are used together, the data in the last column of Table 5-8 indicate that the First Contributing Factor attribute is a *better* screen than “right-angle.” Their combined net benefit of 778 exceeds the 764 obtained from “right-angle.” The net benefit of four of the remaining five categories for First Contributing Factor also provide a positive net benefit and could be combined with “disregard stop and go signal” and “disregard stop sign or light.” However, the standard deviation of the individual net benefit estimates for these four categories is sufficiently large that there is chance that the corresponding category truly provides no net benefit (i.e., that the benefit shown is due solely to random variation). Hence, these other four categories were not considered further.

Closer examination of the data in Table 5-8 provides further insight into the benefits of using the combined “disregard stop and go signal” and “disregard stop sign or light” categories for First Contributing Factor. Specifically, the data in columns 5 and 6 indicate that their combined use will identify a total of 413 (= 331 + 82) crashes. Of this amount, 16 (= 10 + 6) are mislabeled crashes and 105 (= 502 − 321 − 76) red-light-running-related crashes were missed. In other words, the combined categories identify about 79 percent (= 100 − 105/502 × 100) of the red-light-running-related crashes and yield a subset database that has 96 percent (= 100 − 16/413 × 100) accuracy.

The last six rows in Table 5-8 explore the merits of combining both the Crash Type and First Contributing Factor attributes. As indicated in the last column, the results are promising, but the maximum cumulative net benefit of 758 does not exceed that found from the sole use of First Contributing Factor (i.e., 778). A closer examination of the “missed” and “mislabeled” columns indicates that the two attributes in combination tend to reduce the number of mislabeled crashes (10 vs. 16), relative to sole use of First Contributing Factor. However, they miss a relatively large number of red-light-running crashes (118 vs 105).

Extension to Databases Based on Interpreted Reports

The aforementioned analysis was based on crashes known to have occurred at signalized intersections. As discussed in the section titled Traffic Control, the databases used by states (e.g., the DPS database) and larger cities tend to translate the intersection location aspect of the written crash report into a milepost (or city block) referencing system. A technique that can be used with the DPS database is to search for crashes identified as “at” an intersection where the Traffic Control is identified as “stop and go signal.” The findings from a previous analysis indicated that this use of Traffic Control is viable on a citywide or statewide basis, although it did increase the chance that some red-light-running-related crashes will be missed.

The analysis described for Table 5-8 was repeated for those crashes at intersections and for which the Traffic Control variable was identified as "stop and go signal." The results of this analysis indicated the same conclusions regarding which attribute category was optimal. Specifically, that the combined "disregard stop and go signal" and "disregard stop sign or light" categories for First Contributing Factor yielded the most complete and accurate subset database. The percentage of red-light-running-related crashes included in the subset database decreased to 73 percent (compared to the 79 percent noted previously). However, the 96-percent accuracy was maintained.

ESTIMATING RED-LIGHT-RUNNING CRASH FREQUENCY

The analyses associated with Tables 5-2 through 5-7 consistently indicate that there is no combination of attributes and attribute categories that: (1) collectively yield a subset database that consists entirely of red-light-running-related crashes (i.e., an accuracy of 100 percent), and (2) identifies a reasonably large percentage of red-light-running-related crashes. The findings noted in the previous section indicate that the combined "disregard stop and go signal" and "disregard stop sign or light" categories for First Contributing Factor yielded the most complete and accurate subset database. However, no combination of attributes was able to identify all the red-light-running-related crashes that were in the crash database.

The objective of this section is to describe the development of an empirical equation for predicting the expected number of red-light-running-related crashes based on the count of crashes obtained after screening a database of "at-intersection" crashes using First Contributing Factor. The general form of this equation is:

$$E[Nt] = b_0 + b_1 Nc \qquad \textbf{(13)}$$

where:

$E[Nt]$ = expected number of red-light-running-related crashes;
Nc = number of crashes with a First Contributing Factor of "disregard stop and go signal" or "disregard stop sign or light;" and
b_0, b_1 = calibration coefficients.

The calibrated form of this equation can be used to estimate the number of red-light-running-related crashes based on the number of intersection crashes in the database that have a First Contributing Factor of "disregard stop and go signal" or "disregard stop sign or light." This estimate can be used to estimate the true impact of red-light-running by accounting for all such crashes that occur.

The crash data for three cities in Texas (as described in the preceding section) were used for this analysis. These data were aggregated by intersection. There are 70 intersections represented in the database. The count of red-light-running-related crashes was determined for each intersection based on a manual review of the officer reports. As noted in the section titled Data Collection, only those crashes that were clearly caused by a red-light violation were considered (there was some doubt as to whether 1.7 percent of the crashes in the database were red-light-running related).

Statistical Analysis Method

Crash data are neither normally distributed nor of constant variance, as is required when using traditional least-squares regression for data analysis. Under these conditions, the generalized linear modeling technique described by McCullagh and Nelder *(54)* is appropriate for statistical analysis of crash data. This technique accommodates the explicit specification of an error distribution and uses maximum-likelihood methods for coefficient estimation.

The distribution of red-light-running-related crash frequency can be described by the family of compound Poisson distributions (i.e., the negative binomial distribution). In this context, there are two different sources of variability underlying the distribution. One source stems from the randomness in red-light-running-related crash frequency at any given intersection, which likely follows the Poisson distribution. A second source of variability stems from the differences in the mean red-light-running-related crash frequency *m* among otherwise "similar" intersections. Given that Equation 13 is relating categories of crashes at a common intersection, the second source of variability is not present and the variability is Poisson distributed. The Generalized Modeling (GENMOD) procedure in the SAS software *(55)* was used to estimate the regression model coefficients.

Model Calibration

The fact that the data follow a Poisson distribution dictated an evaluation of the following modified form of Equation 13:

$$E[Nt] = Nc^{b_1} \, e^{(b_0 + b_2 I_2 + b_3 I_3)} \qquad \textbf{(14)}$$

where:

I_2 = indicator variable for City 2 (1.0 if data apply to City 2, 0.0 otherwise); and
I_3 = indicator variable for City 3 (1.0 if data apply to City 3, 0.0 otherwise).

The evaluation revealed that there is no significant difference among the three cites (i.e., that b_2 and b_3 were not significantly different from 0.0). Moreover, the analysis indicated that the exponent on the *Nc* term (i.e., b_1) was not significantly different from 1.0. The remaining regression constant b_0 was significant at a 95 percent level of confidence. As a result of this analysis, Equation 14 was reduced to the following form:

$$E[Nt] = Nc \, e^{b_0} \qquad \textbf{(15)}$$

The statistics related to the calibrated red-light-running model are shown in Table 5-9. The calibrated coefficient b_0 can be used with Equation 15 to estimate the frequency of red-light-running-related crashes at an intersection or within a city. The Pearson χ^2 statistic for the model is 22, and the degrees of freedom are 67 (= n-p-1 = 68-0-1). As this statistic is less than $\chi^2_{0.05,\,67}$ (= 87), the hypothesis that the model fits the data cannot be rejected. The R^2 for the model is 0.90 indicating that almost all of the variability was explained by the equation.

Table 5-9. Calibrated Model Statistical Description.

Model Statistics		Value		
	R^2:	0.90		
	Pearson χ^2:	22 ($\chi^2_{0.05,\,67}$ = 87)		
	Observations:	68 intersections		
	Standard Error:	±1.4 crashes		
Range of Model Variables				
Variable	**Variable Name**	**Units**	**Minimum**	**Maximum**
N_c	Number of crashes with First Contributing Factor listed as "disregard stop and go signal" or "disregard stop sign or light."	crashes	0	22
Calibrated Coefficient Values				
Variable	**Definition**	**Value**	**Std. Dev.**	**t-statistic**
b_0	Intercept	0.197	0.045	4.4

The regression coefficient b_0 for the model is listed in the last row of Table 5-9. The *t*-statistic shown indicates that this coefficient is significant at a 95 percent level of confidence. Its positive value indicates that red-light-running-related crashes increase with an increase in the number of crashes with a First Contributing Factor of either "disregard stop and go signal" or "disregard stop sign or light."

The fit of the model was assessed using the prediction ratios plotted against the predicted red-light-running-related crash frequency. The prediction ratio PR_i for intersection i represents its residual error standardized (i.e., divided) by the square root of its predicted variance. This ratio is computed as:

$$PR_i = \frac{y_{o,i} - y_{p,i}}{\sqrt{V(x)}} \qquad \textbf{(16)}$$

with,

$$V(x)_i = y_{p,i} \qquad \textbf{(17)}$$

where,

PR_i = prediction ratio for intersection i;
$V(x)_i$ = variance of red-light-running-related crashes for intersection i;
$y_{o,i}$ = observed red-light-running-related crash frequency for intersection i; and
$y_{p,i}$ = predicted red-light-running-related crash frequency for intersection i.

The plot of prediction ratios for the study intersections is provided in Figure 5-1. The trends shown in this figure indicate that the model provides a good fit to the data. In general, the prediction ratios exhibit the desired feature of being centered around zero (i.e., the average *PR* is 0.0). With the exception of one intersection, the pattern in the data indicates that the ratios are distributed normally about zero and within the range of ±2.0. This trend is the desired result; it is a consequence of the specification of the negative binomial error distribution in the regression model.

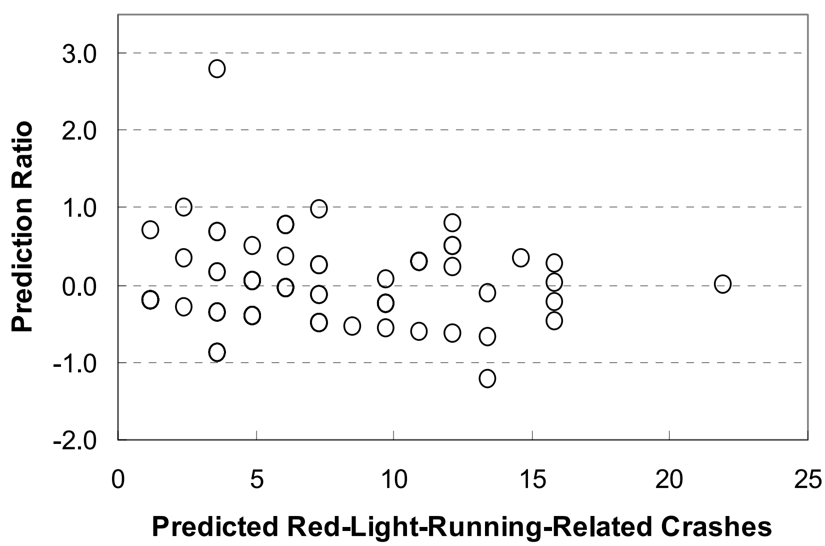

Figure 5-1. Prediction Ratio versus Predicted Red-Light-Running-Related Crash Frequency.

A second means of assessing the model's fit is through the graphical comparison of the observed and predicted red-light-running-related crash frequencies. This comparison is provided in Figure 5-2. The trend line in this figure does *not* represent the line of best fit; rather, it is a "$y = x$" line. The data would fall on this line if the model predictions exactly equaled the observed data. The trends shown in this figure indicate that the model is able to predict crash frequency without bias. The scatter in the data suggests that there is still a small amount of unexplained variability in the data.

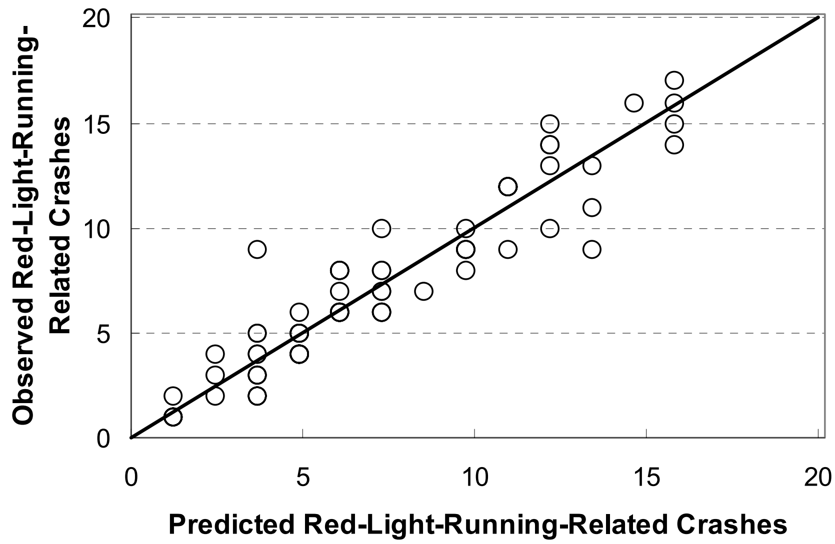

Figure 5-2. Comparison of Observed and Predicted Red-Light-Running-Related Crashes.

The calibrated regression coefficient from Table 5-9 can be inserted into Equation 15 to yield the following model form:

$$E[Nt] = 1.22\ Nc \quad \textbf{(18)}$$

The standard error of this estimate s_e can be computed as:

$$s_e = 0.57 \sqrt{E[N_t]} \quad \textbf{(19)}$$

where:

s_e = standard error of the expected number of red-light-running-related crashes *E[Nt]*.

As noted previously, the expected number of red-light-running-related crashes estimated with Equation 18 is conservative in that only the 502 crashes that were clearly related to a red-light violation were included in the database. It was impossible to verify whether 57 of the crash reports in the database were red-light-running related. Thus, the value obtained from this equation would need to be multiplied by 1.11 (= 1 + 57/502) to obtain a liberal estimate of the red-light-running-related crash frequency.

Extension to Databases Based on Interpreted Reports

The development of Equation 18 was based on crashes known to have occurred at signalized intersections. As discussed in the section titled Traffic Control, the databases used by states (e.g., the DPS database) and larger cities tend to translate the intersection location aspect of the written crash report into a milepost (or city block) referencing system. A technique that can be used with the DPS database is to search for crashes identified as "at" an intersection where the Traffic Control is identified as "stop and go signal." The findings from a previous analysis indicated that this use of Traffic Control is viable on a citywide or statewide basis, although it did increase the chance that some red-light-running-related crashes will be missed.

The development described in the previous section was repeated for those crashes at intersections and for which the Traffic Control variable was identified as "stop and go signal." The results of this analysis indicated the same conclusions regarding the most appropriate equation form and yielded a similarly good quality of fit (R^2 = 0.88). The calibrated model is:

$$E[Nt] = 1.32\ Nc \qquad \textbf{(20)}$$

The standard error of this estimate s_e can be computed as:

$$s_e = 0.63 \sqrt{E[N_t]} \qquad \textbf{(21)}$$

RED-LIGHT-RUNNING CRASH DISTRIBUTION IN TEXAS

This section uses the findings from the previous sections to quantify the number of red-light-running crashes occurring annually in Texas. This section also serves to illustrate the procedure for using these findings to evaluate the extent of red-light-running-related crashes in any crash database.

Crash Frequency

The DPS database was used to illustrate the procedure for identifying red-light-running-related crashes, by severity, occurring at signalized intersections in Texas. Crash data for the years 1997, 1998, 1999, and 2000 were used for this purpose. The specific attributes and attribute categories used to create the subset database included:

- Intersection Relationship: "at" the intersection,
- Control Type: "stop and go signal," and
- First Contributing Factor: "disregard stop and go signal" or "disregard stop sign or light."

The subset database obtained from the use of these attributes is summarized in the top half of Table 5-10. These crashes are referred to hereafter as the "disregard" crashes.

Table 5-10. Red-Light-Running-Related Crashes at Texas Intersections.

Category	Severity [1]	Crashes by Year [2]				Total	Percent of Total, %	Annual Crashes
		1997	1998	1999	2000			
Crashes at Signalized Intersection Attributed to Disregard of Signal or Sign	K	91	96	81	97	365	0	91
	A	1176	1081	1020	1085	4362	5	1091
	B	4152	4116	4241	4137	16,646	21	4162
	C	9220	8893	8822	8815	35,750	45	8938
	PDO	5319	5663	5738	5679	22,399	28	5600
	Subtotal	19,958	19,849	19,902	19,813	79,522	100	19,882
	Percent of Total, %	25	25	25	25	100		
Estimated Actual Red-Light-Running-Related Crashes	K	120	127	107	128	482	0	121
	A	1552	1427	1346	1432	5757	4	1439
	B	5481	5433	5598	5461	21,973	15	5493
	C	12,170	11,739	11,645	11,636	47,190	31	11,798
	PDO	19,323	18,726	18,696	18,657	75,402	50	18,851
	Subtotal	38,646	37,452	37,392	37,314	150,804	100	37,702
	Percent of Total, %	25	25	25	25	100		
Distribution of Crashes by Severity								
Crashes at...	Injury/Total, %	73	71	71	71	72		
	PDO/Total, %	27	29	29	29	28		
Estimated Actual...	Injury/Total, %	50	50	50	50	50		
	PDO/Total, %	50	50	50	50	50		

Notes:
1 - Crashes are identified by the most serious injury that results. K: fatal injury. A: Incapacitating injury. B: Non-incapacitating injury. C: Possible injury. PDO: property damage only.
2 - Table includes all crashes at intersections with Traffic Control identified as "stop and go signal."

The "disregard" crashes identified in the upper half of Table 5-10 represent reported crashes whereas those in the bottom half of the table represent estimates of crash frequency using the methods developed previously in this chapter. The data in the upper half indicate that about 28 percent of the "disregard" crashes have property damage only. The balance of the crashes (i.e., 72 percent) include one or more injuries. The annual number of fatal crashes varied from 81 to 97, with an average of 91 per year. The trend over time indicates that the number of crashes in the K, A, and B severity classes has remained unchanged during the four analysis years. On the other hand, the number of crashes in the C severity class has decreased slightly and the PDO crashes have tended to increase with time. Overall, there number of crashes has decreased slightly with time.

On an annual basis, the average number of "disregard" crashes is 19,882. Based on the discussion following Table 5-8, about 96 percent of these crashes are truly red-light-running related. Moreover, the true red-light-running-related crashes in the 19,882 account for about 73 percent of all red-light-running-related crashes. Equation 20 indicates that these reported crashes should be multiplied by 1.32 to produce an accurate estimate of the true number of red-light-running-related crashes. The crash counts listed in the middle portion of Table 5-10 reflect this adjustment.

The data in the middle portion of Table 5-10 suggest that there are truly about 121 fatal crashes each year attributable to red-light violations. This number represents about 3.8 percent of the 3200 fatal crashes that occur annually on Texas streets and highways. About 37,702 red-light-running-related crashes occur each year. This number represents about 7.9 percent of the 478,000 crashes that occur annually on Texas streets and highways.

As noted previously, the predicted red-light-running frequency obtained from Equation 20 is conservative in that only those crashes that were clearly red-light-running related were used for its calibration. A liberal estimate of the red-light-running-related crash frequency can be obtained by multiplying the value obtained from this equation by 1.11. In other words, the estimated red-light-running-related crashes listed in Table 5-10 could be increased by 11 percent if "possible" red-light-running-related crashes are also included in the estimate.

The last four rows of Table 5-10 report the percentage of injury and PDO crashes in the database. In general, the DPS database includes between 27 and 29 percent PDO crashes. This percentage is much lower than the percentages found at each of the three Texas cities studied. Table 5-6 indicates that the PDO percentages in these cities ranged from 37 to 52 percent (using only the red-light-running-related crashes). This difference is likely due to the fact that, starting in 1995, only those crashes that involved one or more vehicles being towed from the scene were included in the DPS database *(3)*, regardless of the reporting threshold.

To further investigate the differences in PDO percentage among cities, the PDO percentage for red-light-running-related crashes was computed for each city in the DPS database. The findings from this investigation are shown in Figure 5-3. The trends in this figure indicate that PDO percentage varies widely among cities in Texas. It is likely that the higher percentages found reflect cities where law enforcement agencies informally use a lower reporting threshold. Based on this evaluation and the conclusion previously reached with regard to Table 5-6 (i.e., that City 1 had the most representative distribution of crashes by severity), a PDO percentage of 50 percent is believed to conservatively reflect the true number of PDO crashes occurring in Texas. Thus, it is recommended that a PDO_{ref} of 0.50 should be used in Equation 5 and that this equation should be used to estimate the true number of PDO red-light-running-related crashes in Texas cities.

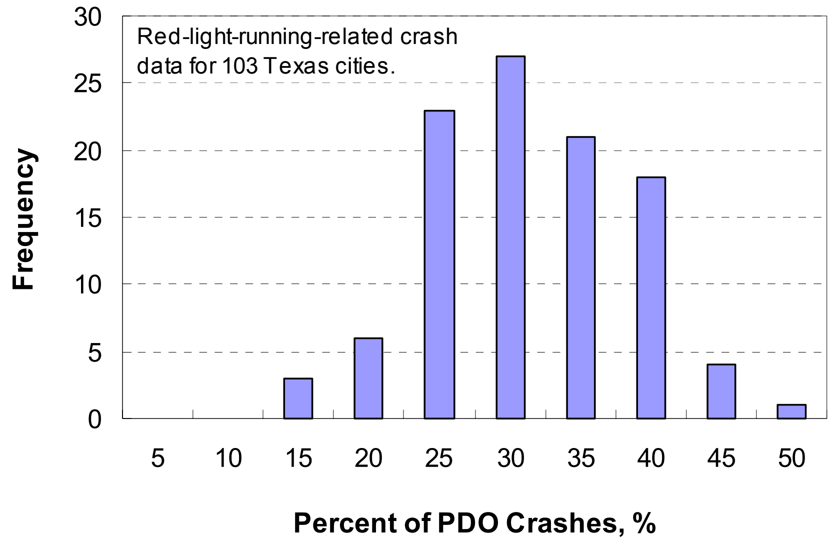

Figure 5-3. Distribution of PDO Percentages for Several Texas Cities.

The estimated number of true PDO crashes is listed in the middle portion of Table 5-10. The last row of this table confirms that the adjusted PDO crashes represent 50 percent of all red-light-running-related crashes. The factor obtained from Equation 5, when applied to the values in Table 5-10, suggests that about 10,000 PDO "disregard" crashes are not reported each year. This translates into an estimated 13,000 unreported PDO red-light-running-related crashes each year.

Number of Injuries

The number of persons injured in each of the crashes identified in Table 5-10 is listed in Table 5-11. The data in this table indicate that there about 27,251 injuries reported each year for "disregard" crashes in Texas. Moreover, the number of fatalities ranged from 90 to 114 per year with an annual average of 101 persons fatally injured.

As noted in the previous section, it is likely that the attributes used to screen this subset database may have missed some red-light-running-related crashes. Therefore, the injuries were increased using Equation 20. The injuries listed in the bottom portion of Table 5-11 represent the adjusted values. These data suggest that there are about 133 fatalities each year due to red-light violations. It also suggests that there are about 35,969 red-light-running-related injuries each year.

The data listed in Tables 5-10 and 5-11 were used to estimate the cost of a red-light-running-related crash. This cost was then used to estimate the total annual cost of red-light-running-related crashes in Texas. The results of this analysis are shown in Table 5-12.

Table 5-11. Number of Red-Light-Running-Related Injuries at Texas Intersections.

Category	Severity [1]	Injuries by Year [2]				Total	Percent of Total, %	Annual Injuries
		1997	1998	1999	2000			
Injuries at Signalized Intersection Attributed to Disregard of Signal or Sign	K	97	103	90	114	404	0	101
	A	1633	1557	1444	1568	6202	6	1551
	B	6915	6640	6956	6723	27,234	25	6809
	C	19,653	18,713	18,389	18,403	75,158	69	18,790
	Subtotal	28,298	27,013	26,879	26,808	108,998	100	27,251
	Percent of Total, %	25	25	25	25	100		
Estimated Actual Red-Light-Running-Related Injuries	K	128	136	119	150	533	0	133
	A	2156	2055	1906	2070	8187	6	2047
	B	9128	8765	9182	8874	35,949	25	8987
	C	25,942	24,701	24,273	24,292	99,208	69	24,802
	Subtotal	37,354	35,657	35,480	35,386	143,877	100	35,969
	Percent of Total, %	25	25	25	25	100		

Notes:
1 - K: fatal injury. A: Incapacitating injury. B: Non-incapacitating injury. C: Possible injury. PDO: property damage only.
2 - Table includes all injuries at intersections with Traffic Control identified as "stop and go signal."

Table 5-12. Cost of Red-Light-Running-Related Crashes for 2003.

Severity [1]	Crash Cost [2]	Annual Crashes [3]	Annual Injuries	Annual Cost
K	3,237,000	121	133	$431,000,000
A	224,000	1439	2047	$458,000,000
B	45,000	5493	8987	$404,000,000
C	24,000	11,798	24,802	$595,000,000
PDO	2500	18,851	0	$94,000,000
Total:	**--**	**37,702**	**35,969**	**$1,982,000,000**
			Average Cost / RLR Crash:	**$52,600**

Notes:
1 - K: fatal injury. A: Incapacitating injury. B: Non-incapacitating injury. C: Possible injury. PDO: property damage only.
2 - Costs from *Motor Vehicle Accident Costs* (*56*) and updated to 2003 costs using the Consumer Price Index for 1994 (= 147) and 2003 (= 183). Costs for K, A, B, and C have units of "$ per person injured or killed;" those for PDO have units of "$ per vehicle."
3 - Table includes all crashes at intersections with Traffic Control identified as "stop and go signal."

The data in Table 5-12 indicate that the average cost of each red-light-running-related crash is $52,600. Moreover, the analysis indicates that these crashes have a societal cost to Texans of about $2.0 billion dollars each year. The costs listed in column 2 of this table represent a comprehensive cost estimate in that they include the direct cost of the crash (such as property damage, medical costs, legal fees) as well as indirect costs associated with lost earnings and a reduced quality of life. The cost of a fatality listed in Table 5-12 is estimated at $3,237,000. Allowing for inflation, this estimate is consistent with the value of $3,000,000 recommended for use by the Office of the Secretary of Transportation, U.S. Department of Transportation (*57*) in 2002.

Comprehensive crash costs are appropriate for comparing alternative transportation improvements because they reflect what motorists are willing to pay for improved safety (*56*). However, for evaluating the direct economic loss resulting from past crashes, the cost of quality-of-life (i.e., pain and suffering due to a crash) should be excluded from the estimate. Crash cost data reported by Blincoe et al. (*58*, Appendix A) were examined to determine the cost contribution of quality-of-life. The procedure described by Rollins and McFarland (*59*) was used to convert the data reported by Blincoe et al. into a direct cost for each of the severity types listed in Table 5-12. Based on this analysis, the resulting direct economic cost per crash is estimated at $37,900 and the direct economic cost of red-light-running to Texans is about $1.4 billion. Based on this analysis, quality-of-life costs account for 28 percent of the comprehensive crash costs.

The techniques used to develop Table 5-10 were also used to develop an estimate of the annual number of red-light-running-related crashes for the Texas cities included in the DPS database. In fact, there are crash reports for 519 cities included in this database. The 25 cities and counties that experienced the most red-light-running-related crashes are listed in Table 5-13.

The data in Table 5-13 indicate that the 25 cities and counties listed account for 77 percent of the crashes (and associated crash costs) while accounting for only 50 percent of the state's population. The annual crash cost estimate in column 4 is based on an average crash cost of $52,600.

When the annual cost is normalized among cities by converting it to a "cost per capita," the resulting costs range from $44 to $258 per person. The statewide average cost per capita is $95. Only three of the cities listed in Table 5-13 have a "cost per capita" that is below this average rate.

It is likely that the five or six cities (or counties) with the largest number of crashes and the five or six cities (or counties) with the highest "cost per capita" would derive the most benefit from increased use of engineering countermeasures, enforcement countermeasures, or public awareness campaigns. However, a more detailed engineering analysis for each city or county is needed to verify this claim and the city's potential for improvement.

Table 5-13. Cost of Red-Light-Running-Related Crashes in Several Texas Cities and Counties.

No.	City or County	Annual RLR-Related Crashes [1]	Annual Crash Cost, $/year	City or County Population [2]	Per Capita Crash Cost, $/person [3]	Rank Based on Per Capita Cost [4]
1	Houston	9606	$505,000,000	1,953,631	$258	1
2	Dallas	4223	$222,000,000	1,188,580	$187	5
3	San Antonio	2408	$127,000,000	1,144,646	$111	21
4	Austin	1713	$90,000,000	656,562	$137	13
5	Fort Worth	1314	$69,000,000	534,694	$129	15
6	Harris County [5]	1221	$64,000,000	1,446,947	$44	25
7	Arlington	886	$47,000,000	332,969	$141	12
8	El Paso	879	$46,000,000	563,662	$82	24
9	Pasadena	626	$33,000,000	141,674	$233	3
10	Corpus Christi	598	$31,000,000	277,454	$112	20
11	Waco	559	$29,000,000	113,726	$255	2
12	Plano	536	$28,000,000	222,030	$126	16
13	Garland	500	$26,000,000	215,768	$120	17
14	Amarillo	484	$25,000,000	173,627	$144	11
15	Lubbock	444	$23,000,000	199,564	$115	19
16	Abilene	394	$21,000,000	115,930	$181	7
17	Beaumont	382	$20,000,000	113,866	$176	9
18	Irving	366	$19,000,000	191,615	$99	22
19	Richardson	324	$17,000,000	91,802	$185	6
20	Grand Prairie	315	$17,000,000	127,427	$133	14
21	Laredo	297	$16,000,000	176,576	$91	23
22	Tyler	290	$15,000,000	83,650	$179	8
23	Odessa	269	$14,000,000	90,943	$154	10
24	Longview	266	$14,000,000	73,344	$191	4
25	Wichita Falls	237	$12,000,000	104,197	$115	18
	Total:	29,137	$1,533,000,000	10,334,884	$148	

Notes:

1 - Estimated average annual number of red-light-running-related crashes based on data in the DPS database for the years 1997, 1998, 1999, and 2000.

2 - Based on 2000 census (*60*).

3 - Average per capita cost for Texas is $95 (= 1,982,000,000 / 20,851,820).

4 - Ranking of the 25 cities or counties having the most red-light-running-related crashes.

5 - Harris County data do not include the residents of the City of Houston.

CHAPTER 6. SUMMARY OF FINDINGS

OVERVIEW

The problem of red-light-running is widespread and growing; its cost to society is significant. A wide range of potential countermeasures to the red-light-running problem exist. These countermeasures are generally divided into two broad categories: engineering countermeasures and enforcement countermeasures. A study by Retting et al. (*4*) has shown that countermeasures in both categories are effective in reducing the frequency of red-light-running.

Unfortunately, guidelines are not available for identifying "problem" intersections and whether engineering or enforcement is the most appropriate countermeasure at a particular intersection. Moreover, there has been concern voiced over the validity of various methods used to identify problem locations (*5, 6*), especially when automated enforcement is being considered. There has also been concern expressed that engineering countermeasures are sometimes not fully considered prior to the implementation of enforcement (*5, 6, 7*).

The objectives of this research project are to: (1) quantify the safety impact of red-light-running at intersections in Texas, and (2) provide guidelines for identifying truly "problem" intersections and whether enforcement or engineering countermeasures are appropriate. This chapter documents the findings from the first year of research and the analyses completed in fulfillment of the first objective.

ENFORCEMENT ISSUES RELATED TO RED-LIGHT-RUNNING

The findings reported in this section relate to the enforcement of intersection traffic control laws, its effectiveness, and related issues. The discussion emphasizes the enforcement of the traffic signal indication and associated red-light violations.

Precursors to Enforcement

Serial versus Parallel Treatment Approach

The best approach in dealing with perceived red-light-running problems is generally recognized as one that combines engineering, education, and enforcement. However, there is some debate as to how and when to use countermeasures in any one of these three categories. A review of the literature on this topic indicates that many agencies prefer a "serial" treatment approach where engineering countermeasures are considered first, followed by education (via a public information campaign), then enforcement. The advantage of a serial approach is that it facilitates the study of individual countermeasure effectiveness. If this effectiveness were known, it would be possible for an agency to optimize the cost-effectiveness of its treatment program, and possibly fund it for a longer period of time.

However, some traffic engineers believe that engineering countermeasures will have a limited effect on drivers who deliberately run the red indication. They feel that a "parallel" treatment approach that combines engineering, education, and enforcement is more effective. One benefit of this approach is that a wide array of resources is immediately concentrated on solving one traffic problem. Obvious problems with this approach are: (1) its implementation is expensive (relative to a serial approach), and (2), if a reduction in crashes is realized, it is very difficult to determine the incremental effectiveness of the individual countermeasures.

Intersection Selection Process

The identification of an intersection with a red-light-running problem is typically based on consideration of several criteria. These criteria range from the frequency of red-light violations, to the frequency of red-light-running-related crashes, to the frequency of citizen complaints.

Bonneson et al. (*11*) describe an alternative method for locating problem intersections. This method considers both red-light violations and related crashes. Instead of looking at just the total number of violations, the method focuses on the *difference* between the observed and expected violations. Problem intersections are defined as those having a large difference between the observed and expected violations. Additional consideration is given to those intersections with a recurring frequency of red-light-running-related crashes. The advantage of this approach is that it is intended to direct resources to locations where countermeasures will be cost-effective.

Public Awareness Campaign

Agencies that conduct citywide, heightened enforcement programs typically combine this program with a public awareness campaign. There are generally three main themes of an effective campaign (*14*). These themes are:

- Educate drivers on red-light-running hazards.
- Use the media to open communications between elected officials and the public about the extent of the problem and the need for treatment.
- Provide motorists advance warning that enforcement will be increased in the near future.

A wide range of methods are often used to convey the campaign message and heighten motorist awareness. Some of the more commonly used methods include: posters, mass mailings, hand outs, electronic media commercials, billboards, warning signs, and bumper stickers.

Enforcement Programs

Program Goals

The need to establish specific goals for an enforcement program is an important, and early, step in the process of treating problem intersections (*9*). These goals provide a benchmark by which program success can be measured. They often include an expected reduction in red-light violations, with complete elimination of these violations as the most extreme expectation.

There is little doubt that increasing enforcement will reduce red-light violations and related crashes. However, it is also likely that there is a point of diminishing returns where further increases in enforcement effort bring little additional safety benefit. In this context, the cost of providing sufficient enforcement to eliminate red-light-running could exceed the available financial resources of most cities. And, even if these resources were available, it could be reasonably argued that they could be more cost-effectively used to combat other road safety problems. This argument suggests that elimination of red-light-running may be an unreasonable goal for most cities.

Reasonable goals should be set prior to the conduct of an enforcement program. These goals should be based on achieving a level of reduction in crashes or violations that: (1) is cost-effective in its use of enforcement, (2) recognizes that a small number of violations will always occur, and (3) is reasonable and acceptable to both the engineer and the public.

Types of Enforcement

Enforcement activities used to treat safety problems can be categorized as one of two types: officer and camera. Typical methods by which each of these two types are used to deal with red-light-running is described in this section.

Officer Enforcement. Many police departments use a team enforcement technique to address red-light-running and other intersection traffic control violations. With this technique, one officer is stationed upstream of the signalized intersection, and a second officer is located downstream of the intersection. When the "upstream" officer observes a violation, he or she sends a radio message to the "downstream" officer, who then proceeds to stop and cite the violator. This technique is generally regarded as successful in reducing violations but is labor-intensive (*16*).

As an alternative to team enforcement, some jurisdictions use enforcement lights (*7*). An enforcement light can be attached to the signal head or to the signal mast arm. These lights are illuminated while the traffic signal indication is red. They allow a single officer stationed downstream of the signal to observe vehicles entering the intersection and note whether the signal indication is red. Enforcement lights eliminate the need for team enforcement and, thus, have a lower operating cost (*7*).

Zaal (*19*) indicates that the benefit of officer enforcement, relative to camera enforcement, is that red-light violators are apprehended immediately after the violation. He cites evidence that the immediacy of the "punishment" (i.e., a citation) has a more lasting, corrective effect on the driver than receipt of a camera-based citation several weeks after the offense. He also notes that police presence at an intersection may have a residual benefit in terms of reducing other types of violations.

Camera Enforcement. A red light camera system at a typical intersection could cost anywhere from $50,000 to $60,000, with installation adding from $10,000 to $25,000 (*9, 17*). Operating costs are reported by Maccubbin et al. (*18*) to be in the vicinity of $5000 per month.

The violation for red-light-running may be treated as a civil or criminal offense, depending on the relevant state statutes. Tickets for civil offenses are sent by mail to violators. Prosecution of the violation as a criminal offense requires proof that the individual committed the offense (e.g., a frontal photograph) and is adjudicated in a criminal court with a fine levied by a judge. Fines can range from $50 to $270 (*18*).

A recent review of grace period values used throughout the world revealed that 0.5 s is the "international standard," and that 0.3 s is commonly used in the U.S. (*6*). A similar review by Milazzo et al. (*7*) of U.S. practice indicated a range of 0.1 to 0.3 s being used as the grace period. Based on their analysis of issues related to the grace period, Milazzo et al. recommended the use of a 0.4-s grace period, with a possible increase for approaches with a significant downgrade.

Program Effectiveness

Basic Measures of Effectiveness. A review of the literature indicates that several measures are used to quantify red-light violations. The more commonly used measures include: "percent of cycles with one or more red-light-runners," "hourly red-light violation rate," and "percent of vehicles that run the red." A review of the literature indicates that no less than 10 different measures have been used to quantify countermeasure effectiveness.

In recognition of the many measures being used, Bonneson et al. (*11*) recommended the use of "red-light violations per 10,000 vehicle-cycles." Their recommendation is based on the finding that red-light violations are highly correlated with both traffic volume and the number of signal cycles that occur each hour. They argue that computation of a violation rate using these exposure factors will facilitate the equitable comparison of intersections among jurisdictions and a better understanding of factors that cause red-light-running.

A primary role of enforcement is to deter motorists from committing violations. Hence, citation data are likely to show an initial increase at the start of a heightened enforcement program and then a reduction as the program matures. This time dependency makes it difficult to accurately quantify overall program effectiveness using citation data. For this reason, the frequency of citations should be avoided as a measure of effectiveness for an enforcement program.

Red-light-running-related crashes have proven difficult to quantify (*9*). This difficulty lies in the fact that many cities and states do not flag crashes as being caused by a red-light violation. Instead, these red-light-running-related crashes are often identified using the more general categories of "disregard stop and go signal" or "right-angle." While this practice is likely to identify a large percentage of the red-light-running-related crashes, it is also likely that some non-red-light-running-related crashes will be included and that some red-light-running-related crashes will be excluded.

Extrapolation of countermeasure effectiveness to other locations is practically impossible without a consistently applied definition of a red-light-running-related crash.

Officer Enforcement Effectiveness. Officer enforcement is generally recognized has having an immediate, positive effect of reducing red-light violations. The extent of this impact appears to vary, depending on whether the officer (and cruiser) is visible. Bankhead and Herms *(21)* found that the visible presence of uniformed officers reduced the frequency of intersection crashes by at least 12 percent. Similarly, Cooper *(22)* found that visible police presence reduced traffic control violations by 28 percent, provided that the enforcement activity was sustained for at least one hour each day.

The covert deployment of officers for red-light-running enforcement appears to be less effective than the overt (or visible) deployment method. The only drivers affected by a covert deployment include those receiving the citation and a portion of those who pass by while the citation is being written. Between citations, the officers remain mostly hidden from view and largely ineffective *(23)*.

The relationship between the amount of enforcement applied and changes in crash frequency has been examined by two researchers *(26, 27)*. One researcher estimated that a 4 percent increase in police department staff size could reduce the number of injury crashes by 2 percent *(26)*. Another researcher *(27)* found that a 100 percent increase in the amount of enforcement hours resulted in a 4 percent reduction in regional crashes. He also found that the estimated benefit of additional officer enforcement outweighed its cost by a factor of four (i.e., a benefit-cost ratio of 4.0).

Cooper *(22)* observed a 28 percent reduction in the number of intersection violations while overt enforcement was taking place. However, the effectiveness of the enforcement diminished rapidly once the officers left the intersection. Field measurements indicated that the benefit of the original enforcement activity was lost after six days.

Camera Enforcement Effectiveness. The effectiveness of camera enforcement in reducing the number of red-light-runners has been widely reported. A review of this literature indicates that camera enforcement has been found to reduce the frequency of red-light violations between 40 and 59 percent. Camera enforcement has also been found to reduce red-light-running-related crashes between 20 and 36 percent (between 9 and 10 percent on a citywide basis). However, rear-end crashes have been found to increase between 20 and 37 percent. A comprehensive study of the impact of camera enforcement on total crashes (including right-angle and rear-end crashes) found that camera enforcement reduced total crashes by 7 percent on a citywide basis.

Several studies *(6, 20)* examined the effect of camera enforcement on other, non-camera-enforced intersections in the same city. Data reported by the California state auditor *(6)* indicated that the application of camera enforcement at six cities coincided with a 10 percent reduction in red-light-running-related crashes on a statewide basis. A closer examination of these data indicated that the reduction in crashes at non-camera-enforced intersections was realized only after about 24 months of continuous camera operation.

The conduct of a formal before-after study of the effectiveness of a camera enforcement activity is essential to the justification of a camera enforcement system (*9*). However, all too often, studies are lacking sufficient rigor to offer convincing evidence of a camera's true effect on violations or crash frequency. One problem that frequently emerges is the lack of a valid "before" data set (*14*). A second problem is the simultaneous implementation of numerous countermeasures by the agency. It is difficult to determine the contribution of an individual countermeasure when several countermeasures are implemented at the same time.

SAFETY STATISTICS RELATED TO RED-LIGHT-RUNNING

The findings reported in this section review the characteristics of red-light-running violations and related crashes. Initially, the extent of red-light-running is quantified through a review of the various violation rates reported in the literature. Then, the effects of red-light-running on crash frequency and the associated costs are discussed.

Red-Light-Running Events

Violation Rates

Red-light violation rates are widely reported in the literature (*11, 35, 37*). For example, Lum and Wong (*35*) observed 8.8 violations per 1000 vehicles at intersections without camera enforcement. Data reported by Baguley (*37*) indicate that drivers were observed to run the red at an average rate of 5.3 violations per 1000 vehicles. Bonneson et al. (*11*) reported an average red-light-running rate of 1.0 violations per 10,000 vehicle-cycles. These rates suggest that the typical busy intersection may experience between 2.0 and 6.0 red-light violations per hour.

Entry Time of the Red-Light-Running Driver

Bonneson et al. (*11*) examined the extent to which a red-light-runner enters after the end of the yellow interval. They found that more than one-half of the red-light violations occurred in the first 0.5 s of red. The average red-running driver entered about 0.7 s after the end of the yellow interval. About 80 percent of the drivers entered within 1.0 s after the end of the yellow interval. This latter statistic is consistent with the trend reported by Lum and Wong (*38*).

The time after the end of the yellow indication at which the red-light-runner enters the intersection is logically correlated with the potential for a right-angle collision. As this "time into red" increases, crash frequency is also likely to increase Right-angle crashes are not likely to occur during the all-red interval. However, the potential for a right-angle crash is likely to increase with a vehicle's entry time after the end of the all-red interval.

In addition to right-angle crashes, left-turn-opposed crashes can also be caused by red-light violations, especially when the left-turn movement can turn permissively through gaps in the oncoming through traffic stream. In this situation, the left-turn driver waiting in the intersection at the end of the phase (i.e., onset of yellow) is highly motivated to complete the turn and often turns in front of an approaching through vehicle as the yellow indication ends. Data reported by Milazzo et al. (*7*) suggest that left-turn-opposed crashes constitute about 20 percent of all red-light-running-related crashes.

Influence of Delay on Red-Light Violations

It is generally recognized that driver frustration due to excessive delay can lead to red-light-running. A survey by Porter and Berry (*39*) indicated that many drivers would run a red light in order to eliminate delay.

An equation was derived for this research to predict the effect of volume-to-capacity ratio on expected red-light violation frequency. The extension of this equation to include delay follows given the direct relationship between delay and volume-to-capacity ratio. A sensitivity analysis of this equation revealed that volume-to-capacity ratios less than 0.88 are not likely to have an effect on the frequency of red-light-running. This analysis also revealed that an intersection with a volume-to-capacity ratio of 1.0 may have up to 80 percent more red-light-running than an intersection with a ratio of 0.88 or less.

Red-Light-Running-Related Crashes

A recent review of the FARS database by the Insurance Institute for Highway Safety provides some indication of the consequences of red-light-running in Texas (*2*). They found that Texas has the fourth highest red-light-running-related fatality rate in the U.S. (with an average of 95 red-light-running-related fatalities per year). Only the states of Arizona, Nevada, and Michigan had more fatalities per capita than Texas. In addition, five Texas cities ranked in the top 28 cities with the highest red-light-running-related fatality rate.

Bonneson et al. (*11*) examined the relationship between violation rate and crash history for 12 intersection approaches. Only right-angle and left-turn-opposed crashes were included in their analysis. They found that crash frequency was higher on those approaches with higher red-light violation rates. They also found that the crash rate increased with an increase in crossroad daily traffic volume.

An examination of the DPS crash database by Quiroga et al. (*3*) revealed that the reported number of persons killed or injured in red-light-running-related crashes in Texas has grown from 10,000 persons/yr in 1975 to 25,000 persons/yr in 1999. They estimate that these crashes currently impose a societal cost on Texans of $1.4 to $3.0 billion annually.

IDENTIFYING AND EVALUATING RED-LIGHT-RUNNING-RELATED CRASHES

When an electronic crash database (e.g., DPS database) is used to identify red-light-running crashes, it should be screened to include only those crashes that occur "at" the intersection. This technique will eliminate differences in crash reporting among cities without reducing the accuracy of the subset database (in terms of the percentage of red-light-running-related crashes it includes).

Many PDO crashes are not included in crash databases. This deficiency is true for the DPS database. Moreover, the percentage of PDO crashes included these databases varies widely among cities and states. This trend is likely due to differences in the reporting threshold used by the responsible agencies. However, this variability makes it difficult to compare the distribution of crashes among cities and states.

It is estimated that 55 percent of all intersection crashes are PDO, and 50 percent of all red-light-running-related crashes are PDO. These percentages suggest that about 13,000 of the 19,000 red-light-running-related PDO crashes that occur each year are not documented in the DPS database.

About 48 percent of red-light-running-related crashes involve injury, whereas only 44 percent of other crashes involve injury. This statistic is influenced by reporting threshold (i.e., higher percentages result when the reporting threshold increases).

Fifteen percent of the red-light-running-related crashes is misidentified as "disregard stop sign or light." This mistake is probably being made by the investigating officer when recording the factors contributing to the crash. It is likely due to: (1) the fact that this attribute and that of the correct attribute, "disregard stop and go signal," have sequential numbers on the crash report and (2) the similarity of their wording.

The combined use of two categories of the First Contributing Factor attribute (i.e., "disregard stop and go signal" and "disregard stop sign or light") yields the optimal red-light-running-related crash database. In this instance, the optimal database contains the largest number of red-light-running-related crashes and the fewest mislabeled crashes. However, the number of crashes obtained from the use of these two categories needs to be multiplied by 1.22 (or 1.32) to obtain an accurate estimate of the true number of red-light-running-related crashes. The choice of multiplier depends on the type of crash database being used.

There are about 121 fatal crashes each year in Texas that are attributable to red-light violations. This number represents about 3.8 percent of the 3200 fatal crashes that occur annually on Texas streets and highways. About 37,702 red-light-running-related crashes occur each year in Texas. This number represents about 7.9 percent of the 478,000 crashes that occur annually on Texas streets and highways.

Crashes associated with red-light violations have a societal cost to Texans of about $2.0 billion dollars each year. This cost includes the direct cost of the crash (such as property damage, medical costs, legal fees) as well as indirect costs associated with lost earnings and a reduced quality of life. The direct economic cost to Texans is estimated at $1.4 billion annually.

Engineering and enforcement countermeasures have been shown to reduce red-light violations, related crashes, or both by at least 10 to 30 percent. If even a 10 percent reduction in crashes were realized by the use of one or more countermeasures, Texas motorists could save $140 million annually.

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APPENDIX

TEXAS PEACE OFFICER CRASH REPORT
(Form ST-3)

TEXAS PEACE OFFICER'S ACCIDENT REPORT ST-3 (Eff. 1/1/00) MAIL TO: ACCIDENT RECORDS, TEXAS DEPARTMENT OF PUBLIC SAFETY, PO BOX 4087, AUSTIN TX 78773-0350

PLACE WHERE ACCIDENT OCCURRED

COUNTY ______ CITY OR TOWN ______ SHOW ONLY IF INSIDE CITY LIMITS

IF ACCIDENT WAS OUTSIDE CITY LIMITS INDICATE DISTANCE FROM NEAREST TOWN ______ MILES ☐ ☐☐☐ NORTH S E W OF ______ CITY OR TOWN

LOC. NO. ______

DO NOT WRITE IN THIS SPACE

LOC. ______ CODE ______ SEVERITY ______ FAT. REC ______ DR. REC. ______

DPS NO.

ROAD ON WHICH ACCIDENT OCCURRED ______ BLOCK NUMBER / STREET OR ROAD NAME / ROUTE NUMBER OR STREET CODE — CONSTR. ZONE ☐ YES SPEED ☐ NO LIMIT ______

INTERSECTING STREET OR RR X'ING NUMBER ______ BLOCK NUMBER / STREET OR ROAD NAME / ROUTE NUMBER OR STREET CODE — CONSTR. ZONE ☐ YES SPEED ☐ NO LIMIT ______

NOT AT INTERSECTION ______ ☐ FT. ☐ MI. ☐☐☐☐ N S E W OF ______ SHOW MILEPOST OR NEAREST INTERSECTING NUMBERED HIGHWAY. IF NONE, SHOW NEAREST INTERSECTING STREET OR REFERENCE POINT.

DATE OF ACCIDENT ______ 20 ____ DAY OF WEEK ______ HOUR ______ ☐ A.M. IF EXACTLY NOON ☐ P.M. OR MIDNIGHT, SO STATE

UNIT NO. 1 - MOTOR VEHICLE VEHICLE IDENT. NO. ______ IF BODY STYLE-VAN OR BUS, INDICATE SEATING CAPACITY ______

YEAR MODEL ______ COLOR & MAKE ______ MODEL NAME ______ BODY STYLE ______ LICENSE PLATE ______ YEAR / STATE / NUMBER

DRIVER'S NAME ______ LAST / FIRST / MIDDLE / ADDRESS (STREET, CITY, STATE, ZIP) PHONE NUMBER ______

DRIVER'S LICENSE ______ STATE / NUMBER / CLASS/TYPE DOB ______ MO DAY YEAR RACE ______ SEX ______ OCCUPATION ______

SPECIMEN TAKEN (ALCOHOL/DRUG ANALYSIS) I-BREATH 2-BLOOD 3-OTHER 4-NONE 5-REFUSED ☐ ALCOHOL/DRUG ANALYSIS RESULT ______ PEACE OFFICER EMS DRIVER FIRE FIGHTER ON EMERGENCY? ☐ YES ☐ NO

LESSEE ☐ OWNER ☐ ______ NAME (ALWAYS SHOW LESSEE IF LEASED, OTHERWISE SHOW OWNER) / ADDRESS (STREET, CITY, STATE, ZIP)

LIABILITY INSURANCE ☐ YES ☐ NO ______ INSURANCE COMPANY NAME / POLICY NUMBER VEHICLE DAMAGE RATING ______

UNIT NO. 2 MOTOR VEHICLE ☐ TRAIN ☐ PEDALCYCLIST ☐ TOWED ☐ PEDESTRIAN ☐ OTHER ☐ VEHICLE IDENT. NO. ______ IF BODY STYLE-VAN OR BUS, INDICATE SEATING CAPACITY ______

YEAR MODEL ______ COLOR & MAKE ______ MODEL NAME ______ BODY STYLE ______ LICENSE PLATE ______ YEAR / STATE / NUMBER

DRIVER'S NAME ______ LAST / FIRST / MIDDLE / ADDRESS (STREET, CITY, STATE, ZIP) PHONE NUMBER ______

DRIVER'S LICENSE ______ STATE / NUMBER / CLASS/TYPE DOB ______ MO DAY YEAR RACE ______ SEX ______ OCCUPATION ______

SPECIMEN TAKEN (ALCOHOL/DRUG ANALYSIS) 1-BREATH 2-BLOOD 3-OTHER 4-NONE 5-REFUSED ☐ ALCOHOL/DRUG ANALYSIS RESULT ______ PEACE OFFICER EMS DRIVER FIRE FIGHTER ON EMERGENCY? ☐ YES ☐ NO

LESSEE ☐ OWNER ☐ ______ NAME (ALWAYS SHOW LESSEE IF LEASED, OTHERWISE SHOW OWNER) / ADDRESS (STREET, CITY, STATE, ZIP)

LIABILITY INSURANCE ☐ YES ☐ NO ______ INSURANCE COMPANY NAME / POLICY NUMBER VEHICLE DAMAGE RATING ______

DAMAGE TO PROPERTY OTHER THAN VEHICLES

OBJECT / NAME AND ADDRESS (STREET, CITY, STATE, ZIP) OF OWNER / FEET FROM CURB / $ DAMAGE ESTIMATE

LIGHT CONDITION ☐	WEATHER ☐☐		SURFACE CONDITION ☐	TYPE ROAD SURFACE ☐	DESCRIBE ROAD CONDITIONS (INVESTIGATOR'S OPINION)
1-DAYLIGHT	1-CLEAR/CLOUDY	6-SMOKE	1-DRY	I-BLACKTOP	
2-DAWN	2-RAINING	7-SLEETING	2-WET	2-CONCRETE	
3-DARK-NOT LIGHTED	3-SNOWING	8-HIGH WINDS	3-MUDDY	3-GRAVEL	
4-DARK-LIGHTED	4-FOG	9-OTHER	4-SNOWY/ICY	4-SHELL	
5-DUSK	5-BLOWING DUST	______	5-OTHER ______	5-DIRT	
				6-OTHER ______	

IN YOUR OPINION, DID THIS ACCIDENT RESULT IN AT LEAST $500.00 DAMAGE TO ANY ONE PERSON'S PROPERTY? ☐ YES ☐ NO

CHARGES FILED

NAME ______ CHARGE ______ CITATION NUMBER ______

NAME ______ CHARGE ______ CITATION NUMBER ______

TIME NOTIFIED OF ACCIDENT ______ DATE / HOUR M HOW ______ TIME ARRIVED AT SCENE OF ACCIDENT ______ DATE / HOUR M

TYPED OR PRINTED NAME OF INVESTIGATOR ______ DATE REPORT MADE ______ IS REPORT COMPLETE ☐ YES ☐ NO

SIGNATURE OF INVESTIGATOR ______ ID NO. ______ DEPARTMENT ______ DIST/AREA ______

Figure A-1. Sample Texas Peace Officer Crash Report.

SOLICITATION (SOL)	EJECTED	CODE FOR TYPE RESTRAINT USED	AIRBAG CODE	HELMET USE	CODE FOR INJURY SEVERITY	ALCOHOL/DRUG ANALYSIS (COMPLETE IF CASUALTIES NOT IN MOTOR VEHICLE)
INDICATES PERSON S DESIRE TO RECEIVE CONTACT FROM PERSONS SEEKING PROFESSIONAL EMPLOYMENT AS/FOR AN ATTORNEY, CHIROPRACTOR PHYSICIAN, SURGEON, PRIVATE INVESTIGATOR OR ANY OTHER PERSON REGISTERED OR LICENSED BY A HEALTH CARE REGULATORY AGENCY Y=0.K. TO SOLICIT N-NO SOLICITATION	A - NOT APPLICABLE Y - YES N - NO P - PARTIALLY U - LINK	A - SEATBELT & SHOULDER STRAP B - SEATBELT & NO SHOULDER STRAP C - CHILD RESTRAINT E - SHOULDER STRAP ONLY N - NONE	Y - DEPLOYED N - NO DEPLOYMENT U - LINK IF DEPLOYED	1 - WORN-DAMAGED 2 - WORN-NOT DAMAGED 3 - WORN-UNK IF DAMAGED 4 - NOT WORN 9 - LINK IF WORN	K - KILLED A - INCAPACITATING INJURY B - NON INCAPACITATING C - POSSIBLE INJURY N - NOT INJURED	I - BREATH 2 - BLOOD 3 - OTHER 4 - NONE 5- REFUSED

UNIT NO. 1

DAMAGE RATING ______________

TOWED DUE TO DAMAGE ☐ YES ☐ NO

VEHICLE REMOVED TO ______________

BY ______________

COMPLETE ALL DATA ON ALL OCCUPANTS' NAMES POSITIONS RESTRAINTS USED, ETC.; HOWEVER, IT IS NOT NECESSARY TO SHOW ADDRESSES UNLESS KILLED OR INJURED.

	OCCUPANT'S POSITION	NAME (LAST NAME FIRST)	ADDRESS (STREET, CITY, STATE, ZIP)	SOL	EJECTED	TYPE RESTRAINT USED	AIRBAG	HELMET	AGE	SEX	INJURY CODE
1	DRIVER	SEE FRONT									
2											
3											
4											
5											

UNIT NO. 2 (COMPLETE ONLY IF UNIT NO. 2 WAS A MOTOR VEHICLE)

DAMAGE RATING ______________

TOWED DUE TO DAMAGE ☐ YES ☐ NO

VEHICLE REMOVED TO ______________

By ______________

COMPLETE ALL DATA ON ALL OCCUPANTS' NAMES POSITIONS RESTRAINTS USED, ETC.; HOWEVER, IT IS NOT NECESSARY TO SHOW ADDRESSES UNLESS KILLED OR INJURED.

	OCCUPANT'S POSITION	NAME (LAST NAME FIRST)	ADDRESS (STREET, CITY, STATE, ZIP)	SOL	EJECTED	TYPE RESTRAINT USED	AIRBAG	HELMET	AGE	SEX	INJURY CODE
6	DRIVER	SEE FRONT									
7											
8											
9											
10											

COMPLETE IF CASUALTIES NOT IN MOTOR VEHICLE

PEDESTRIAN PEDALCYCLIST ETC.	CASUALTY NAME (LAST NAME FIRST) CASUALTY ADDRESS (STREET, CITY, STATE, ZIP)	SOL	TYPE SPECIMEN TAKEN	RESULT	HELMET	AGE	SEX	INJURY CODE

DISPOSITION OF KILLED AND INJURED			IF AMBULANCE USED, SHOW		
ITEM NUMBERS	TAKEN TO	BY	TIME NOTIFIED	TIME ARRIVED AT SCENE	NO ATTENDANTS INC. DRIVER

COMPLETE THIS SECTION IF PERSON KILLED

ITEM NUMBER	DATE (IF DEATH	TIME OF DEATH	ITEM NUMBER	DATE OF DEATH	TIME OF DEATH	ITEM NUMBER	DATE OF DEATH	TIME OF DEATH

INVESTIGATOR'S NARRATIVE OPINION OF WHAT HAPPENED (ATTACH ADDITIONAL SHEETS IF NECESSARY)

DIAGRAM ☐ ONE WAY ☐ TWO WAY ☐ DIVIDED

INDICATE NORTH

FACTORS AND CONDITIONS LISTED ARE THE INVESTIGATOR'S OPINION

FACTORS/ CONDITIONS CONTRIBUTING

UNIT 1	1	2	3
UNIT 2	1	2	3

OTHER FACTORS/ CONDITIONS MAY OR MAY NOT HAVE CONTRIBUTED

UNIT 1	1	2
UNIT 2	1	2

TRAFFIC CONTROL

O-NO CONTROL OR INOPERATIVE
I-OFFICER OR FLAGMAN
2-STOP AND G0 SIGNAL
3-STOP SIGN
4-FLASHING RED LIGHT
5-TURN MARKS
6-WARNING SIGN
7-RR GATES OR SIGNALS
8-YIELD SIGN
9-CENTER STRIPE OR DIVIDER
10-NO PASSING ZONE
11-OTHER CONTROL

1. ANIMAL ON ROAD - DOMESTIC
2. ANIMAL ON ROAD - WILD
3. BACKED WITHOUT SAFETY
4. CHANGED LANE WHEN UNSAFE
5. DEFECTIVE OR NO HEADLAMPS
6. DEFECTIVE OR NO STOP LAMPS
7. DEFECTIVE OR NO TAIL LAMPS
8. DEFECTIVE OR NO TURN SIGNAL LAMPS
9. DEFECTIVE OR NO TRAILER BRAKES
10. DEFECTIVE OR NO VEHICLE BRAKES
11. DEFECTIVE STEERING MECHANISM
12. DEFECTIVE OR SLICK TIRES
13. DEFECTIVE TRAILER HITCH
14. DISABLED IN TRAFFIC LANE
15. DISREGARD STOP AND GO SIGNAL
16. DISREGARD STOP SIGN OR LIGHT
17. DISREGARD TURN MARKS AT INTERSECTION
18. DISREGARD WARNING SIGN AT CONSTRUCTION
19. DISTRACTION IN VEHICLE
20. DRIVER INATTENTION
21. DROVE WITHOUT HEADLIGHTS
22. FAILED TO CONTROL SPEED
23. FAILED TO DRIVE IN SINGLE LANE
24. FAILED TO GIVE HALF OF ROADWAY
25. FAILED TO HEED WARNING SIGN
26. FAILED TO PASS TO LEFT SAFELY
27. FAILED TO PASS TO RIGHT SAFELY
28. FAILED TO SIGNAL OR GAVE WRONG SIGNAL
29. FAILED TO STOP AT PROPER PLACE
30. FAILED TO STOP FOR SCHOOL BUS
31. FAILED TO STOP FOR TRAIN
32. FAILED TO YIELD ROW - EMERGENCY VEHICLE
33. FAILED TO YIELD ROW - OPEN INTERSECTION
34. FAILED TO YIELD HOW - PRIVATE DRIVE
35. FAILED TO YIELD ROW - STOP SIGN
36. FAILED TO YIELD ROW - TO PEDESTRIAN
37. FAILED TO YIELD ROW - TURNING LEFT
38. FAILED TO YIELD ROW - TURN ON RED
39. FAILED TO YIELD ROW - YIELD SIGN
40. FATIGUED OR ASLEEP
41. FAULTY EVASIVE ACTION
42. FIRE IN VEHICLE
43. FLEEING OR EVADING POLICE
44. FOLLOWED TOO CLOSELY
45. HAD BEEN DRINKING
46. HANDICAPPED DRIVER (EXPLAIN IN NARRATIVE)
47. ILL (EXPLAIN IN NARRATIVE)
48. IMPAIRED VISIBILITY (EXPLAIN IN NARRATIVE)
49. IMPROPER START FROM PARKED POSITION
50. LOAD NOT SECURED
51. OPENED DOOR INTO TRAFFIC LANE
52. OVERSIZE VEHICLE OR LOAD
53. OVERTAKE AND PASS INSUFFICIENT CLEARANCE
54. PARKED AND FAILED TO SET BRAKES
55. PARKED IN TRAFFIC LANE
56. PARKED WITHOUT LIGHTS
57. PASSED IN NO PASSING ZONE
58. PASSED ON RIGHT SHOULDER
59. PEDESTRIAN FAILED TO YIELD ROW TO VEHICLE
60. SPEEDING - UNSAFE (UNDER LIMIT)
61. SPEEDING - OVER LIMIT
62. TAKING MEDICATION (EXPLAIN IN NARRATIVE)
63. TURNED IMPROPERLY - CUT CORNER ON LEFT
64. TURNED IMPROPERLY - WIDE RIGHT
65. TURNED IMPROPERLY - WRONG LANE
66. TURNED WHEN UNSAFE
67. UNDER INFLUENCE - ALCOHOL
68. UNDER INFLUENCE - DRUG
69. WRONG SIDE - APPROACH OR IN INTERSECTION
70. WRONG SIDE - NOT PASSING
71. WRONG WAY - ONE WAY ROAD
72. DRIVER INATTENTION- CELL/MOBILE PHONE USE
73. ROAD RAGE
74. OTHER FACTOR (WRITE IN ON LINE BELOW)

Figure A-1. Sample Texas Peace Officer Crash Report (continued).