An Analysis of a Red-Light Camera Program in the City of Milwaukee

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Foreword

This report on the feasibility of adopting a red-light camera enforcement program in Milwaukee is the product of a collaboration between the Robert M. La Follette School of Public Affairs at the University of Wisconsin–Madison and the Budget Office of the City of Milwaukee. Our objective is to provide graduate students at La Follette the opportunity to improve their policy analysis skills while contributing to the capacity of the city government to effectively provide public services to the citizens of Madison.

The La Follette School offers a two-year graduate program leading to a master's degree in public affairs. Students study policy analysis and public management, and pursue a concentration in a public policy area of their choice. They spend the first year and a half taking courses that provided them with the tools needed to analyze public policies. The authors of this report are all enrolled in Public Affairs 869, Workshop in Public Affairs, Domestic Issues. Although acquiring a set of policy analysis skills is important, there is no substitute for doing policy analysis as a means of learning policy analysis. Public Affairs 869 provides graduate students that opportunity.

The students in the course were assigned to one of three project teams. One team worked on this project for the City of Milwaukee, while the other teams worked on projects for the Joint Legislative Council and the Wisconsin Department of Revenue. The topic of this report—a cost-benefit analysis of the feasibility of using cameras placed at selected intersections to catch motorists who run red lights—was chosen by Mark Nicolini, the Budget Director of the City of Milwaukee, in consultation with his staff.

Unfortunately, in Milwaukee as elsewhere, some motorists drive through red lights. Throughout the country running red lights leads to both accidents and injuries, and sometimes death. A number of other cities have installed red-light cameras at dangerous intersections as a means of increasing the probability of catching motorists who run red lights and hopefully reducing the occurrence of red-light running. The authors of this report carried out a comprehensive cost-benefit analysis of installing red-light cameras at a number of dangerous intersections in Milwaukee. Their careful analysis focuses on measuring the benefits of the cameras in reducing the number of accidents at these intersections. They also estimated the additional revenue the city could raise from increasing the number of citations for running red lights that would be possible because of the use of cameras.

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This report does not provide the final word on the complex issue the authors address. The graduate student authors are, after all, generally new to policy analysis, and the topic they have addressed is large and complex. Nevertheless, much has been accomplished, and I trust that the students have learned a great deal, and that Mayor Barrett and the staffs of the City's Budget and Management Division and the Police Department will profit from their analysis.

This report would not have been possible without the support and encouragement of Budget Director Mark Nicolini. Eric Pearson, who served as the project coordinator for the Budget and Management Division, solicited ideas for policy analysis projects from the Budget Office staff and coordinated the efforts of the staff in support of the project. A number of other people in the Budget Office and in the Police Department also contributed to the success of the report. Their names are listed in the acknowledgments.

The report also benefited greatly from the active support of the staff of the La Follette School. Terry Shelton, the La Follette outreach director, contributed logistic support for the project. Karen Faster, La Follette publications director, edited the report and shouldered the task of producing the final bound document.

I am very grateful to Wilbur R. Voigt whose generous gift to the La Follette School supports the La Follette School public affairs workshop projects. With his support, we are able to finance the production of the final reports, plus other expenses associated with the projects.

By involving La Follette students in one of the many tough issues faced by city government in Milwaukee, I hope the students not only have learned a great deal about doing policy analysis but have gained an appreciation of the complexities and challenges facing city governments in Wisconsin and elsewhere. I also hope that this report will contribute to policy discussions concerning the advisability of the city installing red-light cameras as a means of better enforcing traffic laws.

Andrew Reschovsky
May 1, 2006

Acknowledgments

We would first like to thank the City of Milwaukee Budget office for such an interesting and challenging project. Several City employees were extremely helpful in providing feedback or necessary information, including David Schroeder, Captain James Galezewski, Jennifer Gonda, Robert Wagler, and Robert Bryson. Their assistance was much appreciated.

We would also like to thank Karen Faster for her editing assistance. Finally, we wish to extend our heartfelt and sincere thanks to our professor, Andrew Reschovsky of the University of Wisconsin-Madison La Follette School of Public Affairs. We cannot thank him enough for the guidance and advice he provided throughout the project.

Executive Summary

Prepared at the request of the City of Milwaukee Budget Office, this report analyzes whether implementing red-light camera systems at dangerous intersections would increase safety and create additional revenue opportunities.

In the United States, more than 100 communities and at least 11 major cities use red-light cameras to help mitigate a serious public safety concern that caused 206,000 crashes, 934 fatalities, and 176,000 injuries throughout the country in 2003. The societal cost of red-light running is approximately $14 billion per year in the United States.

Drawing on relatively consistent crash data for the years 2001 to 2004, this study estimates that, on average, red-light running in the City of Milwaukee causes approximately 1,342 crashes, 650 involving injuries and three involving fatalities, each year. The estimated societal cost of these crashes is approximately $131 million per year.

In this report, we calculated the potential safety benefits and revenues generated during a five-year period by installing red-light cameras at 13 of the city's 44 most dangerous intersections. We selected these intersections because red-light running was the most frequent cause of the crashes at these locations. This study assumes that during five years, red-light cameras at the 13 intersections would reduce right-angle crashes by 35 percent, from 735 to 478. Based on red-light camera programs in other cities, rear-end crashes, however, are expected to increase by 58 during the same period.

The net present benefits under a five-year red-light camera program are estimated to be approximately $7.6 million. In other words, the sum of annual benefits due to a reduction in red-light-running crashes and avoided enforcement costs, discounted to the present year, exceeds the sum of the annual costs resulting from an increase in rear-end crashes and the costs of implementing a red-light camera system, discounted to the present year, by $7.6 million. An estimated $4.8 million in additional citation revenue would be generated for the City's general fund during the same period. The result is a total net present benefit over five years equal to $12.4 million ($7.6 million + $4.8 million).

Our recommendation is that the City of Milwaukee implement a red-light camera program. For the purpose this report's analysis, we relied on 2001 accident rate statistics to choose the intersections to be equipped with cameras. If the City decides to implement a red-light camera enforcement program, more recent data on accidents due to red-light running should be used to determine at which intersections cameras would be most effective. We also recommend that before implementing a red-light camera program, City staff carefully review the Federal Highway Administration's *Red-Light Camera Systems Operational Guidelines*.

Introduction

Disregard for traffic signals, or red-light running, is a serious national public safety concern, causing 206,000 crashes, 934 fatalities and 176,000 injuries in the United States in 2003 (Federal Highway Administration, 2005). The Federal Highway Administration (2005) estimates the cost to society of red-light running to be $14 billion per year. This estimate includes productivity losses, property damage, medical costs, rehabilitation costs, travel delays, legal and court costs, emergency services (such as medical, police, and fire services), insurance administration costs, and costs to employers (Blincoe et al., 2002). Our study estimates that there are more than 1,340 crashes caused by red-light running in Milwaukee each year with a societal cost of approximately $131 million.

Some local governments have sought to reduce this problem by implementing automated enforcement systems. As of April 2006, more than 100 U.S. communities in at least 21 states have cameras positioned at selected intersections to photograph red-light runners (Insurance Institute for Highway Safety, n.d.b).[1] Before cameras may be used, laws must authorize enforcement agencies to cite red light violators by mail. Citations are mailed to the registered owner or driver of the vehicle, depending on state or local law. In many cases local governments hire private vendors to install and maintain these systems and to process violations. For example, Redflex Traffic Systems Inc. provides red-light photo enforcement services to at least 64 cities and towns across 13 states (Redflex Traffic Systems, 2005).

While many cities report that red-light cameras have significantly reduced red-light running within their jurisdictions, the empirical evidence on the safety effects of these systems is far from conclusive. On average, after red-light cameras are installed, right-angle crashes decrease, and rear-end crashes increase, however, the decrease in right-angle crashes is usually greater than the increase in rear-end crashes. In the most comprehensive and statistically sound study we were able to obtain, Council et al. (2005) found that red-light cameras provide a modest annual aggregate crash-cost benefit of $39,000 to $50,000 per intersection per year. Thus, the authors suggest placing red-light cameras at intersections where there are a high number of right-angle crashes attributed to red-light running and few rear-end crashes.

At the request of the City of Milwaukee Budget Office, we conducted analyses to determine whether implementing an automated enforcement system in Milwaukee

[1] According to the Insurance Institute for Highway Safety, major U.S. cities that use red-light cameras include: Atlanta, Baltimore, Charlotte, Chicago, Denver, Los Angeles, New York City, Phoenix, San Diego, San Francisco, and Washington, D.C.

would be an efficient and cost-effective way to increase safety and create opportunities to produce revenue. This report is divided into two sections. The first is a cost-benefit analysis that provides an estimate of the societal impact a red-light camera program would have on the City of Milwaukee. In this section we quantify the costs and benefits of a red-light camera program and calculate whether, compared to the current system, such a program would result in overall net benefits to the city. The second section of the report is an analysis of the revenue generating potential of a red-light camera program in the City of Milwaukee.

Red-Light Running

According to the Federal Highway Administration (2005), a motorist runs a red light when he or she enters and proceeds through a signalized intersection after the signal has turned red. Motorists already in an intersection when the signal turns red are not considered to be red-light runners (Insurance Institute for Highway Safety, n.d.a). The frequency of red-light running is estimated to be between three and five vehicles per 1,000 passing through a signalized intersection (Bonneson et al., 2002). As the volume of traffic at a given intersection increases, so does the frequency of red-light running (Quiroga et al., 2003). To put this in perspective, on any given day a signalized intersection with a traffic volume of 50,000 vehicles will experience anywhere from 150 to 250 red-light-running violations.[2]

Crashes attributed to red-light running can occur in one of two ways. The first occurs when a motorist running a red light broadsides a vehicle as it crosses an intersection from the adjacent street. The second occurs when two vehicles are approaching from opposite directions on the same street. In this scenario, a motorist turning left on a red light is hit by a motorist proceeding through the intersection on a green or vice versa. Because both of these types of red-light-running crashes occur at right angles, it follows that red-light cameras would be most effective at reducing this type of collision.[3] This is consistent with what the research on the safety effects of red-light cameras suggests.

Red-light running is a major contributor to crashes, especially those that occur in urban areas. Taken together, running red lights, running stop signs, and failing to yield are the most frequent causes of crashes in urban areas. Using crash data

[2] In 2004, Milwaukee had at least 40 intersections that had a daily average traffic volume of 40,000 vehicles or more. At this rate, each one of these intersections averaged at least 120 red light running violations per day.
[3] Throughout this report we use the terms right-angle crash and red-light-running crash interchangeably.

collected from four urban areas, Retting et al. (1995) found “ran traffic control” was the most common type of crash accounting for 22 percent of total crashes and 27 percent of injury crashes.[4] Of crashes due to “ran traffic control,” 24 percent were a direct result of red-light running (Retting et al., 1995).

Crashes caused by red-light running are more likely to result in injury compared to other crash types. According to one study, 45 percent of red-light-running crashes resulted in occupant injury compared to 30 percent for other crash types (U.S. Department of Transportation, n.d.b.). This disparity is due in part to the fact that red-light-running crashes frequently involve high speeds and side impact, which can result in passenger compartment intrusion (Retting et al., 1998). As a result, injuries sustained in red-light-running crashes are often more severe compared to other crash types. In addition, not only is there a positive correlation between the degree of vehicle compartment intrusion and injury severity, but individuals involved in side impact crashes are also at risk for ejection from the vehicle (Warner et al., 1990).

Making this problem even graver is the fact that fatalities at intersections are increasing. Crashes attributed to red-light running play a significant role in this trend. Nationwide, fatal motor vehicle crashes at intersections are rising faster than all other types of fatal crashes (Institute of Transportation Engineers, 2004). Fatal motor vehicle crashes at traffic signals increased 13.2 percent between 1993 and 2003, which is significantly greater than the 6.6 percent increase in all other fatal crashes (National Highway Traffic Safety Administration, 2004). Researchers at the Insurance Institute for Highway Safety (n.d.) determined that during this same time period the number of fatalities resulting from red-light-running crashes rose from 853 to 934, an increase of about 10 percent.

Although red-light running is a common occurrence that imposes tremendous costs on society, the current process used to catch individuals who run red lights is far from ideal. Appendix A provides a detailed description of the current Milwaukee Police Department procedures for citing red-light running violators. For a police officer to apprehend a motorist for running a red light the officer must first see the violation occur and then follow the offending vehicle through the intersection. Because the chances of an officer actually seeing a red light violation occur are low, red-light runners are rarely caught.[5] On the off chance an officer does see a violation occur, to pull over and cite the offending driver, he or she will often have to run the red light as well. The result is that public safety is put in jeopardy not once but twice.

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[4] The crash in this study came from Akron, Ohio; Arlington, Virginia; New Orleans; and Yonkers, N.Y.

[5] In general, the greater the certainty of punishment, the less likely an individual is to break the law. Because the certainty of punishment associated with red light running is so low under the current process, it is likely that it does not adequately deter individuals from committing this violation.

Red-Light Cameras

The objective of red-light cameras is to improve safety. The key assumption underlying the use of these cameras is that they will positively change driver behavior, resulting in fewer red-light violations and a reduction in the number of crashes, injuries, and deaths attributed to them.

Although red-light camera systems have been available for almost 40 years and have been used in other countries since the late 1960s, photo enforcement was not used in the United States until 1992.[6] One of the main reasons the United States was, and continues to be, slow to embrace this technology is because of questions and concerns surrounding the legality of these systems (see Appendix B for a discussion of the legal issues surrounding the use of red-light cameras). Nevertheless, the danger red-light runners pose and the ineffective nature of the traditional process used by law enforcement to catch violators has led a growing number of cities and states to look to red-light photo enforcement as an alternative to the traditional process. Growing public concern and awareness regarding the substantial safety threat created by red-light runners and widespread public support for the use of photo enforcement have played a significant role in the growing trend towards red-light camera usage (See Appendix C for public opinion of red-light cameras).[7]

Camera Technology

Cameras are stored in a box to shield them from the environment and vandalism, and are located at the top of 15-foot poles. One red-light camera can typically cover the three travel lanes closest to the camera. A computer is wired to the red-light cameras, the induction-loop triggers, and the traffic light circuit to monitor the traffic signal and triggers. An induction-loop trigger is a piece of electrical wire buried under the concrete that is placed in several rectangular loops. Each intersection typically has two induction-loop triggers per lane of traffic (U.S. Department of Transportation, n.d.a). See Figure 1 in Appendix D for an illustration of the placement of a red-light camera at an intersection.

The camera system is not activated until the stoplight turns red. If a vehicle is in the middle of the intersection when the light turns red, the system will not

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[6] Jackson, Mississippi was the first city in the United States to use red-light cameras, installing them at two intersections.

[7] For example, The National Campaign to Stop Red Light Running (n.d.) is an advocacy group dedicated to increasing safety by reducing red-light running. Their goals include informing the public and elected officials about the dangers of red light running and how it can effectively be addressed. They promote public education and support law enforcement efforts aimed at increasing roadway safety, including red-light photo enforcement technology.

activate. To activate the system, the light must be red and a vehicle must cross the induction-loop triggers at a certain speed. If a vehicle passes over both induction-loop triggers relatively quickly, after the light turns red, the system is activated and the cameras take two pictures of the vehicle. The first picture captures the vehicle entering the intersection and the second captures the vehicle in the middle of the intersection. These pictures show that the vehicle entered the intersection when the light was red and that the vehicle continued through the light (Harris, n.d.). If a picture of the driver is required, an additional picture of the violating vehicle would be taken from the front of the car in order to capture an image of the driver. The computer prints the following information on each photograph: date, time, intersection location, and the speed of the car (U.S. Department of Transportation, n.d.a).

System Approaches

The process of issuing a red-light running citation is different depending on which type of camera is used. When using 35-mm cameras, at the end of the day, an individual must go to each camera and replace the used film with new film. The film is processed, developed, and then reviewed for accuracy and converted to a digital image. When using a digital or video camera, a picture is taken and immediately uploaded over a designated telephone line to the citation processing system. Under any of the three camera systems, qualified police officers carefully review photographs to determine that the vehicle was actually in violation (U.S. Department of Transportation, n.d.a).

Red-light running citations may be issued either to the driver or the owner of the violating vehicle. If the registered owner of the violating vehicle is responsible, only photographs of the rear of the vehicle are required. If the driver of the violating vehicle is responsible, photographs of the front and rear of the violating vehicle are required to capture a picture of both the driver and the license plate. Under this system, if a clear view of the driver is obstructed or not clear, no citation should be given (Federal Highway Administration, 2005).

Safety Effects

A red-light camera system causes red-light-running violations to decrease as individuals become more careful when crossing signalized intersections. As the number of violations decreases, so does the number of crashes attributed to red-light running. However, several studies have shown rear-end crashes to increase at signalized intersections with cameras. Overall, positive safety effects result if the decrease in red-light running crashes more than offsets the increase in rear-end crashes.

Violation Reduction

Red-light cameras improve safety by reducing red-light-running violations. The majority of the evidence supporting this conclusion comes from the experiences of cities that use red-light photo enforcement technology. While violation reductions vary from city to city, the results of a literature review by Maccubbin et al. (2001) suggest that, on average, violation reductions range from 20 to 87 percent. The authors also report that of the total number of jurisdictions included in their review, more than half experienced red-light-running violation reductions between 40 and 62 percent (Maccubbin et al., 2001). Table 1 highlights the reductions in red-light-running violations experienced by several U.S. cities that have installed red-light photo enforcement technology.

Table 1
Red-Light-Running Violation Reduction Due to Red-Light Cameras

Location	Violation Reduction	Source
Oxnard, CA	42% across camera and non-camera sites after 3-4 months.	Retting et al. (1998)
Fairfax, VA	44% at camera sites, 34% at non-camera sites after 1 year.	Retting et al. (1999)
San Francisco, CA	42% at camera sites after 6 months.	Fleck and Smith (1999)
Baltimore, MD	60% at camera sites.	Baltimore Department of Transportation, n.d.
Washington, D.C.	73% at camera sites after 6.5 years.	Washington, D.C., Metropolitan Police Department, n.d.
New York, NY	34% at camera sites between 1994 and 1997.	Federal Highway Safety Administration, n.d.

Crash Effects

Numerous studies have attempted to evaluate the impact red-light cameras have on motor vehicle crashes. Despite considerable variation across the results of these studies, the general consensus is that red-light cameras lead to a reduction right-angle crashes and to an increase in rear-end crashes.

The increase in rear-end collisions caused by red-light cameras is a result of motorists stopping more abruptly for yellow lights and the motorists behind them not expecting the vehicle in front of them to stop. In other words, when a driver stops abruptly at a yellow light the driver of the vehicle behind them is surprised and unprepared, and ultimately cannot react in time to prevent the rear end collision from occurring. It is important to note that the increase in rear-end crashes caused by red-light cameras could be transitional and that as public awareness of the cameras grows and motorists' behavior changes, the incidence of these crashes would revert to pre-camera levels.

The majority of the studies on the safety effects of red-light cameras contain methodological design and analysis flaws that call into question the accuracy and validity of their results. A review of the literature and an explanation of these flaws are provided in Appendix E.

Although these design and analysis flaws should not be overlooked, we believe the literature contains sufficient evidence to support the conclusion that, overall, red-light cameras have a positive impact on safety. What is less certain is the magnitude of this impact. In other words, are the safety effects minimal or significant, and what portion of these effects results from the presence of the cameras themselves versus what portion results from other factors such as the increased public awareness red-light cameras generate?

Council et al. (2005) conducted the most comprehensive and methodologically sound study to date on the safety effects of red-light cameras. This study improves on previous research by: 1) including a large enough number of observations for the results to achieve statistical significance; 2) using an experimental design that takes into account the potential for spillover effects; and 3) developing a consistent definition of the term "red-light-running crash."

Consistent with the much of the previous the literature, this study shows that the implementation of a red-light camera program results in fewer right-angle crashes and more rear-end crashes. Researchers analyzed crash data from red-light cameras at 132 intersections in seven cities and found right-angle crashes decreased by 24.6 percent, while rear-end crashes increased by 14.9 percent. Injuries attributed to right-angle crashes decreased by 15.7 percent, while injuries attributed to rear-end crashes increased by 15.0 percent. Results of this analysis indicate that red-light cameras provide a crash cost benefit of between $39,000 and $50,000 per camera-equipped intersection, per year (Council et al, 2005).

Spillover

When drivers improve their behavior at intersections that are not equipped with photo enforcement, the effects of red-light cameras are said to "spillover." To the extent that photo enforcement can deter drivers from running red lights at intersections that are not equipped with cameras, then this spillover, or halo effect, could enhance safety benefits. There is very limited research on spillover and what does exist contains conflicting results. However, the information we were able to obtain suggests that signage practices may affect the extent to which this phenomenon occurs, and that spillover is more likely when signs notify motorists of photo enforcement areas or zones as opposed to specific camera equipped intersections (Transportation Research Board, 2003). Assuming this is true, red-light cameras could have the greatest impact on safety if they are strategically dispersed throughout the city and accompanied by signs alerting motorists that they are driving in a photo enforcement zone.

Long-Term Safety Effects

To date, there have been no longitudinal studies conducted on the long-term safety effects of red-light cameras. This is due largely to the fact that, at least in the United States, red-light camera technology has been used for a relatively short time. The only information we were able to obtain regarding the long term safety effects of red-light cameras comes from a study by the Transportation Research Board (2003), which found the rate of red-light running crash reduction slows as the length of time after the cameras' implementation increases. While these results provide some preliminary indication that the safety effects of red-light cameras lessen over time, there is no question that further research is needed. However, to echo the study's authors, even if the safety benefits decline, this does not negate the fact that an overall safety benefit has been produced.

Pedestrian safety

Although our discussion of red-light cameras and safety has been limited to crash reduction benefits, it is safe to assume that red-light cameras positively affect the safety of pedestrians as well. While we have not come across any information in the literature definitively stating that red-light cameras increase pedestrian safety, given that red-light cameras, in general, lead to a reduction in red-light-running violations, it follows that the risk to pedestrians of being hit by a red-light runner is also decreased.

Maximizing the Effectiveness of a Red-Light Camera Program

There are steps a city can take to maximize the safety effects and net benefits of a red-light camera program. Given the variation in outcomes experienced by other cities, following this advice will help increase the likelihood of a program's success. Analysis conducted by Council et al. (2005) highlights six factors that affect the effectiveness of red-light cameras and subsequently are associated with a greater degree of economic benefits. These include:

1. High as opposed to medium publicity levels.
2. A penalty consisting of a fine and demerit points, rather than a fine only.
3. Warning signs at intersections and city-limits, rather than at intersections only.

4. Cameras placed at signals with protected left-turn lights and lanes as opposed to those without.
5. Cameras placed at intersections with the highest average annual daily traffic volume and a high ratio of right angle to rear-end collisions.
6. Cameras used in congruence with shorter signal cycles and shorter inter-green periods.

Current Societal Cost of Red-Light Running in Milwaukee

We calculated the current societal cost of red-light running in Milwaukee to be approximately $130.8 million per year. This includes the cost of crashes attributed to red-light running and the cost of enforcing red-light-running violations. The cost of crashes attributed to red-light running captures medical, emergency services, property damage, lost productivity, travel delay, insurance administration and legal costs, as well as the monetized value of pain, suffering and lost quality of life. Enforcement costs include police officer salary and benefits spent apprehending red-light runners. We did not include the court and administrative costs associated with alleged violators who contest a red-light-running citation in court, as this information is not available to us. We also did not include the cost of citations issued for red-light running, as these just represent a transfer of funds from citizens to the government and as such have no societal cost. A more detailed discussion on the monetary value of the costs used in our analysis and the origins of these costs is located in the Crash Costs section.

Expected Cost of a Red-Light-Running Violation

In addition to examining the societal cost of crashes attributed to red-light running, it is useful to consider the societal cost of a single red-light-running violation. Based on our calculation, we estimate this cost to be approximately $138.

In deriving this amount we assumed that 0.2 percent of red-light-running violations result in an accident. This assumption is based on the findings of a study on red-light running in Fairfax, Virginia (Retting et al., 1998). The probabilities of other outcomes (i.e., property damage only, injury severity, and death) and societal crash costs used in this calculation can be found in the Crash Estimates and Costs and Benefits sections. Table 2 summarizes the probabilities and costs used in this estimate.

Table 2
Estimated Expected Cost of Running a Red Light

Result	Probability	Cost/Case	Estimated expected cost
No Accident	0.998	$0	$0
Injury			
Unreported	0.0002	$30,000	$6
Reported Disabling (A)	0.0001	$484,773	$26
Reported Evident (B)	0.0002	$202,605	$44
Reported Possible (C)	0.0004	$79,519	$34
Property damage only			
Unreported	0.001	$1,000	$1
Reported	0.001	$21,923	$13
Fatality	0.000003	$4,803,555	$14
Total	1.000		$138

Source: Authors' calculations

Under Wisconsin law the penalty for running a red light is a forfeiture of $20 to $40 for a first offense. If one accepts the notion that a penalty should fit the crime, it seems reasonable to suggest that the Wisconsin Legislature should consider increasing the penalty for running a red light to around $140 for a first offense, as this is the estimated expected cost of this violation to society. It could be also argued that higher penalties for first-time offenses may deter offenders from committing subsequent offenses. See Table 32 in Appendix L for red-light-running citation costs in other cities that use red-light photo enforcement.

Cost-Benefit Analysis

One objective of this report is to provide the City of Milwaukee Budget Office with a comprehensive cost-benefit analysis on the use of red-light photo enforcement by the city's police department. Our estimate is based on a comparison of the societal cost of red-light running under the current system, without cameras, to the societal cost of red-light running with photo enforcement at 13 signalized intersections citywide during a five-year period.

We selected the intersections included in our analysis from crash data we obtained from the Milwaukee Department of Public Works (n.d.a.). This data provided us with a list of the city's 44 most dangerous intersections in 2001, measured by number of crashes, and cited the most frequent cause of crashes at each intersection. Of these 44 intersections, we chose to include the 13 where red-light running (or disregard for traffic signal), was the most frequent cause of collisions. A list of these intersections can be found in Table 31 in Appendix L.

Our decision to calculate the societal cost of red-light running during a five-year period was twofold. First, almost all of the studies on the safety effects of red-light cameras use before and after periods to measure changes in crash frequency. To draw on the results of these studies we needed to structure our analysis in a similar way, using a period of several years as our unit of analysis as opposed to discrete year-by-year changes. Second, there are no long-term longitudinal studies of the safety effects of red-light cameras. Because of this, to improve the accuracy and reliability of our results, we limited the period covered in our analysis to be consistent with those in the literature, which generally covers one to five years.

Crash Estimates

We estimated the number of red-light-running crashes that would occur at the 13 selected intersections during a five-year period under the current system and with red-light photo enforcement. All of the crash costs in our analysis are based on the crash estimates discussed in this section. An expanded explanation of the calculations used in our crash estimates can be found in Appendix F.

Current System

We estimated the number of red-light-running crashes at the 13 selected intersections during a five-year period using 2001 crash data provided by the Milwaukee Department of Public Works (n.d.a.).[8] First, we applied the percentage of crashes due to disregard for traffic controls to the total number of crashes at each intersection to estimate that 92 red-light-running crashes would occur at these 13 intersections in our base year. Of the total, we further estimated that 44 would be injury crashes and 47 would be property-damage-only crashes.[9] This was based on citywide red-light-running crash data from 2001-2004 showing that, on average, 51 percent of collisions attributed to red-light running were injury crashes and 48 percent were property-damage-only crashes.

Because the data provided by the Department of Public Works consisted only of reported crashes, we also estimated the number of unreported crashes attributed to red-light running that would occur at these 13 intersections. Relying on Blincoe et al. (2002), which found 21.4 percent of injury crashes are unreported and 48 percent of property-damage-only crashes are unreported, we estimated that in our base year there would be 12 unreported injury crashes and 43 unreported property-damage-only crashes attributed to red-light running at the selected intersections.

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[8] This is the only year for which we have disaggregate, intersection level data. However, because citywide, red-light-running crashes did not increase between 2001 and 2004, for the purposes of our analysis we assumed the number of red light running crashes at these 13 intersections has remained constant as well and will continue to do so.
[9] Because the probability of a fatality occurring is so low, our base case assumes there will be zero fatalities caused by red-light-running crashes at these 13 intersections during the five-year period.

Red-Light Cameras

To estimate the number of red-light-running crashes that would occur at the 13 intersections with red-light photo enforcement, we assumed the implementation of cameras would result in a 35 percent reduction in red-light-running crashes during the five-year period. This assumption is based on a careful review of the relevant literature as well as the experiences of other cities that have used red-light camera technology. As Table 3 shows, according to our estimates, installing red-light cameras at the 13 selected intersections would prevent 257 red-light-running crashes during the five-year period. With this decline, the total number of crashes attributed to red-light running at these intersections would drop from 735 under the current system to 478 with cameras.

Table 3
Red-Light-Running Crashes at the 13 Selected Intersections During a Five-Year Period

Crash Type	Current System	With Red-Light Cameras
Reported Injury	222	144
Reported Property Damage Only	235	153
Unreported Injury	60	39
Unreported Property Damage Only	217	141
Total	**735**	**478**

Note: Totals may not sum due to rounding.

Because red-light cameras cause more rear-end collisions, we estimated the five-year increase in rear-end crashes for the 13 selected intersections. First, using the 2001 intersection level crash data we obtained from the Department of Public Works (n.d.a.), we estimated the total number of rear-end crashes that would occur at these intersections in the absence of cameras. We based this estimate on the assumption that 18 percent of the total crashes at these intersections were rear end. Eighteen percent represents the probability of a crash being a rear end given it occurs at an intersection in an urban area (Road Management and Engineering Journal, 1999). Based on our calculation we estimate there would be 45 reported rear-end crashes across these 13 intersections in our base year.

Next, we broke the total number of reported rear-end crashes down by category — injury or property damage only — using the results of a study by the U.S. Department of Transportation (n.d.b.), which found 45 percent of all red-light-running crashes resulted in injury compared to 30 percent for other crash types. Assuming 30 percent of the rear-end crashes were injury crashes and 70 percent were property damage only, we estimated that of the 45 total reported rear-end crashes, 13.5 would be injury and 31.5 would be property damage only.

To estimate the number of unreported rear-end crashes at the 13 selected intersections, we relied on the findings of Blincoe et al. (2002) mentioned previously. Based on our calculations, we estimate there would be approximately four unreported rear-end-injury crashes and 29 unreported rear-end property-damage-only crashes at the 13 selected intersections in our base year.

Finally, we estimated the increase in rear-end collisions due to red-light cameras by assuming that at camera-equipped intersections rear-end crashes would increase by 15 percent over five years. As with our previous assumptions, this was based on a thorough review of the literature as well as the experiences of other cities. According to our results outlined in Table 4, red-light cameras would cause the number of rear-end crashes at the 13 selected intersections to increase by 58, from 387 under the current system to 445 with cameras, during a five-year period.

Table 4
Rear-End Crashes at the 13 Selected Intersections During a Five-Year Period

Crash Type	Current System	With Red-Light Cameras
Reported Injury	67	77
Reported Property Damage Only	157	180
Unreported Injury	18	21
Unreported Property Damage Only	145	167
Total	**387**	**445**

Note: Totals may not sum due to rounding

Costs and Benefits

This section provides an overview of the costs and benefits used in the base case of our analysis. Our base case includes our most plausible assumptions and represents the outcome that has the highest probability of occurring. See Appendix G for a more detailed explanation of these costs and benefits.

Crash Costs

Our base case assumes that red-light-running crashes at the 13 camera-equipped intersections would decrease by 35 percent during a five-year period following the implementation of cameras. The societal benefit of this crash reduction is captured in the avoided costs associated with preventing these crashes. Our base case also assumes that rear-end crashes at the 13 camera-equipped intersections would increase by 15 percent over five years following the implementation of cameras. We captured the societal cost of this crash increase in the costs directly associated with the crashes.

The crash costs used in this analysis are based on two separate studies published by the U.S. Department of Transportation. Our estimates of medical costs, emergency services, property damage, lost productivity (wage and household work), and the monetized value of pain and suffering come from Council et al. (2005). Our estimates of legal and court costs, insurance and administrative costs, and travel delay costs come from Blincoe et al. (2002).

All crash costs were all increased to 2005 dollars using the consumer price index (CPI) for all items and all urban consumers. While increasing some costs in our analysis by the CPI for medical care would have been beneficial, we were unable to adjust the medical costs separately because our analysis does not separate medical costs from other crash costs. However, it is worth noting that the CPI for medical care has increased much faster than the CPI for all items (Bureau of Labor Statistics, n.d.), and because of this our estimate of crash costs in 2005 dollars may be somewhat conservative.

Total crash costs capture the entirety of the costs resulting from a car crash over the victim's expected life span. These costs include medical, emergency services, property damage, lost productivity (wage and household work), the monetized value of pain, suffering, and lost quality of life, travel delay, insurance administration, and legal and court costs. Crash costs used in our analysis are in present value terms and were discounted at a rate of 4 percent. Our decision to use this discount rate was twofold. First, the social rate of time preference has been estimated to be between 1 percent and 5 percent, based on rate of returns on stock and three-month treasury bills (Blincoe et al., 2002). And second, a number of other studies that estimate the economic impact of motor vehicle crashes use a 4 percent social discount rate.

Costs are broken out by crash type (i.e. right-angle versus rear-end) and injury severity, which is represented by the KABCO scale that police officers use at an accident scene to classify injuries. These classifications are: K- killed, A- disabling injury, B- evident injury, C- possible injury, and O- no apparent injury.[10] The total crash costs for reported right-angle crashes are $4,803,555 per fatal crash; $484,773 per disabling-injury crash; $202,605 per evident-injury crash; $79,519 per possible-injury crash; and $21,923 per property-damage-only crash. Similarly, total crash costs for rear-end crashes included in our analysis are $4,463,845 per fatal crash; $445,084 per disabling injury crash; $118,326 per evident-injury crash; $96,123 per possible-

[10] This report uses the term "property damage only" instead of "no apparent injury."

injury crash; and $25,000 per property-damage-only crash. The total reported crash costs can be found in Table 5.

Table 5
Crash Costs by Injury Severity for Reported Right-Angle and Rear-End crashes in 2005 Dollars

KABCO Scale	Right-Angle	Rear-End
K – Killed	$4,803,555	$4,463,845
A – Disabling Injury	484,773	445,084
B – Evident Injury	202,605	118,326
C – Possible Injury	79,519	96,123
O – Property Damage Only	21,923	25,000

To use these crash costs in our analysis, we estimated the number of injury crashes that involved a disabling injury, an evident injury, and a possible injury for right-angle and rear-end crashes. These estimates are based on the results of the 2005 study by Council et al., which found for right-angle crashes 7.7 percent resulted in a disabling injury, 30.8 percent resulted in an evident injury, and 61.1 percent resulted in a possible injury. For rear-end crashes, these numbers were 3.1 percent, 10.9 percent, and 86.0 percent respectively.

Because data on per-crash costs for unreported crashes are not available, our base case assumes a per-crash cost of $30,000 for unreported injury crashes and $1,000 for unreported property-damage-only crashes. Compared to reported injury-per-crash costs, $30,000 represents a reasonable, if not conservative estimate. We vary this per-crash cost from $5,000 to $60,000 in our sensitivity analysis. Our per-crash cost for unreported property-damage-only crashes is based on the Wisconsin statute requiring all accidents resulting in injury or property damage of $1,000 or more to be reported to the police (Wisconsin State Legislature, 2006). Because in all likelihood this is a conservative estimate, we later assumed a per-crash cost of $5,000 in our sensitivity analysis.

RedLight Camera System Costs

Our base case assumes that one 35-millimeter camera would be placed at each of the 13 selected intersections. It also assumes that Milwaukee would operate under an "owner responsibility" system, whereby the owner of the violating vehicle would be held responsible for the citation.

We assumed one-time costs for the purchase of each 35-millimeter camera equal to $55,000 and one-time costs equal to $25,000 per camera for system equipment, setup, and implementation.[11] Our base case also assumes annual system

[11] Maccubbin et al. (2001) report that camera prices range from $50,000-$60,000.

maintenance costs equal to $60,000 per camera, which are discounted to the present year using a discount rate equal to 4 percent. Based on these assumptions, if the city were to install 13 cameras, it would cost $715,000 to purchase the cameras, $325,000 for equipment, setup, and implementation, and $3.5 million to maintain each camera during a five-year period (Maccubbin et al., 2001).

Administrative Costs

Because red-light camera programs require personnel to administer them, our base case also assumes annual administrative costs of $30,000, which are discounted to the present year using a discount rate equal to 4 percent. During a five-year period this would amount to $133,600. We based our estimate of these costs on information obtained from Clement Gibson, the program administrator for Charlotte, North Carolina's red-light photo enforcement program, SafeLight. According to Gibson, her duties and responsibilities include: SafeLight's budget, review of red-light running citations, customer service, marketing, and public education. Because her role extends beyond just SafeLight administration, Gibson estimates that, on average, between 40 and 50 percent of her full-time position is spent on SafeLight-related activities (Gibson, 2006). Assuming the job duties of a red-light camera program administrator in Milwaukee would be similar, we estimated administrative costs based on 50 percent of a full-time position with yearly salary plus benefits equal to approximately $60,000.

Public Awareness Costs

Our base case also assumes Milwaukee would launch a public awareness campaign to inform its citizens of the red-light camera program and educate them on the dangers of red-light running. We estimate this cost at $30,000 during the five-year period. Mayors and public officials in cities that use red-light photo enforcement technology regard these efforts as vital for maintaining public support and crucial to the program' success. Examples of these activities include: the issuance of warning letters to red-light-running violators during the first days of camera use; the distribution of fliers that discuss why red-light cameras are being used; radio and local cable television public service announcements; media releases; public speaking engagements; and talk radio spots (U.S. Conference of Mayors, 2004).

Avoided Enforcement Costs

Under the current system, Milwaukee police officers spend a portion of their time pulling over red-light runners and issuing them citations; however, if the city were to implement a red-light camera program, officers would no longer be required to do this. We account for these avoided enforcement costs using data from the Milwaukee Police Department on the average amount of time officers spend pulling over individuals and issuing them citations. The number used in our analysis was found by calculating the average number of disregard for traffic signal citations at each of the 13 selected intersections for years 2001 to 2004. The Milwaukee Department of Public Works (n.d.c.) provided this data. These numbers were then multiplied by the total amount of time officers spent on this violation (35 minutes) and by the current per-minute wages and benefits ($1.61) of a "full-time officer," which was derived from the current yearly salary of $57,386, plus an additional 34 percent to account for fringe benefits. Based on our calculations, the annual enforcement costs for the 13 selected intersections are approximately $1,859. We used the same procedures for our sensitivity analysis involving five and 10 intersections, and found enforcement costs to be $1,578 and $986, respectively. The annual avoided enforcement costs during each of the five years were discounted to the present year using a discount rate equal to 4 percent.

Summary

Table 6 summarizes all of the costs and benefits used in our base case analysis. Crash costs include injury and vehicle, legal, insurance administrative, and travel delay costs. Red-light system costs include one-time costs for cameras, equipment and installation, annual operating costs, annual administrative costs, and public education costs. Avoided enforcement costs include personnel costs related to issuing red-light running citations under the current system.

Table 6
Assumptions Used in Base Case

Variable	Value		Source
Vehicle Crash Costs (Per Crash)			
Injury & Vehicle Costs	Right-Angle Crashes	Rear-End Crashes	
K – Killed	$4,510,363	$4,170,652	1
A – Disabling Injury	$133,225	$93,537	1
B – Evident Injury	$114,101	$29,822	1
C – Possible Injury	$38,255	$54,858	1
O – Property Damage Only	$9,564	$12,641	1
Legal Costs			
K – Killed	$129,501	$129,501	2
A – Disabling Injury	$168,372	$168,372	2
B – Evident Injury	$21,916	$21,916	2
C – Possible Injury	$316	$316	2
O – Property Damage Only	$231	$231	2
Insurance Administrative Costs			
K – Killed	$47,065	$47,065	2
A – Disabling Injury	$143,789	$143,789	2
B – Evident Injury	$27,201	$27,201	2
C – Possible Injury	$1,562	$1,562	2
O – Property Damage Only	$0	$0	2
Traffic Delay Costs			
Property-Damage-Only Crashes	$12,128	$12,128	2
Injury Crashes	$39,386	$39,386	2
Fatal Crashes	$116,627	$116,627	2
Unreported Crash Costs			
Property-Damage-Only Crashes	$1,000	$1,000	
Injury Crashes	$30,000	$30,000	
Red-Light Camera System Costs			
Cost of public education	$30,000		3
Cost of camera	$55,000		4
Equipment & installation per camera	$25,000		4
Annual operating cost per camera	$60,000		4
Annual administrative costs	$30,000		5
Avoided Enforcement Costs			
Current personnel costs related to issuing red-light-running citations	$1,859		6

Sources for Table 6:

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4. Maccubbin, R.P., Staples, B.L., and Salwin, A.E. 2001. Automated Enforcement of Traffic Signals: A Literature Review. Washington, DC: Federal Highway Administration. Retrieved April 18, 2006, from http://www.itsdocs.fhwa.dot.gov//jpodocs/repts_te//13603.html.
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6. Galezewski, James A. 2006. In-person interview with Milwaukee Police Department Captain by Erik Johnson, Karyn Kriz, and Molly Reagan. 15 February 2006. Notes in possession of Karyn Kriz.

Cost-Benefit Analysis Results

Based on our cost benefit analysis, implementing a red-light camera program and installing cameras at the 13 selected intersections would be an improvement compared to the current system. The present benefits that would accrue during a five-year period following implementation of a red-light camera program total slightly more than $14.0 million. These benefits include the avoided crash costs associated with a 35 percent reduction in right-angle crashes ($14 million) and avoided enforcement costs associated with the amount of police officer time spend stopping red-light running violators and issuing them citations ($8,300). The present costs that would accrue during a five-year period following implementation of a red-light camera program total $6.4 million. These costs include increased crash costs associated with a 15 percent increase in rear-end collisions ($1.8 million), red-light camera system costs ($4.5 million), as well as costs associated with program administration and generating public awareness ($133,600 and $30,000 respectively) . The resulting net present benefits assuming the city installs cameras at the 13 selected intersections are approximately $7.6 million ($14 million - $6.4 million) higher than under the current system during a five-year period.

Sensitivity Analysis Results

Because many of the variables used in this analysis are based on various assumptions, we conducted several sensitivity analyses to test the effects of these assumptions on the outcome of our analysis. First, we tested our assumptions regarding camera system costs and the costs of administering a red-light camera program. We also tested our assumptions regarding the costs of unreported injury and property-damage-only crashes. Neither of these analyses yielded significant changes in our results. The details of these analyses and all other analyses in this section can be found in Appendix H.

Other sensitivity analyses produced more interesting results. For example, if the implementation of a red-light camera program prevented one fatal crash from occurring, the net present benefits accrued during a five-year period would be $12.4 million, $4.8 higher than in our base case.

We also tested several assumptions regarding the reduction in right-angle crashes and the increase in rear-end crashes resulting from the implementation of a red-light camera program. In this analysis, we used a range of 15 to 50 percent for the reduction in right-angle crashes and a range of 5 to 25 percent for the increase in rear-end crashes. The resulting net present benefits ranged from -$1.6 million under our most conservative assumptions, to $14.8 million.

In addition to the above analyses, we performed several analyses in which we assumed cameras would be placed at five or 10 intersections, rather than the 13 included in our base case. This included an analysis in which we varied the number of cameras placed at each intersection. Under these various scenarios, the resulting net present benefits ranged from $2.9 million to $7.6 million.

Finally, we performed an analysis in which we used the most conservative estimates for all of our assumptions. While the resulting net benefits under this scenario were -$2.0 million, we believe this outcome would be highly unlikely based on our review of the relevant literature.

To make our analysis as comprehensive as possible, we also conducted several additional analyses, the results of which can be found in Appendix I.

Budget Background

This section provides context on the budget environment in which discussions about a red-light camera program proposal will take place. Basically, the police department budget continues to increase despite cuts in most other city departments. Milwaukee Police Chief Nanette Hegerty believes it is important to hire more officers. The Common Council is conducting a study on how efficiently the Police Department delivers services and is exploring ways to enhance efficiency.

City of Milwaukee

The City of Milwaukee budget for general city purposes for 2006 is approximately $536.5 million. This represents an almost 4.5 percent increase from the $513.4 million that was budgeted for these expenditures in 2005. Growth in the general city budget was funded with increases of about $4.9 million in the property tax levy and more than $18 million in non-levy tax sources.

Despite a net increase in City expenditures, revenue growth will not be enough to maintain base expenditures. In fact, in his 2006 State of City address, the Milwaukee Mayor Tom Barrett estimated that next year’s total City budget would require $20 million in service cuts. The primary forces that are driving costs include rising employee health-care benefit costs, higher debt service payments, increased Workers Compensation expenditures, and higher fuel and electricity costs. Revenues are also constrained by the state imposed property tax levy cap, reduced federal funding for Community Development Block Grants, and decreased state shared-revenue funding. In fact, after adjusting for inflation, shared-revenue payments for 2006 are expected to be $65 million less than the amount the City received in 1995 (City of Milwaukee, 2006).

Looking to the future, it is important to consider the ramifications for the City's budget of proposals being considered in the State Legislature to amend the State Constitution to impose annual revenue limits on almost all levels of government in Wisconsin. While the status and details of these "Taxpayer Protection Amendments" are very fluid as of this writing, it seems reasonable to suggest that any new revenue raising limits imposed by the state would most likely require the City of Milwaukee to significantly cut its public services.

Milwaukee Police Department

The Milwaukee Police Department's budget for 2006 is almost $207 million, or about 39 percent of the City's general purpose budget. Despite a budget increase of more than 10 percent from the previous year, Police Chief Hegerty and Alderman Robert G. Donovan have been publicly saying that more police officers are needed to meet the demands of city residents. Currently, the Department has about 240 vacant sworn positions, 228 of which are under the Police Officer title (Schroeder, 2006).

According to press reports, Hegerty has said that the Police Department has "enough officers now to respond to violent crime and arrest the perpetrators of violent crime," but that residents want more beat officers to respond quickly to "barking dog, loud party and suspicious people in alley" calls (Borowski, 2006). Some members of the Common Council also pursued a failed effort earlier this year to have the following question placed on the April 4 ballot: "Do you agree that the City of Milwaukee cannot allow any further reduction in basic city services such as police and fire protection, and street paving and maintenance, and that the city leadership should find new ways to pay for these to offset property taxes?"

Other members of the Common Council, such as President Willie Hines, have called for a review of how the Police Department delivers services. Included in this year's budget is a $125,000 study on Police Department staffing. Additionally, a Common Council amendment moved $1.5 million from the Milwaukee Police Department to a special purpose account to create a task force responsible for implementing a civilian community service officer force to handle low priority, non-emergency calls (Schroeder, 2006).

Given the constraints on the police department's budget, the amount of time (and money) spent apprehending red-light violators could potentially be shifted to other departmental activities with the implementation of a red-light camera program. Police officers usually only catch red-light runners if they, by chance, see a violation occur. Red-light running is also a much too frequent occurrence for officers to apprehend a significant percentage of violators. Nevertheless, last year Milwaukee police department officers spent approximately 1,300 hours apprehending red-light runners. In terms of economic costs, this translates into $47,924 in police officer salary and benefits (i.e., health, disability, and pension).

Estimated Revenue Increase from Red-Light Cameras

The primary motivation behind the installation of red-light cameras is to increase safety. However, a secondary effect of installing red-light cameras is a potential increase in revenues for the cities that install such cameras. Placing red-light cameras at 13 selected Milwaukee intersections would provide a significant new revenue source for the City of Milwaukee general fund.

We calculated our revenue estimates using data we obtained from the Milwaukee Department of Public Works (n.d.b.). Based on 2004 daily traffic flow data, we derived an estimate of the number of red-light-running violations that occurs at each of the 13 selected intersections every day. We did this by applying the rate of red-light-running violations per 1,000 vehicles to each of the 13 intersections and then summing the results.[12] Our base case assumes four red-light-running violations per 1,000 vehicles entering an intersection. This assumption is based on the results of a study by Bonneson (2002), which found the rate of red-light-running violations to be three to five per 1,000 vehicles. To extend our estimate during a five-year period, we converted the number of daily violations to annual violations and multiplied the total by 5.

We calculated an estimate of the number of red-light-running violations at the 13 selected intersections over five years based on the assumption that these intersections would experience a 60 percent reduction in red-light-running violations during the entire five-year period. This assumption is based on our review of the literature as well as the experiences of other cities that use photo enforcement technology. According to the results of our calculation, we estimate that at the 13 camera-equipped intersections, the number of red-light-running violations summed over a five-year period would drop from approximately 3.6 million to approximately 1.5 million.

[12] Our estimate of the number of daily red-light-running violations at each intersection was obtained using the following equation:
Number of Daily Red-Light-Running Violations = Daily Traffic Flow / 1,000 * 4

Based on our calculations, Table 7 shows the number of red-light-running violations at the 13 selected intersections during a five-year period with and without photo enforcement technology.

Table 7
Red-Light-Running Violations at the 13 Selected Intersections During a Five-Year Period with and Without Cameras*

Intersection	Daily Traffic Volume	Red-Light-Running Violations per day	Red-Light-Running Violations During Five Years, without Cameras	Red-Light-Running Violations During Five Years, with Cameras
W. Silver Spring & Zoo Freeway	51,200	205	373,760	149,504
W. Capitol & N. 51st	41,900	168	305,870	122,348
W. Walnut & N. 12th	32,500	130	237,250	94,900
S. Layton & W. National	66,500	266	485,450	194,180
N. James Lovell & W. Wells	20,900	84	152,570	61,028
W. Lincoln & S. 13th	30,500	122	222,650	89,060
W. Center & N. 7th	17,000	68	124,100	49,640
W. Good Hope & N. Teutonia	22,100	88	161,330	64,532
S. Howell & E. Layton	59,800	239	436,540	174,616
W. Hampton & N. 650th	43,700	175	319,010	127,604
W. Locust St & N. Martin Luther King Dr	39,400	158	287,620	115,048
W. Mill & N. 91st	37,300	149	272,290	108,916
N. Teutonia & W. Villard	33,900	136	247,470	98,988
Total	496,700	1,987	3,625,910	1,450,364

*This assumes red-light cameras cause red-light-running violations to decrease by 60%.

To estimate the amount of revenue that placing red-light cameras at the 13 selected intersections would generate, we assumed there would be one camera at each intersection, which would result in 25 percent of the total red-light-running violations being photographed. We further assumed that of the total number of violations captured by the cameras, 50 percent would result in the issuance of a citation. In other words, we assumed that half of all violations captured on cameras contain sufficient information, such as a clearly identifiable license plate, to issue a citation. This issuance rate is based on New York City's experiences with red-light cameras. In their experience, 50 percent of violations captured by 35-mm cameras resulted in the issuance of a citation and 65 percent of violations captured by digital cameras resulted in the issuance of a citation (New York City Department of Transportation, 2003). See Appendix J for revenue estimates based on the assumption that digital cameras are used.

After adjusting for the above assumptions, we calculated the total amount of revenue the city would receive over five years if it were to install red-light cameras at the 13 selected intersections. We obtained our estimate by multiplying the total number of red-light running citations issued by $30, which is the amount of revenue per citation the city keeps for its General Fund (See Appendix K for more detailed discussion on citation costs and surcharges).

Based on the results of our calculation, we estimate that placing red-light cameras at each of the 13 intersections would generate approximately $4.8 million over five years, our base case. This is in net present value terms and assumes a discount rate of 4 percent. It is important to note that this estimate assumes 100 percent of the citations issues are actually paid. Table 8 summarizes our results.

Table 8
Amount of Revenue Generated at the 13 Selected Intersections During a five-year period With Cameras

Intersection	Number of Red-Light-Running Violations During Five Years, with Cameras	Number of Violations Captured by Cameras	Number of Red-Light-Running Citations Issued	Amount of Revenue Generated
W. Silver Spring & Zoo Freeway	149,504	37,376	18,688	$499,174
W. Capitol & N. 51st	122,348	30,587	15,294	$408,504
W. Walnut & N. 12th	94,900	23,725	11,863	$316,858
S. Layton & W. National	194,180	48,545	24,273	$648,341
N. James Lovell & W. Wells	61,028	15,257	7,629	$203,764
W. Lincoln & S. 13th	89,060	22,265	11,133	$297,359
W. Center & N. 7th	49,640	12,410	6,205	$165,741
W. Good Hope & N. Teutonia	64,532	16,133	8,067	$215,464
S. Howell & E. Layton	174,616	43,654	21,827	$583,020
W. Hampton & N. 650th	127,604	31,901	15,951	$426,053
W. Locust St & N. Martin Luther King Dr	115,048	28,762	14,381	$384,130
W. Mill & N. 91st	108,916	27,229	13,615	$363,656
N. Teutonia & W. Villard	98,988	24,747	12,374	$330,508
Total	1,450,364	362,591	181,296	$4,842,572

We conducted a sensitivity analysis to determine the effects red-light cameras would have on revenue if the frequency of red-light-running violations and/or the violation reduction rate were lower or higher than assumed in our base case. For the frequency of red-light running we used a range of three to five violations per 1,000 vehicles, and for the violation reduction rate we used a range of 45 to 75 percent.

Under these alternative scenarios, the revenue generating potential of placing red-light cameras at the 13 selected intersections ranges from a low of $2.3 million to a high of $8.3 million during the five-year period. While we believe that our base estimate is sound and reflects the most likely outcome, it is important to note that even if the amount of revenue generated by cameras is on the lower end of the spectrum, it would still be higher than under the current system. The results of our sensitivity analysis are summarized in the Table 9.

Table 9
Amount of Revenue Generated
Under Various Combinations of Assumptions

Frequency of red-light-running per 1,000 vehicles	**Violation Reduction**		
	45%	60%	75%
3	$4,993,903	$3,631,929	$2,269,956
4	$6,658,537	$4,842,572	$3,026,608
5	$8,323,171	$6,053,215	$3,783,259

Recommendation

Our base case results in net present benefits of $7.6 million, which means that higher net present benefits are associated with implementation of a red-light camera system, compared to no system. The assumptions made in our base case represent what we believe to be the most viable. However, we conducted several sensitivity analyses, including a conservative scenario analysis and several Monte Carlo analyses in order to test the effects of our assumptions on our results. Under our most conservative assumptions, the resulting net present benefits are –$2.0 million, but we think that this scenario is rather unlikely to occur. Our Monte Carlo analyses show that net present benefits would most likely be positive.

While we have concluded that we believe the implementation of a red-light camera system would likely result in substantive safety benefits, we have also shown that such a system would yield a reasonable amount of revenue to the city of Milwaukee. Under our base case, the City of Milwaukee would receive approximately $4.8 million in revenue (in present value terms) during the five-year period following implementation of a red-light camera system. Therefore, the total present net benefits of a red-light camera system would be $12.4 million ($4.8 million + $7.6 million). We therefore recommend the city of Milwaukee implement a red-light camera system. The intersections chosen to be equipped with cameras for the purposes of this analysis were based on 2001 accident rate statistics. In choosing the intersections where cameras will be placed, the City should look at more recent data on accidents due to red-light running to determine at which intersections camera placement would be most effective.

If the administration wishes to pursue implementation of a red-light camera program, we suggest that staff begin by reviewing *Red-Light Camera Systems*

Operational Guidelines (Federal Highway Administration, 2005). This guide is primarily intended for local officials, traffic engineers, and law enforcement. Chapter 5 will be of particular interest, as it discusses key steps for successful implementation of a red-light camera program based on the experiences of other communities that have such programs. We further suggest that if the City of Milwaukee chooses to move forward with our recommendation to implement a red-light camera system, that all relevant stakeholders are included in the planning process, as the success of a red-light camera program is dependent on the collaborative efforts of these individuals.

Finally, because the results of our sensitivity analyses under the digital camera scenario and with two cameras per intersection indicate that the combined net present benefit would be at least equal to if not greater than those in our base case, we recommend that the City of Milwaukee carefully consider these options if it chooses to move forward with our recommendation.

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Appendix A: Current Milwaukee Police Department Procedures for Citing Red-Light-Running Violators

On average there are about 177 officers working the first shift in the city of Milwaukee. These officers spend a portion of their time, which varies from day to day and officer to officer, patrolling the streets and searching for traffic law violators. As a result of experience in the field, officers know where the problem areas in their districts are, and, as a result, they pay particular attention to streets and intersections where speeding and red-light running is problematic. (Galezewski, 2006).

Once a citation is issued, a lieutenant reviews it and sends it to the Traffic Records Division. Employees in Traffic Records correct any visible errors on the citation, attach a driving record to the ticket, and send it to Pam E-Tech, the private contractor responsible for entering citation data for the Milwaukee Police Department. Pam E-Tech employees enter the ticket information and send it back to Traffic Records where the citation is again corrected for any errors. The citation is then sent to the Municipal Court, which keeps two copies of the citation and returns the original to the Milwaukee Police Department. (Galezewski, 2006).

Appendix B: Legal Issues Arising from the Use of Red-Light Cameras

The legal issues concerning the use of photographic identification to determine compliance with traffic laws is straightforward: Does the use of such photographic identification violate either the U.S. Constitution or Wisconsin statute? Although a memorandum from attorneys representing the City of Milwaukee discusses some of the legal concerns surrounding this issue, it does not specifically address the issue of using photographic identification to judge compliance with traffic laws. This section discusses the specific legal issues involved in using photographic identification to judge compliance with traffic laws in the City of Milwaukee. In its discussion, this section examines the issue from a constitutional and state law perspective.

In a letter dated August 24, 2005, Milwaukee City Attorney Grant F. Langley and Assistant City Attorney Edward M. Ehrlich answered legal questions from Alderman Robert G. Donovan concerning the use of information and/or images the Milwaukee Police Department (MPD) obtains from privately owned video cameras. This response does not provide adequate legal answers to the question of whether the MPD can use mounted cameras to detect moving violations that occur at intersections controlled by traffic lights for two reasons:

1) The response only discusses the use of cameras trained to focus on activities occurring on the public right-of-way in a general sense.
2) As a result of this general discussion, the response does not explore the issue of using cameras to detect moving violations at intersections regulated by traffic lights in the proper constitutional and statute statutory context.

Cameras trained to focus on activities occurring on the public right-of-way are not uncommon, because public places and right-of-ways are just that — public. Although the U.S. Constitution recognizes the right of the people to be secure in their persons, houses, papers, and effects (U.S. Constitution, Fourth Amendment), the Supreme Court has clarified the bounds of this right through the creation of a division between the expectation of privacy when one is in a private building and the expectation of privacy when in a public place or thoroughfares. Regardless of whether one is in a vehicle, an individual generally does not have an expectation of privacy in a public place or thoroughfare (*U.S. v. Knotts*, 460 U.S. 276, 103 S.Ct. 1081 [1982]).

Generally speaking, because a right to privacy in a public place or thoroughfare does not exist, cameras in private places or thoroughfares are legal. One cannot automatically assume from this general allowance of cameras that all uses of cameras in public places are allowed under the Constitution. The use of cameras by police to photograph vehicles that violate traffic laws has the potential to violate the Constitution not because such use automatically violates an individual's right to privacy — although the courts have not explicitly rules on the issue of a Fourth Amendment violation as a result of this use of cameras — it appears that such a use would not be a "search" under the Fourth Amendment. Instead, the use of cameras to photograph moving vehicles has a high probability of violating the Fifth, Sixth and Fourteenth amendments.

The Fifth Amendment grants individuals the right to remain silent when charged with a crime. In some states that use cameras to photograph vehicles (rather than actual individuals) violating traffic laws, an affidavit as to who was driving the vehicle while it was photographed violating traffic laws is required. Such a requirement may violate an individual's right not to testify.

The Sixth Amendment guarantees the right, in all criminal cases, to confront one's accusers. To avoid this issue, some jurisdictions have made photo red-light violations civil rather than criminal acts. The issue surrounding the conflict between the right to confront one's accusers and photo red-light cameras is, thus, twofold: 1) whether individuals have Sixth Amendment rights if the photo red-light violation is a criminal matter and 2) whether a jurisdiction has the right to made a photo red light violation a civil rather than a criminal violation. Wisconsin courts have not had to deal with this issue since red-light cameras are not in use in this state. Other states have been forced to deal with Sixth Amendment questions surrounding the categorization of moving violations as civil rather than criminal violations. The attorney general of Texas opined that a city could authorize a photo red light program to identify violators, but could not make the violations civil. Other state appellate courts (California, Maryland, and North Carolina) have had cases concerning Sixth Amendment issues come to them on review. These appellate courts have been able to decide the cases on procedural grounds rather than on the substantive grounds. As a result, the conflict between the use of red-light cameras to identify violators and Sixth Amendment rights has not been settled.

The Fourteenth Amendment grants the right of due process. Simply put, one of the rights granted to an individual under this amendment is the right to a presumption of innocence rather than one of guilt. When authorities judge an individual's guilt from a photograph of a car and its license plate rather than by an officer stopping a vehicle and issuing a ticket to the actual driver of the vehicle or even from a photograph of the driver committing the moving violation, then a probability exists that the right to due process is violated.

Just as important as these potential violations of the U.S. Constitution is the potential of the City of Milwaukee to violate Wisconsin law if it proceeds with the installation and use of cameras to catch moving violations at intersections controlled by traffic lights. State law cannot revoke the rights guaranteed by the U.S. Constitution, but state law can strengthen these rights through additional provisions and can penalize behavior not regulated by the Constitution. Wisconsin is one of five states that have some restrictions on the use of photographic identification of a vehicle to determine violations of traffic laws (Alaska, Nebraska, New Jersey, and Utah are the other four). Specifically, Wisconsin Statute § 349.02(3)(b) prohibits the use of photo-radar speed detection to determine compliance with any speed restriction. In this subsection, "photo-radar speed detection" is defined as the detection of a vehicle's speed by use of a radar device combined with *photographic identification* of the vehicle. (Italics added by authors; also see §§ 349.02(3)(a) and (b)).

The above statutes do not explicitly prohibit the use of photographic identification to cite a motorist who proceeds through a red light; however, when examining whether a law is violated state law, judges base their decisions on one of two possible readings of the statute: a reading which strictly follows the letter of the law or one that attempts to follow what the judge perceives to be the spirit of the law.

When basing a decision on the letter of the law, a judge does not expand on the specific language. Instead, he or she interprets the law as it is written and applies it restrictions only to the actual behaviors mentioned in the statute. A non-expansive reading of Wisconsin Statute § 349.02(3)(b), or a reading that follows the letter of the law, states that the statute only restricts the use of photographic identification to determine compliance with any *speed restriction*.

When basing a decision on the spirit of the law, a judge interprets the statute in a broader sense, a decision that acknowledges the specifics of a text and expands the prohibited action to related actions. A reading of § 349.02(3)(b) that follows the spirit of the law might be one that prohibits the use of photographic identification to determine compliance with any moving violation, including that of proceeding through a red light.

Appendix C: Public Opinion of Red-Light Cameras

The majority of the American public supports the use of red-light cameras. In general, the percentage of Americans favoring the use of these cameras ranges from approximately 60 to 80 percent (Maccubin et al., 2001). A 2002 Gallup Poll sponsored by the National Highway Traffic Safety Administration found that nationwide 75 percent of drivers favored the use of red-light cameras (National Highway Traffic Safety Administration, 2004). Public support for red-light cameras is even higher in large cities, such as Milwaukee, where red-light running is more frequent and poses a greater threat to public safety compared to non-urban areas (Insurance Institute for Highway Safety, n.d.a).

Research also shows there is a high level of public support for red-light cameras in cities that have red-light camera programs. In Fairfax, Virginia, for example, when respondents were asked one month prior to the cameras' implementation if they favored or opposed the use of red-light cameras to enforce against red-light running as a supplement to police efforts, 75 percent favored them and 48 percent strongly favored them. After one year public support for the cameras grew, with 84 percent of respondents favoring the cameras and 56 percent strongly favoring them (Retting et al., 1999). Other cities with red-light camera programs where public support is high include:

- Charlotte, North Carolina: Prior to the implementation of the city's red-light camera program, 80 percent of the residents surveyed felt that red-light cameras would be beneficial in reducing red-light running (SafeLight Charlotte, First-Year Report, n.d.).

- Oxnard, California: Among respondents who knew about the red-light cameras' use, 75 percent favored the cameras, and 51 percent strongly favored the cameras six weeks prior to implementation; six weeks after implementation these numbers climbed to 81 percent and 59 percent respectively (Retting et al., 1998).

The fact that the public generally favors the use of red-light cameras is directly related to the perceived danger that red-light runners pose. Williams (2003) asked drivers to rate the level of threat posed by various types of drivers on a scale of 1 to 10, with 10 being a major threat. Red-light runners received an average rating of 8.8, second only to drunk drivers. Additionally, red-light runners and drunk drivers were the only two types of drivers whom the majority of respondents, 55 percent and 75 percent respectively, ranked as major threats.

While the vast majority of Americans support the use of red-light cameras, there is a small but often vocal minority that opposes them. One of the most common arguments cited by those who oppose red-light cameras is that they are too "Big Brother" and infringe on the privacy rights of American citizens. The validity of this claim is questionable though, as the majority of red-light cameras only photograph the license plate of offending vehicles. Others oppose the use of red-light cameras and argue that they are inaccurate and that they fail to provide individuals with their legal right to confront their accuser (USA Today, 2001).

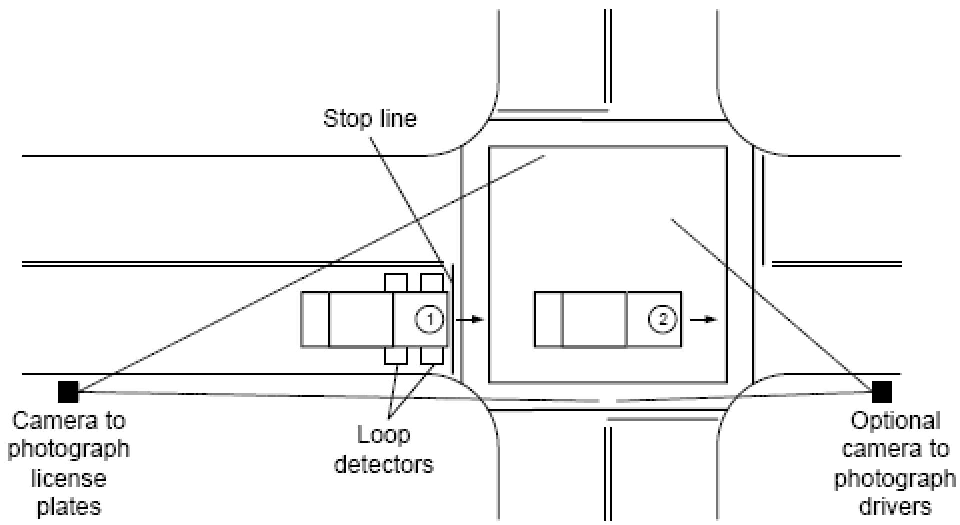
Another argument frequently made by individuals who oppose red-light cameras is that they are being used primarily as a revenue generating mechanism. A 2001 USA Today article cites a report drafted for U.S. Senator Dick Armey that claims traffic engineers reduce the length of the yellow signal at intersections equipped with cameras in order to increase the number of red-light-running violations and subsequently raise additional revenue. However, the same article cites the spokesperson for red-light-camera manufacturer Lockheed Martin who says these claims are "inaccurate" and "misinformed." It also mentions the executive director of the Institute for Transportation Engineers who says the claims are an "insult" to the integrity of traffic engineers and that as a profession they "care very much about reducing injuries and reducing accidents" (USA Today, 2001).

While red-light cameras can result in increased revenue for the jurisdictions that use them, our understanding is that the primary motivation behind the use of these cameras is to increase public safety. Regardless of the validity of claims by opponents, the most important point to take away of the discussion on public opinion is that the vast majority of the public favors red-light camera programs.

Appendix D: Red-Light Camera Setup and Technology

Figure 1 demonstrates the setup of a red-light camera system. Each camera is placed several feet in front of the intersection to photograph vehicles entering the intersection after the light has turned red and again once the vehicle is in the middle of the intersection while the light is red. The photographs must clearly show the rear license plate of the violating vehicle and that the traffic signal is red. Each camera can photograph up to three lanes of traffic (U.S. Department of Transportation, n.d.a). However, as seen in Figure 1, each camera can only photograph traffic heading in one direction on one street. As a result, each camera can only cover vehicles traveling on about one-fourth of an intersection. Cities that charge the driver, rather than the owner, of the violating vehicle would have a second camera on the other side of the intersection to photograph the driver as well.

Figure 1
Diagram of a Red-Light Camera System



Source: Quiroga, 2003.

Camera Technology: Wet Film/35-mm

Currently, 35-mm cameras are the most commonly used for photographing vehicles that run red lights. Usually black-and-white film is used, but color can be easily substituted. While black-and-white film is less expensive, problems can result when it is difficult to determine the color of the stoplight in the photographs. Color film can eliminate this problem. Almost daily, an individual must replace the film. The film is developed, reviewed, and converted to digital images. (U.S. Department of Transportation, n.d.a). The cost of a 35-mm camera is about $50,000-$60,000 and the cost of equipment and installation is about

$25,000 per camera. Monthly maintenance costs per camera total $5,000. (Maccubbin, et al. 2001). In New York City, approximately 50 percent of red-light runners photographed with 35-mm cameras actually receive citations. (New York City Department of Transportation, 2003)

Camera Technology: Digital

There are several advantages of using digital rather than 35-mm cameras for photographing red-light running. First, digital cameras produce higher resolution photographs and can prevent reflections or headlights from distorting images. Second, an individual is not needed to replace film. Instead, the digital image can be electronically sent to the location where it is reviewed. Digital cameras save on the costs of film, processing photographs, and personnel required to replace film (U.S. Department of Transportation, n.d.a). Digital cameras cost about $100,000, with equipment and installation costs of $20,000-$40,000 per camera. (Maccubbin, et al. 2006). Approximately 65 percent of red-light runners photographed with digital red-light cameras in New York City actually receive citations (New York City Department of Transportation, 2003).

Camera Technology: Video

The use of video cameras for capturing red-light running is gaining in popularity. Video cameras determine a vehicle’s speed as it approaches the intersection, which allows it to estimate the likelihood the vehicle will stop for the red light. If it is predicted that the vehicle will not stop for the red light, the video camera records the image of the vehicle running the red light. Video cameras are able to capture the front and rear license plates (U.S. Department of Transportation, n.d.a).

Video surveillance for red-light running has several advantages. First, a digital video camera reduces costs for film, processing, and personnel in the same manner as a digital camera. Second, because the video camera is able to estimate the probability of a vehicle stopping, the length of the all-red signal could be extended in order to avoid a collision if the vehicle is expected to proceed through the intersection. Finally, video surveillance can monitor traffic and better determine the cause of a collision (U.S. Department of Transportation, n.d.a).

Appendix E: Summary of Studies and Explanation of Common Methodological Design and Analysis Flaws

The majority of studies on the safety effects of red-light cameras, including those outlined in tables 10 and 11, contain flawed experimental design and/or erroneous data analysis. This raises concerns regarding the validity of such research, as the results of numerous studies may over- or underestimate the impact that red-light cameras have on safety. Consequently, the results of studies on this topic must be interpreted in this light.

Table 10
Research on the Safety Effects of Red-Light Cameras: United States

Study	Location	Evaluation period	Camera Sites	Results**
Retting and Kyrchenko (2001)	Oxnard, California	29 months before/after	11	At signalized intersections city-wide, angle crashes < 32%, rear-end crashes > 3%.
Maryland House of Delegates (2001)	Howard County, Maryland	16 to 33 months before/after	25	At camera sites, angle crashes < 42%, rear-end crashes < 32%.
SafeLight Charlotte (n.d.)	Charlotte, North Carolina	3 years before/after	17	At camera sites, angle crashes < 37%, rear-end crashes > 16%.
PB Farradyne, Inc. (2002)	San Diego, California	3 years before/after	19	At camera sites, right angle and ran signal crashes < 29.8%, all other crashes > 24.4%
Fleck and Smith (1998)	San Francisco, California	5 years before/after	6	Citywide, injury collision caused by red-light runners < 9%.

** All of these studies contain at least one methodological design and/or analysis flaw.

Table 11
Research on the Safety Effects of Red-Light Cameras: Other Countries

Study	Location	Evaluation period	Camera sites	Results**
South, et al. (1998)	Melbourne, Australia	5 years before and 2 years after	46	Results not significant.
Hillier, et al. (1993)	Sydney, Australia	2 years before and after	16	At camera sites, right angle and left turn opposed crashes < 50%, rear-end crashes > 25-60%.
Ng, et al. (1997)	Singapore	3 years before and after	42	At camera sites, angle crashes < 26%, rear-end crashes < 22%, total crashes < 26%.
Fox (1996)	Glasgow, Scotland	6 years	6	At signalized intersections throughout the city, personal injury crashes < 25%.
Andreassen (1995)	Melbourne, Australia	11 years	41	At camera sites, 0% crash reduction, significant increase in rear-end collisions.
Winn (1995)	Glasgow, Scotland	3 years before and after	6	At camera sites, injury crashes < 62%.

** All of these studies contain at least one methodological design and/or analysis flaw.

The ideal method for researching the safety effects of red-light cameras would be an experiment that uses a before and after design with a randomized control group (Transportation Research Board, 2003). In this scenario, all the intersections in an experiment would have the exact same set of characteristics (including the same number of red-light-running violations and the same number of accidents attributed to red-light running), the exception being that half of them would be equipped with red-light cameras. The camera-equipped intersections would be randomly selected, with the remaining intersections serving as the control group. Crash data would then be collected at the control and treatment sites prior to and after the installation of cameras. Using this design, researchers would be able to attribute any differences between the control and treatment sites to red-light cameras, and we would know with certainty the nature and magnitude of the safety effects these cameras have.

Control vs. Comparison Groups

To date, no studies have employed this type of experimental design. This is largely because in the real world red-light cameras are installed at intersections that are known to have a high number of red-light running related violations and crashes. As a result, researchers are unable to design experiments that employ the type of control group noted above. Instead, they must substitute comparison groups, using intersections as similar to the treatment group as possible on all factors that affect intersection safety (Transportation Research Board, 2003). In terms of the literature on the safety effects of red-light cameras, this lack of a perfect control group means that any difference between treatment and comparison groups could be due to factors other than the cameras themselves. It also means that, depending on how closely the comparison group matches the treatment group, results on the safety impact of red-light cameras could be over estimated.

Lack of Comparison Groups

Some studies do not even make use of comparison groups. This type of simple before and after evaluation is problematic because it fails to account for factors other than red-light cameras that could affect the safety conditions of a road over time. For example, lane expansion, changes in traffic volume, changes in traffic signals, or improved road engineering and design could all increase safety at signalized intersections. If changes in these factors are not included in an analysis, the safety effects of red-light cameras could again be overestimated. Or, in the case of unaccounted for increases in traffic volume, these safety effects could be underestimated.

Regression to the Mean

Because red-light cameras are installed at intersections with a high number crashes related to red-light running, another problem that arises and affects the outcomes of some studies is what is known as regression to the mean. This is the tendency for the frequency of crashes at a given intersection to decrease over time without intervention or treatment. Because of this phenomenon, what appears to be a crash reduction due to red-light cameras may in fact be a natural crash reduction that would have occurred even in the absence of cameras. Without taking this into account, the safety of effects of red-light cameras could be overestimated.

Spillover

Failing to include spillover or halo effects can also skew a study’s results. Spillover occurs when the safety effects of red-light cameras extend to intersections that are not equipped with cameras. The greater the crash reduction at intersections without red-light cameras, the greater the spillover effects. Because of this, to the extent that spillover effects are present, failing to account for them will result in an underestimation of the cameras’ benefits.

Small Sample Size

Another common methodological flaw that taints the validity of much of the current literature is small sample size, or too few observations. Studies that contain this flaw are unreliable because they are more likely to contain results due purely to chance. It is also likely that studies using an insufficient number of observations will obtain results that fail to reach statistical significance. In either case, the results of such a study could lead to an over- or underestimation of the safety effects of red-light cameras.

Statistical Significance

Finally, some studies do not test for statistical significance at all. While the results of these studies may suggest that red-light cameras lead to a reduction in red-light running collisions or an increase in rear-end collisions, without testing for statistical significance, there is no way to know whether the results could have just as easily been obtained by chance.

Appendix F: Explanation of Crash Estimates Used in the Cost-Benefit Analysis

This appendix explains how we calculated our crash estimates for the 13 selected intersections during a five-year period for both the societal cost of red-light running under the current system and with red-light photo enforcement. These numbers provided the basis for the crash cost and avoided crash cost estimates in our cost-benefit analysis.

Current System

We derived the number of red-light-running crashes at the 13 intersections using crash data we obtained from the Milwaukee Department of Public Works (n.d.a.). For each intersection, we multiplied the total number of crashes by the percent of crashes attributed to red-light running, which is also called disregard for traffic controls. This gave us the number of red-light-running crashes at each intersection, which we summed to obtain the total number of red-light-running crashes across all 13 intersections. Based on the results of this calculation, we estimated there were 92 reported crashes attributed to red-light running at these intersections in 2001. We further estimated that approximately half of these 92 crashes were injury crashes and half were property-damage-only crashes. We assume zero fatalities resulting from red-light running at these 13 intersections. This is based on aggregate, citywide crash data from 2001-2004 that show that, on average, 48 percent of red-light-running crashes are injury crashes, and 51 percent are property-damage-only crashes. The number of right-angle and rear-end crashes for property damage only, injury, and fatal accidents is shown for each of the 13 intersections in Table 31 in Appendix L.

Table 12
Estimated Base Year
Red-Light-Running Crashes by Severity

Type	Number
Fatal	3
Injury	650
Property Damage Only	689
Total	1,342

Source: Authors' calculations

Because the data we obtained from the city consisted only of reported crashes, to capture the entire cost of red-light running, we estimated the number of unreported red-light-running crashes at the 13 selected intersections. Using the estimates of Blincoe et al. (2002), we assumed that 21.4 percent of injury crashes are unreported and 48.0 percent of property-damage-only crashes are unreported.

By applying these estimates to the data on reported red-light-running crashes, we calculated that during the course of the year there were approximately 12 unreported injury crashes and 43 unreported property-damage-only crashes attributed to red-light running at these intersections. We used the following equations to calculate these estimates:

Unreported red-light running injury crashes =
[reported red-light running injury crashes / (1-percentage of injury crashes unreported)] – reported red-light running injury crashes

$$12.1 = \frac{44}{(1-.214)} - 44$$

Unreported red-light running property-damage-only crashes =
[reported red-light running property-damage-only crashes /
(1-percentage of property-damage-only crashes unreported)]
– reported red-light running property-damage-only crashes

$$43.4 = \frac{47}{(1-.48)} - 47$$

We calculated the total number of crashes attributed to red-light running across the 13 intersections by adding the number of reported and unreported collisions. The results are presented in Table 13.

Table 13
Red-Light-Running Crashes at the 13 Selected Intersections, 2001

	Property Damage Only	**Injury**	**Fatal**	**Total***
Reported Crashes	47	44	0	91
Unreported Crashes	43	12	0	55
Total*	90	56	0	146

*Rows and columns may not sum due to rounding.
Source: Authors' calculations

For our analysis we assumed the number of red-light-running crashes at the 13 selected intersections has remained constant and that this trend will continue. While national statistics suggest that crashes attributed to red-light running are increasing, we based our assumption on citywide red-light-running crash statistics that show that between 2001 and 2004 the number of reported red-light-running crashes has held steady at approximately 1,300 per year. If our assumption is incorrect and red-light-running crashes at these intersections has increased or does increase, then our estimate of the societal cost of red-light running with photo enforcement will be on the conservative side. Based on this assumption, we estimated the number of red-light-running crashes at the 13 intersections during five years by multiplying the one-year totals in each category by five. Our five-year estimates are provided in Table 14 below.

Table 14
Red-Light-Running Crashes
at the 13 Selected Intersections During Five Years

	Property Damage Only	Injury	Fatal	Total*
Reported crashes	235	222	0	457
Unreported crashes	217	60	0	278
Total*	452	282	0	735

*Rows and columns may not sum due to rounding.
Source: Authors' calculations

Red-Light Camera System

To calculate the societal cost of red-light running with photo enforcement, we estimated the number of crashes attributed to red-light running for the same 13 intersections over five years under the assumption they are equipped with cameras. After a careful review of the literature on the safety effects of red-light cameras, we based our estimate on the assumption that camera equipped intersections would experience a 35 percent reduction in crashes attributed to red-light running. This assumption is well within the range of crash reductions documented in the literature and consistent with the experiences of other cities that use red-light photo enforcement. We reduced the estimated number of red-light-running crashes that would occur over five years under the current system by 35 percent to calculate the number of red-light-running crashes that would occur if the city installed red-light cameras. Table 15 shows the number of red-light-running crashes at the 13 intersections equipped with red-light cameras over a five-year period.

Table 15
Red-Light-Running Crashes
at the 13 Selected Intersections Equipped
with Cameras During Five Years

	Property Damage Only	Injury	Fatal	Total*
Reported crashes	153	144	0	297
Unreported crashes	141	39	0	180
Total*	294	184	0	478

*Rows and columns may not sum due to rounding.
Source: Authors' calculations

Because the relevant literature shows that red-light cameras lead to an increase in rear-end crashes, we also estimated the additional number of rear-end collisions that would occur at the 13 camera equipped intersections during a five-year period. We calculated this estimate based on the crash data we obtained from the Milwaukee Department of Public Works (n.d.a.). First, we estimated the total number of rear-end crashes that would occur at the 13 selected intersections during a five-year period under the current system, without cameras. This procedure was similar to the one we used when calculating the number of crashes attributed to red-light running at these intersections. We multiplied the total number of crashes at each intersection by 18 percent to find the number of rear-end crashes at each intersection. Eighteen percent represents the probability of a rear end collision given the collision occurs at an intersection in an urban area (Road Management and Engineering Journal, 1999). We then summed the number of rear-end crashes at each of the intersections to estimate the total number of reported rear-end collisions across all 13 intersections over the entire year. Based on the results of these calculations, we estimated there were 45 reported rear-end crashes at these intersections in 2001.

We broke the total number of reported rear-end crashes down by category, injury or property damage only, using the results of a study by the U.S. Department of Transportation (n.d.b.) that found 45 percent of all red-light-running crashes resulted in injury compared to 30 percent for other crash types. Assuming 30 percent of the rear-end crashes were injury crashes and 70 percent were property-damage-only, we estimated that of the 45 total reported rear-end crashes, 13 were injury, and 31 were property damage only.

To estimate the number of unreported rear-end crashes at the 13 selected intersections, we relied on the findings of Blincoe et al. (2002) and the same equations used to estimate the number of unreported red-light-running crashes. Based on our calculations, we estimated there were approximately four unreported rear-end injury crashes and 29 unreported rear-end property-damage-only crashes across all 13 intersections over the course of the year.

We estimated the total number of rear-end crashes at the 13 intersections by adding the number of reported and unreported collisions. The results can be found in the Table 16.

Table 16
Rear-End Crashes at the 13 Selected Intersections in 2001

	Property Damage Only	Injury	Fatal	Total*
Reported crashes	31	13	0	45
Unreported crashes	29	4	0	33
Total*	60	17	0	77

*Rows and columns may not sum due to rounding.
Source: Authors' calculations

Operating under the same assumptions used to estimate the number of red-light-running crashes during a five-year period, we estimated the number of rear-end crashes during a five-year period. We multiplied the one-year totals by five to obtain the results in Table 17 below.

Table 17
Rear-End Crashes
at the 13 Selected Intersections During Five Years

	Property Damage Only	Injury	Fatal	Total*
Reported crashes	157	67	0	224
Unreported crashes	145	18	0	163
Total*	302	86	0	387

*Rows and columns may not sum due to rounding.
Source: Authors' calculations

To estimate the increase in rear-end collisions caused by red-light cameras we assumed that over five years, rear-end crashes would increase by 15 percent at camera-equipped intersections. As with our assumption regarding red-light-running crash reductions, we based this assumption on a thorough review of the literature, and it is consistent with the results of previous studies as well as the experiences in other cities. We calculated our estimate of the increased number of rear-end collisions due to red-light cameras by multiplying the five-year totals of rear-end crashes under the current system by 15 percent. Table 18 shows the increase in rear-end crashes during a five-year period.

Table 18
Increase in Number of Rear-End Crashes
at the 13 Selected Intersections over Five Years

	Property Damage Only	Injury	Fatal	Total*
Reported crashes	24	10	0	34
Unreported crashes	22	3	0	24
Total*	45	13	0	58

*Rows and columns may not sum due to rounding.
Source: Authors' calculations

Appendix G: Details of Reported Crash Costs

The U.S. Department of Transportation's "Safety Evaluation of Red-Light Cameras" lists crash costs by injury severity (i.e. K-A-B-C-O scale) for right-angle and rear-end crashes that occur at a signalized intersection where the speed limit is no greater than 45 mile per hour. These costs were taken from a 2005 study by Zaloshnja et al. published in the *Accident Analysis and Prevention* journal. This study included medically related, emergency services, property damage, lost productivity (wage and household work), and the monetized value of pain, suffering, and lost quality of life in total crash costs. Details on the derivation of these costs used in the Zaloshnja et al. (2005) study are outlined in the following couple of paragraphs.

Medical cost estimates are based on data on physician and emergency department fees from the Civilian Health and Medical Program of the Uniformed Services (Zaloshnja et al., 2005).

Both short- and long-term productivity losses resulting from crash injuries are included in the comprehensive crash costs. Productivity loss was based on information from the crashworthiness data system and the 1993 Survey of Occupational Injury and Illness regarding the probability an employee would lose work due to a specific injury and the number of days of work lost per person. Long-term productivity loss was based on detailed claims information on the likelihood that certain injuries would result in permanent disability. (Zaloshnja et al., 2005)

The lost quality of life resulting from crash injuries is based on physicians' estimates of the loss in functionality by injury severity and a survey literature review on the lost value of life resulting from the different losses in functionality. The loss in quality of life by injury severity was monetized based on meta-analyses, which discussed people's willingness to pay for changes in fatality risk. (Zaloshnja, et al., 2005)

Zaloshnja, et al., Miller, and the National Highway Traffic Safety Administration use a conservative value of a statistical life of $3.3 million in 2001 dollars. This is more conservative than the $4 million to $6 million that Viscusi recommends (Zaloshnja, et al., 2005; Miller, 1990; and Viscusi, 1993). The estimated value of a statistical life is based on people's willingness to pay for a reduced risk of fatality. The health of an individual can be estimated in terms of utility. A utility of 1 represents perfect health and a utility of 0 represents death. An individual injured in a traffic accident will not be in a state of perfect health after the accident. Depending on the severity of the injury, the person may have a utility of health of less than 1 for a few days, several years, or a lifetime following the traffic accident.

A 2002 study for the U.S. Department of Transportation estimates the cost of each injury resulting from a car crash by injury severity. The study also estimates the cost per vehicle damaged in a property-damage-only crash. The costs include in this study are medical, emergency services, market and household productivity, insurance administrative, workplace, legal, travel delay, and property damage costs. Our study uses legal, insurance administrative, and travel delay costs found in this study. Details on the derivation of these costs are outlined in the following paragraphs (Blincoe, et al., 2002).

Our analysis includes the legal and insurance administrative costs associated with traffic crashes. Insurance administrative costs consist of the costs associated with processing insurance claims and defense attorney fees resulting from a vehicle crash. Legal costs consist of fees and court costs associated with litigation resulting from a vehicle crash (Blincoe, et al. 2002).

Insurance administrative and legal costs are in terms of per-injured person and per-damaged vehicle, rather than per-crash. In the United States, there were 2,221,773 reported non-fatal injury crashes and 4,130,403 non-fatal injuries resulting from car crashes in 2000. Therefore, there were about 1.9 (4,130,403 / 2,221,773) non-fatal injuries per reported non-fatal car crash. There were 41,821 fatalities and 37,409 fatal car crashes in 2000, resulting in an average of 1.1 (41,821 / 37,409) fatality per fatal car crash. There were 12,288,482 vehicles involved in reported property-damage-only crashes and 7,013,424 property-damage-only crashes in 2000, resulting in an average of 1.8 vehicles per reported property damage only crash. For our analysis, we found the total insurance administrative and legal costs per crash by assuming that there were about 1.9 non-fatal injuries per reported non-fatal car crash, 1.8 vehicles per property damage only crash, and 1.1 fatalities per fatal crash (Blincoe, et al. 2002).

Travel delay costs resulting from a motor vehicle crash are also included in our analysis. Relying on Blincoe, et al. we valued each hour of traffic delay at $15.72 in 2005 dollars. Our assumptions for the length of travel delay by type of street and severity are summarized in Table 19 (Blincoe, et al. 2002).

Table 19
Hours of Travel Delay for Red-Light-Running Crashes by Road Type and Severity for United States

Type of Road	Property Damage Only	Injury	Fatal
Major Arterial	949	3,082	9,127
Minor Arterial	594	1,929	5,711

Source: Blincoe, et al. (2002

The costs associated with traffic delay were calculated as such: ($15.72) x (hours of delay) x (number of crashes). For example, we assume 50 percent of injury accidents (324) occur on major arterial roads and that there are 3,082 hours of travel delay. Therefore, we did the following simple multiplication to calculate the cost of traffic delay for these types of crashes in Milwaukee:($15.72 x 3082) x 324 = $15.7 million. The same calculation was done for the other five location/severity crash types and the six costs were added together to calculate a total estimated traffic delay cost for all reported red-light-running accidents of approximately $34.1 million.

Appendix H: Sensitivity Analysis

Variations in Camera System Costs

Because many of the variables used in this analysis are based on various assumptions, we conducted several sensitivity analyses to test the effects of these assumptions on the outcome of our analysis. First, we tested several assumptions made in calculating the cost of implementing a red-light camera system. Our base case assumes the purchase price per camera is $55,000. Our sensitivity analysis assumes a range of $50,000-$60,000 for camera costs. We also assume annual administrative costs equal to $30,000 in our base case and will test this assumption using a range of $20,000-$60,000. Table 20 shows the net present benefits assuming various combinations of red-light camera system costs.

Table 20
Net Present Benefits Assuming Various Combinations of Red-Light Camera System Costs (2005 Dollars)

One-Time Camera Costs	Annual Administrative Costs		
	$20,000	**$30,000**	**$60,000**
$50,000	$7,683,000	7,638,000	7,505,000
$55,000	7,618,000	7,573,000	7,440,000
$60,000	7,553,000	7,508,000	7,375,000

Source: Authors' calculations

Variations in Right-Angle Crash Reductions and Rear-End Crash Increases

We tested our assumptions of a 35 percent decrease in right-angle crashes and a 15 percent increase in rear-end crashes at the 13 camera intersections during a five-year period. Our sensitivity analysis assumes a range of 15 percent to 50 percent for a decrease in right-angle crashes and a range of 5 percent to 25 percent for an increase in rear-end crashes. Table 21 shows the net present benefits resulting from assuming various combinations of changes in right angle and rear-end crashes due to implementation of a red-light camera system. While negative net present benefits result when assuming a 15 percent decrease in right-angle crashes combined with a 15 percent or 25 percent increase in rear-end crashes, we believe that both of these outcomes are very unlikely based on our literature review.

Table 21
Net Present Benefits Assuming Various Combinations of Changes in Right-Angle and Rear-End Crashes (2005 Dollars)

	Percent Decreases in Right-Angle Crashes		
Percent Increases in Rear-End Crashes	**15%**	**35%**	**50%**
5%	$749,000	8,770,000	14,785,000
15%	-447,000	7,573,000	13,589,000
25%	-1,644,000	6,376,000	12,392,000

Source: Authors' calculations

Variations in Unreported Crash Costs

Our base case assumes the cost of an unreported property-damage-only accident is $1,000 and the cost of an unreported injury accident is $30,000. Our sensitivity analysis will assume a range of $500 to $3,000 for a property damage only accident and $5,000 to $60,000 for an injury accident. Table 22 shows the net present benefits resulting from various combinations of unreported injury and property-damage-only crashes.

Table 22
Net Present Benefits Assuming Various Combinations of Unreported Injury and Property-Damage-Only Crashes (2005 Dollars)

	Cost of Unreported Injury Crash		
Cost of Unreported Property-Damage-Only Crash	**$5,000**	**$30,000**	**$60,000**
$500	$7,086,000	7,546,000	8,098,000
$1,000	7,113,000	7,573,000	8,125,000
$3,000	7,222,000	7,682,000	8,234,000

Source: Authors' calculations

Variation in Avoided Fatalities

Our base case assumed that zero lives would be saved as a result of the red-light camera system. We conduct a sensitivity analysis assuming that one and then two lives would be saved as a result of the red-light cameras. If we assume that the red-light camera system saves one life during the five-year period of time, the net benefits would increase from $7.6 million to $12.4 million. If we assume the system saves two lives during the same time period, the net benefits would be $17.2 million.[13]

[13] Our analysis assumes a value of a statistical life equal to about $3.3 million in 2001 dollars. This is a conservative estimate in that a statistical life is typically valued at between $4 million and $6 million. (Viscusi, 1993).

Variations in Number of Camera-Equipped Intersections and Number of Cameras per Intersection

We performed a sensitivity analysis in which we assumed that one camera would be placed at each of five intersections. These five experience the most red-light-running crashes of the 13 we examine in our base case. Under this assumption, the present net benefits are $4.6 million, as seen in Table 25. The present benefits under this assumption are $7.3 million in terms of the avoided costs associated with a 35 percent reduction in right-angle crashes and the avoided enforcement costs. The present value of costs are $2.7 million in terms of the costs associated with a 15 percent increase in rear end accidents and the costs associated with the red-light camera system.

If cameras were placed only at these five intersections, the estimated amount of revenue the City of Milwaukee would generate for its general fund over five years in present value terms is approximately $1.8 million. Taken together, the combined net present benefit of placing cameras at the five intersections with the greatest number of crashes attributed to red-light running is $6.4 million ($4.6 million + $1.8 million) during a five-year period. Table 23 summarizes the results of our sensitivity analysis in which the rate of red-light-running violations ranges from three to five per 1,000 vehicles entering the intersection and the rate of violation reductions ranges from 45 percent to 75 percent.

Table 23
Amount of Revenue Generated by Red-Light Cameras at Five Intersections During a Five-Year Period

	Violation Reduction		
Frequency of red-light-running per 1,000 vehicles	**45%**	**60%**	**75%**
3	$1,829,858	$1,330,806	$831,753
4	$2,439,810	$1,774,407	$1,109,005
5	$3,049,763	$2,218,009	$1,386,256

Source: Authors' calculations

We performed a sensitivity analysis in which we assumed that two cameras would be placed at each of the 13 intersections, a total of 26 cameras. The net present benefits resulting from this analysis are $3.1 million, as seen in Table 25. The present benefits under this assumption are $14.0 million in terms of the avoided costs associated with a 35 percent reduction in right-angle crashes and avoided enforcement costs. The present value of costs are $11.0 million in terms of the costs associated with a 15 percent increase in rear-end accidents and the costs associated with the red-light camera system.

If the City of Milwaukee were to place two cameras at each of the 13 selected intersections, the revenue figures would double because the total number of red-light-running violations captured by cameras would increase from 25 to 50 percent. Based on this assumption, red-light cameras would generate approximately $9.7 million in present value terms for the City's General Fund during a five-year period. The combined net present benefit of placing two cameras at each of the 13 selected intersections is approximately $12.8 million ($9.7 million + $3.1 million). This is approximately equal to the combined net present benefits we estimated in our base case. While in this scenario, the net present benefits from our cost-benefit analysis are lower than in our base case, this is offset by the additional citation revenue that placing two cameras at each of the 13 selected intersections would generate.

Table 24 summarizes the results of the sensitivity analysis for our revenue estimates assuming the city places two cameras at each of the 13 selected intersections.

Table 24
Amount of Revenue Generated
During Five Years with Two Cameras per Intersection

	Violation Reduction		
Frequency of red-light-running per 1,000 vehicles	**45%**	**60%**	**75%**
3	$9,987,805	$7,263,858	$4,539,911
4	$13,317,073	$9,685,144	$6,053,215
5	$16,646,342	$12,106,430	$7,566,519

Source: Authors' calculations

Under the base case, the City would purchase 13 cameras, placing one at each of 13 intersections. We performed a sensitivity analysis in which we made the same assumption, but also assumed the City would purchase equipment for and install two red-light camera systems per each of the 13 intersections. Under this system, the camera would be periodically moved from one location to the other at each intersection. This would allow the City to catch red-light runners on both cross streets or those heading in opposite directions on the same street. It may also result in increased safety if the public assumes more of the intersection is being recorded. Under this assumption the net present benefits would be $7.2 million. This is different from our base case due to installation and equipment costs of $325,000 for 13 additional system setups.

Table 25 summarizes the net present benefits resulting from our cost benefit analysis in which we assume various combinations of intersections and cameras per intersection. These numbers do not include the revenue generated from red-light camera systems under these various assumptions.

Table 25
Net Present Benefits Under Various Combinations of Intersections and Cameras per Intersection

Number of camera-equipped intersections	1 camera per intersection	2 cameras per intersection
5	$4,586,000	$2,851,000
10	6,663,000	3,192,000
13	7,573,000	3,061,000

Source: Authors' calculations

Most Conservative Estimate

Finally, we perform an analysis in which all of the assumptions we make are on the conservative end. This assumes a cost of unreported injury and property-damage-only crashes equal to $5,000 and $500, respectively, per crash. The scenario also assumes annual administrative costs of $60,000 and per-camera purchases for the camera equal to $60,000. This scenario also assumes a percent reduction in right-angle crashes equal to 15 percent and an increase in rear-end crashes equal to 25 percent during the five-year period. The net benefits under this conservative analysis are equal to -$2.0 million during the five years. According to the ranges for each of the variables in our analysis, this would be our most conservative scenario. However, we do not believe that this conservative scenario is very likely. Based on previous studies, we believe it would be very unlikely that rear-end crashes would increase by 25 percent, while right-angle crashes only decrease by 15 percent.

Appendix I: Monte Carlo Analysis

We performed several Monte Carlo analyses to determine the effects of some of our assumptions on our results. A Monte Carlo analysis involves varying the values used for several variables over a specified range. The net present benefits of a red-light camera system are calculated 1,000 times based on randomly selected values between a specified minimum and maximum value for each of the variables. The results of each analysis are presented in this appendix, including a histogram illustrating the distribution of present net benefits and the descriptive statistics associated with the distribution for each analysis.

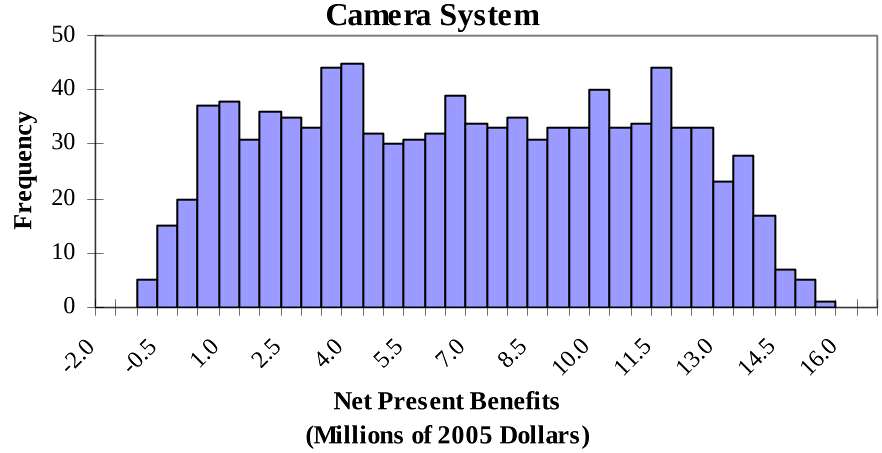
In each Monte Carlo, we vary the reduction in right-angle crashes from 15 percent to 50 percent and we vary the increase in rear-end crashes from 5 percent to 25 percent. We also vary the unreported PDO and injury crash costs from $500 to $3,000 and $5,000 to $60,000, respectively. Finally, we vary the annual administrative system costs and the one-time camera costs from $20,000 to $60,000 and $50,000 to $60,000, respectively. Table 26 presents the minimum and maximum values used for each of these variables.

Table 26
Variable Values Used in Monte Carlo Analyses

	Values	
Variable	**Minimum**	**Maximum**
Five-year decrease in right-angle crashes	15%	50%
Five-year increase in rear-end crashes	5%	25%
Unreported injury crash cost	$5,000	$60,000
Unreported property-damage-only crash cost	$500	$3,000
Annual administrative system costs	$20,000	$60,000
One-time camera cost	$50,000	$60,000

Source: Authors' calculations

Figure 2
Distribution of Net Present Benefits of Red Light Camera System



Source: Authors' calculations

Figure 2 shows the distribution of net present benefits of a red-light camera system resulting from performing a Monte Carlo analysis using variable value ranges presented in Table 26. The descriptive statistics for this analysis are shown in Table 27. The net present benefits range from -\$1.4 million to \$15.2 million and the distribution has a mean net present benefits of \$6.5 million.

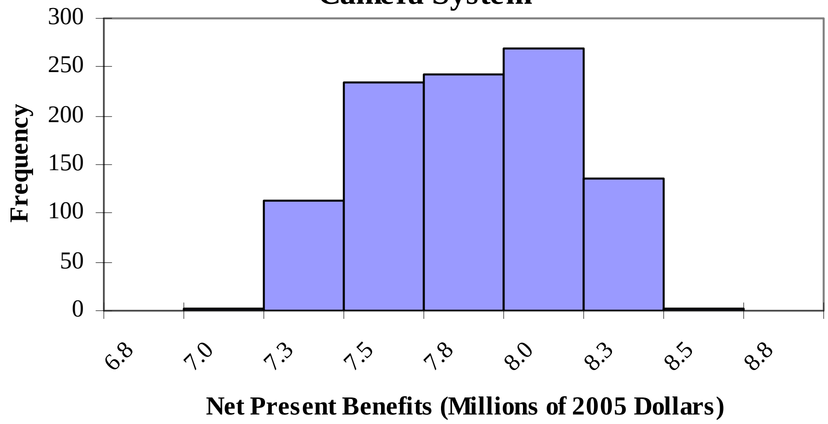
Table 27
Descriptive Statistics
for Monte Carlo Analysis (1)

Statistic	Value
Mean	$6,528,952
Range	$16,584,509
Minimum	-$1,388,746
Maximum	$15,195,763
Count	1,000

Source: Authors' calculations

We find that if we hold constant the percent reduction in right-angle crashes and the percent increase in rear-end crashes at 35 percent and 15 percent, respectively, while varying all other variables as shown in Table 26, the resulting net benefits range from \$7.0 million to \$8.3 million, as seen in Figure 3. This informs us that the most important assumptions in our analysis are the percent reduction in right-angle crashes and the percent increase in rear-end crashes. The distribution of net present benefits resulting from this analysis can be found in Figure 3, along with the descriptive statistics in Table 28.

Figure 3
Distribution of Net Present Benefits of Red Light Camera System



Source: Authors' calculations

Table 28
Descriptive Statistics
for Monte Carlo Analysis (2)

Statistic	Value
Mean	$7,646,100
Range	$1,329,555
Minimum	$6,959,349
Maximum	$8,288,904
Count	1,000

Source: Authors' calculations

Appendix J: Digital Camera Scenario

While the majority of cities that use red-light photo enforcement rely on 35-mm cameras, there is a growing trend toward the use of digital cameras (Maccubin et al., 2001). Because of this, we conducted both our cost-benefit and revenue analyses if the city of Milwaukee were to install digital cameras at the 13 intersections selected for our base case.

Because digital cameras are more expensive than 35-mm cameras, in this scenario, the camera costs used in our cost-benefit analysis are higher. Based on Maccubbin et al. (2001) under this scenario we assumed per camera costs of $100,000 plus an additional $30,000 per camera for equipment and installation costs. Because we were unable to obtain monthly maintenance costs specifically for digital cameras, we assumed $5,000 per camera per month, which represents the monthly maintenance costs for 35-mm cameras (Maccubbin et al., 2001). However, because digital cameras save on the cost of film, processing photos, and personnel, our estimate of maintenance costs is likely to be on the high side (Federal Highway Administration, 2005).

Digital cameras also result in a higher citation issuance rate compared to 35-mm cameras. While with 35-mm cameras the issuance rate for citations is approximately 50 percent in New York City; this rate is approximately 65 percent with digital cameras (New York City Department of Transportation, 2003). This is because digital cameras result in higher resolution photographs and are able to prevent reflections or headlights from distorting the image (U.S. Department of Transportation, n.d.a). As a result, the amount of revenue generated for the city's general fund would be higher if intersections were equipped with digital as opposed to 35-mm cameras. Aside from camera costs and citation issuance rates, all the other variables in our analyses remained the same.

According to the results of our cost-benefit analysis we estimate that installing digital cameras at the 13 selected intersections would yield $6.9 million in net present benefits during a five-year period. Based on the results of our revenue analysis, we estimate that using digital cameras at the 13 selected intersections would generate $6.3 million over five years. With digital cameras, the combined benefits total $13.2 million during a five-year period ($6.9 million + $6.3 million). This is approximately $800,000 more than our base case, which assumed 35-mm cameras would be used.

Tables 29 and 30 include the results of our sensitivity analyses showing the ranges of revenue that would be generated for the general fund if the city were to install 35-mm or digital red-light photo enforcement technology.

Table 29
Amount of Revenue Generated During Five Years with 35-mm Cameras Installed at 13 Intersections

	Violation Reduction		
Frequency of red-light-running per 1,000 vehicles	**45%**	**60%**	**75%**
3	$4,993,903	$3,631,929	$2,269,956
4	$6,658,537	$4,842,572	$3,026,608
5	$8,323,171	$6,053,215	$3,783,259

Source: Authors' calculations

Table 30
Amount of Revenue Generated During Five Years with Digital Cameras Installed at 13 Intersections

	Violation Reduction		
Frequency of red-light-running per 1,000 vehicles	**45%**	**60%**	**75%**
3	$6,492,073	$4,721,508	$2,950,942
4	$8,656,098	$6,295,344	$3,934,590
5	$10,820,122	$7,869,180	$4,918,237

Source: Authors' calculations

Appendix K: Citation Costs and Surcharges

The revenue generated from red-light violations is divided in many different ways. Citations for red-light running in Milwaukee are issued for $77.20, but the fee will soon be raised to $78.80 (Galezewski, 2006). Unlike parking tickets, the fine amount does not increase if the red-light running ticket is not paid on time. In addition to a fine, red-light-running violations result in a deduction of three points from the violator's driver's license. According to Wisconsin Statutes 346.43(1)(b)1, the penalty for running a red light may be between $20 and $40 for a first offense, and between $50 and $100 for each additional offense within the same year (Wisconsin State Legislature, 2006). The Wisconsin Judicial Conference, a panel of judges from different Wisconsin courts, each year issues a deposit schedule for various offenses. The Conference determines what the penalty for specified violations should be if the offender does not contest the violation in court. For red-light running, the deposit is set at $30. The total citation amount of $78.80 consists of the $30 deposit, a 26 percent state penalty surcharge of $7.80, an $18 surcharge, and a $23 court cost. The $30 deposit goes to the municipality's general fund. The rationale for setting the deposit below the maximum of $40 is to encourage offenders to pay the ticket and not come to the already overcrowded courts. If they go to court, they risk paying the higher fine.

Appendix L: Additional Tables

Table 31
2001 Reported Traffic Accidents at the 13 Signalized Intersections in Milwaukee that have the Most Accidents and that have Red-Light Running as the Most Frequent Cause of these Accidents

					Right-angle crashes			Rear-end crashes		
Intersection	**Total Accidents**	**% Due to Red-Light Running**	**Number of Red-Light Running Accidents**	**Number of Rear-End Accidents***	**Property Damage Only**	**Injury**	**Fatal**	**Property Damage Only**	**Injury**	**Fatal**
Silver Spring Drive & Zoo Freeway	45	21%	9	8	5	5	0	6	2	0
W. Capital Drive & N. 51st St	20	47%	9	4	5	5	0	3	1	0
W. Walnut St. & N. 12th St.	20	47%	9	4	5	5	0	3	1	0
S. Layton Blvd & W. National Ave.	19	28%	5	3	3	3	0	2	1	0
N. James Lovell St. & W. Wells St.	18	41%	7	3	4	4	0	2	1	0
W. Lincoln Ave. & S. 13th	18	27%	5	3	2	2	0	2	1	0
W. Center St & N. 7th St	17	71%	12	3	6	6	0	2	1	0
W. Good Hope Rd & N. Teutonia Ave.	17	38%	6	3	3	3	0	2	1	0
S. Howell Ave & E. Layton Ave	15	33%	5	3	3	2	0	2	1	0
W. Hampton Ave & N. 50th St	15	33%	5	3	3	2	0	2	1	0
W. Locust St. & N. Martin Luther King Dr	15	50%	8	3	4	4	0	2	1	0
W. Mill Rd & N. 91st St	15	33%	5	3	3	2	0	2	1	0
N. Teutonia Ave & W. Villard Ave	15	33%	5	3	3	2	0	2	1	0
Total	**249**		**92**	**45**	**47**	**44**	**0**	31	13	0

*Assumes that 18% of accidents at urban intersections are rear-end crashes

Table 32
Red-Light-Running Citation Amounts
in Select U.S. Cities with Red-Light Cameras

City	Citation Amount
San Francisco	$321
Chicago	$90
Washington, D.C.	$75
Phoenix	$175
Charlotte	$50
Baltimore	$75
Seattle	$86
Denver	$75
Minneapolis	$142

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